Xcel Energy®

Monticello Nuclear Generating Plant
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Monticello, MN 55362

September 28, 2012

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10 CFR 50.90

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

Monticello Nuclear Generating Plant
Docket 50-263
Renewed License No. DPR-22

Monticello Extended Power Uprate and Maximum Extended Load Line Limit Analysis Plus License Amendment Requests: Supplement to Address SECY 11-0014 Use of Containment Accident Pressure (TAC Nos. MD9990 and ME3145)

References:

1) Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "License Amendment Request: Extended Power Uprate (TAC MD9990)," L-MT-08-052, dated November 5, 2008. (ADAMS Accession No. ML083230111)
2) Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "License Amendment Request: Maximum Extended Load Line Limit Analysis Plus," TAC ME3145, L-MT-10-003, dated January 21, 2010. (ADAMS Accession No. ML100280558)
3) Letter from J G Giitter (NRC) to T J O'Connor (NSPM), "Subject: Monticello Nuclear Generating Plant - Linking of the Proposed Extended Power Uprate Amendment and the MELLLA+ Amendment (TAC NOS. MD9990 AND ME2449)," dated November 23, 2009. (ADAMS Accession No. ML093160816)
4) SECY 11-0014, Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents, dated January 31, 2011. (ADAMS Accession No. ML102780586)

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5) Letter from E J Leeds (NRC) to T J O'Connor (NSPM), "Subject: Monticello Nuclear Generating Plant – Revised Schedule for Review of Extended Power Uprate Amendment Application (TAC No. MD9990)," dated October 1, 2009. (ADAMS Accession No. ML092600850)

6) Staff Requirement Memorandum from Annette L. Vietti-Cook to R. W. Borchardt, Subject: Staff Requirements – SECY-11-0014 – Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents, dated March 15, 2011. (ADAMS Accession No. ML110740254) Voting Record for Staff Requirement Memorandum, dated March 5, 2011. (ADAMS Accession No. ML110740604)

7) Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "Monticello Extended Power Uprate: Updates to Docketed Information (TAC MD9990)," L-MT-10-072, dated December 21, 2010. (ADAMS Accession No. ML103570026)

Pursuant to 10 CFR 50.90, the Northern States Power Company, a Minnesota corporation (NSPM), doing business as Xcel Energy, requested in Reference 1 an amendment to the Monticello Nuclear Generating Plant (MNGP) Renewed Operating License (OL) and Technical Specifications (TS) to increase the maximum authorized power level from 1775 megawatts thermal (MWt) to 2004 MWt. This is also known as an extended power uprate (EPU).

Also pursuant to 10 CFR 50.90, NSPM requested in Reference 2 an amendment to the MNGP Renewed OL and TS to allow operation within the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain.

The Nuclear Regulatory Commission (NRC) permitted these two license amendment requests to be linked in Reference 3.

NSPM has taken credit for containment accident pressure (CAP) for the MNGP Emergency Core Cooling System (ECCS) analyses. Credit for CAP is part of the licensing basis for the MNGP core cooling analyses as presented in both the EPU and MELLLA+ License Amendment Requests (LARs) (References 1 and 2) discussed above. In recent years, the Advisory Committee on Reactor Safeguards (ACRS) and the NRC staff have focused their discussions on available net positive suction head (NPSHa) in license amendment requests for extended power uprates (EPUs) that credit CAP. A power uprate increases the decay heat level following a reactor trip. This results in an increase in the temperature of the suppression pool water for Boiling Water Reactors (BWRs), which reduces the NPSH margin (i.e. the difference between NPSHa and net positive suction head required (NPSHr)).

Use of CAP in determining NPSHa was challenged by the ACRS and by participants in the NRC hearing process and by members of the public. Published regulatory guidance allowing use of CAP in determining NPSHa was not entirely consistent, which caused the challenge. The practice was also thought to result in degradation of the regulatory philosophy of defense-in-depth (independence of fission product barriers). For these reasons, the NRC staff reexamined this issue.

Reference 4 presents a technical description of the use of CAP, provides a regulatory history of this issue and describes new draft staff guidance developed by the staff to quantify uncertainties and margins and address the relevant phenomena.

As a result of these discussions between the NRC staff and ACRS, the MNGP EPU application was placed on hold by the NRC staff until a decision regarding the use and applicability of CAP could be obtained from the NRC Commissioners (Reference 5). In Reference 4, the NRC staff provided the Commissioners with two options. Option 1 was defined as:

> *"The staff resumes work on EPU applications. The staff's evaluation of current EPU applications, as well as future applications for new or increased credit for CAP, would be consistent with staff practice in implementing the current risk review guidance (SRP Section 19.2), including the review of nonrisk-informed applications such as EPUs (Appendix D of SRP Section 19.2) and the recently-developed deterministic guidance based on ACRS recommendations to include uncertainty and margins in CAP calculations. The staff would not further consider the issue of CAP credit, per se, as a generic safety matter. The staff will update the regulatory guidance to remove the specific guidance disfavoring the use of CAP in determining NPSH margin."*

Option 2 was defined as:

> *"The staff will resume work on EPU applications, and in parallel with these reviews, the staff will conduct a backfit/regulatory analysis of the use of CAP. Depending upon the results of the backfit/regulatory analysis, the staff may backfit plants currently approved to use CAP credit and plants with current EPU applications where the applications are approved before the completion of the backfit analysis. The staff will update the regulatory guidance to reflect the results of the backfit/regulatory analysis."*

The NRC staff also stated that use of CAP in determining the NPSHa of emergency core cooling system and containment heat removal pumps is not the subject of a regulation. Use of containment accident pressure in safety analyses (with the implicit assumption of containment integrity) is not unique to determining NPSHa. Several other important areas of safety analysis, including loss-of-coolant accident analyses and offsite radiological dose analyses assume containment integrity. Reference 4, Enclosure 1, Section 6.6 provides detailed guidance concerning uncertainties and margins that would satisfy the NRC staff with respect to use of CAP.

The NRC Commissioners considered SECY 11-0014 and voted in Reference 6 to approve Option 1 as described above. In the NRC Commissioners' vote on SECY 11-0014 the philosophy that was endorsed stated:

> *"The Commission, ... defines defense in depth as "an element of the NRC's safety philosophy that employs successive compensatory measures to prevent accidents or mitigate damage if a malfunction, accident, or naturally caused event occurs at a nuclear facility". This definition does not state that the compensatory measures must be independent."*

In approving Option 1, the NRC Commissioners also requested that applications relying on CAP use the recently-developed deterministic guidance and include uncertainty and margins in CAP calculations (included in Enclosure 1 of SECY 11-0014).

Since the Commissioners approval of Option 1, NSPM has been working through the Boiling Water Reactor Owners Group (BWROG) to meet the SECY 11-0014 guidance concerning ECCS pump NPSH uncertainty and margins by establishing pump NPSH uncertainties for the MNGP Residual Heat Removal (RHR) and Core Spray (CS) pumps.

The BWROG working through Sulzer Pumps, will provide information to the NRC regarding pump studies and engineering evaluations used as a baseline to determine pump NPSH uncertainties. The results of the BWROG work are expected to be transmitted to the NRC in the near future.

The purpose of this letter is to provide a detailed assessment of the MNGP RHR and CS pumps' ability to meet the uncertainties and margins described in SECY 11-0014. The enclosure to this letter provides a detailed assessment of CAP in relation to the MNGP RHR and CS pumps using the uncertainties in the BWROG work as a baseline. This enclosure assumes the operating conditions of EPU and MELLLA+ including the most limiting events. The enclosure provides the assessment based on comparison to sections 6.6.1 through 6.6.10 of Enclosure 1 to SECY 11-0014, with the exception of sections 6.6.4, Assurance that Containment Integrity is not Compromised, and 6.6.7, Assurance of no Pre-existing leak.

Sections 6.6.4 and 6.6.7 have been excluded from the enclosure since NSPM is currently evaluating the potential for multiple spurious operations (MSO) at MNGP in accordance with Regulatory Guide (RG) 1.189, Rev. 2. This project is performing an assessment of components susceptible to MSOs following NEI-00-01, Rev. 2 Guidelines. The MSOs are being evaluated to assess the worst case combination of any four MSOs on containment accident pressure. The impact on CAP is being completed using the analysis code GOTHIC to evaluate the impact on containment response. The results of the ongoing RG 1.189, Rev. 2 evaluation to determine the effects, if any, of MSOs on RHR and CS pump NPSH is planned to be submitted to the NRC by November 30, 2012.

This enclosure concludes that the MNGP ECCS pumps can reliably perform their required design functions to mitigate the consequences of accidents and events for the required mission time while using appropriate uncertainties defined for NPSHreff for Design Bases Accident – Loss of Coolant Accident (DBA-LOCA) and NPSHr for other events. The ECCS pumps meet the requirements of SECY-11-0014, Enclosure 1.

In addition to the application of uncertainties on the pump NPSH required values assuming EPU conditions; conservative assumptions of post-accident conditions were considered in the calculation of the NPSHa, including: worst single failure, pool temperature maximized, calculated suppression pool level response, pump run-out flow and other conservatisms listed in Table 4 of SECY 11-0014, Enclosure 1. Previously, NSPM had evaluated the RHR and CS pumps' ability to meet design functions for EPU conditions and did not consider the 21% uncertainty in the DBA-LOCA. These evaluations were provided in the original EPU and MELLLA+ LARs (References 1 and 2) and in subsequent Request for Additional Information responses. This supplement supersedes and augments statements made throughout the EPU and MELLLA+ correspondence record for the design and capability of the RHR and CS pumps in the DBA-LOCA.

The supplemental information provided herein does not change the conclusions of the No Significant Hazards Consideration and the Environmental Consideration evaluations provided in Reference 1 as revised by Reference 7 for the Extended Power Uprate LAR. Further, the supplemental information provided herein does not change the conclusions of the No Significant Hazards Consideration and the Environmental Consideration evaluations provided in Reference 2 for the MELLLA+ LAR.

In accordance with 10 CFR 50.91(b), a copy of this application supplement, without enclosures is being provided to the designated Minnesota Official.

Summary of Commitments

This letter makes no new commitments. This letter provides a portion of the closure of a commitment associated with the MELLLA+ LAR. In letters L-MT-09-100 and L-MT-10-003, NSPM committed to resolve the CAP issue in the same manner as the issue is resolved for the delayed EPU amendment. The analysis included herein provides analysis of CAP assuming EPU and MELLLA+ conditions. Therefore, a portion of this commitment is satisfied. The commitment will be fully closed when the complete CAP supplement, including the RG 1.189, Rev. 2 evaluation, is provided to the NRC.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: September 28, 2012

Mark A. Schimmel

Mark A. Schimmel
Site Vice-President
Monticello Nuclear Generating Plant
Northern States Power Company-Minnesota

Enclosure

cc: Administrator, Region III, USNRC (w/o enclosure)
Project Manager, Monticello Nuclear Generating Plant, USNRC
Resident Inspector, Monticello Nuclear Generating Plant, USNRC (w/o enclosure)
Minnesota Department of Commerce (w/o enclosure)

ENCLOSURE

NORTHERN STATES POWER – MINNESOTA

EVALUATION OF THE RESIDUAL HEAT REMOVAL AND CORE SPRAY PUMPS FOR THE MONTICELLO NUCLEAR GENERATING PLANT WHEN APPLYING THE GUIDANCE OF SECY 11-0014

57 pages follow

1.0 INTRODUCTION

Northern States Power - Minnesota (NSPM) has taken credit for containment accident pressure (CAP) for the Monticello Nuclear Generating Plant (MNGP) Emergency Core Cooling System (ECCS) analyses. NSPM also took credit for CAP in both the Extended Power Uprate (EPU) and Maximum Extended Load Line Limit Analysis Plus (MELLLA+) License Amendment Requests (LARs) (References 1 and 2).

In recent years, the Advisory Committee on Reactor Safeguards (ACRS) and the U.S. Nuclear Regulatory Commission (NRC) staff have focused their discussions on available net positive suction head (NPSHa) in license amendment requests for extended power uprates (EPUs) that credit CAP. A power uprate increases the decay heat level following a reactor trip. This results in an increase in the temperature of the suppression pool water for Boiling Water Reactors (BWRs), which reduces the NPSH margin (i.e. the difference between NPSHa and net positive suction head required (NPSHr)).

Use of CAP in determining NPSHa was challenged by the ACRS, by participants in the NRC hearing process and by members of the public. Published regulatory guidance allowing use of CAP in determining NPSHa was not consistent, which caused the challenge. The practice was also thought to result in degradation of the regulatory philosophy of defense-in-depth (independence of fission product barriers). For these reasons, the NRC staff reexamined this issue.

Reference 4 presents a technical description of the use of CAP, provides a regulatory history of this issue and describes new draft staff guidance developed by the staff to quantify uncertainties and margins and address the relevant phenomena.

As a result of these discussions between the NRC staff and ACRS, the MNGP EPU application was placed on hold by the NRC staff until a decision regarding the use and applicability of CAP could be obtained from the NRC Commissioners (Reference 5).

The NRC commissioners considered SECY 11-0014 and voted in Reference 6 to approve Option 1 as described above. In the NRC Commissioners' vote on SECY 11-0014 the philosophy that was endorsed stated:

> *"The Commission, ... defines defense in depth as "an element of the NRC's safety philosophy that employs successive compensatory measures to prevent accidents or mitigate damage if a malfunction, accident, or naturally caused event occurs at a nuclear facility". This definition does not state that the compensatory measures must be independent."* (Reference 21)

In approving Option 1, the NRC Commissioners also requested that applications relying on CAP use the recently-developed deterministic guidance and include uncertainty and margins in CAP calculations (included in Enclosure 1 of SECY 11-0014).

Since the Commissioners approval of Option 1, NSPM has been working through the Boiling Water Reactor Owners Group (BWROG) to meet the SECY 11-0014 guidance concerning ECCS pump NPSH uncertainty and margins by establishing pump NPSH uncertainties for the MNGP Residual Heat Removal (RHR) and Core Spray (CS) pumps.

The BWROG developed the following tasks to address the SECY 11-0014 guidance.

- Task 1: Production of NPSHr Curves and analysis of NPSHr Uncertainties using Computational Fluid Dynamics (CFD) analyses
  - Task 1 Subtask A: Generation of NPSHr Curves
  - Task 1 Subtask B: Effect of inlet temperature variation on 3% NPSHr
  - Task 1 Subtask C: Effect of non-uniform inlet geometry variation on 3% NPSHr
  - Task 1 Subtask D: Effect of dissolved gas evolution on 3% NPSHr
  - Task 1 Subtask E: Effect of mechanical wear ring clearance on 3% NPSHr
  - Task 1 Subtask F: Combined effects of uncertainty factors on 3% NPSHr
- Task 2: Evaluate adequacy of equation to account for pump speed difference
- Task 3: Operation at NPSHa < NPSHr conditions
- Task 4: Operation in Maximum Erosion Rate Zone
- Task 5: Effects of Non-condensable Gas on Pump Mechanical Seal Performance
- Task 6: NPSHR test instrument accuracy effect on the published results.

The CFD analysis approach in Task 1 for the MNGP pump was determined not to provide the pump uncertainties with the precision necessary to satisfy the NRC's needs and was abandoned in favor of a deterministic analysis approach. References 9 – 14 are the outputs of the BWROG effort and address each of the tasks identified above, respectively. These BWROG reports are the starting point (bases) for the summary of the MNGP specific analyses provided in this enclosure. As such, the details concerning the bases for the NPSH uncertainty analyses provided herein are located in these reports and are not provided in this enclosure. The BWROG anticipates providing these reports to the NRC in the near future.

Sections 6.6.1 through 6.6.10 of Enclosure 1 to SECY 11-0014 provide the NRC staff guidance with respect to determining uncertainty and margins for relying on CAP in accident and transient analysis. Section 3.0 below provides a response to each section (6.6.1 – 6.6.10) of Enclosure 1 to SECY 11-0014, with the exception of sections 6.6.4, Assurance that Containment Integrity is not Compromised, and 6.6.7, Assurance of no Pre-existing leak.

Sections 6.6.4 and 6.6.7 have been excluded from the enclosure based on activities currently occurring in the MNGP Regulatory Guide (RG) 1.189, Rev. 2 project. This project is performing an assessment of components susceptible to multiple spurious operation (MSO) following RG 1.189 and NEI-00-01, Rev. 2 guidance. All MSOs are being evaluated to assess the worst case combination of any four MSOs on containment accident pressure. The impact on CAP is being completed using the analysis code GOTHIC to evaluate the impact on containment response. The results of the ongoing RG 1.189, Rev. 2 evaluation to determine the effects, if any, of MSOs on RHR and CS pump NPSH is planned to be submitted to the NRC by November 30, 2012.

The requirements from each section of Enclosure 1 to SECY 11-0014 except as noted above are shown below with a discussion of how MNGP satisfies this guidance. This evaluation assumes the operating conditions of EPU and MELLLA+. Alternative approaches to meeting the NRC staff guidance are provided in some cases with appropriate justification.

This enclosure concludes that the MNGP ECCS pumps can reliably perform their required design functions to mitigate the consequences of accidents and events for the required mission time while using appropriate uncertainties defined for NPSHreff for DBA-LOCA and NPSHr for other events. The ECCS pumps meet the requirements of SECY-11-0014, Enclosure 1.

Previously, NSPM had evaluated the RHR and CS pumps' ability to meet design functions for EPU conditions and did not consider the 21% uncertainty in the DBA-LOCA. These evaluations were provided in the original EPU and MELLLA+ LARs (References 1 and 2) and in subsequent Request for Additional Information responses. This supplement supersedes and augments statements made throughout the EPU and MELLLA+ correspondence record for the design and capability of the RHR and CS pumps in the DBA-LOCA...

2.0 BACKGROUND

At MNGP, the limiting Design Basis Accident (DBA) for consideration of the impact of NPSHr is the large break LOCA with failure of the LPCI loop select logic. The analysis is divided into two parts; a short-term analysis and a long-term analysis. The short-term analysis covers that period from the time of the break until operator action is taken to throttle the ECCS pumps and establish containment cooling. This period is defined as occurring at or before 600 seconds. For conservatism, during the short-term analysis, LPCI flow is assumed to be injected into the broken loop for this event. This results in the minimum system resistance for LPCI and therefore the maximum pump run-out flow rate for these pumps. Two CS pumps are available to quench fuel temperatures and reflood the core to 2/3 core height. Since all six ECCS pumps are available for this scenario, the pump suction piping system resistance is maximized which results in the minimum NPSHa. NPSH is assessed for these conditions and the potential impact on pump reliability has been assessed. Pump reliability and ability to provide safety analysis required flow rates has been shown and is discussed further below.

With the indicated water level recovered to 2/3 core height, use of long-term core cooling requirements is appropriate. The pump flow rate required to ensure long-term cooling is rated CS flow for one CS pump with the core reflooded to the jet pump suction (2/3 core height). Rated CS flow is a flow rate of 3020 gpm delivered to the core which is a pump flow rate of 3388 gpm when accounting for leakage and pump minimum flow line flow. This flow rate is an increase over values previously used in MNGP DBA-LOCA analyses (Reference 16). See Section 6.6.2 for more information.

The long-term analysis, begins at >600 seconds after the break. The long-term DBA-LOCA analysis is provided in Section 2.6.5 of Reference 1, Enclosure 5. Operator action occurs before 600 seconds to throttle ECCS pump flow rate and to establish containment cooling. Failure of an emergency diesel generator or battery in combination with a loss of off site power results in the availability of one CS pump to maintain core cooling, one RHR pump to cool containment and one RHRSW pump to remove decay heat from the RHR heat exchanger. This configuration defines the limiting set of equipment in service for the long-term analysis. In this mode of operation the operators will control RHR pump flow through the RHR heat exchanger at 4000 gpm.

3.0 DETAILED ANALYSES

SECY 11-0014 (Reference 4), Enclosure 1, Section 6.6 provides a breakdown of the guidance that the NRC has provided with respect to determining uncertainty and margins for relying on CAP in accident and transient analysis. The detailed analyses provided below demonstrate the margin available in the NPSH analysis for the RHR and CS pumps. Similarly, the detailed analyses also demonstrate the uncertainties that have been applied to the NPSH analysis for the DBA-LOCA event.

In the discussion below, the NRC guidance from SECY 11-0014, Enclosure 1, Section 6.6 is provided in italics and then followed immediately by NSPM's response to the NRC guidance.

6.6.1 NPSHreff

For DBAs, a value of NPSHreff should be used in the analyses concerning the use of containment accident pressure. NPSHreff includes the uncertainty in the value of NPSHr3% based on vendor testing and installed operation. The effects of motor slip, suction piping configuration, and air content, and wear ring leakage should be included.

$$NPSHreff = (1 + uncertainty)NPSHr_{3\%}$$

For non-DBAs, NPSHr3% may be used.

NSPM Response to Section 6.6.1

NPSHr for a pump is defined as the suction head at which cavitation impacts the head performance leading to a three percent loss in head at a given flow and pump speed. During an NPSHr test, the pump is run at a constant flow and speed with the suction head reduced gradually to the point where cavitation and head loss are observed. This is written as NPSHr3%, likewise, a five percent loss in head at a given flow and pump speed is identified as NPSHr5%

The uncertainties in NPSHr included in the staff's guidance address the possibility that conditions during the NPSHr vendor tests could be different than those seen by the pumps during operation at the plant, effectively increasing the NPSHr values. The differences could arise due to pump inlet temperature variation, pump inlet geometry variation, dissolved gas evolution, and increase in mechanical wear ring clearance. Based on an NRC pump consultant report on uncertainties, an average variation in the NPSHr of between +9 percent to +21 percent could be expected depending on differences in installation and operation between the NPSHr test and plant conditions (Reference 15).

The BWROG defined the uncertainties for NPSHreff for the MNGP double suction pumps[1]. NPSHreff includes the uncertainty in the value of NPSHr3% that was defined based on vendor testing. The effects of suction piping configuration, air content, pump speed, NPSHr test instrument accuracy and wear ring leakage are included in the BWROG assessment of uncertainties.

The RHR and CS pumps at MNGP are CVDS pumps and are very similar in design and operating speed (Reference 20). The individual ECCS pump suction piping configurations use a common suction supply source from the suppression pool through a ring header and include four independent suction strainers that supply the ring header.

The status of the BWROG uncertainty analysis work was discussed with the NRC staff in a meeting on April 3, 2012. At that meeting the NRC staff was notified that computational fluid dynamics (CFD) had not been able to successfully analyze uncertainty for CVDS pumps. The CFD analysis was benchmarked against the original vendor test results for the MNGP RHR pump. CFD was not able to provide results for NPSHr that were representative of the original test and therefore the CFD analysis effort was abandoned. Further information on this analysis is provided in Reference 9.

An alternative approach to the use of CFD was proposed at the meeting on April 3, 2012 to demonstrate adequate core and containment cooling. The proposed approach would use engineering principles justified by the BWROG to determine uncertainty values.

The evaluations provided by the BWROG and the pump manufacturer as part of References 9 – 14 support that the use of 21% uncertainty for the long-term analysis is conservative, i.e. 1.21 times NPSHr3%. This value is denoted as NPSHr effective (NPSHreff) for the assessment of ECCS pump capability for the Design Basis Accident (DBA). The BWROG and pump manufacturer analysis included uncertainties for piping geometry, factory test instrument uncertainty, speed uncertainty, dissolved gas, mechanical wear rings and temperature. Consideration was provided for an appropriate method to combine uncertainties.

The BWROG justifies an NPSHr uncertainty value that supports the use of a 21% uncertainty in evaluation of the long-term analysis for DBA-LOCA. The random uncertainties include instrument measurement uncertainty associated with the original factory NPSHr test and a speed uncertainty that causes an NPSHr uncertainty (Reference 9).

The discussion of speed and air content below clarifies how these two factors were evaluated at MNGP.

[1] The pump manufacturer's designation for this type of pump is called a CVDS pump. Both the MNGP pumps (RHR and CS) evaluated in this report are CVDS type pumps.

Pump Speed Uncertainty

Section 6.6.1 of SECY-11-0014, Enclosure 1 includes consideration of motor slip. The original factory NPSHr test for RHR was performed at a speed of 3578 rpm and for CS at 3560 rpm. The currently installed RHR motors have full load motor speed ratings 3560 rpm to 3570 rpm. The CS motors have full load motor speed ratings of 3560 rpm. Consideration of motor slip speed impact on NPSHr uncertainty is therefore conservative as the currently installed motors will not operate at speeds above the original factory test for nominal frequencies of 60 Hz and consideration of emergency diesel generator speed uncertainty bounds the pump speed uncertainty.

The BWROG justified that the approach used to define speed uncertainty is valid up to the maximum variation in speed required at MNGP in Reference 10. The random speed uncertainty of 2% that was used is based on Technical Specification Surveillance Requirement 3.8.1.2 which specifies a maximum allowed diesel generator output frequency above the nominal value of 60 Hz.

Air Content Uncertainty

Section 6.6.1 of SECY-11-0014, Enclosure 1 requires consideration of air content uncertainty. The emergency operating procedures (EOPs) define the lowest suppression pool water level that ensures air entrainment will not occur. The Vortex Limit is -3.2 feet (approximately 200,000 gallons) from normal suppression pool water level for the pump flow rates used in the NPSH analysis in the first 10 minutes of the event. The loss of this amount of inventory in this time frame is not credible. Therefore, the impact of air content is limited to dissolved gas only.

The BWROG evaluated the potential impact of the evolution of non-condensable gases on the mechanical seals of Monticello RHR pumps in Reference 13.

The MNGP assessment of pump capacity for the DBA-LOCA short-term analysis is based on use of an NPSHreff that includes consideration of dissolved gas uncertainty for the CS pumps. The maximum dissolved gas uncertainty is based on all gas that can be dissolved in water at a temperature 60°F coming out of solution and forming a blockage at the pump inlet. Use of additional uncertainty for the short-term analysis ensures a bounding consideration of NPSHreff.

The dissolved gas uncertainty for the DBA-LOCA long-term analysis has been eliminated since it is offset by the NPSHr decreases due to higher suppression pool temperatures that exist at this time. Therefore dissolved gas is not considered as an uncertainty for the DBA-LOCA long-term analysis (Reference 9).

Other Uncertainties

Other uncertainties that have been evaluated are discussed in more detail in the following documents:

- Piping Geometry Uncertainty is discussed in Reference 9
- Vendor Testing Uncertainty is discussed in Reference 14
- Wear Ring Leakage Uncertainty is discussed in Reference 9

Overall Results

For the short-term analysis of DBA-LOCA the margin of uncertainty was evaluated. Table 6.6.1-1 below shows the available margin for all pumps based on use of $NPSHreff_{3\%}$ and $NPSHreff_{5\%}$ curves. Margin is available to allow consideration of NPSHreff based on use of $NPSHr_{5\%}$ curves. Further evaluation of these data is provided in Section 6.6.6 below.

Table 6.6.1-1 – NPSH Margin for DBA Short-term Analysis

DBA Short-term pump	Run-out Flow** (gpm)	NPSHr 3% (ft)	NPSHreff 3% (ft)	NPSHa [min] (ft)	Margin to NPSHr 3%	Margin to NPSHreff 3%	NPSHr 5% (ft)	NPSHreff 5% (ft)	Margin to NPSHr 5%	Margin to NPSHreff 5%	5% degr Run-out Flow** (gpm)
P-202A (RHR A)	4278	25.50	31.37	31.59	23.90%	0.73%	23.8	29.27	32.75%	7.92%	N/A*
P-202B (RHR B)	4327	25.50	31.37	30.04	17.82%	-4.21%	24.1	29.64	24.66%	1.35%	4300
P-202C (RHR C)	4330	25.50	31.37	30.62	20.09%	-2.36%	24.1	29.64	27.07%	3.31%	4295
P-202D (RHR D)	4347	25.50	31.37	30.96	21.43%	-1.28%	24.3	29.89	27.42%	3.60%	4318
P-208A (CS A)	4129	25.11	30.88	29.37	16.98%	-4.89%	23.11	28.42	27.10%	3.34%	4065
P-208B (CS B)	4058	24.25	29.83	29.80	22.88%	-0.10%	22.25	27.37	33.93%	8.88%	3980

* NPSHr3% curve was adequate

** System capability based on system resistance calculations.

The long-term assessment of DBA-LOCA is based on conservatively using 21% uncertainty which bounds the BWROG recommended value. Table 6.6.1-2 below shows NPSHreff margin during the long-term scenario, see Sections 6.6.2 and 6.6.6 for more information. Only the limiting RHR pump results are shown.

Table 6.6.1-2 – NPSH Margin for DBA Long-term Analysis

DBA Long-term pump	Throttled Flow (gpm)	NPSHr 3% (ft)	NPSHreff 3% (ft)	NPSHa [minimum] (ft)	Margin to NPSHr 3%	Margin to NPSHreff 3%
P-202B (RHR B)	4178	23.5	28.435	32.53	38.43%	14.40%
P-202C RHR C)	4178	23.5	28.435	32.78	39.49%	15.28%
P-208A (CS A)	3388	23.3	28.193	31.33	34.46%	11.13%
P-208B (CS B)	3388	23.3	28.193	31.33	34.46%	11.13%

All other events were evaluated based on the use of NPSHr3% as discussed in Reference 1, Enclosure 5, Section 2.6.5. Some events had changes in assumed pump flow that were evaluated as shown in Section 6.6.2 below.

Task 1 (Reference 9) evaluated the impact on uncertainty of dissolved gas, fluid temperature and piping geometry. This evaluation in combination with Task 2 (Reference 10) and Task 6 (Reference 14) justify that the use of 21% uncertainty for the long-term analysis is bounding for the assessment of DBA-LOCA.

6.6.2 Maximum Pump Flow Rate for the NPSHa Analysis

The maximum flow rate chosen for the NPSHa analysis should be greater than or equal to the flow rate assumed in the safety analyses that demonstrate adequate core and containment cooling. This ensures that the safety analysis and the NPSH analysis are consistent. If the NPSHa is assumed to equal the NPSHr3% (the usual assumption for determining the amount of containment accident pressure used), then the flow rate used in the core and containment cooling analyses should also be equal to or greater than the flow rate resulting from a 3-percent decrease in pump TDH.

NSPM Response to Section 6.6.2

The maximum flow rate chosen for the NPSHa analysis is greater than or equal to the flow rate assumed in the safety analyses that demonstrate adequate core and containment cooling as described below.

The ECCS analysis includes assumptions for pump flow for the short-term (≤600 seconds after the event and prior to reaching 2/3 core height) and the long-term (>600 seconds after the event or after reaching an indicated water level of 2/3 core height). The pump flow rates, containment response and NPSHr used for the various events were provided in response to NRC SCVB RAI No. 5 as part of NSPM letter L-MT-09-073 (Reference 16). Some changes to this response are discussed here. The flow rates and NPSHr values for all cases will remain the same with the exception of:

1. DBA-LOCA long-term for CS and RHR
2. Anticipated Transient Without Scram (ATWS) Loss of Offsite Power (LOOP) RHR flow long-term
3. Appendix R RHR flow long-term

<u>DBA-LOCA Analysis</u>

The CS flow assumed in the short-term analysis for DBA-LOCA is not changed since the pumps operate with all injection valves fully open during this time. Pump flow rate is established by system resistance and changes as the reactor depressurizes. CS flow assumed by the ECCS analysis for core cooling during the short-term is based on USAR Figure 14.7-8, CS Flow Delivery Assumed for SAFER and is adequate for core cooling.

For the long-term analysis there is a change to the CS flow rate assumed to be required for the NPSH analysis. The CS flow rate was changed to match the definition of adequate core cooling for the long-term analysis which is based on use of rated CS flow. In the previous analyses NSPM had defined rated CS flow for long-term cooling as 2835 gpm at 130 psid. However, rated CS flow is now defined by the original design rating of the CS system. This increases the CS flow required to ensure adequate core cooling during the long-term analysis from 2700 gpm delivered to the core to 3020 gpm delivered to the core. The actual CS pump flow increases by an additional 128 gpm to account for leakage inside the reactor and by 240 gpm to cover pump minimum flow line capacity such that a total required pump flow of 3388 gpm is required for the long-term analysis of core cooling for the evaluation of NPSH. This applies only to events where level can not be recovered above top of active fuel. $NPSHr_{3\%}$ does not change substantially from 3029 gpm ($NPSHr_{3\%}$ value of 23 feet provided in Reference 16) to the new flow rate of 3388 gpm ($NPSHr_{3\%}$ value of 23.3 feet) used in the analysis. The impact on NPSHa due to the increased flow rate was assessed and is shown in Table 6.6.2-1 below.

NSPM also identified that accumulators for the RHR pump minimum flow valves were sized to maintain the valves closed for the first 10 minutes of the accident, but could not maintain the minimum flow valves closed during the long-term portion of the accident. Maintaining these valves closed during the short-term portion of the accident response ensures no impact on pump flow rates during the time when fuel temperatures are quenched and the core is reflooded. During the long-term portion of the accident response, higher pump flow rates will result because the minimum flow valves may fail open. The limiting increase in individual pump flow from these valves failing open is 178 gpm. This increases the flow rate required by the RHR pumps to 4178 gpm to maintain 4000 gpm through the RHR heat exchangers as required for containment heat removal during the long-term analysis.

This effect results in changes to pump and system response as shown in Table 6.6.2-1 below. This is a change from the values previously provided in Reference 16.

<u>ATWS and Appendix R</u>

The NPSHr or NPSHreff values shown in Table 6.6.2-1 are based on comparison to the containment response time histories used in Reference 1, Enclosure 5, Section 2.6.5 for evaluation of ECCS pump NPSHr for ATWS and Appendix R.

The ATWS evaluation is based on the containment response for an ATWS event under MELLLA+ conditions. ATWS is the only MELLLA+ event that affects NPSH and thus is the limiting event as compared to the EPU ATWS evaluation previously provided in Section 2.6.5 of Reference 1, Enclosure 5. All events other than ATWS evaluated for NPSH are based on the EPU results which remain bounding for MELLLA+ conditions. A further discussion of margins for NPSHr is provided in Section 6.6.9 below.

Figures 6.6.2-1 through 6.6.2-5 below, demonstrate the impact of changes in flow rates on the non-LOCA events. Changes in available pressure are due to increased system resistance that reduces pressure available at pump suction (NPSHa). This is shown on the graphs by a small reduction in the available pressure curves that reflect pump suction pressure.

Changes in required pressure are due to changes in NPSHr for the pump operating at the higher flow rate. The higher pump flow rate results in an increase in the NPSHr values for the pumps. This is shown on the curves as an increase in the required pressure curves which reflects the increased NPSHr value. Atmospheric pressure of 14.26 psia (atmospheric pressure at MNGP) is shown to demonstrate the length of time when CAP credit is required. These are the only events that are impacted by these changes.

Table 6.6.2-1 NPSHr for MNGP RHR and CS Pumps

Event	Pump	Flow rate (gpm)	Peak Suppression Pool Temp (°F)	Maximum Containment Pressure Needed (psia)	Containment Pressure Available @ Time of Max Containment Pressure Needed (psia)	Duration of Use of Containment Accident pressure	Min NPSHa (ft) (For most limiting pump)	NPSHr *NPSHreff for DBA* (ft)
DBA-LOCA	CS 1	0						*NA*
–	CS 2	3388	207.1	23.36	24.24	126.4 hours	30.22 – CS 2	*28.2*
Long-term	RHR 1	0						*NA*
(>600	RHR 2	4178[3]					32.21 – RHR 2	*28.5*[3]
seconds)	RHR 3	0						*NA*
Case 2	RHR 4	0						*NA*
DBA-LOCA	CS 1	3388	207.1	23.36	24.24	126.4 hours	30.22 – CS 1	*28.2*
–	CS 2	0						*NA*
Long-term	RHR 1	0						*NA*
(>600	RHR 2	0						*NA*
seconds)	RHR 3	4178[3]					32.21 – RHR 3	*28.5*[3]
Case 3	RHR 4	0						*NA*
ATWS	CS 1	3029[1]						23
LOOP for	CS 2	0						NA
MELLLA+	RHR 1	4178[3]						23.5[3]
	RHR 2	4178[3]						23.5[3]
	RHR 3	4178[3]	202.8	20.5	23.88	7.6 hours	23.9	23.5[3]
	RHR 4	4178[3]						23.5[3]
APP R –	CS 1	0						NA
SORV	CS 2	3029[2]						23
(Case 1)	RHR 1	0						NA
	RHR 2	4178[3]	195.4	17.6	21.23	28.7 hours	31.22	23.5[3]
	RHR 3	0						NA
	RHR 4	0						NA
APP R -	CS 1	0						NA
No SORV	CS 2	3029[2]						23
(Case 2)	RHR 1	0						NA
	RHR 2	4178[3]	194.7	17.4	21.11	28.8 hours	30.98	23.5[3]
	RHR 3	0						NA
	RHR 4	0						NA

1. For the ATWS and Appendix R events CS flow rate is not assumed changed. ATWS uses level power control in the EOP to reduce reactor power level. CS is not a preferred injection system in the EOPs for this event. Flow rates would be much <3000 gpm for this scenario to maintain level.
2. For the Appendix R event procedure C.4-C, Shutdown Outside the Control Room, is used to control reactor cooldown. The procedure controls CS flow rate between 2700 gpm and 4100 gpm. See Figures 6.6.2-4 and 6.6.2-5 for further information. Results shown are based on a flow rate of 3029 gpm.
3. For ATWS LOOP case and Appendix R, it is assumed that the normal air supply for the RHR accumulators associated with the minimum flow valves is lost. This will result in the higher RHR pump flow rates shown here to evaluate the impact on NPSHr. The new NPSHr value is 23.5 feet at 4178 gpm. The NPSHreff value is 1.21 x NPSHr or 28.5 feet for DBA-LOCA.

Figures 6.6.2-1, 6.6.2-2 and 6.6.2-3 show the impact on ECCS pump NPSH margins for containment cooling capability for non-DBA-LOCA events with required flow changes. This information supplements information provided in Reference 1, Enclosure 5, Section 2.6.5. NPSH margins for DBA-LOCA are shown in Figure 6.6.6-4 for CS pumps (core cooling) and in Figure 6.6.6-5 for RHR pumps (containment cooling).

Figure 6.6.2-1 – ATWS LOOP for MELLLA+

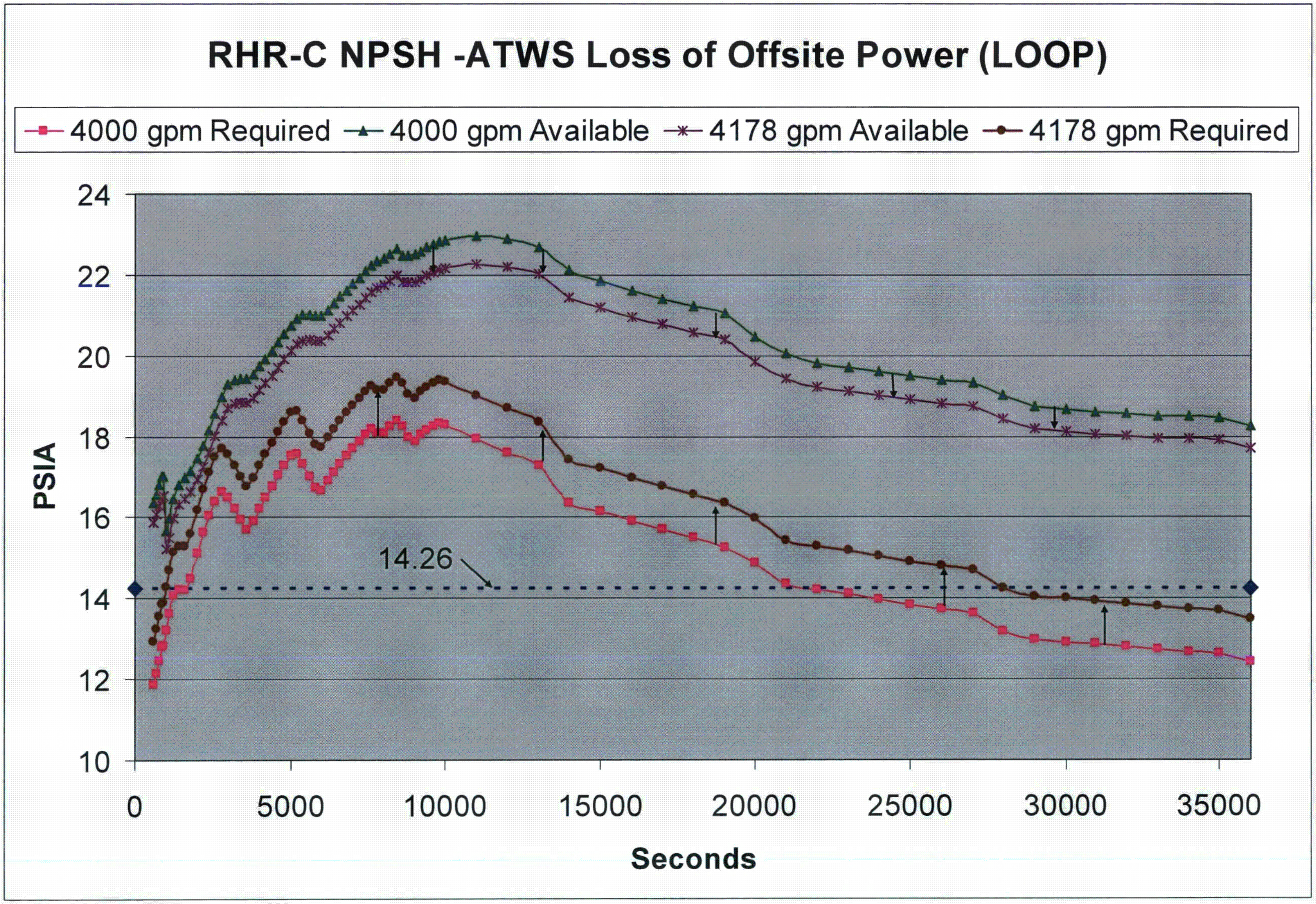


Figure 6.6.2-2

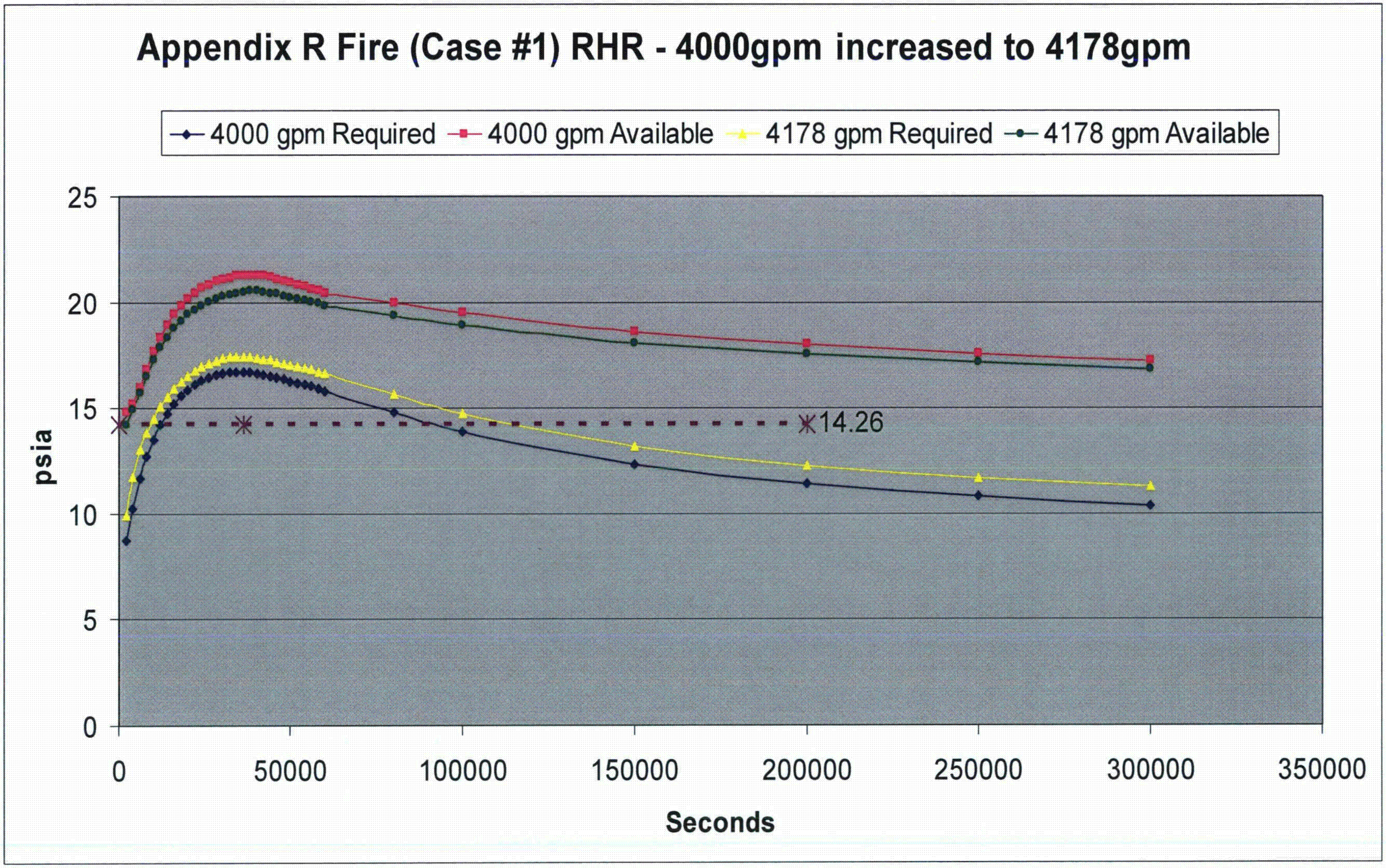

Appendix R Fire (Case #1) RHR - 4000gpm increased to 4178gpm
4000 gpm Required
4000 gpm Available
4178 gpm Required
4178 gpm Available
25
20
15
10
5
0
psia
14.26
0
50000
100000
150000
200000
250000
300000
350000
Seconds

Figure 6.6.2-3

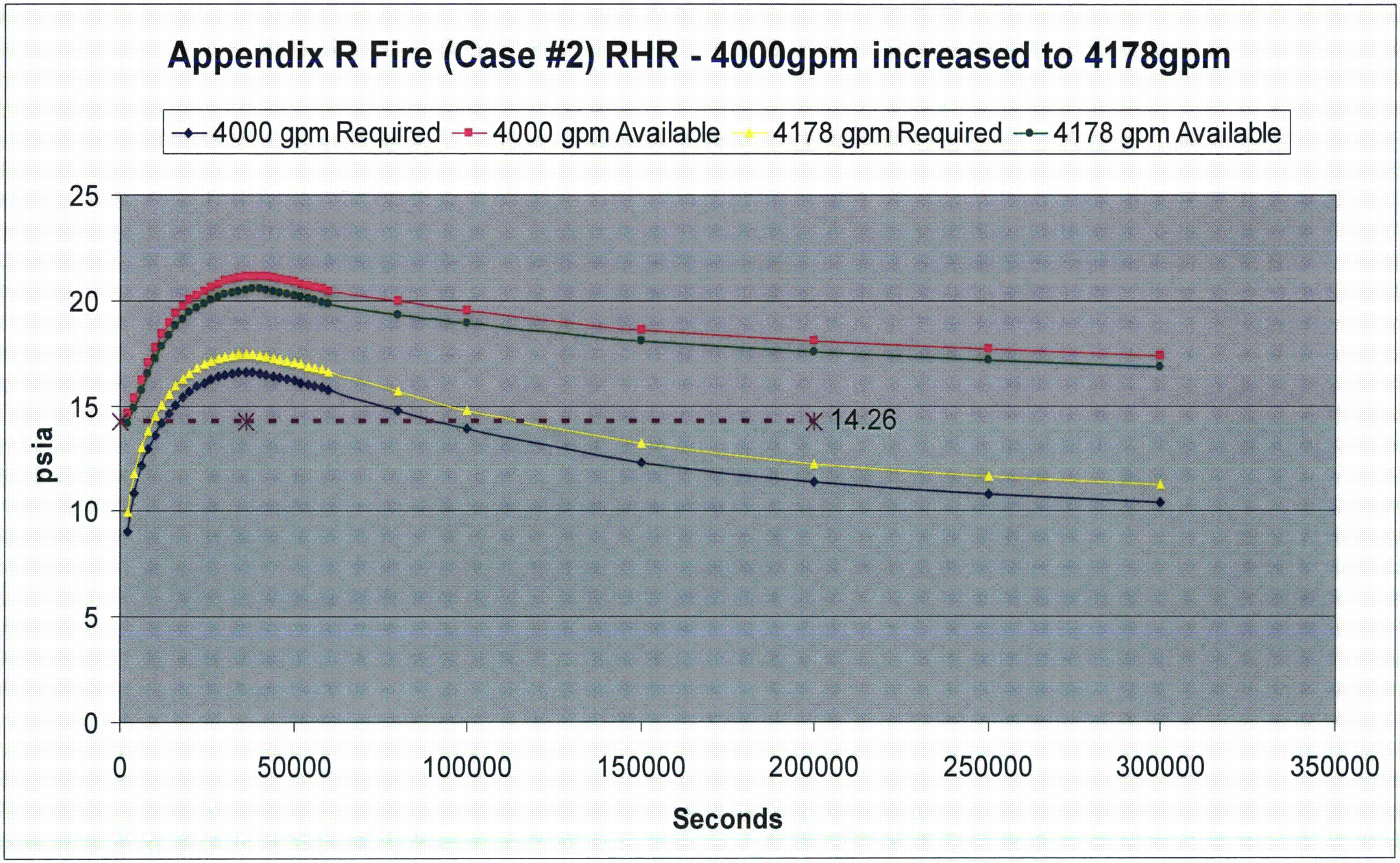

Appendix R Fire (Case #2) RHR - 4000gpm increased to 4178gpm
4000 gpm Required
4000 gpm Available
4178 gpm Required
4178 gpm Available
25
20
15
10
5
0
psia
14.26
0
50000
100000
150000
200000
250000
300000
350000
Seconds

Table 6.6.2-2, RHR and CS Dependence on CAP Credit for DBA-LOCA, shows the impact on the time duration that CAP credit is needed by application on uncertainties required by SECY-11-0014, Enclosure 1.

Table 6.6.2-2 - RHR and CS Dependence on CAP Credit for DBA-LOCA

Long-term DBA	Start (sec)	End (sec)	Duration (hours)
RHR	3455	167130	45.47
RHR (*1.21)	1057	330633	91.55
CS	2440	206950	56.81
CS (*1.21)	568	455567	126.39

Table 6.6.2-3, Maximum CAP Credit during DBA-LOCA, shows the magnitude of CAP credit required for RHR and CS pumps with and without uncertainties applied.

Table 6.6.2-3 - Maximum CAP Credit during DBA-LOCA

	RHR (no unc.)	**RHR (21% unc.)**	**CS (no unc.)**	**CS (21% unc.)**
Max Req (psia)	20.58	22.64	21.33	23.36
Max Avail.(psia)	24.24	24.24	24.24	24.24
Max Req (psig)	6.32	8.38	7.07	9.10
Max Avail. (psig)	9.98	9.98	9.98	9.98

As noted in the response to RAI No. 12 in Reference 22, the Appendix R procedure controls CS injection flow rates in a band of 2700 to 4100 gpm. The 3029 gpm CS flow value used in the NPSH analysis is within this band.

The operators may increase flow above 3029 gpm if adequate containment pressure has been verified to be available. This verification is accomplished by comparing real time data for CS flow, torus water temperature, and containment pressure to EOP graphs that indicate adequate NPSH.

Figures 6.6.2-4 and 6.6.2-5 below demonstrate the impact of operating CS at the higher flow rate of 4100 gpm for Appendix R Fire NPSH evaluation. Case 1 for Appendix R Fire NPSH evaluation assumes one (1) Stuck Open Relief Valve (SORV) and Case 2 assumes no SORV. This demonstrates that margin remains for NPSH over the procedure range.

Figure 6.6.2-4

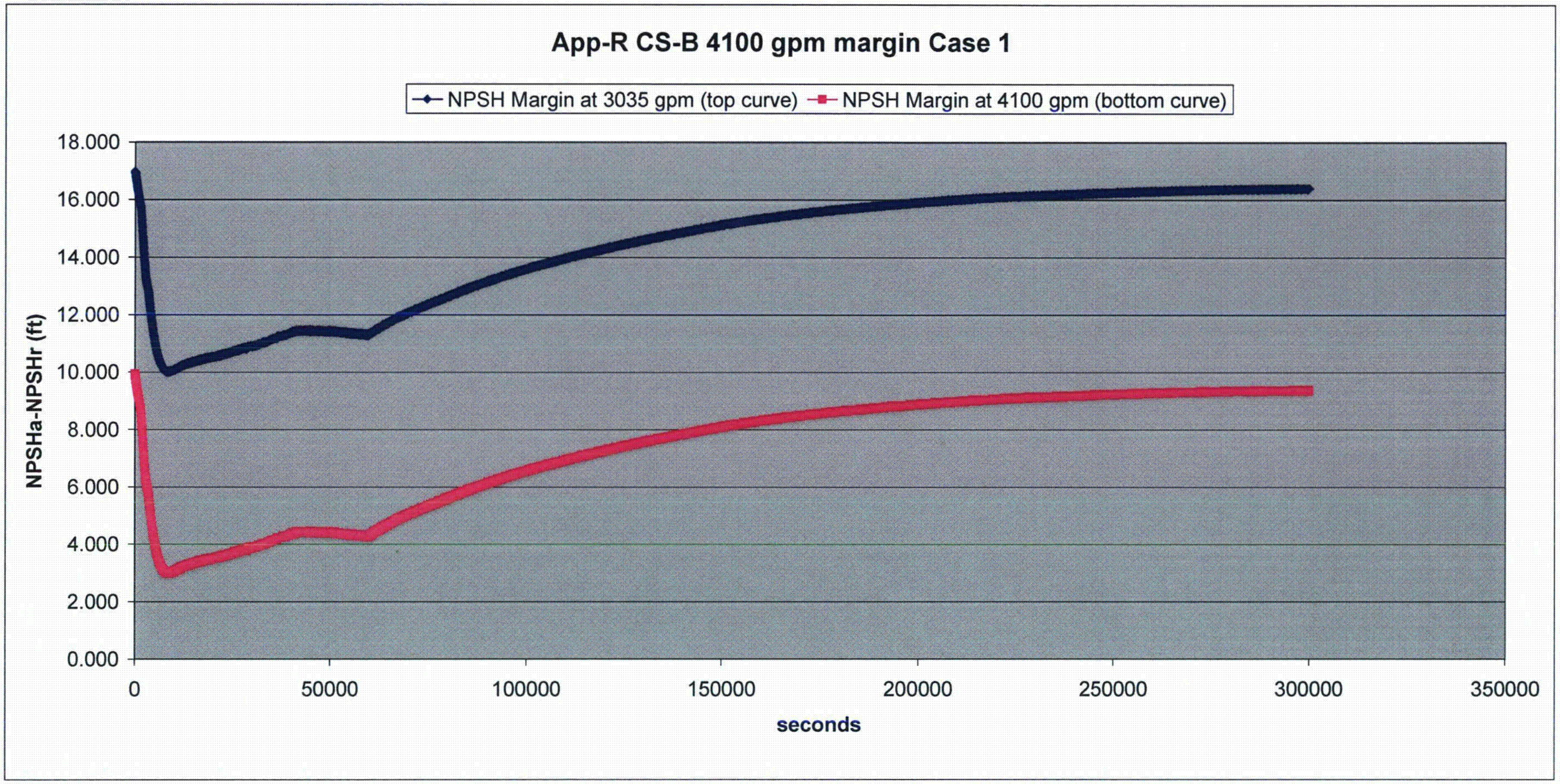
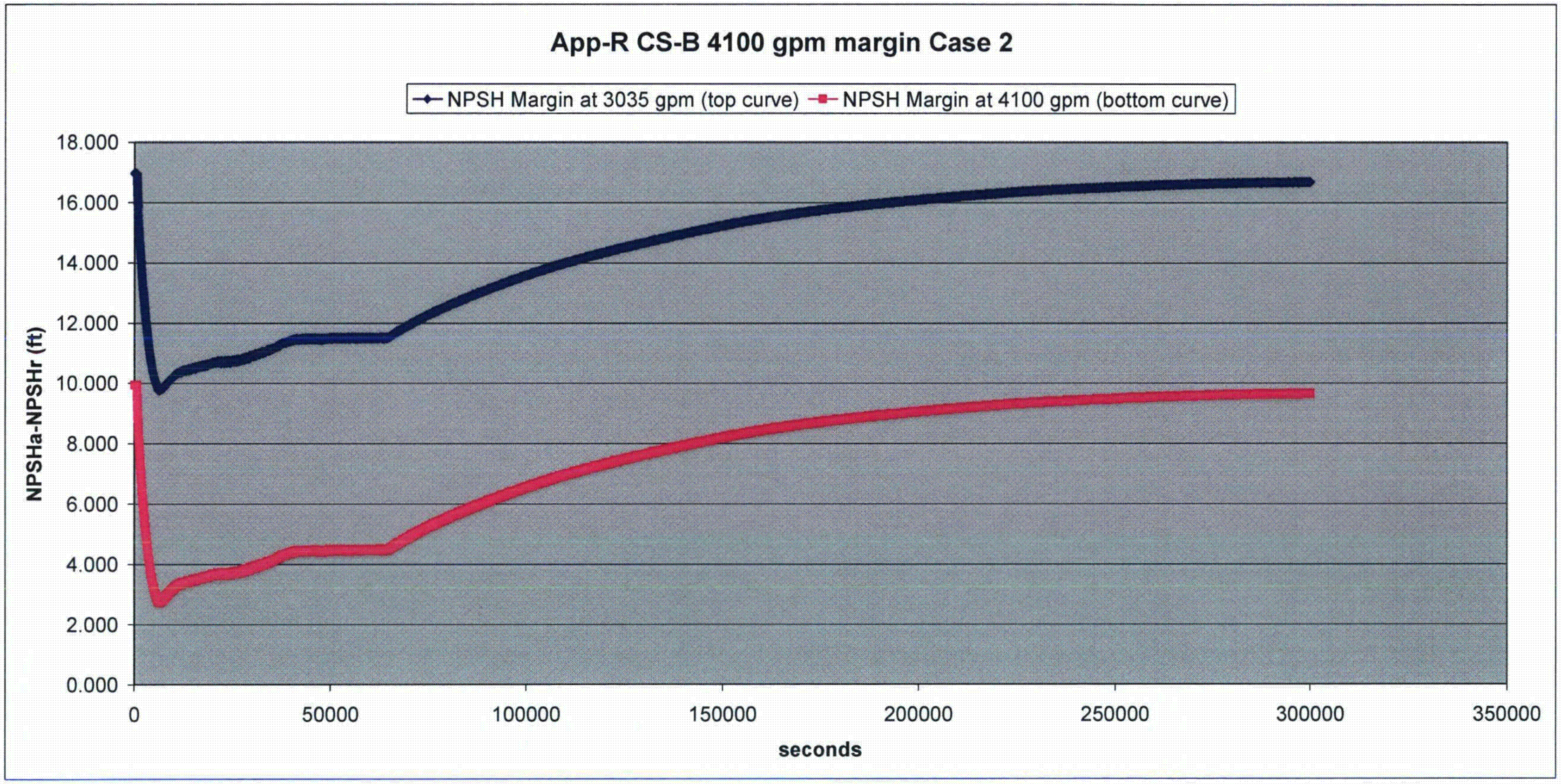

App-R CS-B 4100 gpm margin Case 1
NPSH Margin at 3035 gpm (top curve)
NPSH Margin at 4100 gpm (bottom curve)
NPSHa-NPSHr (ft)
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
0
50000
100000
150000
200000
250000
300000
350000
seconds

Figure 6.6.2-5


App-R CS-B 4100 gpm margin Case 2
NPSH Margin at 3035 gpm (top curve)
NPSH Margin at 4100 gpm (bottom curve)
NPSHa-NPSHr (ft)
18.000
16.000
14.000
12.000
10.000
8.000
6.000
4.000
2.000
0.000
0
50000
100000
150000
200000
250000
300000
350000
seconds

6.6.3 Conservative Containment Accident Pressure for Calculating NPSHa

A 95/95 lower tolerance limit should be used to calculate the containment accident pressure used to determine the NPSHa.

NSPM Response to 6.6.3

Evaluation of the DBA-LOCA event required the development of limiting containment response time histories that define a bounding response that maximizes containment temperature and pressure to ensure margin exists to design limits and a separate response that minimizes containment pressure to evaluate acceptable NPSHr for the ECCS pumps. The containment analyses used to support EPU are described in Reference 1, Section 2.6, Containment Review Considerations.

Section 6.6.9 below shows how the various time histories of containment response compare. This includes consideration of realistic analysis results that have been created to demonstrate margin.

A Monte Carlo analysis of containment response was completed for MNGP as part of work performed by the BWROG (Reference 18). The Monte Carlo analysis was presented to the staff and is discussed in Reference 4, Enclosure 1. As noted in Reference 4, Enclosure 1, an acceptance criterion of a 95% probability at a 95% confidence level (95/95) is used for the Monte Carlo pressure calculation. However, since conservative values are used for other inputs to the available NPSH calculation, the tolerance limit on NPSHa is greater than the 95/95 value.

The Super HEX (SHEX) containment response analysis provided in Reference 1, Enclosure 5 bounds the Monte Carlo analysis based on a comparison of NPSH margin, see Figure 6.6.9-3, and as such bounds a 95/95 lower tolerance limit analysis. Use of the original deterministic SHEX analysis provided in Reference 1, Enclosure 5 is therefore acceptable to define the containment response for NPSH evaluations.

6.6.4 Assurance that Containment Integrity is not Compromised

It should be demonstrated conservatively that, for the plant examined, loss of containment integrity from containment venting, circuit issues associated with an Appendix R fire, or other causes cannot occur or that they would occur only after use of containment accident pressure is no longer needed.

NSPM Response to 6.6.4

There are no losses of containment integrity from any design basis event. For special events, NSPM is currently evaluating the potential for circuit issues associated with an Appendix R fire to create impacts to containment integrity.

The results of the circuit issues associated with an Appendix R fire are planned to be submitted to the NRC by November 30, 2012.

6.6.5 Operator Actions

Operator action to control containment accident pressure is acceptable. The NRC staff should approve any operator actions, and the appropriate plant procedures (e.g., emergency, abnormal) should include them.

NSPM Response to 6.6.5

The MNGP EOPs require placing all available containment cooling into service if suppression pool temperature exceeds 90°F. Drywell spray is used if drywell pressure cannot be restored and maintained below 12 psig. The EOPs also include a caution that identifies to the operators that if containment pressure falls below 7 psig (the value required for CAP based on use of $NPSHr_{3\%}$) then this may result in inadequate NPSH. This NPSHr value does not change for EPU. Containment spray is stopped before pressure drops to 0 psig. The EOPs provide operator actions to control torus temperature, torus level, drywell temperature, drywell and torus pressure and hydrogen concentration.

The EOPs include guidance to determine if adequate NPSH exists. This guidance includes possible variables such as pump flow rate, suppression pool level, containment pressure and temperature. The existing EOP guidance is adequate to ensure appropriate control of containment pressure to ensure adequate NPSHr exists for the ECCS pumps. No changes are required to support operation at EPU and MELLLA+ conditions.

6.6.6 NPSHa less than NPSHr or NPSHreff

It is possible that the NPSHa may be less than NPSHreff (LOCA) or NPSHr3% (non-DBA).

Operation in this mode is acceptable if appropriate tests are done to demonstrate that the pump will continue to perform its safety functions. The following conditions should apply:

a. *Predicted operation during the postulated accident below NPSHreff (LOCA) or NPSHr3% (nondesign-basis event) is of limited duration (less than 100 hours).*
b. *The tests are conducted on the actual pump with the same mechanical shaft seal (including flush system) or at least a pump of the same model, size, impeller diameter, materials of construction, and pump seal and flush system.*
c. *The test is conducted at the same (field application) speed.*
d. *The test is conducted at the actual predicted NPSHa since testing at a lower NPSHa can actually reduce, rather than increase, the cavitation erosion rate in some cases.*
e. *The test duration should be for the time NPSHa is predicted to be less than NPSHreff (LOCA) or NPSHr3% (nondesign-basis event).*
f. *The flow rate and discharge head must remain above the values necessary to provide adequate core and containment cooling.*

NSPM Response to 6.6.6

There is no accident or event that results in predicted operation with NPSHa below NPSHr3%. The DBA-LOCA is expected to have a short period of time (from 360 seconds after the break until 600 seconds after the break) with operation where NPSHa is below NPSHreff3%. The conditions associated with a test to demonstrate that the pumps will perform the required safety function have been met and are discussed below:

a. *Predicted operation during the postulated accident below NPSHreff (LOCA) or NPSHr3% (nondesign-basis event) is of limited duration (less than 100 hours).*

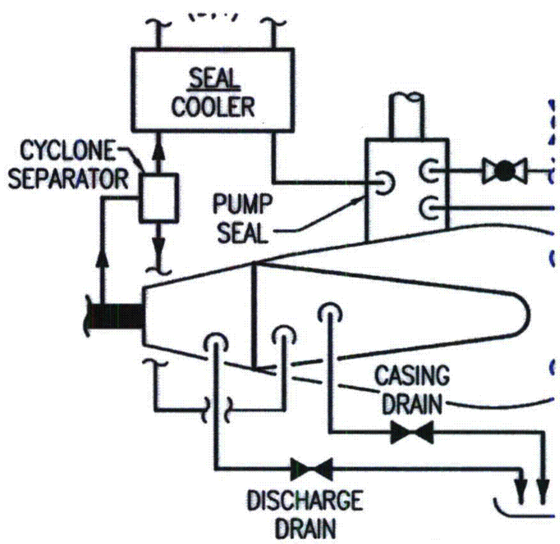
The DBA-LOCA is expected to have a short period of time (from 360 seconds after the break until 600 seconds after the break) with operation where NPSHa is below NPSHreff3%. This period of time is approximately 4 minutes in length. The predicted operation with NPSHa less than NPSHreff is therefore of limited duration and is much less than 100 hours.

b. *The tests are conducted on the actual pump with the same mechanical shaft seal (including flush system) or at least a pump of the same model, size, impeller diameter, materials of construction, and pump seal and flush system.*

Operating a pump in the vicinity of the NPSHr3% condition requires consideration of the potential for damage that water vapor or entrained air, or both, could do within the pump to the mechanical shaft seal faces, which could fail in a very short period of time if the seal faces run dry. Both RHR and CS pumps have a similar design for the seal flushing system (see Figure 6.6.6-1). BWROG Task 5 (Reference 13) evaluated the potential for damage to pump mechanical seals. The MNGP RHR pumps are provided with a mechanical seal flush piping system that takes water from pump discharge and provides flushing flow through the seals before returning the flow to the pump suction. Sufficient flushing flow exists to remove bubbles that may be created in the process stream from gas coming out of solution. The vertical configuration of the pump seals also supports removal of any non-condensable gas. This is also true for any gas that may be centrifuged inward to the shaft. Therefore, gas will not cause damage to pump internals.

Reference 20 confirmed the applicability of this analysis to the CS pump.

FIGURE 6.6.6-1 – MNGP RHR and CS PUMP SEAL FLUSHING ARRANGEMENT



Original factory testing was conducted on the MNGP ECCS pumps; the test was completed on the actual pumps installed in the field. This test was conducted at the same speed as the field application and included a similar mechanical shaft seal. The flush system is a feature of design for the original pump supplied by the manufacturer.

c. *The test is conducted at the same (field application) speed.*

Original factory testing was conducted on the MNGP ECCS pumps; the test was completed on the actual pumps installed in the field. This test was conducted at approximately the same speed as the field application. Motor replacements for the pumps have resulted in some very small variations in motor slip for some motors since original installation. For example, the original RHR pump test was completed at 3578 rpm. Current drawings show RHR motor full load speed ratings that vary from 3560 rpm to 3570 rpm. The CS motors have full load rated speeds of 3560 rpm which is identical to the original factory test speeds that defined NPSHr for these pumps. Therefore, factory test speeds are considered the same as field application speeds.

d. *The test is conducted at the actual predicted NPSHa since testing at a lower NPSHa can actually reduce, rather than increase, the cavitation erosion rate in some cases.*

Cavitation erosion rate is addressed by Task 4 (Reference 12) that provides a conservative assessment of impeller life under worst case NPSHa conditions of pump operation. This issue is further addressed by Section 6.6.8 below. Substantial margin exists for impeller life such that operation under worst case conditions predicted for impeller erosion will not challenge the ability of the pumps to operate for their required mission time. Worst case conditions are at an NPSHr value that is between $NPSHr_{3\%}$ and the inception point for cavitation, $NPSHr_{0\%}$. The RHR impeller is projected to have a service life of >6,200 days when operated at the worst case conditions that result in the maximum impeller wear rate. This is well beyond the 30 day mission time required for these pumps and therefore cavitation erosion will not impact pump capability. This analysis bounds the results from the requested testing for NPSHa.

Reference 20 confirmed the applicability of this analysis to the CS pump.

e. *The test duration should be for the time NPSHa is predicted to be less than NPSHreff (LOCA) or $NPSHr_{3\%}$ (nondesign-basis event).*

The predicted period when NPSHa is below $NPSHreff_{3\%}$ is 4 minutes in length and the only event where this condition exists is for DBA-LOCA. NPSHa is typically reduced to values below $NPSHr_{3\%}$ to establish the "breakdown knees" used to define NPSHr curves. The standard NPSHr characterization test establishes a 3% NPSHr curve by incrementally reducing the NPSHa until a 3% reduction in head is measured. Previous testing included operation for durations that bound this time period. Testing at each data point typically takes a few minutes for loop stabilization and then data collection occurs. Establishment of an NPSHr curve requires data acquisition at various flow rates to define NPSHr capability at each flow rate. The MNGP pumps have been tested to $NPSHr_{5\%}$.

The information presented in Reference 11 provides ample evidence that cavitation induced vibration in the CVDS pumps of similar frame size, hydraulics and mechanical configuration, operating under conditions similar to those evaluated for the MNGP pumps, is not expected to lead to pump component failure during the thirty days of operation under DBA-LOCA conditions. Reference 20 confirmed the applicability of this analysis to the CS pump. Any further testing (none is proposed) of similar CVDS pumps would not be expected to yield results different from those reported herein or change the basic conclusion that the Monticello CVDS pumps will perform their intended design function during a postulated DBA-LOCA event.

For nondesign-basis events $NPSHa > NPSHr_{3\%}$ exists for all portions of the event responses.

f. The flow rate and discharge head must remain above the values necessary to provide adequate core and containment cooling.

The flow rate and discharge head for both the CS and RHR pumps remain above the values necessary to provide adequate core and containment cooling as demonstrated below.

In the first 600 seconds following a DBA-LOCA the following sequence of events occurs. Some variations in specific times are possible with various events evaluated by the ECCS analysis. For example, at MNGP the ECCS analysis considered the LPCI injection valve failure event and a postulated battery failure event as limiting events that were analyzed for core cooling capability. The range of variations in timing was considered and required flow rates and discharge head will remain above required values. This analysis bounds the results from the requested testing for NPSHa.

Sequence of Events Timeline for DBA-LOCA	
1	Reactor depressurizes to < 50 psia prior to 60 seconds after LOCA
2	ECCS flow to reactor established prior to 60 seconds after LOCA
3	Fuel temperature peak reached and fuel cooldown started prior to 200 seconds
4	Core flooded to 2/3 core height prior to 225 seconds
5	Fuel zone level indication of 2/3 core height occurs before 300 seconds. Adequate long-term core cooling* requirements are met and operator action to throttle ECCS pumps with transfer of RHR pumps to containment cooling mode can be initiated at 300 seconds.
6	NPSHa may be less than NPSHreff (LOCA) after 360 seconds for the limiting analysis if ECCS pump flow has not been throttled
7	By 600 seconds CS pumps are throttled and RHR is in containment cooling mode

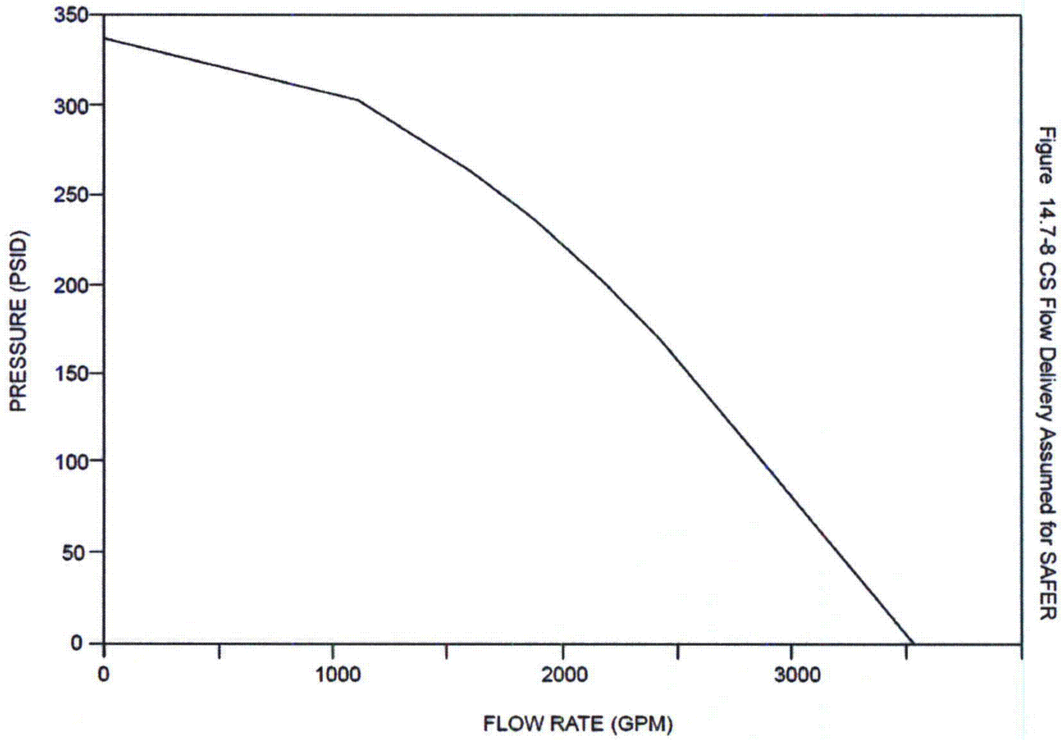
*Adequate long-term core cooling requirements are:

(1) core can be reflooded above top of active fuel, or

(2) core can be reflooded to the elevation of the jet pump suction and one core spray system is placed in operation at rated flow of 3020 gpm delivered to the core with a pump flow rate of 3388 gpm

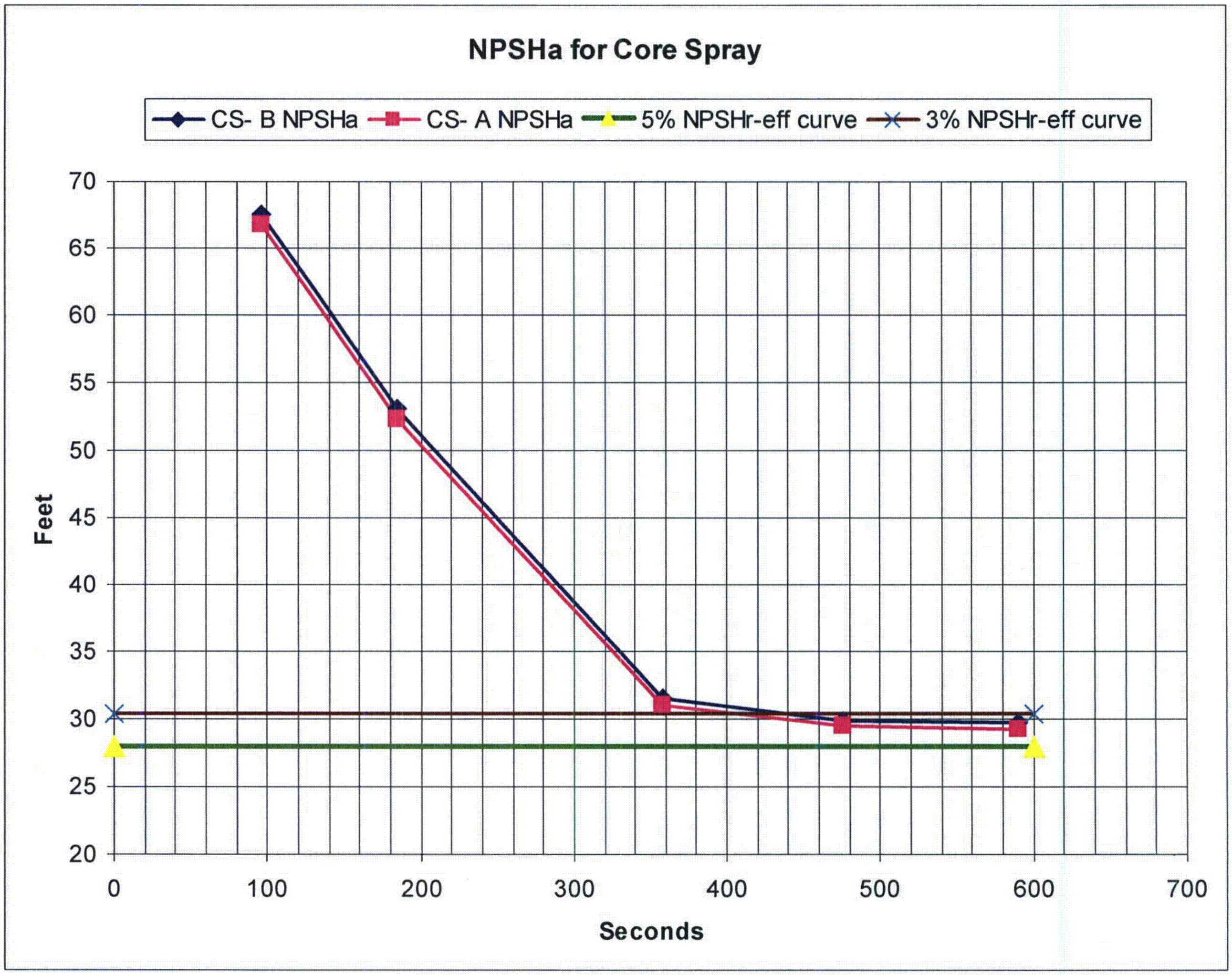
The CS flow rate delivered to the reactor for SAFER analysis is shown in USAR Figure 14.7-8, CS Flow Delivery Assumed for SAFER (Figure 6.6.6-2, below). This is the flow assumed in the short-term analysis prior to the core being reflooded to the jet pump suction elevation.

Figure 6.6.6-2 – CS Flow Delivery Assumed for SAFER Analysis



Following a DBA-LOCA the CS pumps will start to inject when they reach rated speed, the injection valves are opened and reactor pressure is reduced below pump shutoff head. With the reactor fully de-pressurized CS flow exceeds 3540 gpm delivered to the core which is a CS pump flow of 3915 gpm as the limiting core cooling flow requirement for the short-term analysis during core reflood. The short-term NPSH analysis assumes a bounding CS pump flow of 4245 gpm for the core reflood period (<300 seconds). NPSHr margins are well above $NPSHreff_{3\%}$ and no degradation of pump capability exists during the core reflood portion of the time history. As shown in Figure 6.6.6-3 below, NPSHa is >38 feet during the time the core is reflooded. There is no period where NPSHa is below $NPSHreff_{5\%}$. Table 6.6.1-1 provides more detail on individual pump uncertainties during the short-term period shown here.

Figure 6.6.6-3 – NPSHa for CS During Short-term Time History

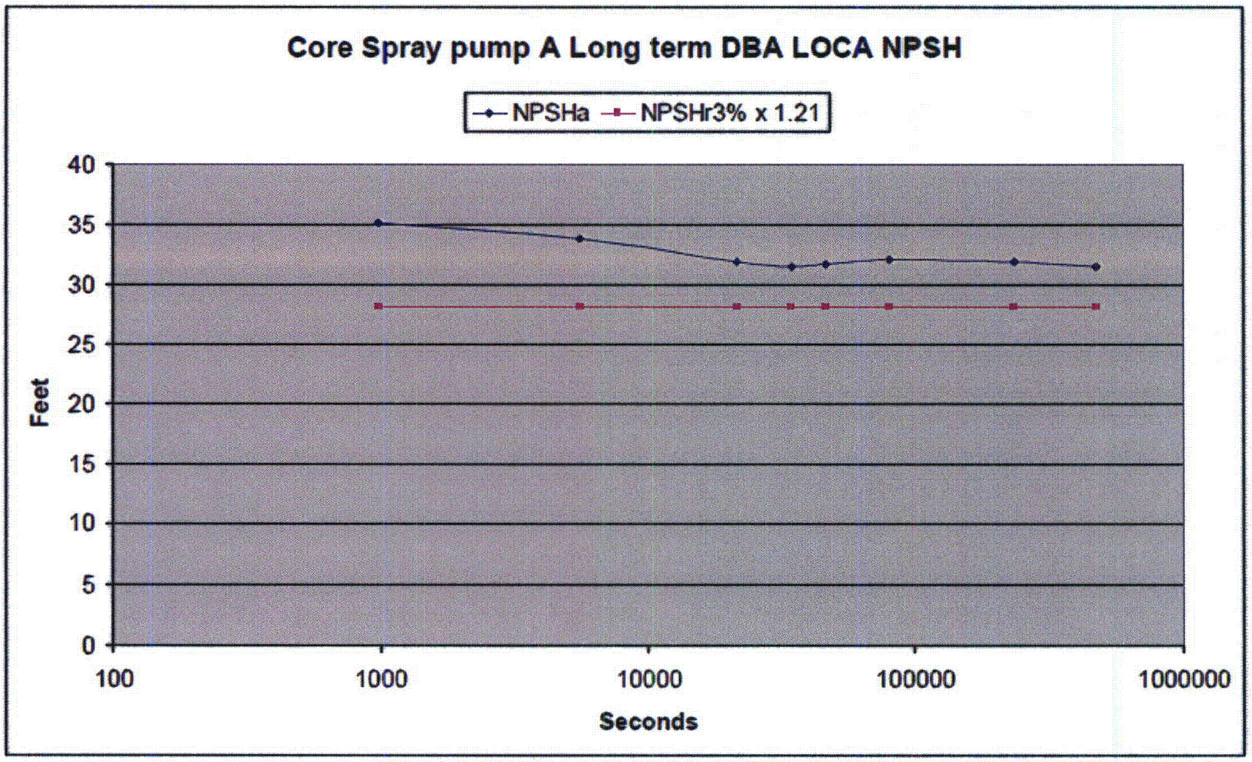


After 360 seconds, if the CS pumps have not been throttled, it is possible to have NPSHa < NPSHreff. The ability of pumps to operate with NPSHa less than NPSHreff (LOCA) is analyzed in BWROG Task 3 (Reference 11). MNGP used this analytical approach (BWROG Task 3 – Reference 11) to demonstrate CS pump flow capability while meeting the requirements for adequate long-term core cooling. As discussed in Section 2.0 above, CS pump flow required during this time period is 3388 gpm (3020 gpm delivered to core). This flow is required for operation of only one CS pump. For the limiting conditions of the NPSHa analysis two CS pumps are available.

The flow available from each CS pump is greater than analysis requirements. CS pump P-208B can provide 3980 gpm and CS pump P-208A can provide 4065 gpm. Substantial margin exists with >7300 gpm delivered to the core versus the required flow of 3020 gpm credited in the safety analysis for long-term core cooling since both pumps are in operation.

The only time that NPSHa is less than NPSHreff for CS is during the short-term analysis. For the short-term analysis CAP credit required is assumed to utilize the containment pressure that is available. As noted in the time line provided above, the operators would be expected to start throttling ECCS pump flow rate after 300 seconds (level at 2/3 core height) in order to establish conditions for cooling containment and for long-term core cooling. The CS pumps may be throttled by operator action prior to 360 seconds when NPSHa < NPSHreff. Once the pumps are throttled to design flow rates, margin will exist so that NPSHa will not be less than NPSHreff at any later time in the DBA-LOCA coping period. Figure 6.6.6-4 shows long-term NPSH margin for the limiting CS Pump A starting at the point where flow is throttled to meet long-term core cooling requirements of 3388 gpm. NPSHreff for CS during this time period is 28.2 feet.

Figure 6.6.6-4 – Long-term CS Pump A NPSH Margin

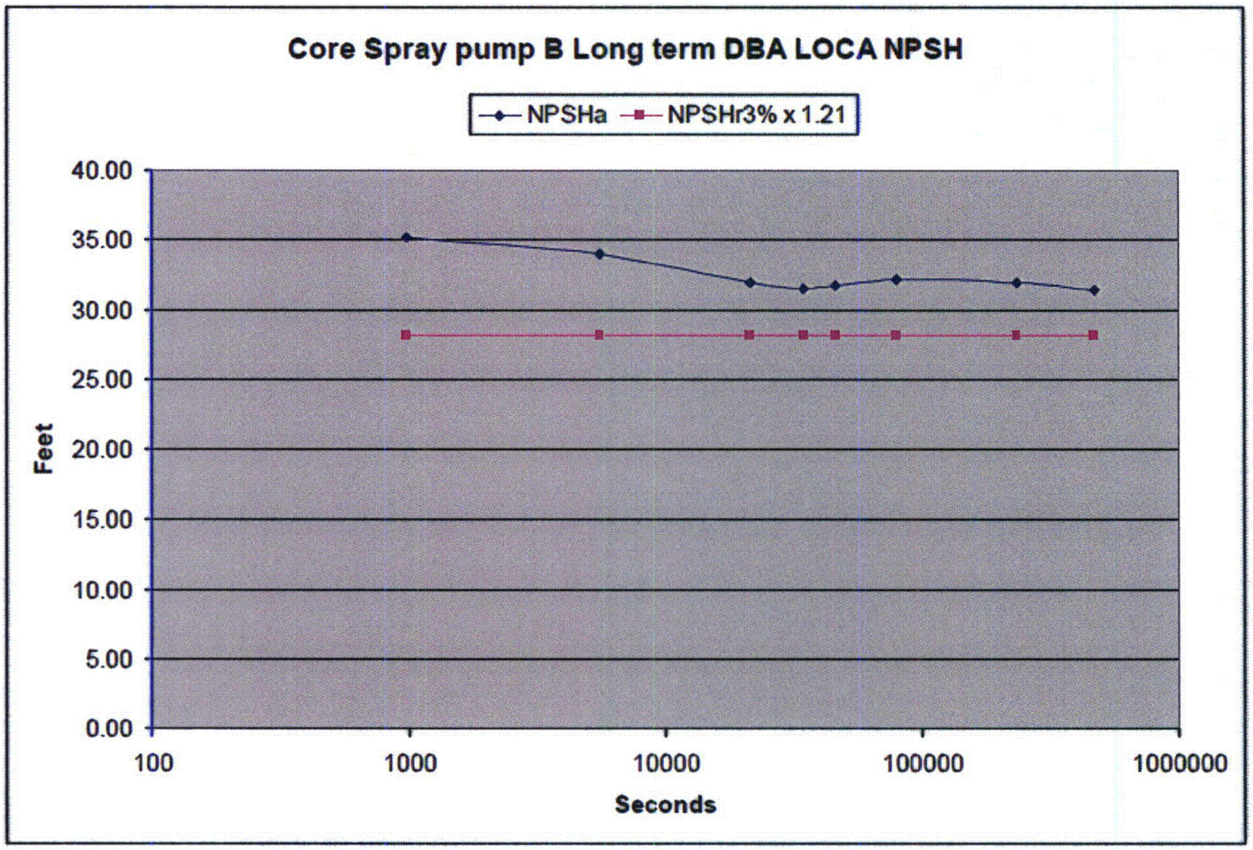


For the assessment of NPSHr, LPCI flow is not credited since it is conservatively assumed to be injected into the broken recirculation piping loop for the limiting NPSH event. Two CS pumps are available to quench fuel temperatures and reflood the core to 2/3 core height. This results in the minimum system resistance for LPCI and therefore, the maximum pump run-out flow rate for these pumps. Since all six ECCS pumps are available for this scenario, the pump suction piping system resistance is maximized which results in the minimum NPSHa.

No assessment of RHR flow capability is required for the limiting NPSH event since no credit is assumed for LPCI for core cooling. As noted above, RHR flow is lost out the break so the only impact on RHR is verification of pump reliability which is assessed in Task 3 (Reference 11). The Task 3 analysis demonstrates that the RHR pump remains reliable for the 30 day mission time.

The long-term analysis begins at >600 seconds after the break. Operator action is assumed at 600 seconds to throttle ECCS pump flow rate and to establish containment cooling. Failure of an emergency diesel generator or battery in combination with a loss of off site power results in the availability of one CS pump to maintain core cooling, one RHR pump to cool containment and one RHRSW pump to remove decay heat from the RHR heat exchanger. This configuration defines the limiting set of equipment in service for the long-term analysis. In this mode of operation the operators will control RHR pump flow through the RHR heat exchanger at 4000 gpm. As shown in Section 6.6.2 above, this flow is now increased to 4178 gpm to account for flow through the RHR minimum flow valve. See Section 6.6.2 for results of the evaluation. Figure 6.6.6-5 shows long-term RHR pump NPSH margin under these conditions. NPSHreff for RHR is 28.5 feet at this time.

Figure 6.6.6–5 – Long-term RHR NPSH Margin



Conclusion

These analyses demonstrate that:

- The results from any testing for NPSHa are bounded by the analysis results,
- References 11 and 20 provide adequate analysis to support operation of the RHR and CS pumps at reduced NPSHa conditions and is not expected to lead to pump component failures,
- References 11 and 20 demonstrate that sufficient testing of the MNGP RHR and CS pumps and similar pumps has occurred with no discernable degradation of the pumps.
- References 12, 13 and 20 demonstrate large margins with respect to the MNGP RHR and CS pumps achieving their mission time,
- The flow available from the MNGP RHR and CS pumps is greater than the analysis requirements, and
- Further testing of the MNGP RHR and CS pumps for NPSHa is not warranted as this would not provide a demonstration of margin that is not obtainable from the performed analyses.

6.6.7 Assurance of no Pre-existing leak

Licensees and applicants should consider a loss of containment isolation that could compromise containment integrity. Possible losses of containment integrity include containment venting required by procedures or loss of containment isolation from a postulated Appendix R fire. It should be demonstrated conservatively that, for the plant examined, loss of containment integrity from these causes cannot occur or that they would occur only after use of containment accident pressure is no longer needed.

To reduce the likelihood of a preexisting leak, licensees proposing to use containment accident pressure in determining NPSH margin should do the following:

(1) Determine the minimum containment leakage rate sufficient to lose the containment accident pressure needed for adequate NPSH margin.

(2) Propose a method to determine whether the actual containment leakage rate exceeds the leakage rate determined in (1) above. For inerted containments, this method could consist of a periodic quantitative measurement of the nitrogen makeup performed at an appropriate frequency to ensure that no unusually large makeup of nitrogen occurs. Monitoring oxygen content is another method. For subatmospheric containments, a similar procedure might be used.

(3) Propose a limit on the time interval that the plant operates when the actual containment leakage rate exceeds the leakage rate determined in (1) above.

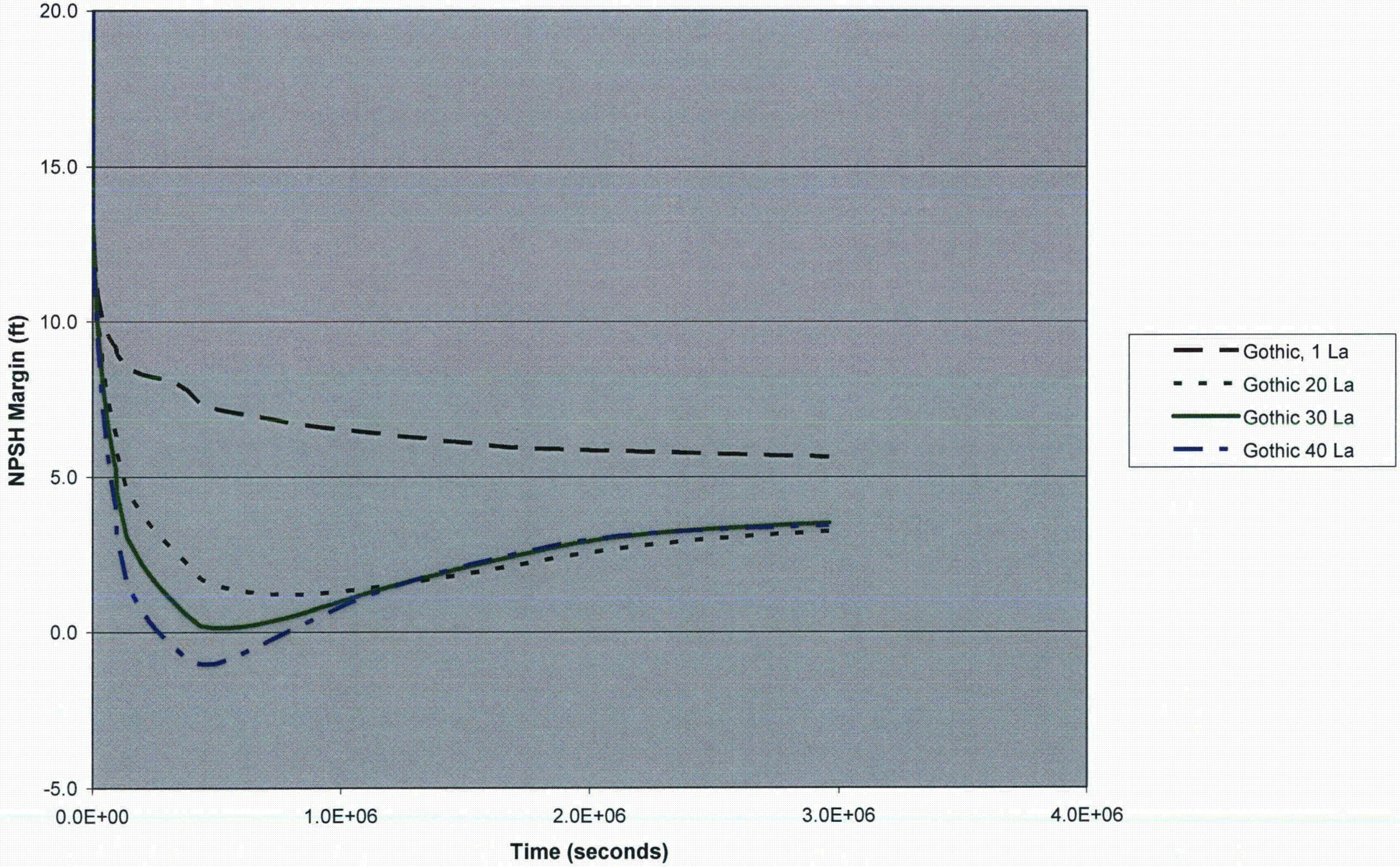
NSPM Response to 6.6.7

Section 6.6.4 above addresses possible loss of containment isolation that could compromise containment integrity for an Appendix R event. There are no other postulated losses of containment isolation that could compromise containment integrity.

(1) minimum containment leakage rate sufficient to lose the containment accident pressure needed for adequate NPSH margin

An evaluation of containment response has been completed using GOTHIC to evaluate containment leakage rates sufficient to lose containment accident pressure. The GOTHIC analysis used conservative inputs used by the SHEX NPSH analysis with the exception of the use of a temperature dependent K-value (see Section 6.6.9 below for further discussion). The reference flow is 1 La (from MNGP Technical Specifications) which is equivalent to a leakage rate of 7.6 scfm. The results of the GOTHIC analysis are shown in the curve below (Figure 6.6.7-1). Figure 6.6.7-1 indicates how margin (NPSHa – NPSHreff) changes with varying sizes of leakage. This shows that a leak of greater than 30 La (228 scfm) will result in loss of margin for NPSHr.

Figure 6.6.7-1 – CS NPSH Margin with Conservative Inputs



(2) Method to determine actual containment leakage rate

The MNGP Technical Specifications (TS) 5.5.11, Primary Containment Leakage Rate Testing Program, requires primary containment leakage to be maintained ≤ La. NSPM has a program that monitors primary containment leakage in accordance with this TS requirement. 1 La is equivalent to a leakage rate of 7.6 scfm. This TS satisfies 10CFR50.36(2)(ii), Criterion 2 as an operating restriction that is an initial condition of a design basis accident or transient analysis that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.

In addition to the existing TS requirements, NSPM has developed the following on-line leakage test and describes below other monitoring that is currently relied on by the operator to indicate abnormal containment leakage conditions.

On-Line Leakage Test:
NSPM has developed and implemented an additional on-line leakage rate test procedure that determines a containment leakage rate during power operation. The test is based on a quantitative measurement of the nitrogen (N2) makeup while the N2 system is operated with a known vent release rate for 8 hours. The test makes use of a computer point that calculates the N2 gas mass inside the inerted primary containment. This procedure is designed for detection of large containment integrity failures and use of instrument uncertainty is not required.

The on-line leakage rate test is to be performed as a beginning of cycle (BOC) benchmark quantitative leak test and will provide a baseline that would allow identification of a significant change in containment leakage rate at any time during cycle operation.

The test will be performed after a refueling outage when the plant has reached stable full power conditions. This test can be repeated at any time during the cycle if inputs identified below for monitoring during normal operation warrant another measurement.

This on-line leakage rate test procedure does not meet the requirements and controls of TS Appendix J testing. Therefore, as a practical matter, the on-line test results will not match the TS 5.5.11 Primary Containment Leakage Rate Test results. Leakage rates in excess of the procedure acceptance criteria will be assessed via the Corrective Action Process. As shown in Figure 6.6.7-1, a large degradation of containment integrity (greater than 30 La) would be required to lose margin for use of CAP.

Monitoring During Normal Operation:
There are a number of inputs available to the control room operators during normal operation that would signal an increase in the containment leak rate. These inputs, provide assurance that such leakage would be identified.

- A computer point is provided that continually calculates the N2 mass in containment and provides a computer alarm in the control room if the N2 mass is too low or too high. The low inventory alarm corresponds to the minimum non-condensable gas mass assumed for the ECCS pump NPSH analysis. Calculated values below the minimum assumed in the NPSH analysis will result in operator action to declare the ECCS pumps inoperable. The computer alarm response procedure includes a note that frequent use of the Nitrogen Makeup System may indicate an increase in N2 leakage from containment.
- A control room annunciator that alarms on drywell high or low pressure is available. The low pressure setpoint is 0.1 psig. The annunciator response procedure includes actions that would require investigation if low pressure exists.
- A flow indicator that measures the N2 flow in the supply to the containment air system is monitored. Data are taken 4 times per day to validate that the makeup flow is within the normal range.
- Operations procedures include a general precaution that any condition that may indicate an increase in containment nitrogen leakage rate during normal operation is to be carefully and promptly assessed.

The on-line leakage rate test and the control room monitoring during normal operation provide adequate indication of possible changes to containment leakage. This will ensure that significant increases to containment leakage are identified promptly. In addition, normal makeup and vent flow for primary containment for nitrogen supply or monitoring with the drywell Continuous Air Monitor (CAM) have a capacity of <5 scfm. The leakage rate that could result in a loss of containment integrity that could challenge CAP required to support NPSHr for the ECCS pumps is >228 scfm. This leakage rate is well within the range that can be detected by procedures that control the use of these systems. Therefore, continuous monitoring of the capability to ensure CAP is available is justified.

(3) Limit on the time interval that the plant operates when the actual containment leakage rate exceeds the leakage rate

Leakage rates above the acceptance criteria will be investigated by the Corrective Action Program. No specific limitation on time of plant operation is proposed for indicated leakage that is above the acceptance criteria since the procedure to determine the containment leakage rate does not meet the requirements and controls of a TS Appendix J Type A test.

However, the Primary Containment Leakage Testing Program includes TS 5.5.11.d which limits containment leakage rate to ≤ 1.0 La, as the maximum allowable containment leakage rate. If at any time during normal operation there is indication of a leakage rate above 1.0 La, then the action required by TS 3.6.1.1, Primary Containment, would be performed. The actions from TS 3.6.1.1 require restoring Primary Containment to an operable status within 1 hour or be in mode 3 within 12 hours and mode 4 within 36 hours.

6.6.8 Maximum Erosion Zone

The zone of maximum erosion rate should be considered to lie between NPSH margin ratios of 1.2 to 1.6. The permissible time in this range, for very-high-suction energy pumps, should be limited unless operating experience, testing, or analysis justifies a longer time. Realistic calculations should be used to determine the time within this band of NPSH ratio values.

NSPM Response to 6.6.8

The method used to address operation in the maximum erosion zone is covered by References 12 and 20. Reference 12 predicts impeller damage for RHR pump operation at the worst case location in the maximum erosion zone. Impeller life is estimated based on use of formulae from Reference 9. The method used determined an impeller life for the RHR pump of >6200 days. This value is significantly greater than the required service life of 30 days. The acceptance criterion is based on maintaining impeller blade thickness at a factor of 3 greater than what is typical for end of life as defined by the original equipment manufacturer. Margins shown are adequate to demonstrate that operation in the maximum erosion zone is not a concern for these pumps.

The CS pump at MNGP is similar to the RHR pump (Reference 20). Impeller life will significantly exceed requirements. Since the analysis considered continuous operation at the worst point of the maximum erosion zone, all possible conditions for EPU and MELLLA+ operation are bounded.

6.6.9 Estimate of NPSH Margin

A realistic calculation of NPSHa should be performed to compare with the NPSHa determined from the Monte Carlo 95/95 calculation.

NSPM Response to 6.6.9

The licensing basis SHEX analysis completed to determine NPSHa for a DBA-LOCA uses many assumptions that are biased to overestimate suppression pool temperature and underestimate wetwell pressure to ensure conservatism. The conservative assumptions listed here ensure this bias exists.

Conservative Assumptions for NPSHa Calculations

- The reactor is operating at 102 percent of licensed power.
- The worst single failure occurs.
- The wetwell air space is maximized.
- The initial drywell and suppression chamber pressures are at the minimum expected values to minimize the containment accident pressure.
- The maximum operating value of the drywell temperature and the maximum relative humidity (100 percent) are used to minimize the initial noncondensable gas mass and minimize the long-term containment pressure.
- The initial suppression pool temperature is the maximum technical specification value to maximize the calculated suppression pool temperature.
- Containment sprays are available to cool the containment. They are initiated at 600 seconds and operate continuously.
- Passive heat sinks are modeled to reduce containment pressure.
- All CS and RHR pumps have 100 percent of the brake horsepower rating (rather than the water horsepower) converted to pump heat that is added to the suppression pool water.
- Core decay heat is based on American National Standards Institute/American Nuclear Society (ANSI/ANS)-5.1-1979, “Decay Heat Power in Light Water Reactors,” decay heat model with 2-sigma uncertainty with custom G-factor
- Feedwater flow into the vessel continues until all feedwater initially greater than 212°F has been added.
- The initial suppression pool water volume is the minimum allowed by the technical specifications to maximize the suppression pool temperature and minimize the positive contribution resulting from the static head.
- Suppression pool level is reduced to account for accumulation of water in the drywell.
- The RHR heat exchanger is assumed to have minimum effectiveness. Bounding values of tube plugging and tube fouling are included. Suppression pool temperature is sensitive to this parameter.
- The service water (ultimate heat sink) temperature is at its technical specification or licensing-basis maximum value.
- For the LOCA, a conservative estimate is made of blockage of the suction strainers resulting from LOCA-generated debris.

- Break flow and containment spray flow are mixed with the containment atmosphere so that the torus pressure is minimized.
- Containment leakage is equal to La.
- The impeller characteristics of the most limiting pump are assumed to apply to all pumps of the same kind.

The most conservative assumption made is that all the conservative assumptions used in an analysis are assumed to occur simultaneously; that is, the break that yields the most adverse NPSH conditions occurs while the parameters specified in the Technical Specifications are all at their limiting values, the worst single failure occurs, and every physical process takes place in the most limiting way.

For non-design basis events (e.g. ATWS, Appendix R and SBO - also called special events in SECY 11-0014), NRC guidance is that more realistic input values may be used. Also, the assumption of a worst single failure is not necessary. Non-design basis events at MNGP use limiting assumptions for most inputs. The use of nominal assumptions would improve margins for NPSH.

<u>NEDC-33347P evaluation of MNGP</u>

SECY-11-0014, Enclosure 1 (Reference 4) discusses NEDC-33347P, Containment Overpressure Credit for Net Positive Suction Head (NPSH) (Reference 18). The MNGP containment response is analyzed as an example plant in Appendix A of NEDC-33347P. Appendix B of NEDC-33347P includes an assessment of the ability to meet NPSHr if no CAP was available. The Appendix B evaluation included the use of all available equipment by assuming single failures did not exist and that no loss of offsite power existed. This assessment showed that with the use of a statistical approach $NPSHr_{3\%}$ is met for all pumps except for the CS pumps from 6 minutes after the event until assumed operator action to throttle the CS pumps at 10 minutes after the event. This assessment did not include uncertainties required to demonstrate the ability to meet NPSHreff.

NEDC-33347P also provided an assessment of containment response using Monte Carlo analysis. Use of the minimum containment response predicted by Monte Carlo met the requirements of a 95/95 assessment of containment response. The NPSH margin results based on this assessment are shown in Appendix A of NEDC-33347P.

<u>Comparisons of Various Analysis Methods and Results</u>

To provide a realistic consideration of NPSH margin, NSPM performed an evaluation of various containment time histories. NSPM used GOTHIC for evaluation of MNGP ECCS pump margins. Shown below are the suppression pool temperature and pressure responses using GOTHIC as compared to the licensing bases analysis provided in Reference 1. The plant is currently licensed based on the use of the SHEX model to predict containment response. Figure 6.6.9-1 shows a benchmark comparison of GOTHIC results as compared to the SHEX results performed to define suppression pool temperature for the NPSH analysis and the maximum containment response.

Figure 6.6.9-2 shows a comparison of wetwell pressure between these evaluations. These results support that the GOTHIC model used compares well with the SHEX model used to support the license basis for MNGP. This comparison supports its use to provide realistic results of containment response presented later in this report.

Figure 6.6.9-1

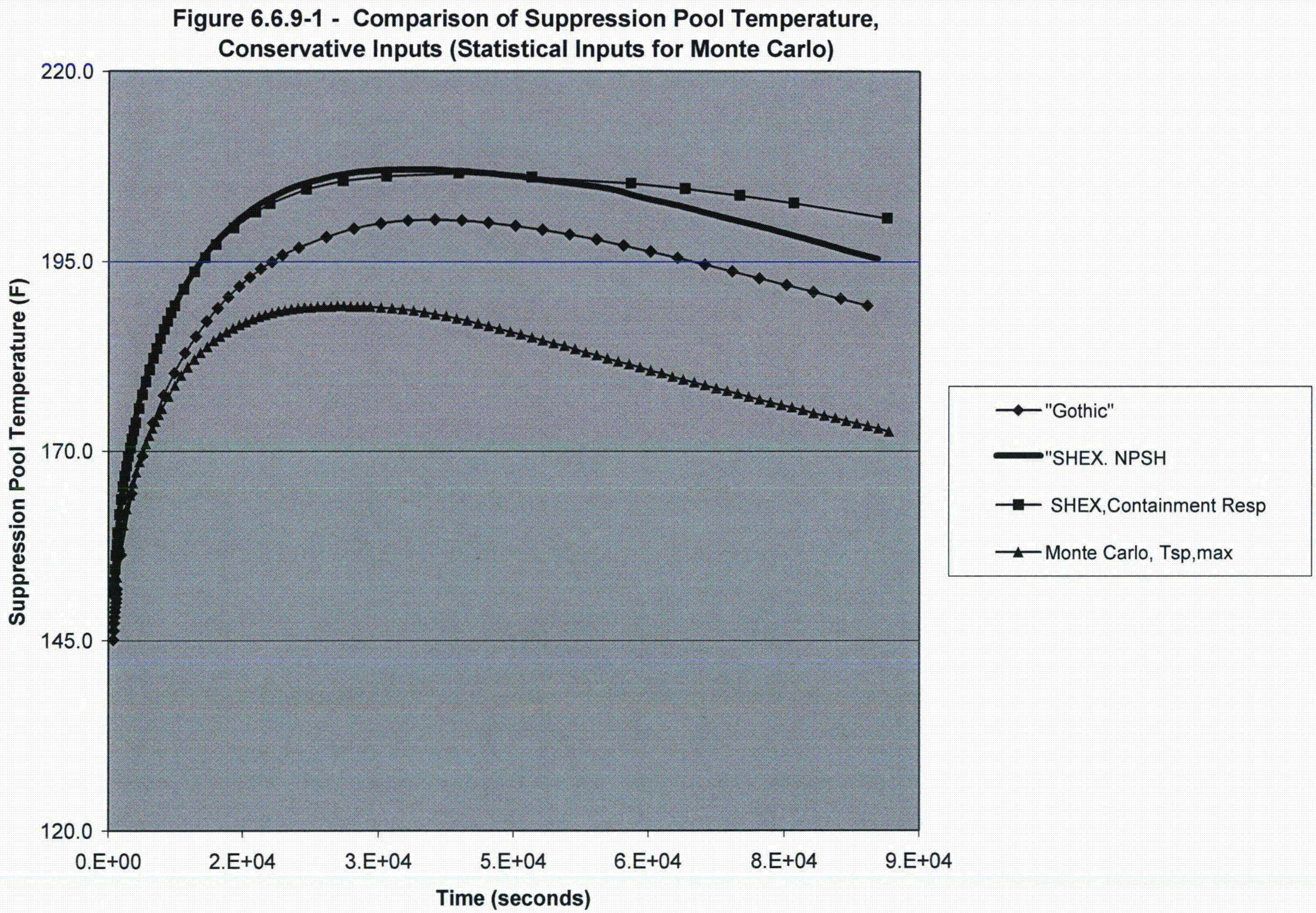


Figure 6.6.9-1 - Comparison of Suppression Pool Temperature, Conservative Inputs (Statistical Inputs for Monte Carlo)
220.0
195.0
170.0
145.0
120.0
Suppression Pool Temperature (F)
0.E+00
2.E+04
3.E+04
5.E+04
6.E+04
8.E+04
9.E+04
Time (seconds)
"Gothic"
"SHEX. NPSH
SHEX,Containment Resp
Monte Carlo, Tsp,max

The GOTHIC analysis in Figure 6.6.9-1 above shows a slightly lower value for suppression pool temperature than the SHEX calculations of containment response that were completed for NPSH and for peak containment response. The SHEX response was performed using drywell and wetwell sprays with RHR heat exchanger performance based on use of a constant K-value of 147 BTU/sec°F. The GOTHIC analysis used a temperature dependent K-value that more accurately predicts RHR heat exchanger performance while using similar inputs for remaining parameters.

The SHEX analysis predicts a peak suppression pool temperature of 207.2°F for the NPSH time history done with a constant K-value and a peak suppression pool value of 202.7°F for the suppression pool cooling mode that used a temperature dependent K-value. The SHEX model showed the impact of the use of a temperature dependent K-value as being 4.5°F based on this comparison. GOTHIC peak temperature response results are similar to the SHEX results based on use of a temperature dependent K-value.

The Monte Carlo, Tsp (temperature of the suppression pool), Max results are shown to provide a comparison between SHEX (NPSH and Containment Response), and the GOTHIC using deterministic inputs. This provides a side-by-side comparison of the different methods used to predict the limiting maximum temperature response for containment and supports the fact that GOTHIC provides a good comparison with SHEX.

Figure 6.6.9-2

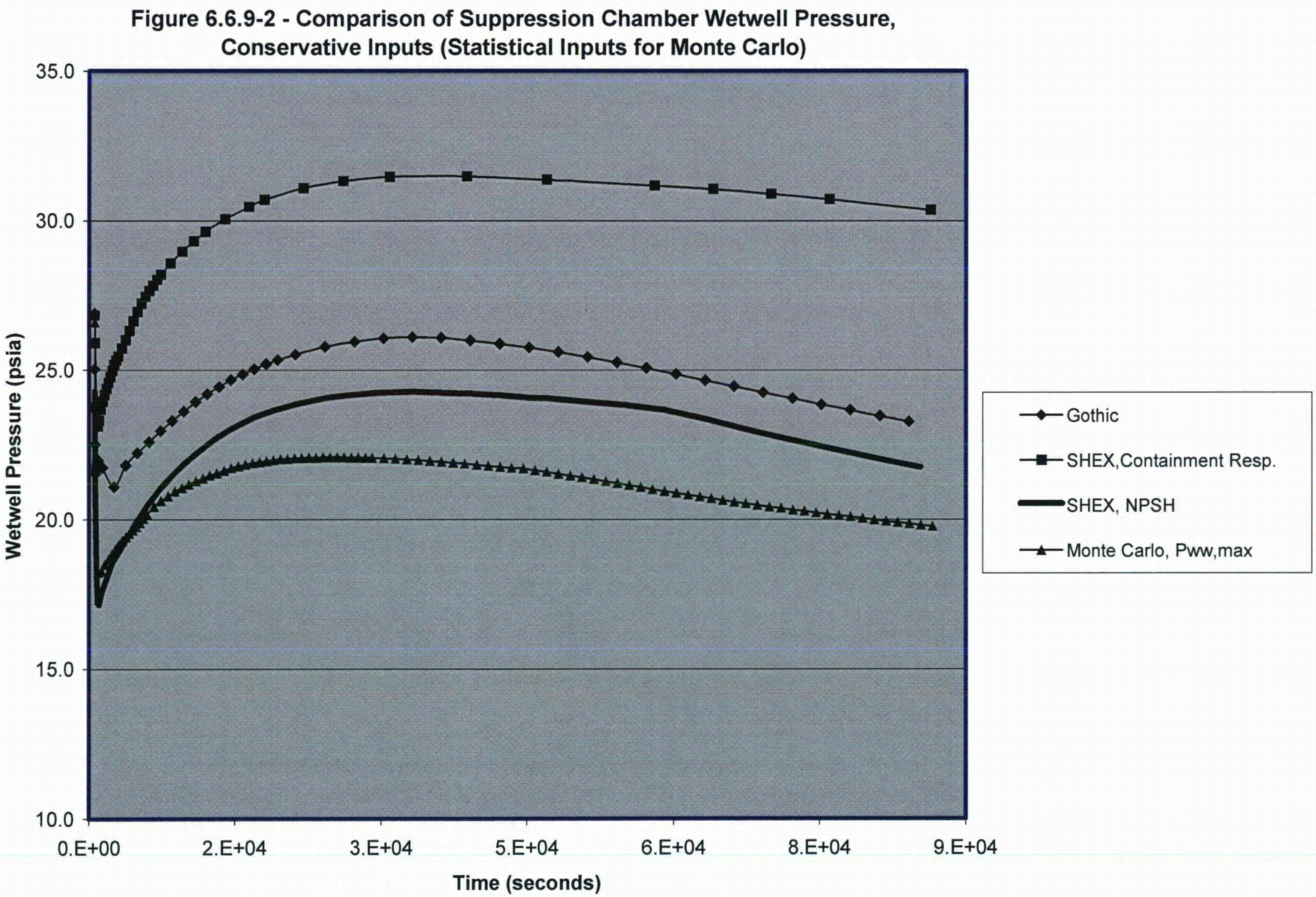


Figure 6.6.9-2 - Comparison of Suppression Chamber Wetwell Pressure, Conservative Inputs (Statistical Inputs for Monte Carlo)
35.0
30.0
25.0
20.0
15.0
10.0
Wetwell Pressure (psia)
0.E+00
2.E+04
3.E+04
5.E+04
6.E+04
8.E+04
9.E+04
Time (seconds)
Gothic
SHEX,Containment Resp.
SHEX, NPSH
Monte Carlo, Pww,max

The suppression chamber wetwell pressure response shows the SHEX containment response provided in Reference 1 for NPSHa, the SHEX containment response that maximizes pressure completed to verify that containment meets design limits, GOTHIC and Monte Carlo, Pww, max results.

The pressure evaluation shows that the deterministic wetwell pressure SHEX containment response to evaluate NPSHa for the ECCS pumps is very conservative. GOTHIC results provide a realistic analysis of wetwell pressure response for definition of margins for NPSHa.

As shown in Section 6.6.7 above, a leak of 30 La is needed to result in loss of all margin between NPSHa and NPSHreff. Shown in Figure 6.6.9-3 below is a comparison of the available NPSHr margin (NPSHreff - NPSHa) between the SHEX analysis and GOTHIC models based on the design leakage rate of La. The different analyses shown are based on:

Table 6.6.9-1 – Assumptions for Analysis in Figures 6.6.9-1, 2 and 3

SHEX	Analysis provided in Reference 1, Enclosure 5, Table 2.6-2
GOTHIC Conservative	Inputs the same as SHEX except that a temperature dependent K-value is used for RHR heat exchanger performance
Monte Carlo	Analysis provided in Reference 18
GOTHIC Realistic	Inputs are shown in Table 6.6.9-2, reflect conditions that are met 98% of the time at MNGP

Figure 6.6.9-3

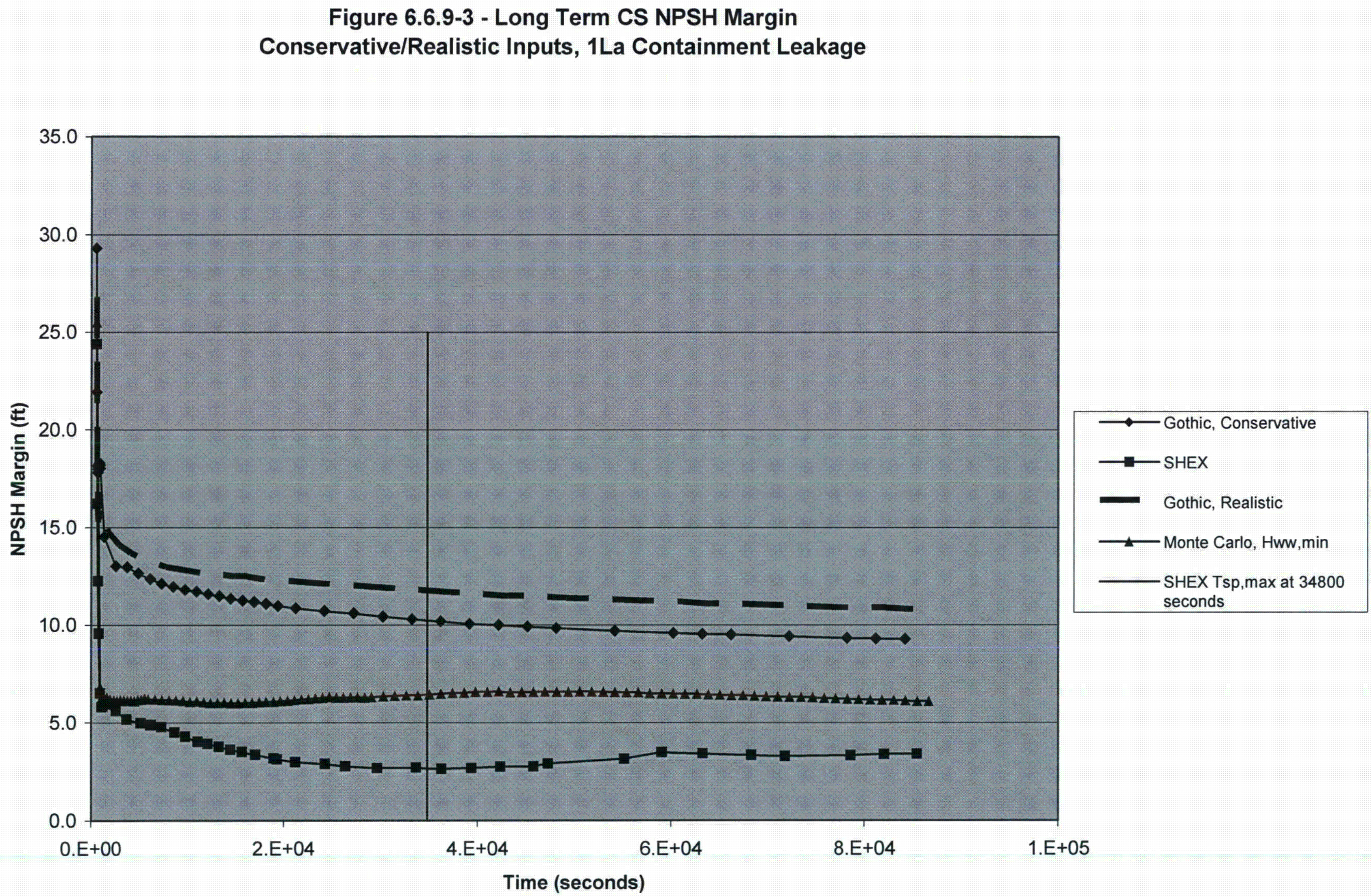


Figure 6.6.9-3 - Long Term CS NPSH Margin
Conservative/Realistic Inputs, 1La Containment Leakage
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
NPSH Margin (ft)
0.E+00
2.E+04
4.E+04
6.E+04
8.E+04
1.E+05
Time (seconds)
Gothic, Conservative
SHEX
Gothic, Realistic
Monte Carlo, Hww,min
SHEX Tsp,max at 34800 seconds

Use of the SHEX analysis for NPSH remains the design bases analysis to define NPSHr margins. Margin between NPSHa and NPSHreff3% is shown above for each containment response. A positive margin exists for the entire long-term time history for all analyses. Additional margin is provided by use of the GOTHIC, Realistic results.

The realistic analysis was completed using a more realistic set of Gothic inputs to define containment response. The significant changes are shown in Table 6.6.9-2. The inputs used typically are exceeded only about 2% of the time based on operating history at MNGP. The peak containment temperature for the SHEX analysis occurs at 34,748 seconds. The SHEX analysis requires 8.6 psig of containment accident pressure to satisfy NPSH requirements for the ECCS pumps.

Table 6.6.9-2 – Inputs Used for Gothic Realistic Analysis Compared to SHEX

Containment Analysis Input	Gothic Realistic	SHEX	Probability of Exceeding*	Comments
Suppression pool temperature	85°F	90°F	1.9%	
Service water temperature	80°F	90°F	1.6%	
Suppression pool volume	69,793 ft^3	68,000 ft^3	98%	Higher volumes are conservative since a larger heat sink is present. Volumes are <69,793 ft^3 only 2% of time
Drywell temperature	118°F	135°F	1.8%	
Relative humidity	100%	100%	N/A	Limiting assumption to minimize non-condensable gas mass
Initial power	2004 MWt	2044 MWt	N/A	2% uncertainty associated with reactor decay heat
Decay heat	1979 ANS 5.1 (1 σ)	1979 ANS 5.1 (2 σ)	N/A	Decay heat uncertainty applied to containment heat load

* This column indicates the probability of exceeding the input value used for the Gothic Realistic analysis.

While there is variation between time of peak containment response and other variables between the different analyses, a comparison to peak CAP credit required at the time when the peak suppression pool temperature exists provides a means of comparing margins. The peak suppression pool temperature for the SHEX analysis occurs at 34,748 seconds. The values shown in Table 6.6.9-3 below are based on the use of an assumed water density at 207°F and use the margins that exist for all curves on Figure 6.6.9-3 at 34,748 seconds.

As discussed above, an evaluation of MNGP included in NEDC-33347P Appendix B, did not include consideration of any single failures, and showed that CAP credit was required for only 4 minutes of the short-term time history. This evaluation is reflected in Table 6.6.9-3 below for comparison since it provides results for the expected equipment condition for a LOCA.

The Monte Carlo, Appendix B results are not provided on Figure 6.6.9-3 since no CAP credit is required for this curve after 600 seconds.

Table 6.6.9-3 - CAP Credit Required for DBA-LOCA Long-term Analysis

	Monte Carlo, App B*	**GOTHIC Realistic**	**GOTHIC Conservative**	**Monte Carlo****	**SHEX**	**Comments**
CAP Credit Required	0 psig	4.4 psig	5.0 psig	6.4 psig	8.6 psig	Comparison to Figure 6.6.9-3 results at 34,800 seconds
Results indicated above are for pressure inside containment required to meet NPSHreff3% except for Monte Carlo App B which is for NPSHr3%.						

* Appendix B of NEDC-33347P (Reference 18). No uncertainties applied to NPSHr and statistical approach results are used based on no single failure considered in analysis.

** Monte Carlo Hww Minimum results of NEDC-33347P (Reference 18)

Figure 6.6.9-4 shows the results of the realistic calculation of NPSHa (Gothic, Realistic) compared to NPSHa determined with the Monte Carlo 95/95 calculation.

Figure 6.6.9-4

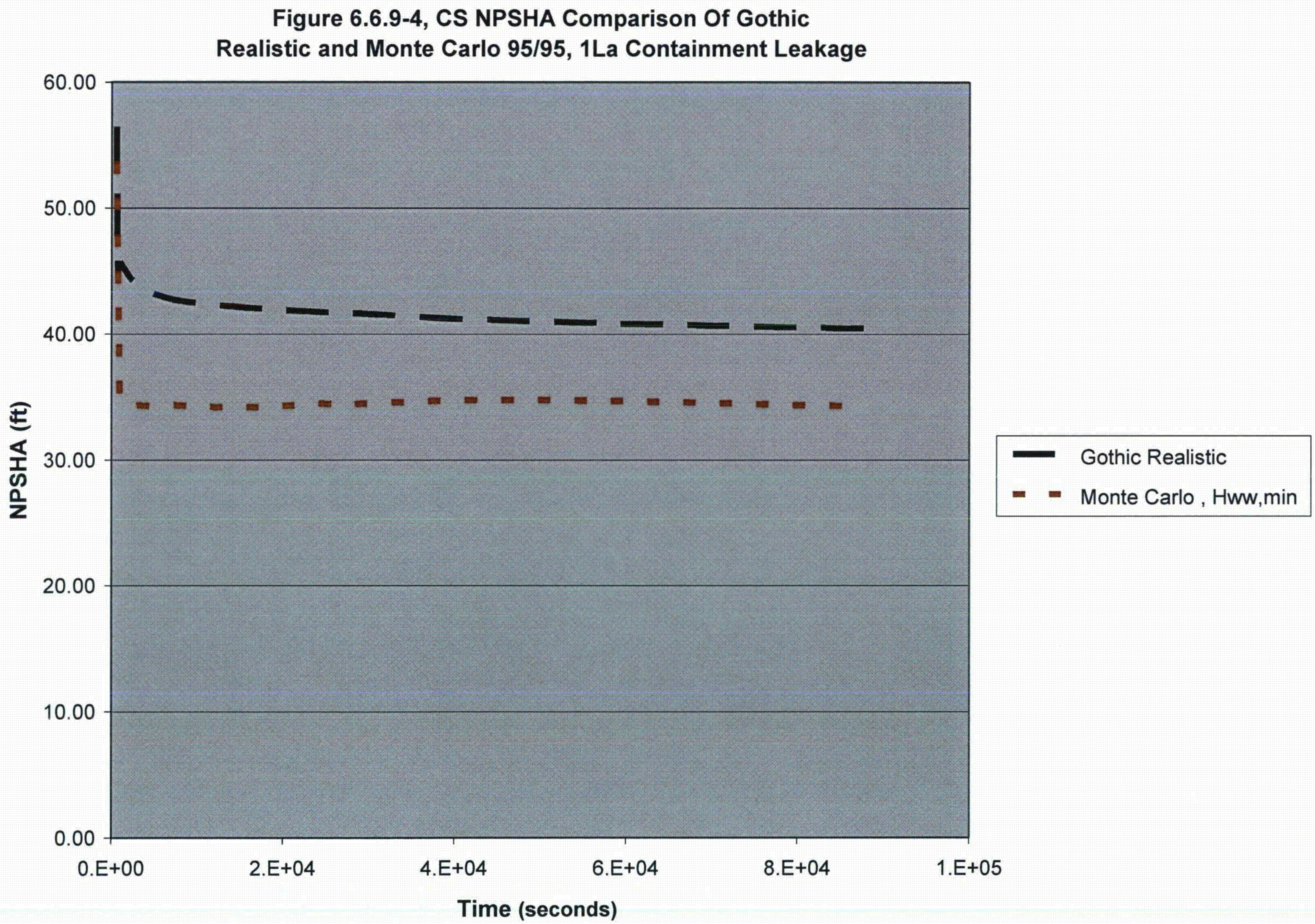


Figure 6.6.9-4, CS NPSHA Comparison Of Gothic Realistic and Monte Carlo 95/95, 1La Containment Leakage
60.00
50.00
40.00
30.00
20.00
10.00
0.00
NPSHA (ft)
0.E+00
2.E+04
4.E+04
6.E+04
8.E+04
1.E+05
Time (seconds)
Gothic Realistic
Monte Carlo , Hww,min

Conclusion

A realistic estimate of NPSH margin is influenced by many factors. Primary among these are the code used to perform the analysis, the conservatism associated with the inputs and consideration of single failure criteria.

SHEX remains the license basis code for MNGP. It is a conservative code and with inputs biased to provide a limiting analysis of NPSH for the ECCS pumps that provides bounding parameters for the assessment of the ability of these pumps to perform their required function.

Monte Carlo, Hww Minimum analysis also used SHEX to evaluate containment response. In this analysis, inputs were varied to provide a greater than 95/95 evaluation of containment response for the assessment of CAP credit.

GOTHIC Conservative uses the same inputs as SHEX with the exception of the use of a variable K-value for RHR heat exchanger performance. The use of a variable K-value is discussed in Reference 1, Enclosure 5, Section 2.6.1.1.1. This increases the heat exchanger K-value as fluid process temperature increases. GOTHIC is also a more realistic code that has been benchmarked as shown here against SHEX results.

GOTHIC Realistic varied selected inputs shown in Table 6.6.9-2 to use values that are met 98% of the time at MNGP.

Monte Carlo, App B used a statistical set of inputs, assumed offsite power is available and assumed no single failure. If all equipment is available and a statistical set of inputs is used, CAP credit is required only for a few minutes and pump reliability would be assured based on BWROG studies shown in Task 3 (Reference 11). Application of pump uncertainties is not used in these results.

As shown in Table 6.6.9-3, a large range of NPSH margins is possible. The realistic results for use of **Monte Carlo, App B** show that the expected conditions with all equipment available for plant response would require credit for only a minimal amount of containment accident pressure. The **GOTHIC Realistic** results show that with the minimum complement of equipment assumed for an accident analysis and the use of inputs that bound plant conditions for 98% of plant operational history that CAP credit required is about 50% of that required by the deterministic SHEX analysis.

6.6.10 Assurance of Pump Operability for Total Time Required

The necessary mission time for a pump using containment accident pressure should include not only the duration of the accident when the NPSH margin may be limited, but any additional time needed for operation of the pump after recovery from the accident when the pump is needed to maintain the reactor or containment, or both, in a stable, cool condition but at a much greater NPSH margin. This additional time is usually taken as 30 days.

NSPM Response to 6.6.10

The mission time used for the evaluation of the DBA-LOCA was 30 days. Other events were evaluated until CAP credit was no longer required to mitigate the event. Figures 6.6.2-1, 6.6.2-2 and 6.6.2-3 indicate the changes in duration of events using CAP credit based on the evaluations conducted herein.

4.0 Probabilistic Risk Assessment (PRA) Considerations

The impact on plant risk if CAP is assumed not present (e.g., postulated pre-existing primary containment failure) in accidents has been previously evaluated by the assessment performed in Reference 1, Enclosure 15, Appendix F. This assessment included an assumed pre-existing leak equivalent to 20 La. The evaluation determined that use of CAP results in a "very small" increase in CDF based on the definition provided in Regulatory Guide 1.174.

SECY 11-0014, Enclosure 1, Section 5.5 (Reference 4) also assessed risk. This assessment noted:

> *"The NRC Office of Nuclear Regulatory Research (RES) has investigated the risk of crediting containment accident pressure for a BWR/3 with a Mark I containment. This analysis was conducted to estimate the increase in CDF that results from relying upon containment accident pressure (CAP) to prevent ECCS pump cavitation. The analysis was limited to the study of all internal initiating events that are currently contained in the Standardized Plant Analysis Risk (SPAR) models (transients and LOCAs). External events were excluded due to lack of detailed cable routing and seismic fragility information. The leak size needed to prevent adequate NPSH margin is plant-specific and is determined through containment thermal-hydraulic analyses. For the plant used in the RES evaluation, the analysis assumed 20 La. Three timeframes were considered: 1) pre-initiator – containment may have a leakage path before an initiating event; 2) upon-initiator – containment may fail to isolate when an initiating event occurs and 3) post-initiator – containment may start to leak after the initiating event occurs.*
>
> *The RES evaluation found that the large LOCA is the only initiating event where the loss of containment integrity leads directly to core damage. These scenarios are dominated by pre-initiator failures of containment. The probability of a pre-initiator containment leak depends on how the containment integrity is determined. This may be done by tracking the amount of nitrogen needed to maintain the containment inerted or oxygen concentration monitoring. Pre-existing leakage probabilities were determined to be sensitive to the interval during which a leak may go undetected ("non-detection interval") and not so sensitive to other parameters. The relationship between this detection interval and pre-existing leakage probability is fairly linear when the leak could be detected monthly or more frequently. The change in CDF due to credit for containment accident pressure for the RES-analyzed plant was found to be very small ($<10^{-6}$/yr, as defined in RG 1.174) when the non-detection interval is one month. This is considered a bounding non-detection interval for an inerted containment."*

The MNGP assessment of the leak size needed to prevent adequate NPSH margin is 30 La based on use of the realistic assessment of containment response shown in Section 6.6.7 above.

NSPM has developed and implemented an on-line leakage rate test procedure that determines a containment leakage rate during power operation. La is the TS acceptable leakage rate of 7.6 scfm. An on-line leakage rate test will be performed at the beginning of operating cycles to ensure that no unacceptable non-detected leakage rate exists. Leakage rates in excess of the procedure acceptance criteria will be assessed via the Corrective Action Process.

There are also a number of inputs available to the control room operators during normal operation that would signal an increase in the containment leak rate. Normal containment monitoring capabilities described in Section 6.6.7 above provide the ability to ensure that significant increases in containment leakage are identified well before a leakage rate occurs that would challenge ECCS pump NPSHr. Continuous monitoring of leakage is provided by existing procedural controls. This supports the conclusions of the NRC risk assessment to ensure that use of CAP results in a "very small" increase in CDF.

5.0 CONCLUSION

This enclosure demonstrates that there is adequate margin for the RHR and CS pumps to perform their design functions when uncertainty is applied to the required NPSH for the DBA-LOCA. In addition to the application of uncertainties on the pump NPSH required values assuming EPU conditions; conservative assumptions of post-accident conditions were considered in the calculation of the NPSHa, including: worst single failure, pool temperature maximized, calculated suppression pool level response, pump run-out flow and other conservatisms listed in Table 4 of SECY 11-0014, Enclosure 1.

For special events such as ATWS, Station Blackout (SBO), and Appendix R Fire, NSPM has demonstrated that sufficient CAP is available for these events to be successfully mitigated.

- For ATWS, CAP is unchanged from results shown in Reference 16 with the exception of the loss of offsite power event which is shown in Section 6.6 above, sufficient margin remains.
- For SBO, CAP is unchanged from results shown in Reference 16.
- The Appendix R events described herein satisfy the SECY 11-0014 guidance. For Appendix R events, NSPM will be providing further analysis in the near future to demonstrate that MSOs associated with an Appendix R fire will not affect the conclusion that sufficient CAP will be available for safe shutdown of MNGP following an Appendix R fire event.

Therefore, NSPM has concluded that use of CAP is justified and available during both DBA-LOCA and special events. The analyses above demonstrate the following conclusions that support the overall conclusion of CAP acceptability:

- Margin exists for NPSHreff during that portion of time when the core is reflooded and for the entire period after the pumps have been throttled to support long-term operation.
- The CS pumps may operate from 6 minutes after the event until 10 minutes after the event with NPSHa < NPSHreff if the pumps have not been throttled. Pump flow capacity during this time remains at greater than twice the flow rate required to meet the definition of adequate core cooling.
- A procedure has been developed to monitor for containment leakage that could challenge the ability to meet NPSHreff. Adequate indication exists with normal operator rounds, annunciators and computer alarms to be able to detect significant containment leakage on a continuous basis. The use of CAP will therefore result in a "very small" increase in CDF as defined by RG 1.174.
- Use of CAP does not challenge the accepted definition of defense-in-depth. (References 4 and 6)

- The evaluation of CAP includes the following:
  - the use of conservative inputs that minimize calculated value of NPSHa
  - consideration of NPSHreff as required by SECY-11-0014, Enclosure 1 for DBA-LOCA
  - use of the high end of the uncertainty range for assessment of NPSHreff
  - operating procedural guidance to ensure the operators do not inappropriately reduce containment pressure when needed to support NPSHr
  - operating procedure guidance to identify if NPSHr limits are being approached

The MNGP ECCS pumps can reliably perform their required design functions to mitigate the consequences of accidents and events for the required mission time while using appropriate uncertainties defined for NPSHreff for DBA-LOCA and NPSHr for other events. The ECCS pumps meet the requirements of SECY-11-0014, Enclosure 1.

6.0 REFERENCES:

1. Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "License Amendment Request: Extended Power Uprate (TAC MD9990)," L-MT-08-052, dated November 5, 2008. (ADAMS Accession No. ML083230111)

2. Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "License Amendment Request: Maximum Extended Load Line Limit Analysis Plus," TAC ME3145, L-MT-10-003, dated January 21, 2010. (ADAMS Accession No. ML100280558)

3. Letter from J G Giitter (NRC) to T J O'Connor (NSPM), "Subject: Monticello Nuclear Generating Plant - Linking of the Proposed Extended Power Uprate Amendment and the MELLLA+ Amendment (TAC NOS. MD9990 AND ME2449)," dated November 23, 2009. (ADAMS Accession No. ML093160816)

4. SECY 11-0014, Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents, dated January 31, 2011. (ADAMS Accession No. ML102780586)

5. Letter from E J Leeds (NRC) to T J O'Connor (NSPM), "Subject: Monticello Nuclear Generating Plant – Revised Schedule for Review of Extended Power Uprate Amendment Application (TAC No. MD9990)," dated October 1, 2009. (ADAMS Accession No. ML092600850)

6. Staff Requirement Memorandum from Annette L. Vietti-Cook to R. W. Borchardt, Subject: Staff Requirements – SECY-11-0014 – Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents, dated March 15, 2011. (ADAMS Accession No. ML110740254)

7. Not Used

8. Not Used

9. E12.5.1959, Revision 0, "BWROG Task 1 – CFD Report and Combined NPSHr Uncertainty for Monticello RHR CVDS Pump," dated August 2012.

10. BWROG-TP-12-011, Revision 0, "Task 2 - Equation for Pump Speed Correction (CVDS Pump)," dated August 2012.

11. E12.5.1911, Revision e, "Task 3 – Pump Operation at Reduced NPSHa," dated August 2012.

12. BWROG-TP-12-012, Revision 0, "Task 4 - Operation in the Maximum Erosion Rate Zone (CVDS Pump)," dated August 2012.

13. BWROG-TP-12-013, Revision 0, "Task 5 - Effects of Non-Condensable Gases on Seals (CVDS Pump)," dated August 2012.

14. BWROG-TP-12-014, Revision 0, "Task 6 – NPSHr Test Instrument Inaccuracy Effect on Published Results (CVDS Pump)," dated August 2012.

15. Letter from J C Paige (NRC) to M. Nazar (Florida Power & Light), "Subject:, Turkey Point Units 3 and 4 – Issuance of Amendments Regarding Extended Power Uprate (TAC NOS. ME4907 and ME4908)," dated June 15, 2012. (ADAMS Accession No.ML11293A365)

16. Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "Monticello Extended Power Uprate: Response to NRC Containment and Ventilation Review Branch (SCVB) Requests for Additional Information (RAIs) dated July 2, 2009 and July 14, 2009 (TAC MD9990)," L-MT-09-073, dated August 21, 2009 (ADAMS Accession No.ML092430088)

17. Not Used

18. NEDC-33347P, "Containment Overpressure Credit for Net Positive Suction Head (NPSH)," January 2008. (ADAMS Accession No. ML080520268)

19. Not Used

20. E12.5.1977, Revision 0, "Monticello Core Spray Pump – DBA-LOCA Analysis," dated September 24, 2012.

21. Commission Voting Record, Decision Item SECY-11-0014, "Title: Use of Containment Accident Pressure In Analyzing Emergency Core Cooling System And Containment Heat Removal System Pump Performance In Postulated Accidents," dated March 15, 2011. (ADAMS Accession No. ML110740604)

22. Letter from T J O'Connor (NSPM) to Document Control Desk (NRC), "Monticello Extended Power Uprate: Response to NRC Containment and Ventilation Review Branch (SCVB) Request for Additional Information (RAI) dated March 19, 2009, and March 26, 2009 (TAC MD9990)," L-MT-09-048, dated July 13, 2009. (ADAMS Accession No. ML092170404)