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Monticello Nuclear Generating Plant
LOCA Containment Analyses
For Use in Evaluation of NPSH for the RHR and Core Spray Pumps

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IMPORTANT INFORMATION REGARDING CONTENTS OF THIS REPORT

PLEASE READ CAREFULLY

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ABSTRACT

This report provides the results from an evaluation of the Monticello suppression pool temperature and suppression chamber airspace pressure response for the limiting short-term and long-term loss-of-coolant accident (LOCA) events with respect to available Net Positive Suction Head (NPSH) for the Residual Heat Removal (RHR) and Core Spray (CS) pumps. Suppression pool temperature in this report refers to the bulk average suppression pool temperature. The LOCA short-term response occurs during the first 10 minutes of the LOCA event when no credit is taken for operator actions to control pump flows or initiate containment cooling. The LOCA long-term response includes the time period after 10 minutes when it is assumed that the operator controls pump flows and initiates containment cooling. The GE SHEX computer code was used for the analyses described in this report.

Several accident event conditions were considered. These include 1) LOCA with loss of normal power and failure of a diesel generator, 2) LOCA with a Low Pressure Coolant Injection (LPCI) loop selection logic failure and loss of normal power, 3) LOCA with a LPCI loop selection logic failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater, 4) LOCA with a LPCI injection valve failure and loss of normal power, and 5) LOCA with a LPCI injection valve failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater. Each event analysis provides the suppression chamber airspace pressure and suppression pool temperature response. The analysis results presented in this report can be used by NSP to evaluate the available NPSH for pumps taking suction from the suppression pool.

Benchmark analyses of the DBA-LOCA were also performed with the GE SHEX containment code to validate the SHEX analysis results. The results of the SHEX benchmark case were compared to the results of analyses performed with the GE HXSIZ code in NEDO-32418 for the DBA-LOCA. The HXSIZ code is the code used in the current licensing basis for Monticello.

1.0 INTRODUCTION

This report provides the results from an evaluation of the Monticello suppression pool and suppression chamber airspace pressure response for the limiting short-term and long-term loss-of-coolant accident (LOCA) events with respect to available Net Positive Suction Head (NPSH) for the Residual Heat Removal (RHR) pumps and Core Spray (CS) pumps. Suppression pool temperature in this report refers to the bulk average suppression pool temperature. The LOCA short-term response occurs during the first 10 minutes of the LOCA event when no credit is taken for operator actions to control pump flows or initiate containment cooling. The LOCA long-term response includes the time period after 10 minutes and past the time of the peak suppression pool temperature when it is assumed that the operator controls pump flows and initiates containment cooling.

Several accident event conditions were considered. These include 1) LOCA with loss of normal power and failure of a diesel generator, 2) LOCA with a Low Pressure Coolant Injection (LPCI) loop selection logic failure and loss of normal power, 3) LOCA with a LPCI loop selection logic failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater, 4) LOCA with a LPCI injection valve failure and loss of normal power, and 5) LOCA with a LPCI injection valve failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater. The analyses presented here provide the suppression chamber airspace pressure and suppression pool temperature response. The analysis results presented in this report can be used by NSP to calculate the available NPSH margin for pumps taking suction from the suppression pool.

Benchmark analyses of the DBA-LOCA were also performed to validate the GE SHEX containment code. The results of the SHEX benchmark case were compared to the results of analyses performed with the GE HXSIZ code in Reference 1 for the DBA-LOCA. The HXSIZ code is the code used in the current licensing basis for Monticello. These comparisons demonstrate the impact on the long-term containment response of switching from the HXSIZ containment code to the SHEX containment code. The benchmark analyses are provided in Appendix A of this report.

1.1 Short-Term Analyses

The suppression pool temperature and suppression chamber airspace pressure responses to the DBA-LOCA were analyzed for a postulated break in the recirculation discharge line with all 4 LPCI pumps and 2 Core Spray (CS) pumps available for vessel injection and with the assumed single failure of the loop selection logic. It is assumed for this analysis that all LPCI pump flow is injected into the broken recirculation loop and subsequently directed into the drywell. This event results in minimum suppression chamber airspace pressures and maximum suppression pool temperatures during the first 10 minutes of an accident when operator actions are not credited. This event is therefore considered to be limiting with respect to NPSH margins for the first 10 minutes of the accident.

Although a recirculation discharge line break was modeled for this analysis, the results will be the same for a recirculation suction line break. This is true because for either break location, the break size is sufficiently large such that the break flows for this event are established by the pump injection flow rate. The discharge break is large enough that the vessel is fully depressurized before the ECCS pumps begin injecting. Because the CS pump flow into the vessel and the LPCI pump flow into the broken loop are the same with either break location, the break flows into the drywell will be the same. Consequently, the drywell and suppression chamber airspace pressure and temperature response will be the same.

Two short-term analysis cases were performed. Case 1 is based on the current rated thermal power (102% of 1670 MWt) and Case 2 is based on a bounding thermal power (102% of 1880 MWt). The use of 1880 MWt for Case 2 conservatively bounds the core shutdown power which would be obtained with 102% of 1670 MWt and the use ANS 5.1 decay power with a 2 sigma uncertainty adder (See Section 3.3 for additional discussion).

For both short-term cases it was assumed that:

1. With a signal for LPCI initiation, all four RHR pumps start in vessel injection mode and inject directly into the drywell (no flow to the vessel) at a combined flow rate of 15500 gpm during the first 10 minutes of this event.

2. After receiving a signal for CS initiation, the 2 CS pumps are injecting into the vessel at a flow rate of 4370 gpm per pump for the first 10 minutes of this event.

1.2 Long-Term Analyses

Five different accident scenarios were evaluated for the long-term analyses. The first scenario assumes a double-ended recirculation suction line break with no off-site power and the assumed failure of one diesel generator. For this case (Case 3), there is one division with one RHR heat exchanger, one RHR pump and one RHR Service Water (SW) pump for long-term containment cooling. This containment cooling configuration is the limiting configuration with respect to maximum suppression pool temperature. Therefore, this event is considered to be potentially limiting with respect to NPSH margins for the long-term.

Even though the peak suppression pool temperature will be lower, accident scenarios with more ECCS pumps running could potentially be more limiting for NPSH due to higher head losses in the common suction header and lower containment pressure due to cooler RHR flow into the containment. This report evaluated four additional potential accident scenarios that may potentially be more limiting due to ECCS pump NPSH considerations. These four events are: LOCA with a LPCI loop selection logic failure and loss of normal power (Case 4), LOCA with a LPCI loop selection logic failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater (Case 5), LOCA with a LPCI injection valve failure and loss of normal power (Case 6), and LOCA with a LPCI injection valve failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater (Case 7). For these four additional events, a double ended break in the recirculation discharge line is assumed.

The long-term analyses were performed with a bounding thermal power (102% of 1880 MWt) and the use of ANS 5.1-1979 nominal decay power.

1.3 Benchmark Analyses

Benchmark analyses of the DBA-LOCA were performed in order to validate the GE SHEX containment code. The results of the SHEX benchmark case were compared to the results of analyses performed with the GE HXSIZ code in Reference 1 for the DBA-

LOCA. The HXSIZ code is the code used in the current licensing basis for Monticello to calculate the long-term containment response for the DBA-LOCA. The comparisons given in Appendix A demonstrate the impact on the long-term containment response of switching from HXSIZ to the SHEX containment code.

Two SHEX benchmark analyses are presented in Appendix A. The benchmark analyses were performed at the current 102% of 1670 MWt (initial power used for the Reference 1 analyses). SHEX Benchmark Case A-1 used the nominal ANS 5.1 -1979 decay heat without adders used for Case 1 of Reference 1. SHEX Benchmark Case A-2 used the May-Witt decay heat curve used for Case A.2 of Reference 1. The remaining input assumptions and input parameters for the two SHEX benchmark cases were consistent with the input assumptions used for Case 1 and Case A.2 of Reference 1.

2.0 RESULTS

2.1 Short-Term Analysis

Table 1 summarizes the results of the short-term analysis results for Cases 1 and 2. Figures B-1 through B-4 in Appendix B show the suppression pool temperature and the drywell and suppression chamber airspace pressure for these two cases. Appendix C contains digitized histories of suppression pool temperature and suppression chamber airspace pressure for Cases 1 and 2.

2.2 Long-Term Analysis

Table 2 summarizes the results of the analysis for the five long-term analysis cases. Figures B-5 through B-14 in Appendix B show the suppression pool temperature and drywell and suppression chamber airspace pressure for the five cases analyzed. Appendix C contains digitized histories of the suppression pool temperature and suppression chamber airspace pressures for these five cases.

Short-Term Response (0-10 minutes)

The SHEX computer analysis of the long-term response for Cases 3 through 7 begins at event time zero. Therefore, calculated suppression pool temperatures and suppression chamber airspace pressures during the first 10 minutes are presented here. However, since the inputs to these cases are formulated to minimize available NPSH in the long-term, the short-term results of Cases 3 through 7 are presented for information purposes only and should not be used to evaluate NPSH for the first 10 minutes of these events. The suppression pool temperature and suppression chamber airspace pressure for Cases 1 and 2 should be used to evaluate the short-term NPSH margins.

For Cases 4 and 5, which assumed LPCI loop selection logic failure, the suppression pool temperatures at 600 seconds for the long-term analysis are essentially the same (~0.2°F) as the value for the short-term analysis Case 2 which models the same event. The ~0.5 psi reduction in the suppression chamber airspace pressure at 10 minutes for Cases 4 and 5 relative to the value for Case 2 is attributed to the different assumptions for the thermal mixing of the break flows. Cases 4 and 5 assumed 20% thermal mixing of the vessel side break flow and 100% mixing of the LPCI injection break flow. Case 2 assumed 100%

thermal mixing for both flow sources. Since the break flow from the vessel is warmer than the LPCI injection break flow, using a low thermal mixing efficiency for the vessel break flow and a high thermal mixing efficiency for the LPCI flow produces a lower drywell temperature and consequently a lower drywell and suppression chamber airspace pressure. As discussed in Section 3.4, this assumption is technically inconsistent since it is expected that both break flow streams will have the same thermal mixing properties. Therefore, the results of Case 2 should continue to be used as the basis for the short-term (10 minute) NPSH evaluations.

The lower suppression pool temperature and higher suppression chamber air space pressure seen for Cases 6 and 7 relative to Cases 4 and 5 is due to the assumed LPCI injection valve failure for Cases 6 and 7. This assumption reduces the cold break flow to the drywell during the first 10 minutes which helps to maintain a higher drywell temperature and high drywell and suppression chamber airspace pressure. This assumption also reduces the energy transfer from the drywell to the suppression pool during the first 10 minutes.

Long-Term (after 10 minutes to beyond the time of peak suppression pool temperature)

A comparison of the peak suppression pool temperature for Cases 4 through 7 with Case 3 shows a significant reduction (25-30°F) in the peak suppression pool temperature when using the higher containment cooling capacity of both divisions.

A comparison of Case 6 to Case 7 demonstrates that the available NPSH pressure term (i.e. suppression chamber airspace pressure minus the vapor pressure corresponding to the peak suppression pool temperature) increases with a higher containment spray flow rate. This is attributed to a larger reduction in the suppression pool temperature relative to the reduction in the drywell and suppression chamber spray temperature with a higher spray flow rate. This trend is due to the fact that with a higher containment spray flow rate (and higher RHR pump flow through the heat exchanger), the total heat removal rate is increased, however the energy removed per unit mass of water flowing through the heat exchanger and sprayed to the drywell and suppression chamber is decreased. Hence, an increase in the containment spray flow rate results in a lower suppression pool temperature but in a higher containment spray temperature. This means that suppression chamber airspace pressure reductions are smaller for a higher RHR pump flow rate

through the heat exchanger. Therefore, the net effect of a higher RHR pump flow rate through the heat exchanger is an increase in the available NPSH pressure term.

Comparisons of Case 4 to Case 6 and Case 5 to Case 7 show that use of LPCI in vessel injection mode with flow through the RHR heat exchanger (Cases 4 and 5) results in a higher suppression chamber airspace pressure near the time of the peak suppression pool temperature than obtained with the use of containment sprays for long-term cooling (Cases 6 and 7). This is attributed in part to the lack of torus spray for Cases 4 and 5. For all cases, the interaction of cold break flow or spray liquid reduces the drywell pressure below the suppression chamber airspace pressure in the long term. As a consequence, the suppression chamber-to-drywell vacuum breakers open which results in a transfer of suppression chamber airspace non-condensible gases to the drywell. This reduces the suppression chamber airspace pressure and cools the suppression chamber airspace due to decompression effects. The cooler suppression chamber airspace temperature produces a reduction in the suppression chamber airspace pressure. For cases with torus sprays, the suppression chamber airspace temperature rapidly approaches the temperature of the torus spray when the sprays are initiated, and the vapor pressure in the suppression chamber airspace approaches the saturation pressure corresponding to the spray temperature. For cases without torus sprays (Cases 4 and 5), the long-term suppression chamber airspace temperature and pressure is controlled by the heat transfer rate from the suppression pool to the suppression chamber airspace and from the evaporation rate on the suppression pool surface which is a slower heat transfer process. Consequently the suppression chamber airspace pressure response for cases with torus sprays is initially higher after 10 minutes, however, by the time of the peak suppression pool temperature, there is sufficient mass and energy transfer from the suppression pool to the suppression chamber airspace to produce a higher suppression chamber airspace temperature and pressure for cases without torus sprays. Therefore, Cases 4 and 5, which do not use torus sprays, have a higher suppression chamber airspace temperature, and higher suppression chamber airspace pressure than Cases 6 and 7 near the time of the peak suppression pool temperature.

3.0 ANALYSIS INPUTS AND ASSUMPTIONS

3.1 Input Assumptions

Input assumptions are used which maintain the overall conservatism in the evaluation by maximizing the suppression pool temperature and conservatively minimizing the suppression chamber airspace pressure and, therefore, minimize the available NPSH. The key input assumptions which are used in performing the Monticello containment LOCA pressure and temperature response analysis are described below. Table 3 provides values of key containment parameters common to all cases, while Table 4 provide case-specific inputs.

1. The reactor is assumed to be operating at 102% of 1880 MWt, except for Case 1 which assumes an initial power of 102% of 1670 MWt.

2. Vessel blowdown flow rates are based on the Homogeneous Equilibrium Model (Reference 2).

3. The core decay heat is based on ANSI/ANS-5.1-1979 decay heat without uncertainty adders (Reference 3).

4. Feedwater flow into the RPV continues until all hot feedwater which maximizes the suppression pool temperature is injected into the vessel.

5. Thermodynamic equilibrium exists between the liquids and gases in the drywell. Mechanistic heat and mass transfer between the suppression pool and the suppression chamber airspace are modeled to minimize the suppression chamber airspace pressure and temperature.

6. Heat transfer from break fluids to the drywell atmosphere is adjusted to minimize the suppression chamber airspace pressure (see Section 3.4).

7. The vent system flow to the suppression pool consists of a homogeneous mixture of the fluid in the drywell.

8. The initial suppression pool volume is at the minimum Technical Specification (T/S) limit to maximize the calculated suppression pool temperature.

9. To minimize the suppression chamber airspace pressure, the initial drywell and suppression chamber airspace pressure are at the minimum expected operating pressure of 14.26 psia which is based on historical minimum average local pressure conditions at Monticello.

10. An initial bulk average drywell temperature of 135°F and a relative humidity of 100% are used to minimize the initial non-condensable gas mass and minimize the long-term containment pressure for the NPSH evaluation.

11. The initial suppression pool temperature is at the maximum T/S value (90°F) to maximize the calculated suppression pool temperature.

12. The initial suppression chamber airspace temperature is at 90°F and the initial relative humidity is at 100%.

13. The RHR service water temperature is at the maximum allowable value of 90°F to maximize the calculated suppression pool temperature.

14. Heat sinks are used for Cases 1, 2, and 4 through 7 to minimize the suppression chamber airspace pressure. Heat sink inputs for these cases were developed based on the Monticello drywell and torus geometry parameters which were compiled and used during the Mark I Containment Long Term Program. The drywell and torus airspace shell film coefficient is based on the Uchida correlation with a 1.2 multiplier. Condensation heat transfer is assumed at all times unless the structural temperature of the heat sink is greater than the airspace saturation temperature in which case natural convection heat transfer is assumed.

    Case 3 was used to evaluate long-term available NPSH for a scenario with the peak long-term suppression pool temperature. Therefore heat sinks were not used for Case 3. This is justified since in the long-term, with drywell and suppression chamber sprays operating, heat sinks have negligible effect on suppression chamber airspace pressure. The short-term response for this event is not limiting since run-

out flow conditions were not assumed. Therefore the effect of heat sinks in the short-term for this event is not critical.

15. All Core Spray and RHR Cooling system pumps have 100% of their horsepower rating converted to a pump heat input which is added either to the RPV liquid or suppression pool water.

16. Heat transfer from the primary containment to the reactor building is conservatively neglected.

17. Containment leakage is not included in the analyses. Including containment leakage has no impact on the peak suppression pool temperature, but will slightly reduce the calculated containment pressure. The Monticello T/S limits the allowable leakage to 1.2 % per day. Use of the leakage rate of 1.2 % per day would result in less than a 0.1 psi reduction in the pressures calculated in the analysis. This effect is negligible considering all other input conditions have been chosen at their limiting values to minimize containment pressure and the assumption of only 20% holdup of the non-flashing liquid flow from the break in the drywell (see assumption no. 6). Therefore containment atmospheric leakage was not included in the analysis.

3.2 Conservatism in the SHEX Containment Pressure Calculation

The GE SHEX code performs realistic calculations of containment pressure and temperature and suppression pool temperature based on classical thermodynamic laws. The conservatism in the SHEX calculation of the suppression pool temperature and suppression chamber airspace pressure for use in evaluating NPSH is obtained in the application of the SHEX code by using conservative inputs which minimize suppression chamber airspace pressure and maximize suppression pool temperature. This modeling approach is consistent with the guidance provided for PWRs in Reference 7 and in the Branch Technical Position CSB 6-1.

The assumptions used in the GE analyses to minimize suppression chamber airspace pressure are discussed below:

Initial Conditions

The following initial conditions are used to minimize the initial non-condensable gas content and thereby to minimize the containment pressure during the LOCA:

1. Initial bulk average drywell temperature is at the maximum operating value of 135°F.

2. Initial suppression chamber airspace temperature is set equal to maximum operating temperature for suppression pool.

3. Initial drywell and suppression chamber airspace relative humidity is set at 100%.

4. Initial drywell and suppression chamber airspace pressure set at minimum expected values

In addition, the initial suppression pool volume is at the minimum operating value. This assumption maximizes the initial suppression chamber airspace volume, while maximizing the suppression pool temperature response. For a given initial pressure, a larger suppression chamber airspace volume should not result in a higher pressure since 1) the increase in the initial non-condensible gas mass with a larger initial volume is offset by the availability of a larger volume to expand in and 2) a larger suppression chamber airspace volume will reduce the pressurization rate for a given evaporation rate from the suppression pool. Therefore by maximizing the suppression chamber airspace volume, the long-term suppression chamber airspace pressure response is minimized which is conservative for evaluating NPSH.

Analysis Assumptions

The following analysis assumptions are used to minimize containment pressure:

1. Drywell and suppression chamber sprays with 100% thermal mixing efficiency between the spray liquid and the drywell and suppression chamber atmosphere.

2. For Cases 1 and 2 which are used to calculate the limiting short-term response with respect to evaluating NPSH, 100% mixing efficiency of cold break flow liquid with the drywell atmosphere prior to initiation of containment sprays. This assumption

minimizes containment pressure since prior to containment spray initiation the break flow temperature is lower than the drywell temperature.

3. For Cases 3 through 7 which are used to calculate the limiting long-term response for NPSH evaluations, a 20% mixing efficiency of break flow liquid with the drywell atmosphere is assumed. Using a reduced mixing efficiency for events with containment sprays minimizes the long-term containment pressure since the temperature of the break flow liquid following initiation of sprays is higher than the drywell temperature.

4. Except for Case 3, heat sink inputs are used to minimize the suppression chamber airspace pressure (see Assumption 13 in Section 3.1).

Based on the above discussions it is concluded that containment analyses performed for Monticello with the SHEX computer code have used initial conditions and analysis assumptions appropriate to conservatively minimize containment pressure for use in NPSH evaluations.

3.3 Application of ANS 5.1 - 1979 Decay Heat Curve

The reactor shutdown power profile used in the SHEX containment analyses is based on the power rerate analysis power level of 1880 MWt and uses the nominal ANS 5.1-1979 decay heat profile with no uncertainty adders. The NRC is currently requiring that an uncertainty of 2σ (i.e. a 95% confidence interval) be included to justify use of the ANS 5.1-1979 decay heat model for certain analyses. The use of the 1880 MWt shutdown power profile bounds the shutdown power profile that would be obtained using the currently licensed core thermal power of 1670 MWt and the ANS 5.1-1979 decay heat profile with a 2σ uncertainty adder.

Figure B-15 shows the reactor power as a function of time after shutdown used in the SHEX containment analyses. This shutdown power profile is based on the power rerate analysis power level of 1880 MWt and uses the nominal ANS 5.1-1979 decay heat profile with no uncertainty adders. Nominal and 2σ shutdown power profiles for the current licensed power level of 1670 MWt are also shown for comparison. As can be seen in Figure B-15, the 1880 MWt nominal shutdown power profile clearly bounds the 1670 MWt 2σ profile for all times.

The long-term suppression pool temperature response is governed primarily by the decay energy added to the pool as compared to the heat removal from the pool. At the approximate time of peak suppression pool temperature, the integrated decay energy for the 1880 MWt nominal shutdown power profile is more than 12 percent higher than the 1670 MWt nominal shutdown power profile. The 1670 MWt 2σ shutdown power profile with two sigma uncertainty on the decay heat is less than 8 percent higher than the 1670 MWt nominal shutdown power profile. Therefore, use of the 1880 MWt nominal shutdown power profile provides more than sufficient conservatism for containment analyses supporting operation at the current licensed power level of 1670 MWt.

The main sources of decay heat energy are fission product decay heat, actinide decay, neutron capture in fission products, and delayed neutron induced fission. The ANS 5.1-1979 decay heat standard addresses the calculation and uncertainty in the decay heat due to fission product decay, actinide decay, and neutron capture in fission products. GE-NE uses a conservative calculation for the fission heat from delayed neutrons which includes the effects of control rod insertion and void reactivity feedback. Because a conservative calculation is used for the delayed neutron induced fission, no additional uncertainty is included for this term in the uncertainty calculation. As shown in Figure B-15, there is little difference between the 1670 MWt nominal shutdown power profile and the 1670 MWt 2σ profile during the first few seconds. This is because most of the shutdown power during this time is due to delayed neutron induced fissions. The decay heat energy is only a small portion of the shutdown power, therefore the contribution for the 2σ uncertainty on the decay heat is small.

3.4 Mixing of Break Fluid with Drywell Atmosphere

Heat transfer from the break flow to the drywell atmosphere is modeled conservatively to minimize suppression chamber airspace pressure for all cases. To model partial heat transfer in the analysis, a fraction of the non-flashing liquid break flow is assumed to be held up in the drywell and to be fully mixed with the drywell fluids before flowing to the suppression pool. Thermal equilibrium conditions are imposed between this held-up liquid and the fluids in the drywell as described in Assumption No. 5 in Section 3.1. The liquid not held up is assumed to flow directly to the suppression pool without heat transfer to the drywell fluids.

For Cases 1 and 2 which are analyzed for the first 10 minutes of the LOCA event, thermal mixing efficiencies of cold break flow liquid with the drywell atmosphere of 100% is modeled. Cold break flow is defined here as the water which spills from a break after the blowdown is completed and ECCS (LPCI and CS) systems are initiated. This water is at a temperature which is lower than the drywell atmosphere temperature and therefore cools the drywell. High values of thermal mixing efficiency minimize the suppression chamber airspace pressure since the break flow temperatures are lower than the drywell atmosphere temperatures during the 10 minute analysis time period. Lower drywell pressures result in lower suppression chamber airspace pressures due to the return flow of steam and non-condensable gases from the suppression chamber airspace to the drywell through the suppression chamber airspace-to-drywell vacuum breakers. According to Reference 6, a thermal mixing efficiency of approximately of 40% produces analysis results with the GE SHEX code which best matches test data with respect to drywell pressure. Therefore a thermal mixing efficiency of 100% is considered to be a conservative value for evaluating the short-term response for this event.

To minimize the long-term containment pressure for the limiting long-term events it is assumed for Cases 3 through 7 that there is only partial heat transfer to the drywell atmosphere from the break flow originating at the vessel. Low values of thermal mixing efficiency minimize the suppression chamber airspace pressure because the vessel break flow temperatures are higher than the drywell atmosphere temperatures during the long-term (after 10 minutes) when containment sprays are initiated or the RHR pump flow is routed through heat exchanger. Lower drywell pressures result in lower suppression chamber airspace pressures due to the return flow of steam and non-condensable gases from the suppression chamber airspace to the drywell through the suppression chamber airspace-to-drywell vacuum breakers. Therefore a low thermal mixing efficiency of 20% is considered to be a conservative value for evaluating the long-term response for this event.

For Cases 4 and 5 a thermal mixing efficiency of 100% between the LPCI injection flow to the drywell and the drywell atmosphere is assumed at all times (short-term and long-term). This is because the LPCI injection flow to the drywell is colder than the drywell atmosphere temperature at all times.

It should be noted that the use of a 20% thermal mixing efficiency for the break flow resulting from vessel reflood and the use of 100% thermal mixing efficiency for the LPCI injection flow through the break is technically inconsistent. Since the flow stream from the break will be made up from both sources of flow, it is expected that the same mixing efficiency would apply to both flow sources. Consequently, the use of a low thermal mixing efficiency for the vessel side break flow and a high thermal mixing efficiency for the LPCI injection flow out the break will result in a unrealistically low drywell and suppression chamber airspace pressure. Therefore, the short-term results of Cases 4 and 5 which use these assumptions are non-prototypical and should not be used to evaluate available NPSH margins. Cases 1 and 2 which assume 100% thermal mixing for both the break flow from the vessel and for the LPCI injection to the drywell and which were conservatively developed to minimize suppression chamber airspace pressure, remain as the basis for the short-term (10 minute) NPSH evaluations.

4.0 CALCULATIONS AND COMPUTER CODES

4.1 Model Description

The GE computer code SHEX is used to perform the analysis of the containment pressure and temperature response. The SHEX code has been validated in conformance with the requirements of the GE Engineering Operating Procedures (EOPs). In addition, a benchmark analysis to validate the code for a plant-specific application to Monticello was performed, which is documented in Appendix A of this Report.

SHEX uses a coupled reactor pressure vessel and containment model, based on the Reference 4 and Reference 5 models both of which have been reviewed and approved by the NRC, to calculate the transient response of the containment during the LOCA. This model performs fluid mass and energy balances on the reactor primary system and the suppression pool, and calculates the reactor vessel water level, the reactor vessel pressure, the pressure and temperature in the drywell and suppression chamber airspace and the bulk average suppression pool temperature. The various modes of operation of all important auxiliary systems, such as SRVs, the MSIVs, the ECCS, the RHR and feedwater, are modeled. The model can simulate actions based on system setpoints, automatic actions and operator-initiated actions.

4.2 Analysis Approach

The objective of the analysis is to determine the short-term (0-600 seconds) and long-term (>600 seconds) suppression pool temperature and suppression chamber airspace pressure for the limiting LOCA events with respect to NPSH. The GE computer model SHEX-04 (References 4 and 5) with decay heat based on the ANS 5.1 1979 decay heat model (without adders) was used in the analyses. The short-term response occurs during the first 10 minutes of the LOCA event when operator actions to control pump flow or initiate containment cooling cannot be assured. The LOCA long-term response includes the time period after 10 minutes when it is assumed that the operator controls pump flows and initiates containment cooling.

Several accident event conditions are considered. These include: LOCA with loss of normal power and loss of a diesel generator failure, LOCA with a LPCI loop selection logic failure and loss of normal power, LOCA with a LPCI loop selection logic failure

with normal power available but no credit taken for non-safety related systems such as condensate-feedwater. LOCA with a LPCI injection valve failure and loss of normal power, and LOCA with a LPCI injection valve failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater. The analyses presented here provide the suppression chamber airspace pressure and suppression pool temperature response. The results can be used by NSP to evaluate available NPSH for pumps taking suction from the suppression pool.

Benchmark analyses of the DBA-LOCA are also performed with the GE SHEX containment code. The results of the SHEX benchmark case are compared to the results of analyses performed with the GE HXSIZ code in Reference 1 for the DBA-LOCA. The HXSIZ code is the code used in the current licensing basis for Monticello. These comparisons are used demonstrate the impact on the long-term containment response of switching from HXSIZ to the SHEX containment code. The benchmark analyses are provided in Appendix A to this report.

4.2.1 Short-Term Analyses

The suppression pool temperature and suppression chamber airspace pressure responses to the DBA-LOCA have been analyzed for a postulated break in the recirculation discharge line with all four LPCI pumps and two Core Spray (CS) pumps available for vessel injection and with the assumed single failure of the loop selection logic. It is therefore assumed for this analysis that all LPCI pump flow is injected into the broken recirculation loop and subsequently directed into the drywell. The cold water spilling into the drywell cools the drywell atmosphere similar to drywell sprays which reduces the drywell pressure and temperature and subsequently the suppression chamber airspace pressure due to the opening of the suppression chamber airspace-to-drywell vacuum breakers. This event results in minimum suppression chamber airspace pressures and maximum suppression pool temperatures during the first 10 minutes of an accident when operator actions are not credited. This event is therefore considered to be limiting with respect to NPSH margins for the first 10 minutes of the accident.

Although a recirculation discharge line break is modeled for this analysis, the results will be similar for a recirculation suction line break. This is because either break location includes a break size sufficiently large such that the break flows for this event are established by the pump injection flow rate. Since the CS pump flows into the vessel and

the LPCI pump flow into the broken loop are the same with either break location, the break flows into the drywell will be the same. Consequently, the drywell and suppression chamber airspace pressure and temperature response will be the same.

Two cases are performed for the current analysis. Case 1 is performed with the current rated thermal power (1670 MWt) and Case 2 is performed with a bounding thermal power (1880 MWt). A 100% thermal mixing efficiency between the liquid break flow and the drywell atmosphere was assumed to minimize the suppression chamber airspace pressure (see Section 3.4)

For both short-term cases it is assumed that:

1. With a signal for LPCI initiation all 4 RHR pumps start vessel injection mode and inject directly into the drywell (no flow to the vessel) at a combined flow rate of 15500 gpm during the first 10 minutes of this event.

2. After receiving a signal for CS initiation, the 2 CS pumps are injecting into the vessel at a flow rate of 4370 gpm per pump for the first 10 minutes of this event.

4.2.2 Long-Term Analysis

With the assumed failure of one diesel generator there is one RHR heat exchanger with only one RHR and one RHR SW pump assumed to be available for long-term containment cooling. This containment cooling configuration is the limiting configuration with respect to maximum suppression pool temperature. Therefore this event (Case 3) is considered to be potentially limiting with respect to NPSH margins for the long-term. However, accident scenarios with more ECCS pumps running could potentially be more limiting for NPSH due to higher head losses in the common suction header and lower containment pressure due to cooler RHR flow into the containment even though the peak suppression pool temperature will be lower. Four potential accident scenarios that may potentially be more limiting due to ECCS pump NPSH considerations are: 1) LOCA with a LPCI loop selection logic failure and loss of normal power, 2) LOCA with a LPCI injection valve failure and loss of normal power, 3) LOCA with a LPCI loop selection logic failure with normal power available but no credit taken for non-safety related systems such as condensate-feedwater, and 4) LOCA with a LPCI injection valve failure with normal power available but no credit taken for non-safety related

systems such as condensate-feedwater. Therefore these additional four events (Cases 4-7) are also evaluated in this report.

The following analysis assumptions were used to minimize the long-term (greater than 10 minutes) containment pressure and maximize the suppression pool temperature:

1. For cases where containment spray is used, it is assumed that 95% of the total RHR flow goes to the drywell spray and 5% goes to the torus spray.

2. A drywell and suppression chamber spray efficiency of 100% is assumed to minimize the suppression chamber airspace pressure.

3. A 20% thermal mixing efficiency is assumed between the break flow originating at the vessel and the drywell atmosphere. A 100% thermal mixing efficiency is assumed between LPCI injection flow into the drywell and the drywell atmosphere (see Section 3.4).

4.2.3 Case Descriptions

Case 3 (DBA-LOCA, No off-site Power, Single Diesel Generator Failure)

Short-Term (0-10 minutes)

In Case 3, no off-site power and a single failure of one diesel generator is assumed. Therefore only one division is assumed available. Vessel injection into the vessel from 2 LPCI pumps with a flow rate of 7740 gpm is assumed. It is assumed that the 1 CS pump injects into the vessel at 2700 gpm during the first 10 minutes. Note that the pump flows assumed for this analysis in the short-term are based on rated pump flows and not based on run-out flow conditions. Therefore the short-term results of this calculation are provided for information only and are not limiting for evaluating NPSH during the first 10 minutes of the DBA-LOCA.

Long-Term (after 10 minutes to beyond the time of peak suppression pool temperature)

For Case 3 it is assumed that at 10 minutes, one of the RHR pump is turned off to allow alignment of one RHR SW pump. The other RHR pump is switched to containment

spray mode and aligned with the RHR SW pump and RHR HX for long term containment cooling. It is further assumed that the operator throttles back the RHR pump flow to 4000 gpm per pump and the CS pump flow to 2700 gpm per pump. The long-term pump configuration is as follows:

1 Division Available

With:

1 RHR heat exchanger (K = 143.1 Btu/sec-°F)

1 RHR pump in containment spray mode with a total flow of 4000 gpm (3800 gpm to the drywell and 200 gpm to the suppression chamber airspace) which is aligned to the RHR HX

1 RHR SW pump with a flow of 3500 gpm

1 CS pump with a flow of 2700 gpm

Cases 4 and 5 (LPCI Loop Selection Logic Failure)

Short-Term (0-10 minutes)

In Cases 4 and 5, it is assumed that 4 RHR pumps in the LPCI mode and 2 CS pumps are available for vessel injection and that the single active failure is failure of the loop select logic to pick the unbroken recirculation loop. It is assumed that during the first 10 minutes, the 4 RHR pumps are injecting at the runout flow rate of 15500 gpm and the 2 CS pumps are injecting at a flow rate of 4370 gpm per pump. Failure of the loop select logic results in the injection of LPCI flow directly through the break into the drywell.

Long-Term (after 10 minutes to beyond the time of peak suppression pool temperature)

Cases 4 and 5 assume that at 10 minutes the RHR pump(s) are kept in the LPCI injection mode and aligned with the RHR SW pump(s) to the RHR heat exchangers to accomplish

the long-term core and containment cooling. It is assumed that the LPCI flow continues to be injected directly through the break into the drywell airspace with a thermal mixing efficiency of 100% between the LPCI flow and the drywell atmosphere. Neither containment sprays nor suppression pool cooling mode are used for Cases 4 and 5.

Case 4 - Long-Term (*no off-site power*)

For Case 4, it is assumed that off-site power is unavailable. For this case, it is assumed that both RHR loops are available (one with each division). At 10 minutes, one of the RHR pumps in each division is turned off to allow alignment of one RHR SW pump. At 10 minutes, the operator throttles back the RHR pump flow to 4000 gpm per pump and the CS pump flow to 2700 gpm per pump. The long-term pump configuration is as follows:

2 Divisions Available

Each division has:

1 RHR heat exchanger (K = 143.1 Btu/sec-°F)

1 RHR pump in LPCI injection mode with a flow of 4000 gpm which is aligned to the RHR heat exchanger (RHR HX)

1 RHR SW pump with a flow of 3500 gpm

1 CS pump with a flow of 2700 gpm

Case 5- Long-Term (*off-site power available*)

For Case 5 off-site power is assumed to be available. Therefore, for Case 5 it is assumed that both RHR pumps for each division can be aligned to the RHR HX along with two RHR SW pumps for long-term cooling after 10 minutes. At 10 minutes, the operator throttles back the RHR pump flow to 4000 gpm per pump and the CS pump flow to 2700 gpm per pump. The long-term pump configuration is as follows:

2 Divisions Available

Each division has:

1 RHR heat exchanger (K = 192.3 Btu/sec-°F)

2 RHR pumps in LPCI injection mode with a flow of 8000 gpm which is aligned to the RHR HX

2 RHR SW pumps with a flow of 7000 gpm

1 CS pump with a flow of 2700 gpm

Cases 6 and 7 (LPCI Injection Valve Failure)

Short-Term (0-10 minutes)

In Cases 6 and 7, the failure of the LPCI Injection Valve is assumed. Therefore, it is assumed that only the two CS pumps are available (one from each division) for vessel injection. It is assumed that the CS pumps inject into the vessel at 4370 gpm per pump during the first 10 minutes.

Long-Term (after 10 minutes to beyond the time of peak suppression pool temperature)

Cases 6 and 7 assume that at 10 minutes, the RHR pump(s) are put into containment spray mode (including drywell and suppression chamber sprays) and aligned with the RHR SW pump(s) to the RHR heat exchangers to accomplish the long-term containment cooling.

Case 6 - Long-Term (*no off-site power*)

For Case 6, it is assumed that off-site power is unavailable. For this case it is assumed that both RHR loops are available (one with each division). At 10 minutes, one of the RHR pumps in each division is turned off to allow alignment of one RHR SW pump.

The other RHR pump is switched to containment spray mode and aligned with the RHR SW pump and RHR HX for long term containment cooling. It is further assumed that the operator throttles back the RHR pump flow to 4000 gpm per pump and the CS pump flow to 2700 gpm per pump. The long-term pump configuration is as follows:

2 Divisions Available

Each division has:

1 RHR heat exchanger (K = 143.1 Btu/sec-°F)

1 RHR pump in containment spray mode with a total flow of 4000 gpm (3800 gpm to the drywell and 200 gpm to the suppression chamber airspace) which is aligned to the RHR HX

1 RHR SW pump with a flow of 3500 gpm

1 CS pump with a flow of 2700 gpm

Case 7 - Long-Term (*off-site power available*)

For Case 7, off-site power is assumed to be available. Therefore, for Case 7 it is assumed that both RHR pumps for each division can be switched to containment spray mode and aligned to the RHR HX along with 2 RHR SW pumps for long-term cooling after 10 minutes. It is further assumed that the operator throttles back the RHR pump flow to 4000 gpm per pump and the CS pump flow to 2700 gpm per pump. The long-term pump configuration is as follows:

2 Divisions Available

Each division has:

1 RHR heat exchanger (K = 192.3 Btu/sec-°F)

2 RHR pumps in containment spray mode with a total flow of 8000 gpm (7600 gpm to the drywell and 400 gpm to the suppression chamber airspace) which is aligned to the RHR HX

2 RHR SW pumps with a flow of 7000 gpm

1 CS pump with a flow of 2700 gpm

Benchmark Analyses

Benchmark analyses of the DBA-LOCA with the GE SHEX containment code are documented in Appendix A which are used to validate the results of the SHEX analyses for Monticello.

5.0 REFERENCES

1. NEDO-32418, "Monticello Design Basis Accident Containment Pressure and Temperature Response for USAR Update," December 1994.

2. NEDO-21052, "Maximum Discharge Rate of Liquid-Vapor Mixtures from Vessels," General Electric Company, September 1975.

3. "Decay Heat Power in Light Water Reactors," ANSI/ANS - 5.1 - 1979, Approved by American National Standards Institute, August 29, 1979.

4. NEDM-10320, "The GE Pressure Suppression Containment System Analytical Model," March 1971.

5. NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," June 1974.

6. NEDE-30911, "SHEX-04 User's Manual," August 1985, (GE Company Proprietary).

7. NRC Information Notice 96-55: Inadequate Net Positive Suction Head of Emergency Core Cooling and Containment Heat Removal Pumps Under Design Basis Accident Conditions.

TABLE 1 - SUMMARY OF SHORT-TERM ANALYSIS RESULTS

CASE	1	2
Initial Power* (MWt)	1670	1880
Heat Sinks	Yes	Yes
% Thermal Mixing	100	100
Initial Drywell Pressure (psia)	14.26	14.26
Initial Suppression chamber airspace Pressure (psia)	14.26	14.26
Suppression Pool Temperature at 600 sec (°F)	148.2	149.1
Suppression chamber air space Pressure at 600 sec (psia)	16.65	16.86
Vapor Pressure at Pool Temp (°F)	3.56	3.64
Available NPSH Pressure Term (Pa-Pv) = Wetwell pressure - Vapor Pressure (psi)	13.09	13.22

* Analyses performed at 102% of initial core thermal power

TABLE 2 - SUMMARY OF LONG-TERM ANALYSIS RESULTS

CASE	3	4	5	6	7
Initial Power[1] (MWt)	1880	1880	1880	1880	1880
Heat Sinks	No	Yes	Yes	Yes	Yes
% Thermal Mixing Vessel Break Flow	20	20	20	20	20
% Thermal Mixing LPCI Inj. Flow	N/A	100	100	N/A	N/A
K (BTU/sec-°F) total	143.1	286.2	384.6	286.2	384.6
Single Failure	1 DIESEL GEN.	LPCI LOOP SELECT	LPCI LOOP SELECT	LPCI INJ. VALVE	LPCI INJ. VALVE
Off-Site Power	NO	NO	YES	NO	YES
Containment Spray	YES	NO	NO	YES	YES
Initial Drywell & Supp. Chamb. Pressure (psia)	14.26	14.26	14.26	14.26	14.26
Pool Temp at 600s (°F)	145.0[4]	149.3[2]	149.3[2]	142.3[3]	142.3[3]
Supp. Chamb. Press. at 600s (psia)	31.61[4]	16.31[2]	16.31[2]	31.10[3]	31.10[3]
Peak Suppression Pool Temperature (°F)	194.2	169.0	162.3	168.7	162.2
Suppression Chamber Airspace Pressure Coincident with Peak Suppression Pool Temperature (psia)	21.13	18.45	17.75	17.75	17.70
Vapor Pressure at Peak Pool Temp (°F)	10.21	5.856	5.008	5.816	4.996
Available NPSH Pressure Term (Pa-Pv) = Wetwell pressure - Vapor Pressure (psi)	10.92	12.59	12.74	11.93	12.70

1. Analyses performed at 102% of initial core thermal power
2. Values obtained at 597 sec
3. Value at 595 sec
4. Value at 590 sec

TABLE 3 - INPUT PARAMETERS FOR CONTAINMENT ANALYSES

Parameter	Units	Value Used In Analysis
Core Thermal Power	MWt	1880*
Vessel Dome Pressure	psia	1040
Drywell Free (Airspace) Volume (including vent system)	ft^3	134,200
Initial Suppression Chamber Free (Airspace) Volume		
Low Water Level (LWL)	ft^3	108,250
Initial Suppression Pool Volume		
Min. Water Level	ft^3	68,000
Number of Downcomers		96
Total Downcomer Flow Area	ft^2	289.65
Initial Downcomer Submergence		
Low Water Level	ft	3.0
Downcomer I.D.	ft	1.96
Vent System Flow Path Loss Coefficient (includes exit loss)		5.17
Supp. Chamber (Torus) Major Radius	ft	49.0
Supp. Chamber (Torus) Minor Radius	ft	13.883
Suppression Pool Surface Area (in contact with suppression chamber airspace, minimum level)	ft^2	8429

* Initial Core Thermal Power of 1670 assumed for Case 1. Analyses performed at 102% of initial core thermal power.

TABLE 3 - INPUT PARAMETERS FOR CONTAINMENT ANALYSES (continued)

Parameter	Units	Value Used in Analysis
Suppression Chamber-to-Drywell Vacuum Breaker Opening Diff. Press.		
- start	psid	0.096
- full open	psid	0.242
Supp. Chamber-to-Drywell Vacuum Breaker Valve Opening Time	sec	1.0
Supp. Chamber-to-Drywell Vacuum Breaker Flow Area (per valve system)	ft^2	1.65
Supp. Chamber-to-Drywell Vacuum Breaker Flow Loss Coefficient (including exit loss)		3.804
No. of Supp. Chamber-to-Drywell Vacuum Breaker Valve Assemblies (2 valves per assembly)		6
RHR Heat Exchanger K in Containment Cooling Mode	Btu/sec-°F	See Table 2
RHR Service Water Temperature	°F	90
RHR Pump Heat (per pump)	hp	600
Core Spray Pump Heat (per pump)	hp	800
Time for Operator to Turn On RHR System in Containment Cooling Mode (after LOCA signal)	sec	600

TABLE 3 - INPUT PARAMETERS FOR CONTAINMENT ANALYSES
(continued)

Feedwater Addition (to RPV after start of event; mass and energy)

For Case 1 (102% of 1670 MWt)

Feedwater Node **	Mass (lbm)	Enthalpy* (Btu/lbm)
1	39,064	341.0
2	27,344	319.7
3	19,956	301.8
4	54,639	282.5
5	113,414	218.0

For Cases 2-7 (102% of 1880 MWt)

Feedwater Node **	Mass (lbm)	Enthalpy* (Btu/lbm)
1	39,064	355.6
2	27,344	333.4
3	19,956	314.7
4	54,639	294.6
5	113,414	227.3

* Includes sensible heat from the feedwater system piping metal.

** Feedwater mass and energy data combined to fit into 5 nodes for use in the analysis.

TABLE 4 - PUMP CONFIGURATION FOR CONTAINMENT ANALYSES

	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7
No of Divisions	2	2	1	2	2	2	2
<u>No. of RHR Pumps Per Division</u>							
0- 600 SEC	2	2	2	2	2	0	0
AFTER 600 SECONDS	N/A	N/A	1	1	2	1	2
<u>No of CS Pumps Per Division</u>							
0-600 SEC	1	1	1	1	1	1	1
AFTER 600 SEC	N/A	N/A	1	1	1	1	1
<u>No of RHR SW Pumps Per Division</u>	N/A	N/A	1	1	2	1	2
<u>CS PUMP FLOW PER DIVISION GPM</u>							
0-600 SEC	4370	4370	2700	4370	4370	4370	4370
AFTER 600 SECONDS	N/A	N/A	2700	2700	2700	2700	2700
<u>RHR PUMP FLOW PER DIVISION</u>							
0-600 SEC							
LPCI vessel injection	0	0	7740	0	0	0	0
LPCI inj. to DW	15,500	15,500	0	15,500	15,500	0	0
AFTER 600 SEC							
LPCI inj. to DW	N/A	N/A	0	8,000	16,000	0	0
Drywell Spray	N/A	N/A	3800	0	0	3800	7600
Suppression Chamber Spray	N/A	N/A	200	0	0	200	400
RHRSW PUMP FLOW PER DIVISION	N/A	N/A	3500	3500	7000	3500	7000

APPENDIX A
SHEX BENCHMARK ANALYSES

To validate the results of the SHEX analyses for Monticello, benchmark analyses are performed with the SHEX code with input assumptions which are consistent with the inputs used in the HXSIZ analyses of NEDO-32418 (Reference A-1). Reference A-1 documents the results of containment analyses performed with the HXSIZ containment code to update the licensing basis for the DBA-LOCA containment pressure and temperature with the assumed failure of one diesel generator.

HXSIZ was used to perform the current USAR DBA-LOCA long-term containment analysis. The HXSIZ code calculates the long-term DBA-LOCA containment response beyond 10 minutes when operator actions to initiate containment cooling are assumed. The HXSIZ analysis also assumes that by 10 minutes into the DBA-LOCA drywell and suppression chamber airspace pressure are equal and that the drywell temperature is equal to the vessel temperature. The GE M3CPT code was used in the current USAR analysis to calculate containment response for the first 10 minutes of the DBA-LOCA. The inputs to the USAR HXSIZ analysis uses the end conditions calculated with the GE M3CPT computer code at 10 minutes to establish the initial conditions for the HXSIZ calculation.

The validation process is as described below:

> Benchmark analyses of the DBA-LOCA are performed with the GE SHEX containment code. The results of the SHEX benchmark cases are then compared to the results of analyses performed with the GE HXSIZ code in Reference A-1 for the DBA-LOCA. The HXSIZ code is the code used in the current licensing basis for Monticello.
>
> Two benchmark cases are included which are performed with the SHEX code at 102% of 1670 MWt (initial power used in Reference A-1 analyses). SHEX Benchmark Case A-1 uses the nominal ANS 5.1 -1979 decay heat without adders used for Case 1 of Reference A-1. SHEX Benchmark Case A-2 uses the May-Witt decay heat curve used for Case A.2 of Reference A-1. Other input assumptions and input parameters for the two SHEX benchmark cases are

consistent with the input assumptions used for Case 1 and Case A.2 of Reference A-1.

The results of SHEX Benchmark Case A-1 are compared to the results of Case 1 of Reference A-1. The results of SHEX Benchmark Case A-2 are compared to the results of Case A.2 of Reference A-1.

Comparisons between SHEX and HXSIZ are made for the long-term response which is defined here as the time between 10 minutes (when operator action is credited including initiation of containment cooling) and the time period past the time of the peak suppression pool temperature.

These comparisons will demonstrate the impact on the long-term containment response of switching from HXSIZ to the SHEX containment code.

It should be noted that the HXSIZ code can only model the long-term response for only the DBA-LOCA and only with assumptions which maximize drywell and suppression chamber airspace pressure. Therefore the validation process is only intended to demonstrate that the SHEX and HXSIZ code produce similar results (suppression pool temperature and suppression chamber airspace pressure) for the DBA-LOCA with consistent assumptions which maximize suppression chamber airspace pressure.

The containment input parameters used in the SHEX benchmark analyses for the DBA-LOCA are very similar to the inputs used for the current SHEX analysis of the DBA-LOCA with a diesel generator failure and no off-site power (Case 3 in the main body of this report).

Differences between the benchmark analyses and Case 3 are; 1) inputs used for feedwater, 2) initial conditions and assumptions which are used to maximize instead of to minimize the long-term suppression chamber airspace pressure, and 3) initial reactor power. The feedwater (FW) inputs for the benchmark SHEX cases use the feedwater enthalpy vs. feedwater mass table from Reference A-1 (see Table A-1). The current SHEX analyses (including Case 3) use FW inputs based on a more rigorous treatment of the metal energy contribution (see Table 3 of this report).

The inputs used for the Reference A-1 analysis and SHEX benchmark analyses are intended to maximize the suppression chamber airspace pressure, not minimize the suppression chamber airspace pressure as for Case 3. These differences include initial drywell and suppression chamber airspace pressure, initial drywell relative humidity, heat and mass transfer between the suppression pool and suppression chamber airspace and use of sprays. Differences in initial conditions and assumptions between Case 3 and the SHEX benchmark analysis for Case A-1 (ANS 5.1 nominal decay heat) are given in Table A-1.

The benchmark analyses are based on an initial reactor power of 102% of 1670 MWt (1703 MWt) which is the initial power used in Reference A-1. Case 3 is based on an initial bounding thermal power of 102% of 1880 MWt.

Decay Power Curves used for Benchmark Analyses

Table A-2 provides the core heat (Btu/sec) based on the May-Witt (Reference A-3) decay heat model. The core heat includes decay heat (May-Witt), metal-water reaction energy, fission power and fuel relaxation energy. The core heat in Table A-2 is normalized to the initial core thermal power of 1703 MWt.

Table A-3 provides the core heat (Btu/sec) based on the ANS 5.1-1979 (Reference A-4) decay heat model. The core heat includes decay heat (ANS 5.1-1979), metal-water reaction energy, fission power and fuel relaxation energy. The core heat in Table A-3 is normalized to the initial core thermal power of 1703 MWt.

RESULTS DISCUSSION.

Table A-4 which summarizes the results of Cases A-1 and A-2 compares the esults of the benchmark analysis with the results from Reference A-1. Figure A-1 compares the suppression pool temperature response obtained with the benchmark SHEX calculation with the results obtained in Reference A-1. Figure A-2 compares the suppression chamber airspace pressure response obtained with the benchmark SHEX calculation with the results obtained in Reference A-1.

Suppression Pool Temperature

A comparison of the peak suppression pool temperatures obtained with the SHEX code to the values obtained with the HXSIZ code show that there is little difference (about 1°F) in the peak suppression pool temperature predicted by both codes with the use of either May Witt or ANS 5.1 decay heat. A comparison of the suppression pool temperature response curves shown in Figure A-1 also shows close comparison between the SHEX and HXSIZ results with the use of either decay heat.

Suppression chamber airspace Pressure

A comparison of the peak long-term secondary containment pressure (near time of peak suppression pool temperature) shows close comparison (<1 psi) between the results obtained with HXSIZ and SHEX. The curves in Figure A-2 also show that the pressure responses near the time of the secondary peak are similar with either containment code.

The large differences in the code predictions indicated between 600 and approximately 10,000 seconds is attributed to simplifying assumptions which are used in the HXSIZ models. These include the assumption that the vessel temperature and drywell temperature are equal and that the drywell and suppression chamber airspace pressure are equal. However, the most significant assumption is that the HXSIZ code assumes that all the vessel metal internals are submerged. Since this included vessel metal nodes which were previously not submerged during the M3CPT simulation portion of the M3CPT/HXSIZ (0-10 min) analysis and which are therefore at a high temperature (>500°F) at ten minutes, this results in a step increase in energy to the vessel at 10 minutes when the HXSIZ calculation starts. This effect is magnified by the fact that at ten minutes vessel injection from the 2 LPCI pumps is terminated and only vessel injection from 1 CS pump is assumed. As a result the vessel temperature rapidly increases which produces a similar increase in drywell temperature and consequently in the containment pressure. This produces the large containment overpressure response between 600 and near 10,000 seconds with HXSIZ.

CONCLUSIONS

Based on the comparisons described above it concluded that the long-term suppression pool temperature and suppression chamber airspace pressure response calculated with the

SHEX model are consistent with the HXSIZ results. The comparisons also demonstrate that the more detailed SHEX containment code allows a more accurate prediction of the containment pressure and temperature response for the entire event duration. The additional features in SHEX such as the modeling of vacuum breakers, heat sinks and containment sprays allow for a better prediction capability for a variety of events which could not be modeled with the HXSIZ code.

TABLE A-1

INPUT DIFFERENCES BETWEEN CASE 3 AND SHEX BENCHMARK CASE A-1 FOR DBA-LOCA

PARAMETER	BENCHMARK CASE A-1			CASE 3		
Code	SHEX			SHEX		
Initial Reactor Power (MWt)	102% of 1670			102% of 1880		
Initial Drywell Pressure (psia)	15.7			14.26		
Initial Drywell Rel. Humidity	20%			100%		
Initial Suppression Chamber Airspace Pressure (psia)	15.7			14.26		
Containment Cooling Mode	Suppression Pool Cooling			Containment Sprays		
Heat and Mass Transfer between Suppression Pool and Suppression Chamber Air Space	Thermal Equilibrium and Saturated Conditions Imposed			Heat and Mass Transfer calculated mechanistically.		
Thermal Mixing Efficiency Between break flow and drywell atmosphere	100%			20%		
Feedwater Inputs*	Node	lbm	Btu/lbm	Node	lbm	Btu/lbm
	1	39063	346.1	1	39063	355.6
	2	27344	308.1	2	27344	333.4
	3	74594	275.9	3	19956	314.7
	4	37361	201.4	4	54639	294.6
				5	113414	227.3

*The feedwater table shown above gives the feedwater mass added and associated feedwater enthalpy. This table reflects feedwater temperature conditions in the feedwater train prior to the DBA-LOCA. Each node corresponds to a section of the feedwater train with feedwater at a lumped temperature. Only the portion of the feedwater in the feedwater train with a temperature higher than the peak suppression pool temperature was added.

TABLE A-2
CORE HEAT (May-Witt)

Time (sec)	Core Heat*	Time (sec)	Core Heat*
0.	1.002	1000.	0.0223
0.1	1.007	2000.	0.0184
0.2	0.9658	4000.	0.0151
0.6	0.7111	6000.	0.0135
0.8	0.6521	8000.	0.0126
1.0	0.5328	10000.	0.0120
2.0	0.4866	20000.	0.0101
4.0	0.5477	40000.	0.008125
6.0	0.5681	1E5	0.006245
8.0	0.5391	2E5	0.005126
10.	0.4825	3E5	0.004096
20.	0.2069	4E5	0.003596
40.	0.05693	8E5	0.003196
60.	0.044	1E6	0.002985
80.	0.0413	1E8	0.002985
100.	0.03993		
200.	0.03365		
400.	0.02827		
600.	0.02549		
800.	0.02365		

*Core Heat (normalized to the initial core thermal power of 1703 MWt)
= decay heat + fission power + fuel relaxation energy + metal-water reaction energy

TABLE A-3

CORE HEAT (ANS 5.1-1979)

Time (sec)	Core Heat*	Time (sec)	Core Heat*
0.	1.006	10000.	0.00972
1.	0.5634	14400.	0.00928
4.	0.5319	18000.	0.00881
10.	0.3479	20000.	0.00859
20.	0.1092	28800.	0.00788
40.	0.0563	36000.	0.00748
60.	0.04050	60000.	0.00658
80.	0.0385	1E5	0.00572
120.	0.0363	4E5	0.00353
120.**	0.0303	8E5	0.00261
200.	0.0274	1E6	0.00237
400.	0.0241	2E6	0.00175
600.	0.0221		
1000.	0.0196		
2000.	0.0160		
4000.	0.0127		
6000.	0.0112		
8000	0.0103		

*Core Heat (normalized to the initial core thermal power of 1703 MWt)
= decay heat + fission power + fuel relaxation energy + metal-water reaction energy

** Metal-water reaction heat is assumed to end at 120 seconds.

TABLE A-4 - SUMMARY OF ANALYSIS RESULTS

CASE	A-1	CASE 1 REF. A-1	A-2	CASE A.2 REF. A-1
Code	SHEX	M3CPT/ HXSIZ	SHEX	M3CPT/ HXSIZ
Rated Power* (MWt)	1670	1670	1670	1670
Decay Heat	ANS 5.1	ANS 5.1	May Witt	May Witt
K (BTU/sec-°F) total	143.1	143.1	143.1	143.1
Initial Drywell & Supp. Chamb. Airspace Pressure (psia)	15.7	15.7	15.7	15.7
Pool Temp at 600s (°F)	142.3	145.0	144.6	146.0
Peak Suppression Pool Temperature (°F)	184.8	184.0	196.7	195.5
Secondary Suppression Chamber Airspace Pressure Peak (psia)	31.4	31.3	36.8	36.3

* Analyses performed at 102% of initial core thermal power.

REFERENCES

A-1 NEDO-32418, "Monticello Design Basis Accident Containment Pressure and Temperature Response for USAR Update," December 1994.

A-2 NEDC-24387-P, "Monticello Nuclear Generating Plant Suppression Pool Temperature Response," Dec. 1981.

A-3 NEDO-10625, "Power Generation in a BWR Following Normal Shutdown or Loss-Of-Coolant Accident Conditions," March 1973.

A-4 "Decay Heat Power in Light Water Reactors," ANSI/ANS-5.1 - 1979, Approved by American National Standards Institute, August 29, 1979.

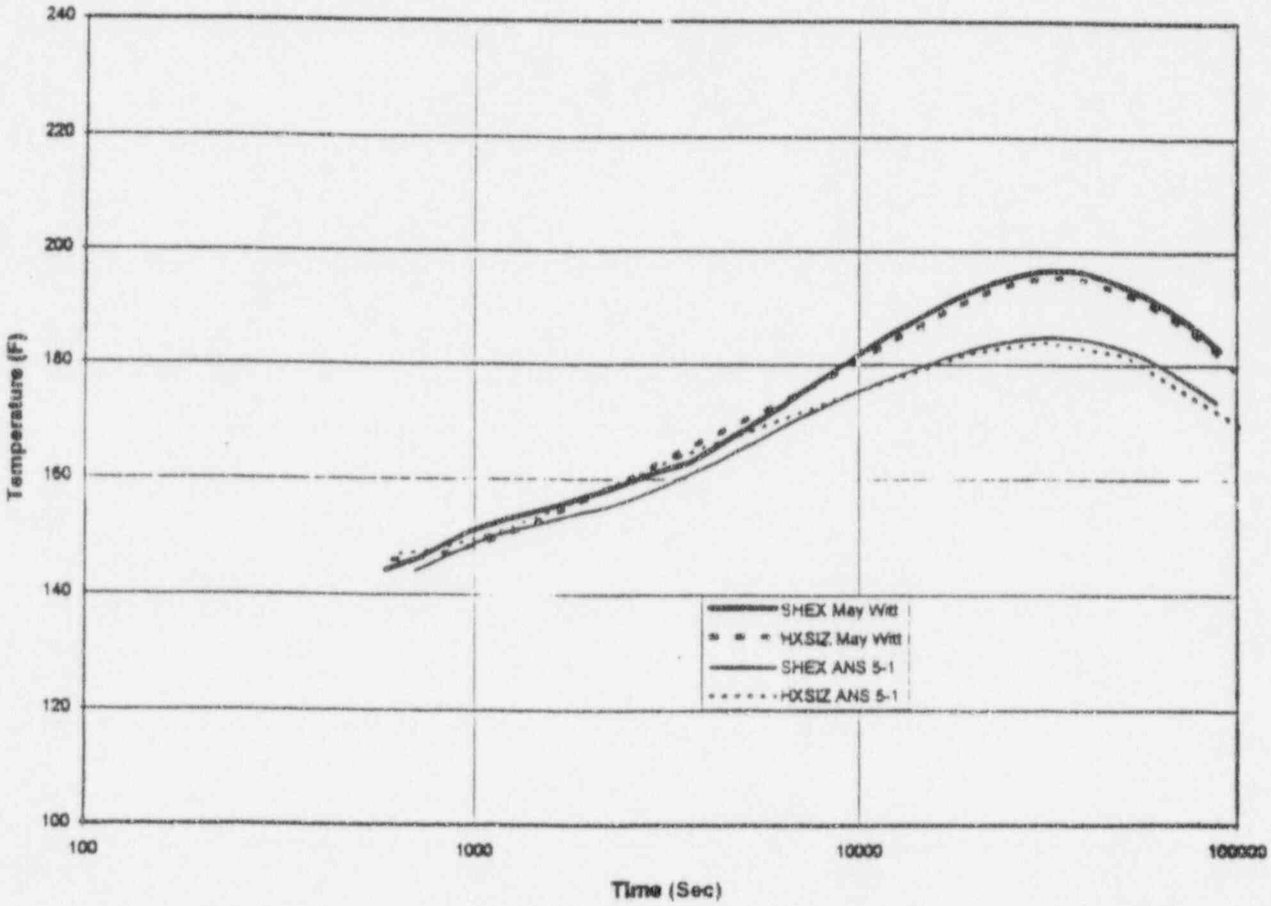

Figure A-1 - Suppression Pool Temperature Comparison

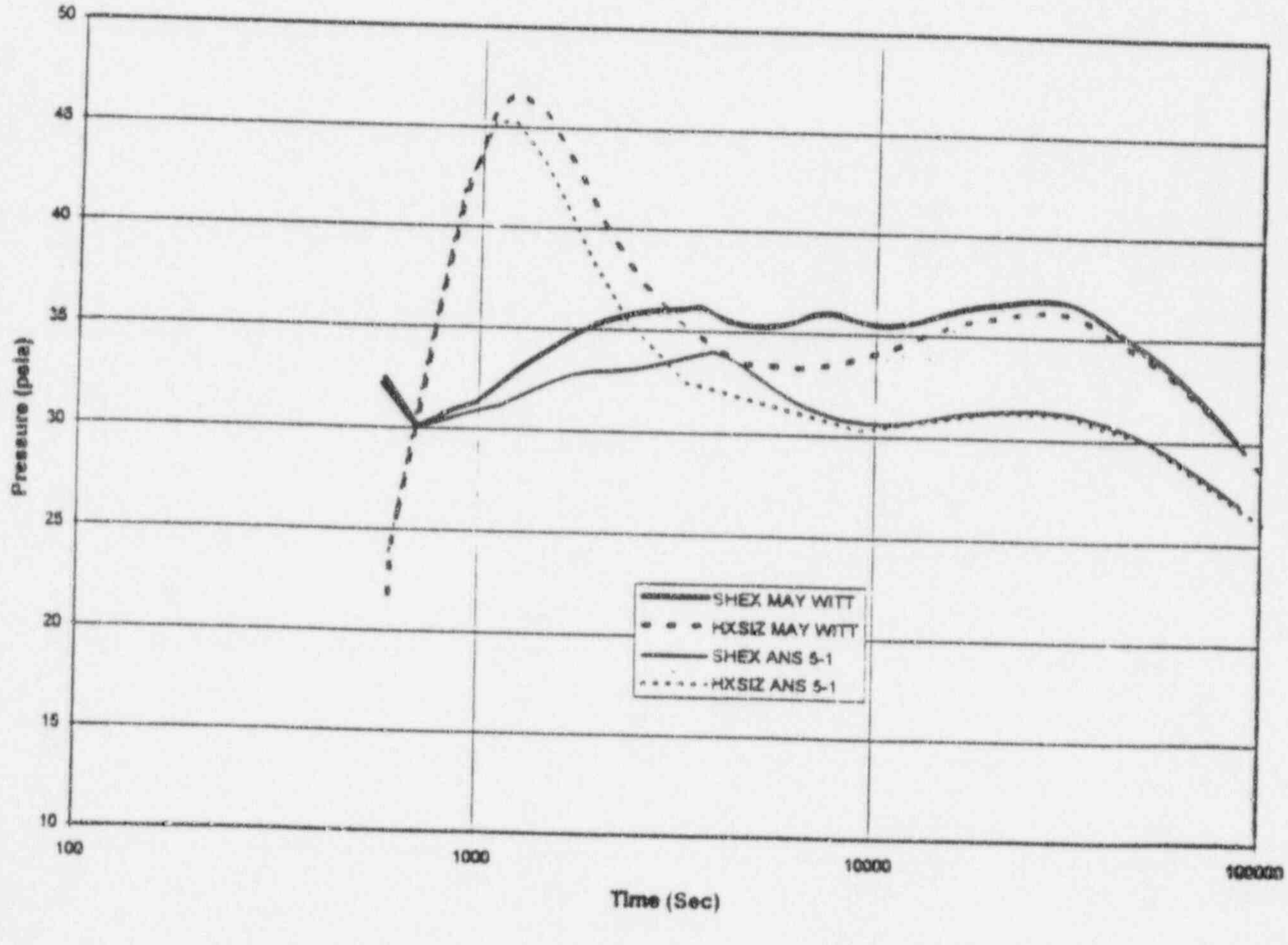

Figure A-2 - Suppression Chamber Pressure Comparison

APPENDIX B

FIGURES FOR SHEX CONTAINMENT ANALYSES

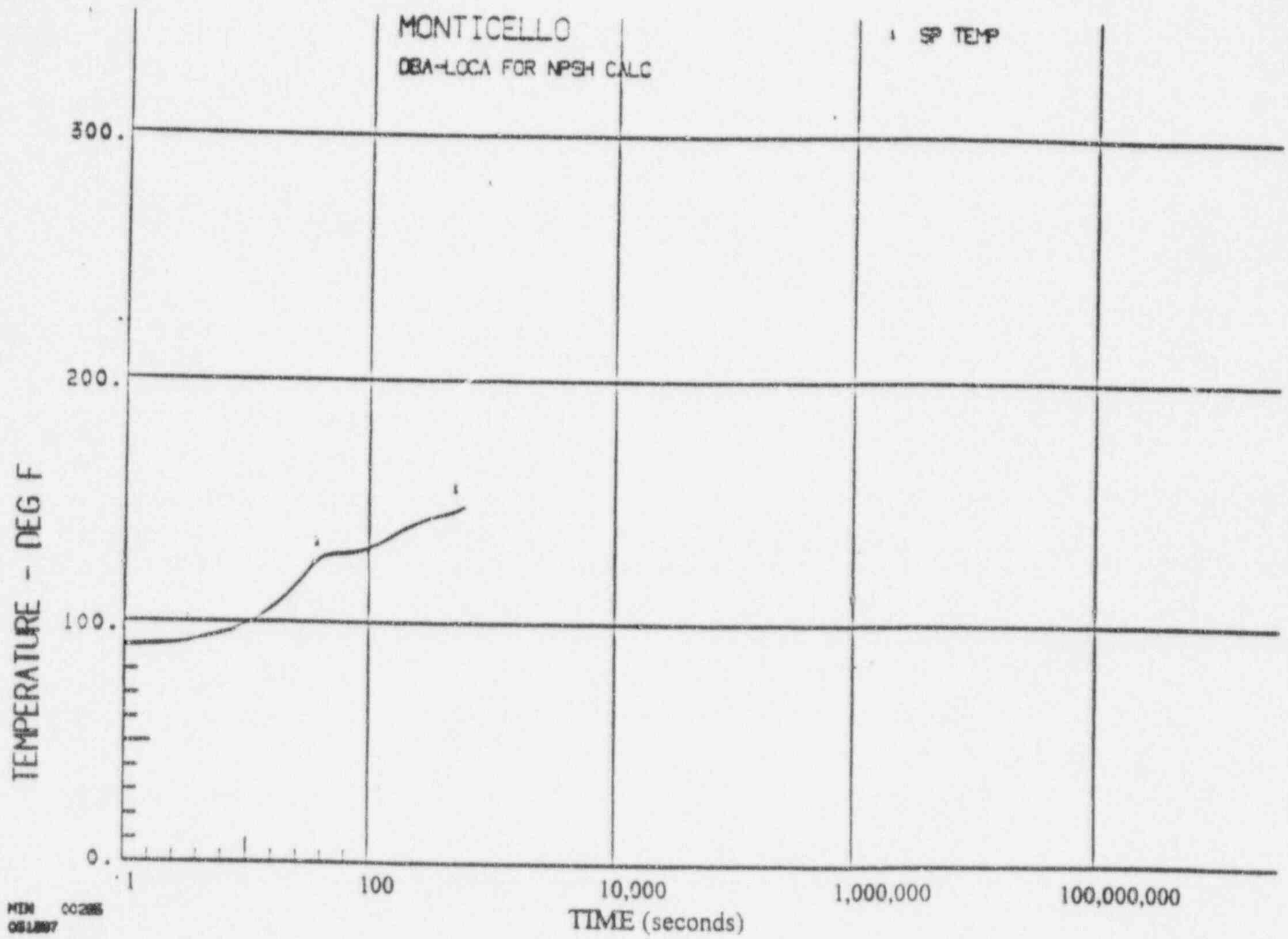

FIGURE B-1 Suppression Pool Temperature Response. Case 1, Short-Term Analysis, 102% of 1670 MWt,

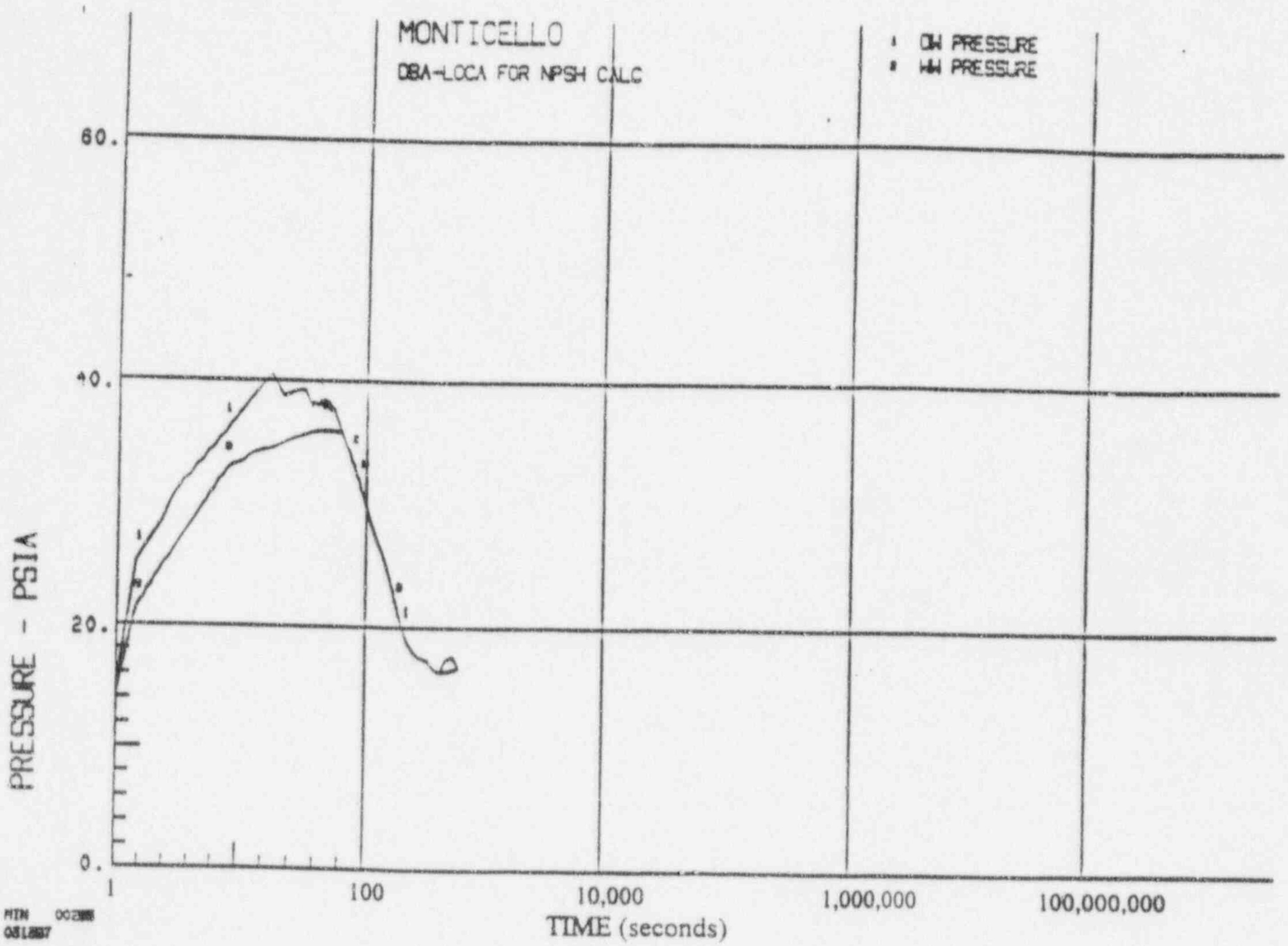

FIGURE B-2 Drywell and Suppression Chamber Pressure Response. Case 1, Short-Term Analysis, 102% of 1670 MWt

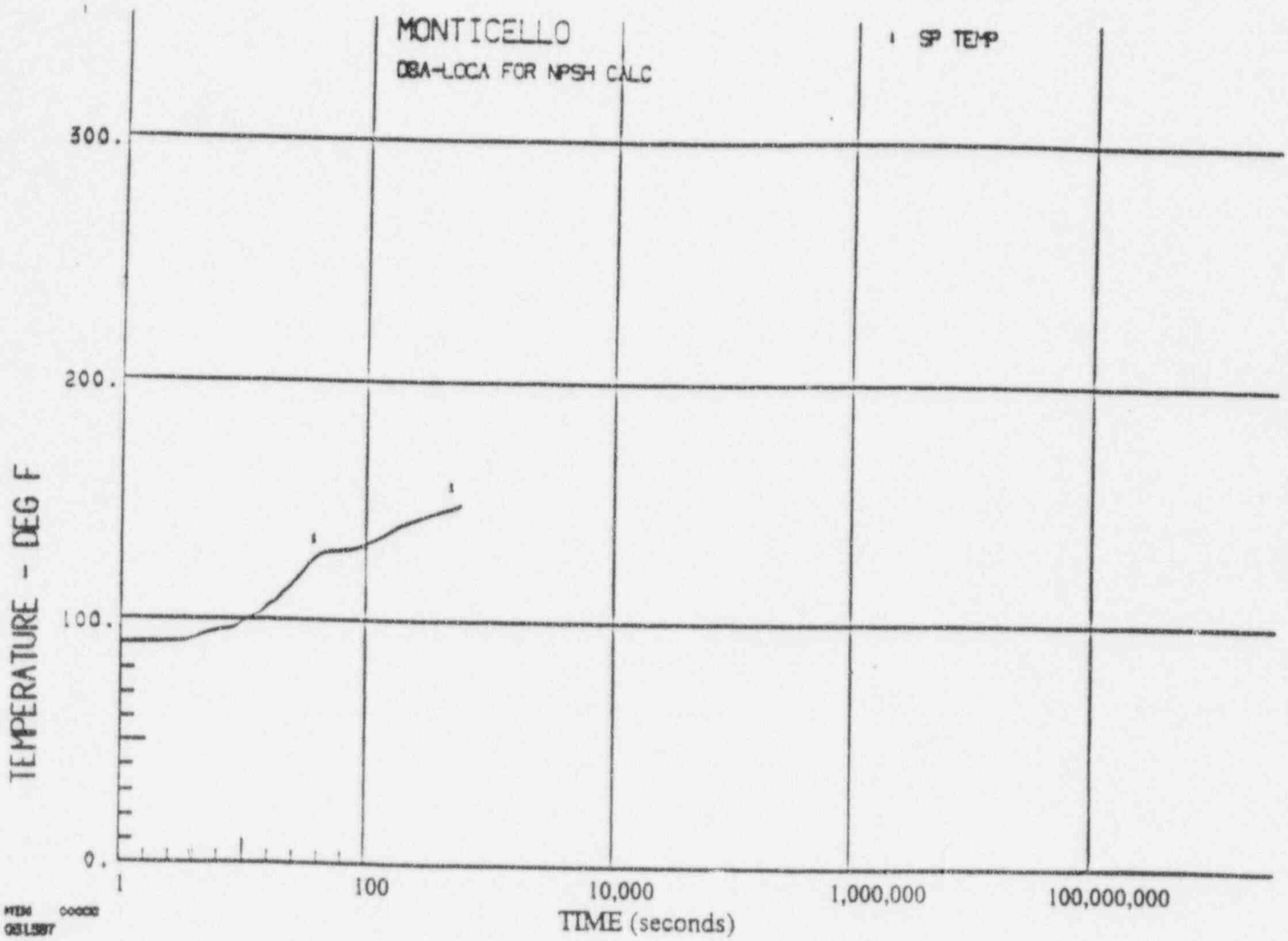

FIGURE B-3 Suppression Pool Temperature Response. Case 2, Short-Term Analysis, 102% of 1880 MWt

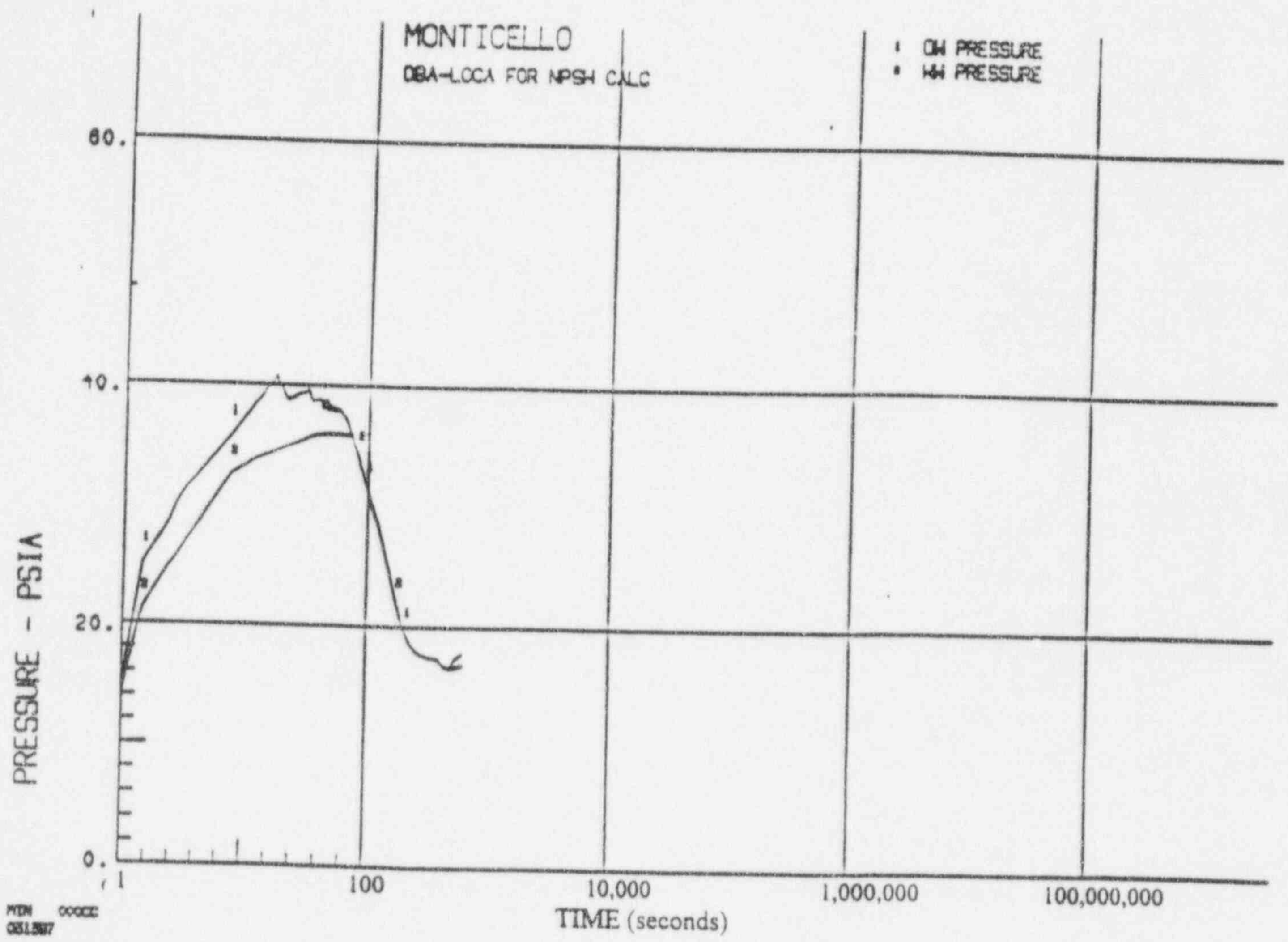

FIGURE B-4 Drywell and Suppression Chamber Pressure Response. Case 2, Short-Term Analysis, 102% of 1880 MWt

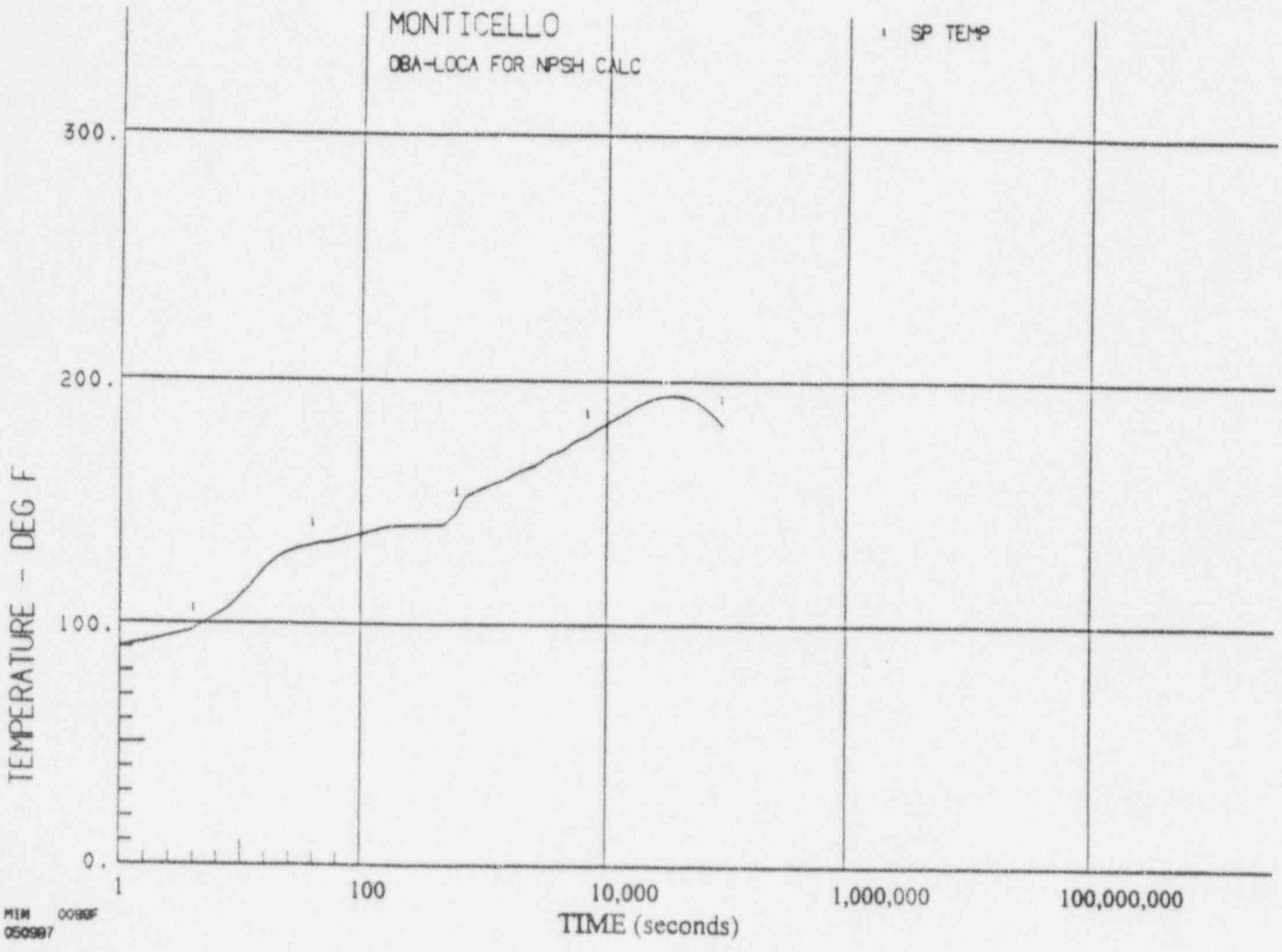

FIGURE B-5 Suppression Pool Temperature Response. Case 3, Long-Term Analysis, DBA-LOCA, No Off-site Power, Diesel Generator Failure, 102% of 1880 MWt

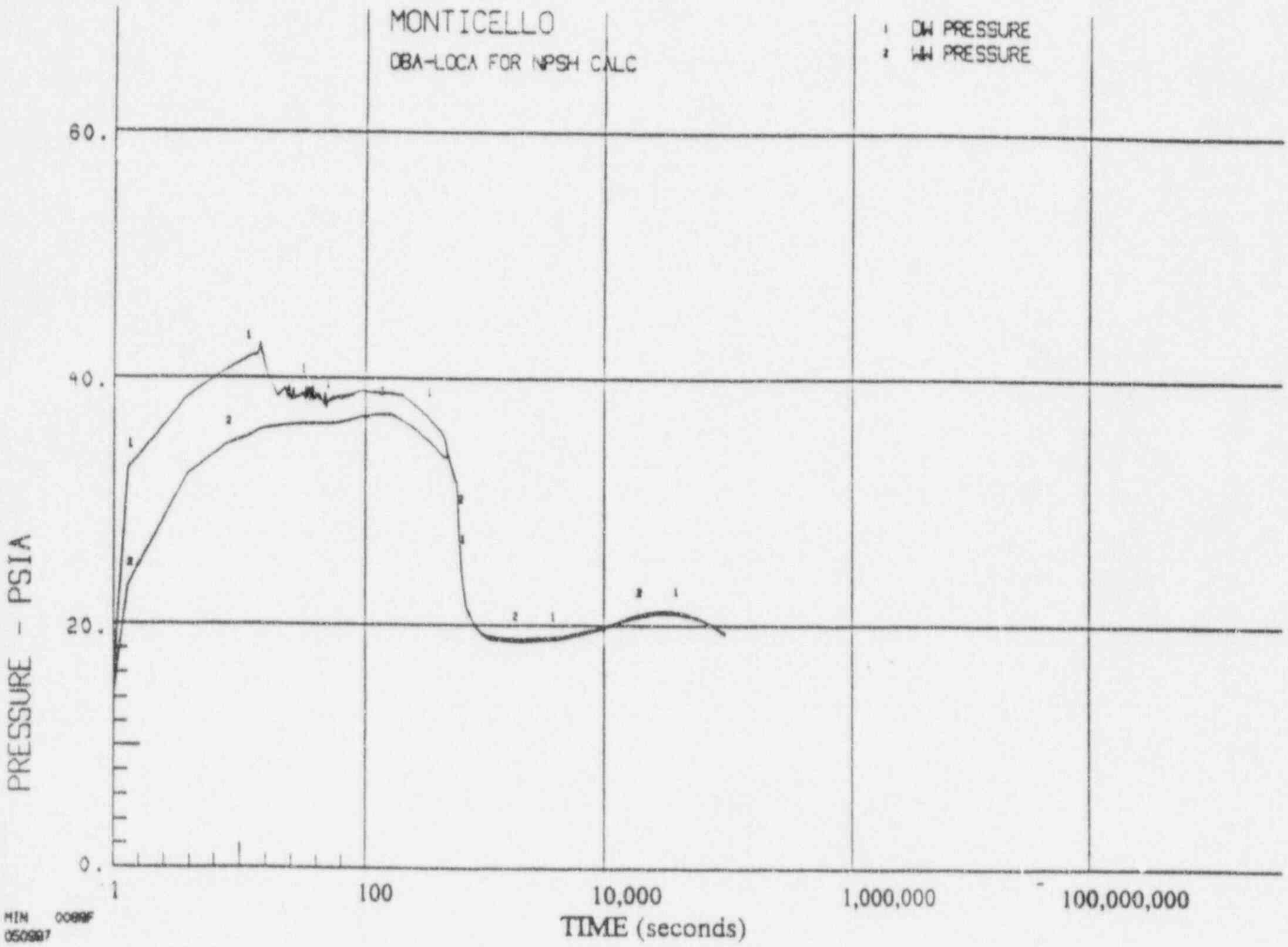

FIGURE B-6 Drywell and Suppression Chamber Pressure Response. Case 3, Long-Term Analysis, DBA-LOCA, No Off-site Power, Diesel Generator Failure, 102% of 1880 MWt

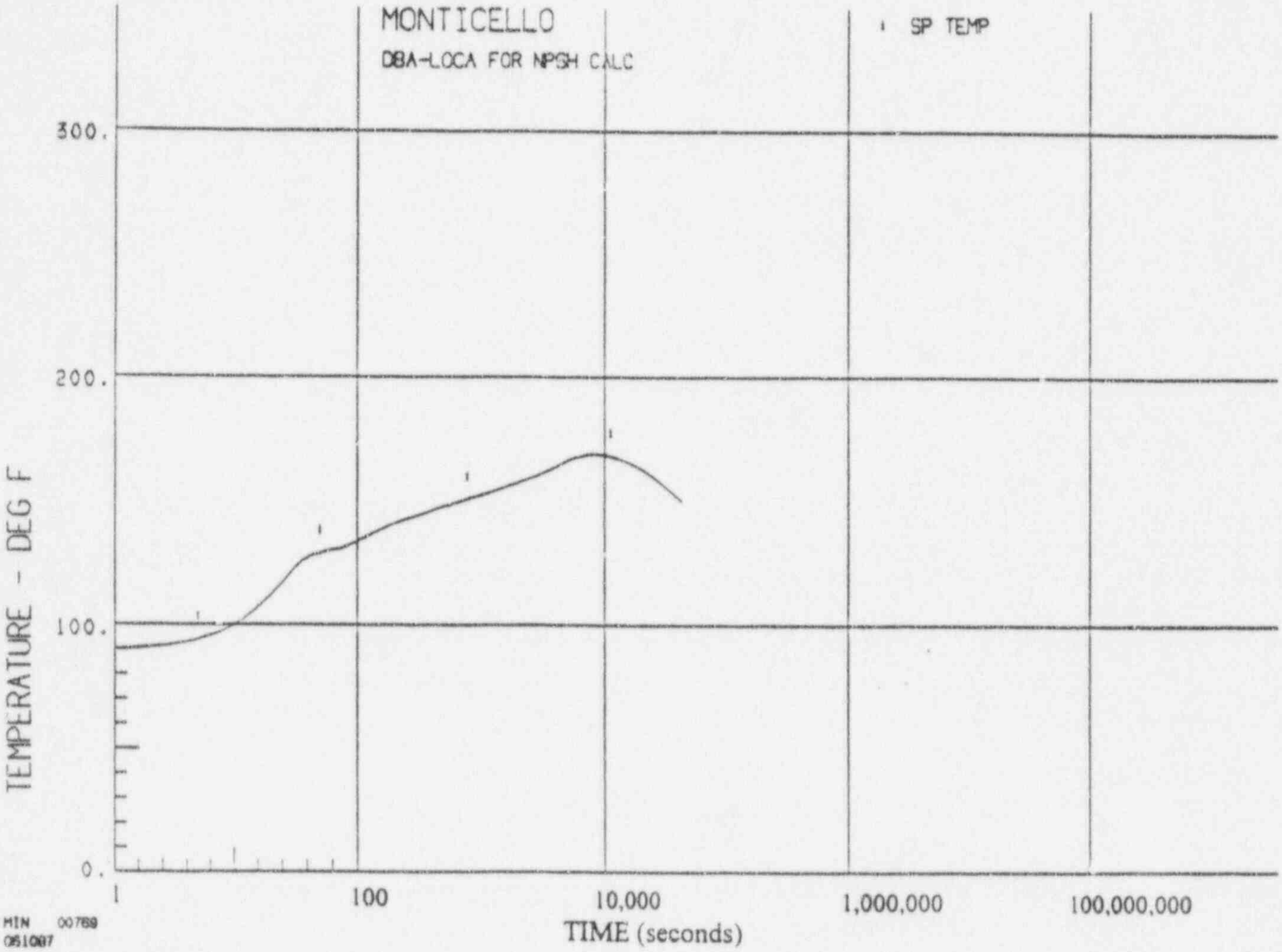

FIGURE B-7 Suppression Pool Temperature Response. Case 4, Long-Term Analysis, LOCA, No Off-site Power, LPCI Loop Select Failure, 102% of 1880 MWt

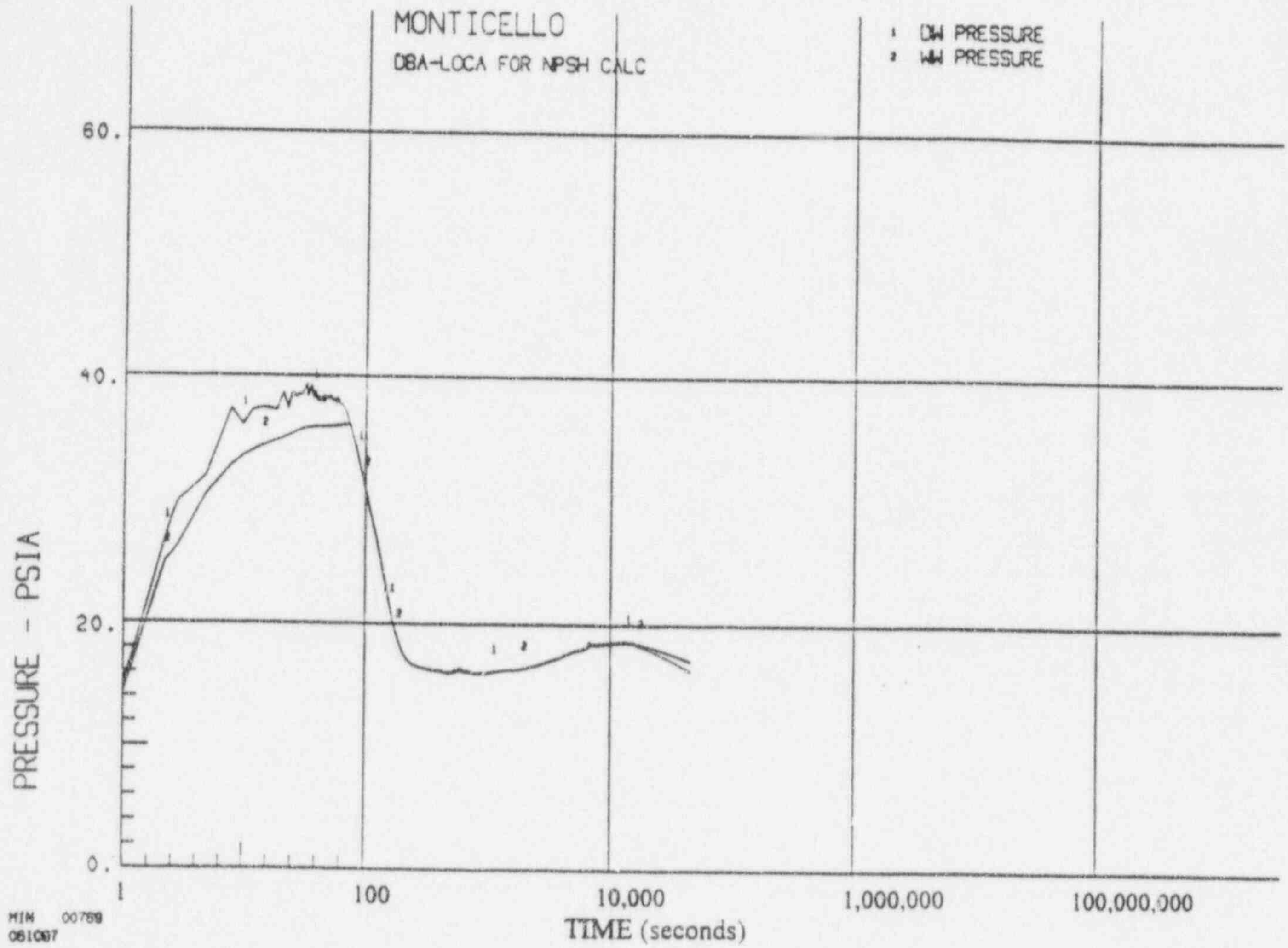

FIGURE B-8 Drywell and Suppression Chamber Pressure Response. Case 4, Long-Term Analysis, LOCA,No Off-site Power, LPCI Loop Select Failure, 102% of 1880 MWt

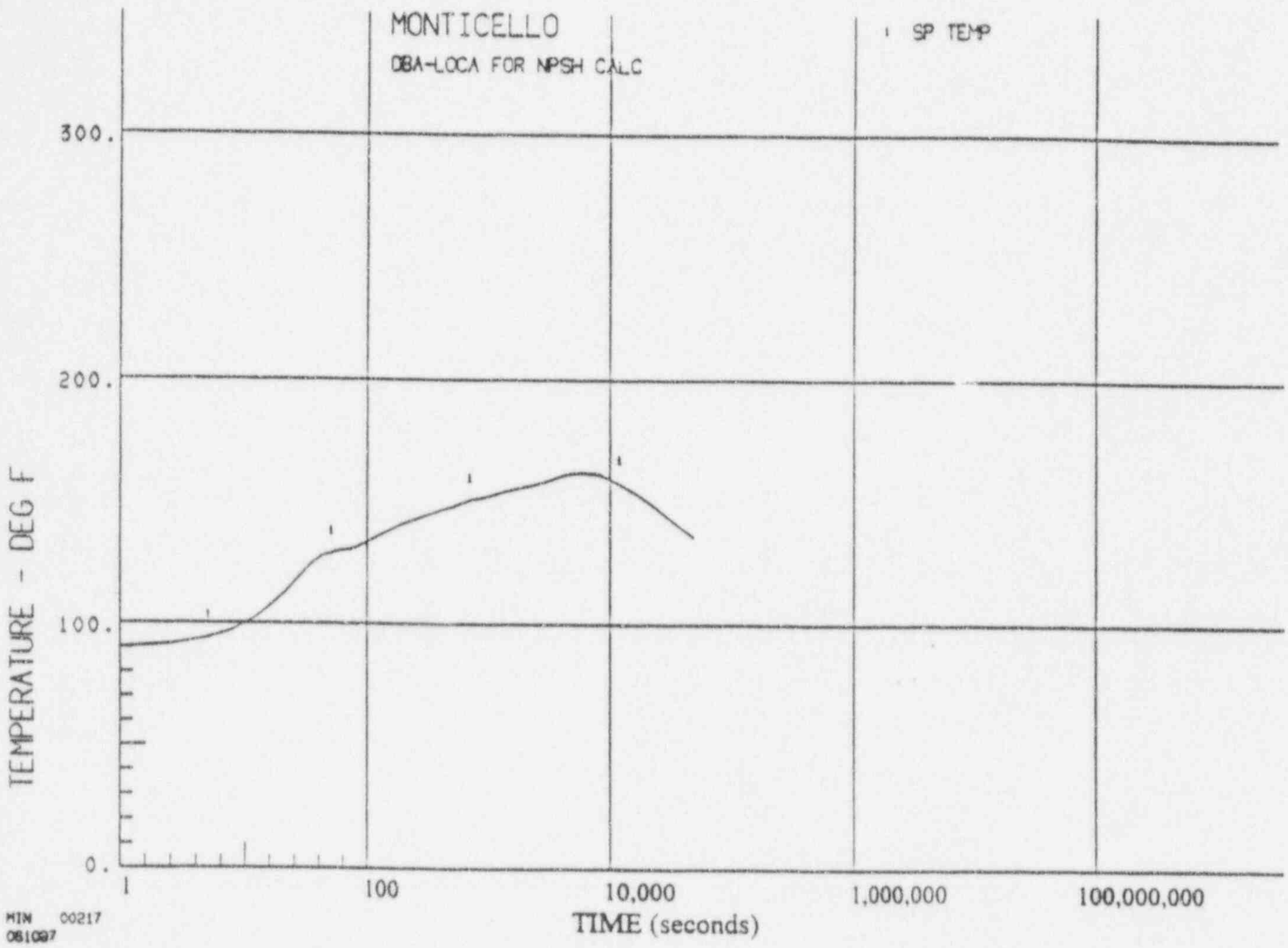

FIGURE B-9 Suppression Pool Temperature Response. Case 5, Long-Term Analysis, LOCA, Off-site Power, LPCI Loop Select Failure, 102% of 1880 MWt

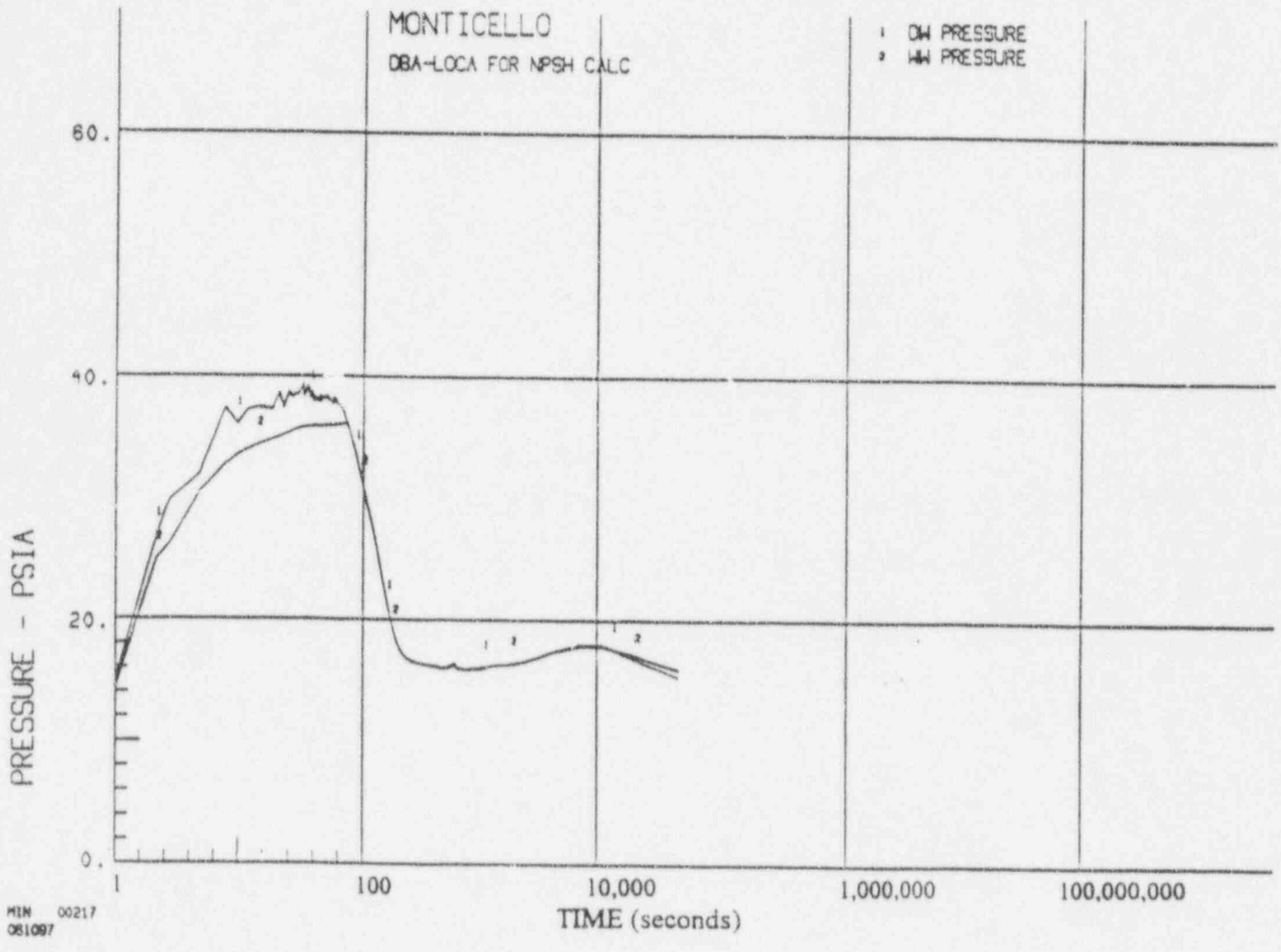

FIGURE B-10 Drywell and Suppression Chamber Pressure Response. Case 5, Long-Term Analysis, LOCA, Off-site Power, LPCI Loop Select Failure, 102% of 1880 MWt

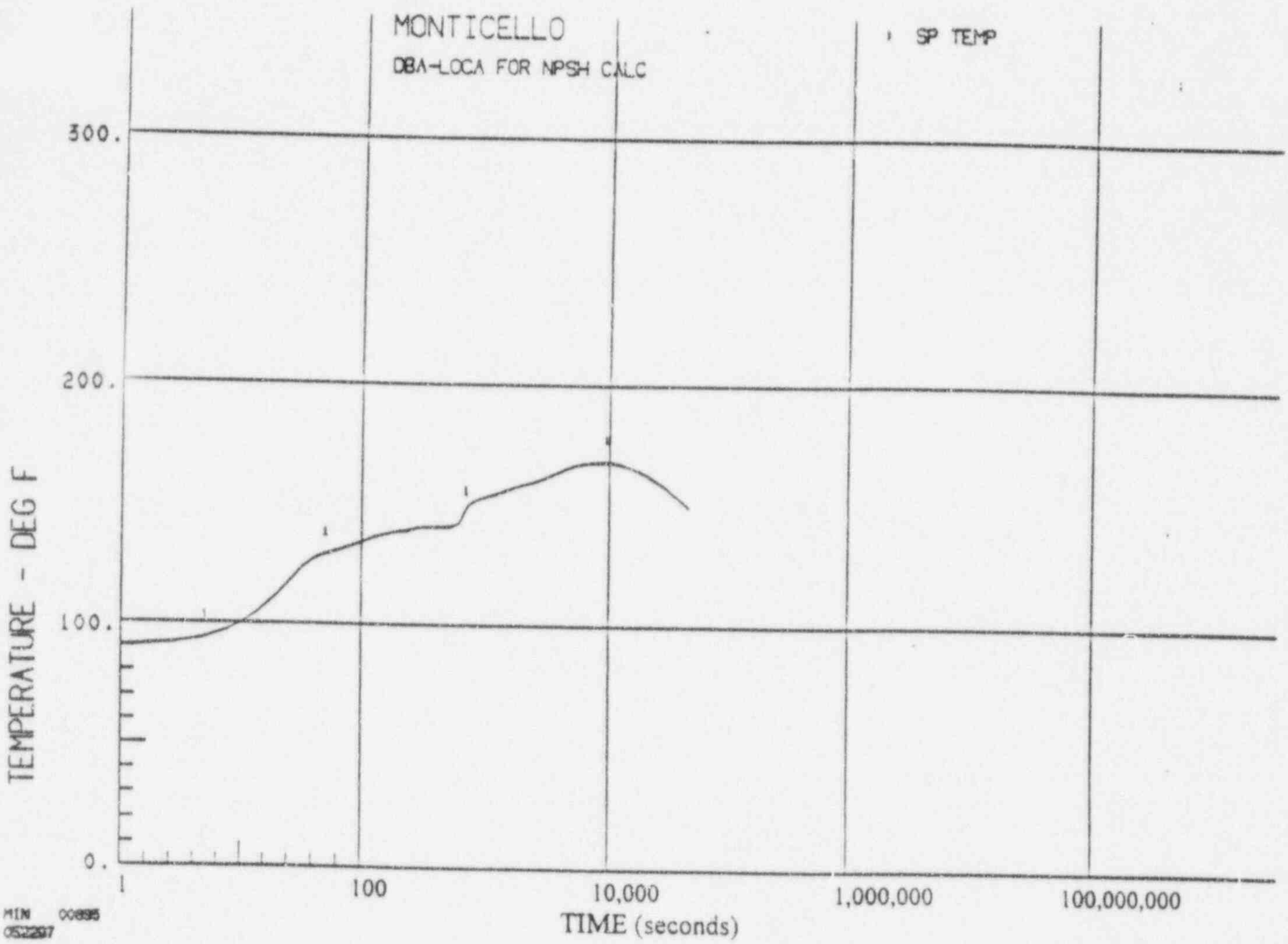

FIGURE B-11 Suppression Pool Temperature Response. Case 6, Long-Term Analysis, LOCA, No Off-site Power, LPCI Inj. Valve Failure, 102% of 1880 MWt

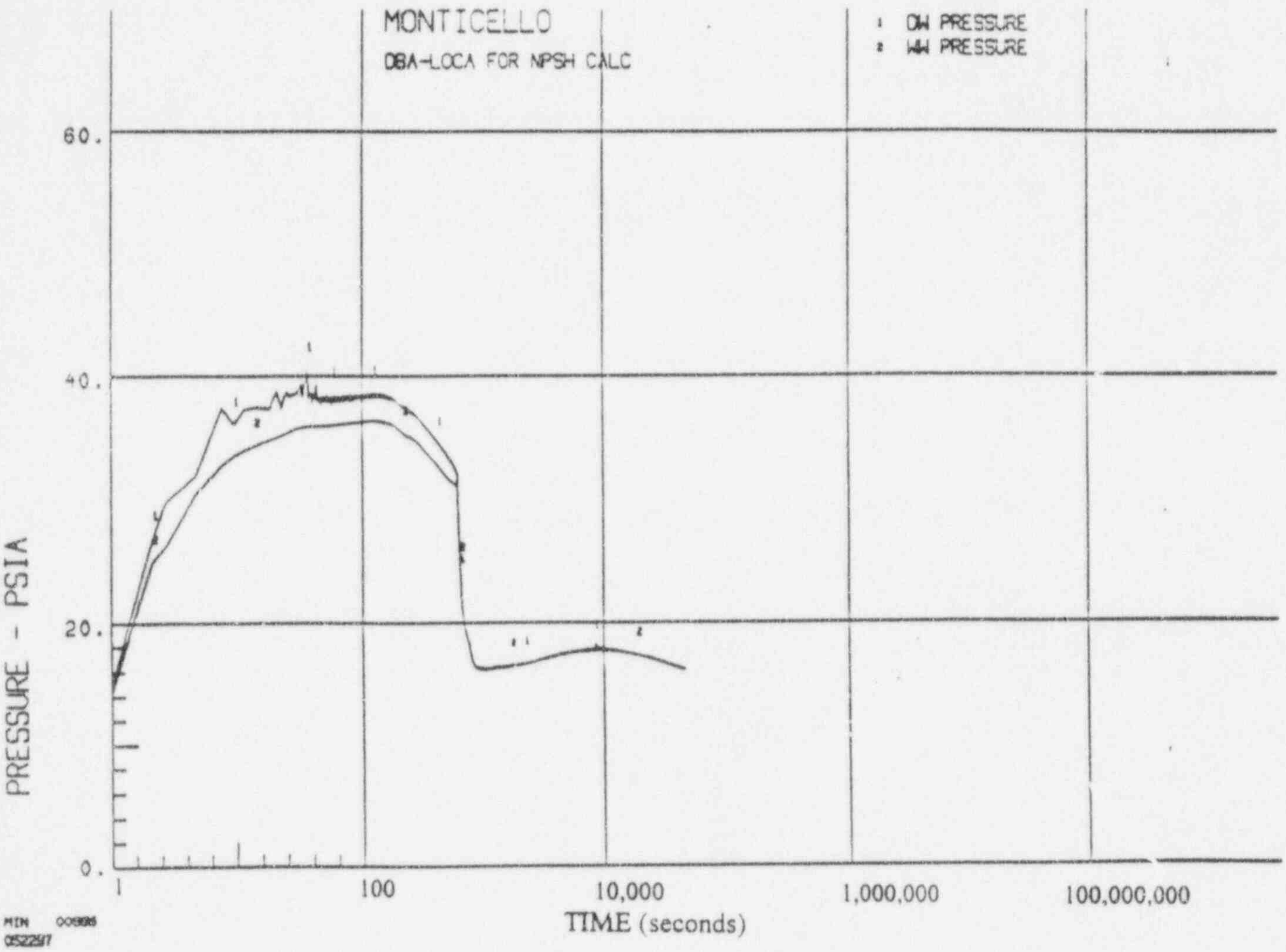

FIGURE B-12 Drywell and Suppression Chamber Pressure Response. Case 6, Long-Term Analysis, LOCA, No Off-site Power, LPCI Inj. Valve Failure, 102% of 1880 MWt

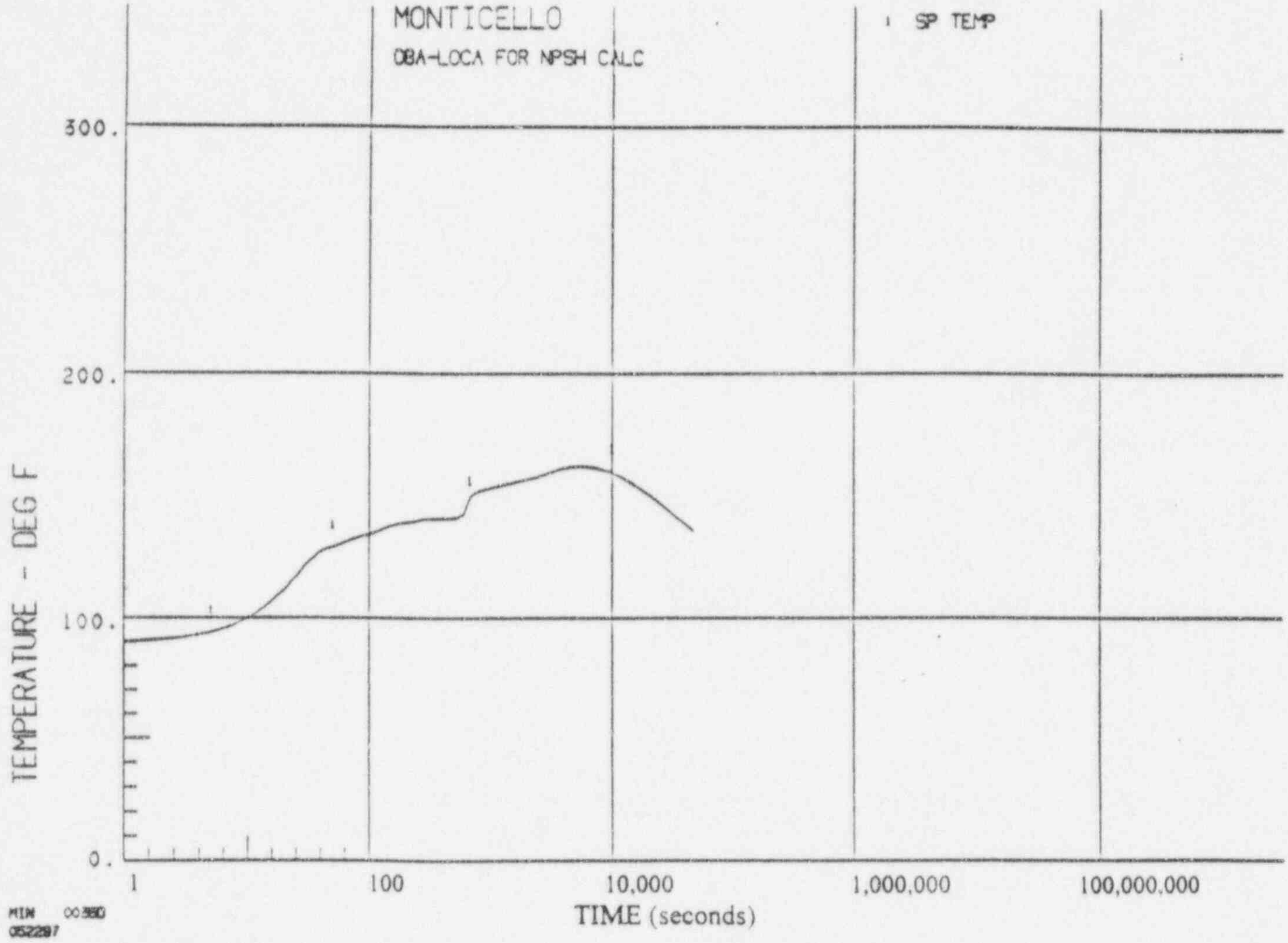

FIGURE B-13 Suppression Pool Temperature Response. Case 7, Long-Term Analysis, LOCA, Off-site Power, LPCI Inj. Valve Failure, 102% of 1880 MWt

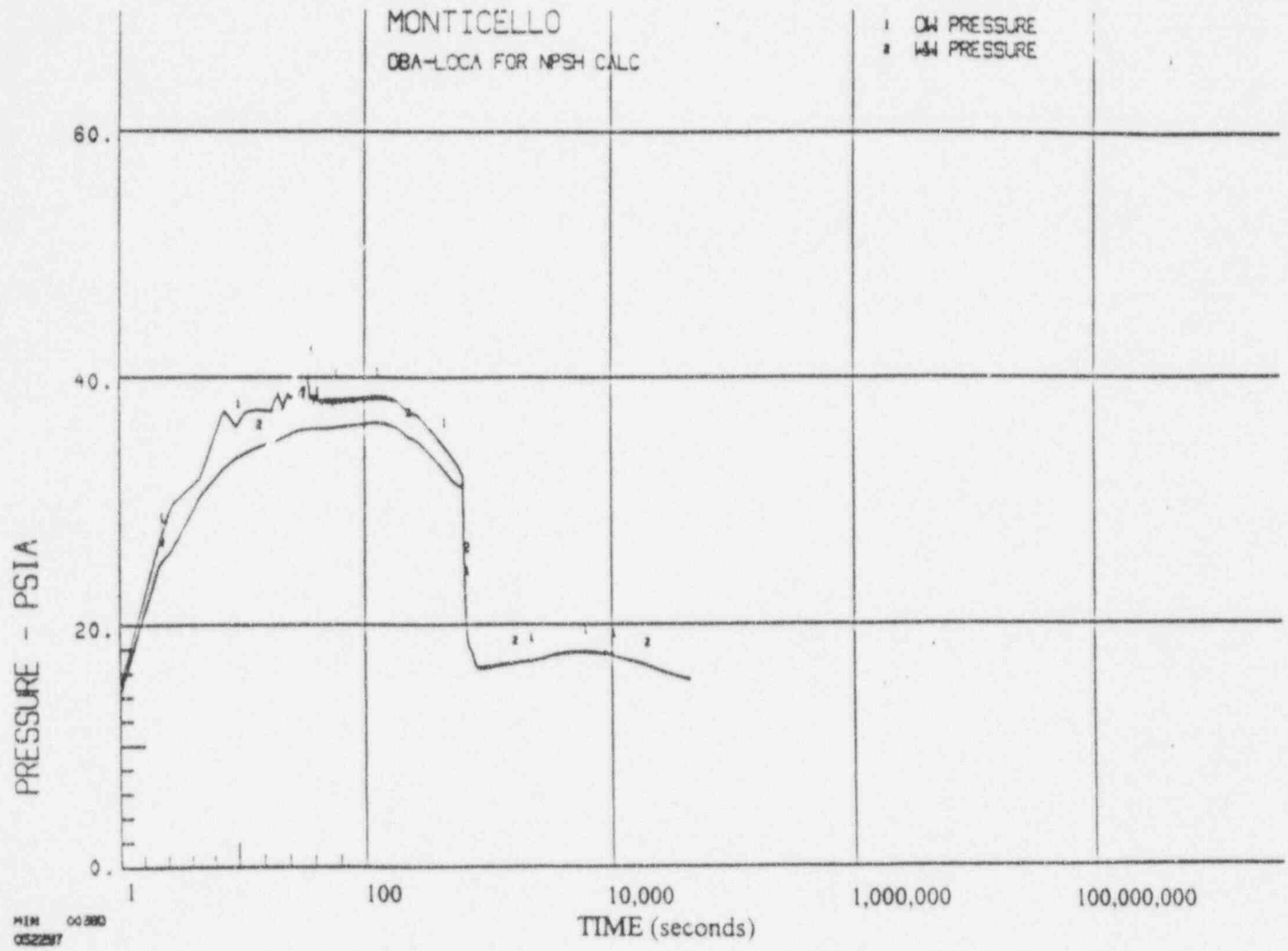

FIGURE B-14 Drywell and Suppression Chamber Pressure Response. Case 7, Long-Term Analysis, LOCA, Off-site Power, LPCI Inj. Valve Failure, 102% of 1880 MWt

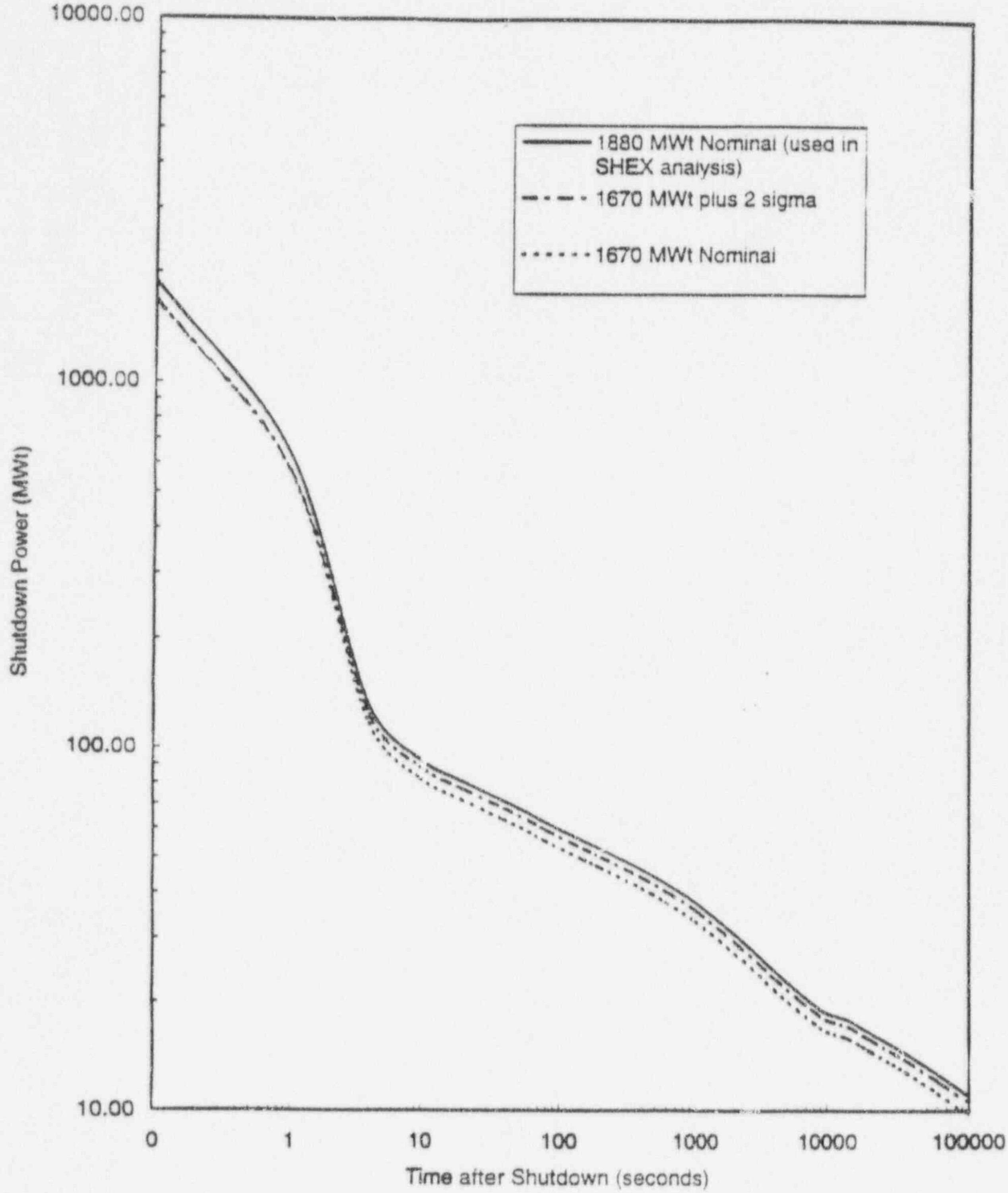

FIGURE B-15 Reactor Shutdown Power Used in Containment Analyses

APPENDIX C

DIGITIZED SUPPRESSION POOL TEMPERATURE AND SUPPRESSION CHAMBER PRESSURE DATA

Suppression Pool Temperature and Wetwell Pressure Data

DBA Discharge Line Break

Short-Term Analysis

Cases 1 and 2

4 LPCI Pumps and 2 CS Pumps

CASE 1

Current Power
1670 MWt, 90°F Initial Pool Temperature
(100% Mixing of Break Water with Drywell Atmosphere)

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
17.7	34.54	108.0
40.6	35.91	127.2
46.2	35.92	128.2
52.4	35.90	128.9
62.9	35.72	129.1
69.2	34.65	129.3
75.4	33.66	129.6
81.7	32.65	130.0
87.9	31.62	130.4
94.2	30.61	130.9
100.4	29.68	131.4
106.7	28.83	131.9
112.9	28.07	132.4
119.2	27.43	132.9
126.1	26.80	133.5
133.3	26.20	134.2
140.1	25.63	134.8
146.4	25.01	135.4
152.7	24.39	135.9
158.9	23.77	136.4
165.2	23.18	136.9
171.7	22.48	137.4
177.9	21.84	137.9
184.2	21.26	138.3
191.7	20.63	138.8
199.1	20.09	139.2
205.3	19.68	139.6
212.6	19.26	140.0
219.1	18.95	140.3
225.3	18.69	140.6
231.6	18.46	140.9
237.8	18.26	141.1

CASE 1 (continued)

Current Power
1670 MWt, 90°F Initial Pool Temperature
(100% Mixing of Break Water with Drywell Atmosphere)

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
244.1	18.10	141.4
250.3	17.97	141.6
256.8	17.84	141.8
263.1	17.75	142.0
269.3	17.67	142.2
275.6	17.60	142.4
281.8	17.52	142.6
288.1	17.47	142.8
294.3	17.42	142.9
300.6	17.39	143.1
306.8	17.35	143.3
313.1	17.31	143.4
319.3	17.28	143.6
325.6	17.25	143.7
331.8	17.22	143.9
338.1	17.12	144.0
344.3	17.02	144.1
350.6	16.89	144.3
356.8	16.79	144.4
363.2	16.69	144.5
369.4	16.62	144.6
375.7	16.54	144.7
381.9	16.49	144.8
388.2	16.43	144.9
394.4	16.40	145.0
400.7	16.36	145.1
406.9	16.34	145.2
413.2	16.32	145.3
419.4	16.30	145.4
425.7	16.29	145.4
432.4	16.30	145.5
438.7	16.31	145.6
444.9	16.33	145.7
451.2	16.34	145.8

CASE 1 (continued)

Current Power
1670 MWt, 90°F Initial Pool Temperature
(100% Mixing of Break Water with Drywell Atmosphere)

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
457.4	16.35	145.9
463.7	16.37	146.0
469.9	16.38	146.1
476.2	16.40	146.2
482.4	16.41	146.3
488.7	16.43	146.4
494.9	16.44	146.5
501.2	16.46	146.6
507.4	16.48	146.7
513.7	16.49	146.8
519.9	16.51	146.9
526.2	16.52	147.0
532.4	16.54	147.2
538.7	16.56	147.3
544.9	16.57	147.4
551.2	16.59	147.5
557.4	16.61	147.6
563.7	16.62	147.7
569.9	16.63	147.8
576.2	16.63	147.8
582.4	16.64	147.9
588.7	16.64	148.0
594.9	16.65	148.1
600.1	16.65	148.2

CASE 2

Rerate Power
1880 MWt, 90°F Initial Pool Temperature
(100% Mixing of Break Water with Drywell Atmosphere)

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
17.7	34.55	108.2
39.9	35.95	127.5
45.7	35.99	128.9
52.4	35.96	129.3
58.9	35.95	129.5
65.1	35.92	129.7
71.4	35.93	129.9
77.6	34.99	130.3
83.9	33.91	130.8
90.1	32.85	131.3
96.4	31.84	131.8
102.6	30.92	132.3
108.9	30.08	132.9
115.1	29.36	133.5
121.4	28.63	134.0
127.6	27.80	134.6
133.9	26.97	135.2
140.1	26.14	135.7
146.4	25.33	136.3
152.6	24.52	136.8
158.9	23.74	137.4
165.1	23.01	137.9
171.4	22.32	138.3
177.6	21.68	138.8
184.2	21.07	139.2
191.6	20.49	139.7
198.7	19.98	140.1
205.7	19.56	140.4
212.1	19.21	140.8
218.4	18.94	141.0
224.6	18.69	141.3
230.9	18.49	141.6
237.1	18.32	141.9

CASE 2 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature
(100% Mixing of Break Water with Drywell Atmosphere)

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
243.4	18.18	142.0
249.9	18.06	142.3
256.1	17.95	142.5
262.4	17.87	142.7
268.6	17.81	142.9
274.9	17.75	143.1
281.1	17.70	143.2
287.4	17.65	143.4
293.6	17.62	143.6
299.9	17.58	143.7
306.1	17.55	143.9
312.4	17.53	144.1
318.6	17.49	144.2
324.9	17.47	144.4
331.1	17.45	144.5
337.4	17.42	144.7
343.6	17.41	144.8
349.9	17.39	144.9
356.1	17.37	145.1
362.4	17.36	145.2
368.6	17.35	145.4
374.9	17.31	145.5
381.1	17.24	145.6
387.4	17.16	145.7
393.6	17.07	145.9
399.9	17.00	146.0
406.1	16.92	146.1
412.4	16.86	146.2
418.6	16.80	146.3
424.9	16.76	146.4
431.1	16.72	146.5
437.4	16.69	146.6
443.6	16.66	146.7
449.9	16.64	146.8

CASE 2 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature
(100% Mixing of Break Water with Drywell Atmosphere)

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
456.1	16.62	146.9
462.4	16.62	147.0
468.6	16.61	147.1
474.9	16.60	147.1
481.1	16.60	147.2
487.4	16.60	147.3
493.6	16.61	147.4
499.9	16.62	147.5
506.1	16.63	147.6
512.4	16.65	147.6
518.6	16.66	147.7
524.9	16.68	147.8
531.1	16.69	147.9
537.4	16.71	148.0
543.6	16.72	148.1
549.9	16.74	148.2
556.1	16.75	148.3
562.4	16.77	148.5
568.6	16.79	148.6
574.9	16.80	148.7
581.1	16.82	148.8
587.4	16.83	148.9
593.6	16.85	149.0
599.9	16.86	149.1
600.1	16.86	149.1

Suppression Pool Temperature and Wetwell Pressure Data

DBA-LOCA Long Term Analysis

No Off-site Power, Diesel Generator Failure

CASE 3

Rerate Power

1880 MWt, 90°F Initial Pool Temperature

CASE 3

Rerate Power
1880 MWt, 90°F Initial Pool Temperature

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
12.3	35.45	116.4
24.7	36.21	129.9
30.9	36.29	131.7
35.2	36.31	132.4
39.2	36.33	132.9
42.3	36.34	133.3
47.7	36.32	133.8
56.7	36.40	134.2
63.6	36.48	134.7
70.6	36.57	135.3
77.8	36.68	135.9
84.5	36.77	136.4
91.0	36.87	136.9
97.2	36.87	137.2
137.2	37.06	139.3
199.7	36.64	140.8
262.2	35.89	141.0
324.7	35.15	141.1
387.2	34.43	141.1
449.8	33.72	141.2
513.3	33.47	142.3
591.0	31.61	145.0
742.8	21.13	152.7
1023.2	19.28	156.2
1357.3	18.88	158.8
1701.6	18.93	160.9
2020.1	18.86	162.7
2280.1	18.80	164.0
2528.6	18.91	165.1
2776.3	18.92	166.2
3024.8	18.95	167.3
3273.3	18.93	168.2

CASE 3 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
3524.3	19.02	169.1
3772.8	19.01	170.0
4021.3	18.98	170.8
4270.6	19.06	171.5
4519.8	19.12	172.2
4769.1	19.17	172.9
5018.3	19.21	173.6
5267.6	19.23	174.2
5517.6	19.33	174.8
5766.8	19.34	175.4
6017.6	19.35	176.0
6267.6	19.43	176.5
6516.8	19.42	177.0
6766.8	19.50	177.5
7016.8	19.57	178.0
7265.6	19.54	178.4
7515.6	19.61	178.9
7765.6	19.67	179.3
8015.6	19.72	179.7
8264.8	19.69	180.1
8514.8	19.75	180.5
8764.8	19.80	180.9
9014.8	19.85	181.3
9264.8	19.90	181.6
9514.8	19.94	182.0
9764.1	19.90	182.3
10039.1	19.95	182.7
10539.1	20.03	183.3
11039.1	20.10	183.9
11539.1	20.18	184.5
12039.1	20.25	185.0
12539.1	20.32	185.6
13039.1	20.38	186.1
13539.1	20.44	186.6

CASE 3 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
14039.1	20.49	187.1
14539.1	20.55	187.5
15039.1	20.60	188.0
15539.1	20.65	188.4
16039.1	20.70	188.8
16539.1	20.75	189.2
17039.1	20.80	189.5
17539.1	20.84	189.9
18039.1	20.88	190.2
18539.1	20.92	190.5
19038.3	20.88	190.8
19538.3	20.92	191.1
20038.3	20.96	191.3
20538.3	21.00	191.5
21038.3	21.03	191.8
21538.3	21.07	192.0
22038.3	21.10	192.2
22538.3	21.13	192.4
23038.3	21.15	192.6
23537.1	21.09	192.7
24037.1	21.13	192.9
24537.1	21.15	193.1
25037.1	21.17	193.2
25537.1	21.18	193.3
26037.1	21.20	193.4
26537.1	21.22	193.5
27036.3	21.15	193.6
27536.3	21.17	193.7
28036.3	21.19	193.8
28536.3	21.21	193.9
29036.3	21.22	193.9
29536.3	21.23	194.0
30035.6	21.16	194.0
30535.6	21.17	194.1

CASE 3 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
31035.6	21.18	194.1
31535.6	21.19	194.1
32035.6	21.20	194.1
32535.6	21.20	194.2
33035.6	21.21	194.2
33534.8	21.13	194.2
34034.8	21.14	194.2
34534.8	21.14	194.2
35034.8	21.15	194.1
35534.8	21.15	194.1
36034.8	21.15	194.1
36534.1	21.07	194.1
37034.1	21.07	194.0
37534.1	21.08	194.0
38034.1	21.08	194.0
38534.1	21.08	193.9
39033.6	21.08	193.9
39533.6	21.08	193.9
40032.3	20.97	193.8
40531.8	20.99	193.8
41031.3	20.99	193.7
41531.3	20.99	193.7
42031.3	20.99	193.6
42530.8	20.99	193.5
43030.3	20.99	193.5
43529.6	20.89	193.4
44029.1	20.90	193.3
44528.6	20.90	193.3
45028.1	20.90	193.2
45528.1	20.90	193.1
46028.1	20.89	193.1
46528.1	20.89	193.0
47027.3	20.80	192.9

CASE 3 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
47527.3	20.80	192.8
48027.3	20.79	192.7
48527.3	20.79	192.6
49027.3	20.78	192.5
49527.3	20.78	192.5
50027.3	20.78	192.4
50527.3	20.77	192.3
51027.3	20.76	192.2
51527.3	20.75	192.1
52027.3	20.73	192.0
52527.3	20.72	191.9
53027.3	20.71	191.8
53527.3	20.70	191.7
54027.3	20.69	191.5
54526.6	20.59	191.4
55026.6	20.58	191.3
55526.6	20.58	191.2
56026.6	20.57	191.1
56530.1	20.56	190.9
57083.1	20.54	190.8
57658.3	20.53	190.7
58323.6	20.52	190.5
59013.8	20.51	190.3
59762.1	20.48	190.1
60503.6	20.45	189.9
61227.6	20.42	189.7
61993.6	20.39	189.5
62762.8	20.36	189.3
63528.1	20.33	189.1
64292.8	20.30	188.9
65027.8	20.27	188.7
65772.1	20.24	188.5
66522.8	20.21	188.3

CASE 3 (continued)

Rerate Power
1880 MWt, 90°F Initial Pool Temperature

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
67281.1	20.19	188.1
68049.3	20.16	187.8
68822.6	20.13	187.6
69585.8	20.10	187.4
70368.3	20.07	187.2
71151.1	20.04	187.0
71932.3	20.01	186.8
72697.8	19.98	186.6
73505.3	19.95	186.4
74308.3	19.92	186.1
75127.8	19.89	185.9
75912.8	19.87	185.7
76721.3	19.84	185.5
77515.3	19.81	185.3
78316.8	19.78	185.0
79136.1	19.75	184.8
79945.1	19.72	184.6
80745.8	19.69	184.4
81535.6	19.66	184.2
82335.6	19.63	183.9
83128.1	19.61	183.7
83938.8	19.58	183.5
84753.1	19.55	183.3
85560.1	19.52	183.1
86368.6	19.49	182.8
87195.8	19.47	182.6
88022.3	19.44	182.4
88858.6	19.42	182.2
89704.3	19.40	182.0
90001.1	19.39	182.0

CONTAINMENT PRESSURE AND TEMPERATURE ANALYSIS FOR MONTICELLO NPSH EVALUATIONS

LONG-TERM DBA-LOCA CONTAINMENT RESPONSE

DBA DISCHARGE LINE BREAK

WETWELL PRESSURE AND SUPPRESSION POOL TEMPERATURE TIME HISTORIES

CASES 4 - 7

CASE 4

LPCI LOOP SELECTION LOGIC FAILURE NO OFFSITE POWER

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
9.7	33.50	99.6
30.5	35.71	121.9
41.5	35.92	127.5
47.0	35.94	128.5
53.2	35.98	129.4
59.9	36.03	130.1
66.4	36.09	130.5
72.6	36.16	130.7
80.1	34.95	131.5
87.6	33.43	132.3
95.1	31.93	133.2
102.6	30.53	134.0
110.1	29.19	134.8
117.6	27.99	135.5
125.1	26.78	136.2
132.1	25.61	136.8
138.4	24.57	137.3
144.6	23.57	137.8
150.9	22.62	138.2
157.1	21.74	138.7
163.4	20.94	139.1
169.6	20.21	139.5
175.9	19.57	139.9
182.1	19.02	140.2
188.4	18.54	140.5
195.4	18.09	140.9
202.4	17.73	141.2
209.2	17.46	141.5
215.5	17.26	141.7
221.7	17.10	141.9
228.0	16.96	142.1
234.2	16.86	142.4
240.5	16.77	142.6
246.7	16.71	142.8
253.0	16.65	142.9
259.2	16.61	143.1

CASE 4 (continued)

LPCI LOOP SELECTION LOGIC FAILURE
NO OFFSITE POWER

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
265.5	16.57	143.3
271.7	16.53	143.5
278.0	16.51	143.6
284.2	16.48	143.8
290.5	16.45	143.9
296.7	16.43	144.1
303.0	16.41	144.2
309.2	16.40	144.4
315.5	16.38	144.5
321.7	16.35	144.7
328.0	16.34	144.8
334.2	16.33	145.0
340.5	16.31	145.1
346.7	16.30	145.3
353.0	16.28	145.4
359.2	16.27	145.5
365.5	16.26	145.7
371.7	16.25	145.8
378.0	16.24	145.9
384.2	16.24	146.1
390.5	16.23	146.2
396.7	16.22	146.3
403.0	16.21	146.4
409.2	16.20	146.6
415.5	16.19	146.7
421.7	16.17	146.8
428.0	16.14	146.9
434.2	16.12	147.0
440.5	16.10	147.1
446.7	16.08	147.2
453.0	16.07	147.3
459.2	16.06	147.4
465.5	16.06	147.5
471.7	16.06	147.6
478.0	16.05	147.6
484.2	16.06	147.7
490.5	16.07	147.8
496.7	16.07	147.9

CASE 4 (continued)

LPCI LOOP SELECTION LOGIC FAILURE
NO OFFSITE POWER

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
503.0	16.09	147.9
509.2	16.09	148.0
515.5	16.11	148.1
521.7	16.12	148.1
528.0	16.13	148.2
534.2	16.15	148.3
540.5	16.17	148.4
546.7	16.19	148.5
553.0	16.20	148.6
559.2	16.22	148.7
565.5	16.24	148.8
571.7	16.25	148.9
578.0	16.27	149.0
584.2	16.28	149.1
590.5	16.30	149.2
596.7	16.31	149.3
611.0	16.29	149.4
634.7	16.19	149.6
660.0	16.14	149.9
692.2	16.19	150.3
778.0	15.99	151.1
1102.5	16.13	153.3
1427.7	16.33	155.3
1757.2	16.37	156.9
2089.5	16.49	158.2
2429.0	16.63	159.3
2765.7	16.79	160.2
3101.0	17.02	161.3
3428.7	17.14	162.3
3749.2	17.29	163.2
4073.0	17.43	164.1
4395.5	17.63	164.9
4712.7	17.76	165.7
5041.0	17.85	166.4
5369.7	17.96	167.0
5697.5	17.98	167.4
6027.2	18.09	167.8
6353.0	18.12	168.0

CASE 4 (continued)

LPCI LOOP SELECTION LOGIC FAILURE
NO OFFSITE POWER

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
6675.5	18.24	168.2
7008.5	18.41	168.6
7331.0	18.43	168.9
7657.2	18.42	168.9
7976.7	18.45	169.0
8304.5	18.51	168.9
8629.2	18.49	168.9
8955.0	18.52	168.8
9287.5	18.52	168.7
9610.0	18.53	168.6
9931.2	18.61	168.5
11045.0	18.60	168.0
12354.0	18.59	167.4
13639.0	18.61	166.7
14951.2	18.51	166.1
16242.2	18.37	165.4
17527.5	18.24	164.6
18834.0	18.13	163.9
20140.0	18.02	163.1
21449.3	17.91	162.3
22797.3	17.80	161.5
24106.0	17.69	160.7
25459.8	17.58	159.9
26796.0	17.47	159.2
28138.3	17.37	158.4
29487.3	17.27	157.6
30833.5	17.17	156.8
32176.3	17.07	156.1
33507.5	16.97	155.4
34869.8	16.87	154.6
36213.3	16.78	153.9
37552.8	16.70	153.3
38914.8	16.61	152.6
40269.8	16.53	152.0
41626.0	16.45	151.4
43012.0	16.38	150.8
44377.8	16.30	150.2
45000.0	16.27	149.9

CASE 5

LPCI LOOP SELECTION LOGIC FAILURE
OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
9.7	33.50	99.6
30.5	35.71	121.9
41.5	35.92	127.5
47.0	35.94	128.5
53.2	35.98	129.4
59.9	36.03	130.1
66.4	36.09	130.5
72.6	36.16	130.7
80.1	34.95	131.5
87.6	33.43	132.3
95.1	31.93	133.2
102.6	30.53	134.0
110.1	29.19	134.8
117.6	27.99	135.5
125.1	26.78	136.2
132.1	25.61	136.8
138.4	24.57	137.3
144.6	23.57	137.8
150.9	22.62	138.2
157.1	21.74	138.7
163.4	20.94	139.1
169.6	20.21	139.5
175.9	19.57	139.9
182.1	19.02	140.2
188.4	18.54	140.5
195.4	18.09	140.9
202.4	17.73	141.2
209.2	17.46	141.5
215.5	17.26	141.7
221.7	17.10	141.9
228.0	16.96	142.1
234.2	16.86	142.4
240.5	16.77	142.6
246.7	16.71	142.8
253.0	16.65	142.9

CASE 5 (continued)

LPCI LOOP SELECTION LOGIC FAILURE OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
259.2	16.61	143.1
265.5	16.57	143.3
271.7	16.53	143.5
278.0	16.51	143.6
284.2	16.48	143.8
290.5	16.45	143.9
296.7	16.43	144.1
303.0	16.41	144.2
309.2	16.40	144.4
315.5	16.38	144.5
321.7	16.35	144.7
328.0	16.34	144.8
334.2	16.33	145.0
340.5	16.31	145.1
346.7	16.30	145.3
353.0	16.28	145.4
359.2	16.27	145.5
365.5	16.26	145.7
371.7	16.25	145.8
378.0	16.24	145.9
384.2	16.24	146.1
390.5	16.23	146.2
396.7	16.22	146.3
403.0	16.21	146.4
409.2	16.20	146.6
415.5	16.19	146.7
421.7	16.17	146.8
428.0	16.14	146.9
434.2	16.12	147.0
440.5	16.10	147.1
446.7	16.08	147.2
453.0	16.07	147.3
459.2	16.06	147.4
465.5	16.06	147.5
471.7	16.06	147.6
478.0	16.05	147.6

CASE 5 (continued)

**LPCI LOOP SELECTION LOGIC FAILURE
OFFSITE POWER AVAILABLE**

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
484.2	16.06	147.7
490.5	16.07	147.8
496.7	16.07	147.9
503.0	16.09	147.9
509.2	16.09	148.0
515.5	16.11	148.1
521.7	16.12	148.1
528.0	16.13	148.2
534.2	16.15	148.3
540.5	16.17	148.4
546.7	16.19	148.5
553.0	16.20	148.6
559.2	16.22	148.7
565.5	16.24	148.8
571.7	16.25	148.9
578.0	16.27	149.0
584.2	16.28	149.1
590.5	16.30	149.2
596.7	16.31	149.3
607.2	16.19	149.4
626.5	16.01	149.6
646.0	15.99	149.8
667.5	16.01	150.1
688.0	16.01	150.4
712.2	15.95	150.7
891.2	16.03	151.9
1136.2	16.18	153.2
1376.0	16.33	154.4
1542.0	16.36	155.0
1707.5	16.37	155.5
1905.2	16.46	156.2
2162.7	16.49	156.8
2414.2	16.64	157.3
2639.7	16.76	157.8
2879.7	16.83	158.3
3135.5	16.95	158.9

CASE 5 (continued)

**LPCI LOOP SELECTION LOGIC FAILURE
OFFSITE POWER AVAILABLE**

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
3384.0	17.09	159.5
3629.5	17.21	160.0
3885.5	17.28	160.5
4136.5	17.40	161.0
4380.2	17.49	161.5
4627.5	17.54	161.8
4853.7	17.60	162.0
5078.5	17.62	162.1
5335.5	17.70	162.2
5567.0	17.75	162.3
5786.0	17.78	162.3
6023.7	17.77	162.3
6217.7	17.79	162.2
6395.7	17.80	162.2
6573.7	17.84	162.1
6781.7	17.83	162.0
6966.5	17.89	162.0
7207.7	17.95	162.1
7448.7	17.95	162.0
7681.5	17.95	161.9
7884.0	17.94	161.7
8118.7	17.94	161.5
8327.2	17.93	161.3
8547.7	17.95	161.1
8779.2	17.93	160.9
8996.0	17.91	160.7
9173.0	17.95	160.5
9434.0	17.83	160.2
9658.0	17.95	160.0
9853.5	17.97	159.8
10186.2	17.97	159.4
10845.7	17.93	158.7
11486.7	17.84	158.0
12111.7	17.75	157.4
12736.7	17.66	156.7
13361.7	17.57	156.1

CASE 5 (continued)

LPCI LOOP SELECTION LOGIC FAILURE
OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
13986.7	17.45	155.5
14611.7	17.37	154.9
15236.7	17.30	154.3
15861.7	17.23	153.7
16486.8	17.16	153.2
17111.8	17.09	152.6
17736.8	17.03	152.1
18361.8	16.97	151.5
18986.8	16.90	151.0
19611.8	16.84	150.5
20236.8	16.79	150.0
20861.8	16.73	149.5
21486.8	16.68	149.0
22111.8	16.62	148.5
22736.8	16.57	148.0
23361.8	16.52	147.5
23986.8	16.48	147.1
24611.8	16.43	146.6
25236.8	16.39	146.2
25861.8	16.34	145.8
26486.8	16.30	145.3
27111.8	16.26	144.9
27736.8	16.22	144.5
28361.8	16.18	144.1
28986.8	16.14	143.7
29611.8	16.11	143.4
30236.8	16.07	143.0
30861.8	16.04	142.6
31486.8	16.01	142.3
32111.8	15.97	141.9
32736.8	15.94	141.6
33361.8	15.91	141.2
33986.8	15.87	140.9
34611.8	15.84	140.6
35404.3	15.80	140.2
36542.8	15.72	139.6

CASE 5 (continued)

LPCI LOOP SELECTION LOGIC FAILURE
OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
37706.5	15.66	139.1
38871.0	15.59	138.5
40055.8	15.54	138.0
41224.5	15.49	137.5
42398.5	15.45	137.0
43579.0	15.40	136.6
44787.0	15.36	136.2
45000.3	15.36	136.1

CASE 6

LPCI INJECTION VALVE FAILURE
NO OFFSITE POWER

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
80.2	36.17	132.8
150.0	36.22	137.7
212.8	35.41	139.4
275.5	34.72	140.5
338.1	33.76	140.9
400.6	32.87	141.0
463.7	32.07	141.0
526.6	31.45	141.3
589.1	31.12	142.2
595.3	31.10	142.3
620.5	25.44	142.7
742.7	18.13	150.2
1019.2	16.18	153.8
1364.0	16.41	155.9
1692.5	16.49	157.4
2019.5	16.59	158.7
2349.0	16.73	159.8
2688.7	16.87	160.8
3025.2	17.02	161.8
3360.5	17.16	162.8
3683.7	17.26	163.7
4007.0	17.35	164.5
4341.2	17.45	165.4
4666.5	17.51	166.1
4995.0	17.52	166.6
5324.0	17.60	167.1
5640.5	17.60	167.5
5972.7	17.66	167.8

CASE 6 (continued)

**LPCI INJECTION VALVE FAILURE
NO OFFSITE POWER**

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
6299.5	17.66	168.0
6632.0	17.71	168.2
6956.7	17.69	168.3
7283.5	17.72	168.4
7612.5	17.69	168.4
7945.2	17.71	168.4
8277.0	17.73	168.4
8605.5	17.71	168.5
8925.5	17.75	168.7
9247.0	17.77	168.7
9571.5	17.72	168.6
9896.5	17.73	168.5
14579.2	17.54	166.3
21269.2	17.17	162.5
28055.0	16.82	158.4
34880.2	16.46	154.6
41793.7	16.19	151.3

CASE 7

LPCI INJECTION VALVE FAILURE
OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
0.0	14.26	90.0
80.2	36.17	132.8
150.0	36.22	137.7
212.8	35.41	139.4
275.5	34.72	140.5
338.1	33.76	140.9
400.6	32.87	141.0
463.7	32.07	141.0
526.6	31.45	141.3
589.1	31.12	142.2
595.3	31.10	142.3
616.1	24.44	142.4
724.0	17.18	150.5
959.3	16.48	153.2
1212.8	16.68	154.4
1413.1	16.78	155.2
1647.3	16.85	156.0
1890.6	16.94	156.7
2117.3	17.01	157.2
2292.1	17.12	157.5
2548.1	17.24	158.2
2794.1	17.31	158.9
3000.8	17.40	159.4
3213.8	17.49	159.9
3428.8	17.56	160.4
3588.1	17.60	160.8
3791.1	17.63	161.1
3979.3	17.64	161.4
4225.8	17.63	161.7

CASE 7 (continued)

LPCI INJECTION VALVE FAILURE
OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
4441.6	17.66	161.9
4621.6	17.69	162.0
4782.3	17.71	162.1
4938.6	17.72	162.1
5094.8	17.73	162.2
5265.3	17.71	162.2
5460.8	17.72	162.2
5676.1	17.72	162.2
5898.3	17.72	162.2
5968.3	17.70	162.2
6106.1	17.70	162.1
6282.8	17.69	162.0
6475.3	17.69	162.0
6631.6	17.68	161.9
6787.8	17.67	161.8
6944.1	17.66	161.7
7100.3	17.65	161.6
7256.6	17.64	161.5
7426.1	17.60	161.4
7582.3	17.59	161.3
7738.6	17.58	161.2
7894.8	17.57	161.0
8051.1	17.57	160.9
8207.3	17.56	160.8
8363.6	17.55	160.6
8519.8	17.53	160.5
8681.1	17.49	160.4
8837.3	17.49	160.4
8993.6	17.49	160.3

CASE 7 (continued)

LPCI INJECTION VALVE FAILURE
OFFSITE POWER AVAILABLE

Time (sec)	Wetwell Pressure (psia)	Suppression Pool Temperature (°F)
9149.8	17.48	160.3
9306.1	17.48	160.2
9462.3	17.47	160.1
9618.6	17.45	159.9
9774.8	17.44	159.8
9931.1	17.42	159.6
11749.8	17.23	157.7
14874.8	16.92	154.7
17999.8	16.66	151.9
21124.8	16.42	149.3
24249.8	16.22	146.9
29207.8	15.93	143.5
35181.6	15.65	140.1
41161.3	15.45	137.4

GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

June 18, 1997
GLN-97-024

cc: NSP
P. Tobin

GE
D.C. Pappone
S. Mintz
E. G. Thacker

Mr. S. J. Hammer
Northern States Power Company
Monticello Nuclear Generating Plant
2807 West Highway 75
Monticello, MN 55362-0637

Subject: Revised Short-Term LOCA Suppression Pool Temperature and Wetwell Pressure for NPSH (GE Proposal No. 523-1HBYF-EK1)

References:

1. Letter, P. A. Tobin to S. Mintz, "Sensitivity Study for Change in ECCS Run Out Flow Rates," June 17, 1997.

2. GE Report, GE-NE-T2300731-2, "LOCA Containment Analyses for Use in Evaluation of NPSH for the RHR and Core Spray Pumps," June 1997.

Dear Steve,

Per Reference 1, Attachment A to this letter provides the results of analyses performed for the limiting short-term LOCA event with respect to NPSH (Cases 1 and 2 of Reference 2) with the revised pump flows from Reference 1. The attachment also provides analyses results which show the effect of using a more realistic mass tranfer rate from the suppression pool to the suppression chamber airspace on the suppression chamber pressure response.

These results will be provided in more detail in a supplement to Reference 2.

Please do not hesitate to call us if you have additional questions on this subject.

Sincerely,

PTTran

P.T. Tran
Monticello Power Rerate Project Manager
M/C 172, Tel. (408) 925-3348

ATTACHMENT A

ESTIMATED EFFECT ON SUPPRESSION POOL TEMPERATURE AND SUPPRESSION CHAMBER AIRSPACE PRESSURE OF USING REVISED CORE SPRAY AND RHR PUMP FLOWS

Introduction

In Reference 1, NSP provided revised values of the maximum Core Spray (CS) pump flow to the vessel and RHR pump break flow injected to the drywell during the first 10 minutes of a LOCA event with the assumption that all pumps are available. Per Reference 1, the CS pump flow is based on the maximum flow condition but with some of the pump flow diverted through the minimum flow line. Since these values are different than assumed in the analyses of Reference 2 the effect of the pump flow changes on the analyses of Reference 2 were evaluated.

In addition, it was determined that the an unrealistically low evaporation rate from the suppression pool was assumed for Cases 1 and 2 of Reference 2. Therefore, the effect of using a more realistic mass transfer rate from the suppression pool to the suppression pool surface than used for Cases 1 and 2 of Reference 2 was also evaluated

For the evaluation, reanalyses were performed with the revised pump flows for the limiting short-term analyses with respect to available NPSH, Cases 1 and 2 of Reference 2. The long-term analyses are not impacted by these changes since it is assumed for the long-term analyses that the operator controls pump flow rates after 10 minutes. The peak long-term containment conditions (wetwell pressure and suppression pool temperature) are insensitive to small changes in the ECCS flowrates assumed during the first 10 minutes.

Four cases were run. Cases 1 and 2 are the same as Cases 1 and 2 of Reference 2 except that the revised flow rates from Reference 1 are used. Cases 1a and 2a use the revised flow rates from Reference 1 and also use a more realistic evaporation rate from the suppression pool.

Results

Table 1 summarizes the results of the analysis with current and rerate power for the four cases. Table 1 also provides the results previously provided in Reference 2 for Case 1 and Case 2.

A comparison of the analysis results between the current Case 1 and Case 1 of Reference 2 and between the current Case 2 and Case 2 of Reference 2 showed that there is very little effect on suppression pool temperature (<1°F), suppression chamber pressure

(~ 0.1 psi) and on the available NPSH pressure term (~0.1 psi) of using the revised pump flow from Reference 1.

A comparison of current Case 1 to Case 1a and current Case 2 to Case 2a shows that the use of a more realistic heat transfer rate results in an increase in the available NPSH pressure term of approximately 0.35 psi. This is attributed to a higher vapor pressure resulting from the increased evaporation.

TABLE 1 - SUMMARY OF ANALYSIS RESULTS

CASE	1 (Ref. 2) Current Power	1 Current Power	1a Current Power	2 (Ref. 2) Rerate Power	2 Rerate Power	2a Rerate Power
Rated Power (MWt)	1670	1670	1670	1880	1880	1880
% Thermal Mixing for LPCI inj. to DW and Vessel Break flow	100	100	100	100	100	100
RHR Injection to DW (gpm)	15550	17400	17400	15500	17400	17400
CS pump flow (gpm)	8740	8100	8100	8740	8100	8100
Mass Transfer Rate from Suppression Pool Surface to Supp. Chamb. Airspace.	small	small	realistic	small	small	realistic
Suppression Pool Temperature at 600 sec (°F)	148.2	148.4	148.4	149.1	148.7	148.7
Suppression Chamber Airspace Pressure at 600 sec (psia)	16.65	16.77	17.12	16.86	16.72	17.09
Vapor Pressure at Pool Temp (°F)	3.56	3.574	3.574	3.64	3.60	3.60
Available NPSH Pressure Term (Pa-Pv) = Sup. Ch. pressure - Vapor Pressure (psi)	13.09	13.196	13.55	13.22	13.12	13.49

REFERENCES:

1. Letter, P. A. Tobin to S. Mintz, "Sensitivity Study for Change in ECCS Run Out Flow Rates", June 17,1997.

2. GE Report, GE-NE-T2300731-2, "LOCA Containment Analyses for Use in Evaluation of NPSH for the RHR and Core Spray Pumps," June 1997.

Exhibit E

Monticello Nuclear Generating Plant

Revision No. 2 to License Amendment Request Dated January 23, 1997

Duke Engineering & Services Calculation Package V75100.NSP97.00501, "Determination of Containment Overpressure Required for Adequate NPSH of the Low Pressure ECCS Pumps," June 18, 1997

Notes:

Containment pressure required to assure adequate NPSH for the low pressure ECCS pumps was calculated for the limiting cases identified in Exhibit D. Plots of the required pressure for the limiting core spray pump and limiting RHR pump for these limiting cases and the wetwell pressure available are provided in Figures E.1, E.2, E.3 and E.4. The figures show that adequate NPSH is available for the limiting pumps for the limiting cases for NPSH.

The NPSH calculation assumes that three of four suction strainer assemblies that supply a common suction header are clean. A suction strainer assembly contains two strainers. The fourth suction strainer assembly (both strainers) is assumed to be completely plugged, and no flow passes through. The blocked strainer assembly is assumed to be in a location that maximizes the suction piping friction losses. This meets the original design basis for the plant and does not take into account additional blockages as identified in NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers By Debris in Boiling Water Reactors." Monticello has committed to resolve the concerns of Bulletin 96-03 during the 1998 refueling outage. Suction strainer assemblies which increase the strainer surface area by a factor of approximately 60 are being installed to resolve an existing strainer head loss problem. Note that resolution of the debris issue may require taking credit for most if not all of the containment pressure margin between the minimum wetwell pressure and pressure required for NPSH shown in Figures E.1, E.2, E.3 and E.4.

The limiting short-term case for ECCS NPSH that was evaluated assumes a single failure of the LPCI Loop Select Logic to select the unbroken reactor recirculation loop. In this case all four LPCI pumps are assumed to be injecting into the broken recirculation loop. The LPCI pumps and the core spray pumps are at maximum flow conditions with no credit for operator action to throttle their flow. This is one of the GE SIL 151 cases. The other case postulated by SIL 151 is a case where all four LPCI pumps inject into both reactor recirculation loops simultaneously, with one loop broken. This case will result in approximately the same flow rates as those evaluated and will result in additional coolant being injected to the reactor. The reduced LPCI flow directly out of the break would result in less cooling of the drywell atmosphere. With less drywell cooling, the minimum containment pressure would be higher which makes this a non-limiting case for NPSH. Therefore, a containment response and associated NPSH calculations were not performed for this case.

The containment pressures required for the core spray pumps for the short term case as provided in the Duke Engineering & Services calculation of this exhibit have been corrected for new NPSH required information provided by the pump manufacturer. The corrected pressure values were determined by NSP Calculation CA-97-166, Corrected Containment Overpressure Required for Adequate NPSH for the Core Spray Pumps Under Runout Conditions. Results of CA-97-166 are utilized in Figure E.1 and are provided as an attachment to this exhibit. The pump manufacturer, Sulzer Bingham Pump Division, confirmed that the suction characteristics for Monticello's core spray pumps were identical to the Quad Cities RHR pumps over the flow range of 4,000 gpm to 5,300 gpm. The letter providing this information is provided as an attachment to this exhibit.

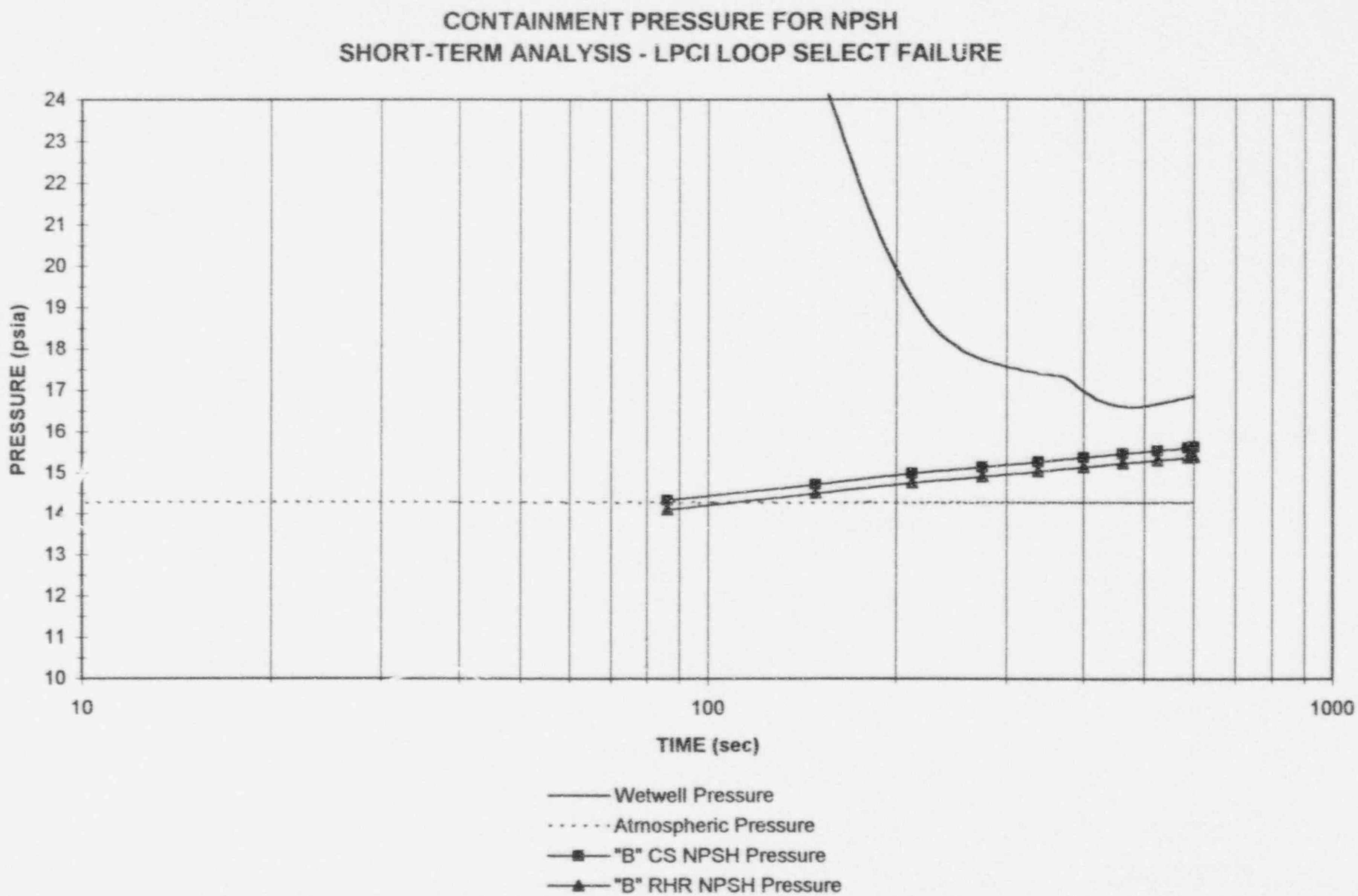
CONTAINMENT PRESSURE FOR NPSH
SHORT-TERM ANALYSIS - LPCI LOOP SELECT FAILURE
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
PRESSURE (psia)
10
100
1000
TIME (sec)
Wetwell Pressure
Atmospheric Pressure
"B" CS NPSH Pressure
"B" RHR NPSH Pressure

FIGURE E.1

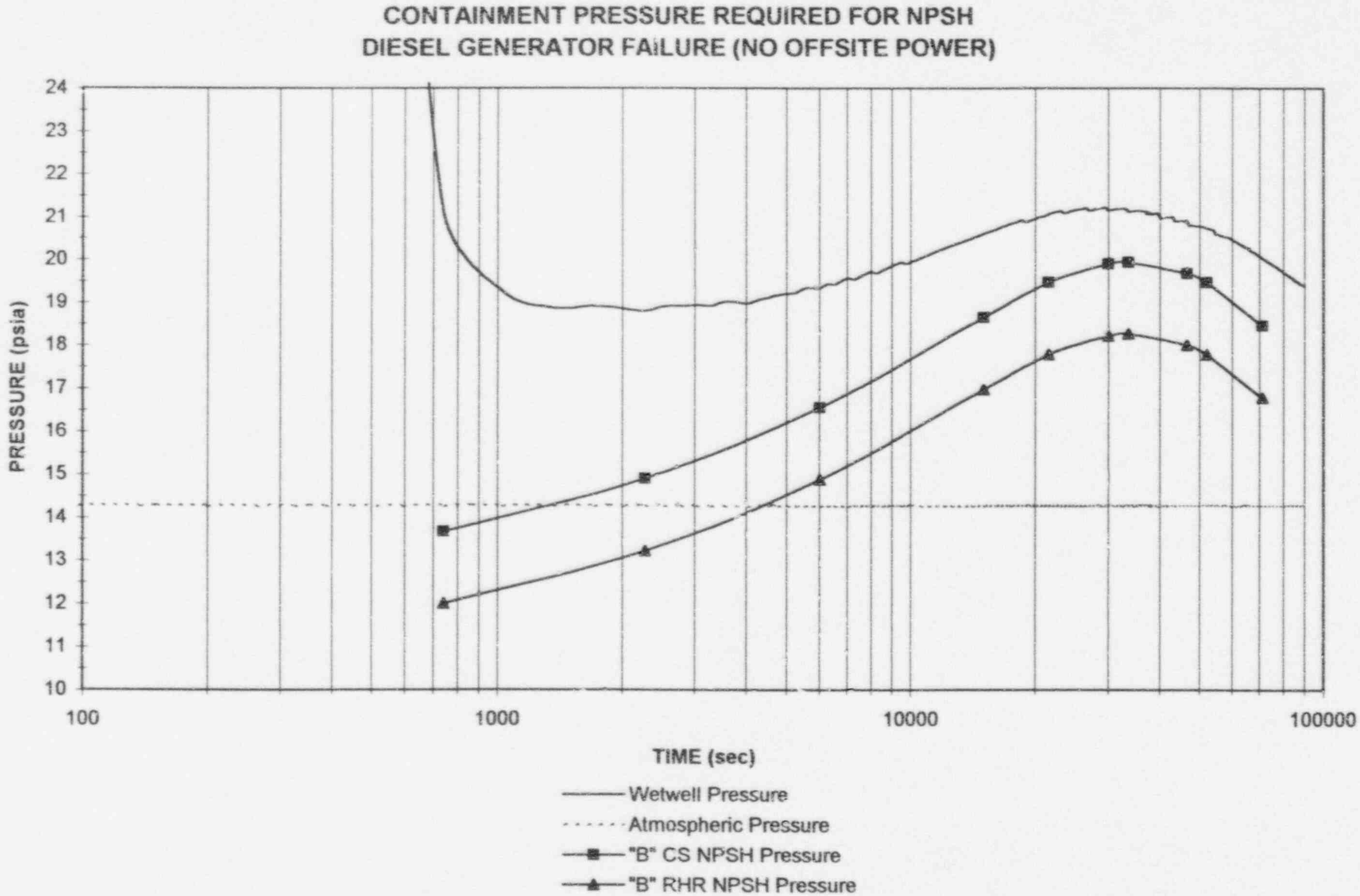
CONTAINMENT PRESSURE REQUIRED FOR NPSH
DIESEL GENERATOR FAILURE (NO OFFSITE POWER)
PRESSURE (psia)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
100
1000
10000
100000
TIME (sec)
Wetwell Pressure
Atmospheric Pressure
"B" CS NPSH Pressure
"B" RHR NPSH Pressure

FIGURE E.2

CONTAINMENT PRESSURE REQUIRED FOR NPSH
LPCI INJECTION VALVE FAILURE (NO OFFSITE POWER)

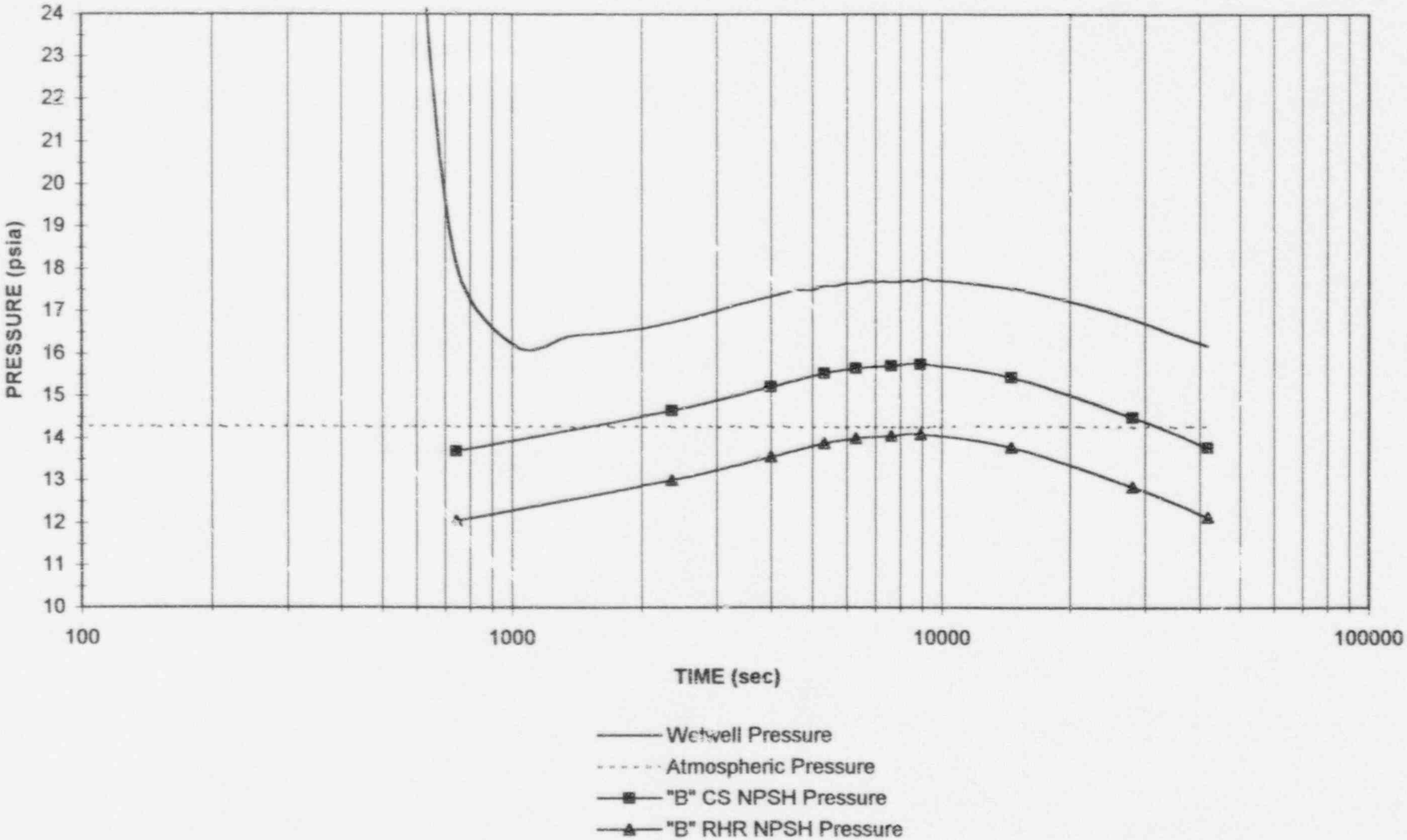

FIGURE E.3

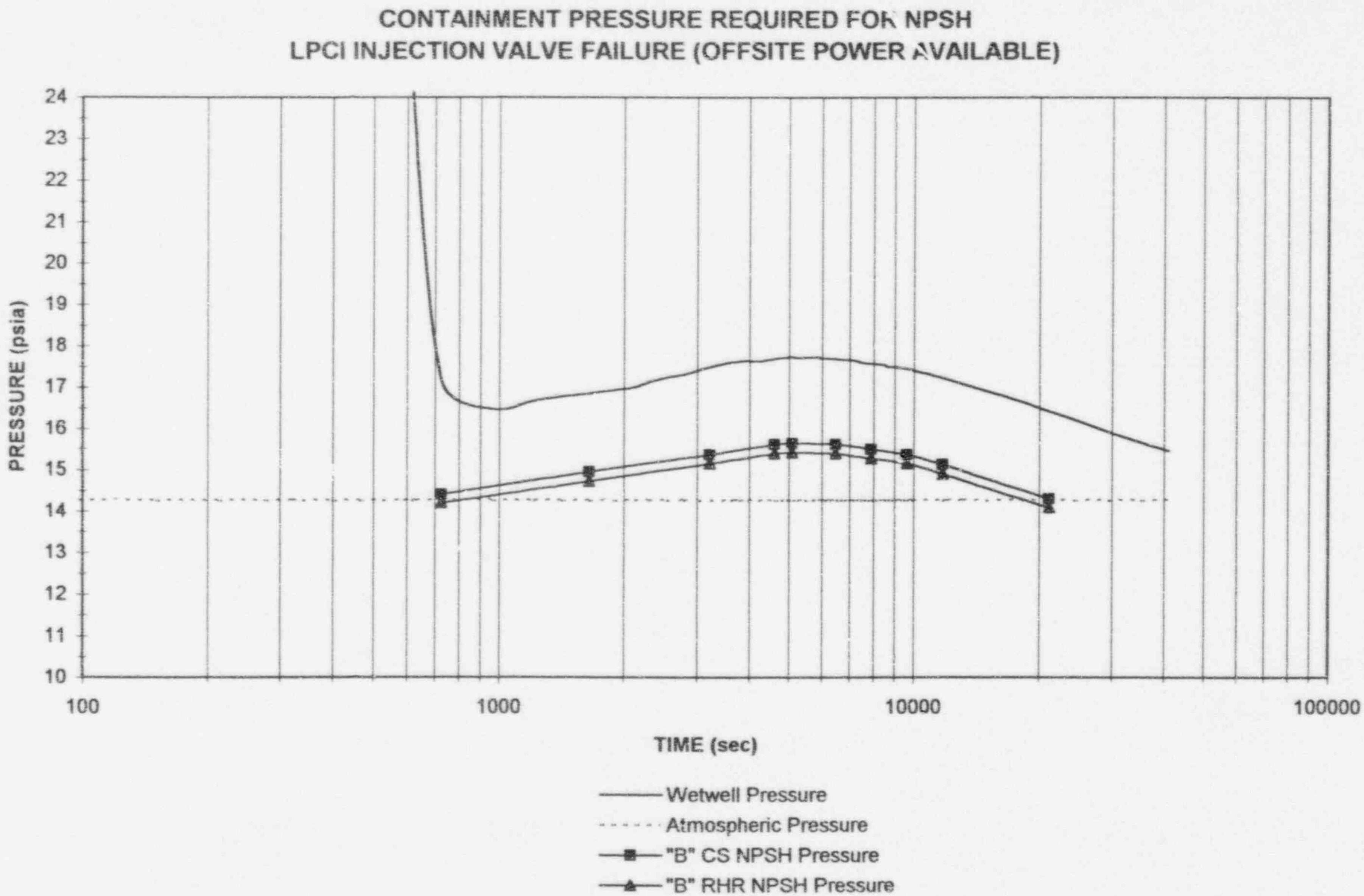
CONTAINMENT PRESSURE REQUIRED FOR NPSH
LPCI INJECTION VALVE FAILURE (OFFSITE POWER AVAILABLE)
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
PRESSURE (psia)
100
1000
10000
100000
TIME (sec)
Wetwell Pressure
Atmospheric Pressure
"B" CS NPSH Pressure
"B" RHR NPSH Pressure

FIGURE E.4