Attachment 3

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GE NUCLEAR ENERGY REPORT, GE-NE-0000-0002-8817-01-R2
MONTICELLO NUCLEAR GENERATING PLANT LONG-TERM
CONTAINMENT ANALYSIS, REVISION 2,
DATED AUGUST 2003, NON-PROPRIETARY VERSION

GE Report follows

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Revision 2
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Monticello Nuclear Generating Plant Long-term Containment Analysis

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Monticello Nuclear Generating Plant
Long-term Containment Analysis

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REVISION

The following changes to the Revision 1 report, GE-NE-0000-0002-8817-01-R1, September 2002, are incorporated in this Revision 2 report.

- The initial DW temperature listed in Tables 3-2 and 3-3 is changed from 150°F to 135°F.
- In 1st sentence of 2nd paragraph, page 4-17, the peak suppression pool temperature and its timing are changed from 195.8°F and 37163 seconds to 196.5°F and 37104 seconds, respectively.
- In 2nd sentence of 2nd paragraph, page 4-17, the long-term peak suppression chamber pressure is changed from 18.8 psig to 19 psig.
- In 1st sentence of 2nd paragraph, page 4-18, the peak suppression pool temperature is changed from 196.5°F to 196.2°F.
- In 1st sentence of 2nd paragraph, page 4-18, the peak suppression pool temperature is changed from 195.8°F to 196.5°F.
- In 2nd sentence of 2nd paragraph, page 4-18, the word "higher" is changed to "slightly lower."

IMPORTANT NOTICE REGARDING THE CONTENTS OF THIS REPORT

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ACRONYMS AND ABBREVIATIONS

ADS	Automatic Depressurization System
ANS	American Nuclear Society
BWR	Boiling Water Reactor
CRD	Control Rod Drive
CS	Core Spray
CST	Condensate Storage Tank
DBA	Design Basis Accident
ECCS	Emergency Core Cooling System
EOP	Emergency Operating Procedure
GE	GE Nuclear Energy
HEM	Homogeneous Equilibrium Model
HPCI	High Pressure Coolant Injection
K	RHR heat exchanger K-value
LOCA	Loss of Coolant Accident
LPCI	Low Pressure Coolant Injection
LWL	Low Water Level
MSIV	Main Steam Isolation Valve
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel
SRV	Safety-Relief Valve
SWT	Service Water Temperature
TAF	Top of Active Fuel
TS	Technical Specifications
UFSAR	Updated Final Safety Analysis Report

1. PROJECT OVERVIEW AND OBJECTIVES

A containment response analysis was performed in support of the power rerate project and the analysis results were documented in References 1 and 2. The power rerate containment analysis was performed for a reactor thermal power of 1880 MWt. The long-term analysis used ANS 5.1 nominal decay values, assuming a service water temperature of 90°F and a residual heat removal (RHR) heat exchanger K-value of 143.1 Btu/sec-°F. All applicable containment requirements associated with the responses analyzed were met at power rerate conditions.

Reference 2 supplemented the results of the Reference 1 analysis, and provided DBA-LOCA (design basis accident – loss-of-coolant accident) evaluations at power rerate conditions for use in analyses of net positive suction head (NPSH) for the residual heat removal (RHR) and core spray pumps. The Reference 3 containment analysis used a containment cooling initiation time based on the maximum time that it takes to establish containment cooling following a loss-of-coolant accident or reactor isolation event, as determined by a SAFER/GESTR analysis. The premise in the Reference 3 analysis was that adequate core cooling must be established before the low-pressure coolant injection (LPCI)/RHR system can be placed into the containment-cooling mode. In Reference 3, a reactor isolation event with the high pressure coolant injection (HPCI) unavailable was determined to be the most limiting event with respect to the maximum time to establish containment cooling. The maximum time required to initiate containment cooling for the isolation event was calculated to be 48.54 minutes from the onset of the event, based on the SAFER/GESTR analysis of the event. This time consists of the time to reach the LPCI injection valve permissive pressure, plus the 5-minute LPCI interlock, plus the 400 seconds to complete system configuration (line-up).

The DBA-LOCA containment response was evaluated, using the 48.6-minute delay in containment cooling, as compared with a 10-minute delay assumed for the Reference 1 power rerate analysis. The purpose of this containment analysis was to determine the impact of the 48.54-minute delay in containment cooling on peak suppression pool

temperature. It should be noted that the analysis is considered very conservative because the DBA-LOCA event was analyzed, using the maximum time delay in containment cooling, which was obtained for the isolation event.

The DBA-LOCA analysis with a 48.54-minute containment cooling initiation time resulted in peak suppression pool temperature above 195°F (the current design temperature for piping system attached to the torus), when the service water (SW) temperature was assumed to be 90°F. With 85°F SW temperature, however, the same case resulted in peak suppression temperature below 195°F. Consequently, a reduction in the maximum allowable SW temperature on the ultimate heat sink (UHS) from 90°F to 85°F was imposed by Monticello.

This project was initiated to restore the maximum acceptable UHS temperature to 90°F (Reference 10). The project is also intended to address the following issues (Reference 10):

a. Delayed cooling time for other small breaks – The reactor isolation event can be considered to conservatively represent small breaks, as far as the maximum time to establish containment cooling is concerned. However, it will be necessary to confirm such is the case by analyzing additional small breaks.

b. Revised decay heat requirements - The containment analyses of References 1, 2 and 3 were calculated at 102% of 1880 MWt using a decay heat curve based on a the nominal ANSI/ANS 5.1-1979 decay heat with no uncertainty adders. However, the NRC currently requires a 2-sigma adder to the ANS 5.1-1979 decay heat in containment analyses. As described in Reference 1, the decay power time-history used for the Reference 1 analysis, using the nominal ANS 5.1-1979 decay heat at 102% of 1880 MWt, is roughly equivalent to the power corresponding to ANS 5.1-1979 with a 2 sigma adder at 102% of 1775 MWt. This provided justification at the time for using the results of the Reference 1 analysis to support a power rerate to 1775 MWt. However, it was understood that future analyses will include generation of a Monticello plant specific ANS 5.1-1979 + 2 sigma decay heat curve.

c. GE SIL 636 - In June 2001, GE issued Service Information Letter (SIL) 636 (Reference 8) which describes a potential non-conservatism in decay heat calculations based on the ANSI/ANS-5.1-1979 standard. The non-conservatism results from failure to account for the cumulative effects of actinides other than ^{239}U and ^{239}Np, as well as activation products in structural materials. This non-conservatism can potentially impact the results of the Reference 1, 2 and 3 analyses.

Consequently, Nuclear Management Company (NMC) requested GE, by Reference 10, to perform a containment analysis based on updated plant data, addressing the above concerns. This report provides the results of the containment analysis that has been performed for Monticello Nuclear Generating Plant, per Reference 10.

Specifically, the objectives of this project are:

1. Update the long-term containment analysis input basis by using updated plant data, and decay heat values that are calculated with additional terms, consistent with SIL 636, and also by adding 2-sigma adders to nominal values for the decay heat values to be used for the analysis.

2. Perform a SAFER/GESTR analysis to determine the ADS activation and containment cooling initiation times for an reactor isolation event, 0.01 and 0.1 ft^2 liquid line breaks at 102% of 1775 MWt core power. The power level and decay heat values used in this analysis will be consistent with those for the containment analysis.

3. Perform a long-term containment analysis for the isolation event and small breaks, using the ADS activation and containment cooling initiation times obtained from the SAFER/GESTR analysis.

4. Perform a long-term containment analysis for the DBA-LOCA with direct suppression pool cooling, using input values that maximize the containment pressure response.

5. Perform a short-term (<600 seconds) and long-term (beyond 600 seconds up to 12 days) containment analysis for the DBA-LOCA with containment spray cooling,

using input values minimizing the containment pressure response. The analysis results will be provided to the NMC for input to the evaluation of NPSH for pumps taking suction from the suppression pool.

6. Determine which event is the limiting event, among the DBA-LOCA, small-break LOCAs and the isolation event, with respect to peak suppression pool temperature. For the limiting event, perform a long-term containment analysis with an updated K-value of 147 Btu/sec-°F for the RHR heat exchanger (Reference 5), as compared with the K-value of 143.1 Btu/sec-°F used in the Reference 1 power rerate analysis. This analysis will be performed with two sets of input assumptions: a) direct pool cooling with input values maximizing the pressure response, and b) containment spray cooling with input values minimizing the pressure response for input to NPSH evaluation.

7. Determine the maximum acceptable service water temperature that keeps the peak suppression pool temperature below 196.7°F, which has been identified, by the NMC, as an acceptable piping temperature limit (Reference 13). For this purpose, a long-term containment analysis will be performed for the limiting event with the RHR heat exchanger K-value of 147 Btu/sec-°F. This analysis will be performed with two sets of input assumptions: a) direct pool cooling with input values maximizing the pressure response, and b) containment spray cooling with input values minimizing the pressure response for input to NPSH evaluation.

2. SUMMARY AND CONCLUSIONS

2.1 Summary

The following summarizes the results of the analyses performed for this project:

1. The long-term containment analysis input basis has been updated, as documented in Reference 6. The key input parameters are listed in Section 3 of this report. Appendix A provides the total core heat values (fission power + decay heat (consistent with SIL 636) + fuel relaxation energy + metal-water reaction energy) that were used in the containment analysis.

2. A SAFER/GESTR analysis has been performed to determine the ADS activation and containment cooling initiation times for the reactor isolation event, 0.01 and 0.1 ft^2 liquid line breaks at 102% of 1775 MWt core power. The containment cooling initiation times for the isolation event, 0.01 and 0.1 ft^2 breaks were determined to be 45.81, 26.0 and 16.76 minutes, respectively. Note that the containment cooling initiation time was determined to be 48.54 minutes in the Reference 3 SAFER/GESTR analysis, which was performed at 1775 MWt with the decay heat values obtained before SIL 636. The use of the 2%-higher initial power level and SIL-636 consistent decay values resulted in a reduction of the delay in containment cooling. For consistency between the SAFER analysis and containment analysis, the 45.81-minute value was used as input to the current containment analysis of the isolation event, which was performed at 102% of 1775 MWt core power.

3. A long-term containment analysis for the isolation event and small breaks with direct suppression pool cooling was performed with a service water temperature of 90°F and the RHR K-value of 143.1 Btu/sec-°F. For all cases, the peak suppression pool temperature was below 195°F, as shown below.

Break Sizes (ft^2)	Containment Cooling Initiation Time (sec)	Peak Suppression Pool Temperature (°F)	Remarks
Reactor Isolation	45.81	194.0	One RHR loop with HPCI unavailable.
Reactor Isolation	45.81	167.0	Two RHR loops with HPCI unavailable.
0.01	26.0	190.0	One RHR loop with HPCI unavailable.
0.1	16.76	191.2	One RHR loop with HPCI unavailable.

Note: Reactor Isolation event with one RHR loop and inoperable HPCI bounds small break cases with HPCI available, as discussed in section 4.2.4.

4. A long-term containment analysis of the DBA-LOCA with direct suppression pool cooling, a 10-minute containment cooling initiation time, a service water temperature of 90°F and the Reference 1 RHR K-value of 143.1 Btu/sec-°F, resulted in a peak suppression pool temperature of 195.6°F.

5. A peak suppression pool temperature of 195.5°F was obtained from a long-term containment analysis for the DBA-LOCA with containment spray cooling for input to the NPSH evaluation. This case was analyzed, assuming a 10-minute containment cooling initiation, with 90°F service water temperature and the Reference 1 RHR K-value of 143.1 Btu/sec-°F

6. The limiting event with respect to peak suppression pool temperature, among the DBA-LOCA, isolation event and small-break LOCAs, was determined to be the DBA-LOCA, as summarized above. When the updated RHR heat exchanger K-value of 147 Btu/sec-°F (Reference 5) was used with a service water temperature of 90°F, the peak suppression pool temperature for the limiting DBA-LOCA event was 194.1°F with direct suppression pool cooling, and 194.2°F with containment spray cooling for NPSH.

7. With the updated RHR heat exchanger K-value of 147 Btu/sec-°F and a service water temperature of 94°F, the peak suppression pool temperature for

the limiting DBA-LOCA event was 196.5°F with direct suppression pool cooling, and 196.2°F with containment spray cooling for NPSH. Thus, the maximum acceptable service water temperature that would keep peak suppression pool temperature below the Reference 13 acceptable piping temperature limit of 196.7°F was determined to be 94°F with the updated RHR heat exchanger K-value of 147 Btu/sec-°F.

2.2 Conclusions

Based upon the analysis performed with the updated plant data, and decay heat values (with 2-sigma adders) obtained with the method consistent with SIL 636, the following conclusions can be drawn for Monticello Nuclear Generating Plant:

- For the limiting DBA-LOCA event, the peak suppression pool temperature at 102% of 1775 MWt reactor power was above 195°F, when the Reference 1 RHR heat exchanger K-value of 143.1 Btu/sec-°F was used with a service water temperature of 90°F. With the updated RHR heat exchanger K-value of 147 Btu/sec-°F, however, the peak suppression pool temperature for the DBA-LOCA was below 195°F with the same service water temperature of 90°F.
- At 102% of 1775 MWt reactor power, the maximum acceptable service water temperature that would keep the peak suppression pool temperature below 196.7°F for the limiting DBA-LOCA, is 94°F with the updated RHR heat exchanger K-value of 147 Btu/sec-°F.

3. EVALUATION

3.1 Method of Evaluation

Long-term containment analyses are performed using the GE computer code SHEX, as was used for the Reference 1 power rerate evaluation, in compliance with the Reference 7 requirements. The key models used in the SHEX code are described in References 9 and 14.

The SHEX code was already used for the Monticello UFSAR analysis, which was preceded by confirmatory calculations (Reference 1) between the SHEX code and the NRC-approved HXSIZ code. Therefore, the use of the SHEX code for Monticello is within the current licensing analysis basis and complies with the NRC requirements. Nevertheless, a benchmarking analysis has been performed by re-analyzing the DBA-LOCA analyzed in Reference 1, using the same decay heat values at the same initial core power, but with updated plant data. Thus, the benchmarking analysis would show the impact of the plant data update and modeling update on the containment response. The benchmarking analysis, which is presented in Appendix B, shows that the current analysis resulted in a 0.2°F increase in peak suppression pool temperature (the key containment response parameter) for the same core power and decay heat values.

The SHEX code is also used to evaluate the containment response for a reactor isolation event, and small breaks. However, for these events, the ADS activation and RHR suppression pool cooling initiation times were determined from the SAFER/GESTR results for the same events, since more detailed vessel models in the SAFER/GESTR

code evaluate the vessel response more accurately. The ADS activation and suppression pool cooling initiation times determined as such are used as input to the SHEX code.

In the SAFER/GESTR analysis, the automatic activation of the ADS is inhibited and the operator is assumed to depressurize the reactor vessel by using the ADS valves when the water level outside the core shroud decreases to the top of the active fuel. The time of ADS activation is obtained directly from the SAFER/GESTR output. The time to initiate containment cooling is determined by selecting a longer time from the results for the following two possible paths:

Thus, the ADS activation and containment cooling initiation times were determined from the SAFER/GESTR analysis, and these values were used as input to containment analyses.

An isolation event is the most limiting case for determining the maximum time to establish pool cooling. For the DBA-LOCA, the vessel is depressurized and the core reflooded within a few minutes. Containment cooling can typically be established within about 10 minutes, and the current analysis assumed a 10-minute containment initiation time for the DBA-LOCA. As the assumed break size decreases, it takes a longer time to depressurize the vessel and reflood the core. The maximum time occurs for a zero size break case (a reactor isolation event) where the only inventory loss from the vessel is done by boil-off through the SRVs. LOCAs for 0.10 ft^2 and 0.01ft^2 recirculation line breaks were also analyzed to further prove the isolation event is the most limiting with regard to containment cooling initiation time. It is noted that for small breaks less than 0.10 ft^2, any increase in the time to reflood due to loop selection logic failure is accounted for by use of an adder based upon a bounding case of no LPCI flow (i.e., all LPCI flow is assumed lost in the broken loop).

Another thing to note is that the current SAFER/GESTR analysis was performed at 102% of 1775 MWt core power with the Reference 4 decay heat values (nominal plus 2 sigma adders) obtained with the method consistent with SIL 636. The power level and decay heat values are the same as those used for the current containment analysis, whereas the Reference 3 SAFER/GESTR analysis was performed at 1775 MWt core power and decay heat values obtained before SIL 636. The containment cooling initiation time from the current SAFER/GESTR analysis performed as such is about 3-minute shorter, compared with the Reference 3 SAFER/GESTR analysis.

More significantly, the current containment analysis for the isolation event is more realistic than the Reference 3 containment analysis. The Reference 3 containment evaluation of the isolation event was done by analyzing a recirculation suction line break (DBA-LOCA break size) with a containment cooling initiation time of 48.54 minutes obtained from a SAFER/GESTR analysis of the isolation event. However, the current

containment analysis models the reactor system response to the isolation event, including the break size (near-zero break size modeled), the ADS activation, and closure of ADS valves at 50 psig.

This modeling approach, as explained above, was used for both direct suppression pool cooling and containment spray cooling. It is noted that this

modeling update has a negligible impact on peak pool temperature, but provides a more realistic suppression chamber airspace pressure and temperature prediction.

3.2 Inputs and Assumptions for SAFER/GESTR Analysis of Isolation Event and Small Breaks

The inputs to the current SAFER/GESTR analysis are essentially the same as those used in the SAFER/GESTR analysis performed for Reference 3, except for the the reactor thermal power, decay heat values, and the input values affected by the power level, which were obtained from heat balance data for 102% of 1775 MWt. (Reference 11). The current SAFER analysis, as in the current containment analysis, used decay heat values (nominal plus 2-sigma adders) obtained with the method consistent with SIL 636. Also, the key input values were confirmed by checking with Monticello Power Rerate OPL-4 (Reference 12). It is noted that there are some differences between the OPL-4 and the OPL-4A developed for this project. The major differences between the two are:

The following assumptions define the events that were analyzed with SAFER/GESTR.

1. Adequate core cooling is defined by restoring reactor water level inside the core shroud to two-thirds core height (elevation of the jet pump suction) with one core spray operating. This is the definition of adequate core cooling used in the Monticello Emergency Operating Procedures (EOPs).

2. The jet pump water level from the SAFER run will be used to determine the time when the water level reaches the jet pump suction. This is the region in the vessel monitored by the fuel zone level instrument.

3. The operators will initiate containment cooling once adequate core cooling has been established. This assumption will result in the longest delay time in establishing containment cooling. This assumption is consistent with the expected scenario for a large break LOCA where the vessel will rapidly depressurize and empty through the break, and then is quickly refilled by the automatic initiation of the ECCS. For a slowly developing event, such as reactor isolation, it is conservative to assume that containment cooling is delayed until the vessel is depressurized and adequate core cooling is established. For this type of event the operator would have time to initiate containment cooling before ECCS initiation occurs. Since the additional cooling time removes energy from the containment, it is also conservative for this type of event to assume no containment cooling until after adequate core cooling is established.

4. The operators will depressurize the vessel using the ADS valves in accordance with the emergency operating procedures (EOPs) when the water level outside the shroud reaches the top of the active fuel. The downcomer elevation corresponding to an indicated level of –126 inches will be used to define the "top of active fuel." This is the action level defined in the EOPs.

5. It takes 400 seconds to realign the RHR system from the LPCI mode to containment cooling and to start the RHR service water system (Reference 3).

6. The LPCI isolation valve control contains a logic that prevents the valves from being opened, unless the reactor vessel pressure falls below the LPCI injection valve pressure permissive. Once the vessel pressure drops below the LPCI injection valve pressure permissive an open signal is given to the LPCI

injection valve and the open signal is maintained for at least the next 5 minutes, assuring the valve stays open.

8. The single failure assumed for this evaluation is a battery failure that eliminates the division of ECCS that has the HPCI. The remaining systems are two LPCI/RHR pumps and one core spray pump. One RHR pump must be shed when the service water pump is started to initiate containment cooling.

9. It is assumed that no high pressure inventory makeup systems (feedwater, HPCI, RCIC) are available and that the water level in the vessel cannot be maintained without depressurizing and using the low pressure ECCS. If the high pressure makeup systems were available, the water level in the vessel will be maintained above the top of the core, thus assuring adequate core cooling at all times. The operators would then be free to establish containment cooling at any time. The impact of HPCI operation on peak suppression pool temperature is qualitatively evaluated in Section 4.2.4.

10. Consistent with the containment analysis, 102% of the current licensed power level of 1775 MWt will be used in the analysis, as well as the ANS 5.1 +2 sigma decay heat from Reference 4.

11. A full core of GE11 fuel will be assumed for this analysis. The core is predominantly GE11.

Although GE11 GESTR data is used, the revised decay heat is based upon GE14 (Reference 4). However, Reference 4, which provides the new decay heat data, concludes that there is negligible difference between the decay heats for GE11 and GE14.

3.3 Inputs and Assumptions for SHEX Containment Analysis

The OPL-4A (Reference 6) lists the containment analysis input parameters used for the current analysis. This section (Section 3.3) lists and discusses key inputs and assumptions used in the SHEX analysis for each of the events analyzed, starting with the DBA-LOCA with direct suppression cooling.

3.3.1 DBA-LOCA with Direct Suppression Pool Cooling

Table 3-1 gives the values of major SHEX input parameters used for the current containment analysis of DBA-LOCA with direct pool cooling. Key inputs and assumptions for SHEX analyses of the DBA-LOCA with direct suppression pool cooling are discussed below.

1. The DBA-LOCA is defined as a double-ended recirculation suction line break. The effective break area is 4.095 ft^2. The RHR inter-tie is assumed open during the break and is included in the break size calculation. There is also a concurrent loss of offsite power and only minimum diesel power is available. Reactor scrams at time zero.

2. The reactor is operating at 102% of rated thermal power of 1775 MWt (i.e. 1810.5 MWt) with an initial reactor pressure of 1040 psia.

3. The reactor core power includes fission energy, fuel relaxation energy, metal-water reaction energy and ANS 5.1 + 2σ decay heat for fuel applicable up to GE14 (see Appendix A). The decay heat values used address the SIL 636 issue.

4. Reactor blowdown flow rates are based on the Homogeneous Equilibrium Model (HEM) described in Reference 15. This is the critical flow model used in the analysis of References 1, 2 and 3.

5. A hot portion of the feedwater inventory is transferred to the vessel to maximize the suppression pool temperature response.

6. MSIV closure starts at 0.5 seconds after the initiation of the event and full closure is achieved at 3.0 seconds after closure is initiated.

7. For the first 10 minutes following the accident, two LPCI pumps and one CS pump inject into the vessel. After 10 minutes, one CS remains available for vessel injection.

8. The initial suppression pool water volume corresponds to the Low Water Level (LWL) to maximize the suppression pool temperature response.

9. The initial drywell and suppression chamber airspace pressure is assumed to be at the scram setpoint pressure of 2 psig. The initial drywell relative humidity is assumed to be 20% with an initial drywell temperature of 135°F. An initial temperature of 90°F is assumed for the suppression pool. The initial suppression chamber airspace temperature is also assumed to be 90°F with 100% relative humidity. Under such containment initial conditions, the total non-condensable gas mass in the containment (the drywell and suppression chamber airspace combined) is 18200 lbm. The assumption of higher containment pressure and lower drywell humidity results in a larger amount of non-condensable gas mass in the containment, which in turn will provide a higher containment pressure response.

10. Drywell fan coolers are inactive.

11. Control rod drive flow is zero.

13. All core spray and LPCI/RHR pumps have 100% of their motor horsepower rating converted to pump heat which is added either to the RPV liquid or suppression pool water. This assumption is used to maximize the suppression pool temperature response.

14. Passive heat sinks corresponding to the drywell metal shell (including the vent system), and torus metal shell are modeled.

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

16. Six suppression chamber-to-drywell vacuum breakers are assumed to be active.

17. CST water inventory is not available for vessel makeup.

18. There is only one RHR loop with one heat exchanger available for containment cooling, starting at 10 minutes.

19. At 10 minutes, one LPCI/RHR pump is turned off and the remaining LPCI/RHR pump is realigned in suppression pool cooling mode with activation of RHR heat exchanger cooling. The RHR pump operates at 4000 gpm with flow through the heat exchanger. One RHR SW pump is aligned with the RHR heat exchanger. This configuration is maintained throughout the remainder of the accident. The corresponding RHR heat exchanger K-value is 143.1 Btu/sec-°F, based on the Reference 1 analysis. In addition to this K-value, an updated K-value of 147 Btu/sec-°F is used in the analysis.

20. The RHR service water temperature is at the Reference 1 maximum value of 90°F to maximize the suppression pool temperature. The DBA-LOCA was also analyzed at a service water temperature of 94°F with the updated K-value of 147 Btu/sec-°F. (A 94°F service water temperature was determined to be the maximum acceptable service water that would keep peak suppression pool below 196.7°F with the updated K-value of 147 Btu/sec-°F during the DBA-LOCA (see Section 4.5).) Thus, the DBA-LOCA with direct suppression pool cooling was analyzed for three different combinations of service water temperature and RHR heat exchanger K-value, as shown below, and the results are presented in Section 4.

SW Temperature (°F)	RHR heat exchanger K-value (Btu/sec-°F)
90	143.1
90	147
94	147

3.3.2 DBA-LOCA with Containment Spray Cooling for NPSH

The DBA-LOCA containment response for NPSH evaluations is analyzed for two time periods: short-term (0-600 seconds) before the operator takes actions (such as initiation of containment cooling and throttling of the pump flow), and long-term (600 seconds-12 days) after initiation of containment cooling. Table 3-2 gives the values of the major SHEX input parameters used for the short-term DBA-LOCA analysis for NPSH, whereas the input values for the long-term DBA-LOCA analysis for NPSH are given in Table 3-3. The inputs and assumptions for this analysis are essentially the same as those for the DBA-LOCA with direct suppression pool cooling listed in the previous section, except that some input values are selected to minimize the containment pressure. Specifically, the following assumptions are different from those for the DBA-LOCA with direct pool cooling. (Note that the following assumptions related are applicable to both short-term (0-600 seconds) and long-term (600 seconds to 12 days) NPSH DBA-LOCA analyses, unless specified for the event duration applicable.)

1. The initial drywell and suppression chamber airspace pressure is assumed to be 14.26 psia. The initial drywell relative humidity is assumed to be 100% with an initial drywell temperature of 135°F. An initial temperature of 90°F is assumed for the suppression pool. The initial suppression chamber airspace temperature is also assumed to be 90°F with 100% relative humidity. Under such containment initial conditions, the total non-condensable gas mass in the containment is 14224 lbm versus 18200 lbm assumed to maximize the pressure response (Section 3.3.1 Assumption 9). The assumption of smaller containment pressure and lower drywell humidity results in a smaller amount of non-condensable gas mass in the containment, which in turn will provide a lower containment pressure response. This is done to minimize the pressure response for use in NPSH analyses.

2. For the long-term (600 seconds-12 days) NPSH DBA-LOCA analysis, at 10 minutes one LPCI/RHR pump (out of the two operable pumps) is turned off and the remaining pump is realigned in containment spray (DW and WW sprays) cooling mode with activation of RHR heat exchanger cooling. The RHR pump operates at 4000 gpm with flow through the heat exchanger. One RHR SW pump is aligned with the RHR heat exchanger. This configuration is maintained throughout the remainder of the accident.

3. For the long-term (600 seconds-12 days) NPSH DBA-LOCA analysis, 3800 gpm, out of the total RHR 4000 gpm flow, goes to the drywell spray and the remaining 200 gpm goes to the suppression chamber spray.

5. For the short-term (0-600 seconds) NPSH DBA-LOCA analysis, two LPCS pumps are operable. However, for the long-term (600 seconds-12 days) analysis, one LPCS pump is assumed to be operable as vessel makeup.

The DBA-LOCA with containment spray cooling for long-term NPSH was analyzed for three different combinations of service water temperature and RHR heat exchanger K-value, as shown below and the results are presented in Section 4. (It is noted that neither the SW temperature nor RHR heat exchanger K-value has any impact on the short-term NPSH DBA-LOCA results.)

SW Temperature (°F)	RHR heat exchanger K-value (Btu/sec-°F)
90	143.1
90	147
94	147

3.3.3 Reactor Isolation and Small Breaks with Direct Suppression Pool Cooling

A SHEX analysis was performed for a reactor isolation event and small breaks with direct suppression pool cooling, using ADS activation and containment cooling initiation

times obtained from the SAFER/GESTR analysis. Table 3-4 gives the values of the major SHEX input parameters used for the containment analysis of these events with direct pool cooling. The analysis inputs and assumptions for this containment analysis are essentially the same as those for the DBA-LOCA with direct suppression pool cooling listed in Section 3.3.1, except for those listed below.

1. The break sizes analyzed are liquid breaks of 0.1 ft^2, 0.01 ft^2, and 0.0001 ft^2. The 0.0001 ft^2 break is used to represent the reactor isolation event. This small break size (equivalent to about 4 gpm leakage at 1040 psia operating pressure) is modeled to account for the effect of the drywell heat sink in the suppression pool temperature response evaluation.

2. ADS initiation occurs as determined from the SAFER/GESTR analysis.

3. Two SRVs are used for the ADS functions, and they are closed at or below 50 psig.

4. Containment cooling (direct suppression pool cooling) is initiated, as determined from the SAFER/GESTR analysis (Table 4-1). One LPCI/RHR pump per loop is turned off and the remaining LPCI/RHR pump is realigned in suppression pool cooling mode with activation of RHR heat exchanger cooling. The RHR pump operates at 4000 gpm with flow through the heat exchanger. One RHR SW pump is aligned with the RHR heat exchanger. This configuration is maintained throughout the remainder of the accident. Only the Reference 1 RHR heat exchanger K-value of 143.1 Btu/sec-°F was analyzed. As shown in Section 4, the peak suppression temperature for the isolation event and also for small breaks was below 195°F. Therefore, an additional containment analysis with the updated K-value of 147 Btu/sec-°F was not necessary.

5. The service water temperature is 90°F. An additional containment analysis with 94°F service water temperature was not necessary.

6. One CS pump remains available for injection into the vessel. This configuration is maintained throughout the remainder of the accident.

7. Two ECCS/RHR configurations: one-loop and two-loop operation, were analyzed for the isolation event represented by 0.0001 ft^2 break. For other two break sizes, only one-loop configuration was analyzed.

8. Mechanistic modeling of heat and mass transfer between the suppression pool and the suppression chamber airspace was used from time zero.

9. HPCI is not available. A qualitative evaluation is performed for the case where HPCI is available to ascertain that the isolation event without HPCI is more limiting with respect to peak pool temperature (see Section 4.2.4).

Thus, the following cases are analyzed:

Break Sizes (ft^2)	HPCI available?	Remarks
Isolation Event	No	One RHR loop.
Isolation Event	No	Two RHR loops.
0.01	No	One RHR loop
0.1	No	One RHR loop
All sizes	Yes	Qualitative evaluation

Table 3-1: Key SHEX Input Values for DBA-LOCA with Direct Pool Cooling

Parameter	Units	Value
Initial Core Thermal Power (102% of rated)	MWt	1810.5
Initial Reactor Vessel Dome Pressure	psia	1040
Initial Drywell Free (Airspace) Volume	ft^3	134,200
Suppression Chamber Airspace Volume	ft^3	108,250
Initial Suppression Pool Volume	ft^3	68,000
Initial Drywell Pressure	psia	16.7
Initial Drywell Temperature	°F	135
Initial Drywell Relative Humidity	%	20
Initial Suppression Chamber Pressure	psia	16.7
Initial Suppression Chamber Airspace and Pool Temperature	°F	90
Initial Suppression Chamber Relative Humidity	%	100
Long-term Core Spray Flow Rate	gpm	4370 at 0 psid 3020 at 130 psid
RHR Flow Rate	gpm	4000
RHR/CC Heat Exchanger K-Value	Btu/sec-°F	143.1 (current) 147 (updated)
RHR/CC Service Water Temperature	°F	90 94 (sensitivity)
Suppression Pool Cooling Start Time	sec	600

Table 3-2: Key SHEX Input Values for DBA-LOCA for Short-term NPSH

Parameter	Units	Value
Initial Core Thermal Power (102% of rated)	MWt	1810.5
Initial Reactor Vessel Dome Pressure	Psia	1040
Initial Drywell Free (Airspace) Volume	ft^3	134,200
Suppression Chamber Airspace Volume	ft^3	108,250
Initial Suppression Pool Volume	ft^3	68,000
Initial Drywell Pressure	Psia	14.26
Initial Drywell Temperature	°F	135
Initial Drywell Relative Humidity	%	100
Initial Suppression Chamber Pressure	psia	14.26
Initial Suppression Chamber Airspace and Pool Temperature	°F	90
Initial Suppression Chamber Relative Humidity	%	100
Core Spray Flow Rate per loop (2 loops available)	gpm	4370 at 0 psid 3020 at 130 psid
Total LPCI Flow Rate from 2 loops (2 pumps per loop) (2 loops available)	gpm	17400

Table 3-3: Key SHEX Input Values for Long-term DBA-LOCA with Containment Spray Cooling for NPSH

Parameter	Units	Value
Initial Core Thermal Power (102% of rated)	MWt	1810.5
Initial Reactor Vessel Dome Pressure	psia	1040
Initial Drywell Free (Airspace) Volume	ft^3	134,200
Suppression Chamber Airspace Volume	ft^3	108,250
Initial Suppression Pool Volume	ft^3	68,000
Initial Drywell Pressure	psia	14.26
Initial Drywell Temperature	°F	135
Initial Drywell Relative Humidity	%	100
Initial Suppression Chamber Pressure	psia	14.26
Initial Suppression Chamber Airspace and Pool Temperature	°F	90
Initial Suppression Chamber Relative Humidity	%	100
Long-term Core Spray Flow Rate	gpm	4370 at 0 psid
		3020 at 130 psid
Drywell Spray Flow Rate	gpm	3800
Suppression Chamber Spray Flow Rate	gpm	200
RHR/CC Heat Exchanger K-Value	Btu/sec-°F	143.1 (current)
		147 (updated)
RHR/CC Service Water Temperature	°F	90
		94 (sensitivity)
Suppression Pool Cooling Start Time	sec	600

Table 3-4: Key SHEX Input Values for Isolation Event, 0.01 ft^2 and 0.1ft^2 Break with Direct Pool Cooling

Parameter	Units	Value
Initial Core Thermal Power (102% of rated)	MWt	1810.5
Initial Reactor Vessel Dome Pressure	psia	1040
Initial Drywell Free (Airspace) Volume	ft^3	134,200
Suppression Chamber Airspace Volume	ft^3	108,250
Initial Suppression Pool Volume	ft^3	68,000
Initial Drywell Pressure	psia	16.7
Initial Drywell Temperature	°F	135
Initial Drywell Relative Humidity	%	20
Initial Suppression Chamber Pressure	psia	16.7
Initial Suppression Chamber Airspace and Pool Temperature	°F	90
Initial Suppression Chamber Relative Humidity	%	100
Long-term Core Spray Flow Rate	gpm	4370 at 0 psid, 3020 at 130 psid
RHR Flow Rate	gpm	4000
RHR Heat Exchanger K-Value	Btu/sec-°F	143.1 (current)
RHR Service Water Temperature	°F	90
Number of ADS Valves Activated		2
ADS Activation Time	sec	1704 (isolation); 513 (0.01ft^2); 58 (0.1 ft^2)
Containment Cooling Initiation Time	min	45.81 (isolation);26 (0.01 ft^2) ; 16.76 (0.1 ft^2)

4. EVALUATION RESULTS

4.1 ECCS-LOCA Results for Isolation Event and Small Breaks without HPCI

The isolation event, and 0.01 and 0.1 ft^2 breaks were analyzed, using SAFER, and the results are summarized in Table 4-1. The tabulated values include: a) ADS activation time, and b) two containment cooling initiation times. As discussed in Section 3.1, these values were determined from the results of a SAFER/GESTR analysis. Plots from the SAFER runs are included in Appendix F of this report. The SAFER results are discussed below.

Isolation Event

The results for the isolation event are presented in Figures F.1-1 through F.1-6. Main steam line isolation and loss of off-site power were assumed to occur at the start of the event. The vessel pressure (Figure F.1-4) rapidly rises and is maintained between the safety relief valve opening and closing setpoints. The vessel water levels both outside and inside the shroud (Figures F.1-3 and F.1-2) decrease due to inventory loss from the boil-off from decay heat. When the vessel water level outside the shroud reaches the elevation of the top of the active fuel at 1704 seconds into the event, the operator initiates the Automatic Depressurization System. Flow through these valves continues until the valves close on low vessel pressure at 2344 seconds. ADS actuation causes the vessel pressure to rapidly decrease. The pressure permissives for the LPCS and LPCI are both reached at 2049 seconds. Once the vessel pressure drops below the shutoff head of the low pressure ECCS, reflooding flow begins to enter the vessel (Figure F.1-6). The LPCS begins injection at 2069 seconds and the LPCI begins injection at 2084 seconds. The vessel water level rapidly recovers due to the ECCS injection and the level to the jet pump suction is restored at 2170 seconds. Therefore based on the jet pump level recovery, containment cooling would be established at 2170 + 400 = 2570 seconds (42.83 minutes). While based on the 5-minute LPCI interlock, containment cooling would be established at 2048.58 + 300 + 400 = 2748.58 seconds (45.81 minutes). These results are summarized in Table 4-1. Thus for this case the time to establish containment cooling is

limited by the LPCI interlock. This table also shows the previous results for the isolation event (Reference 3).

Compared with the Reference 3 analysis, a 2% higher power and ANS 5.1 + 2 sigma decay heat values (consistent with SIL 636) were used in the current analysis, as discussed in Section 3.1. With these new input values, the containment cooling initiation time was determined to be 45.81 minutes, based on clearing of the 5-minute LPCI interlock. This time is about 3 minutes shorter than the Reference 3 analysis value of 48.54 minutes due to the higher power and new updated decay heat.

<u>**Recirculation Line Small Break Cases**</u>

Additional SAFER runs were performed assuming recirculation line breaks of 0.01 ft^2 and 0.10 ft^2. The system response to a small break is similar to the isolation case discussed above with the transient events occurring earlier due to the increased inventory mass loss through the break.

The results of the 0.01 ft^2 break analysis are presented in Figures F.2-1 through F.2-6. Main steam line isolation and loss of offsite power were assumed to occur at the start of the event. The vessel pressure (Figure F.2-4) rapidly rises and is maintained between the safety relief valve opening and closing setpoints. The vessel water levels both outside and inside the shroud (Figures F.2-3 and F.2-2) decrease due to inventory loss through the break and the boil-off from decay heat. When the vessel water level outside the shroud reaches the elevation of the top of the active fuel at 513 seconds into the event, the operator initiates the Automatic Depressurization System. Flow through these valves continues until they close on low vessel pressure at 1189 seconds. ADS actuation causes the vessel pressure to rapidly decrease. The pressure permissives for the LPCS and LPCI are both reached at 860 seconds. Once the vessel pressure drops below the shutoff head of the low pressure ECCS, reflooding flow begins to enter the vessel (Figure F.2-6). The LPCS begins injection at 880 seconds and the LPCI begins injection at 895 seconds. The vessel water level rapidly recovers due to the ECCS injection and the level to the jet pump suction is restored at 985 seconds. Therefore based on the jet pump level recovery,

containment cooling would be established at 985 + 400 = 1385 seconds (23.08 minutes). While based on the 5 minute LPCI interlock, containment cooling would be established at 860.13 + 300 + 400 = 1560.13 seconds (26.00 minutes). It is noted that the 985-second time is approximate. This is because, for recirculation line breaks less than 0.10 ft^2, loop selection logic failure (i.e., LPCI injection into the broken loop) should be considered for accurate PCT results. Since PCTs are not an output of this study, and since containment cooling initiation times based upon jet pump level recovery are significantly bounded by (a) LPCI pressure permissive plus 5 minute calculations and (b) smaller line break sizes approaching the isolation case, this additional analysis with subsequent SAFER overlays was deemed not necessary for this application. However, a bounding case of no LPCI flow (i.e., all LPCI flow assumed lost in the broken loop) resulted in a jet pump level recovery delay of 38 seconds. Adding this margin to the first result above yields establishment of containment cooling at 1423 seconds (23.72 minutes).

The results of the 0.1 ft^2 break analysis are presented in Figures F.3-1 through F.3-6. Main steam line isolation and loss of offsite power were assumed to occur at the start of the event. The vessel pressure (Figure F.3-4) rapidly rises and is maintained between the safety relief valve opening and closing setpoints. The vessel water levels both outside and inside the shroud (Figures F.3-3 and F.3-2) decrease due to inventory loss through the break and the boil-off from decay heat. When the vessel water level outside the shroud reaches the elevation of the top of the active fuel at 58 seconds into the event, the operator initiates the Automatic Depressurization System. Flow through these valves continues until they close on low vessel pressure at 530 seconds. ADS actuation causes the vessel pressure to rapidly decrease. The pressure permissives for the LPCS and LPCI are both reached at 305 seconds. Once the vessel pressure drops below the shutoff head of the low pressure ECCS, reflooding flow begins to enter the vessel (Figure F.3-6). The LPCS begins injection at 325 seconds and the LPCI begins injection at 340 seconds. The vessel water level rapidly recovers due to the ECCS injection and the level to the jet pump suction is restored at 459 seconds. Therefore based on the jet pump level recovery, containment cooling would be established at 459 + 400 = 859 seconds (14.32 minutes).

While based on the 5 minute LPCI interlock, containment cooling would be established at 305.49 + 300 + 400 = 1005.49 seconds (16.76 minutes).

The SAFER/GESTR results for the isolation event, and two LOCA cases are summarized in Table 4-1.

4.2 Containment Analysis Results for Isolation Event, Small Breaks and DBA-LOCA with 143.1 Btu/sec-°F K-Value and 90°F Service Water

A long-term containment analysis was performed for a reactor isolation event, and DBA-LOCA, using the SHEX code, with the pre-updated RHR heat exchanger K-value of 143.1 Btu/sec-°F and 90°F service water temperature. Essentially, the long-term containment responses to the DBA-LOCA and isolation events previously analyzed are re-analyzed in this section with the updated plant data, addressing concerns about the decay heat requirement (nominal plus 2-sigma uncertainty), and SIL 636. Additionally, two small-break LOCAs were analyzed. (See Section 1 for more detailed information on the decay heat requirement and SIL 636.)

The analysis was performed at 102% of 1775 MWt (current rated thermal power), using a decay heat profile based on the ANSI/ANS-5.1-1979 standard with an added conservatism corresponding to a two-sigma uncertainty, satisfying the revised decay heat requirement. The Reference 4 decay heat values based on the method consistent with SIL 636 were used. Two small-break (0.01 and 0.1ft^2) LOCAs were also analyzed to ascertain that the isolation event is the limiting event (with respect to peak suppression pool temperature), among small-break LOCAs. The results presented in this section show that the DBA-LOCA is the limiting event with respect to peak suppression pool temperature, as opposed to the Reference 3 result that the isolation event was the limiting event.

4.2.1 Isolation Event, Small-break LOCAs and DBA-LOCA with One RHR Loop

A reactor isolation event and two small-break (0.01 and 0.1ft^2) LOCAs were assumed to occur with a concurrent loss of offsite power. As the MSIVs are closed, the RPV pressure is maintained between SRV closing and opening setpoints. The vessel liquid inventory is depleted due to steam discharge through SRVs and break flow. As the vessel water level reaches the top of active fuel (TAF), the operator is assumed to initiate the ADS, using two SRVs. Low-pressure systems (one core spray pump and two LPCI pumps) are activated for vessel inventory makeup. After ensuring that long-term core cooling will be maintained, the operator initiates the containment cooling (one RHR loop) by switching one LPCI pump to RHR pool cooling mode, turning off the other LPCI pump, and turning on one RHR service water pump.

A SAFER/GESTR analysis was performed for a reactor isolation event, 0.01 and 0.1ft^2 breaks with one ECCS division available and without HPCI to determine the times of ADS activation and containment cooling initiation (see Table 4-1). Using the SHEX code, a long-term containment analysis was performed with the ADS activation and containment cooling initiation times determined from the SAFER/GESTR analysis, assuming direct suppression cooling (as opposed to containment spray cooling). It is noted that the isolation event was analyzed by assuming that there is a 0.0001 ft^2 liquid line break, which is equivalent to a leakage of approximately 4 gpm at operating pressure of 1040 psia. This small break was assumed to take into account the effect of the drywell shell (heat sink) on peak suppression pool temperature. In the SHEX calculation, the sensible heat of the vessel wall is transferred to the fluid inside the vessel and then to the suppression pool via SRV flow (and break flow if there is a break), assuming that heat transfer from the vessel surface to the drywell is negligible, relative to the energy transfer via break flow and SRV flow. Since the heat transfer from the vessel surface may not be negligible in determining the drywell temperature and pressure for the isolation event, the containment pressure response given in Figure G.1-2 was underestimated, and therefore, should not be used for design purposes. However, the vessel wall sensible heat is properly accounted for in the calculation of suppression pool temperature response. It is

noted that the primary objective of this analysis is to evaluate the suppression pool temperature response.

The DBA-LOCA with direct suppression pool cooling was also analyzed for the same containment initial conditions. For the DBA-LOCA, a double-ended break of a recirculation suction line is assumed to occur with a concurrent loss of off-site power. Due to a diesel generator failure (by itself or caused by a battery failure, as a single failure), only one core spray pump and two LPCI pumps are available for vessel inventory makeup. At 600 seconds into the event, the operator initiates the containment cooling (one RHR loop) by switching one LPCI pump to RHR pool cooling mode, turning off the other LPCI pump, and turning on one RHR service water pump. Using the SHEX code, a long-term containment analysis was performed, assuming direct suppression cooling.

The peak values of suppression pool temperature for the isolation event, and 0.01 and 0.1 ft^2 breaks and DBA-LOCA are given in Table 4-2. Plots from the SHEX runs for these events are included in Appendix G of this report. As shown in this table, the highest peak suppression pool temperature of 195.6°F was obtained for the DBA-LOCA among the five events analyzed. Thus, the DBA-LOCA is the limiting event with respect to peak suppression pool temperature, as compared to the Reference 3 analysis that showed the isolation event is more limiting. The following provides an explanation why such is the case.

First, the event sequences for the isolation event and DBA-LOCA were compared. As Figure G.1-3 shows, the RPV pressure for the isolation event oscillates between SRV opening and closing setpoints until around 1700 seconds, at which time the operator opens ADS valves. Upon opening of the ADS valves, the RPV pressure decreases rapidly, and the suppression pool temperature increases rapidly due to steam discharge from the ADS valves (Figure G.1-1). The ADS valves are closed at the RPV pressure of 50 psig, and the RPV pressure is maintained around 50 psig for a long time after that. Additionally, for the isolation event the vessel water level is maintained above the TAF by core spray flow. The suppression pool temperature continues to increase until around

32,000 seconds, at which time heat removal by the RHR is equal to heat addition to the suppression pool. The peak suppression pool temperature for this isolation event was 194.0°F (see Table 4-2), and the RPV temperature at the time of peak suppression pool temperature was around 300°F, corresponding to the saturation temperature at 50 psig pressure.

As noted in Section 3.1, in Reference 3 the isolation event was analyzed in a very conservative manner, and the peak suppression pool temperature for the isolation event was obtained by analyzing a DBA-LOCA break size with the containment cooling initiation delayed from 10 minutes to 48.54 minutes.

The sequence of events for the two small breaks (0.01 and 0.1 ft^2) is similar to that for the isolation event, except for the ADS and containment cooling initiation times (see Figures G.2-3 and G.3-3). The containment cooling was initiated earlier than the isolation event, and the peak suppression pool temperature for these events was lower than the peak value for the isolation event (see Table 4-2).

Additionally, the long-term containment response to the limiting DBA-LOCA with containment spray cooling was analyzed, using containment initial conditions and assumptions that minimize the containment pressure response, for input to NPSH evaluations. The peak suppression pool temperature for the DBA-LOCA with such assumptions was 195.5°F, as compared with 195.6°F obtained for the direct suppression pool cooling case discussed above. The 0.1°F difference between the two cases is due to the difference in cooling mode (direct pool cooling vs. spray cooling) and the modeling differences mentioned in Section 3.

4.2.2 DBA-LOCA as Limiting Event

The analysis results presented in Section 4.2.1 show that the DBA-LOCA is the limiting event with respect to peak suppression pool temperature. It is also noted that the peak suppression pool temperature with containment spray cooling for NPSH was slightly lower than the value obtained with direct suppression pool cooling. As part of this project, additional DBA-LOCA analyses were performed with the updated RHR heat exchanger K-value of 147 Btu/sec-°F and 90°F service water temperature (see Section 4.4), and with the updated RHR heat exchanger K-value of 147 Btu/sec-°F and 94°F service water temperature (see Section 4.5). Since the peak suppression pool temperature is different (although slightly) between spray cooling for NPSH and direct suppression pool cooling, it was necessary to ascertain that the peak suppression pool temperature for either DBA-LOCA case is acceptable.

4.2.3 Isolation Event with Two RHR Loops

A long-term containment analysis for the isolation event with two ECCS loops (two RHR containment cooling loops) was also performed, using the SHEX code. Relative to the one-ECCS loop case, the ADS activation time will be the same, whereas the containment cooling initiation time will be shorter with two ECCS loops (one CS pump and two LPCI pumps for each loop). The current analysis conservatively assumed that these times with two ECCS loops are the same as those for the one-ECCS loop case. However, for the containment analysis two loops were assumed to be available for both the ECCS and RHR containment cooling system. It was assumed that each RHR loop has one RHR pump and a heat exchanger K-value of 143.1 Btu/sec-°F and a service water temperature of 90°F.

As Table 4-3 shows, the peak suppression pool temperature for this event with two ECCS/RHR loops was calculated to be 167.0°F, as compared with 194.0°F obtained with one ECCS/RHR loop; a 27°F reduction in peak suppression pool temperature. Plots from the SHEX run for this case are given in Figures G.5-1 through G.5-3.

4.2.4 Containment Response to LOCAs with Operable HPCI

In Section 4.2.1, the containment response to three events with HPCI unavailable (a reactor vessel isolation event, and two small breaks) was evaluated, using the ADS activation and pool cooling initiation times obtained from the SAFER/GESTR analysis. The results show that the isolation event without HPCI resulted in highest peak suppression pool temperature among the three events. Since the peak value for the isolation event was bounded by the DBA-LOCA peak value, the containment response for small breaks without HPCI is bounded by the DBA-LOCA result, as far as the suppression pool temperature response is concerned. To ascertain that the same conclusion can be drawn for small breaks with HPCI available, the containment response for such cases is evaluated qualitatively in this section.

When the HPCI system is in operation during a postulated LOCA, three different scenarios depending upon the LOCA break size can be conceived, as follows:

- Small breaks within HPCI capacity
- Large breaks above HPCI capacity
- Intermediate breaks comparable to HPCI capacity

The impact of HPCI operation on the suppression pool temperature response is assessed qualitatively for the above three scenarios, by comparing with the scenario for the isolation event without HPCI, as explained below.

a) Small break within HPCI capacity - For a long period of time, the vessel water level can be maintained above the top of active fuel (TAF) with HPCI flow and vessel energy including decay heat will be released into the primary containment. As a result, the suppression pool temperature will increase above 90°F, an Emergency Operating Procedure (EOP) entry condition. The suppression pool-cooling mode of RHR will be initiated in accordance with the EOPs and suppression pool cooling will be initiated within 10 minutes into the event. This case with HPCI system available and the break

size within HPCI flow capacity is clearly less limiting than the isolation event without HPCI, in which the RHR pool cooling is initiated at 45.81 minutes.

b) Large break above HPCI capacity - For this case, the break flow exceeds HPCI makeup, and the water level will drop to the TAF relatively quickly. ADS will be initiated earlier than the isolation event. The vessel reflood will occur earlier compared with the isolation event without HPCI. Therefore, the delay in containment cooling will be less, and this case with HPCI will be no worse than the isolation event without HPCI from a pool heat up standpoint.

c) Intermediate breaks comparable to HPCI capacity - It's possible that certain break sizes will be large enough that HPCI will not be able to maintain the vessel water level above the TAF, but small enough that the time it takes for the level to drop to the TAF could be longer than the time for the isolation event without HPCI. In this case, the RHR suppression pool cooling will be initiated within 10 minutes in accordance with the EOPs, as the pool temperature will be above 90°F shortly after initiation of the event, due to the release of vessel energy and decay heat into the pool.

4.3 DBA-LOCA Analysis for Short-term NPSH Evaluation

The DBA-LOCA containment response for NPSH evaluations is analyzed for two time periods: short-term (before 600 seconds) before containment cooling is initiated, and long-term (after 600 seconds) after initiation of containment cooling. For this analysis for input to NPSH evaluations, the containment initial conditions are selected such that the containment pressure response can be minimized, as pointed out in Section 3.3.2. This section presents the short-term NPSH DBA-LOCA results. Since the short-term DBA-LOCA for NPSH is performed for the time period before initiation of containment cooling, the RHR heat exchanger K-value and service water temperature have no impact on the short-term NPSH DBA-LOCA analysis.

Table C-1 of Appendix C provides time versus suppression pool temperature, suppression chamber airspace pressure with and without leakage, and suppression pool volume.

The

leakage rate is specified in Reference 6. It is noted that the tabulated values show no differences between the suppression chamber airspace pressures with and without leakage, since the 1.2%/day leakage during the 600-second time period is negligible. Appendix H provides plots from the SHEX run for this case.

4.4 DBA-LOCA with 147 Btu/sec-°F K-Value and 90°F Service Water

The NMC performed an extensive analysis to update the RHR heat exchanger K-value with the use of updated data, and provided GE, by Reference 5, with a new updated value of 147 Btu/sec-°F for use in the containment analysis of the limiting DBA-LOCA. Using this updated K-value, a long-term containment analysis of the DBA-LOCA was performed for two cases: a) direct suppression pool cooling, b) containment spray cooling for input to NPSH evaluations. This section presents the results of the long-term DBA-LOCA containment analysis performed with the updated RHR heat exchanger K-value of 147 Btu/sec-°F and 90°F service water temperature.

The analysis was performed at 102% of 1775 MWt (current rated thermal power), using the Reference 4 decay heat profile based on the ANSI/ANS-5.1-1979 standard with an added conservatism corresponding to a two-sigma uncertainty (see Appendix A for the core heat values used in the analysis). It is noted that the Reference 4 decay heat values were obtained with the method consistent with SIL 636.

4.4.1 DBA-LOCA with Direct Suppression Pool Cooling

This long-term DBA-LOCA analysis is performed to maximize the long-term pool temperature response, while maximizing the long-term pressure response. To maximize the pressure response, the maximum initial containment pressure is assumed, along with the minimum value for the initial drywell humidity.

Containment cooling in the suppression pool cooling mode was assumed to start at 600 seconds. Only one RHR loop was assumed to be available with the updated RHR heat exchanger K-value of 147 Btu/sec-°F. The service water temperature for the RHR was

assumed to be 90°F. The inputs and assumptions used for the SHEX analysis of this event are listed in Section 3.3.1.

The peak suppression pool temperature of 194.1°F occurred at 36,135 seconds into the event. This peak value is below the existing power rerate design temperature of 195°F for the piping attached to the torus. (Note that in a recent evaluation (Reference 13) a piping temperature increase to 196.7°F was found to be acceptable (see Section 4.5).) The long-term (after 600 seconds) suppression chamber airspace pressure was 18.3 psig, which is well below the suppression design pressure of 56 psig (Reference 1). The containment pressure and temperature responses are plotted in Figures K-1 through K-4 of Appendix K.

4.4.2 DBA-LOCA with Containment Spray Cooling for NPSH

The DBA-LOCA containment response for NPSH evaluations is analyzed for two time periods: short-term (before 600 seconds), and long-term (after 600 seconds). For this analysis for input to NPSH evaluations, the containment initial conditions are selected such that the containment pressure response can be minimized. The short-term NPSH DBA-LOCA analysis results, which are independent of RHR heat exchanger K-value and service water temperature, are presented in Section 4.3. This section presents the long-term NPSH DBA-LOCA analysis results.

For the long-term NPSH DBA-LOCA analysis, only one RHR loop was assumed to be available with the updated RHR heat exchanger K-value of 147 Btu/sec-°F. Containment cooling in the containment spray mode is initiated at 600 seconds with a service water temperature of 90°F. The inputs and assumptions used for the SHEX analysis of this event are listed in Section 3.3.2. Table D-1 of Appendix D provides the suppression chamber airspace pressure, suppression pool temperature and suppression pool volume responses vs. time for a one-day time period. The results for a 12-day time period are given in Table D-2. These tables provide two values for the suppression chamber airspace pressure: one with leakage effects considered and the other without leakage. The suppression chamber airspace pressure was calculated without leakage, and the

suppression chamber airspace pressure with leakage was calculated by subtracting non-condensable gas mass at the rate of 1.2% per day from the non-leakage result. The leakage rate is specified in Reference 6. It is noted that the difference between the suppression chamber airspace pressures with and without leakage at one day into the event is less than 0.2 psi, since the 1.2%/day leakage during the one-day period is not significant. On the other hand, the leakage effect on the suppression chamber airspace pressure at 12 days was more than 2 psi. Figures I.1-1 through I.1-4 present the suppression pool temperature, suppression chamber airspace pressure with and without leakage, and suppression pool responses for the one-day period. The results for the 12-day period are plotted in Figures I.2-1 through I.2-4.

The peak suppression pool temperature from this NPSH DBA-LOCA analysis was 194.2°F, which is below the existing the piping design temperature of 195°F. The 194.2°F peak value is 0.1°F higher than 194.1°F obtained for the direct suppression pool cooling case. The 0.1°F difference between the two cases is due to the difference in cooling mode (direct pool cooling vs. spray cooling) and the modeling difference, as discussed in Section 4.2.1.

4.4.3 Impact of 60-second Delay in Realignment to Containment Cooling Mode

The concept that LPCI injection through the heat exchanges is equivalent to placing RHR into suppression pool cooling was assessed for its impact during transfer from LPCI mode to suppression pool cooling mode of RHR. During the most limiting DBA-LOCA scenario, after adequate core cooling is achieved, an RHR pump is secured and RHRSW pump is placed into service. At this time the remaining RHR pump is providing LPCI flow through the heat exchanger. In order to complete the transfer from LPCI mode to suppression pooling cooling mode, the suppression pool return valves have to be opened and the LPCI injection valves have to be closed. Operating procedures require that the suppression pool return valves be opened then closing the LPCI injection valves. The LPCI injection valves closure times are approximately 60 seconds. The net effect is that equivalent long-term containment cooling has been implemented prior to closure of the LPCI injection valves.

In order to specifically evaluate this concept in a bounding way, an analysis was performed that assumed it would take 660 seconds for the operator to realign the LPCI/RHR system to the containment-cooling mode for the LPCI mode during the DBA-LOCA. The impact of the 60 second time delay on the peak suppression pool temperature would be negligible (<0.1°F).

Reference 1 evaluated an alternative mode available to Monticello to achieve long-term containment cooling. This alternative mode would be to keep the RHR pumps in LPCI injection mode. The RHR flow is routed through the heat exchangers, injected into the vessel via the unbroken recirculation loop, passes through the lower plenum, spills out through the break, and returns to the suppression pool. Since LPCI injection through the heat exchanger in this mode would not be assumed to begin until 10 minutes into the event, the vessel would, by this time, be depressurized to the containment pressure. Therefore, the LPCI pumps flow rates to the vessel, and the flow through the heat exchanger, would be equal to the flow rate assumed with the RHR pumps in pool cooling mode. Since the flow through the heat exchanger would not be expected to change, the heat exchanger performance with the RHR pumps maintained in LPCI mode would be the same as that assumed with RHR pool cooling mode in the analysis. Since heat exchanger performance does not change with the RHR pumps in LPCI injection mode, the energy removed for primary containment is not expected to change, and the difference in the peak suppression pool temperature between operating the RHR pumps in LPCI mode versus suppression cooling mode is expected to change by less than one degree Fahrenheit (<±1°F). Thus, even with 1°F increase the DBA-LOCA peak suppression temperature for this alternative mode is below the maximum acceptable piping temperature of 196.7°F given in Reference 13.

4.5 DBA-LOCA with 147 Btu/sec-°F K-Value and 94°F Service Water

The Reference 13 letter provides the results from an analysis that was performed to assess the impact on the piping design temperature for all lines communicating with the torus, due to an increase in the suppression pool temperature from 195°F to 196.7°F. It

was concluded, in Reference 13, that all the affected lines, and their associated supports, penetrations and nozzles met Code acceptance criteria for the elevated suppression pool temperature of 196.7°F. A sensitivity analysis of the long-term DBA-LOCA response has been performed to determine the maximum acceptable service water temperature that would keep peak suppression temperature below 196.7°F with the updated RHR heat exchanger K-value of 147 Btu/sec-°F. The sensitivity analysis was performed for two cases: a) direct suppression pool cooling, and b) containment spray cooling for input to NPSH evaluations. For this sensitivity analysis, the initial suppression pool temperature was assumed to be 90°F, the Monticello Technical Specification limit (Reference 5).

Based on sensitivity analyses, the maximum acceptable service water temperature was determined to be 94°F, and this section presents the results of the long-term DBA-LOCA containment analysis performed with the updated RHR heat exchanger K-value of 147 Btu/sec-°F and 94°F service water temperature. As shown later in this section, the peak suppression pool temperature was below 196.7°F under such conditions, thus confirming that a service water temperature of 94°F with the RHR heat exchanger K-value of 147 Btu/sec-°F is the maximum acceptable service temperature that would keep peak suppression pool temperature below 196.7°F for the limiting DBA-LOCA.

The analysis was performed at 102% of 1775 MWt (current rated thermal power), using a decay heat profile based on the ANSI/ANS-5.1-1979 standard with an added conservatism corresponding to a two-sigma uncertainty. The Reference 4 decay heat values based on the method consistent with SIL 636 were used.

4.5.1 DBA-LOCA with Direct Suppression Pool Cooling

This long-term DBA-LOCA analysis is performed to maximize the long-term pool temperature response, while maximizing the long-term pressure response. To maximize the pressure response, the maximum initial containment pressure is assumed, along with the minimum value for the initial drywell humidity.

Containment cooling in the suppression pool cooling mode was assumed to start at 600 seconds. Only one RHR loop was assumed to be available with the updated RHR heat exchanger K-value of 147 Btu/sec-°F. The service water temperature for the RHR was assumed to be 94°F, as determined to be acceptable based on sensitivity analyses. The inputs and assumptions used for the SHEX analysis of this event are listed in Section 3.3.1.

The peak suppression pool temperature of 196.5°F occurred at 37,104 seconds into the event. This peak value is below the acceptable temperature of 196.7°F for the piping attached to the torus (Reference 13). The long-term (after 600 seconds) suppression chamber airspace pressure was 19 psig, which is well below the suppression design pressure of 56 psig (Reference 1). The containment pressure and temperature responses are plotted in Figures L-1 through L-4 of Appendix L.

4.5.2 DBA-LOCA with Containment Spray Cooling for NPSH

The DBA-LOCA containment response for NPSH evaluations is analyzed for two time periods: short-term (before 600 seconds), and long-term (after 600 seconds). For this analysis for input to NPSH evaluations, the containment initial conditions are selected such that the containment pressure response can be minimized. The short-term NPSH DBA-LOCA analysis results, which are applicable to any RHR heat exchanger K-value and service water temperature, are presented in Section 4.3. This section presents the long-term NPSH DBA-LOCA analysis results.

For the long-term NPSH DBA-LOCA analysis, only one RHR loop was assumed to be available with the updated RHR heat exchanger K-value of 147 Btu/sec-°F. Containment cooling in the containment spray mode is initiated at 600 seconds with a service water of 94°F. The inputs and assumptions used for the SHEX analysis of this event are listed in Section 3.3.2. Table E-1 of Appendix E provides the suppression chamber airspace pressure, suppression pool temperature and suppression pool volume responses vs. time for a one-day time period. The results for a 12-day time period are given in Table E-2. These tables provide two values for the suppression chamber airspace pressure: one with

leakage effects considered and the other without leakage. Figures J.1-1 through J.1-4 present the suppression pool temperature, suppression chamber airspace pressure with and without leakage, and suppression pool responses for the one-day period. The results for the 12-day period are plotted in Figures J.2-1 through J.2-4.

The peak suppression pool temperature from this NPSH DBA-LOCA analysis was 196.2°F, which is below the acceptable piping temperature of 196.7°F. The slightly lower peak suppression pool temperature with NPSH-related assumptions, relative to the 196.5°F for the direct pool cooling case, is due to the difference in cooling mode (direct pool cooling vs. spray cooling) and the modeling difference, as discussed in Section 4.2.1.

Table 4-1: SAFER/GESTR Analysis Results

Case Description	Reactor Isolation	Reactor Isolation	0.01 ft^2 recirculation line break	0.10 ft^2 recirculation line break
Power (MWt)	1775	1810.5	1810.5	1810.5
Decay Heat	Original	ANS 5.1+2 σ	ANS 5.1 + 2 σ	ANS 5.1+ 2 σ
Single Failure	Battery	Battery	Battery	Battery
Jet Pump Recovery. Time (sec)	2336	2170	985	459
Cont. Cool. Init. (Based on Jet Pump Recovery Time +400(1) sec.) (minutes)	45.60	42.83	23.08 (loop selection logic failure would add less than 0.64 min)	14.32
LPCI Pressure Permis. Time (sec)	2212.62	2048.58	860.13	305.49
Cont. Cool. Init. (Based on LPCI Pressure Permissive + 700(2) sec.) (minutes)	48.54	45.81	26.00	16.76
ADS Initiation time (sec.)	1867	1704	513	58

1) It takes 400 seconds to realign the RHR system from the LPCI mode to containment cooling and to start the RHR service water system (Reference 3).

2) The RHR system will remain locked in the LPCI mode for five minutes (300 seconds) following the pressure permissive. Plus an additional 400 seconds for note 1.

Table 4-2: Peak Suppression Pool Temperature for Various Events with Direct Pool Cooling - RHR Heat Exchanger K=143.1 Btu/sec-°F and 90°F Service Water

Break Sizes (ft^2)	Peak Suppression Pool Temperature (°F)	Remarks
Reactor Isolation	194.0	One RHR loop with inoperable HPCI
Reactor Isolation	167.0	Two RHR loops with inoperable HPCI
0.01	190.0	One RHR loop with inoperable HPCI
0.1	191.2	One RHR loop with inoperable HPCI
DBA-LOCA	195.6	One RHR loop with inoperable HPCI

5. REFERENCES

1. GE-NE-T2300721-00-01 "Containment Response Evaluation Task 6.0" April 2, 1999. (Monticello Power Rerate Task Report).

2. GE-NE-T23-00731-2 "Monticello Nuclear Generating Plant LOCA Containment Analyses for Use in Evaluation of NPSH for the RHR and Core Spray Pumps," dated June 1997.

3. Letter, NSA 01-134, S. Mintz to G. Maxwell, "Monticello Nuclear Power Station – Response to NMC Question Regarding Maximum Time to Vessel Reflood and Initiation of Containment Cooling," dated March 25, 2001.

4. Letter, NSA-01-293, C. L. Martin to G. E. Maxwell, "Decay Heat Tables for Monticello Nuclear Generating Plant," dated July 10, 2001.

5. Letter, A. Wojchouski to K. Narayan, "Containment Analyses for Monticello Heat Exchanger K-Value and Suppression Pool Temperature," dated May 9, 2002.

6. Monticello Final OPL-4A attached to Letter, NSA 02-241, S. Mintz to G. Maxwell, "Monticello Containment Analysis Project – Final OPL-4A," dated April 12, 2002. (Per WIN KHN-008 dated June 14, 2002, the initial drywell temperature used in the analysis of the DBA-LOCA for input to NPSH was changed to 135°F from the 150°F value specified in the OPL-4A dated April 12, 2002.)

7. "Use of SHEX Computer Program and ANSI/ANS 5.1-1979 Decay Heat Source Term for Containment Long-Term Pressure and Temperature Analysis," Letter from Ashok Thadani (NRC) to Gary L. Sozzi (GE), July 13, 1993.

8. GE Nuclear Energy Services Information Letter (SIL) Number 636, Revision 1, June 6, 2001.

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

10. NMC PO 439, GE Proposal 523-JX7EY-EK1, Monticello Containment Analyses Project, Project Work Plan, Revision 1, February 2002.

11. Letter, GLN-95-020, PT Tran (GENE) to SJ Hammer (NSP), "Reactor Heat Balances for Monticello Power Rerate (Task 2.1)," dated July 12, 1995.

12. Letter, SJ Hammer (NSP) to PT Tran (GENE), "Emergency Core Cooling Parameters for Use in Monticello SAFER/GESTR Power Rerate Analyses – Task 7.5 (Approved copy)," dated November 21, 1997.

13. Letter, Joe Attwood (Automated Engineering Service Corp.) to A. Wojchouski (NMC), "Post-LOCA Torus Water Temperature Increase," dated August 15, 2001.

14. "The GE Pressure Suppression Containment Analytical Model," NEDO-10320, April 1971.

15. "Maximum Discharge of Liquid-Vapor Mixtures from Vessels," NEDO-21052, September 1975.

APPENDIX A: CORE HEAT VALUES USED IN CONTAINMENT ANALYSIS

The total core heat used in the containment analysis consists of shutdown power (composed of fission power and decay heat), fuel relaxation energy and metal-water reaction energy. The three components and the total core heat, which are normalized against 102% of 1775 MWt, are given in Table A-1.

Reference A-1 provides the shutdown power (decay heat +fission power) values. The decay heat was calculated, using the ANSI/ANS 5.1-1979 standard, with the method consistent with SIL 636 (Reference A-2). The decay heat component of the shutdown power used in the current analysis was calculated by adding a 2-sigma uncertainty to nominal decay heat.

The metal-water reaction occurs as a result of a large LOCA. A LOCA results in a rapid drop in the vessel water level, before any makeup water can be injected, exposing part of the fuel bundles and the external zirconium claddings. This exposure leads to higher temperatures, resulting in reaction of the claddings with the surrounding water. This metal-water reaction energy is applied to all of the current containment analysis cases including the isolation event.

Note that Regulatory Guide 1.7 specifies that the metal-water reaction energy shall be based on 0.00023 inches of cladding reacting with water or 5 times the maximum amount calculated per NRC approved ECCS evaluation model (currently, GE's SAFER code) for demonstrating compliance with 10CFR50.46, Paragraph (b)(3), whichever is greater.

References Used in Appendix A

A-1. Letter, NSA-01-293, C. L. Martin to G. E. Maxwell, "Decay Heat Tables for Monticello Nuclear Generating Plant," dated July 10, 2001.

A-2. GE Nuclear Energy Services Information Letter (SIL) Number 636, Revision 1, June 6, 2001.

Table A-1: Normalized Core Heat Values Used in Containment Analysis

Time (sec)		Fuel Relaxation	Metal-water Reaction	Total Core Heat

Note: Normalized against 102% of 1775 MWt.

APPENDIX B: SHEX BENCHMARKING ANALYSIS FOR DBA-LOCA

The SHEX code was already used for the MNGP UFSAR analysis, which was preceded by confirmatory calculations (Reference B-1) between the SHEX code and the NRC-approved HXSIZ code. Therefore, the use of the SHEX code for MNGP is within the current licensing basis analysis and complies with the NRC requirements.

Relative to the values used in the Reference B-1 power rerate analysis, the input values for the long-term containment analysis (OPL-4A form) have been updated for the current analysis, as documented in Reference B-2. In addition, the modeling of heat transfer between the suppression chamber airspace and pool for the DBA-LOCA is updated for the current analysis, as described in Reference B-2.

Benchmark calculations have been performed to quantify the impact of the OPL-4A input and modeling update on the SHEX results by re-analyzing the DBA-LOCA case analyzed in Reference B-1. The re-analysis of the DBA-LOCA case for benchmarking assumes exactly the same core power and decay heat values as used in Reference B-1, but with the updated OPL-4A input values and modeling.

Table B-1 shows the difference in peak suppression pool temperature (the key containment response parameter for the current analysis) between the Reference B-1 analysis and the current benchmarking analysis. As this table shows, the benchmarking analysis results in 0.2°F increase in peak suppression pool temperature. This comparison indicates that the OPL-4A input and modeling update results in a slightly more conservative prediction of peak suppression pool temperature.

<u>References Used in Appendix B</u>

B-1. GE-NE-T2300721-00-01 "Containment Response Evaluation Task 6.0" April 2, 1999. (Monticello Power Rerate Task Report).

B-2 MONTICELLO OPL-4A, attached to NSA 02-241, S. Mintz to G. Maxwell "Monticello Containment Analysis Project –Final OPL-4A," dated 4/12/02.

Table B-1: Benchmarking Results with Reference B-1 Core Power and Decay Heat Values

	Current Benchmarking Analysis	Reference B-1 Analysis
Peak suppression pool temperature (°F)	193.6	193.4
Time of peak suppression pool temperature (sec)	31,937	34,082

APPENDIX C

TABLE FOR SHORT-TERM CONTAINMENT RESPONSE TO DBA-LOCA FOR INPUT TO NPSH

Table C-1
Short-Term (<600 seconds) Response

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure without Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
0.0	14.26	14.26	90.0	68000
33.7	32.70	32.70	132.2	74280
53.4	32.66	32.66	134.6	74430
62.9	32.70	32.70	134.9	74660
73.5	32.79	32.79	135.8	74980
86.9	32.93	32.93	137.2	75430
98.8	32.94	32.94	138.5	75550
108.6	32.90	32.90	139.1	75560
118.0	32.22	32.22	139.4	75560
127.4	30.29	30.29	139.9	75550
137.0	27.71	27.71	140.5	75550
148.2	24.83	24.83	141.3	75570
160.0	22.38	22.38	142.0	75580
174.1	20.32	20.32	142.9	75610
191.4	19.03	19.03	143.8	75630
210.2	18.23	18.23	144.7	75650
229.4	17.72	17.72	145.3	75680
249.4	17.38	17.38	146.0	75700
271.6	17.12	17.12	146.6	75710
294.7	16.95	16.95	147.1	75730
319.1	16.80	16.80	147.7	75750
344.4	16.63	16.63	148.3	75750
368.4	16.51	16.51	148.7	75700
393.9	16.42	16.42	149.1	75580
419.0	16.36	16.36	149.5	75430
441.6	16.31	16.31	149.8	75250
465.7	16.32	16.32	150.1	75070
489.1	16.33	16.33	150.3	74860
512.4	16.35	16.35	150.6	74660
535.4	16.37	16.37	150.8	74470
559.6	16.39	16.39	151.1	74300
583.2	16.42	16.42	151.3	74160

APPENDIX D

TABLES FOR LONG-TERM CONTAINMENT RESPONSE TO DBA-LOCA FOR INPUT TO NPSH (K=147, SWT=90 °F)

Table D-1
One-Day Long-Term (600 Seconds to 1 Day) Response with RHR Heat Exchanger K-Value of 147 Btu/sec-°F and 90 °F Service Water Temperature

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
0.0	14.26	14.26	90.0	68000
591.3	23.11	23.11	149.1	71040
875.9	17.89	17.89	155.1	75510
1223.9	17.84	17.84	158.5	76260
1606.1	17.79	17.79	161.1	76320
2010.1	17.74	17.75	163.4	76220
2411.6	17.86	17.86	165.2	75770
2807.4	18.05	18.06	166.8	75400
3210.8	18.23	18.23	168.3	75050
3608.6	18.45	18.46	169.8	74850
4003.4	18.62	18.63	171.2	74710
4393.7	18.76	18.77	172.4	74580
4777.2	18.97	18.98	173.6	74500
5179.0	19.14	19.16	174.7	74440
5570.1	19.32	19.33	175.8	74340
5970.0	19.54	19.55	176.8	74300
6367.7	19.63	19.64	177.8	74290
6768.1	19.76	19.78	178.7	74270
7161.3	19.88	19.90	179.5	74260
7564.3	20.00	20.01	180.3	74250
7970.1	20.10	20.12	181.1	74240
8368.0	20.20	20.22	181.8	74230
8764.4	20.29	20.31	182.4	74230
9165.6	20.38	20.39	183.1	74230
9568.6	20.46	20.48	183.7	74240
9972.0	20.54	20.56	184.3	74240
10374	20.61	20.64	184.8	74240
10778	20.69	20.71	185.4	74250
11579	20.84	20.86	186.3	74260
12374	20.98	21.00	187.2	74270
13176	21.13	21.16	188.0	74250
13976	21.24	21.27	188.8	74270
14777	21.32	21.35	189.5	74270
15579	21.41	21.44	190.1	74270
16380	21.48	21.51	190.6	74270

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
17184	21.54	21.58	191.1	74270
17981	21.60	21.63	191.5	74270
18787	21.65	21.68	191.9	74200
19589	21.72	21.75	192.3	74240
20383	21.73	21.77	192.6	74240
21191	21.76	21.80	192.9	74240
21992	21.78	21.83	193.1	74240
22790	21.80	21.85	193.3	74230
23594	21.82	21.87	193.5	74230
24390	21.84	21.89	193.6	74210
25191	21.85	21.90	193.7	74210
25985	21.86	21.92	193.9	74190
26784	21.87	21.93	193.9	74180
27584	21.88	21.94	194.0	74150
28389	21.88	21.94	194.1	74140
29190	21.89	21.95	194.1	74110
29987	21.89	21.95	194.1	74110
30783	21.89	21.95	194.1	74090
31582	21.89	21.95	194.2	74060
31623*	21.89	21.95	194.2	74060
32381	21.88	21.95	194.2	74040
33177	21.88	21.94	194.1	74020
33973	21.87	21.94	194.1	73990
34773	21.86	21.93	194.1	73970
35571	21.85	21.92	194.0	73940
36375	21.84	21.92	194.0	73900
37175	21.83	21.91	193.9	73880
37972	21.82	21.90	193.9	73840
38773	21.81	21.89	193.8	73810
39579	21.80	21.87	193.7	73770
40382	21.78	21.86	193.6	73730
41185	21.77	21.85	193.5	73700
41984	21.75	21.84	193.4	73670
42780	21.74	21.82	193.2	73640
43572	21.72	21.81	193.1	73610
44366	21.71	21.79	193.0	73580
45163	21.69	21.78	192.9	73540
45968	21.67	21.76	192.7	73520
46777	21.65	21.74	192.6	73480
47580	21.62	21.71	192.4	73450
48382	21.59	21.68	192.3	73430
49190	21.55	21.65	192.1	73390
49988	21.53	21.62	192.0	73360

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
51589	21.46	21.56	191.7	73290
53198	21.39	21.49	191.3	73230
54800	21.32	21.43	191.0	73200
56403	21.27	21.38	190.7	73190
57998	21.22	21.33	190.5	73170
59601	21.16	21.27	190.3	73070
61195	21.08	21.20	189.9	72970
62794	21.00	21.12	189.5	72900
64391	20.91	21.04	189.0	72820
65986	20.83	20.96	188.6	72770
67588	20.75	20.88	188.2	72710
69180	20.67	20.80	187.8	72640
70776	20.59	20.73	187.3	72590
72372	20.51	20.65	186.9	72540
73962	20.43	20.58	186.5	72470
75555	20.36	20.50	186.1	72410
77152	20.28	20.43	185.7	72350
78738	20.21	20.36	185.3	72300
80327	20.14	20.29	184.9	72230
81917	20.07	20.22	184.5	72180
83501	20.00	20.16	184.1	72120
85094	19.92	20.09	183.7	72070
86683	19.85	20.02	183.3	72020
87000	19.84	20.00	183.2	72010

*Time of Peak Suppression Pool Temperature

Table D-2
Twelve-Day Long-Term (1 to 12 Days) Response with RHR Heat Exchanger K-Value of 147 Btu/sec-°F and 90 °F Service Water Temperature

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
0.0	14.26	14.26	90.0	68000
85013	19.93	20.09	183.7	72080
96925	19.42	19.61	180.8	71690
108836	18.96	19.16	178.0	71360
120766	18.57	18.79	175.6	71100
132690	18.23	18.48	173.4	70850
144598	17.94	18.20	171.4	70650
156508	17.67	17.96	169.6	70450
168405	17.43	17.74	167.9	70260
180314	17.20	17.53	166.2	70080
192210	17.01	17.35	164.6	69920
204123	16.79	17.16	163.0	69770
216042	16.60	16.99	161.6	69640
227971	16.44	16.85	160.4	69540
239934	16.30	16.73	159.4	69440
251899	16.17	16.62	158.4	69340
263862	16.05	16.52	157.5	69260
275838	15.94	16.43	156.7	69180
287820	15.83	16.34	155.9	69100
299816	15.73	16.26	155.1	69030
311812	15.63	16.18	154.4	68960
323807	15.53	16.10	153.6	68880
335815	15.43	16.02	152.9	68820
347826	15.33	15.94	152.1	68750
359822	15.24	15.87	151.4	68680
371837	15.15	15.80	150.6	68620
383825	15.05	15.73	149.9	68560
395851	14.96	15.66	149.2	68500
407879	14.88	15.59	148.5	68440
419910	14.80	15.53	147.9	68390
431954	14.74	15.49	147.4	68350
443978	14.68	15.45	147.0	68320
456030	14.63	15.42	146.6	68280
468055	14.57	15.39	146.2	68240
480095	14.52	15.36	145.9	68210
492139	14.48	15.33	145.6	68180
504214	14.43	15.30	145.3	68150

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
516267	14.38	15.27	145.0	68120
528322	14.34	15.25	144.7	68090
540385	14.29	15.22	144.5	68060
552454	14.25	15.20	144.2	68030
564515	14.20	15.18	143.9	68000
576588	14.16	15.15	143.6	67970
588643	14.12	15.13	143.3	67940
600710	14.07	15.10	143.1	67920
612773	14.03	15.08	142.8	67880
624843	13.98	15.06	142.5	67860
636905	13.94	15.03	142.2	67830
648974	13.90	15.01	142.0	67800
661033	13.86	14.99	141.7	67780
673076	13.81	14.97	141.4	67750
684190	13.77	14.94	141.2	67730
694142	13.74	14.93	140.9	67710
704024	13.71	14.91	140.7	67680
713852	13.67	14.89	140.5	67670
723670	13.64	14.87	140.3	67650
733497	13.60	14.86	140.0	67630
743309	13.58	14.85	139.8	67610
753101	13.56	14.85	139.6	67590
762884	13.53	14.83	139.4	67570
772653	13.50	14.82	139.2	67560
782441	13.47	14.80	139.0	67540
792188	13.43	14.78	138.8	67520
801969	13.40	14.76	138.6	67500
811741	13.37	14.75	138.3	67480
821513	13.33	14.73	138.1	67470
831278	13.30	14.71	137.9	67450
841037	13.27	14.69	137.7	67430
850808	13.23	14.68	137.5	67410
860552	13.20	14.66	137.2	67400
870316	13.17	14.64	137.0	67390
880099	13.13	14.62	136.8	67370
889834	13.10	14.61	136.6	67350
899549	13.07	14.59	136.4	67340
909281	13.03	14.57	136.1	67320
919004	13.00	14.55	135.9	67300
928736	12.97	14.54	135.7	67290
938472	12.93	14.52	135.5	67280
948209	12.90	14.50	135.2	67260
957928	12.87	14.49	135.0	67240

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
967651	12.84	14.47	134.8	67230
977376	12.81	14.45	134.6	67220
987101	12.77	14.44	134.4	67200
996801	12.74	14.42	134.1	67190
1006513	12.71	14.41	133.9	67180
1016193	12.68	14.39	133.7	67160
1025880	12.65	14.38	133.6	67150
1035557	12.63	14.37	133.5	67150
1045366	12.59	14.35	132.8	67180
1055177	12.54	14.32	132.4	67100
1064919	12.50	14.29	132.1	67050
1074656	12.48	14.29	131.9	67200
1084339	12.44	14.26	131.7	67040
1093969	12.41	14.24	131.6	66960
1100000	12.40	14.25	131.5	67030

APPENDIX E

TABLES FOR LONG-TERM CONTAINMENT RESPONSE TO DBA-LOCA FOR INPUT TO NPSH (K=147, SWT=94 °F)

Table E-1
One-Day Long-Term (600 Seconds to 1 Day) Response with RHR Heat Exchanger K-Value of 147 Btu/sec-°F and 94 °F Service Water Temperature

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
0.0	14.26	14.26	90.0	68000
591.3	23.11	23.11	149.1	71040
871.1	17.94	17.94	155.0	75420
1208.6	17.91	17.91	158.4	76260
1583.4	17.86	17.86	161.0	76330
1986.6	17.82	17.83	163.4	76220
2387.9	17.93	17.93	165.2	75770
2786.2	18.13	18.14	166.9	75400
3190.9	18.32	18.32	168.5	75040
3594.9	18.56	18.57	170.0	74850
3994.9	18.73	18.74	171.5	74700
4396.3	18.92	18.93	172.8	74590
4771.6	19.07	19.08	174.0	74510
5167.5	19.27	19.28	175.2	74450
5563.7	19.45	19.46	176.3	74390
5971.7	19.70	19.71	177.4	74310
6369.3	19.79	19.81	178.4	74310
6760.6	19.93	19.95	179.3	74290
7156.4	20.06	20.08	180.2	74280
7554.9	20.19	20.20	181.0	74270
7951.7	20.30	20.31	181.8	74260
8352.9	20.40	20.42	182.5	74250
8751.3	20.50	20.52	183.2	74260
9153.3	20.59	20.61	183.9	74260
9555.3	20.68	20.70	184.5	74270
9955.4	20.77	20.79	185.2	74270
10350	20.85	20.87	185.7	74280
10751	20.93	20.95	186.3	74300
11550	21.08	21.11	187.3	74310
12345	21.23	21.26	188.3	74330
13145	21.42	21.44	189.2	74320
13937	21.51	21.54	190.0	74350
14727	21.62	21.65	190.7	74360
15524	21.72	21.75	191.3	74350
16320	21.81	21.84	191.9	74360

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
17115	21.88	21.91	192.5	74360
17914	21.94	21.98	192.9	74360
18716	22.00	22.04	193.4	74370
19520	22.04	22.08	193.8	74290
20316	22.12	22.16	194.2	74330
21114	22.15	22.19	194.5	74350
21912	22.18	22.22	194.8	74350
22706	22.21	22.25	195.0	74350
23504	22.23	22.28	195.2	74350
24297	22.26	22.31	195.4	74340
25097	22.28	22.33	195.6	74340
25895	22.30	22.35	195.7	74320
26690	22.32	22.37	195.9	74310
27486	22.33	22.38	196.0	74290
28281	22.34	22.39	196.0	74280
29085	22.35	22.40	196.1	74270
29889	22.35	22.41	196.2	74240
30692	22.35	22.41	196.2	74220
31494	22.35	22.42	196.2	74210
32292	22.35	22.42	196.2	74180
32422*	22.35	22.42	196.2	74180
33099	22.35	22.42	196.2	74160
33898	22.34	22.41	196.2	74150
34696	22.34	22.41	196.2	74120
35486	22.33	22.40	196.2	74090
36279	22.32	22.39	196.2	74070
37076	22.32	22.39	196.1	74030
37865	22.30	22.38	196.1	74000
38664	22.29	22.37	196.0	73970
39468	22.28	22.36	195.9	73940
40262	22.27	22.35	195.9	73910
41063	22.26	22.34	195.8	73870
41857	22.25	22.33	195.7	73840
42656	22.23	22.32	195.6	73810
43452	22.22	22.31	195.5	73780
44252	22.21	22.29	195.4	73760
45044	22.19	22.28	195.3	73730
45841	22.18	22.27	195.2	73700
46639	22.16	22.25	195.0	73660
47431	22.14	22.24	194.9	73630
48235	22.12	22.22	194.8	73610
49033	22.10	22.20	194.7	73580
49830	22.07	22.17	194.5	73540

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure w/o Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
51425	22.01	22.11	194.3	73490
53036	21.95	22.05	194.0	73420
54636	21.88	21.99	193.6	73360
56246	21.81	21.92	193.3	73290
57846	21.74	21.85	193.0	73240
59433	21.67	21.79	192.7	73220
61024	21.62	21.74	192.4	73210
62617	21.57	21.69	192.2	73170
64213	21.50	21.63	191.9	73060
65806	21.43	21.55	191.6	72980
67396	21.34	21.47	191.2	72910
68987	21.26	21.39	190.8	72850
70574	21.18	21.32	190.4	72790
72165	21.11	21.25	190.0	72740
73752	21.03	21.17	189.6	72680
75341	20.95	21.10	189.2	72620
76939	20.88	21.03	188.8	72570
78529	20.81	20.96	188.4	72510
80120	20.73	20.88	188.0	72450
81710	20.65	20.81	187.6	72390
83301	20.58	20.74	187.3	72340
84897	20.51	20.67	186.9	72280
86492	20.44	20.60	186.5	72230
87000	20.42	20.58	186.4	72200

*Time of Peak Suppression Pool Temperature

Table E-2
Twelve-Day Long-Term (1 to 12 Days) Response with RHR Heat Exchanger K-Value of 147 Btu/sec-°F and 94 °F Service Water Temperature

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure without Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
0.0	14.26	14.26	90.0	68000
84817	20.51	20.67	186.9	72290
96735	20.00	20.19	184.1	71890
108615	19.54	19.74	181.5	71560
120459	19.15	19.37	179.2	71280
132330	18.81	19.05	177.2	71040
144180	18.50	18.77	175.3	70830
156013	18.22	18.51	173.5	70630
167850	17.97	18.27	171.8	70430
179661	17.73	18.06	170.2	70250
191489	17.50	17.85	168.6	70080
203344	17.30	17.67	167.0	69910
215199	17.11	17.49	165.6	69790
227040	16.94	17.34	164.5	69670
238901	16.79	17.21	163.4	69560
250764	16.65	17.10	162.5	69470
262666	16.52	16.99	161.6	69380
274548	16.40	16.89	160.8	69290
286448	16.29	16.80	160.0	69210
298349	16.18	16.71	159.2	69140
310280	16.07	16.62	158.5	69060
322204	15.96	16.54	157.7	68980
334115	15.86	16.45	157.0	68900
346058	15.76	16.37	156.2	68840
357997	15.66	16.29	155.5	68770
369957	15.56	16.21	154.8	68700
381907	15.47	16.14	154.0	68640
393845	15.37	16.06	153.3	68580
405793	15.28	15.99	152.6	68510
417742	15.20	15.93	152.0	68460
429706	15.13	15.88	151.5	68420
441677	15.06	15.83	151.0	68380
453683	15.01	15.80	150.7	68340
465648	14.95	15.76	150.3	68300
477615	14.90	15.73	150.0	68270

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure without Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
489576	14.85	15.70	149.7	68230
501509	14.80	15.67	149.4	68190
513499	14.75	15.64	149.1	68160
525485	14.71	15.62	148.8	68130
537476	14.66	15.59	148.5	68100
549455	14.61	15.56	148.2	68070
561455	14.57	15.54	148.0	68040
573455	14.52	15.51	147.7	68010
585433	14.47	15.48	147.4	67970
597425	14.43	15.46	147.1	67950
609406	14.38	15.43	146.9	67920
621398	14.34	15.41	146.6	67890
633347	14.29	15.38	146.3	67860
644665	14.25	15.36	146.1	67830
654698	14.21	15.34	145.8	67810
664494	14.18	15.32	145.6	67790
674245	14.14	15.30	145.4	67760
684006	14.11	15.28	145.2	67740
693765	14.07	15.26	144.9	67720
703547	14.04	15.24	144.7	67700
713274	14.00	15.22	144.5	67680
723047	13.97	15.20	144.3	67660
732808	13.93	15.19	144.1	67640
742558	13.90	15.17	143.8	67620
752305	13.86	15.15	143.6	67600
762028	13.83	15.13	143.4	67580
771758	13.79	15.11	143.2	67560
781475	13.77	15.10	143.0	67540
791186	13.74	15.10	142.7	67520
800896	13.72	15.09	142.5	67510
810600	13.69	15.07	142.3	67490
820310	13.65	15.05	142.1	67470
829994	13.62	15.03	141.9	67460
839696	13.58	15.01	141.7	67440
849428	13.55	15.00	141.5	67420
859157	13.52	14.98	141.3	67400
868864	13.48	14.96	141.1	67380
878568	13.45	14.94	140.8	67360
888287	13.41	14.92	140.6	67350
898018	13.38	14.90	140.4	67330
907726	13.34	14.89	140.2	67310
917416	13.31	14.87	140.0	67300

TIME (Seconds)	Wetwell Pressure with Leakage (PSIA)	Wetwell Pressure without Leakage (PSIA)	Suppression Pool Temperature (F)	Suppression Pool Volume (CU FT)
927111	13.28	14.85	139.7	67280
936799	13.24	14.83	139.5	67260
946487	13.21	14.81	139.3	67260
956176	13.18	14.79	139.1	67240
965872	13.14	14.78	138.9	67230
975534	13.11	14.76	138.6	67210
985230	13.07	14.74	138.4	67190
994904	13.04	14.72	138.2	67180
1004609	13.01	14.71	138.0	67160
1014311	12.98	14.69	137.8	67150
1023981	12.95	14.68	137.6	67140
1033678	12.92	14.67	137.5	67130
1043356	12.90	14.66	137.4	67120
1053033	12.87	14.65	137.3	67110
1062711	12.85	14.64	137.2	67100
1072379	12.82	14.63	137.1	67080
1082070	12.80	14.63	137.0	67080
1091757	12.78	14.62	136.9	67070
1100000	12.76	14.61	136.8	67060

APPENDIX F

PLOTS FROM SAFER/GESTR RUNS

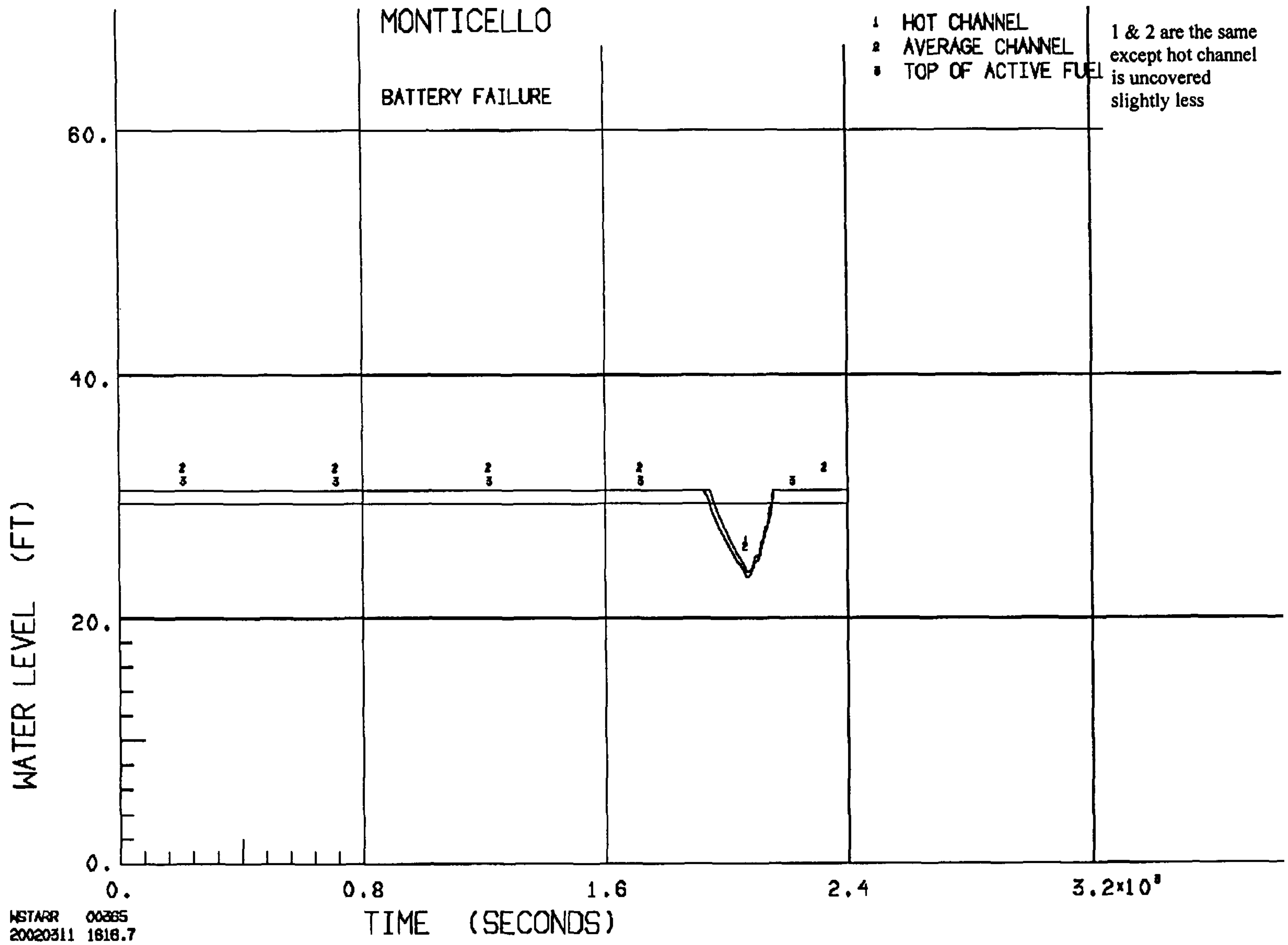
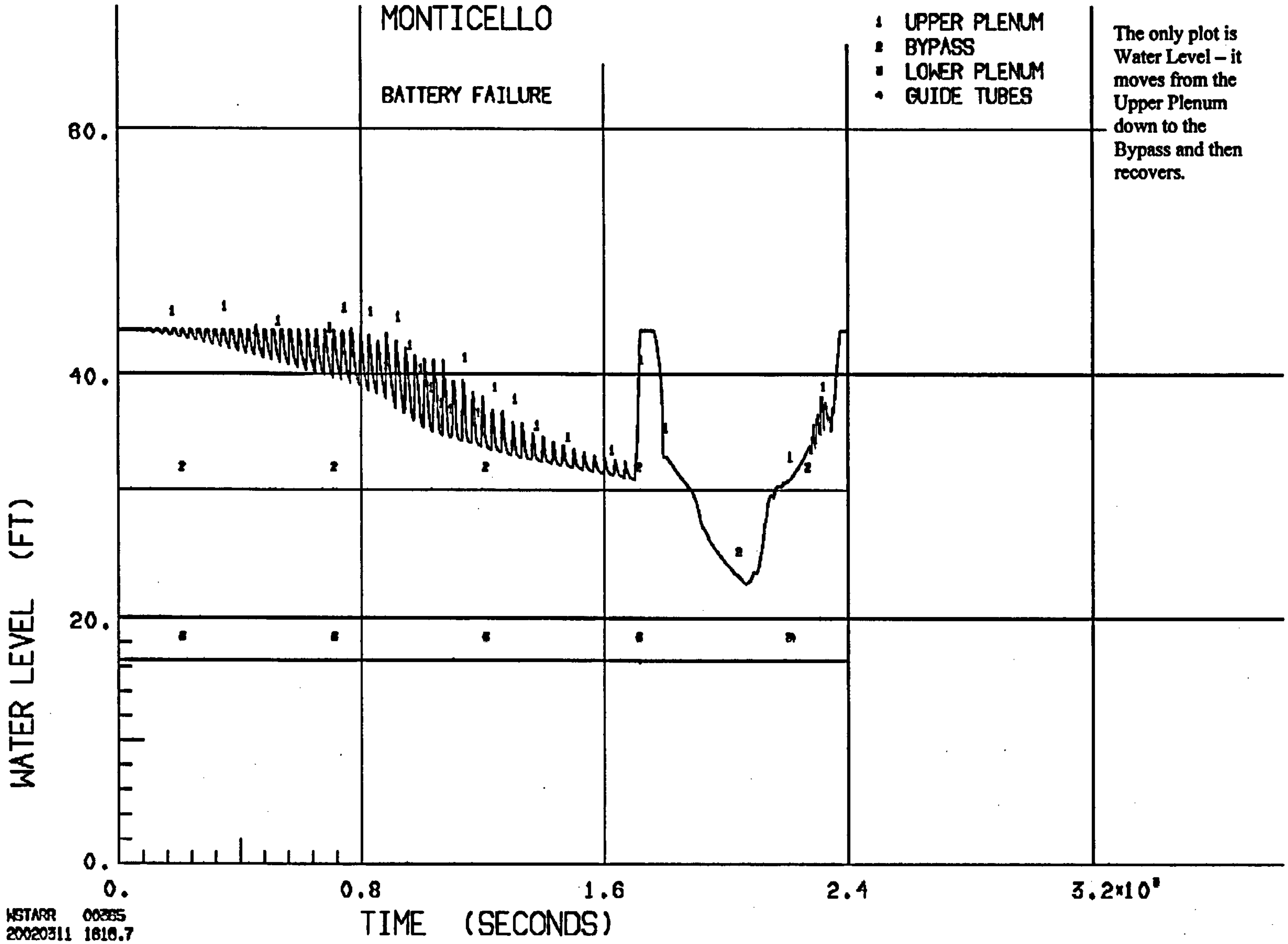


Figure F.1-1 Water Level in Hot and Average Channels.
SAFER Results for Isolation Event, 102% of 1775 MWT, ANS 5.1 + 2σ D.H.



The only plot is Water Level – it moves from the Upper Plenum down to the Bypass and then recovers.

Figure F.1-2 Water Level in Upper Plenum and Bypass.
SAFER Results for Isolation Event, 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

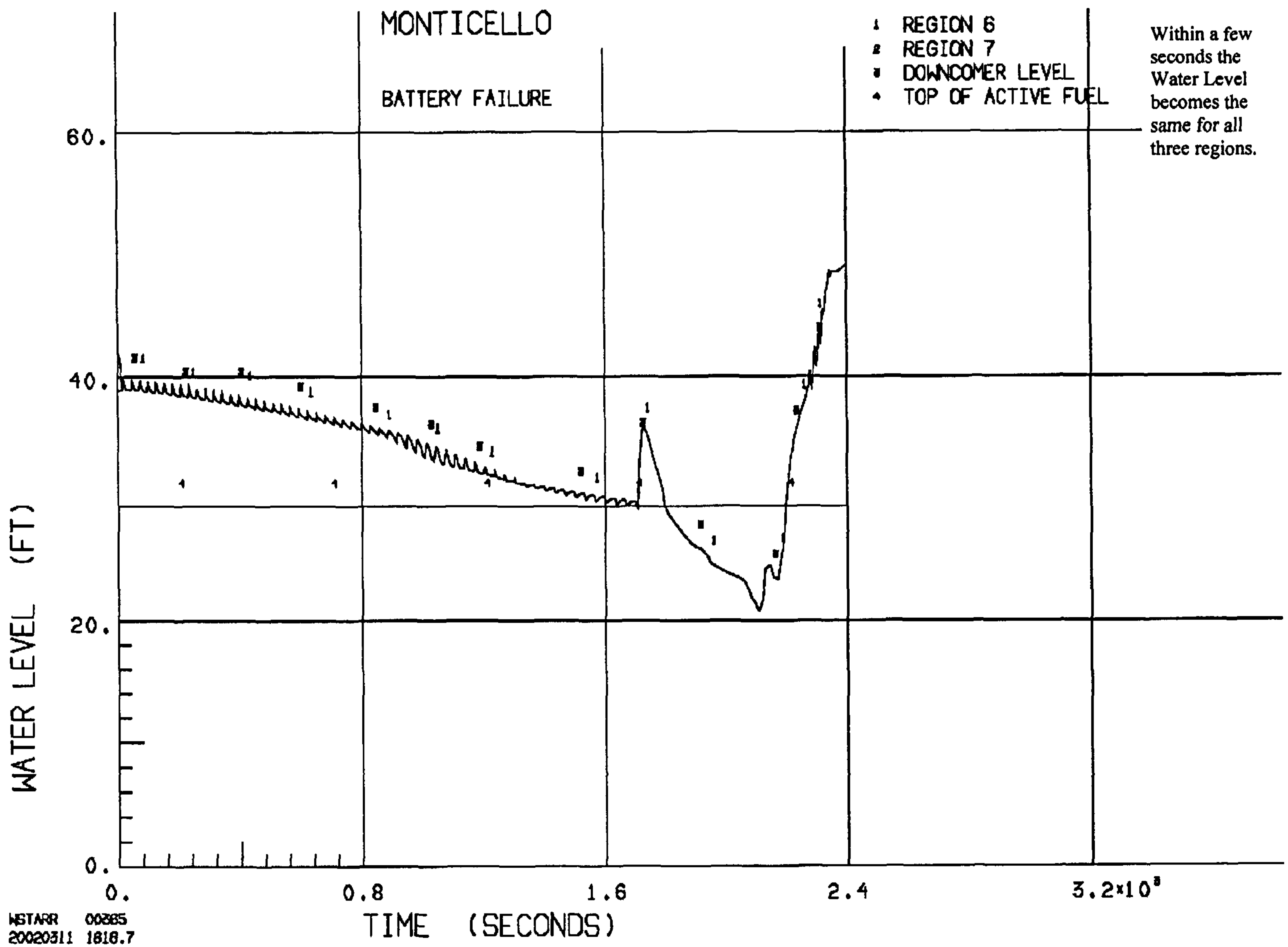


Figure F.1-3 Water Level in Regions 6 and 7 and Downcomer.
SAFER Results for Isolation Event, 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

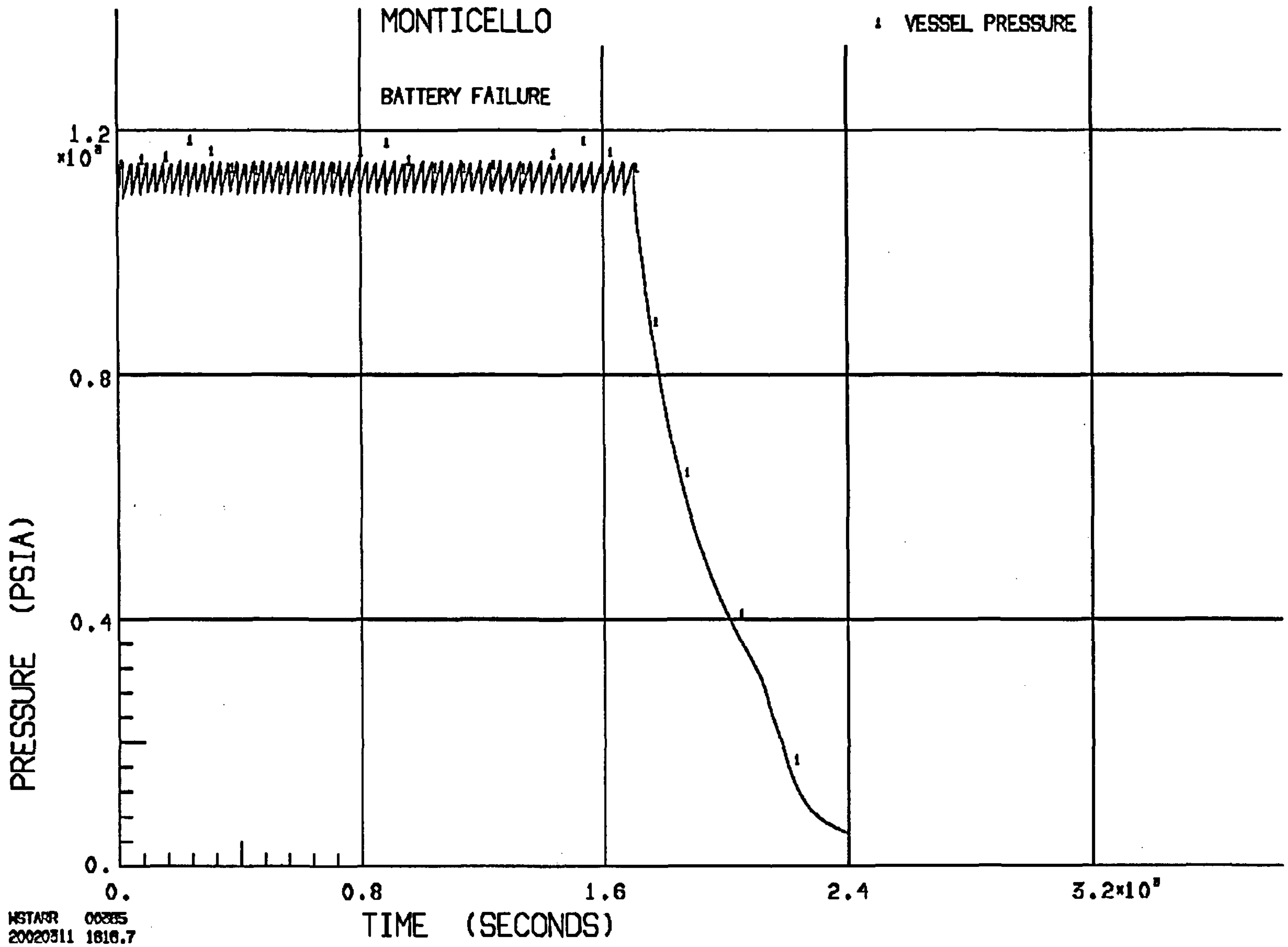


Figure F.1-4 Reactor Vessel Pressure.
SAFER Results for Isolation Event, 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

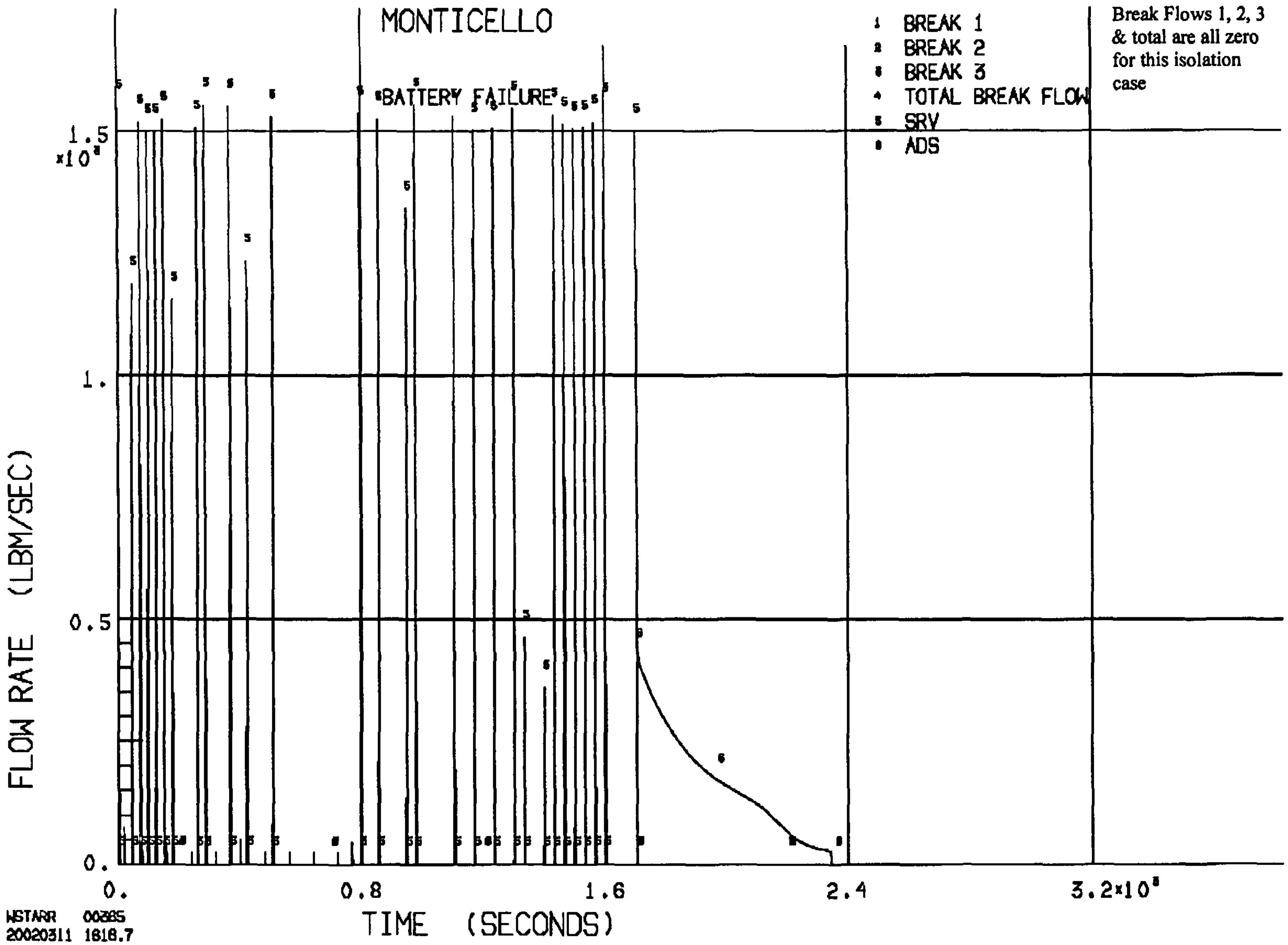


Figure F.1-5 SRV, ADS and Break Flows.
SAFER Results for Isolation Event, 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

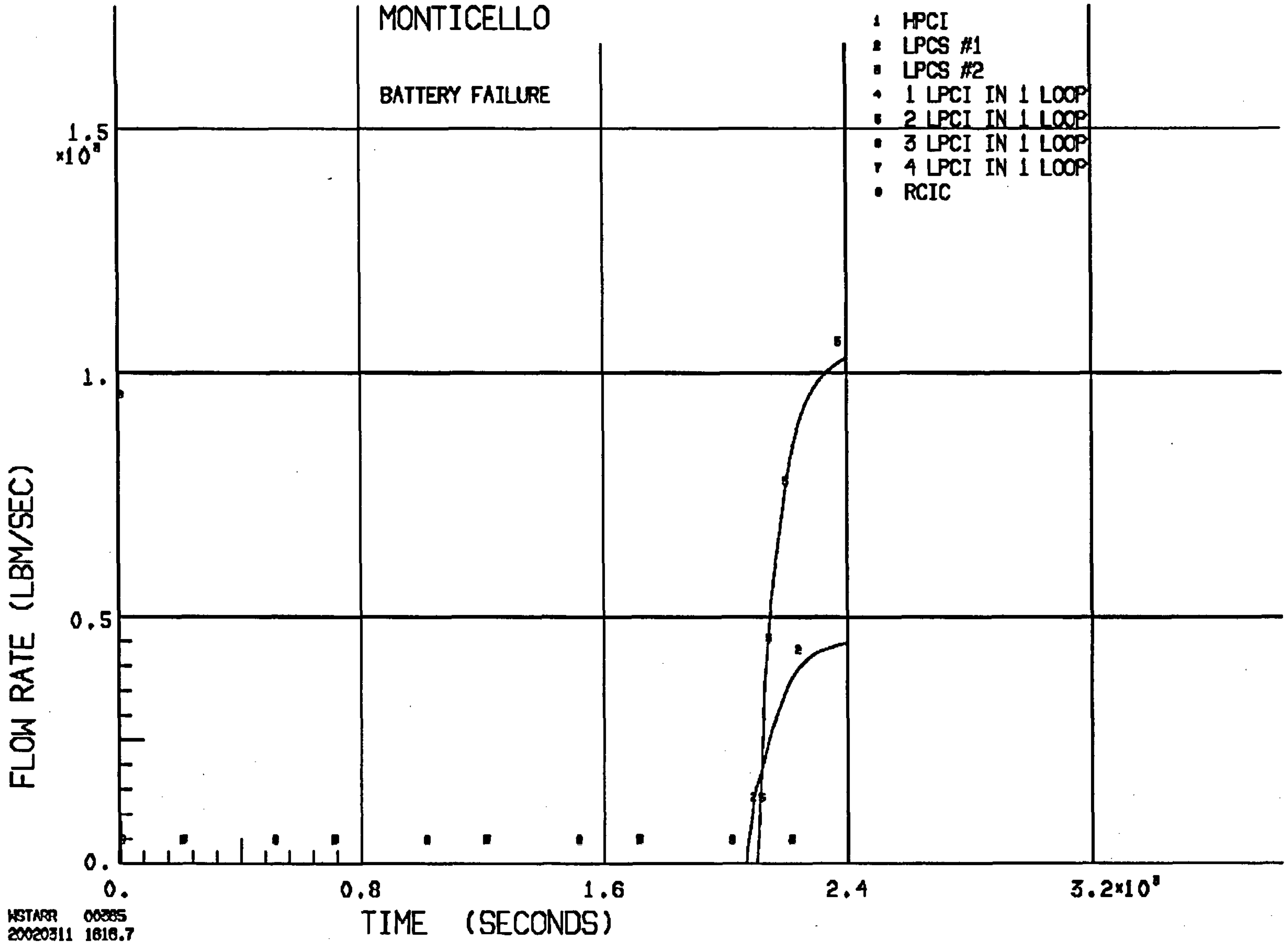


Figure F.1-6 ECCS Flows.
SAFER Results for Isolation Event, 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

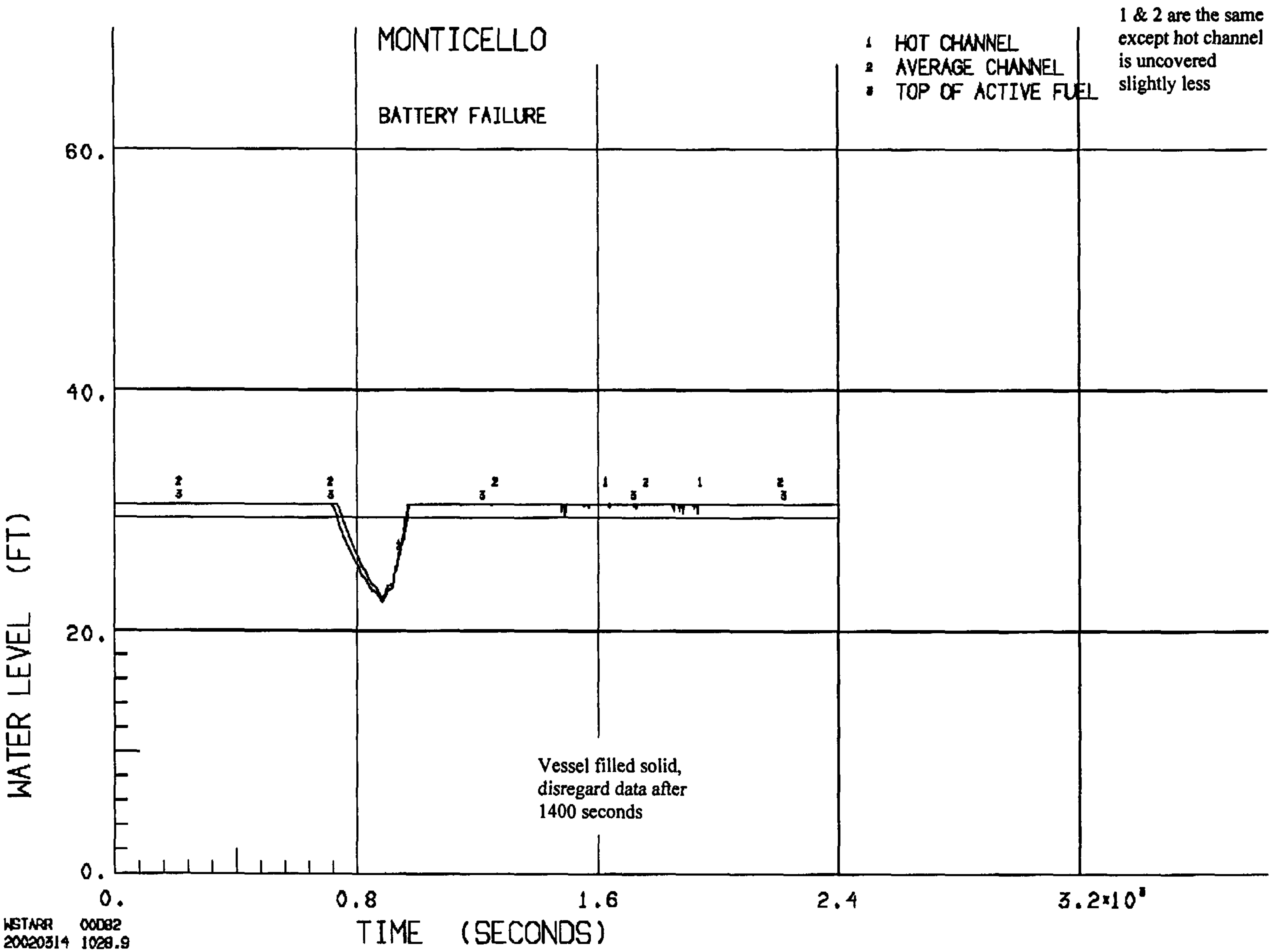


Figure F.2-1 Water Level in Hot and Average Channels.
SAFER Results for 0.01 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

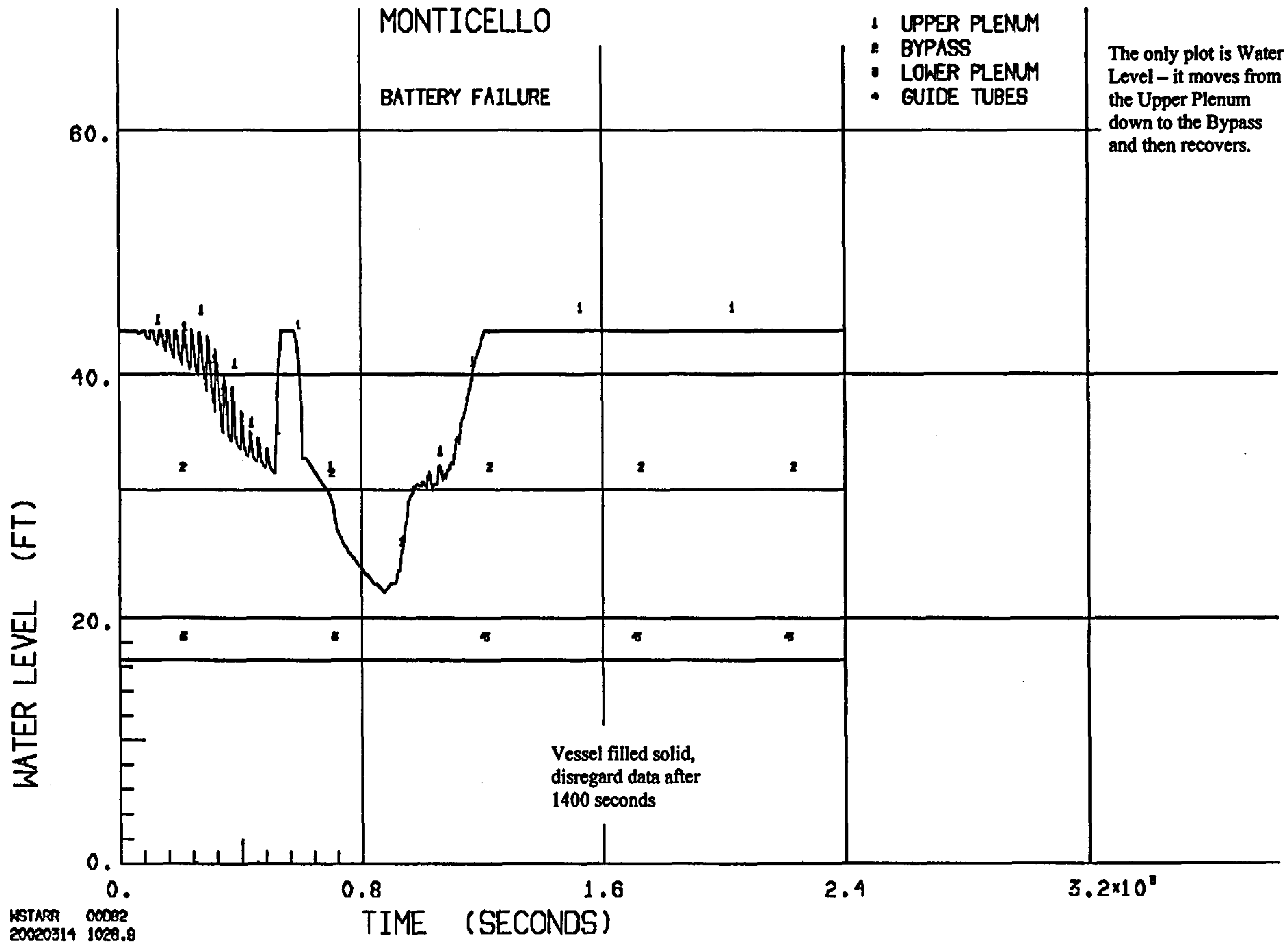


Figure F.2-2 Water Level in Upper Plenum and Bypass.
SAFER Results for 0.01 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

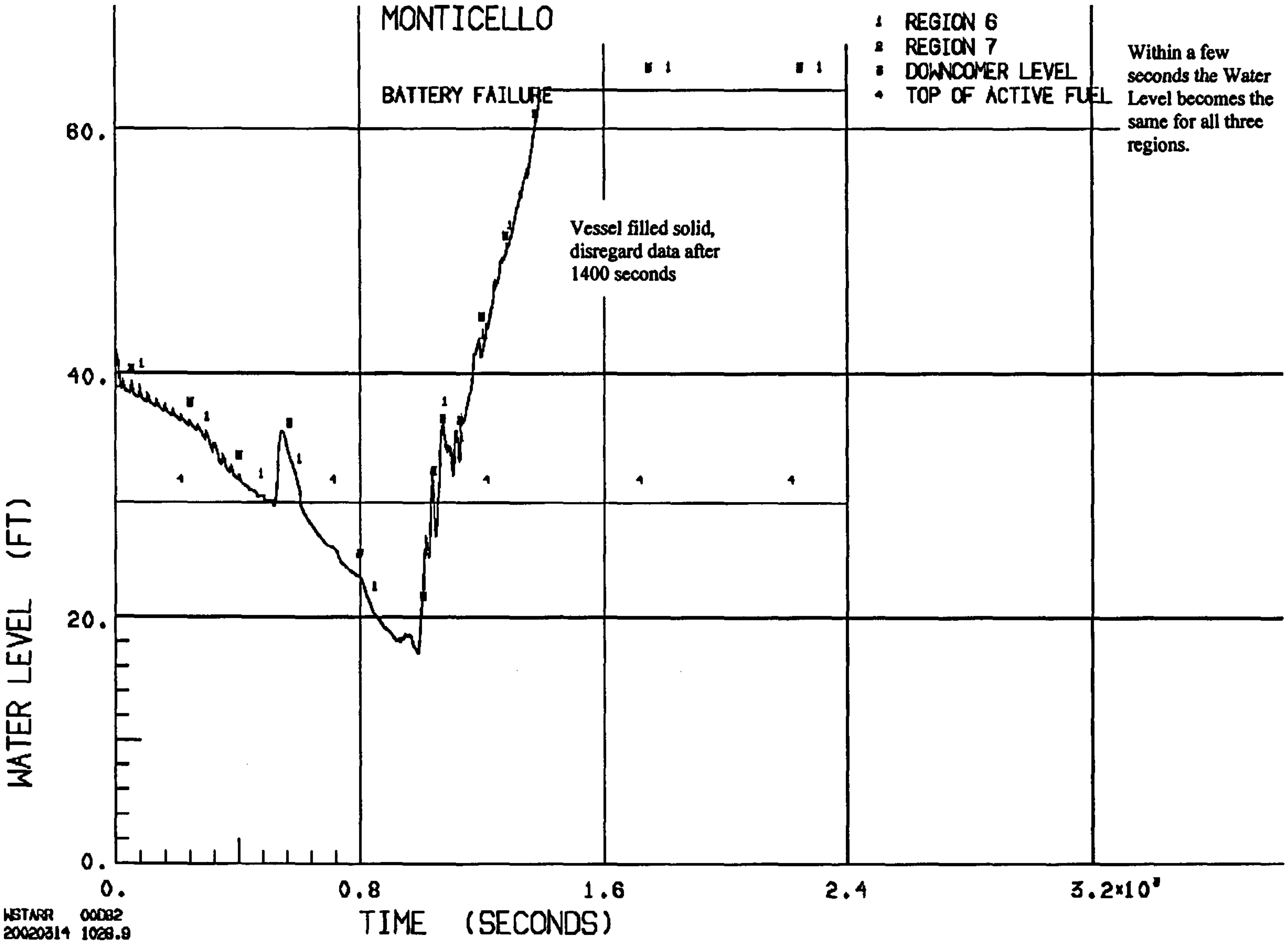


Figure F.2-3 Water Level in Regions 6 and 7 and Downcomer.
SAFER Results for 0.01 ft² Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

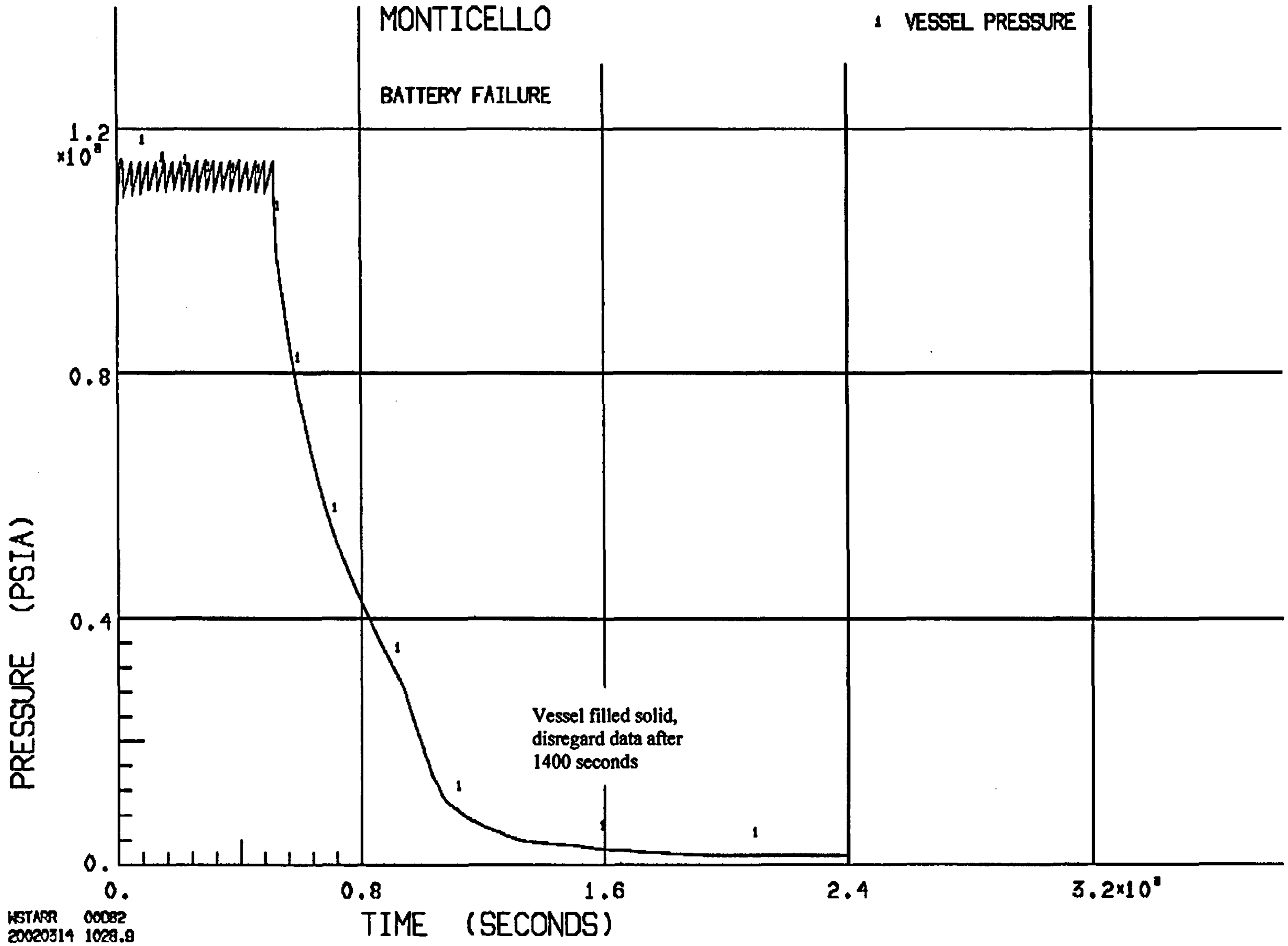


Figure F.2-4 Reactor Vessel Pressure.
SAFER Results for 0.01 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

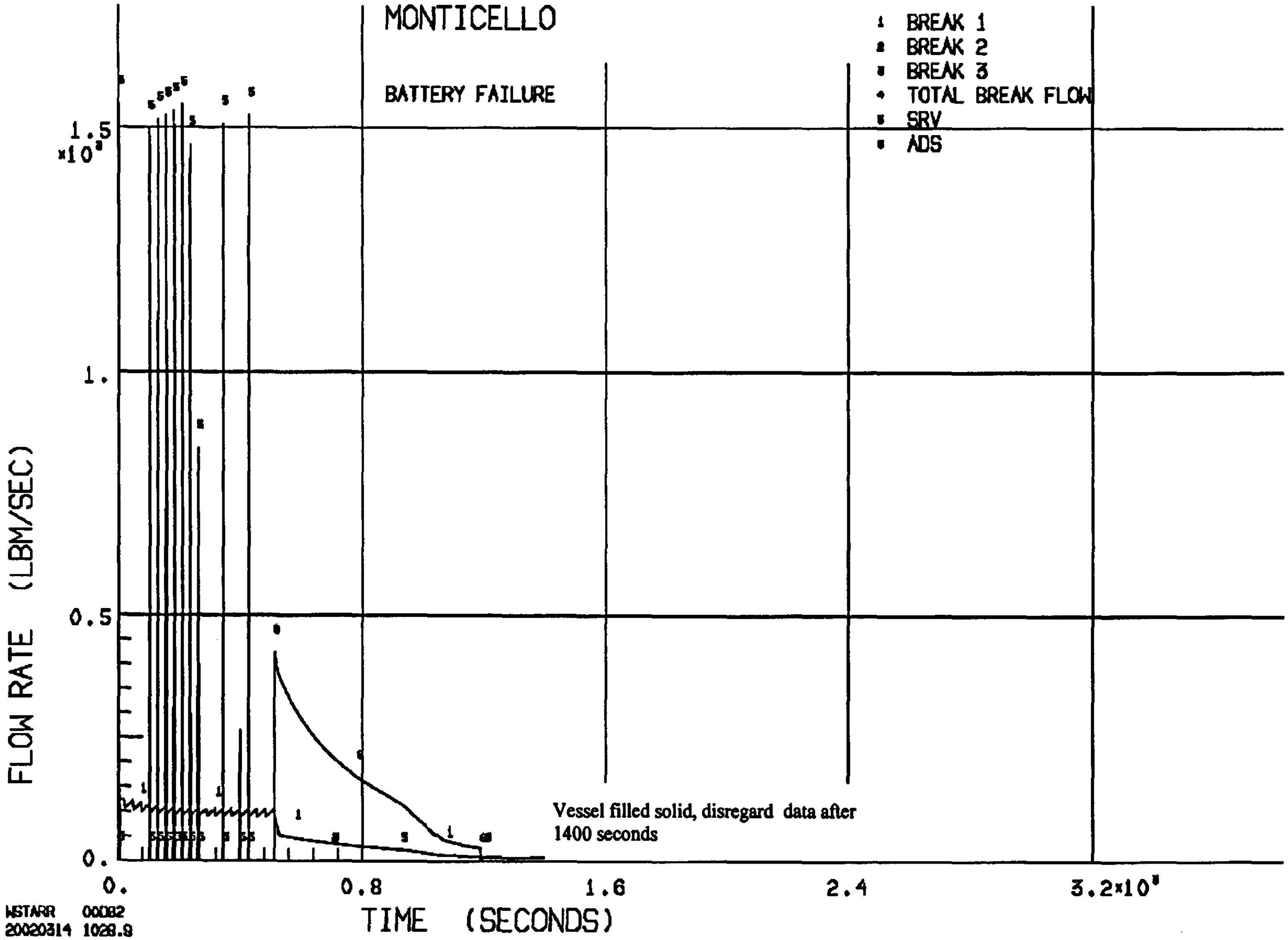


Figure F.2-5 SRV, ADS and Break Flows.
SAFER Results for 0.01 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

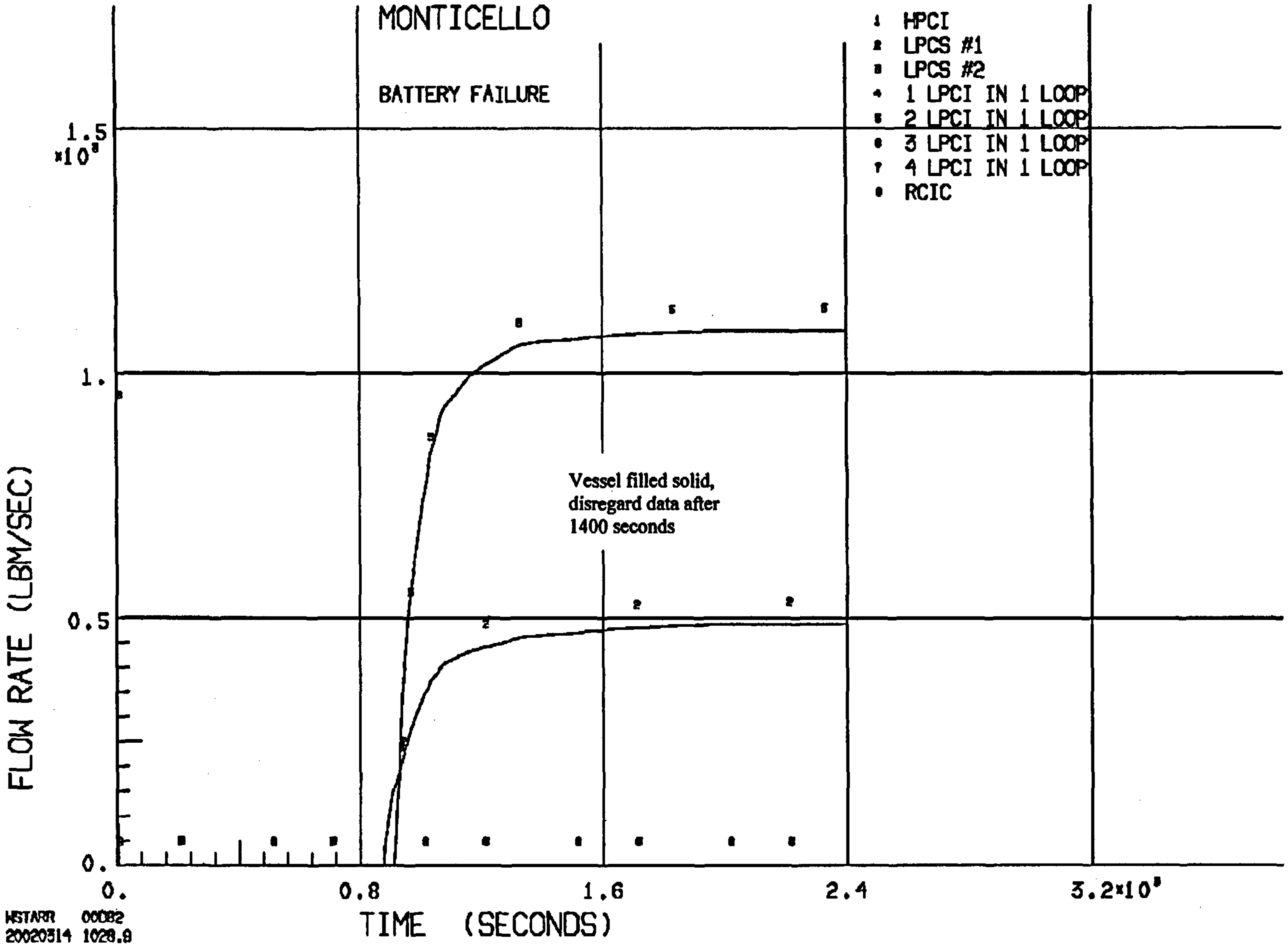


Figure F.2-6 ECCS Flows.
SAFER Results for 0.01 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

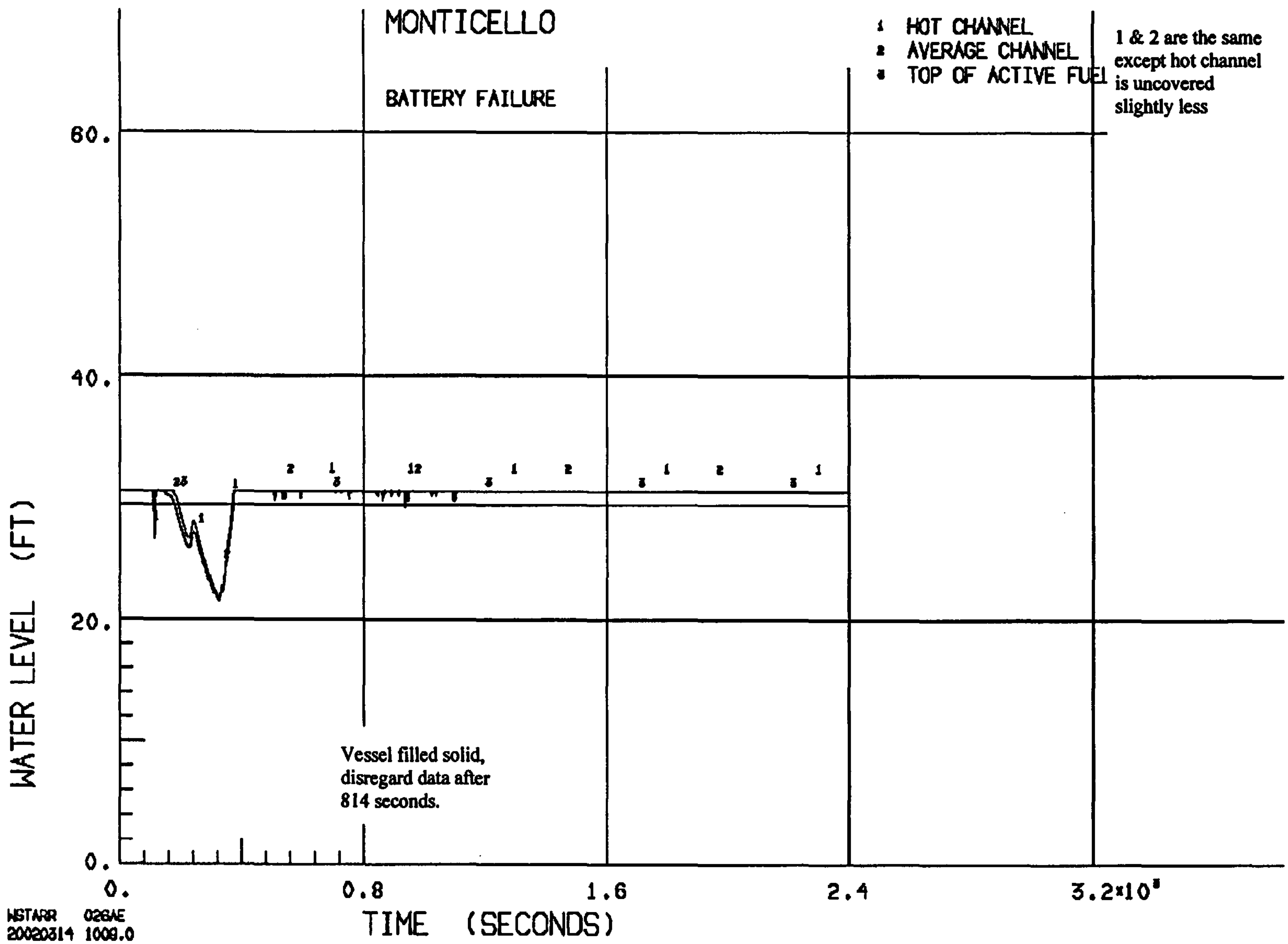


Figure F.3-1 Water Level in Hot and Average Channels.
SAFER Results for 0.10 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

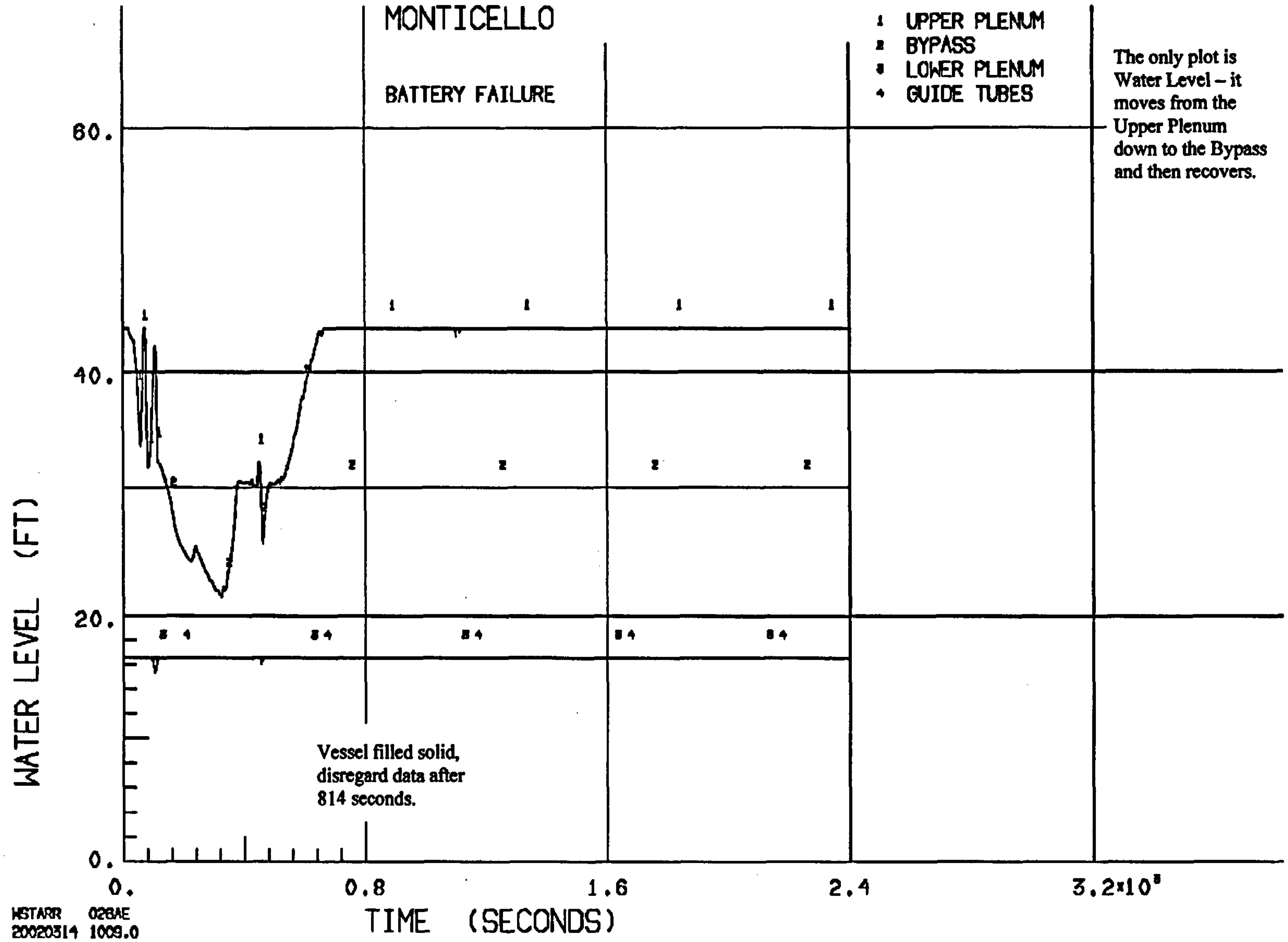


Figure F.3-2 Water Level in Upper Plenum and Bypass.
SAFER Results for 0.10 ft² Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

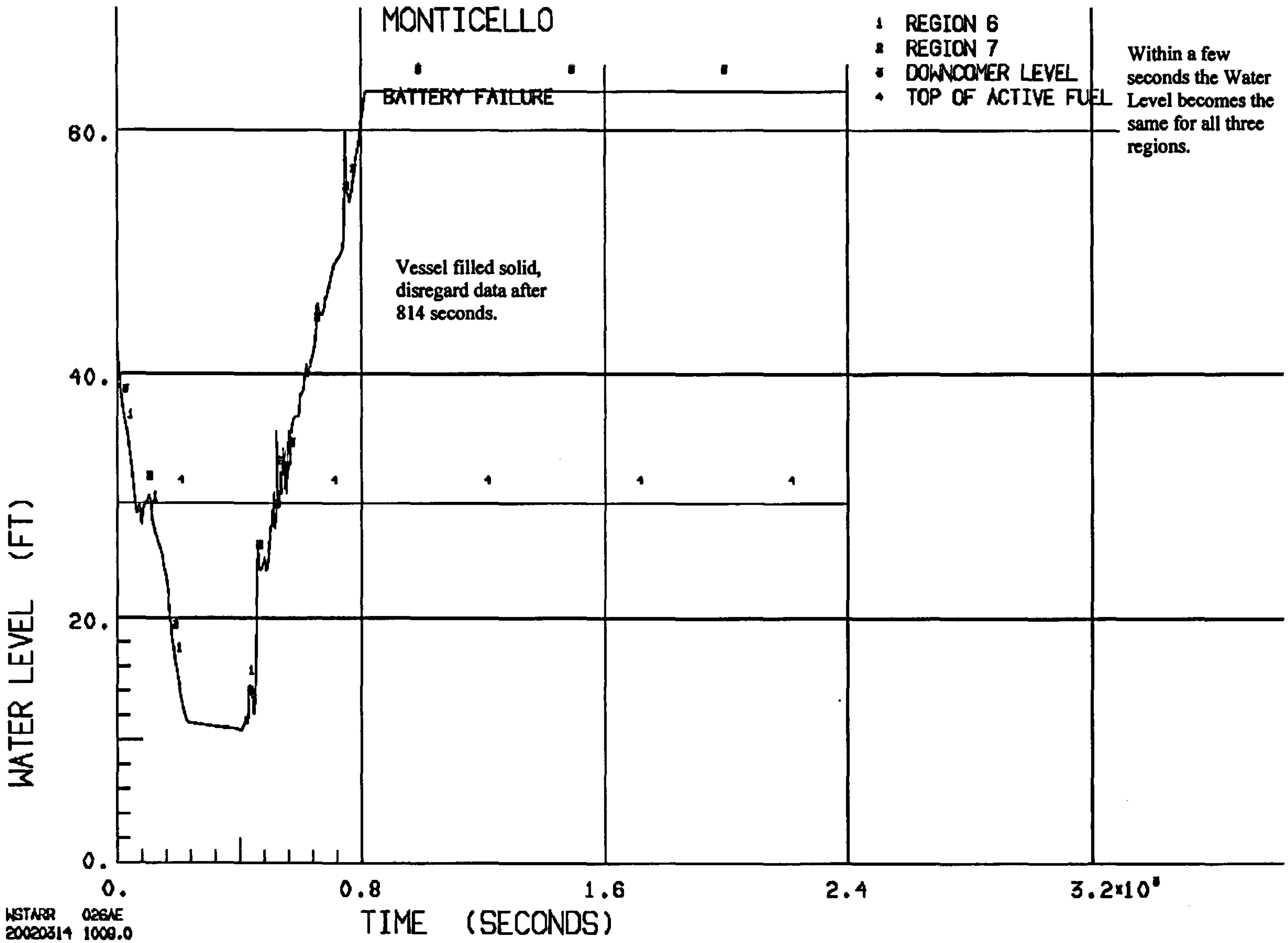


Figure F.3-3 Water Level in Regions 6 and 7 and Downcomer.
SAFER Results for 0.10 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

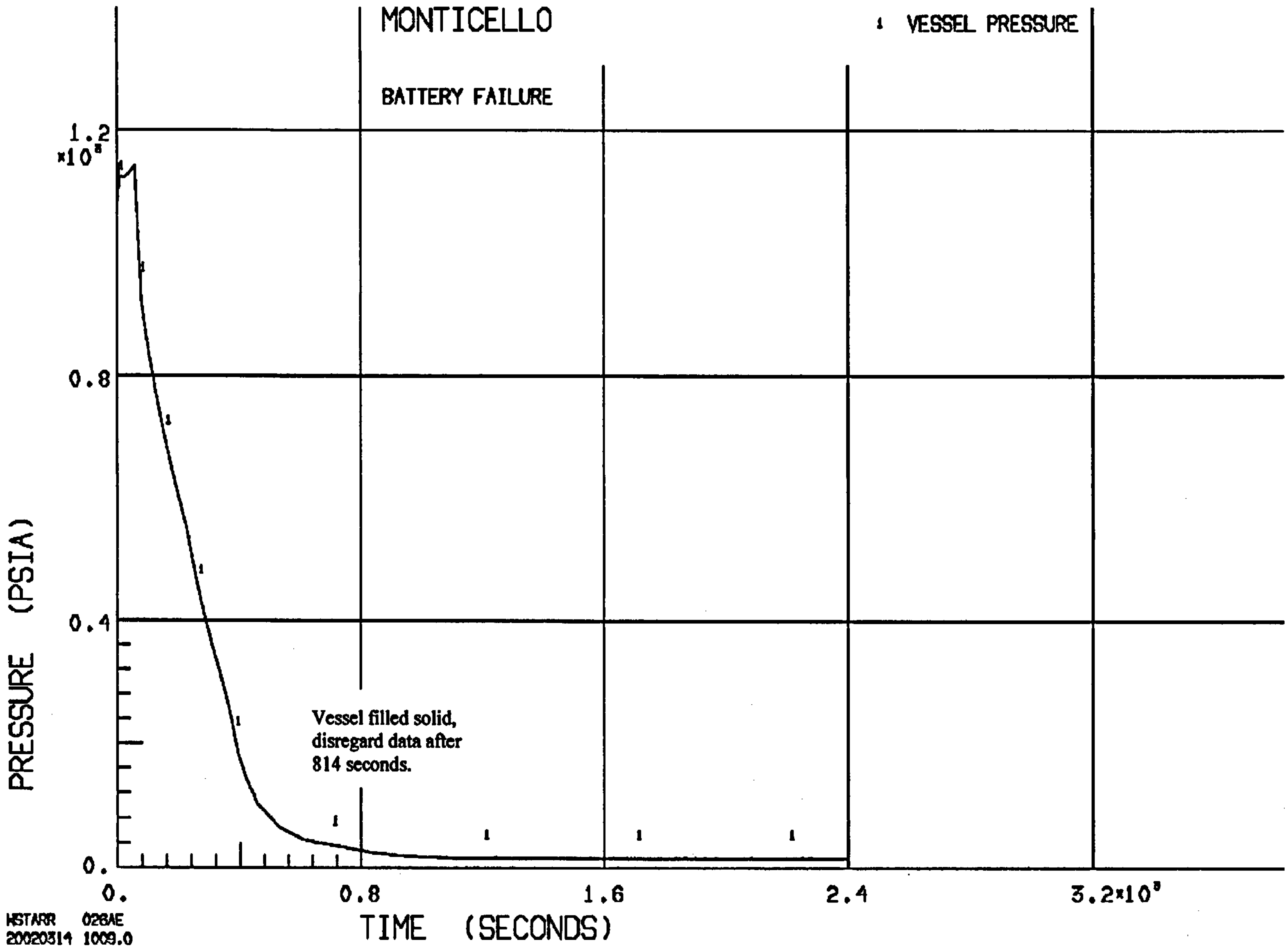


Figure F.3-4 Reactor Vessel Pressure.
SAFER Results for 0.10 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

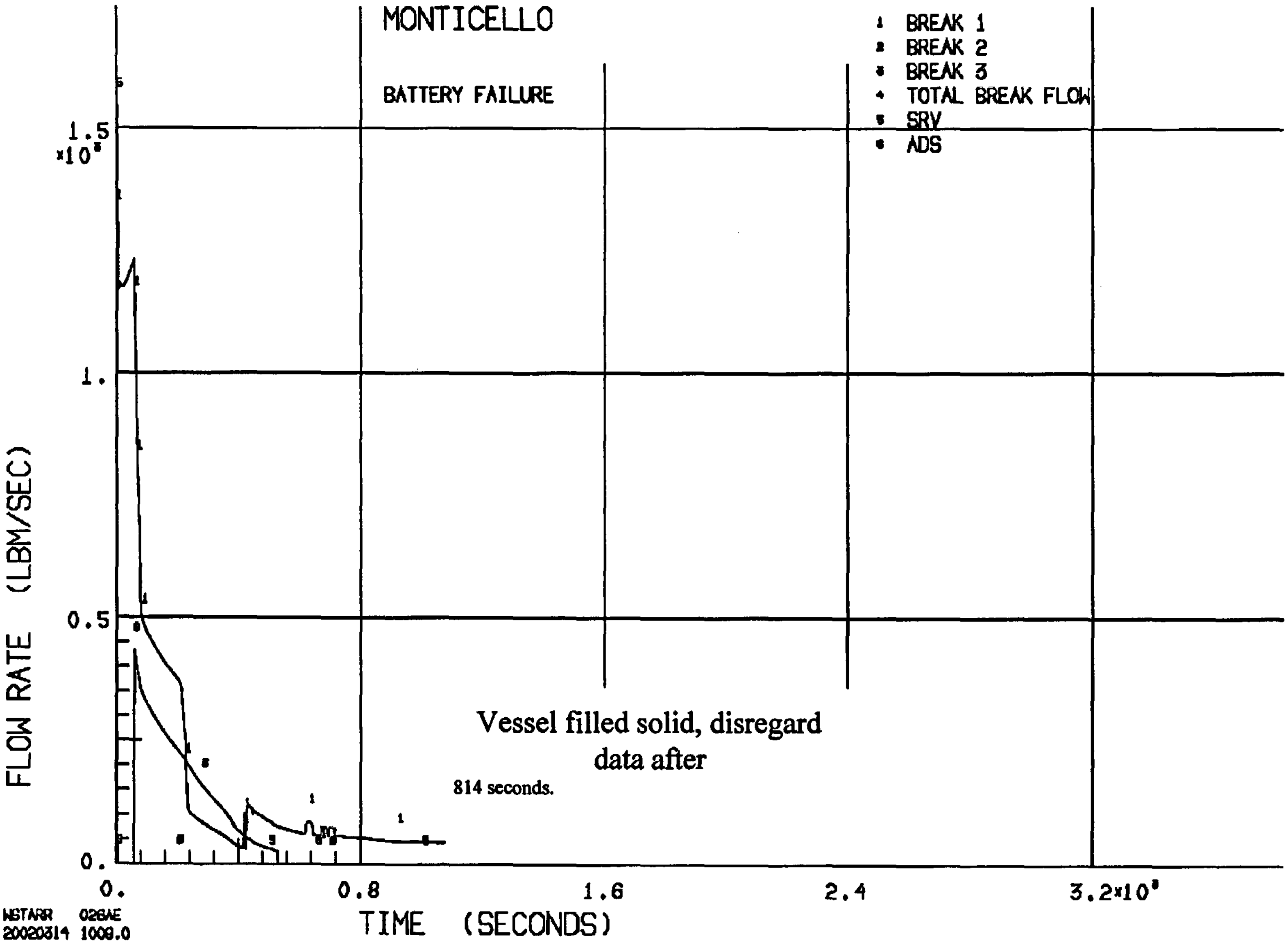


Figure F.3-5 SRV, ADS and Break Flows.
SAFER Results for 0.10 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

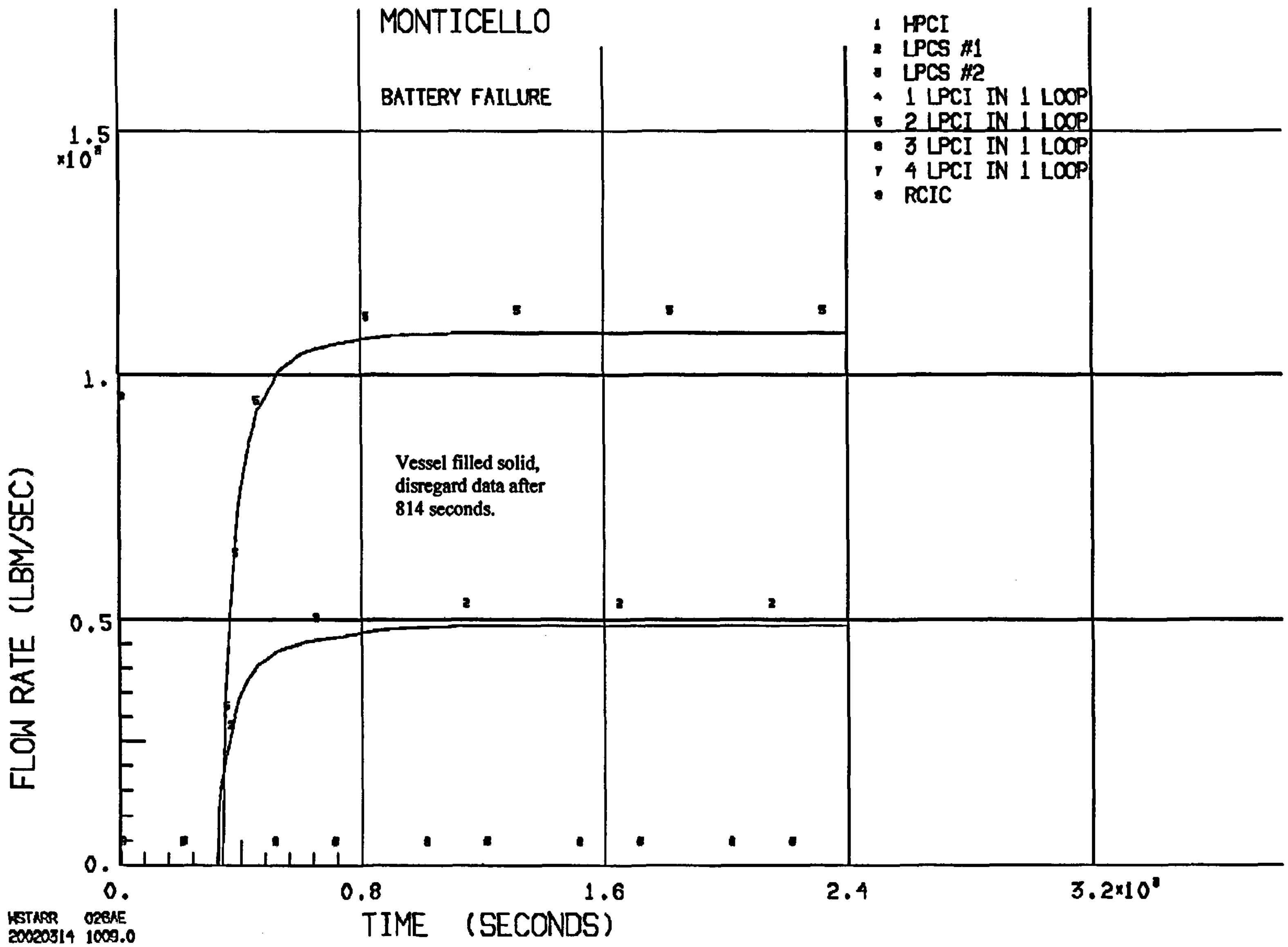


Figure F.3-6 ECCS Flows.
SAFER Results for 0.10 ft^2 Rec. Ln. Brk., 102% of 1775 MWT, ANS 5.1 + 2σ D.H.

APPENDIX G

PLOTS FROM SHEX RUNS FOR ISOLATION EVENTS, SMALL BREAKS, AND DBA-LOCA WITH DIRECT POOL COOLING (K= 143.1, SWT= 90°F)

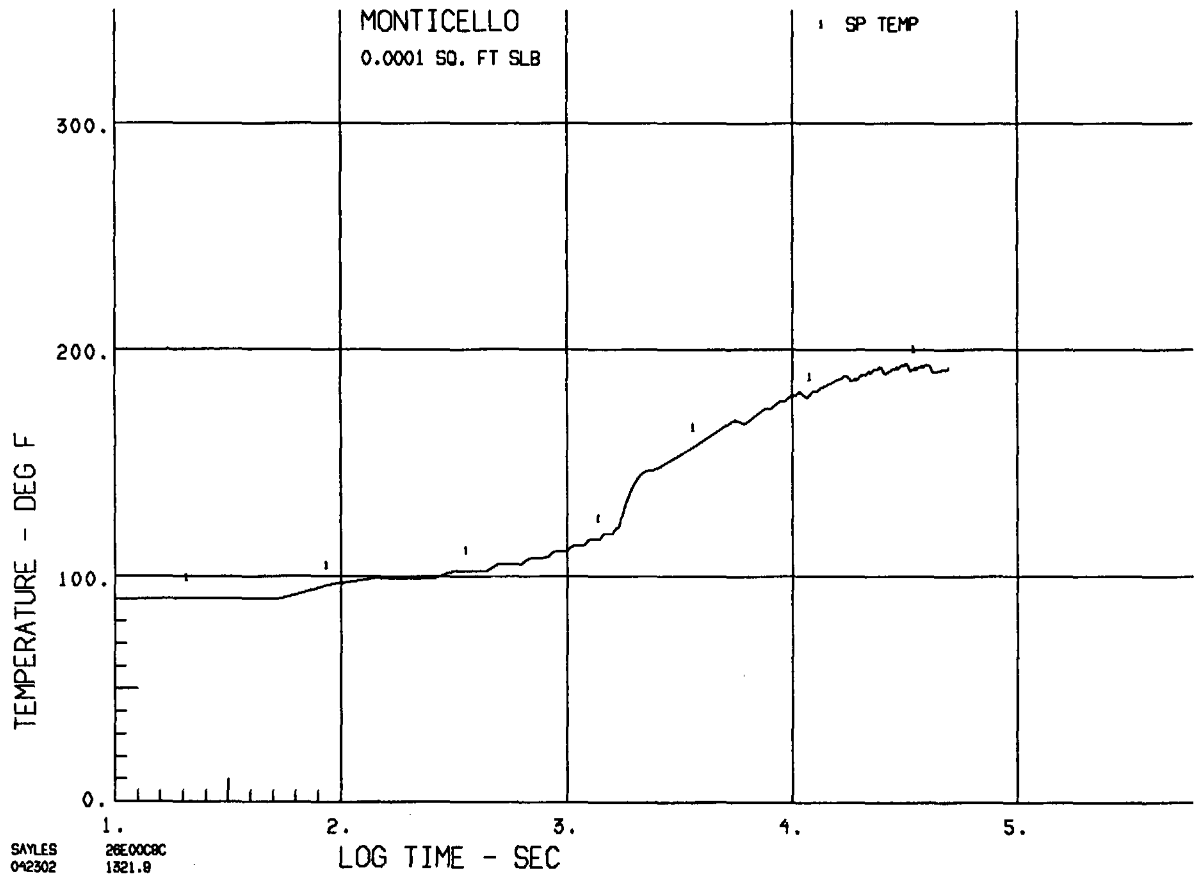


Figure G.1-1 Suppression Pool Temperature - Reactor Isolation with One RHR Loop (K=143.1 Btu/Sec-°F, SWT = 90°F)

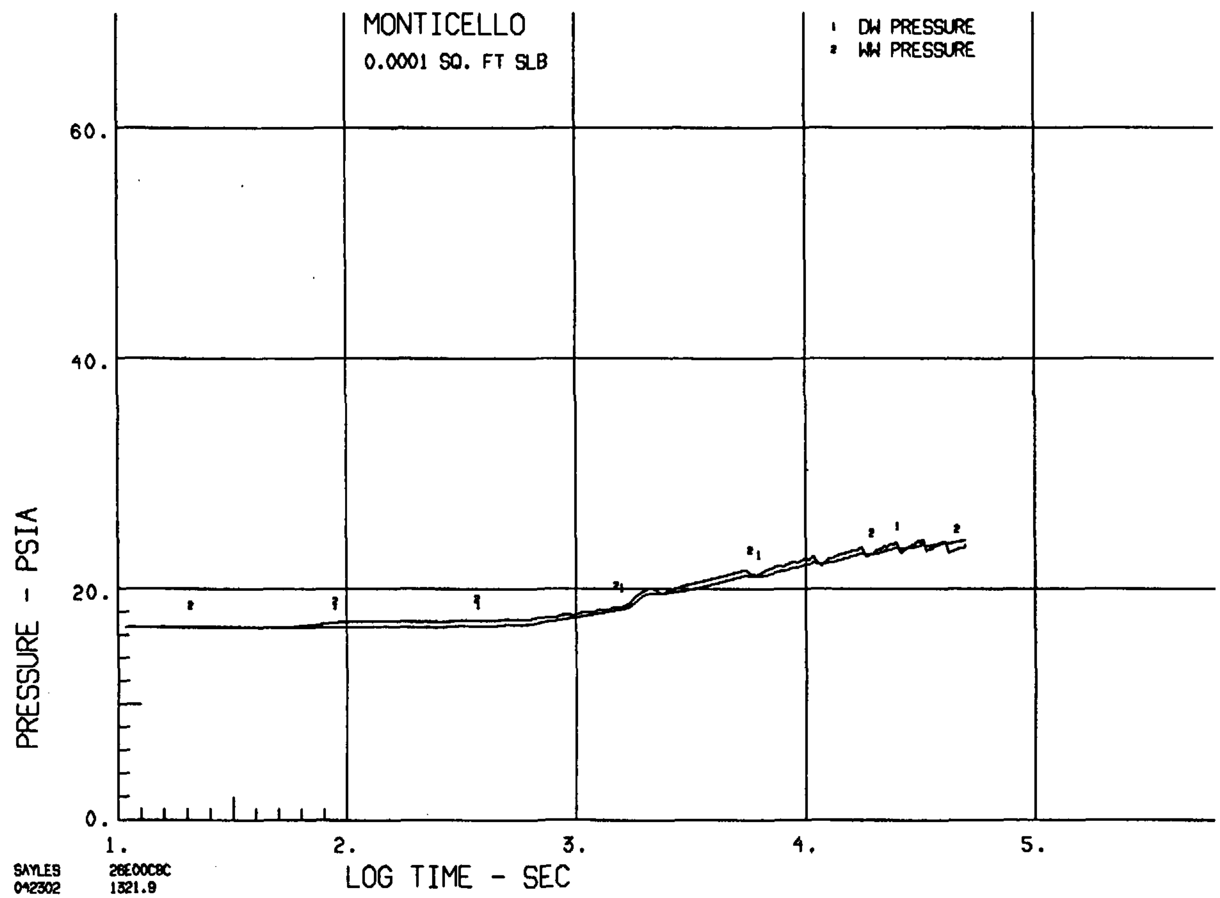


Figure G.1-2 Drywell and Wetwell Pressure - Reactor Isolation with One RHR Loop (K=143.1 Btu/ Sec-°F, SWT = 90°F) (Since vessel surface heat transfer to the drywell was not modeled, the containment pressure response is underestimated.)

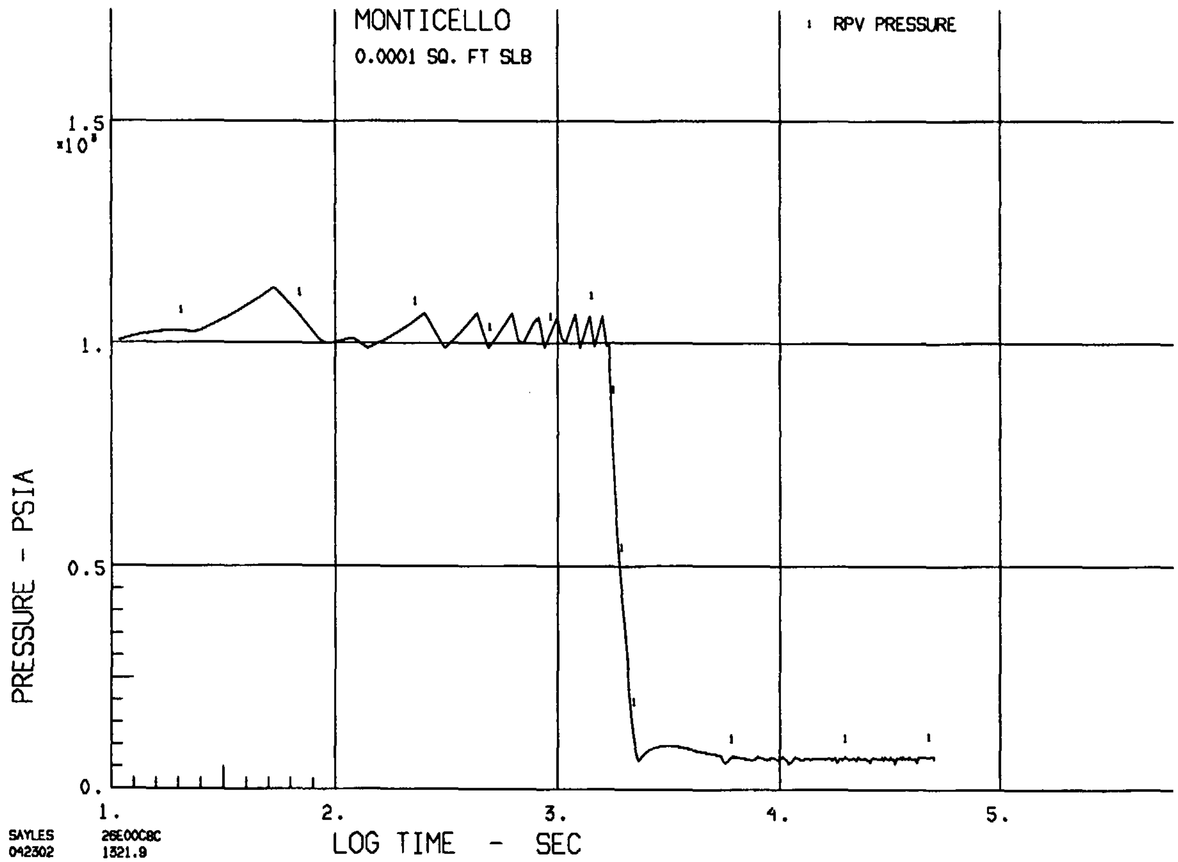


Figure G.1-3 Reactor Pressure Vessel Pressure - Reactor Isolation with One RHR Loop (K=143.1 Btu/ Sec-°F, SWT = 90°F)

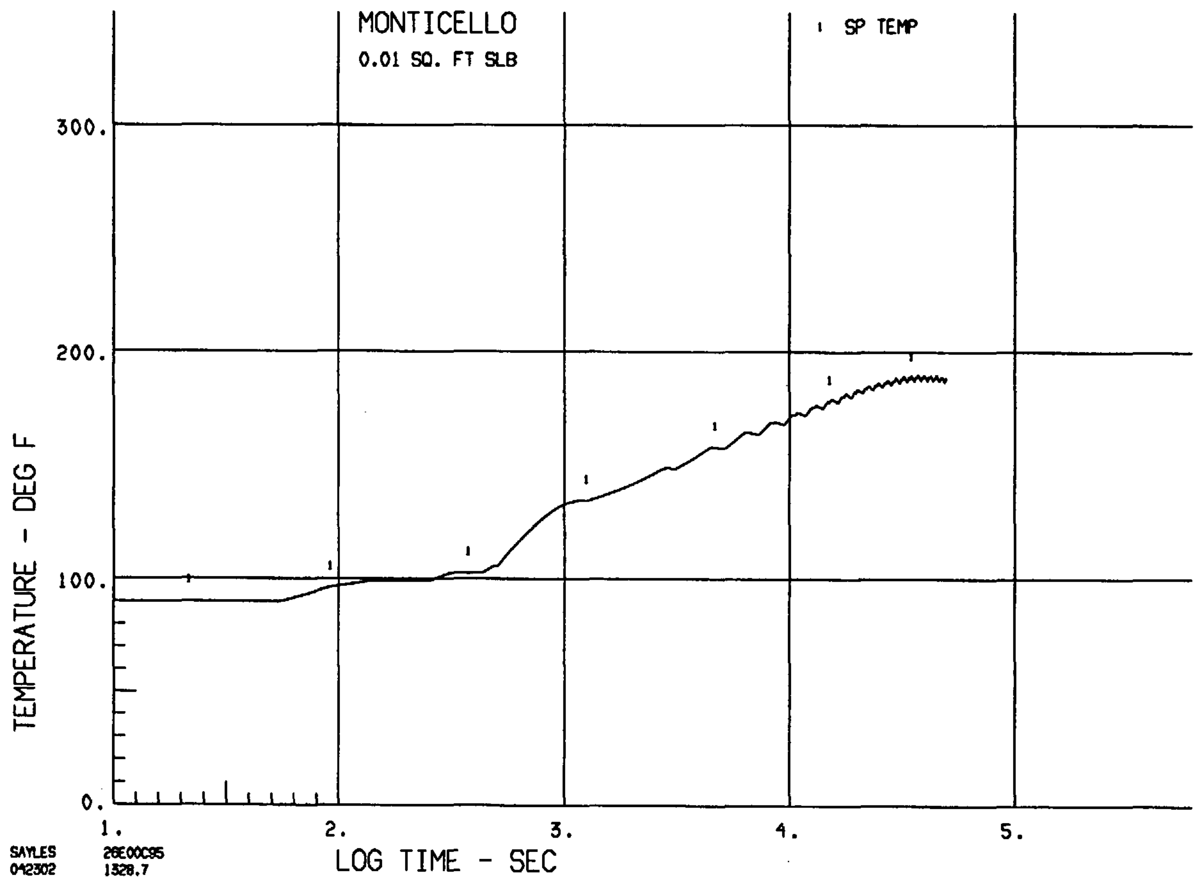


Figure G.2-1 Suppression Pool Temperature - Liquid Line Break 0.01 Ft² with One RHR Loop (K=143.1 Btu/Sec-°F, SWT = 90°F)

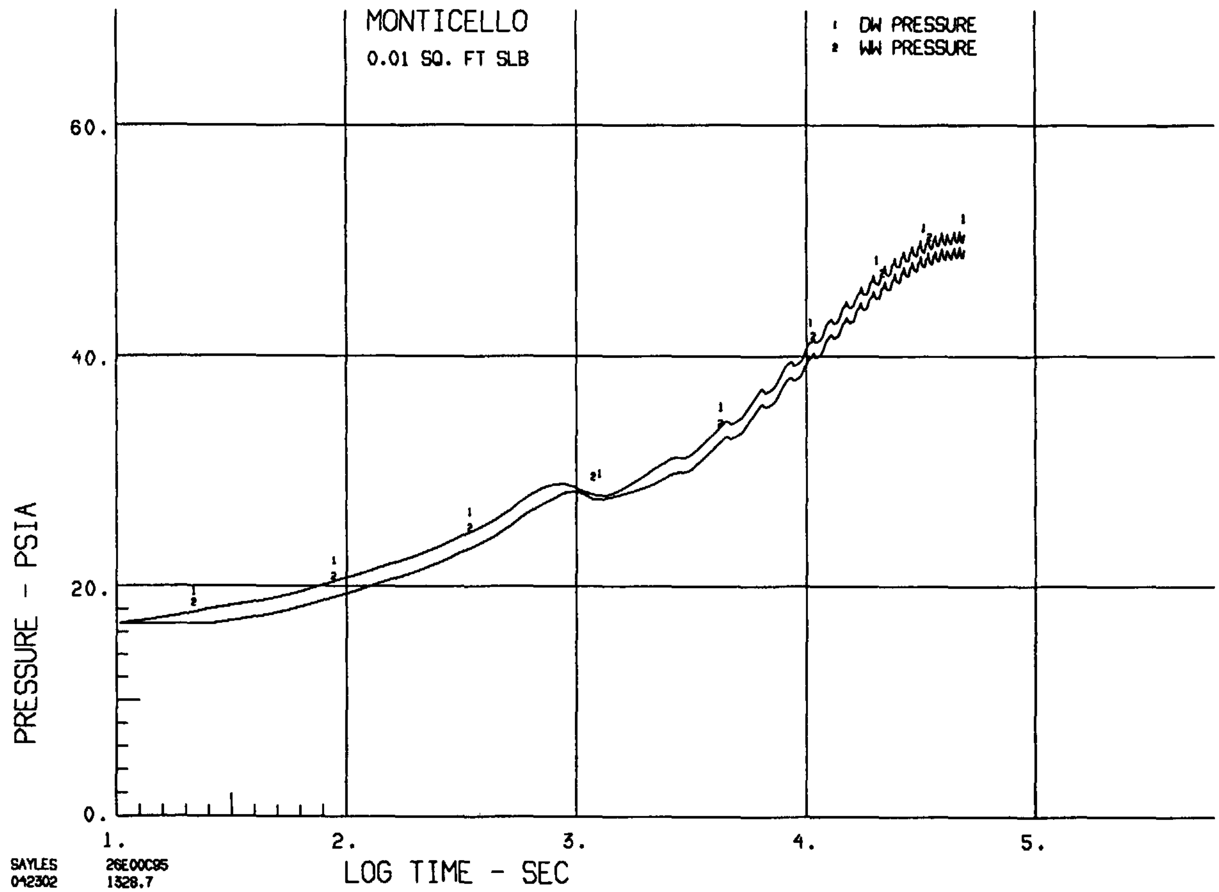


Figure G.2-2 Drywell and Wetwell Pressure - Liquid Line Break 0.01 Ft² with One RHR Loop (K=143.1 Btu/Sec-°F, SWT = 90°F)

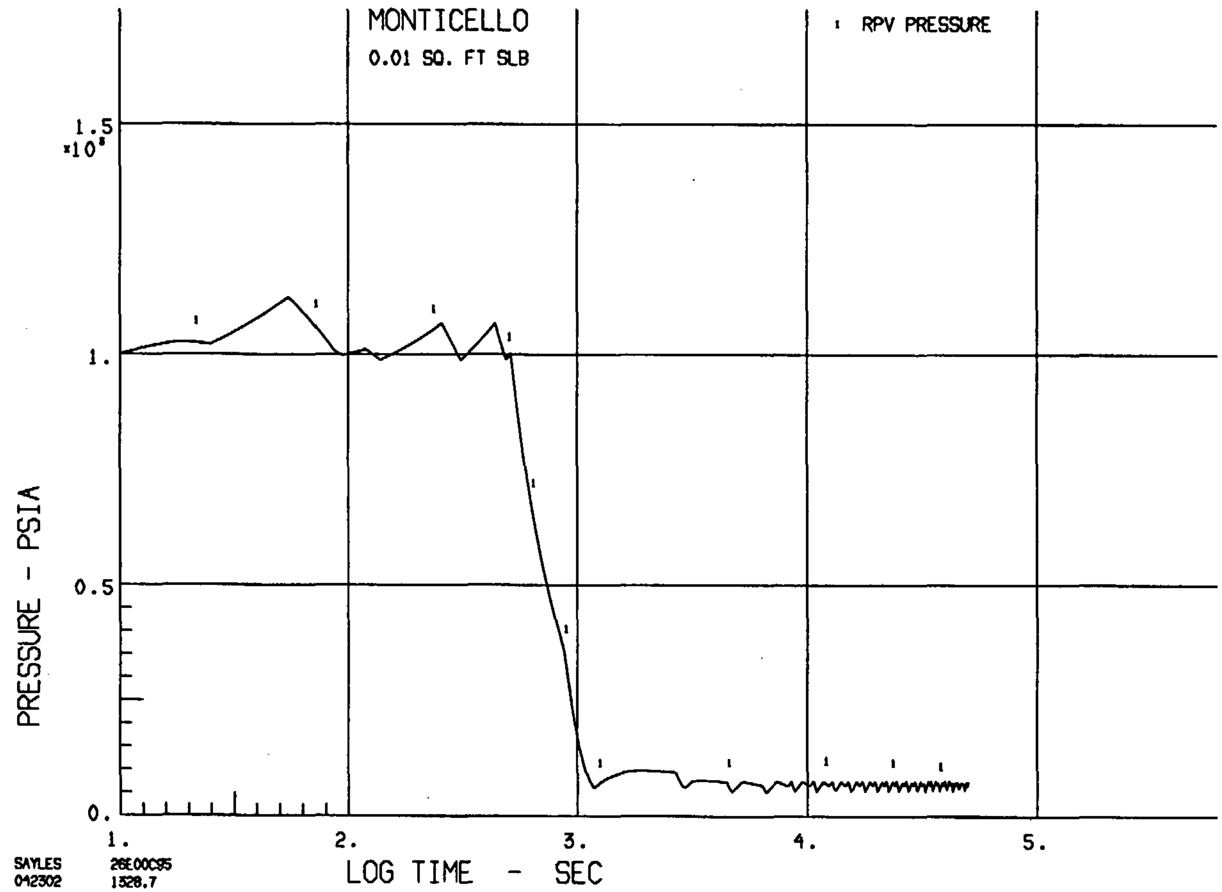


Figure G.2-3 Reactor Pressure Vessel Pressure - Liquid Line Break 0.01 Ft² with One RHR Loop (K=143.1 Btu/Sec-°F, SWT = 90°F)

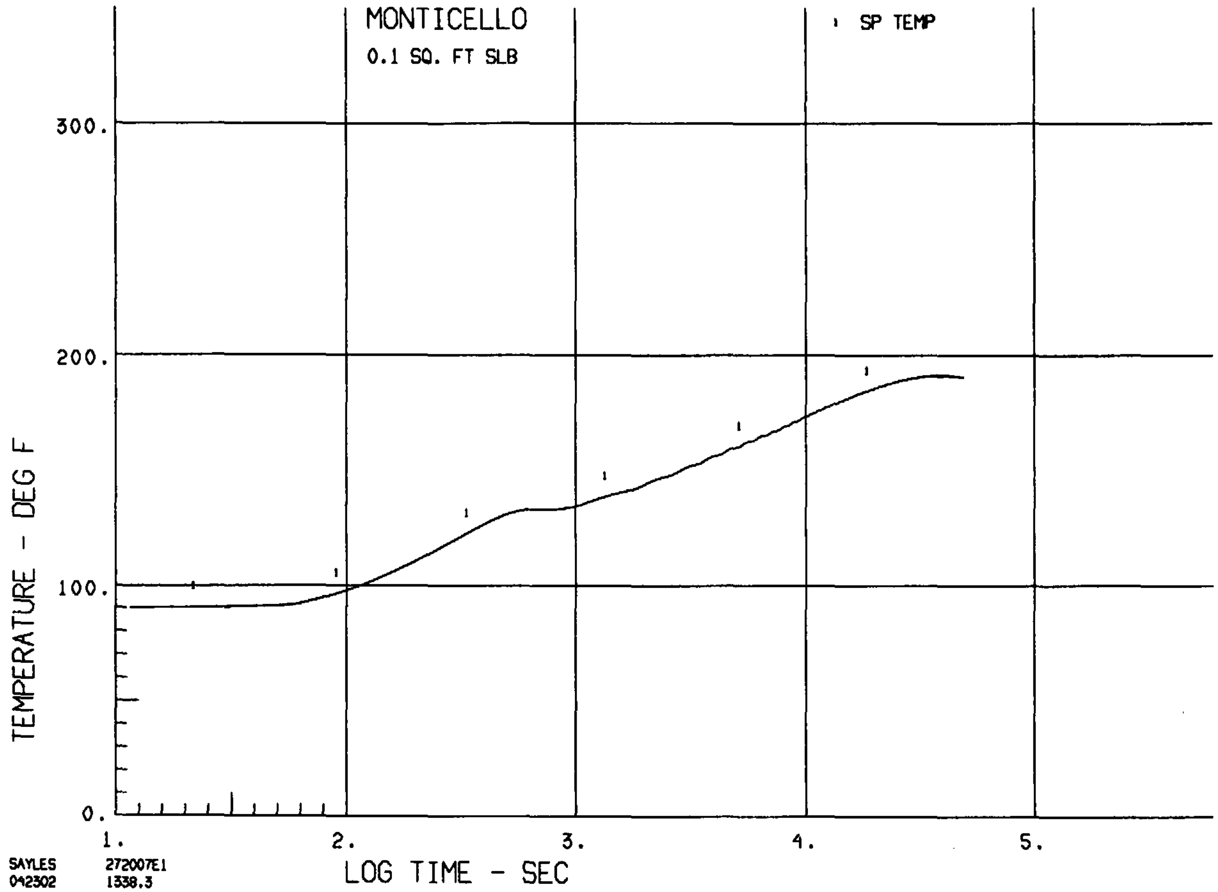


Figure G.3-1 Suppression Pool Temperature - Liquid Line Break 0.1 Ft^2 with One RHR Loop (K=143.1 Btu/ Sec-°F, SWT = 90°F)

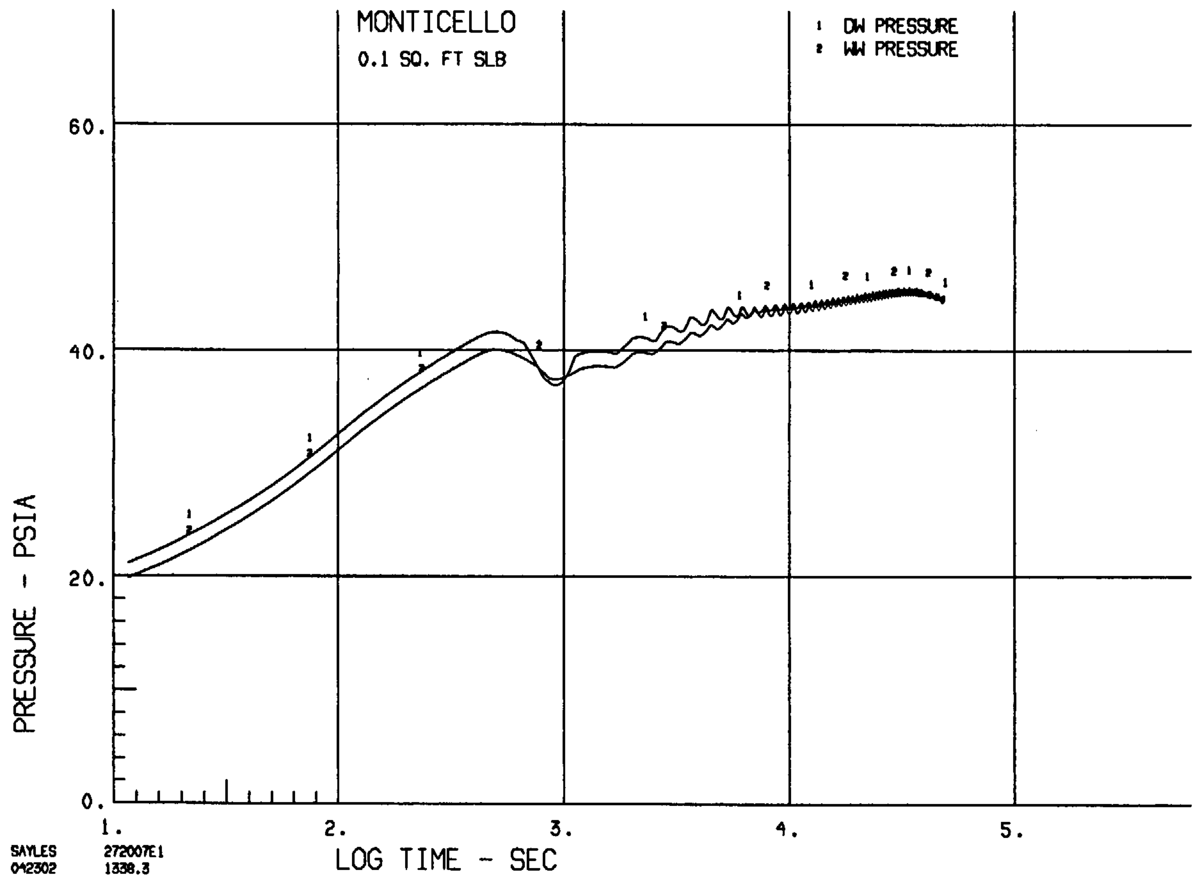


Figure G.3-2 Drywell and Wetwell Pressure - Liquid Line Break 0.1 Ft² with One RHR Loop (K=143.1 Btu/Sec-°F, SWT = 90°F)

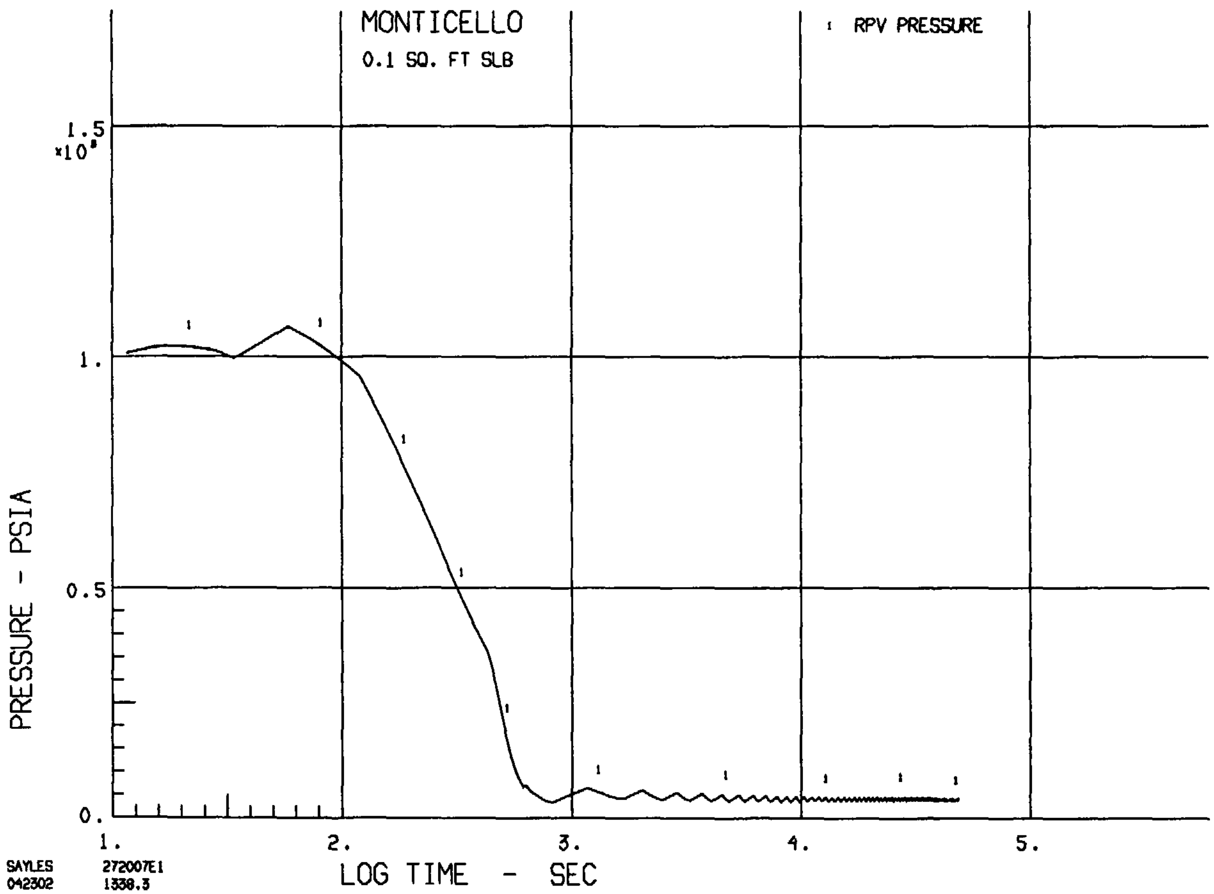


Figure G.3-3 Reactor Pressure Vessel Pressure - Liquid Line Break 0.1 Ft² with One RHR Loop (K=143.1 Btu/ Sec-°F, SWT = 90°F)

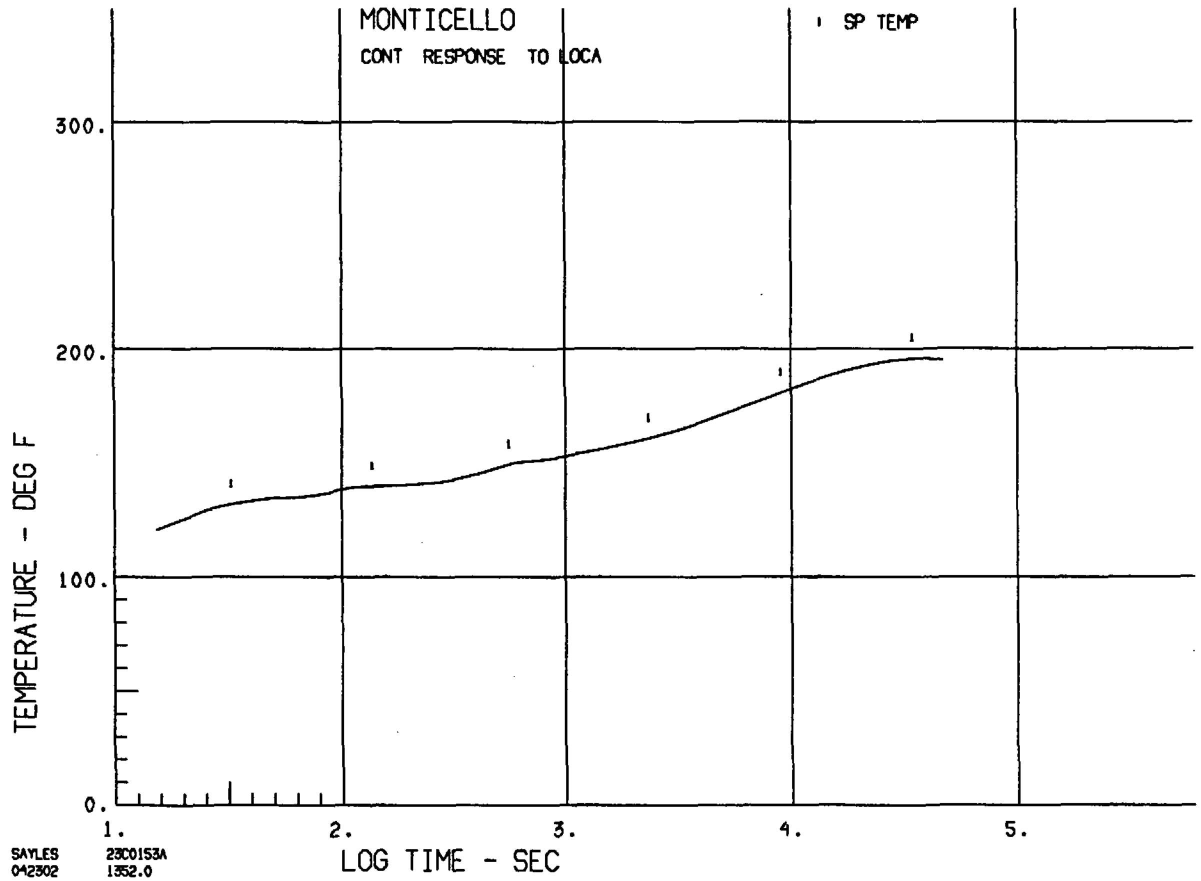


Figure G.4-1 Suppression Pool Temperature - DBA-LOCA - Loss of Diesel Generator (K=143.1 Btu/ Sec-°F, SWT = 90°F)

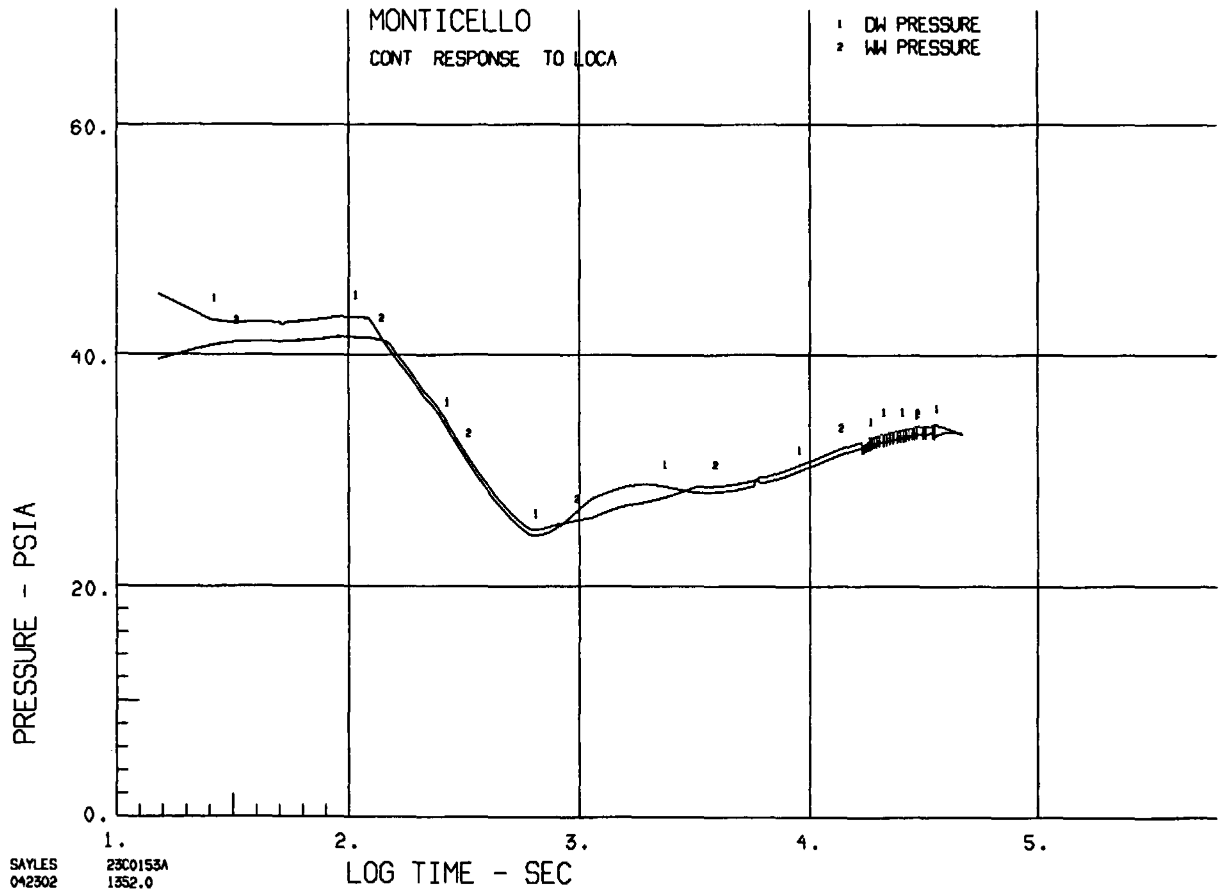


Figure G.4-2 Drywell and Wetwell Pressure - DBA-LOCA - Loss of Diesel Generator (K=143.1 Btu/ Sec-°F, SWT = 90°F)

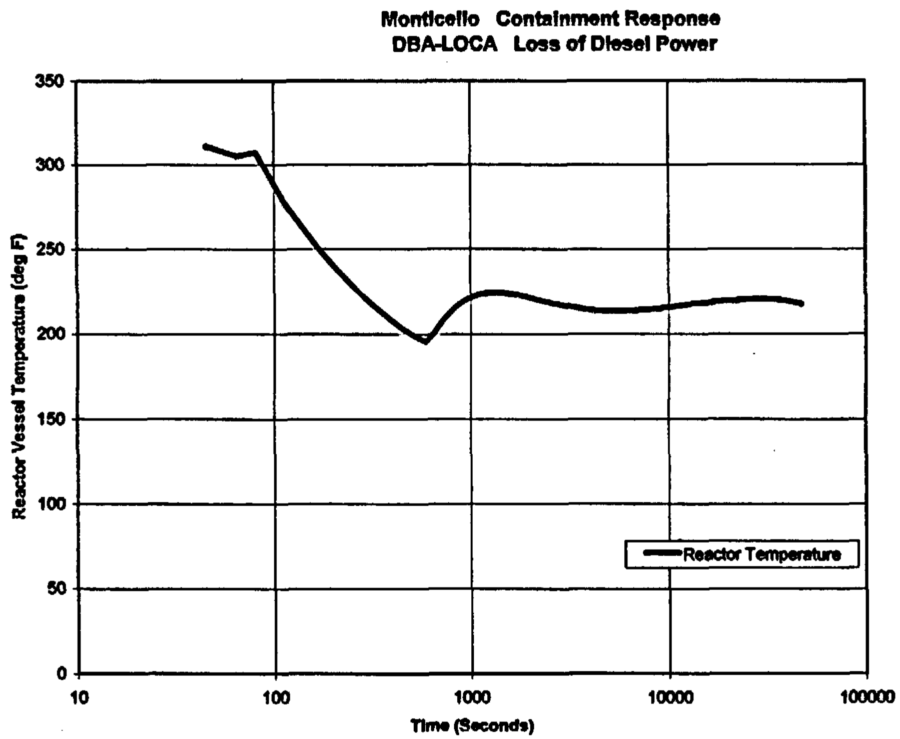


Figure G.4-3 Reactor Pressure Vessel Temperature - DBA-LOCA - Loss of Diesel Generator (K=143.1 Sec-°F, SWT = 90°F)

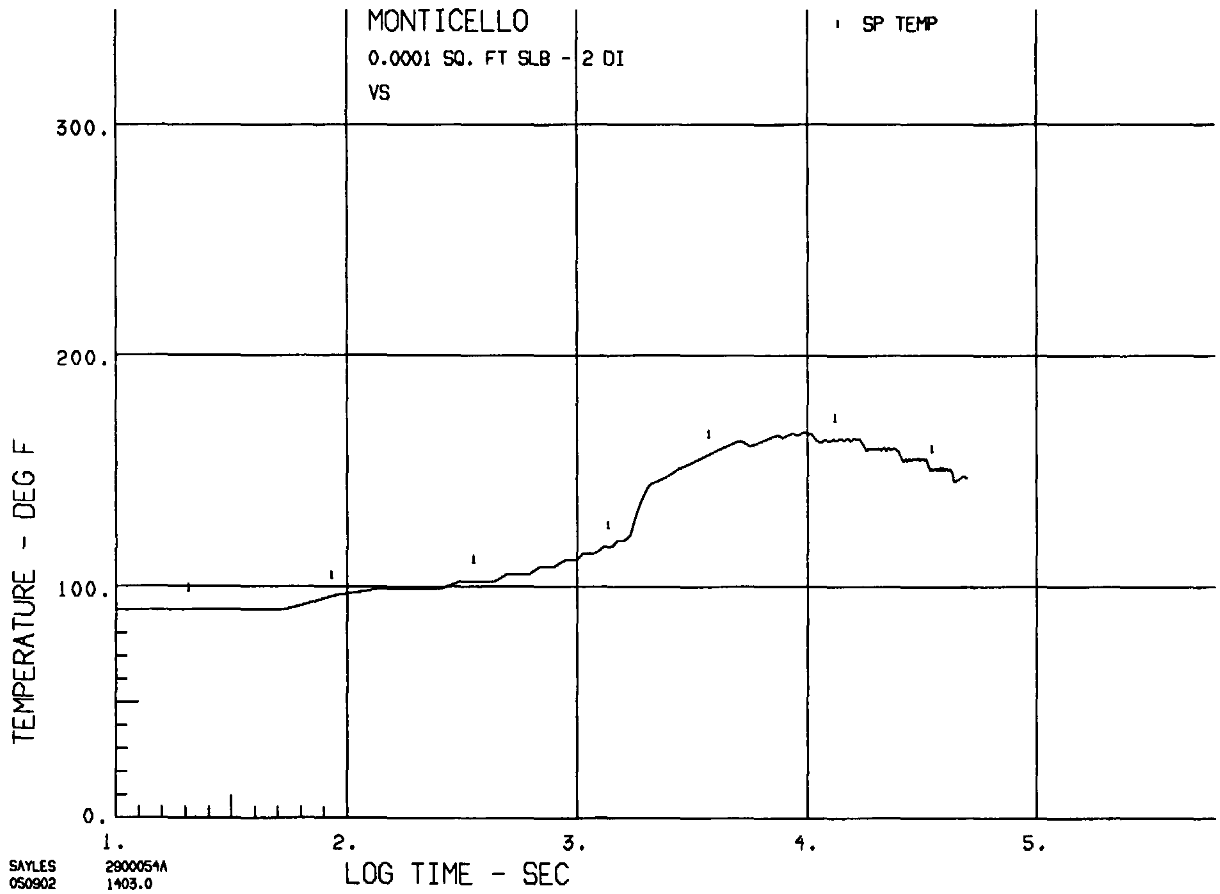


Figure G.5-1 Suppression Pool Temperature - Reactor Isolation with Two RHR Loops (K=143.1 Btu/ Sec-°F, SWT = 90°F)

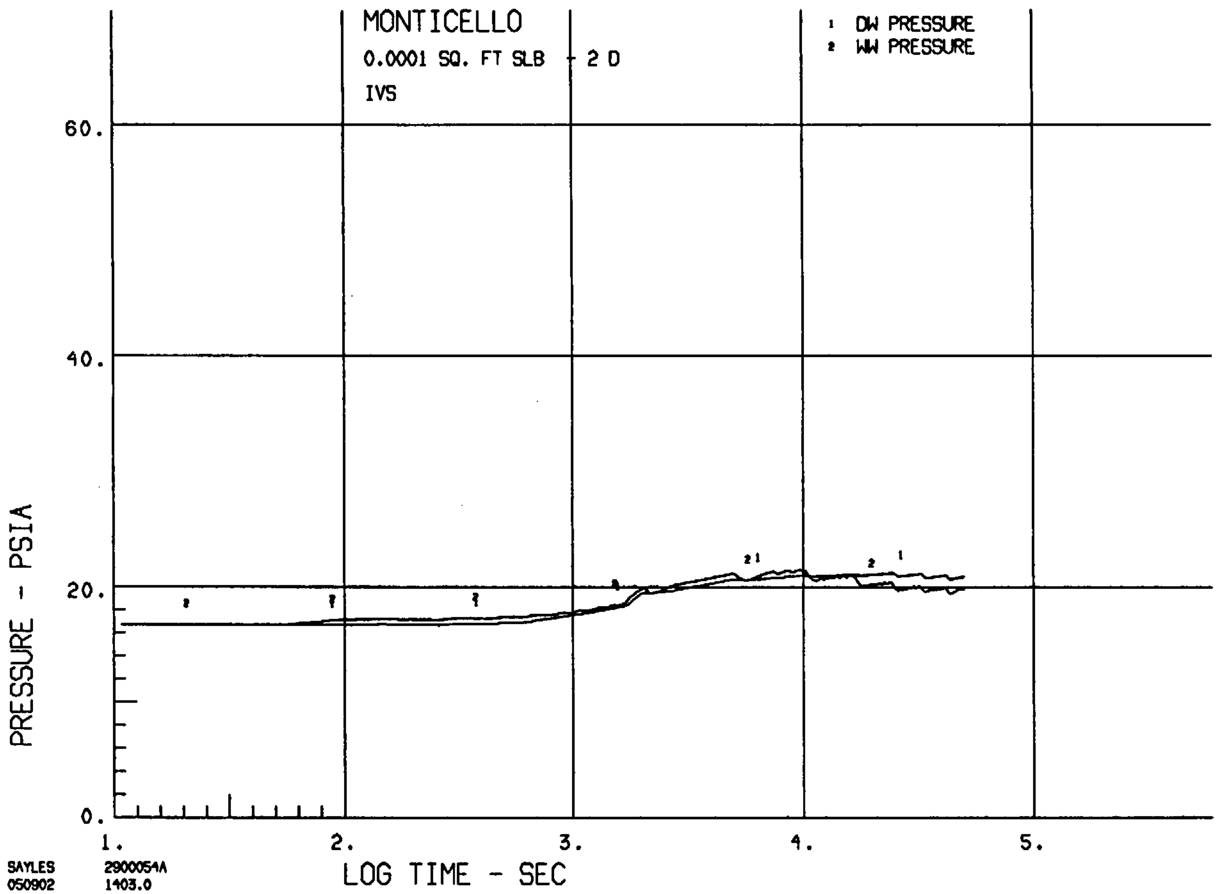


Figure G.5-2 Drywell and Wetwell Pressure - Reactor Isolation with Two RHR Loops **(K=143.1 Btu/ Sec-°F, SWT = 90°F)**
(Since vessel surface heat transfer to the drywell was not modeled, the containment pressure response is underestimated.)

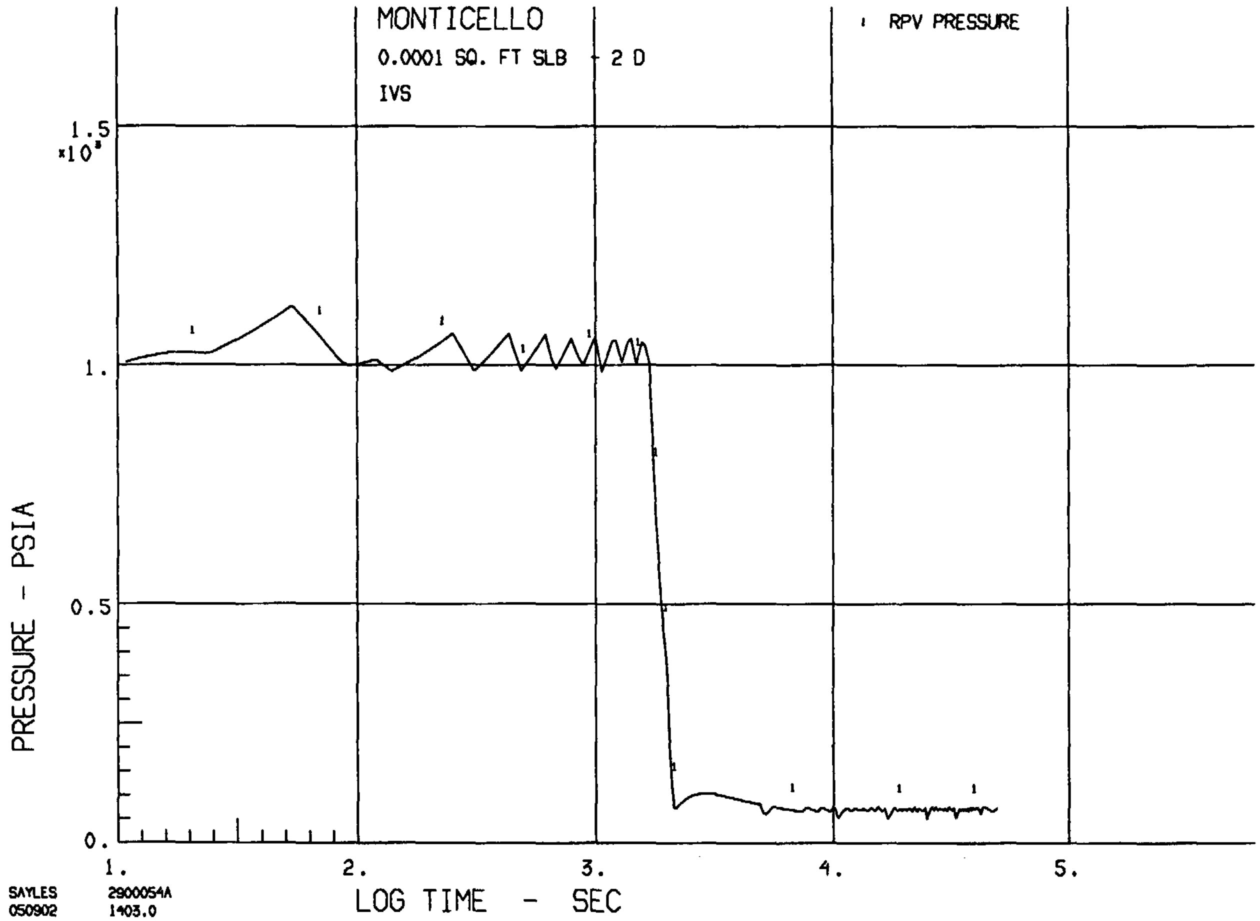


Figure G.5-3 Reactor Pressure Vessel Pressure - Reactor Isolation with Two RHR Loops (K=143.1 Btu/ Sec-°F, SWT = 90°F)

APPENDIX H

PLOTS FROM SHEX RUNS FOR SHORT-TERM NPSH DBA-LOCA

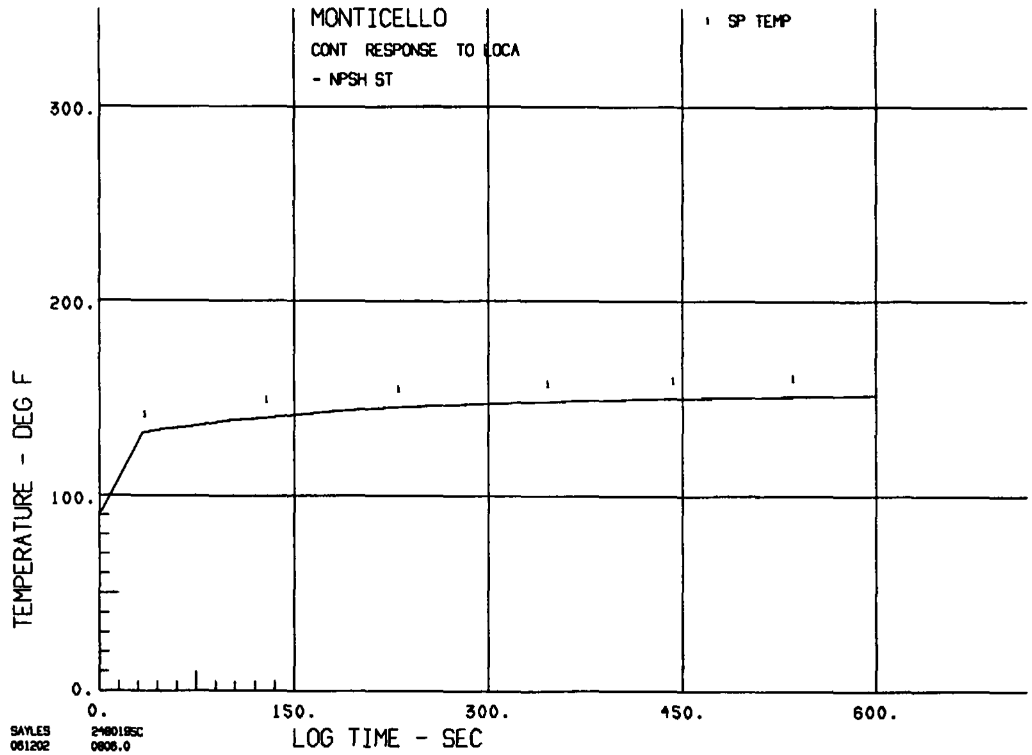


Figure H-1 Suppression Pool Temperature - Short-Term NSPH DBA-LOCA

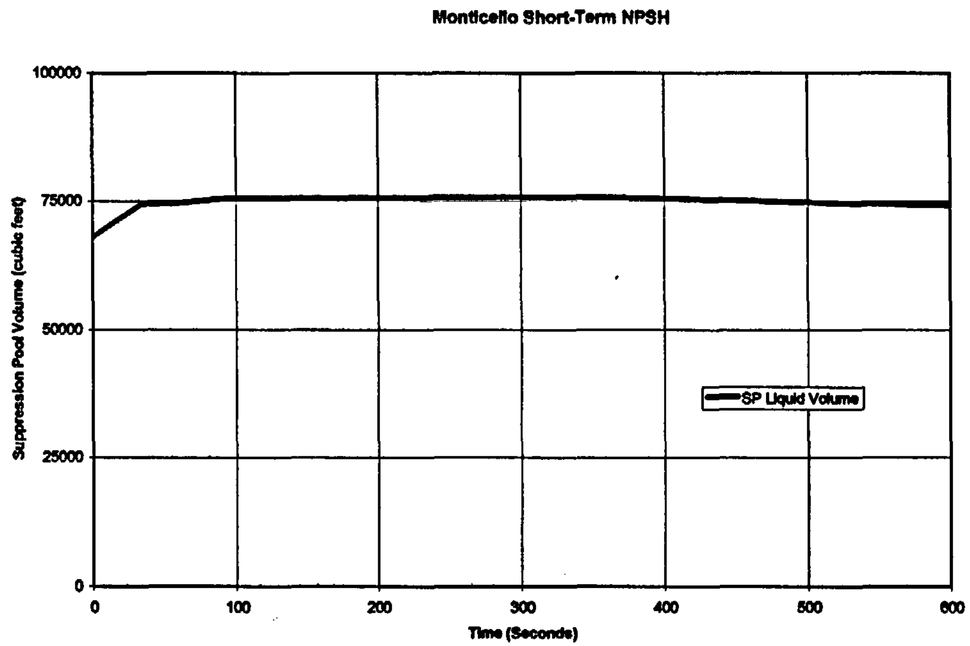


Figure H-2 Suppression Pool Volume - Short-Term NSPH DBA-LOCA

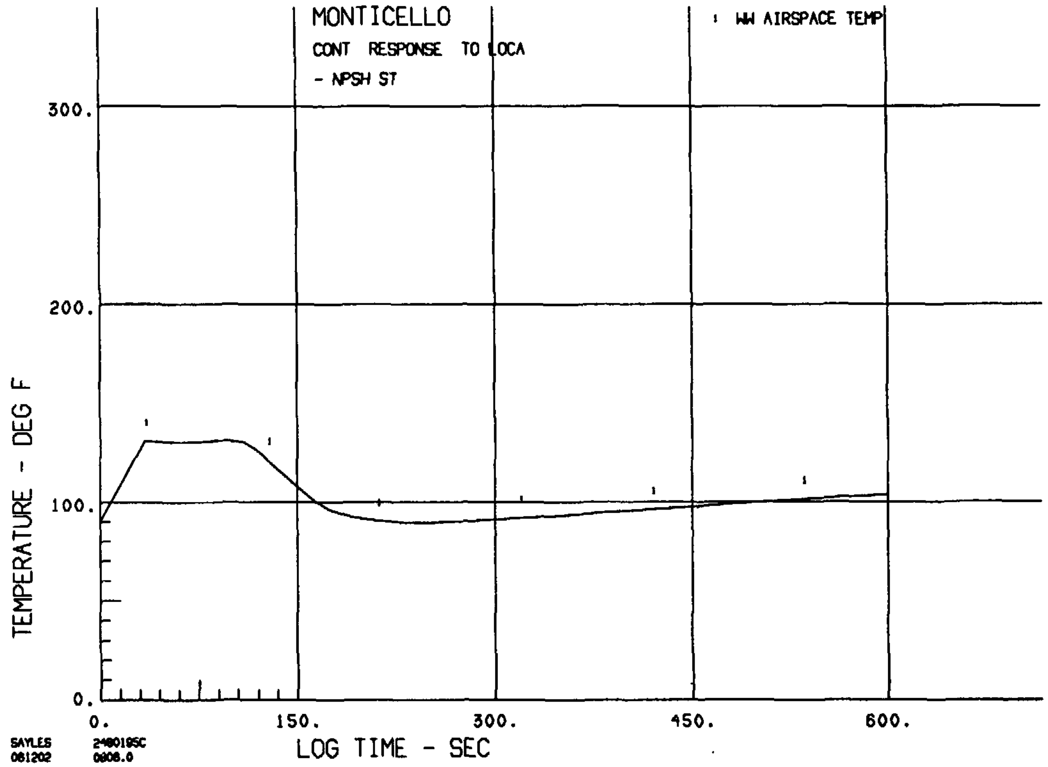


Figure H-3 Wetwell Temperature - Short-Term NSPH DBA-LOCA

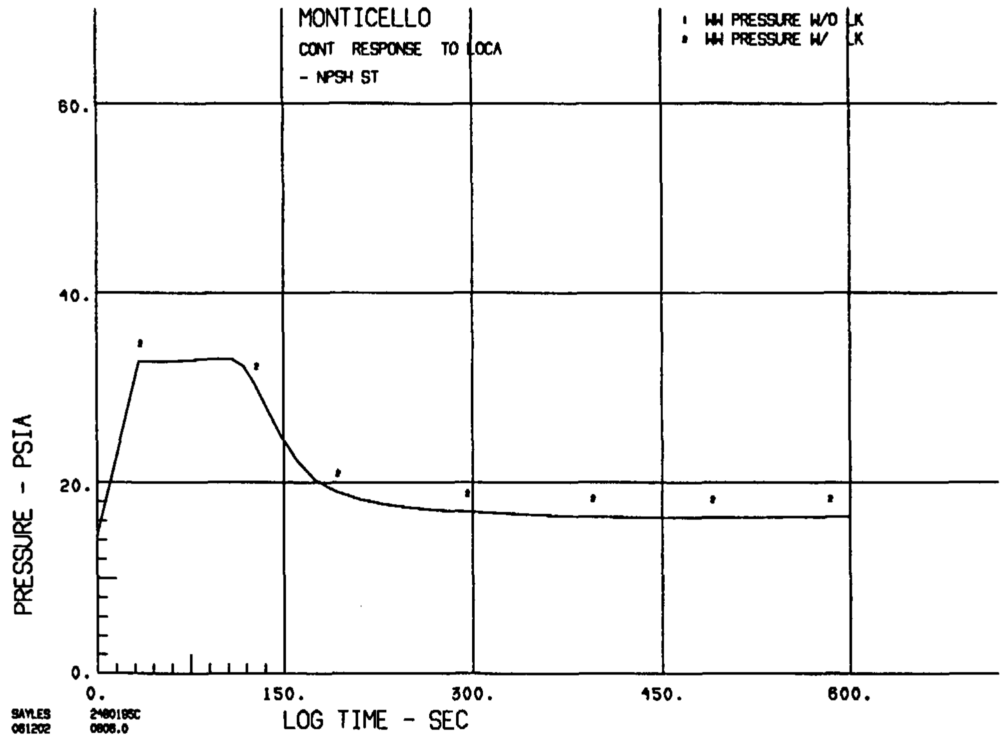


Figure H-4 Wetwell Pressure with/without Containment Leakage - Short-Term NSPH DBA-LOCA

APPENDIX I

PLOTS FROM SHEX RUNS FOR DBA-LOCA FOR LONG-TERM NPSH (K=147,SWT= 90°F)

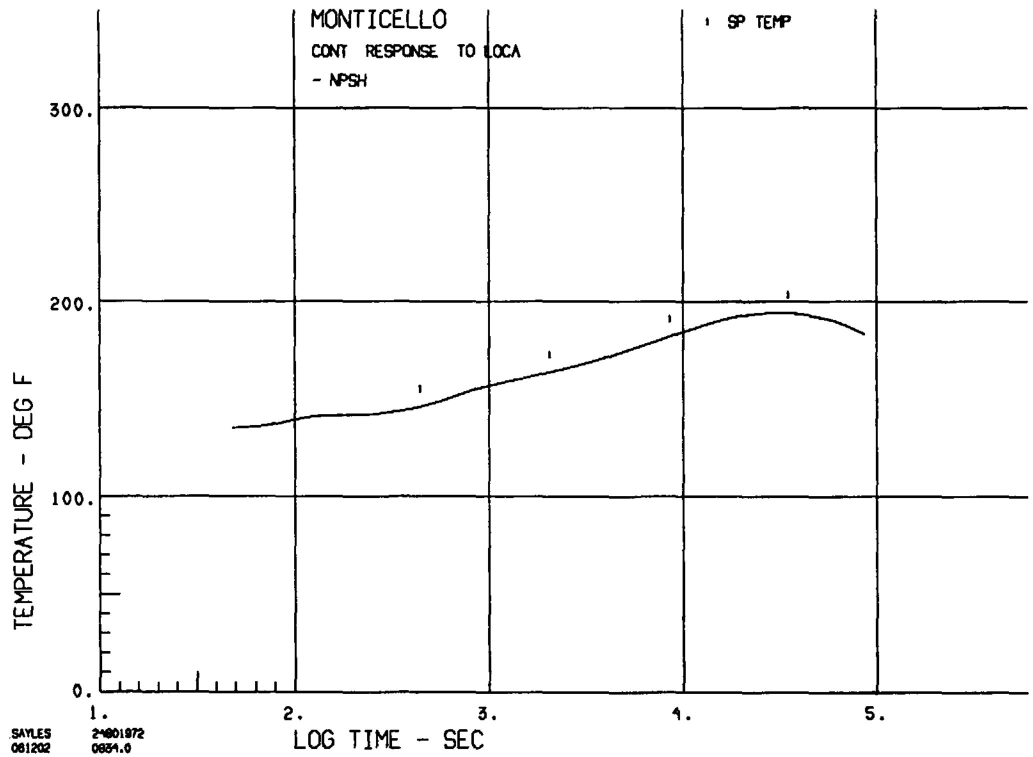


Figure I.1-1 Suppression Pool Temperature Long--Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

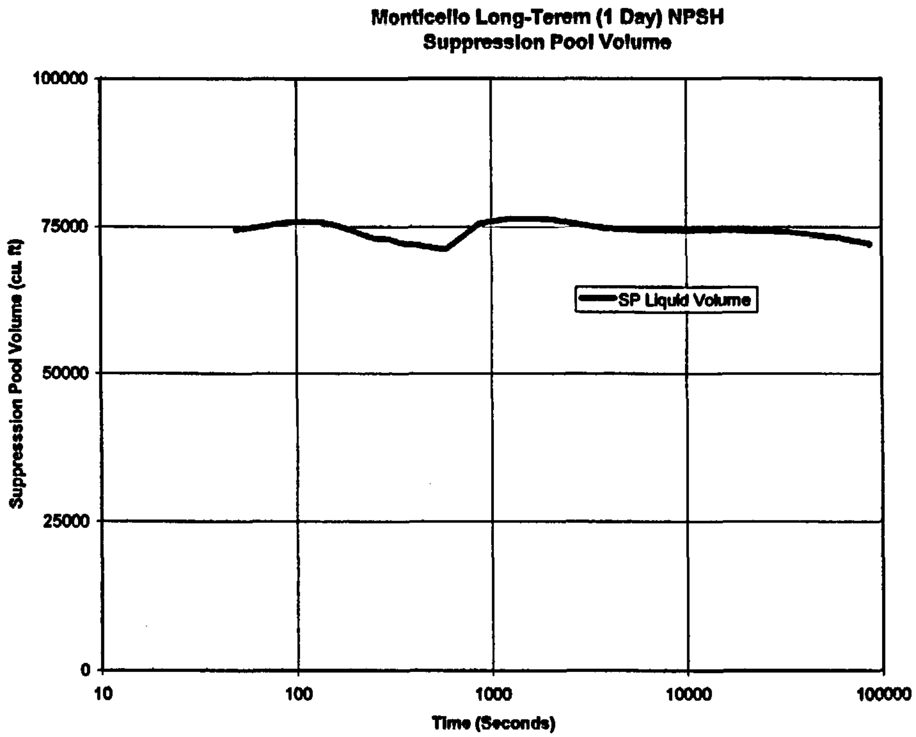


Figure I.1-2 Suppression Pool Volume Long--Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

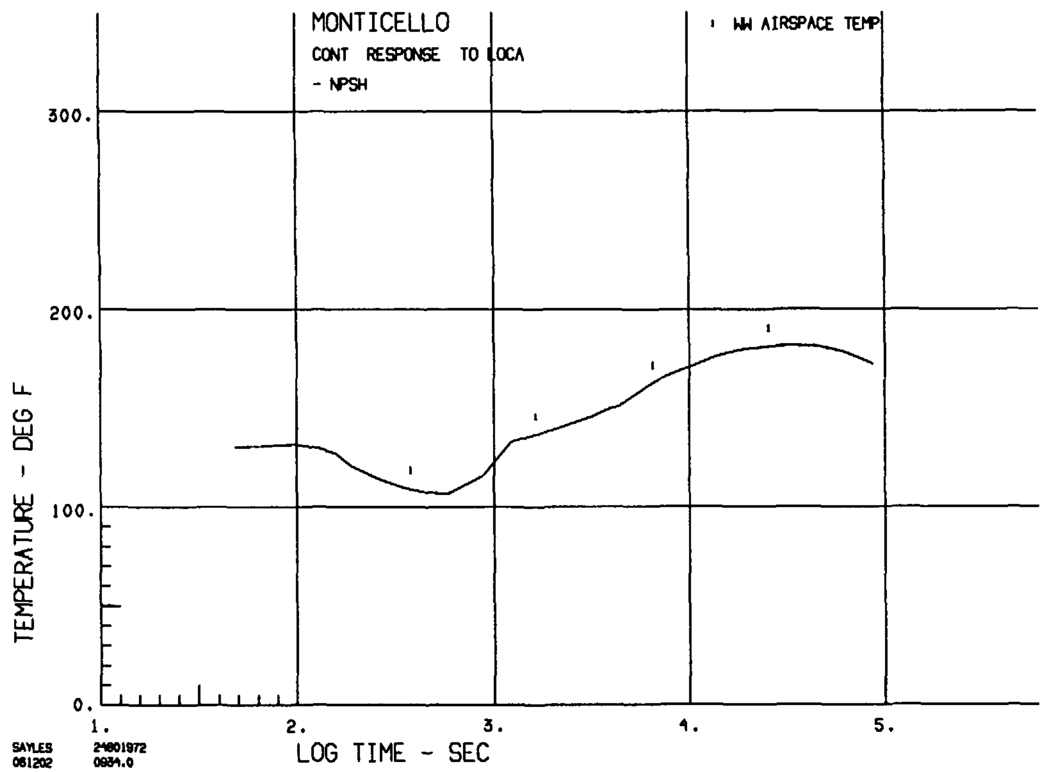


Figure I.1-3 Wetwell Temperature Long–Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

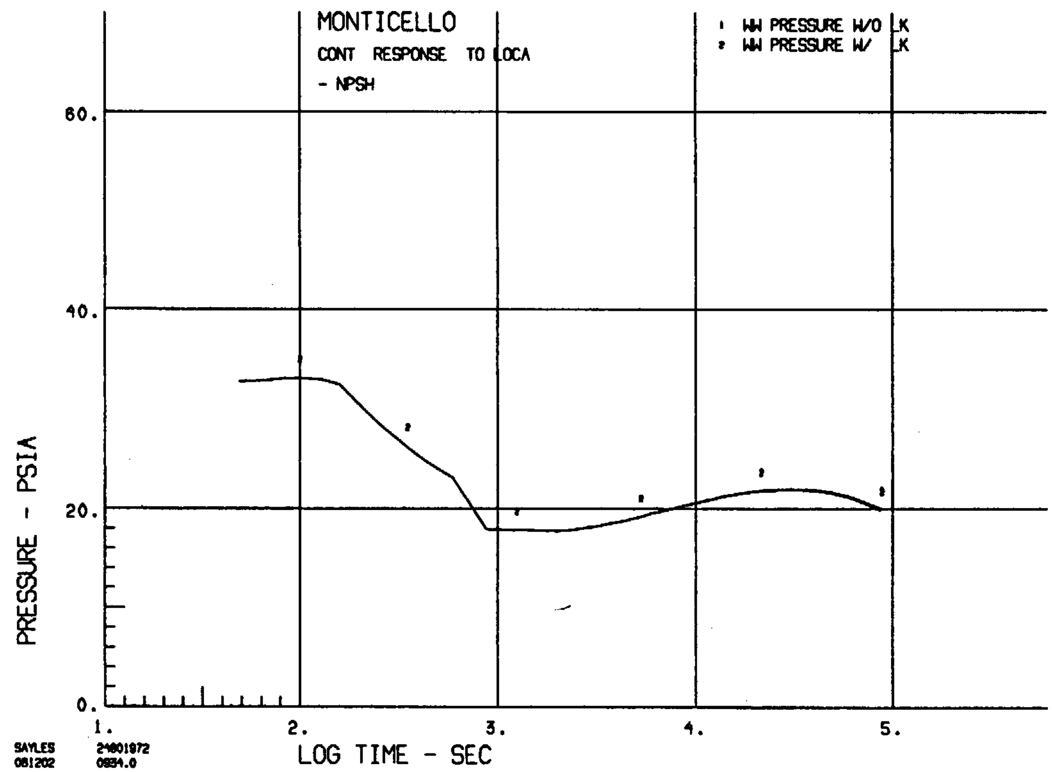


Figure I.1-4 Wetwell Pressure with/without Leakage Long--Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

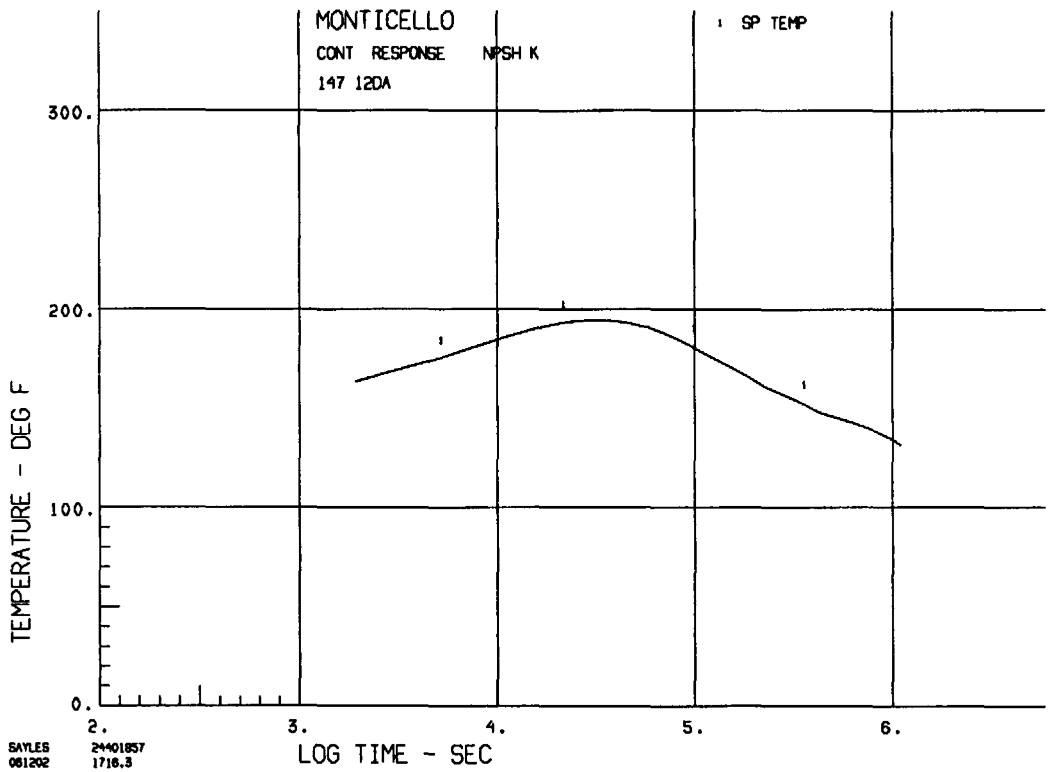


Figure I.2-1 Suppression Pool Temperature Long–Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

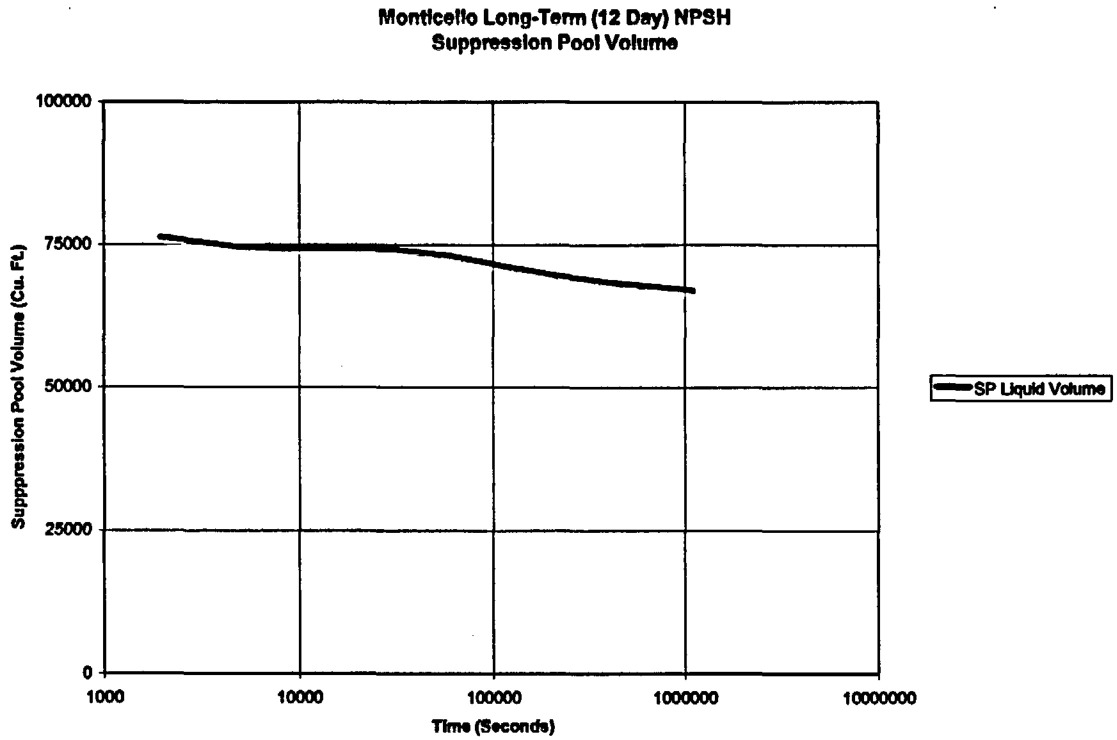


Figure I.2-2 Suppression Pool Volume Long–Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

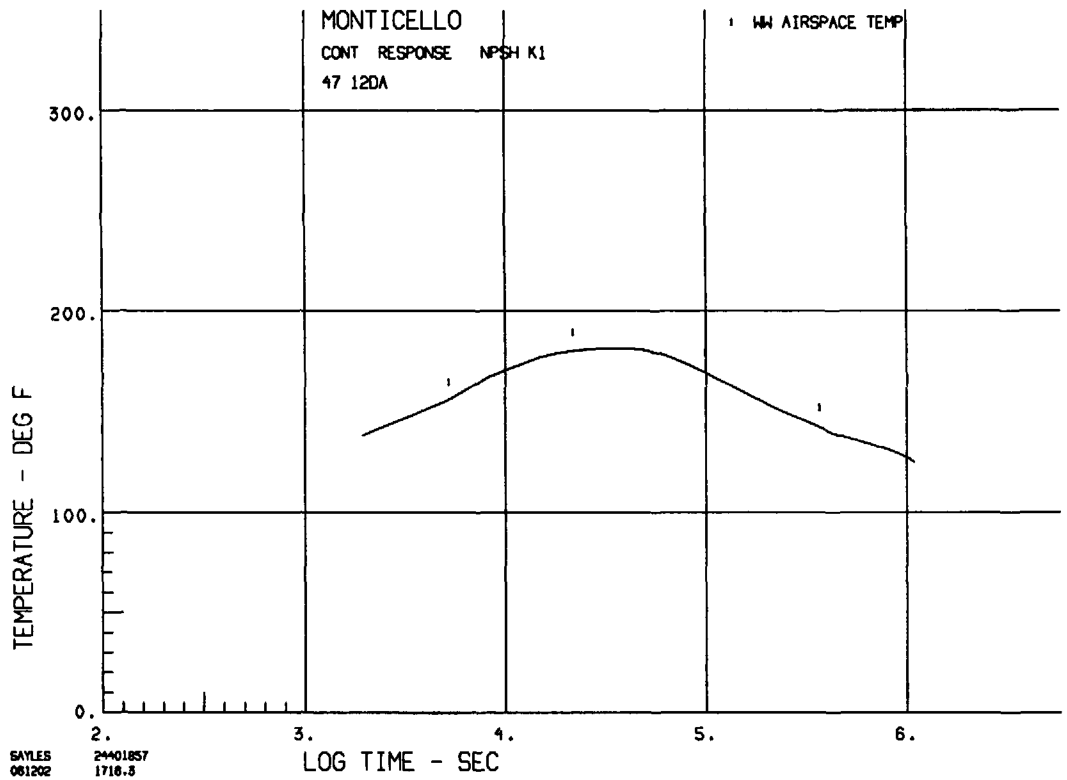


Figure I.2-3 Wetwell Temperature Long–Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

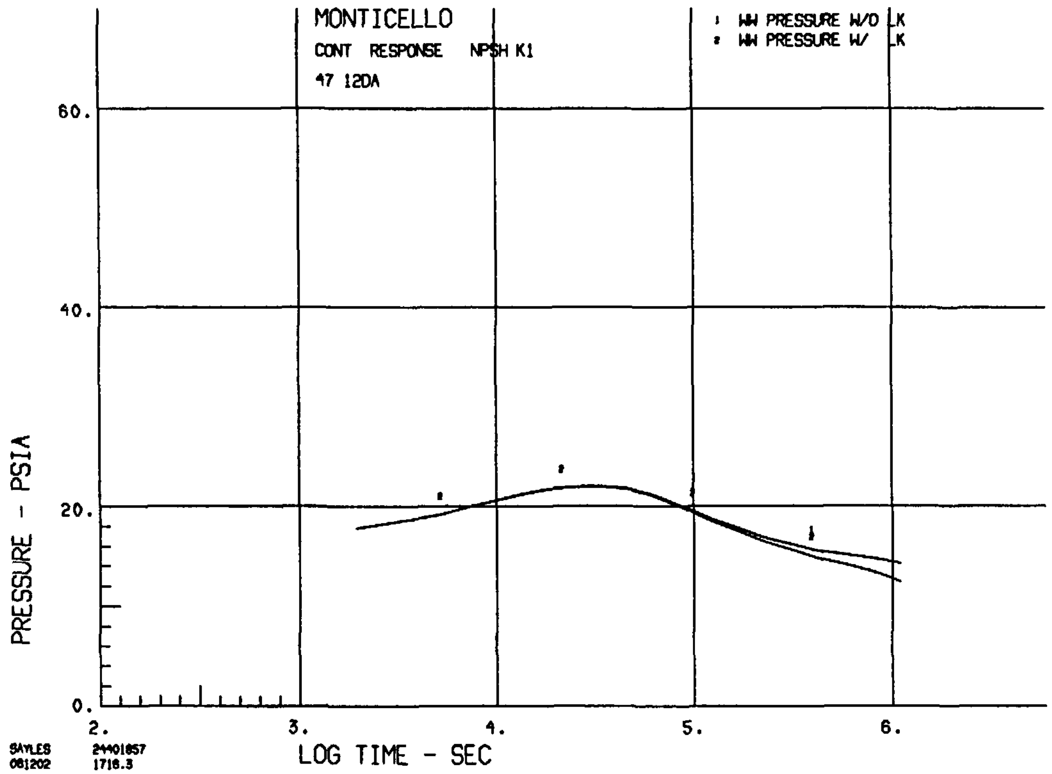


Figure I.2-4 Wetwell Pressure with/without Leakage Long–Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 90°F)

APPENDIX J

PLOTS FROM SHEX RUNS FOR DBA-LOCA FOR LONG-TERM NPSH (K=147,SWT= 94°F)

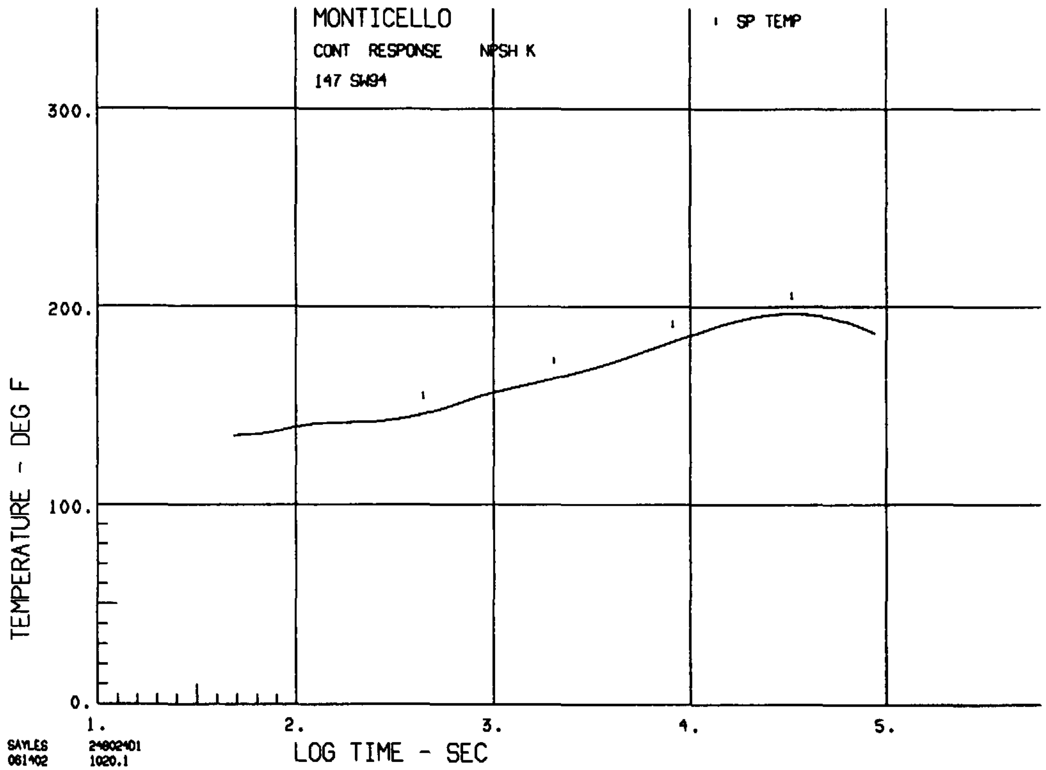


Figure J.1-1 Suppression Pool Temperature Long-Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

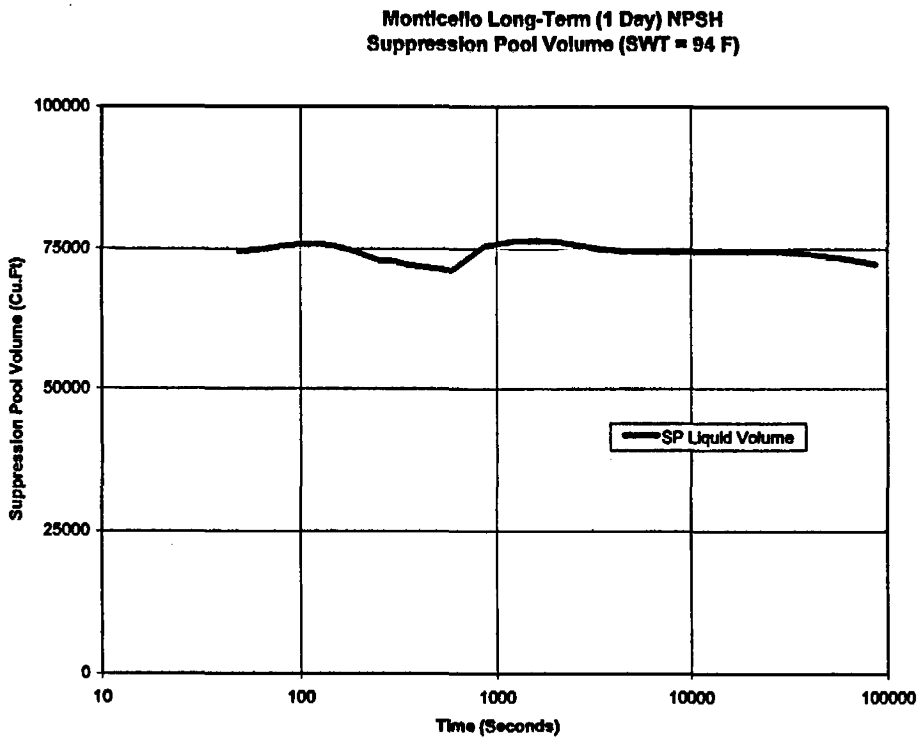


Figure J.1-2 Suppression Pool Volume Long-Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

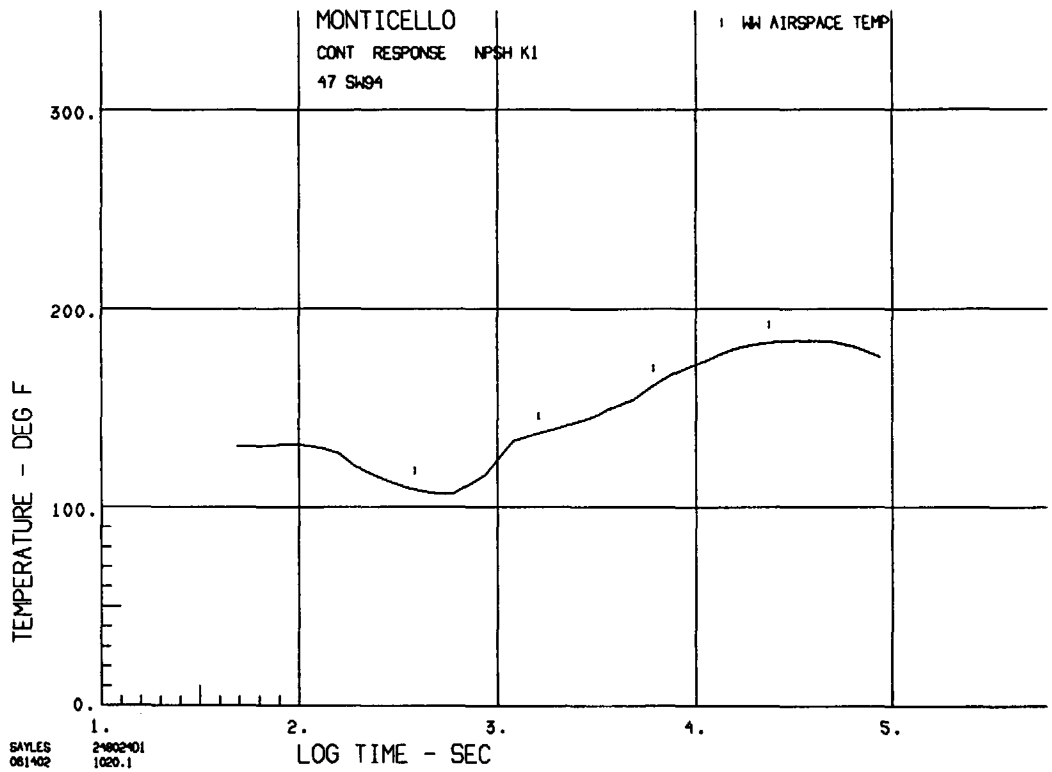


Figure J.1-3 Wetwell Temperature Long-Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

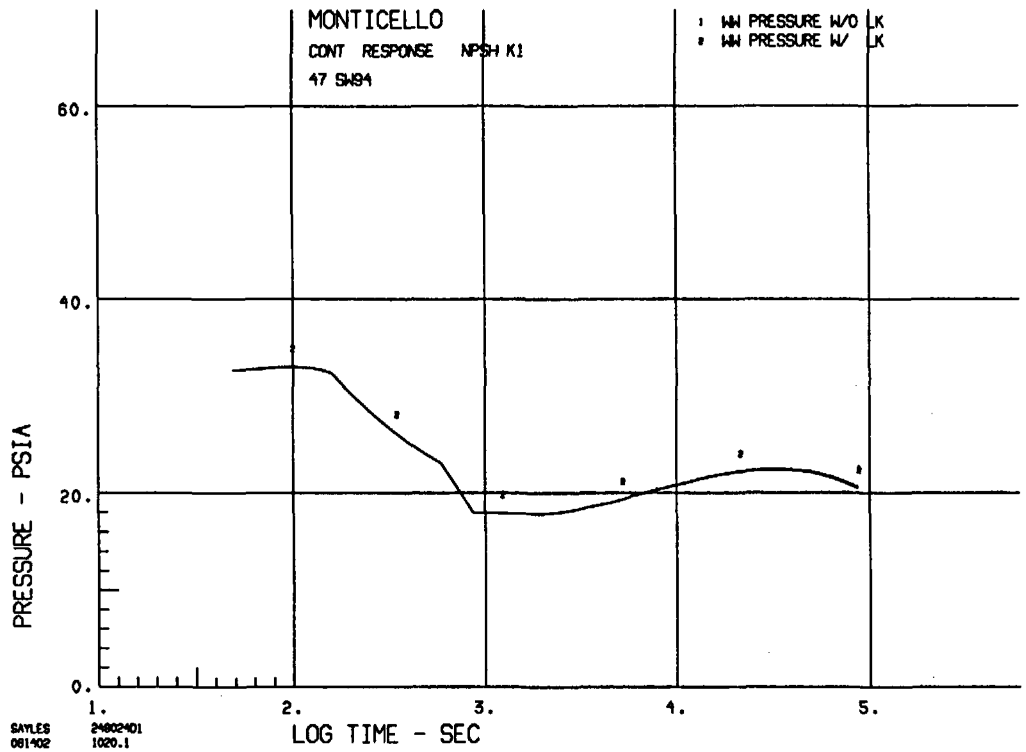


Figure J.1-4 Wetwell Pressure with/without Leakage Long-Term (1 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

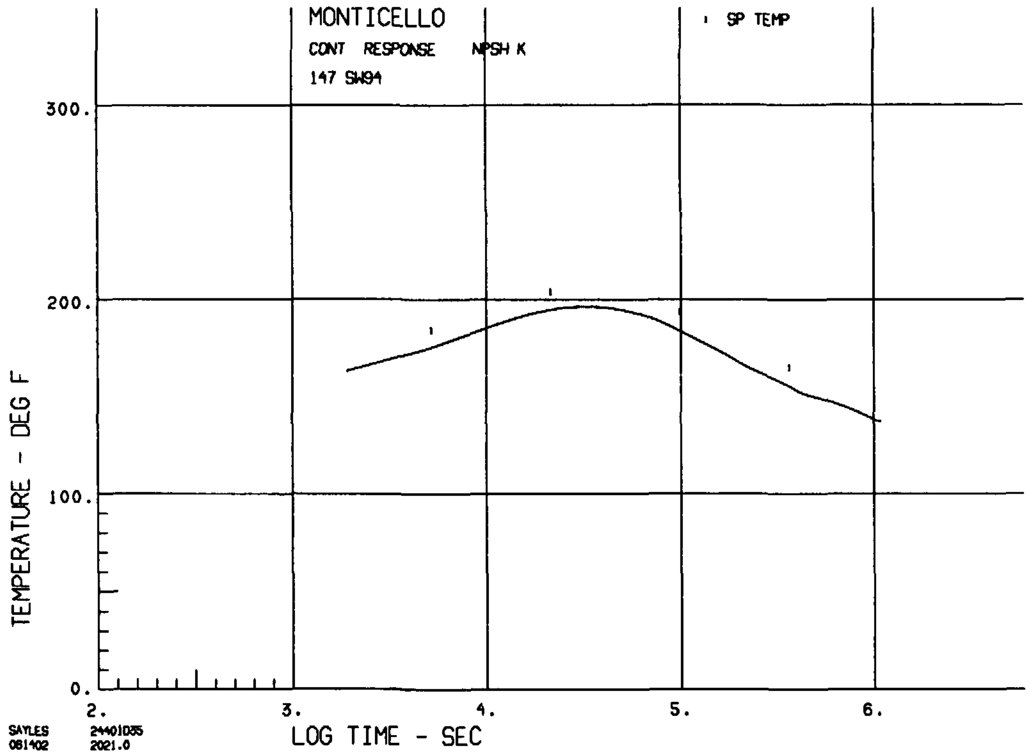


Figure J.2-1 Suppression Pool Temperature Long-Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

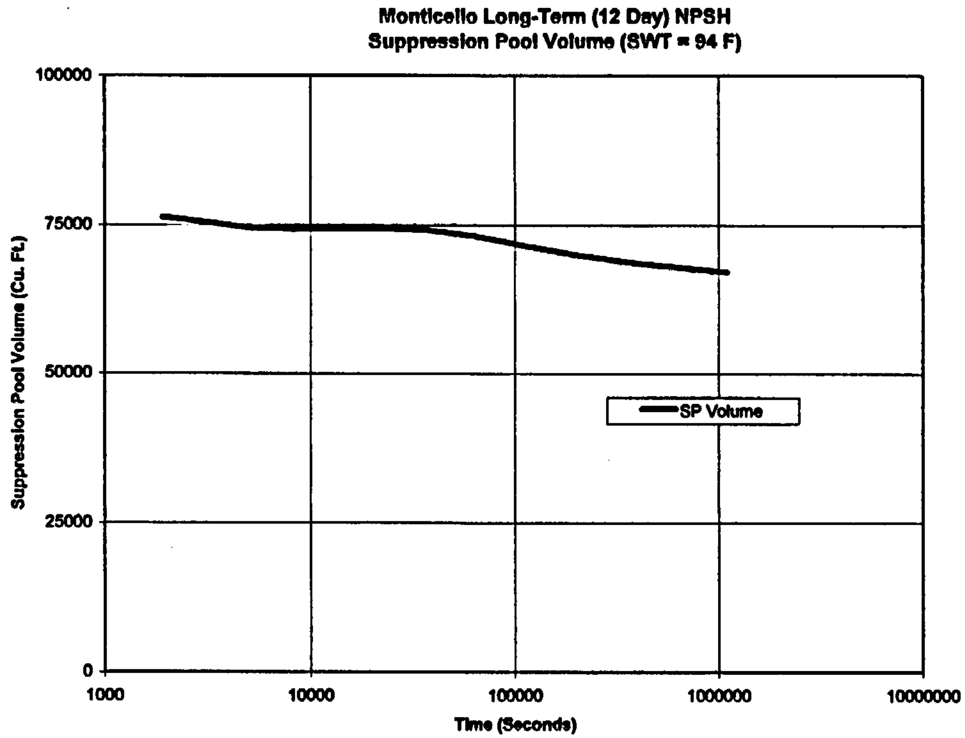


Figure J.2-2 Suppression Pool Volume Long-Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

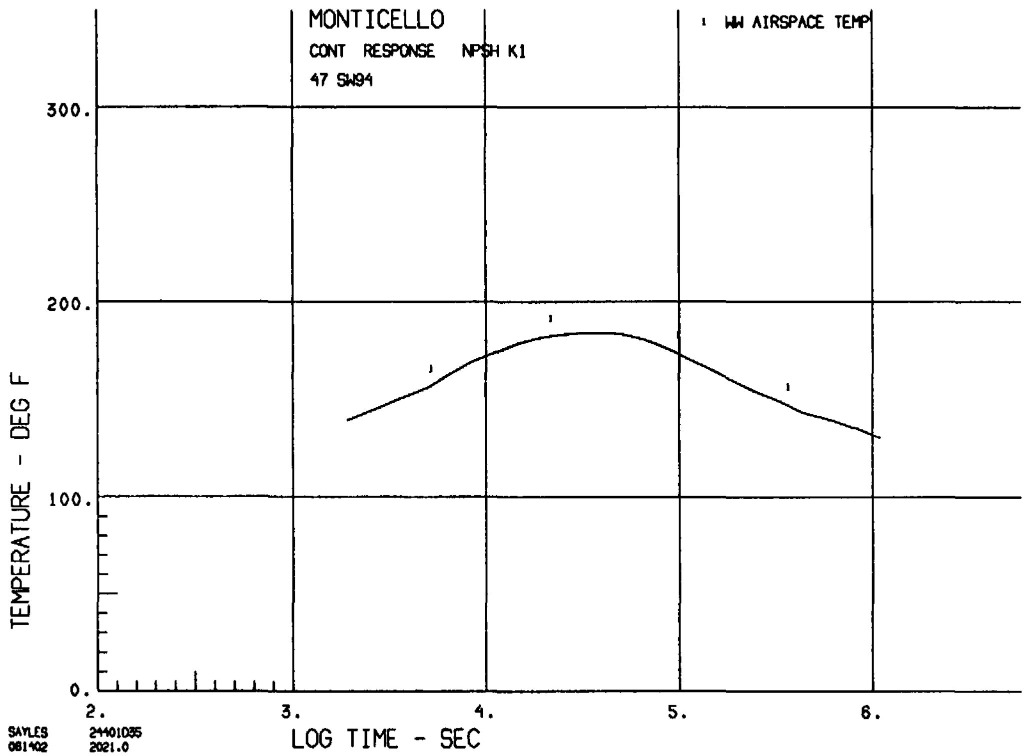


Figure J.2-3 Wetwell Temperature Long-Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SW Temp = 94°F)

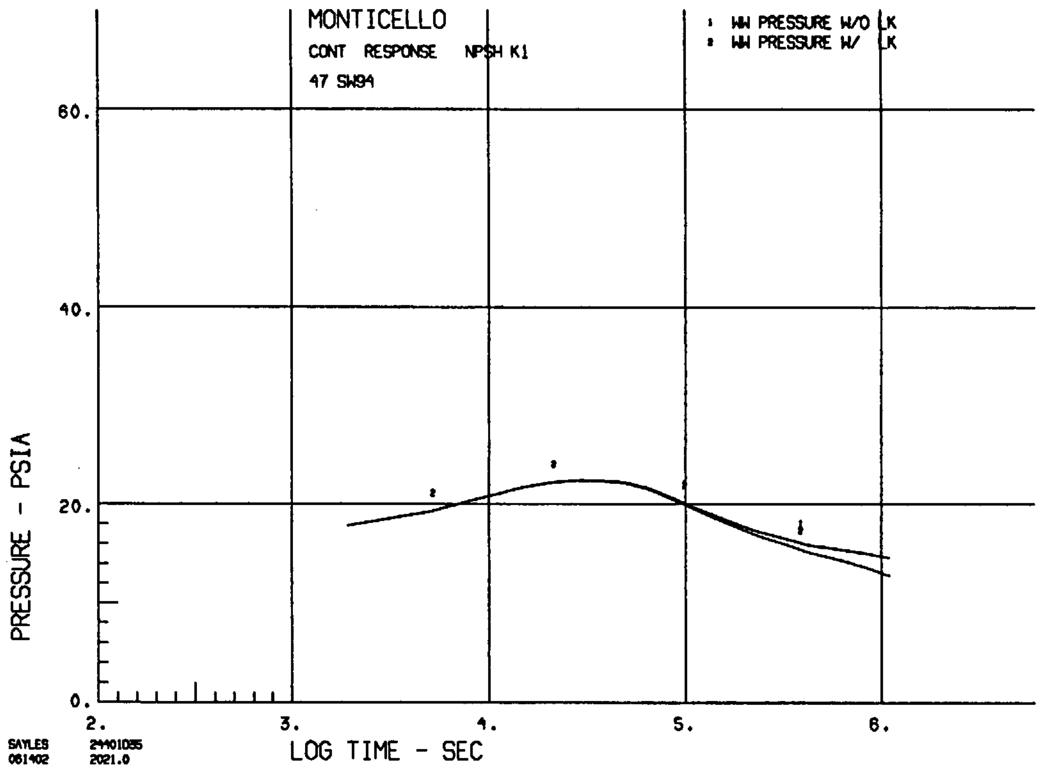


Figure J.2-4 Wetwell Pressure with/without Leakage Long-Term (12 Day) DBA-LOCA for NPSH Evaluation (K=147 Btu/Sec-°F, SWT = 94°F)

APPENDIX K

PLOTS FROM SHEX RUNS FOR DBA-LOCA WITH DIRECT POOL COOLING (K=147,SWT= 90°F)

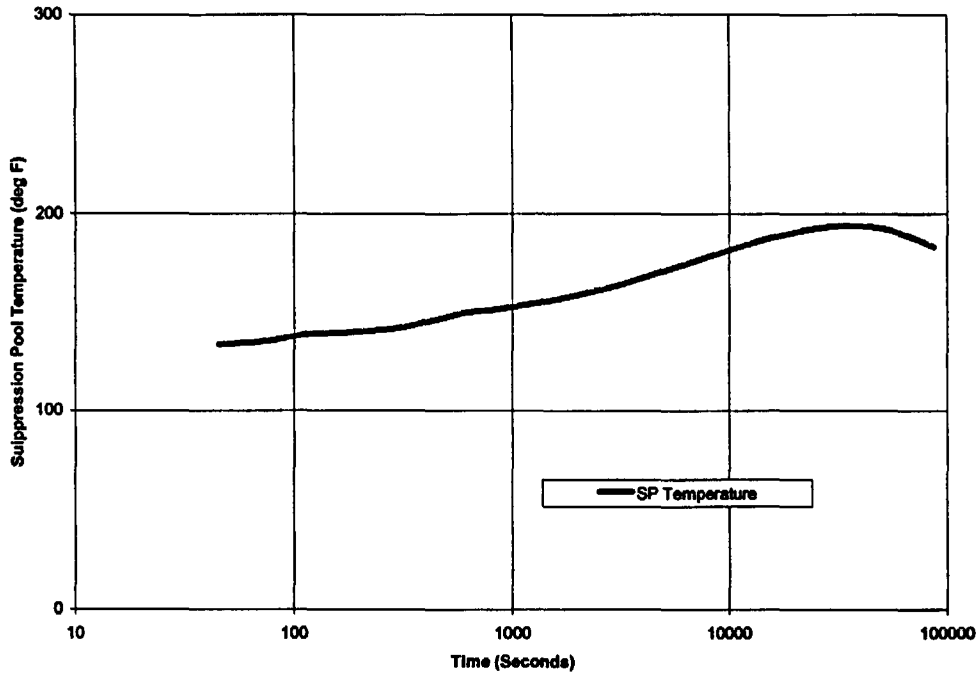


Figure K-1 Suppression Pool Temperature DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 90°F)

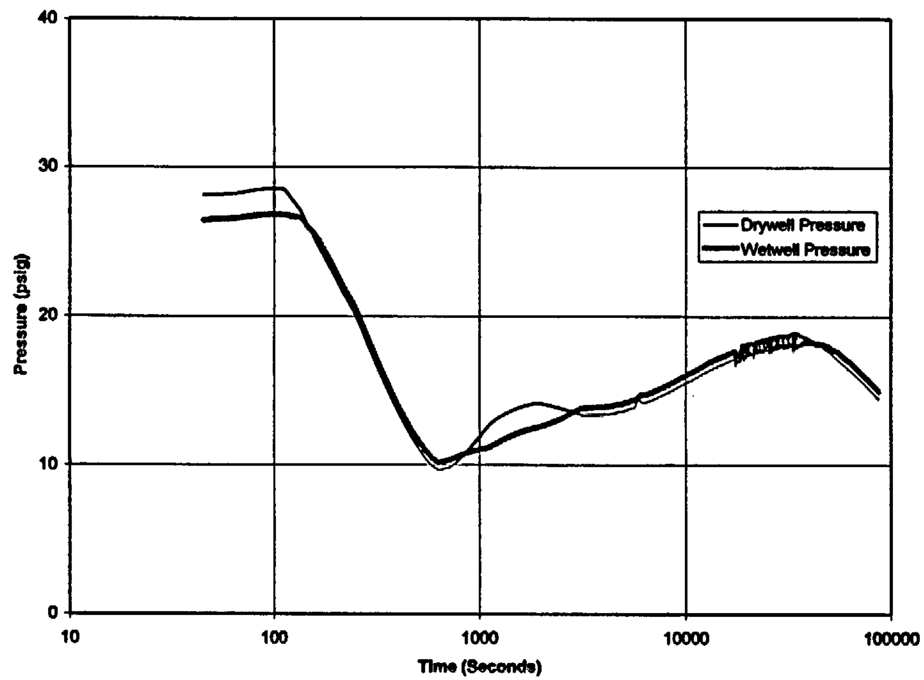


Figure K-2 Drywell and Wetwell Pressure DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 90°F)

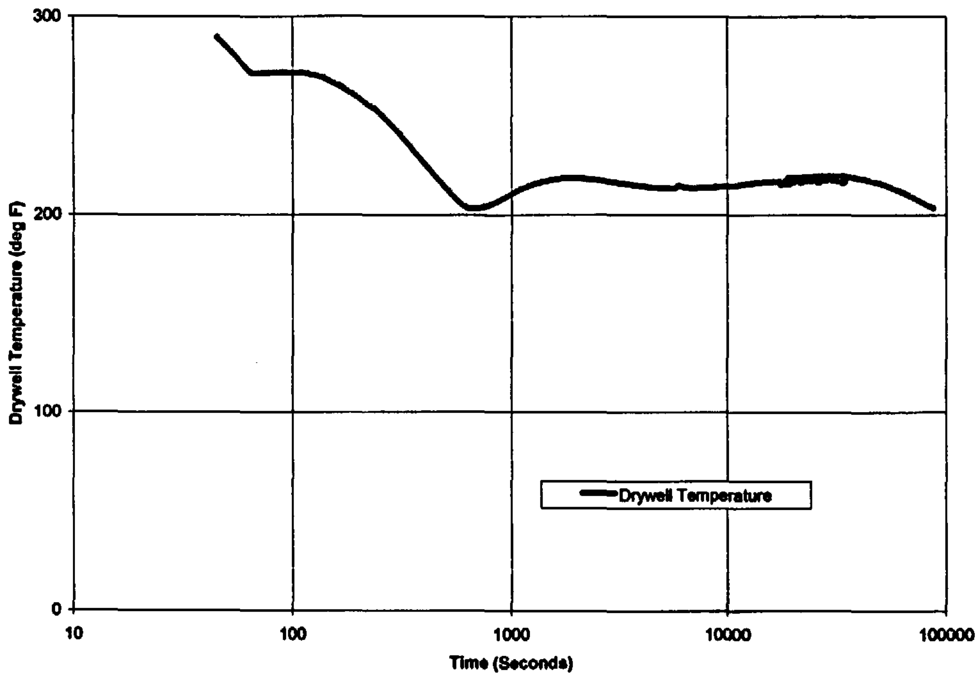


Figure K-3 Drywell Temperature DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 90°F)

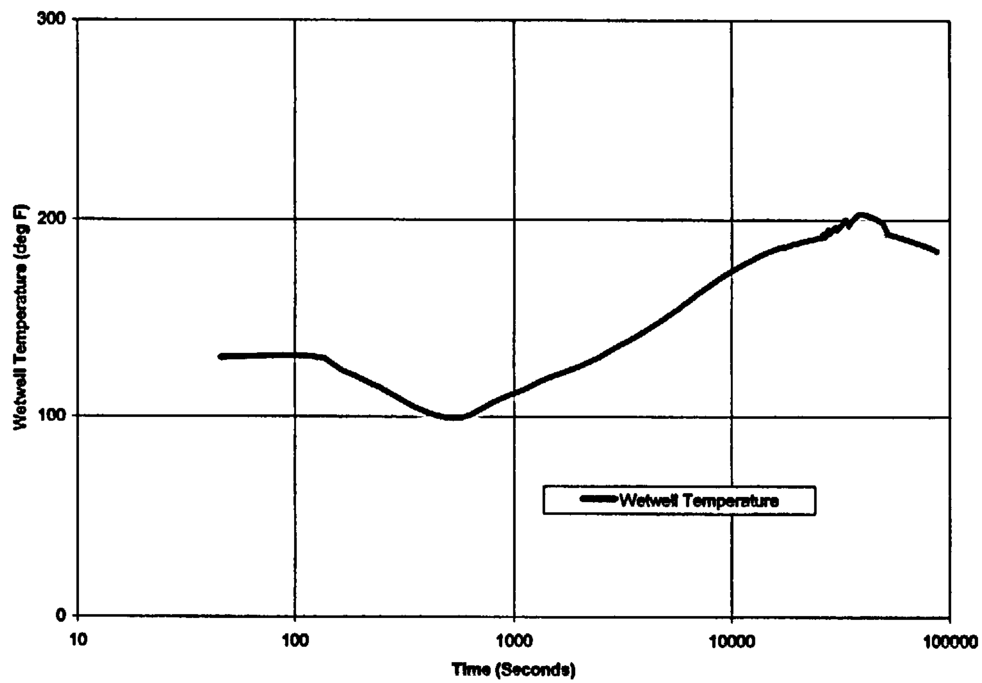


Figure K-4 Wetwell Temperature DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 90°F)

APPENDIX L

PLOTS FROM SHEX RUNS FOR DBA-LOCA WITH DIRECT POOL COOLING (K=147,SWT= 94°F)

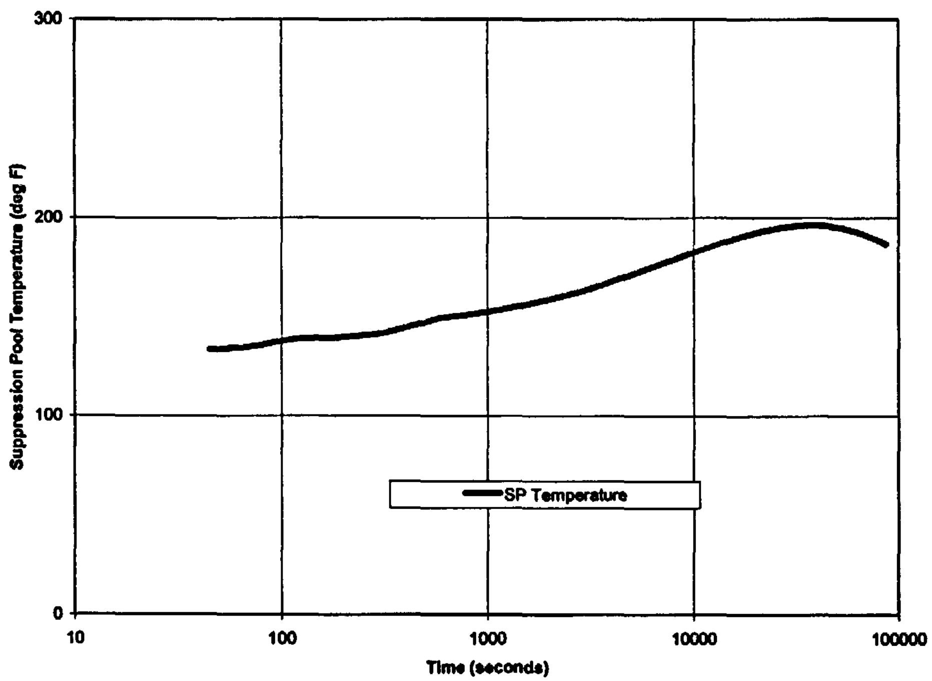


Figure L-1 Suppression Pool Temperature DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 94°F)

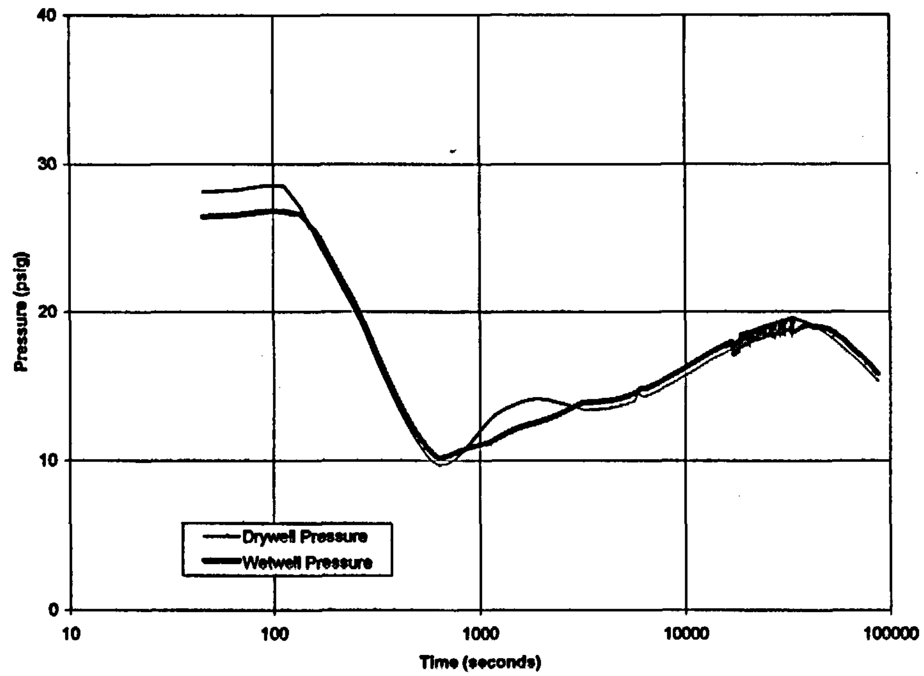


Figure L-2 Drywell and Wetwell Pressure DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 94°F)

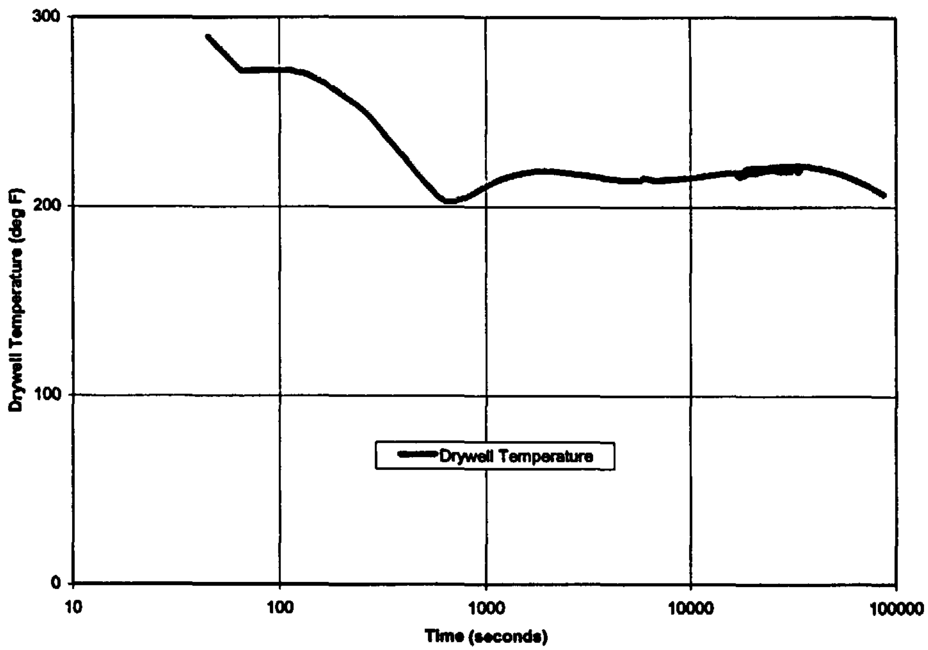


Figure L-3 Drywell Temperature DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 94°F)

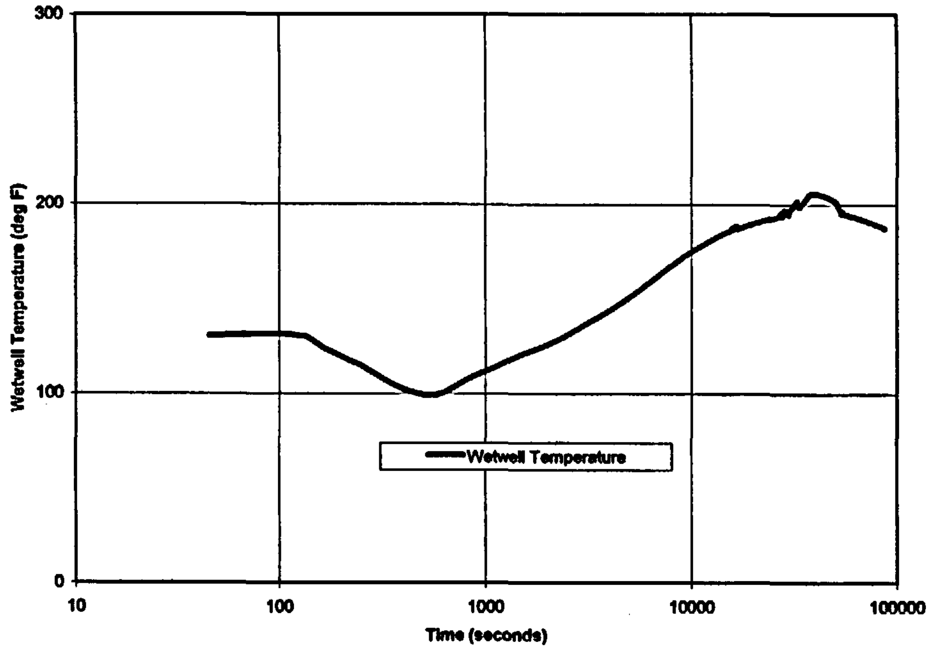


Figure L-4 Wetwell Temperature DBA-LOCA with Loss of Diesel Generator (K=147 Btu/Sec-°F, SWT = 94°F)