Exelon® Nuclear

Exelon Nuclear
200 Exelon Way
Kennett Square, PA 19348

www.exeloncorp.com

10 CFR 50.54(f)

TMI-09-107
November 9, 2009

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

Three Mile Island Nuclear Station, Unit 1
Renewed Facility Operating License No. DPR-50
NRC Docket No. 50-289

Subject: Response to Request for Additional Information Regarding Generic Letter 2004-02

References:

(1) Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004

(2) Letter from K. R. Jury (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Exelon/AmerGen Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated March 7, 2005

(3) Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Exelon/AmerGen Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 1, 2005

(4) Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Exelon/AmerGen Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated December 28, 2007

(5) Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Response to Request for Additional Information Regarding NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated July 27, 2005

(6) Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Three Mile Island, Unit 1 Response to Request for Additional Information Related to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"," dated November 10, 2008

A116
NRR

(7) Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Supplemental Information to the Three Mile Island, Unit 1 Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"," dated February 12, 2009

(8) Letter from P. Bamford (U.S. Nuclear Regulatory Commission) to C. Pardee (Exelon Generation Company, LLC), "Three Mile Island Nuclear Station, Unit 1 -Request for Additional Information Regarding Generic Letter 2004-02, Supplemental Response," dated July 23, 2009 (TAC No. MC4724)

The U.S. Nuclear Regulatory Commission (USNRC) issued Generic Letter (GL) 2004-02 (Reference 1) on September 13, 2004, requesting that addressees perform an evaluation of the emergency core cooling system (ECCS) and building spray system (BSS) recirculation functions in light of the information provided in the GL and, if appropriate, take additional actions to ensure system function. Additionally, the GL requested addressees to provide the USNRC with a written response in accordance with 10 CFR 50.54(f). The request was based on identified potential susceptibility of the pressurized water reactor recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of ECCS or BSS and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and BSS recirculation and containment drainage.

Reference 2 provided the initial AmerGen Energy Company, LLC, now Exelon Generation Company, LLC (Exelon), response to the GL followed by supplemental responses in References 3, 4, and 7. References 5 and 6 responded to requests for additional information regarding the Reference 2 and 4 responses to the GL, respectively.

During the review of the Reference 6 submittal, the USNRC identified various issues that required additional clarification as detailed in the Reference 8 RAIs. Additionally, the NRC staff requested, via email from P. Bamford to W. Croft dated May 27, 2009, Three Mile Island, Unit 1 (TMI, Unit 1) provide a Safety Case that describes how the measures credited in the TMI, Unit 1 licensing basis demonstrate compliance with the applicable USNRC regulations as discussed in GL 2004-02.

The USNRC staff conducted three (3) public meetings (teleconferences) to discuss these remaining issues with TMI, Unit 1 on August 11, 2009, September 23, 2009, and October 19, 2009. The purpose of these meetings was for Exelon to discuss its proposed path forward for resolving the remaining issues regarding GL 2004-02 at TMI, Unit 1. A written response from Exelon was requested by the USNRC within 90 days of the August 11, 2009, public meeting (teleconference).

The Exelon Safety Case is provided in Attachment 1 to this letter The Exelon responses to the RAIs are provided in Attachments 2 and 3 to this letter.

There is one (1) regulatory commitment provided in this submittal, shown in Attachment 4. The commitment states that within 90 days of issuance of the final USNRC decision on the acceptability of WCAP-16710-P, and its related supplemental information, TMI, Unit 1 will report how it has addressed the set of 10 questions titled "Issues Generic to Westinghouse Debris Generation Testing," issued in the USNRC RAI dated July 23, 2009 (Reference 8).

In addition to the RAI responses, and the associated commitment, TMI, Unit 1 is providing revised Tables 14 and 15 associated with References 4 and 7, in Attachment 5. The revised tables provide the current data from the TMI, Unit 1 NPSH Margin Calculation and include the newly analyzed configuration (Case V- one operating LPI pump and two operating BS pumps) requested in the attached RAI responses (USNRC Question 8, Attachment 2). In the NPSH Margin Calculation revision, the limiting (minimum excess NPSH) margin remains 0.1 ft-H_2O. Revised Tables 14 and 15 are being provided in Attachment 5 to this letter for use during the continuing USNRC staff review, and supersede previous submittal of these tables.

This information is being provided in accordance with 10 CFR 50.54(f).

If you have any questions or require additional information, please contact Wendi Croft at (610) 765-5726.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 9th day of November 2009.

Respectfully,

Pamela B. Cowan

Pamela B. Cowan
Director - Licensing and Regulatory Affairs
Exelon Generation Company, LLC

Attachment (1) Three Mile Island, Unit 1, Response to Request for Additional Information Related to USNRC Generic Letter 2004-02, Safety Case

(2) Three Mile Island, Unit 1, Response to Request for Additional Information Related to USNRC Generic Letter 2004-02, Questions Specific to TMI, Unit 1

(3) Three Mile Island, Unit 1, Response to Request for Additional Information Related to USNRC Generic Letter 2004-02, Questions Generic to Westinghouse Debris Generation Testing

(4) Three Mile Island, Unit 1, Response to Request for Additional Information Related to USNRC Generic Letter 2004-02, Summary of Regulatory Commitments

(5) Three Mile Island, Unit 1, Response to Request for Additional Information Related to USNRC Generic Letter 2004-02, Revised Tables 14 and 15

cc: Regional Administrator, USNRC Region I
Project Manager, NRR, USNRC – Three Mile Island, Unit 1
Senior Resident Inspector, USNRC – Three Mile Island, Unit 1
R. R. Janati, Commonwealth of Pennsylvania

ACRONYMS

Used for Attachments 1-5

Alion	Alion Science and Technology, LLC
BS	Building Spray
BWST	Borated Water Storage Tank
CFD	Computational Fluid Dynamics
DDTS	Drywell Debris Transport Study
DH	Decay Heat
DP	Differential Pressure
EQ	Environmentally Qualified
GL	Generic Letter
GL 2004-02 SR	TMI, Unit 1 GL 2004-02 Supplemental Response dated 12/28/07 (Reference 1)
GR	Guidance Report
LANL	Los Alamos National Labs
LB LOCA	Large Break LOCA
LDFG	Low-Density Fiberglass
LOCA	Loss-of-Coolant Accident
LPI	Low Pressure Injection
MSDS	Material Safety Data Sheet
NPSH	Net Positive Suction Head
NPSHa	Net Positive Suction Head available
NPSHr	Net Positive Suction Head required
NPSHm	Net Positive Suction Head margin
OTSG	Once Through Steam Generator
PWR	Pressurized Water Reactor
PWROG	Pressurized Water Reactor Owners Group
PZR	Pressurizer
RAI	Request for Additional Information
RCP	Reactor Coolant Pumps
RCS	Reactor Coolant System
SE	Safety Evaluation
TMI, Unit 1	Three Mile Island, Unit 1
TPI	Transco Products, Inc
UNM	University of New Mexico
USNRC	United States Nuclear Regulatory Commission
ZOI	Zone-of-Influence
*X*D	*X* No. of Diameters related to ZOI (e.g., 7D or 17D)

REFERENCES
Used for Attachments 1-5

1. Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Supplemental Response to NRC Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," dated December 28, 2007

2. Letter from P. Bamford (U.S. Nuclear Regulatory Commission) to C. Pardee (Exelon Generation Company, LLC), "Three Mile Island Nuclear Station, Unit 1 -Request for Additional Information Regarding Generic Letter 2004-02, Supplemental Response," dated July 23, 2009

3. Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Three Mile Island, Unit 1 Response to Request for Additional Information Related to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors"," dated November 10, 2008

4. Letter from P. B. Cowan (Exelon Generation Company, LLC and AmerGen Energy Company, LLC) to U.S. Nuclear Regulatory Commission, "Supplemental Information to the Three Mile Island, Unit 1 Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors"," dated February 12, 2009

5. WCAP-16710-P, Revision 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants" dated October 2007

6. Letter from W. Ruland (U.S. Nuclear Regulatory Commission) to A. Pietrangelo (Nuclear Energy Institute) "Revised Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors" dated March 28, 2008

7. NEI 04-07, Revision 0, Volume 1, "Pressurized Water Reactor Sump Performance Evaluation Methodology," dated December 2004

8. NEI 04-07, Revision 0,Volume 2, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02,"dated December 6, 2004

9. Letter from S. Smith (U.S. Nuclear Regulatory Commission) to M. Scott (U.S. Nuclear Regulatory Commission), "Staff Observations of Testing For Generic Safety Issue 191 During March 8 and March 9 Trip to the Alion Hydraulics Laboratory," dated June 12, 2007

10. NUREG/CR 6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," dated February 2003

<u>ATTACHMENT 1</u>

Three Mile Island, Unit 1

Response to Request for Additional Information Related to

USNRC Generic Letter 2004-02

Safety Case

Attachment 1
Three Mile Island, Unit 1
Safety Case Related to Generic Letter 2004-02

USNRC Request: Safety Case

This safety case should describe, in an overall or holistic manner, how the measures credited in the TMI, Unit 1 licensing basis demonstrate compliance with the applicable NRC regulations as discussed in GL 2004-02. This safety case should inform your approach to responding to the RAIs, as well as the staff's review of the RAI responses. As appropriate, it may describe how you have reached compliance even in the presence of remaining uncertainties.

TMI, Unit 1 Response:

The recirculation functions for the ECCS and the BS System for TMI, Unit 1 continue to be in compliance with the regulatory requirements listed in the applicable Regulatory Requirements section of the subject GL under debris loading conditions. The response to USNRC-requested information by TMI, Unit 1 in Reference 1, supported by additional information provided in References 3, 4, and this current submittal, describe the completed corrective actions that ensure this compliance.

Conservatisms

Listed below are some of the conservatisms, which TMI, Unit 1 has incorporated into its methodology for meeting GL 2004-02:

1. TMI, Unit 1 utilized a bounded loading strategy for testing inputs. The debris quantities for each major debris category were calculated for the limiting break location for the specific debris type. The maximum insulation debris was generated by a hot leg break, the maximum coating debris (excluding structural steel) was generated by a cold leg break, and the maximum coating debris from structural steel was generated by a hot leg break. The debris quantities from the limiting break locations were combined to provide a bounding debris load.

2. TMI, Unit 1 analyses assumed that 100% of unqualified coatings will fail and applied a transport fraction of 100% to this debris. The quantity of unqualified coatings was increased approximately 25% over the amount documented at each elevation in containment. Many of the components that are coated with an unqualified coating are not exposed to direct spray which would minimize the transport of the failed coating to the sump.

3. TMI, Unit 1 utilized a 5D ZOI for qualified coatings which is greater than the 4D ZOI recommended by WCAP-16568-P.

4. TMI, Unit 1 utilized a latent debris load of 300 lbs versus a walkdown determined value of approximately 193 lbs. A transport fraction of 100% was applied to latent debris although some surfaces are protected from direct spray by intermediate level floors or other equipment.

5. TMI, Unit 1 utilized a total of 400 ft^2 of tags, tape, and labels versus a walkdown determined value of approximately 332 ft^2. The walkdown report added 25% to the estimated surface area of tags/labels/tape for each of the 3 containment levels outside of the D-Rings. The surface area estimated for the "A" D-Ring was doubled and applied to

the "B" D-Ring. This is conservative as the "A" D-Ring includes the PZR and associated equipment. An additional 25% was added to the estimated surface area inside the D-Rings. A transport fraction of 100% was applied to tags/labels/tape although it would be unlikely that many of the tags would be washed from upper levels of containment to the sump.

6. TMI, Unit 1's minimum 15" submergence of the top hat modules at minimum credited water level is greater than that used in the testing. Testing was conducted at a submergence of approximately 6" above the top hat modules at prototypical plant conditions, and no vortexing was observed for the postulated operating conditions of the TMI, Unit 1 sump strainer design.

7. The TMI, Unit 1 NPSH analysis conservatively applies the full debris load at the start of recirculation. In an actual event, several pool turnovers would be required before the full debris load would be present on the strainer. The TMI containment pool contains approximately 231,000 gallons (30,885 ft^3) at minimum level. At the maximum recirculation flow rate of 8582 gpm, it would take approximately 27 minutes for one pool turnover to occur. In the most limiting case, NPSH margin begins to recover after the first BS pump is secured. The NPSH analysis assumes this pump is secured one hour after initiation of recirculation to allow time for the operator to complete the procedurally required actions to secure the pump. Even in the most limiting case, additional NPSH margin would be available before the full debris bed would be present on the strainer.

8. The TMI, Unit 1 NPSH analysis applies the full impact of the aluminum precipitates as soon as the sump temperature is reduced to 140°F. The full impact is applied even in the maximum cooldown cases where sump temperature is reduced to 140°F within 1 to 6 hours following the start of the event. Although there would be limited time for the aluminum precipitates to form in these cases, the full impact is applied in evaluating the NPSH margin and strainer differential pressure.

<u>Impact of OTSG Replacement</u>

TMI, Unit 1 will replace both steam generators during the fall 2009 refueling outage (T1R18). As part of this effort, the Nukon® insulation on the steam generators will be replaced with RMI. In addition, the Nukon® insulation on the hot legs near the steam generators will also be replaced with RMI. Approximately 160 ft^3 of Nukon® will be removed from the "A" D-Ring and approximately 130 ft^3 will be removed from the "B" D-Ring. The reduction in the Nukon® debris quantity for the "A" D-Ring, which contains the largest amount of Nukon®, is provided in Table I below. Results are provided for both a 17D and 7D ZOI for comparison purposes. Following steam generator replacement, the most significant source of Nukon® insulation inside the D-Ring will be the insulation on the pressurizer in the "A" D-Ring.

Table I: Reduction in Nukon® Insulation from the "A" D-Ring following OTSG Replacement in T1R18

	Quantity of Nukon® Debris Generated 17D ZOI	Quantity of Nukon® Debris Transported to the Sump 17D ZOI	Quantity of Nukon® Debris Generated 7D ZOI	Quantity of Nukon® Debris Transported to the Sump 7D ZOI
Prior to Steam Generator Replacement	682* ft^3	369 ft^3	237 ft^3	199 ft^3 (tested quantity)
After Steam Generator Replacement	523* ft^3	300 ft^3	147* ft^3	100 ft^3

*These values include 60 ft^3 Nukon® added as margin.

The Debris Generation and Transport Analyses have been updated to reflect the changes that will occur as a result of the steam generator replacement. TMI, Unit 1 has not conducted additional debris head loss testing based on the lower debris quantities. The existing head loss test, based on the 199 ft^3 of Nukon® as described in the TMI, Unit 1 Supplemental Response to GL 2004-02 (Reference 1) is bounding for the post-T1R18 condition and remains the test of record. The NPSH Margin Analysis is based on the test results for the 199 ft^3 of Nukon® and has not been updated based on the post-T1R18 condition.

> **NOTE**: Although the Debris Generation and Transport Analyses have been revised to reflect the reduction in the Nukon® debris quantities, the responses to the RAIs contained in this submittal are based on the debris loading prior to steam generator replacement. This was done so that the information provided would be consistent with previous submittals and discussions with the USNRC.

ATTACHMENT 2

Three Mile Island, Unit 1

Response to Request for Additional Information Related to

USNRC Generic Letter 2004-02

Questions Specific to TMI, Unit 1

The USNRC RAI questions specific to TMI, Unit 1 were formatted to correspond to a previous TMI, Unit 1 RAI submittal (Reference 3). Where a previous RAI reference is applicable it is shown in parenthesis (e.g., USNRC Question X (RAI XX)).

USNRC Question 1 (RAI 2)

The NRC staff (the staff) requested that the licensee justify the 60% small fines/40% large pieces size distribution assumed for jacketed low-density fiberglass debris (e.g., Nukon®) generated within a 7D ZOI. This assumption made by the licensee is stated on page 10 of the supplemental response dated December 28, 2007. However, on page 8 of the same response, debris size distribution information presented in Table 2 appears inconsistent with the information on page 10. Specifically, Table 2 indicates that 100% small fines were used within 5D of a break for all Nukon® insulation systems, and that a 60%/40% distribution was used between 5D and 7D. In light of the cited information, please clarify the size distribution assumed for jacketed low-density fiberglass debris generated within a 7D ZOI.

Additionally, as shown in Figure II-2 in Appendix II to the Generic Safety Issue (GSI) -191 Safety Evaluation Report "Confirmatory Debris Generation Analysis," dated December 6, 2004, for ZOIs smaller than 17D (e.g., 7D or a spherical shell from 5D to 7D), a percentage of up to 100% small fines, higher than the 60/40 distribution assumed by the licensee, may be conservatively expected. Thus, the licensee's assumption of a 60%/40% distribution at distances less than 7D from the break location does not appear consistent with the data in Figure II-2 in Appendix II to the safety evaluation, and the staff requested further justification for this assumption in RAI 2. In response to the staff's information request, the licensee stated that results from Westinghouse debris generation testing described in WCAP-16710-P were used to justify the assumed size distribution. The staff is reviewing the methodology used for this testing, and the PWROG is currently in the process of generically responding to the staff's questions on this testing. After the PWROG generically responds to the staff's questions on the Westinghouse ZOI testing, the staff expects the licensee to provide plant-specific justification to resolve this item for TMI-1.

TMI, Unit 1 Response:

Clarification of Size Distribution for Jacketed Nukon® (LDFG) within a 7D ZOI

The size distribution for jacketed Nukon® insulation within a 7D ZOI provided in Table 2 (Reference 1) reflects the size distribution applied in the TMI, Unit 1 Debris Generation Analysis. For jacketed Nukon® insulation within a 5D ZOI, a debris size distribution of 100% small fines was applied. This size distribution was also applied to unjacketed Nukon® insulation within a 5D ZOI. For jacketed Nukon® insulation within the 5D to 7D ZOI, a size distribution of 60% small fines and 40% large pieces was applied. This size distribution is also reflected in Table 2 of Reference 3.

The USNRC noted that the information in Table 2 (Reference 1) appears inconsistent with the information provided in response to Issue 3c.1 (Reference 1, page 10). The information in the previous response to Issue 3c.1 (Reference 1) briefly described the two approaches that were incorporated in the Debris Generation and Transport Analysis. Initially, a 17D ZOI was applied to Nukon® in the first versions of the Debris Generation Analysis. Later, the 7D ZOI was applied to jacketed Nukon® insulation based on a comparison of the TMI, Unit 1 insulation system to the insulation tests reported in WCAP-16710-P (Reference 5). Both approaches, 17D ZOI and 7D ZOI, are still included in the Debris Generation Analysis.

Discussion of Assumption of 60%/40% Distribution within 5D-7D ZOI

Based on a review of the results of insulation tests reported in WCAP-16710-P (Reference 5), an assumption of 100% small fines for Nukon® insulation (jacketed and unjacketed) within a 5D ZOI combined with a distribution of 60% small fines and 40% large pieces beyond 5D (i.e., from 5D to 7D for jacketed Nukon and from 5D to 17D for unjacketed Nukon®) was considered to be conservative (Table II, below). As noted in USNRC Question 1, above, the size distributions assumed in the TMI, Unit 1 analysis are not completely consistent with the information provided in the SE (Reference 8). For ZOIs smaller than 17D, (e.g., 7D or a spherical shell from 5D to 7D), the USNRC noted that data in Appendix II of the SE (Reference 8) indicates a percentage of up to 100% small fines may be conservatively expected.

In response to USNRC Question 1, above, the Nukon® insulation sources for the limiting break location were regrouped into two categories (Table III, below). All jacketed Nukon® insulation (to which a 7D ZOI was applied) was grouped into one category and a size distribution of 100% small fines was assumed consistent with Appendix II of the SE (Reference 8). All unjacketed Nukon® insulation (to which a 17D ZOI was applied) was grouped into a second category and a size distribution of 60% small fines and 40% large pieces was assumed. The transport fractions of 100% for small fines and 15% for large pieces were applied consistent with Table 2 (Reference 3). The net result is a reduction in the quantity of Nukon® debris transported to the sump from 199 ft^3 to 187 ft^3.

Based on a comparison of the two methods, the size distribution provided in Table 2 (Reference 3) is slightly more conservative (results in larger amount of debris at the sump) when compared to the result based on the information provided in the SE (Reference 8).

Table II: Nukon® Fiber Locations, Characteristics and Transport Fractions as Provided in Previous Response to RAI 4 (Table 2, Reference 3)

Break Location w/top of Hot Leg Boundary	ZOI Placed at Break Location	Components Affected	Total Fiber Generated (ft³)	Size[1]	% of Total Nukon® Destroyed	Transport Fraction	Nukon® Transported to the Sump (ft³)
5D	5D	OTSG Top Head, Hot Leg Top Loop	125.19	Small Fines	100%	100%	125.19
5D	7D – 5D	PZR middle section (Shadowed by RCP)	32.7	Large Pieces	40%	15%	1.96
				Small Fines	60%	100%	19.62
5D	17D	PZR Top and Bottom Heads (no shadowing credited)	37.91	Large Pieces	40%	15%	2.27
				Small Fines	60%	100%	22.75
5D	17D	PZR Spray Line	1.08+1.30+4.81	Large Pieces	40%	15%	0.43
				Small Fines	60%	100%	4.31
5D	17D	OTSG "A" Manway	2.24+2.24	Large Pieces	40%	15%	0.27
				Small Fines	60%	100%	2.69
5D	17D	OTSG "A" Handhole	0.77+0.77	Large Pieces	40%	15%	0.09
				Small Fines	60%	100%	0.92
5D	17D	Hot Leg "A" Blanket	27.37	Large Pieces	40%	15%	1.64
				Small Fines	60%	100%	16.42
5D	17D	PZR Surge Line	1.03	Large Pieces	40%	15%	0.06
				Small Fines	60%	100%	0.62
Total Nukon® Generated (ft³)			**237.41**				
Total Nukon® Transported to the Sump (ft³)							**199.26**

[1] Table 2, Reference 3 originally listed the "Small Fines" as "Fines"

Table III: Revised Nukon® Fiber Locations, Characteristics and Transport

Components Affected	Total Fiber Generated (ft^3)	Size	% of Total Nukon® Destroyed	Transport Fraction	Nukon® Transported to the Sump (ft^3)
Jacketed Nukon® Insulation – 7D ZOI Applied					
Hot Leg "A"	57.12*	Small Fines	100%	100%	57.12
PZR middle section	32.7	Small Fines	100%	100%	32.7
Unjacketed Nukon® Insulation – 17D ZOI Applied					
OTSG "A" Top	62.04*	Large Pieces	40%	15%	3.72
		Small Fines	60%	100%	37.2
OTSG "A" Outlet Nozzle	6.03*	Large Pieces	40%	15%	0.36
		Small Fines	60%	100%	3.62
PZR Top and Bottom heads	37.91	Large Pieces	40%	15%	2.27
		Small Fines	60%	100%	22.75
PZR Spray Line	1.08+1.30 +4.81	Large Pieces	40%	15%	0.43
		Small Fines	60%	100%	4.31
OTSG "A" Manway	2.24+2.24	Large Pieces	40%	15%	0.27
		Small Fines	60%	100%	2.69
OTSG "A" Handhole	0.77+0.77	Large Pieces	40%	15%	0.09
		Small Fines	60%	100%	0.92
Hot Leg "A" Blanket	27.37	Large Pieces	40%	15%	1.64
		Small Fines	60%	100%	16.42
PZR Surge Line	1.03	Large Pieces	40%	15%	0.06
		Small Fines	60%	100%	0.62
Total Nukon® Generated (ft^3)	237.41				
Total Nukon® Transported to the Sump (ft^3)					**187.19**

* Included in 5D ZOI in Table II

<u>USNRC Question 2 (RAI 4)</u>

The staff requested that the licensee provide the post-transport size distributions for the reflective metal insulation, and jacketed and unjacketed Nukon® insulation debris with justifications for the transport fractions (e.g., erosion effects). The GSI-191 Safety Evaluation Report, "Pressurized Water Reactor Sump Performance Evaluation Methodology," states that erosion may be neglected if the licensee follows the baseline methodology and considers transport fractions for large debris pieces. The staff noted one apparent inconsistency in the information that was provided regarding the transport of large pieces of fiberglass. Specifically, the information provided in Table 2 of the RAI response indicates that a transport percentage of

15% for large pieces was assumed; however, a note to Table 2 indicates that large pieces are not transported to the sump, and that erosion is also not considered. Further, the licensee has not provided adequate justification (e.g., computational fluid dynamics and experimental debris transport metrics, test results, etc.) for the 15% assumption. The staff requests that the licensee clarify the transport fraction assumed for large pieces of fiberglass debris, state whether it transports as intact large pieces or eroded fines, and provide the technical basis used to derive this transport fraction. Please also clarify whether the transported large debris was modeled in the head loss testing conducted for TMI-1 and identify its prepared size distribution.

TMI, Unit 1 Response:

Clarification of Assumption for Transport of Large Debris Pieces

The USNRC Question 2, above, states that the information in Table 2 (Reference 3) is not consistent with the information provided in Note 2, listed under the same Table. Specifically, Note 2 states that large pieces are not transported to the sump, whereas the information in the Table indicates a 15% transport fraction for large pieces.

Note 2 under Table 2 (Reference 3) was taken from a report that evaluated the applicability of WCAP-16710-P (Reference 5) to the Nukon® insulation systems used on components in the TMI, Unit 1 RCS. The applicability review provided a comprehensive review of WCAP-16710-P (Reference 5) and provided recommendations for ZOIs and damage level for Nukon® insulation. This applicability review included the recommendation to assume large pieces of Nukon debris would not be transported to the sump.

The information contained within Table 2 (Reference 3) was taken from the TMI, Unit 1 Debris Generation Calculation. Although the applicability report recommended that large pieces could be assumed to not transport to the sump, the Debris Generation Calculation applied a 15% transport fraction for large pieces as identified in Table 2 (Reference 3) and Note 2, Table 2 (Reference 3) is not applicable.

Basis for 15% Transport Fraction Applied to Large Pieces of Nukon® Debris

A transport fraction of 15% for large pieces was determined in the TMI, Unit 1 Debris Generation Calculation. The CFD model showed that turbulence in the pool is not high enough to suspend large pieces of Nukon® throughout most of the pool. Since the large pieces of Nukon® would settle in most of the pool, the tumbling velocity is the predominant means of transport. The large pieces of Nukon® were assumed initially to be uniformly distributed between the locations where it would be destroyed and the sump (Figure 1, below). This area was overlaid on top of the plot showing the tumbling velocity and flow vectors to determine the recirculation transport fraction. The area where large pieces of Nukon would transport is approximately 15% (856/5582 ft^3) of the total initial distribution area (Figure 2, below).

Additional description of the transport analysis was provided in the previous response to RAI 5 (Reference 3).

Modeling of Large Debris in Head Loss Testing

The 15% of large pieces assumed to be transported was included in the total quantity of Nukon® transported to the sump as identified in Table 2 (Reference 3). This total quantity of Nukon® (199 ft^3) was used to determine the quantity of debris to be used in the head loss testing based on the appropriate scaling factors. All Nukon® debris used in the head loss test was prepared in the same manner, regardless of whether it was assumed to be transported as small or large pieces. The debris preparation procedure was described in the previous response to RAI 7 (Reference 3) and additional information is provided in the response to USNRC Question 3, below.

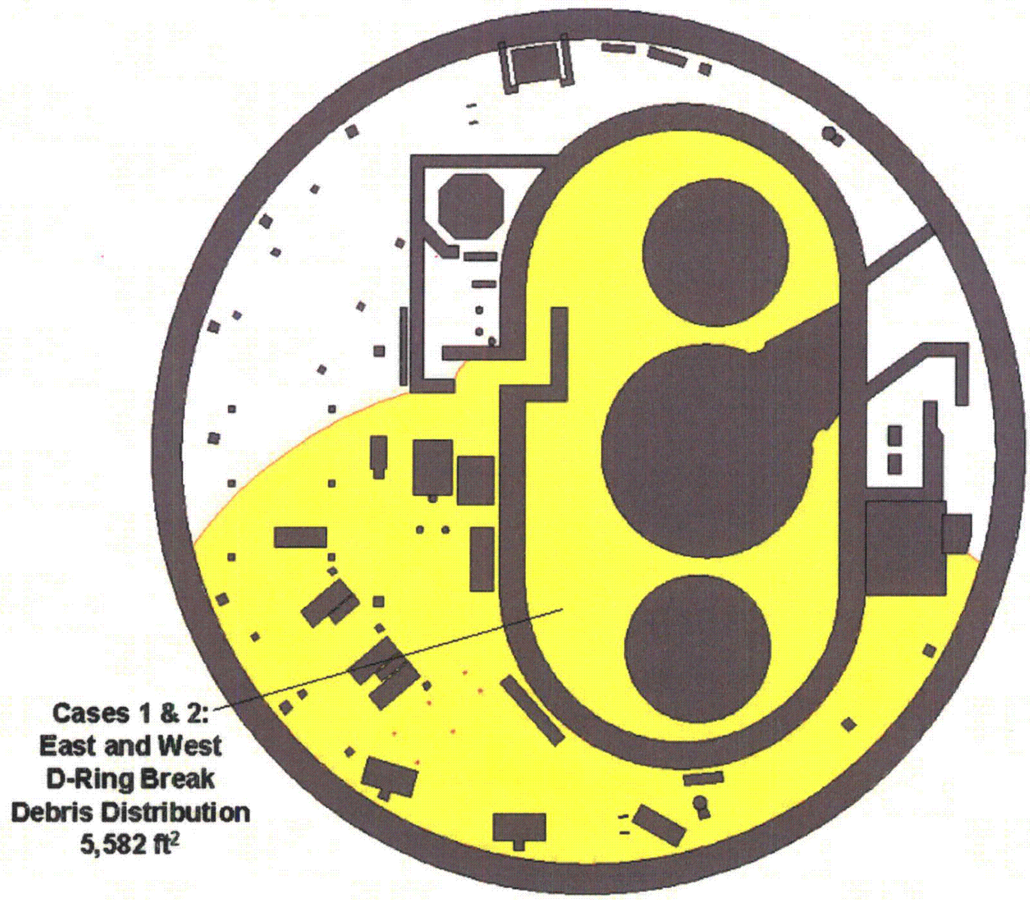


Figure 1: Distribution of small and large piece debris in lower containment (yellow area)

Figure 2: Floor area where large pieces of Nukon® would transport to the sump

USNRC Question 3 (RAI 7)

The staff requested additional information on the size distribution of fibrous debris used during testing and requested that the licensee provide information that justified the fibrous debris used during testing. The licensee stated that small fines were used. However, the staff guidance requests that the fibrous debris sizing be further broken down into small and fine debris categories. Current staff guidance states that thin bed testing should be conducted with only fine (easily suspendable) fiber (until all predicted fine fibers have been added to the test). The licensee response to the RAI did not address the referenced guidance. It is possible, but unlikely, that a thin bed test conducted in accordance with the latest guidance could result in higher head losses than were attained during the TMI-1 testing. It is more likely that the full load test, if conducted with prototypically sized fiber could have resulted in higher head losses. The licensee should provide information that justifies that the head losses attained during testing were not influenced non-conservatively by the sizing of the fibrous debris used during testing.

<u>TMI, Unit 1 Response:</u>

Response Summary:

The USNRC March 2008 guidance (Reference 6) indicated that the use of excessively coarse fibrous debris in testing will likely result in non-conservative results. Compared to the debris size distributions assumed in the TMI, Unit 1 debris analyses, the test debris preparation procedure resulted in debris sizes that were biased toward the smaller debris size classes described in NEI 04-07 (Reference 7). Test photographs and records provide evidence that the material transported to the strainers was not excessively coarse. Therefore, it is concluded that the TMI, Unit 1 test results were not influenced non-conservatively by the sizing of the fibrous debris used during testing.

Although the TMI, Unit 1 strainer tests were conducted prior to the USNRC March 2008 guidance (Reference 6), the extensive test program conducted by TMI, Unit 1 demonstrated that the thin bed head losses are not controlling for the TMI, Unit 1 strainer design. The test preparation procedure and test methodology utilized for TMI, Unit 1 testing did result in covering the strainer with a mat of fine fibers as shown in the photographs provided below. In all cases, the head losses for the thinner beds were less than the head losses measured for the full load tests.

Response Details:

<u>I. Discussion of Full Load Test:</u>

<u>I.A Discussion of LDFG Debris Size Distribution Assumed in the Debris Analyses:</u>

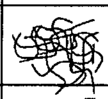
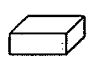
As noted in Table 2 (Reference 1), the debris size distribution for Nukon® assumed in the TMI, Unit 1 debris analysis included small-fines and large pieces. The TMI, Unit 1 analysis application of "small-fines" is consistent with the NEI 04-07 GR (Reference 7) which is fibers and small pieces of sufficient size to pass through grating and readily transport. The division between the small-fines and large pieces is nominally 4". Regarding the further classification and size distribution of "small-fines", there is no specific definition or guidance in the NEI GR (Reference 7), associated SE (Reference 8), or the USNRC March 2008 guidance (Reference 6). However, Appendix II, Section II.3.1.1 of the SE (Reference 8) stated:

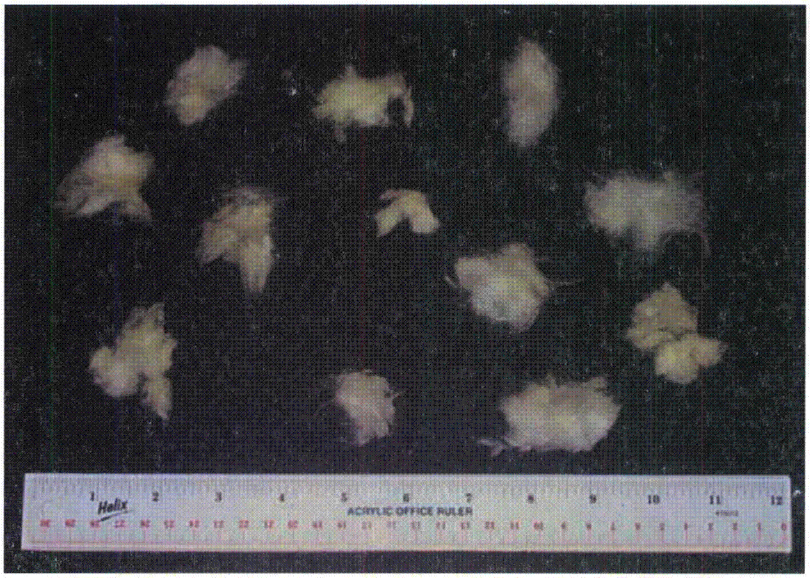
> "In the debris generation tests conducted during the DDTS, 15 to 25 percent of the debris from a completely disintegrated TPI fiberglass blanket was classified as nonrecovereable. The nonrecovereable debris either exited the test chamber through a fine-mesh catch screen or deposited onto surfaces in such a fine form that it could not be collected by hand (it was collected by hosing off the surfaces). Therefore, it would be reasonable to assume that 25 percent of the baseline small fine debris

(F_{ZOI}) is in the form of individual fibers and that the other 75 percent is in the form of small-piece debris."

Small-fines have been considered to be Class 1 through 6 as described in NUREG/CR-6808 Table 3-2 (From Reference 10, reproduced as Table IV, below). Based on the assumed size definition of less than 4" nominally, Classes 1 through 6 represent "small-fines." For illustration, Class 5 debris is shown in Photograph 1 (From Reference 10, reproduced as Photograph 1, below), below, and represents fiberglass fragments that are defined as "transportable" as they tumble and slide along the floor.

Table IV: NUREG/CR-6808 Table 3-2, Size Classification Scheme for Fibrous Debris

No.	Description	
1		Very small pieces of fiberglass material; "microscopic" fines that appear to be cylinders of varying L/D.
2		Single, flexible strands of fiberglass; essentially acts as a suspending strand.
3		Multiple attached or interwoven strands that exhibit considerable flexibility and that, because of random orientations induced by turbulent drag, can exhibit low settling velocities.
4		Fiber clusters that have more rigidity than Class 3 debris and that react to drag forces as a semi-rigid body.
5		Clumps of fibrous debris that have been noted to sink when saturated with water. Generated by different methods by various researchers but easily created by manual shredding of fiber matting.
6		Larger clumps of fibers lying between Classes 5 and 7.
7		Fragments of fiber that retain some aspects of the original rectangular construction of the fiber matting. Typically precut pieces of a large blanket to simulate moderate-size segments of original blanket.



Photograph 1: Fiberglass shreds in size Class 5

I.B Discussion of Prepared LDFG Debris Size Distribution for Testing:

The Alion Debris Preparation Procedure used for all TMI, Unit 1 prototype tank testing, including the November 2007 test of record, was designed to produce "small-fine" debris of Classes 1 through 4, finer than that required by NEI 04-07 (Reference 7) (i.e., no pieces in Classes 5 through 7 or 4" debris). The following fiber preparation steps are excerpted from the procedure:

3.0 PROCEDURE (Fiber Preparation)

3.1 This section is used to prepare low density fibrous insulation to be used for testing in the vertical test loop or large flume. These low density fibrous insulations include, but are not limited to Nukon, MINERAL WOOL, and THERMAL-WRAP.

3.1.1 Prepare the insulation material for the shredder by cutting it into 12" square pieces. Note: If material was procured in a shredded form, skip to step 3.1.4[2].

3.1.2 Process the insulation material through a shredder. If only a small amount of material is required, it is acceptable to shred the insulation by hand.

3.1.3 Collect the shredded insulation.

3.1.4 Using a representative sample of the shredded insulation, compare the size distribution of shredded insulation with that identified in NUREG/CR-6808, Table 3-2, "Size Classification scheme for Fibrous Debris", or NEA/CSNI/R (95)11, Table 3.1, "Fibrous Debris Classification' and Figure 3.1, "Examples of Fibrous Debris Fragments Tested". The desired size classification would be Numbers 1 through 4. Refer to Appendix 1 of this document.

3.1.5 If all of the shredded insulation, or a portion of all of the shredded insulation is too large compared to the classifications of Table 3-2 in NUREG/CR-6808, or Table 3.1 of NEA/CSNI/R (95)11, then process the large pieces of insulation through the shredder or shred by hand.

3.1.6 Using a representative sample of the shredded insulation, compare the size distribution of shredded insulation with that identified in the previously referenced Tables. The desired size classification would be Numbers 1 through 4.

3.1.7 Repeat the insulation shredding as needed to achieve the desired quantity and size distribution of insulation to be used for the testing as required by the Test Plan.

3.1.8 Shredded insulation that does not satisfy the desired size distribution should be removed from the insulation sample and discarded per the MSDS or the ALION Science & Technology Environmental Health and Safety Manual.

3.1.9 Weigh out the required quantity of processed insulation for testing that meets the desired size distribution as required by the Test Plan.

---

[2] All TMI, Unit 1 fibrous debris was procured in bulk form (i.e., not shredded).

3.1.10 If the insulation is new (i.e. not aged) use one of the following methods as required by the Test Plan or as directed by the Test Engineer.

Method 1: boil the insulation for 60 minutes. (Note: boiling insulation for 60 minutes is part of the debris preparation methodology adopted by the NRC for use at the UNM vertical loop testing facility.)

Method 2: boil the insulation for 5 minutes. (Note: boiling insulation for 5 minutes is part of the debris preparation methodology adopted by LANL for use at the LANL vertical loop testing facility.)

NOTE: Method 2 was used for TMI, Unit 1.

3.1.11 Put the insulation in a bucket of water at a temperature within ± 10 °F of the temperature of the water to be used in the testing.

3.1.12 Mix / beat the insulation with paint mixer attached to an electric drill for five minutes or until a homogeneous slurry is formed.

3.1.13 The insulation is now ready for testing.

I.C Comparison of Prepared Test Debris to Debris Analysis Assumptions:

Although the prototype testing for TMI, Unit 1 was performed prior to the USNRC March 2008 guidance (Reference 6), the debris size distribution established by the debris preparation procedure for the head loss testing was consistent and conservative with respect to the TMI, Unit 1 Debris Generation and Transport Analysis per the definition of "small-fines". The analyses definition considers small fines to include Classes 1 through 6 whereas the debris preparation procedure produces Classes 1 through 4. The TMI, Unit 1 Debris Transport Analysis assumes that 100% of the small fines are transported to the sump as shown in Table 2 (Reference 3). The amount of small fines plus 15% of large pieces were included in the total debris quantity used in the head loss test (see Response to USNRC Question 2, above). Therefore, with respect to the debris size distribution, the analysis and the testing definitions are conservative and in alignment.

II. Discussion of Thin Bed Test:

The testing of the TMI, Unit 1 prototype screen with Class 1 through 4 fibers at Alion was performed for both the thin and thick bed testing for TMI, Unit 1. The protocol made no attempt to segregate individual fibers through sieving or other means from the debris mixture. The testing involved a series of tests with debris quantities that would produce debris bed thicknesses from 1/8" up to 2.43". Although the test protocol was designed to encourage debris deposition on the screen through tank turbulence (stirring and trolling motors), this was not always successful in the earlier tests, as was witnessed on one of the USNRC visits (Reference 9).

Table V presents the TMI, Unit 1 prototype testing sequences. The November 2006 test series did not include chemical effects. The data provided below for the 2007 tests was recorded after stabilization of the fiber and particulate debris bed but before addition of the WCAP predicted precipitates. The November 2007 Test 2B is the current design basis loading case.

Table V: TMI, Unit 1 Prototype Testing Sequences

Test	Date	Bed Thickness	Head Loss (@ nominally 85^{0}F)	Debris Volume
4	Nov-2006	0.1"	0.22'	Latent Only
1	Nov-2006	3/8"	0.22'	Amount added to equivalent to 3/8" uniform bed thickness
3	Nov-2006	1.3"	0.36'	250 ft^3
2B	Nov-2006	2.03"	2.51'	388 ft^3
2C	Nov-2006	2.43"	5.98'	465 ft^3
1B	Mar-2007*	1.4"	0.4'	269 ft^3
2B	Nov-2007	1.1"	1.7'	218 ft^3

*USNRC Witness

It should be pointed out that the USNRC witnessed the March 2007 Test 1B as documented in a USNRC Trip Report (Reference 9). This report indicated that settling occurred with the small pieces in Test 1B. As a result of this report, Alion implemented additional attention to "agitation" in the November 2007 testing to facilitate transport to the sump screen. The differences in settling between the two tests are illustrated in the response to USNRC Question 6, below. As a result of the preferential sedimentation of the small debris fragments from within the "small-fine" debris used for the testing, the debris actually reaching the screen tended to be comprised predominantly of "fine" debris. This is consistent with the conditions preferred by the USNRC March 2008 guidance (Reference 6).

Review of the 2006 Tests 1, 3, 4 and 2007 Test 1B indicates that under a variety of load conditions, the screen design is not susceptible to thin-bed effects. This is consistent with Alion's experience with this particular screen design. This is due to the non-uniform approach velocity and debris deposition. The March 2007 1B testing, as well as the earlier 2006 testing, did notice debris settling of small pieces; however, the screen was completely covered in fines, which is a realistic scenario to produce a thin-bed effect considering some settling of small pieces. In all four cases involving small debris quantities with sedimentation of the larger "small/fine" debris fragments (2006 tests 1, 3, and 4 and 2007 test 1B), the thin-bed head loss is consistently much lower than the limiting load cases head losses. Based on these results, it can be concluded that the thin-bed does not produce limiting head losses. In particular, 2006 Test 3 and 2007 Test 1B produced essentially identical results, and both tests were completely covered in "fines." Photographs 2 and 3 were taken, by Alion, following draindown after the USNRC witnessed 2007 Test 1B. Note the uniform deposition and "fine" quality of the debris at the screen surface in Photograph 4.

Photograph 2: March 2007 Test 1B

Photograph 3: March 2007 Test 1B

Photograph 4: November 2007 Test 2B

Photograph 5: November 2007 Test 2B

The debris load from the November 2007, Test 2B (1.1") represents the design full load. This is the latest test and incorporated the USNRC Staff's feedback on non-prototypical settling in the earlier tests identified in the trip report (Reference 9). Alion implemented additional measures (stirring and trolling motor) to ensure transport to the test screen. The increased agitation and attention to settling produced a head loss consistent with the thicker debris loads from the earlier tests (2006 2B & 2C) and provides a limiting head loss. For this reason, it can be concluded from the head losses produced by the Alion testing that the thin-bed head losses are not limiting in this strainer design, and the maximum or full load debris head loss test is the limiting loading condition.

USNRC Question 4 (RAI 9)

The staff requested additional information on how the extrapolation of head loss results to the strainer mission time would affect the head loss evaluation. The licensee provided additional information that clarified some aspects of the need to perform an extrapolation of the data to the pump mission time. The licensee response to the RAI is reasonable. In addition, the rate of increase of head loss over the last 12 hours was very small such that less than one foot additional head loss would likely occur over the strainer mission time. However, the TMI-1 supplemental response states that the limiting NPSH margin for the low pressure injection (LPI) pump single operation is 0.1 ft. This is a relatively small margin. The variance of margin related to time was not provided. Because of the low margin available, the licensee should verify that the evaluation of the head loss test data did not include a non-conservative assumption regarding extrapolation that could affect the available pump margin throughout the mission time.

TMI, Unit 1 Response:

Response Summary:

Based on a review of the application of the head loss test data as discussed below, it is concluded that the TMI, Unit 1 NPSH margin and maximum strainer differential pressure analyses did not include a non-conservative assumption regarding extrapolation of the test data throughout the mission time.

Response Details:

During the TMI, Unit 1 prototype testing, the conventional debris (fibrous insulation, Thermolag®, coatings, dirt/dust, and latent fiber) was initially batched into the test tank. Next, the calcium phosphate precipitate was batched into the test tank to determine the stable head loss. After the head loss stabilized with the calcium phosphate precipitate, the aluminum precipitates were added to determine the total strainer head loss (Figure 7, Reference 1). As discussed in the previous RAI response to Issue 3f.10 (Reference 1) the head loss value resulting from the calcium phosphate precipitates applies for sump temperatures above 140^{0}F. Below 140^{0}F, the head loss value including the aluminum precipitates is applied.

Sump Temperatures Above 140^{0}F

The maximum stable strainer head loss measured after the addition of the calcium phosphate precipitates in the TMI Unit 1 head loss test was 1.7 ft. As discussed in the previous response to Issue 3f.10 (Reference 1), the test head loss is adjusted for flow rate and temperature when applied in the NPSH analysis. The adjusted head loss due to the total amount of calcium precipitates is applied from the beginning of recirculation to the time when sump temperatures reach 140^{0}F. This includes the time of minimum NPSH margin, which occurs in the first few hours following initiation of sump recirculation. No non-conservative assumptions that could affect the available pump NPSH margin were identified in the application of the head loss test data to the time in which sump temperatures are above 140^{0}F.

Plots of NPSH margin for the minimum margin cases for both the LPI and BS pumps are provided in the response to USNRC Question 7, below.

Sump Temperatures Below 140^{0}F

The maximum strainer head loss measured after the addition of the aluminum based precipitates was applied in the NPSH analysis for sump temperatures below 140^{0}F. As discussed in the responses to USNRC RAIs 6 and 9 (Reference 3), the test debris bed failed after the addition of about 96.5% of the chemical debris. The maximum head loss value recorded prior to failure of the debris bed (21.3 ft) was applied in the NPSH Margin Analysis. As discussed in the previous RAI response to Issue 3f.10 (Reference 1), the test head loss is adjusted for flow rate and temperature when applied in the NPSH analysis.

The adjusted head loss based on the maximum observed value of 21.3 ft is applied in the NPSH Margin Analysis when sump temperatures reach 140^{0}F. The increase in head loss at 140^{0}F is applied as a step change and is not phased in over time. Following the step change in strainer head loss, the minimum NPSH margin for the LPI pumps is 11.9 ft (See Tables in Attachment 5). The minimum NPSH margin for the BS pumps is 13.6 ft (See Tables in Attachment 5). The minimum margins for both pumps occur in the maximum cooldown Case I and are coincident with the step change at 140^{0}F. NPSH margin for both pumps increases later in the event as shown in the figures below. With the significant NPSH margins that are available at the lower temperatures, no non-conservative assumptions that could affect the available pump NPSH margin were identified in the application of the head loss test data to the time in which sump temperatures are below 140^{0}F.

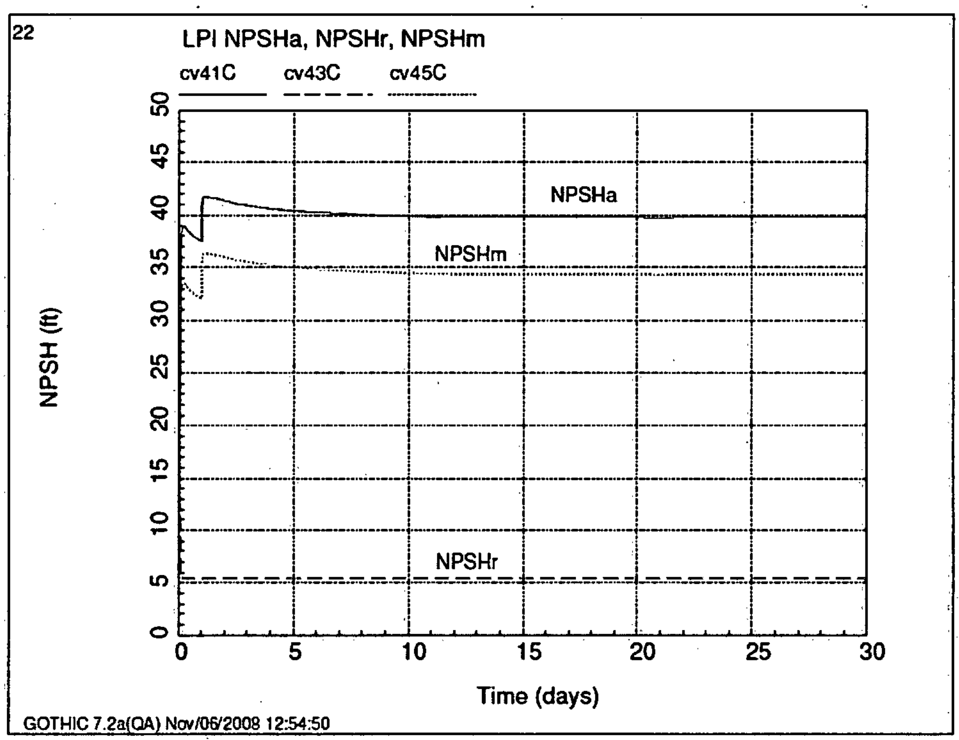


Figure 3: LPI NPSH - Maximum Reactor Building Cooldown – Case I

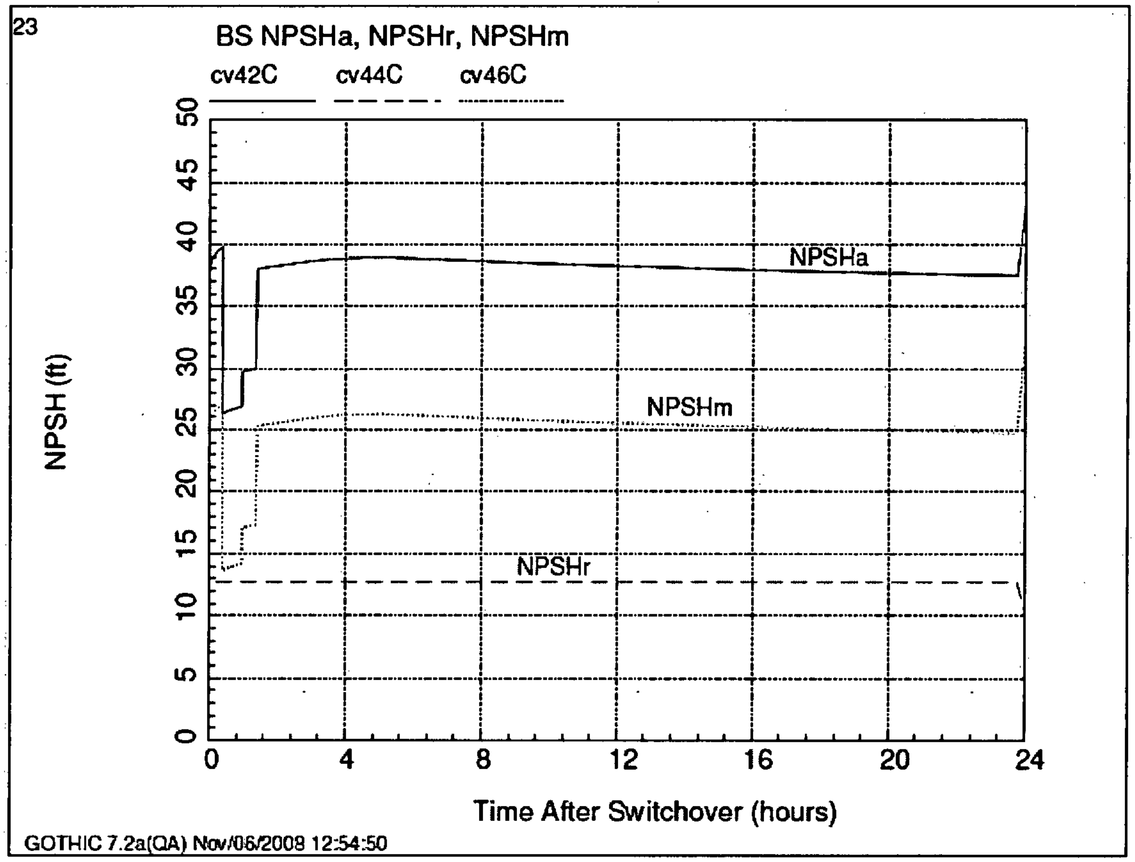


Figure 4: BS NPSH – Maximum Reactor Building Cooldown – Case I

The maximum strainer head loss is also evaluated to ensure that the maximum strainer design differential pressure is not exceeded. The maximum strainer head loss always occurs after the sump temperature reaches 140^{0}F, but is dependent upon the timing of termination of BS flow and throttling of LPI flow. As discussed in the previous RAI response to Issue 3f.10 (Reference 1), credit is taken for operator action to secure the BS pumps and reduce LPI flow to ensure the structural limit of 16.15 ft (7 psi) is met for all cases. The maximum strainer head loss of 15.6 ft occurs for the maximum cooldown Case I (See Tables in Attachment 5). Strainer head loss decreases and remains below this value due to the action of securing the first BS pump and subsequent operator actions to throttle LPI flow as shown in the plot below. The operator actions credited for maintaining strainer differential pressure below the design value were shown to be effective. No non-conservative assumptions that could affect the maximum strainer differential pressure were identified in the application of the head loss test data to the time in which sump temperatures are below 140^{0}F.

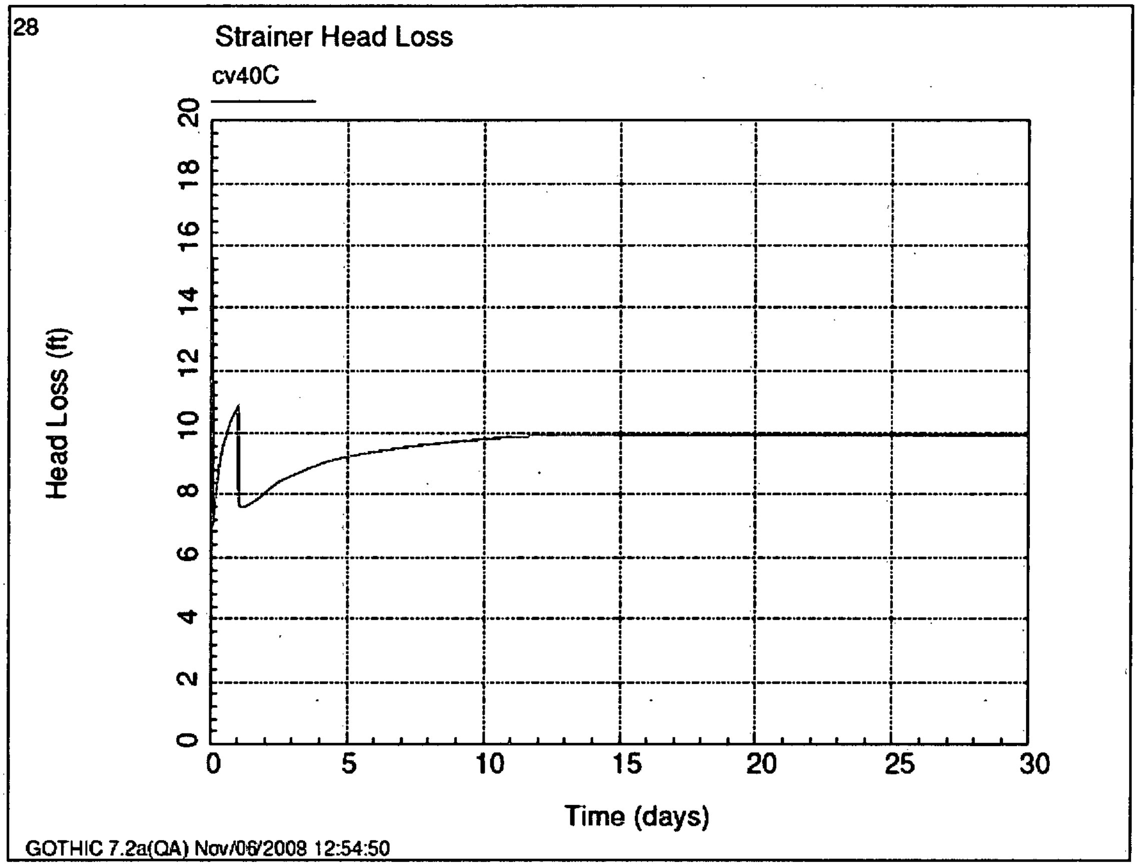


Figure 5: Strainer Head Loss – Maximum Reactor Building Cooldown – Case I

USNRC Question 5 (RAI 11)

The staff requested additional information on whether containment overpressure was credited for the strainer flashing evaluation. The licensee provided additional information in this area, but it seemed that the question was not understood. The licensee evaluated flashing at the pump suction, but did not address potential flashing in the debris bed or within the strainer. Flashing within the strainer or debris bed can result in additional head losses. The licensee should verify that the potential for flashing at the strainer has been evaluated or provide the parameters such that the staff can verify that flashing will not occur. The minimum margin to flashing at the strainer should be provided. For example, provide strainer submergence, sump temperature, and strainer head loss as a function of time. If required, provide the minimum available containment pressure at the evaluated times.

TMI, Unit 1 Response:

Response Summary:

An analysis has been performed to evaluate the potential for flashing within the debris bed. The analysis concludes that flashing of the fluid at the debris bed will not occur. The analysis does not take into account any containment overpressure (pressure over the initial containment pressure).

Response Details:

Based on the review of the vertically oriented screen design in the sump pit, the greatest potential for flashing occurs at the top of the strainer due to the minimum submergence. An illustration of the TMI, Unit 1 strainer is provided in Figure 6. The minimum water level is at elevation 283.9' and the top of the strainer top hat is at elevation 282.6' which provides 1.3' of submergence to the top of the strainer top hat.

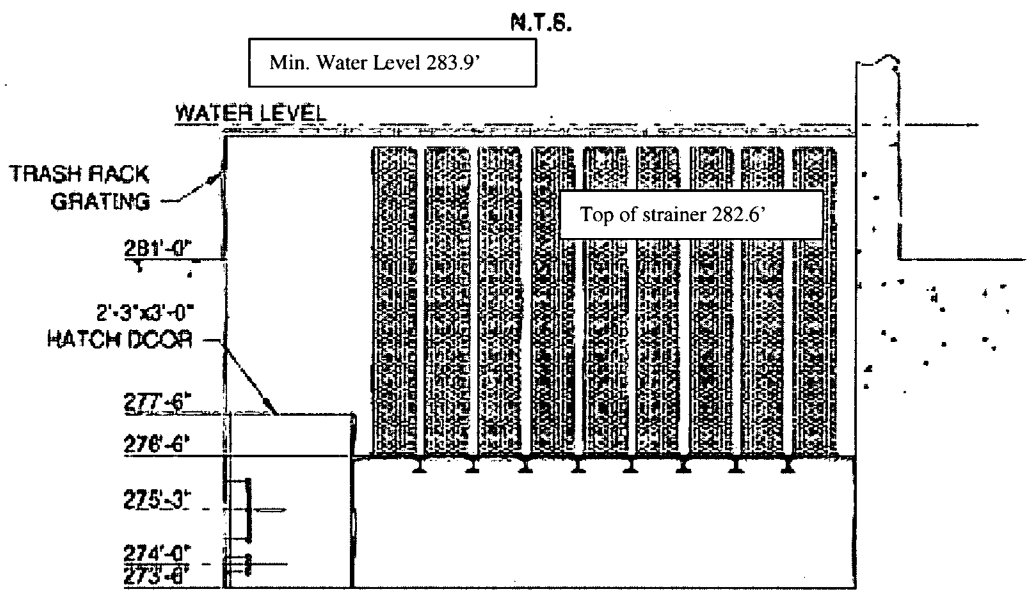


Figure 6: TMI, Unit 1 Containment Sump Configuration

To evaluate the potential for flashing to occur, the following criteria were considered:

1. If the submergence is greater than the debris head loss, then the fluid pressure within the debris bed is greater than the fluid pressure at the pool surface (the containment pressure) and clearly no flashing within the debris will occur, or

2. If the submergence is less than the debris head loss, the potential for flashing within the debris bed does exist. To determine whether or not flashing does actually occur, one must calculate the fluid pressure on the inside of the strainer

surface (containment pressure + submergence – debris head loss) and compare this to the fluid vapor pressure. If the vapor pressure is greater than this calculated fluid pressure, flashing would occur unless credit is taken for overpressure. If the fluid pressure is greater than the vapor pressure, no flashing occurs.

Table VI: Containment Flashing Parameters

Time	Containment Pressure (psia)	Sump Temp (°F)	Vapor Pressure (psia)	Debris Head Loss (ft)	Submergence (ft)	Submergence greater than debris head loss (Y/N)
1681 sec	42	260	36.4	0.75	1.3	Yes
3433 sec	32	244	27.4	0.79	1.3	Yes
Long Term	13.7	208	13.7	0.9	1.3	Yes
Long Term	13.7	141	2.9	1.32	1.3	No
Long Term	13.7	140	2.9	16.0	1.3	No

<u>Temperatures above 140°F:</u>

As described in the previous response to Issue 3o.2.9.i (Reference 1), the head loss across the strainer at temperatures above 140°F is based on the contribution of calcium phosphate precipitates. As described in the Response to Issue 3f.13 (Reference 1), the measured debris head loss is adjusted based on the temperature of the fluid. Due to the effect of fluid density and viscosity, the debris head loss increases as temperature decreases. The submergence of the strainer is greater than the debris head loss until the sump temperature decreases to approximately 141°F. For the temperatures around 141°F, the fluid pressure determined per criteria 2, above, is above the vapor pressure (see example below for temperatures at or below 140°F). Therefore, flashing does not occur for temperatures above 140°F.

<u>Temperatures at or below 140°F:</u>

As described in the response to Issue 3o.2.9.i (Reference 1), the head loss across the strainer at temperatures below 140°F includes the contribution of aluminum based precipitates. This results in a significant increase in strainer head loss as discussed in the response to USNRC Question 4 (RAI 9). As described in the Response to Issue 3f.10 (Reference 1), operator actions to secure the BS pumps and reduce LPI flow will maintain the strainer DP below the strainer design limit. The flashing evaluation conservatively uses the strainer design DP (16 ft) as the maximum debris head loss. The debris head loss is greater than the submergence of the strainer below 140°F, therefore criteria 2 is applied. The fluid pressure at the top of the strainer is slightly greater than 7 psia [13.7 psia + 0.5 psia (or 1.3 ft.) – 6.9 psia (or 16 ft.)], which is well above the vapor pressure of 2.9 psia. Therefore, flashing does not occur for temperatures below 140°F.

USNRC Question 6 (RAI 13)

The staff requested justification for why the settlement that occurred during integrated chemical effects testing did not result in non-conservative head loss values. The licensee stated that multiple attempts were made to re-entrain settled debris into the test flume. The staff was present at a test of the TMI-1 strainers. During the test the staff noted non-prototypical settlement of both chemical and non-chemical debris in the test tank. The trip report reference may be found at ADAMS Accession No. ML071230203. As noted in the trip report, the test tank geometry was significantly less conducive to transport than actual plant conditions. The trip report noted that the effects of debris settling should be addressed during the evaluation of the testing. The licensee should evaluate the effects of the settling on the test results.

TMI, Unit 1 Response:

Response Summary:

The USNRC observed head loss testing that was performed for TMI, Unit 1 in March of 2007 and noted non-prototypical settling of chemical and non-chemical debris in the test tank. Improvements were made to both the test tank configuration and test procedures prior to the test of record for TMI, Unit 1 which occurred in November 2007. Although some minor settling did occur in the November test, the settling is not considered to be non-prototypical and did not significantly affect the test results.

Response Details:

Background

USNRC representatives were present at the initial TMI, Unit 1 chemical strainer test performed at Alion in March 2007 (Reference 9). This test was an early implementation of the prototype strainer array tests that utilize both physical (fiber/particulate/dirt/dust) and chemical precipitate debris. During this test, it was observed that significant quantities of debris settled on the floor of the test tank. Subsequent to this test, the design basis (full load) test was performed in November 2007. This test, which was not witnessed by the USNRC, incorporated enhanced methods to agitate the tank throughout the testing process. These methods proved effective in reducing the quantity of settled debris. The TMI, Unit 1 Supplemental Response (Reference 1) and the subsequent RAI response (Reference 3) and supplemental information submittal (Reference 4) were based on the results from the November 2007 test.

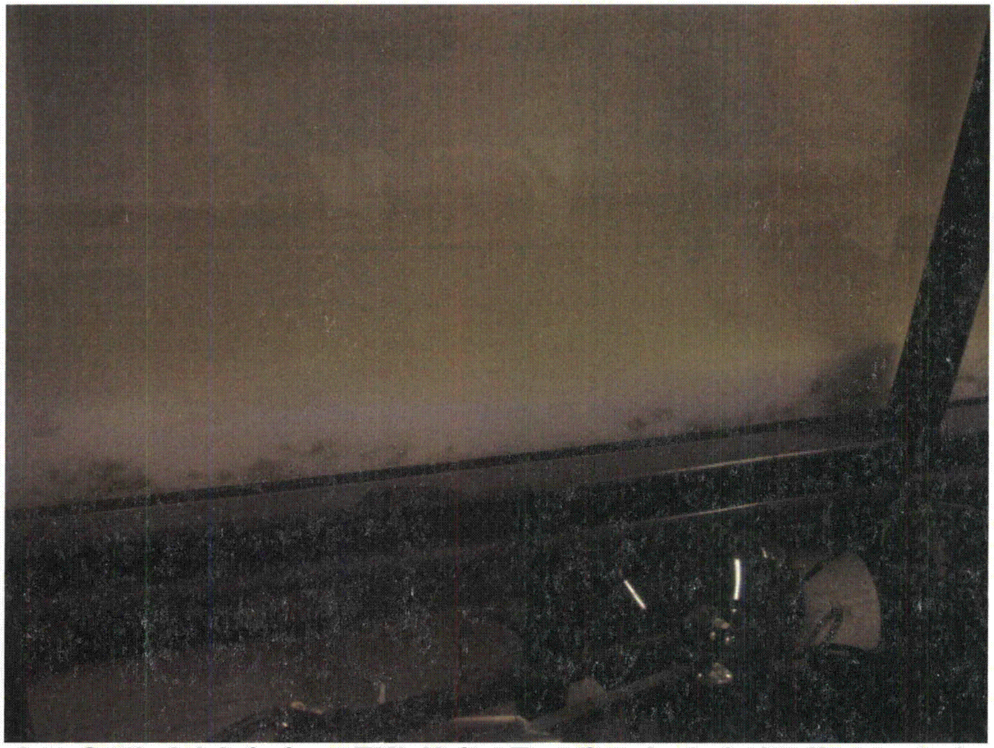
Discussions

March 2007 Testing

The initial test performed in March 2007 utilized an Alion Hydraulic test with a standard, barrel-shaped diffuser. Top hats were mounted vertically on the discharge base plenum to reflect the TMI, Unit 1 sump strainer orientation. A plywood box structure was installed around the top hat array to simulate the TMI, Unit 1 sump pit. The box structure included three "full height" walls that extended above the top of the prototype top hats, and one partial height wall to facilitate the transfer of debris onto the strainers. Flow through the array was discharged from the base plenum and returned to the tank through a flow diffuser to provide a degree of debris mixing. The diffuser used in this test was barrel shaped, approximately 24" diameter and 36" tall with an array of 2" diameter holes to diffuse the supply water in multiple directions. The diffuser was located near an outer tank wall, away from the plywood box structure to ensure that the discharge from the diffuser did not disturb the debris as it accumulated on the strainer surfaces.

The test configuration previously used in Alion tests employed top hat arrays consisting of 9 total top hats (3 x 3 array). However, in order to accommodate the volume of chemical precipitates introduced to the tank in the March 2007 test, the array size was reduced to utilize a total of 4 top hats (2 x 2 array). This required a lower overall test flow rate to maintain the proper approach velocity at the strainer surface. For the 2 x 2 array, flow was reduced to 44% of the rate associated with the 3 x 3 arrays previously tested. This greatly reduced the effectiveness of the standard diffuser and allowed for the accumulation of settled physical and chemical debris on the floor of the test tank. Manual agitations of the tank were also not effective in suspending the settled debris sufficiently. Photograph 6 and Photograph 7 show the settled debris visible in the tank at the end of the March 2007 testing.

Photograph 6: Settled Debris from TMI, Unit 1 Test Conducted 3/07 (southwest corner)



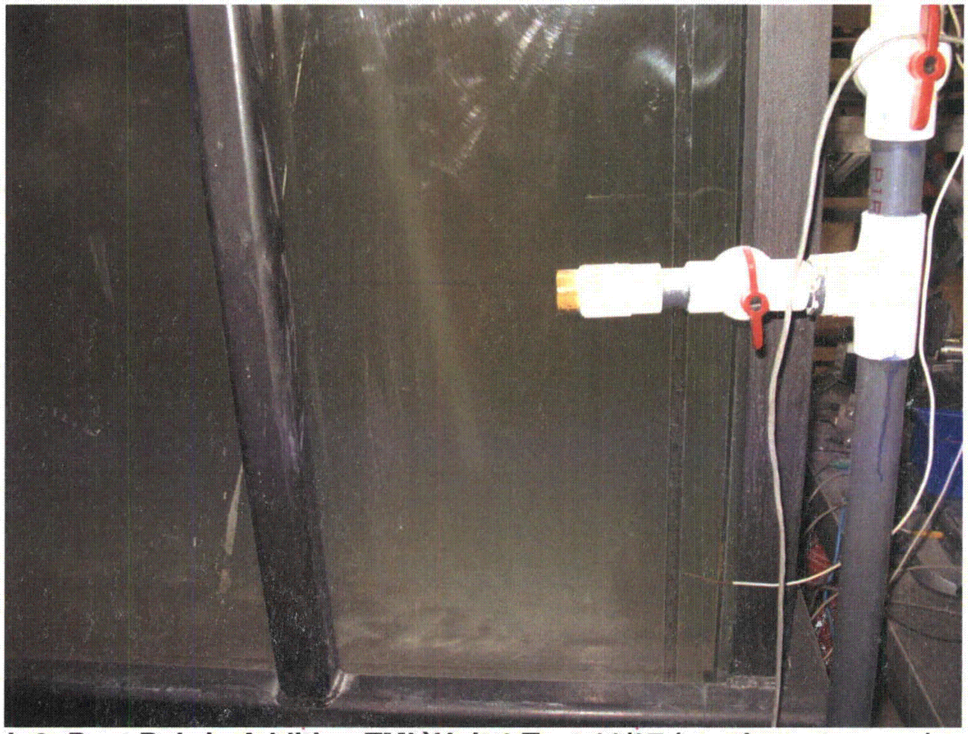
Photograph 7: Settled debris from TMI, Unit 1 Test Conducted 3/07 (front edge)

November 2007 Testing

Alion incorporated improvements to the test tank that would enhance agitation of the water to provide better suspension of debris. The barrel diffuser used in the March 2007 testing was replaced with a "tee-sparger" piping system. This arrangement distributed the water at floor level as it was re-circulated from the strainer plenum back into the tank. This configuration also generates somewhat higher velocities from water entering the tank than were achieved with the barrel diffuser. The distribution piping was configured such that the debris accumulated on the strainer screen would not be disturbed by discharge from the sparger.

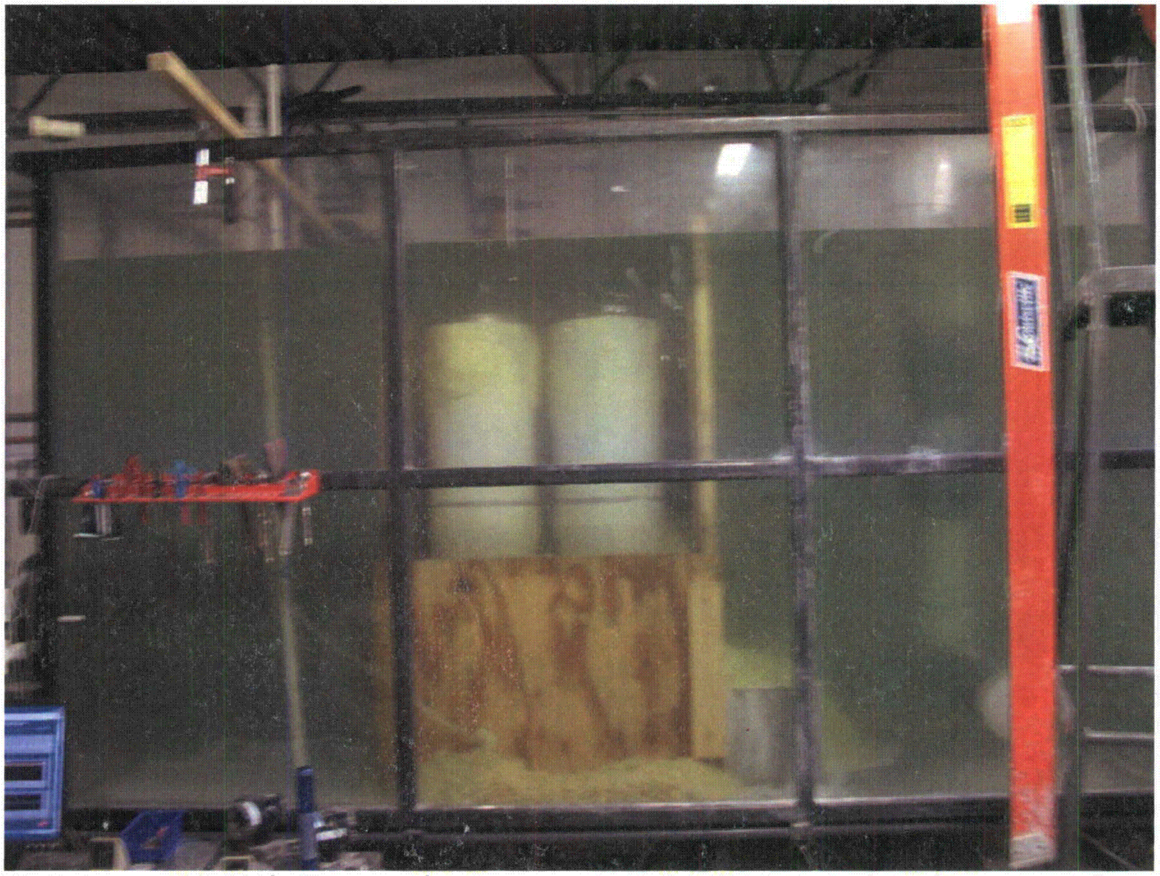
The full load test (Test 2B) was initiated in November 2007. As debris was slowly introduced to the tank over approximately 25 minutes, manual agitation was performed with a propeller style trolling motor and a rowing oar to supplement the sparger system. All agitation activities were carefully monitored to ensure they did not affect debris that had accumulated on the strainer. Review of the test logs reveals that supplemental agitation actions were performed throughout the entire debris addition process until head loss was observed to be stabilized.

At the conclusion of the test, it could be seen that Alion's improvements to tank agitation methods greatly reduced the amount of settled debris. Photograph 8 below illustrates the tank condition after all debris had been introduced to the experiment. This photograph shows the southwest corner of the tank and can be directly compared to Photograph 6 from the March 2007 test (1B).



Photograph 8: Post Debris Addition TMI `Unit 1 Test 11/07 (southwest corner)

After all debris had been introduced to the tank and consistent attempts to keep the debris in suspension were performed, a small amount of fibrous debris could still be observed in isolated areas of the test tank floor. Photograph 9 shows the final condition of the test. By observation, the only debris component observed to have settled is the largest fiber class. The majority of the fibrous debris, along with the particulate and chemical precipitate debris had accumulated on the sump screen. The amount of settled fiber at the end of TMI, Unit 1 November 2007 Test 2B is estimated to be approximately 10%. Based on the clarity of the water, the particulate has been filtered and the head loss is in general higher with higher particulate to fiber ratios assuming fiber loads that do not fill in the interstitial volume (which is the case here). The head loss at this point is dominated by the tightly packed debris layer on the surface of the screen. The settled debris on the floor is extremely loose and non-compacted; therefore, the impact of this debris on the measured head loss would not be significant. As seen in Photograph 9, there is already a considerable amount of the non-compacted debris within the sump box. Based on this, the settled debris does not have a significant effect on the results.



Photograph 9: TMI, Unit 1 Test 11/07

Prototypical Features

The TMI, Unit 1 sump pit design incorporates framing and structural components that form surfaces and confined volumes which are all within the volume of the pit, but are elevated above the base of the top hat mounting frame, or isolated from the primary sump volume. Figure 7 shows an isometric representation of the TMI, Unit 1 top hat framing structure that is installed within the sump pit. The entire assembly illustrated below is installed at the bottom of the sump pit, such that approximately 18" of the top of the tallest strainer cylinders extends above the containment floor elevation.

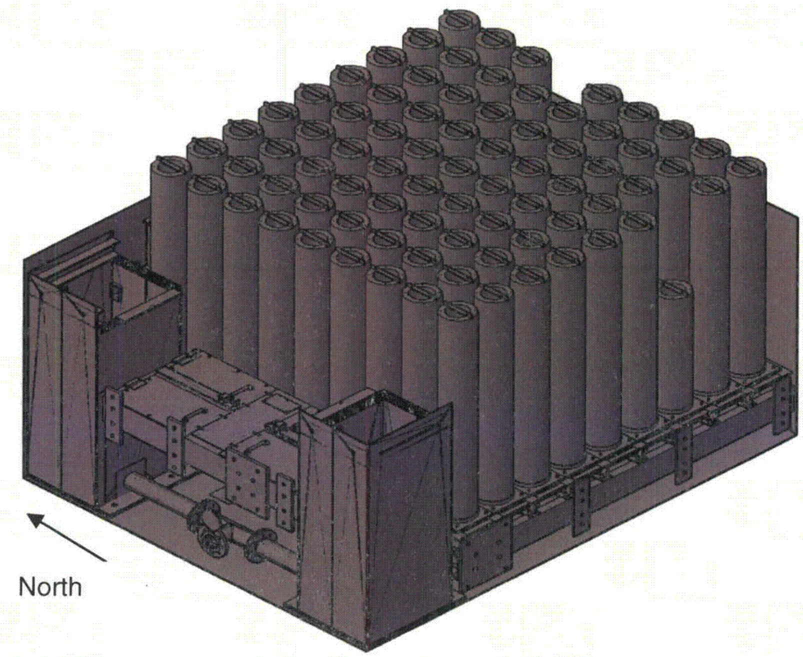


Figure 7: TMI, Unit 1 Top Hat Framing Structure

For reference, Figure 8 below illustrates flow patterns and relative velocities generated within the flooded containment during ECCS operation. From this figure, it can be seen that the majority of the water entering the sump pit approaches from the west side of the structure.

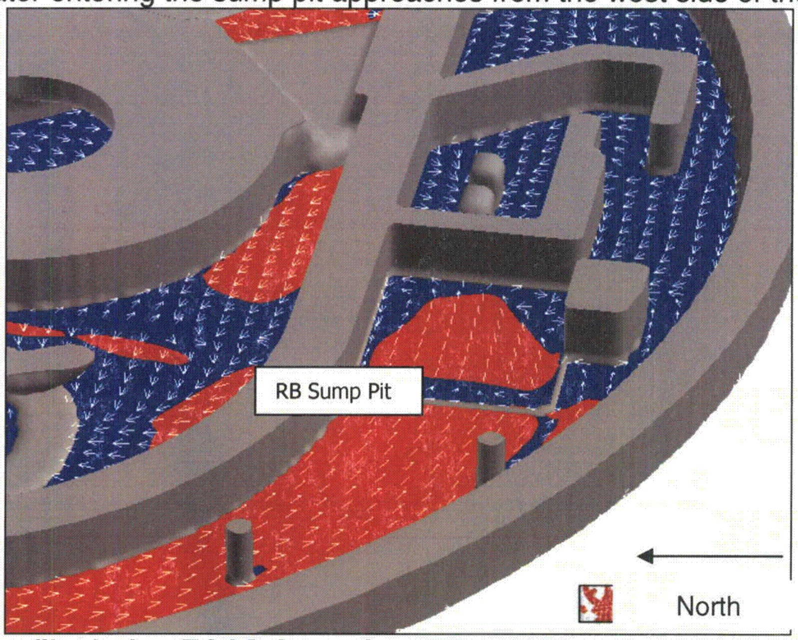


Figure 8: Flow Profile during ECCS Operation, RB 281' Elevation

Examination of the physical layout reveals that the design contains inherent surface features that result in locations where debris could accumulate without coming into contact with the strainer screen. Specifically, the west side of the structure incorporates multiple flat plate hatches that provide access to the ECCS sump suction inlets (not shown) entering the pit.

These hatches are closed during operation. On either side of these hatches are the normal sump drain tanks. These tanks have open tops and are cross tied with a discharge (shown) independent from the ECCS discharge. The volume within these tanks is isolated from the general sump volume. As sump water flows into the west edge of the sump pit, the entrained debris will initially interface with these surfaces and volumes of the framing structure.

Since these areas are separated from the base of the top hats, any debris that accumulates on these surfaces within the sump pit would not contribute to head loss. By examination of design drawings, the area of the framing structure above the top hat mounting framework is calculated to be 20% of the total pit cross section. This represents 36 ft^2 of surface within the sump where debris with greater settling velocities could accumulate without contributing to head loss across the strainer.

As illustrated by the test, some types of standardized debris, which can analytically be expected to transport to the sump, could in fact settle on available surfaces in the immediate vicinity of the strainer array. The limited amount of settled debris in the November 2007 test is separated from the strainer in a manner similar to what could occur in the actual sump installation. Therefore, the minor settling noted in the full load test is prototypical and of a relatively small amount, such that the head loss results are not affected in any significant manner.

USNRC Question 7 (RAI 16)

The staff requested that the licensee provide a more detailed description of the NPSH margin calculation methodology, including a description of the time-dependent analysis specifying selected values for NPSHa (NPSH available) and NPSHr (NPSH required) throughout the mission time. Although some information was provided in response to this request, the staff did not consider the response complete because sufficient information was not provided for the dependence of NPSHa on the sump pool water temperature as well as the time-dependence of the NPSH margin. While it is clear that the available margins are very small at the worst point in the limiting accident sequence (i.e., the minimum NPSH margin is 0.1 ft), it is unclear to the staff when this minimum margin occurs, how long it persists, and how much margin exists at other times during the accident. Therefore, to fully resolve this RAI, the staff is requesting that the licensee provide plots of NPSH margin versus time (or sump temperature if this parameter was used in lieu of time) for the limiting case (or cases) for both the LPI and building spray (BS) pumps that demonstrate the periods of minimum NPSH margin and the behavior of the NPSH margin as a function of time (or sump temperature).

TMI, Unit 1 Response:

Plots of NPSH margin for both the LPI and BS pumps for the limiting cases are provided below. These plots were taken from the most recent revision of the NPSH Margin Analysis.

The TMI, Unit 1 NPSH Margin Analysis has undergone two revisions since the Supplemental Response to GL 2004-02 (Reference 1) was submitted to the USNRC. Both of these revisions to the NPSH Margin Analysis resulted in minor changes to Tables 14 and 15 of Reference 1. Supplemental information regarding the first revision was provided to the USNRC by Reference

4. The second revision to the NPSH Margin Analysis is discussed in Attachment 5 to this submittal.

The five system configurations listed below have been evaluated with respect to LPI and BS pump NPSH and maximum strainer differential pressure:

- Case I represents two trains of LPI and two trains of BS in service. Each train of LPI is throttled to an indicated flow of 3000 gpm, with the BS pumps independently delivering 1180 gpm. The LPI system is configured with the cross-connect line (DH-V-38A/B) closed.
- Case II represents the same LPI configuration as described in Case I with both BS pumps secured. The LPI cross-connect line via DH-V-38A/B is closed.
- Case III represents a single LPI pump in operation feeding both trains of injection through DH-V-4A and DH-V-4B (i.e. DH-V-38A and DH-V-38B open). The total indicated flow is 2800 gpm. In this mode, the opposite train LPI pump minimum flow line is open and circulating water back to the DH pump suction. The BS pumps are not operating.
- Case IV represents the same LPI pump configuration as described in Case III with the corresponding train BS pump operating at 1180 gpm.
- Case V represents the same LPI pump configuration as described in Case III with both trains of BS independently operating at 1180 gpm.

Cases I through IV were included in the previous TMI, Unit 1 Response to Issue 3g.16 (Reference 1). Case V was added to evaluate the one LPI/ two BS pump combination as discussed in the response to USNRC Question 8, below. Each of the cases described above were evaluated for both high temperature and low temperature conditions. As described in the previous response to Issue 3g.16 (Reference 1), the high temperature conditions are referred to as the EQ cases and the low temperature conditions are presented as the Maximum Cooldown cases.

The limiting case for LPI pump NPSH margin is EQ Case V (Table IX, Attachment 5). Short and long term NPSH plots for both Cases IV and V for the LPI pumps are provided.

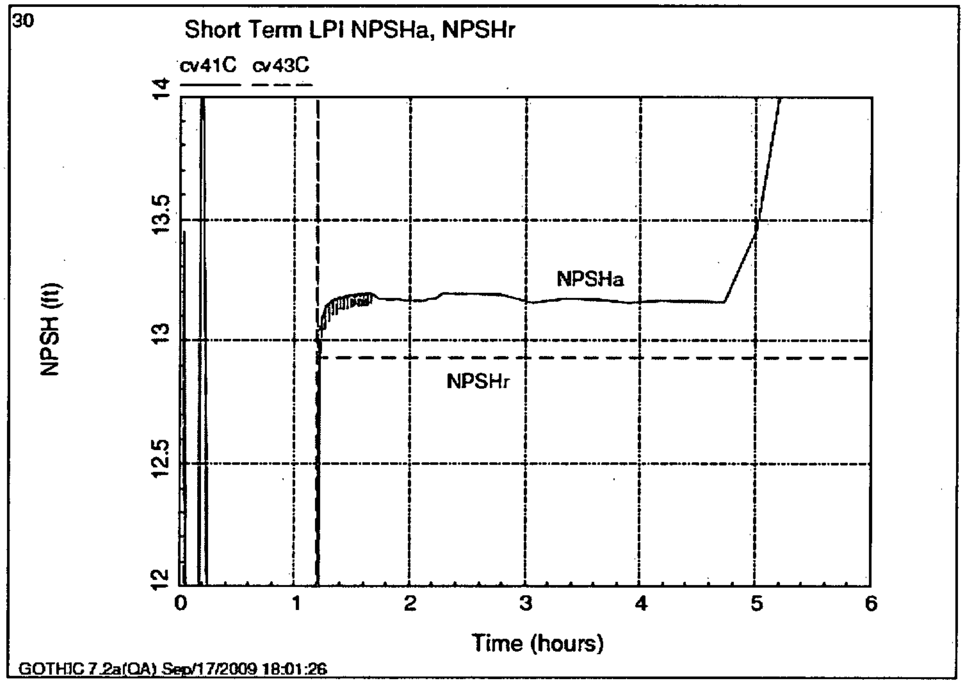


Figure 9: LPI NPSH – EQ Reactor Building Response – Case IV (Hours)

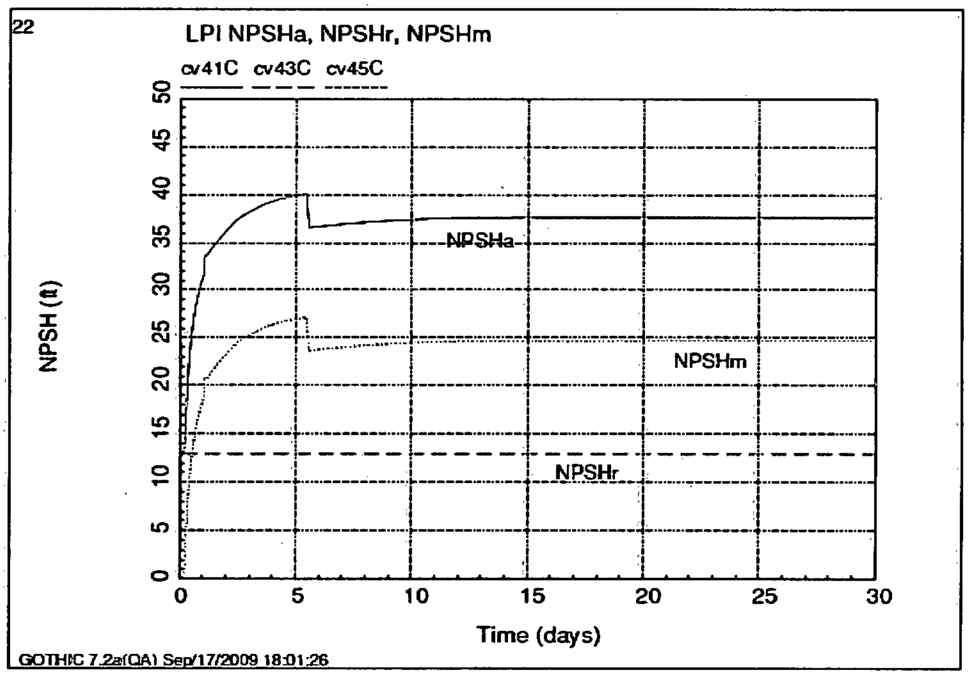


Figure 10: LPI NPSH – EQ Reactor Building Response – Case IV (Days)

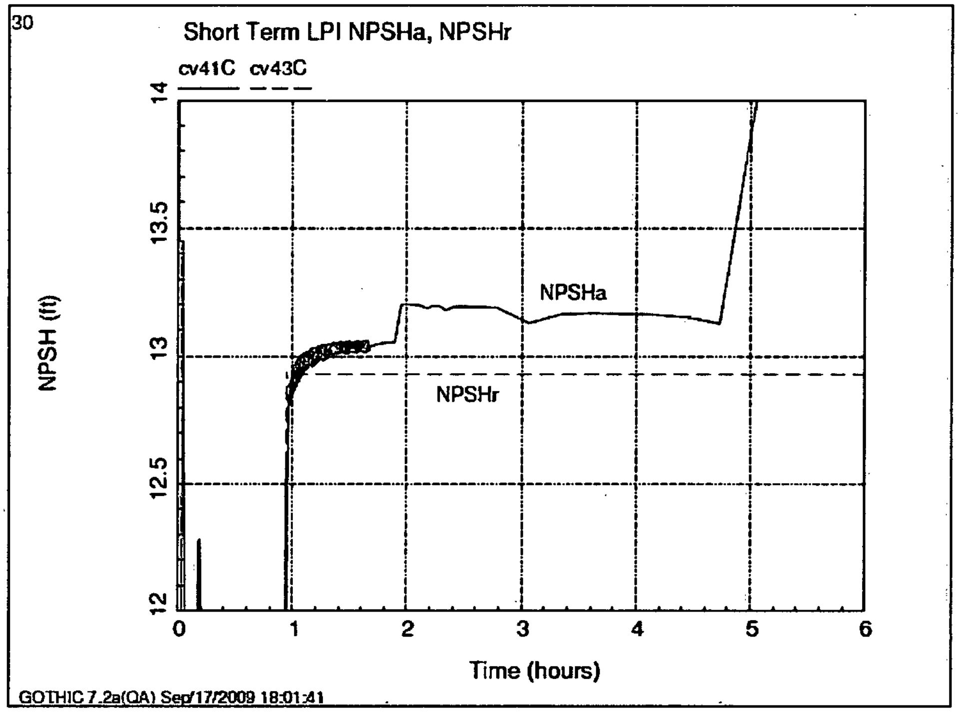


Figure 11: LPI NPSH – EQ Reactor Building Response – Case V (Hours)

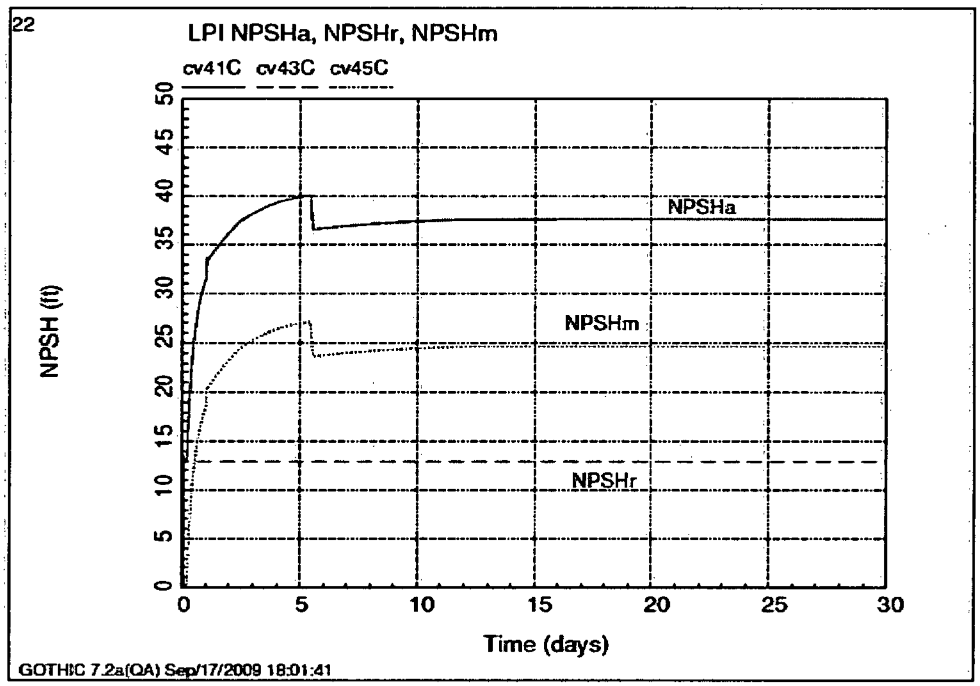


Figure 12: LPI NPSH – EQ Reactor Building Response – Case V (Days)

The limiting case for BS pump NPSH margin is EQ Case I (Table X, Attachment 5).

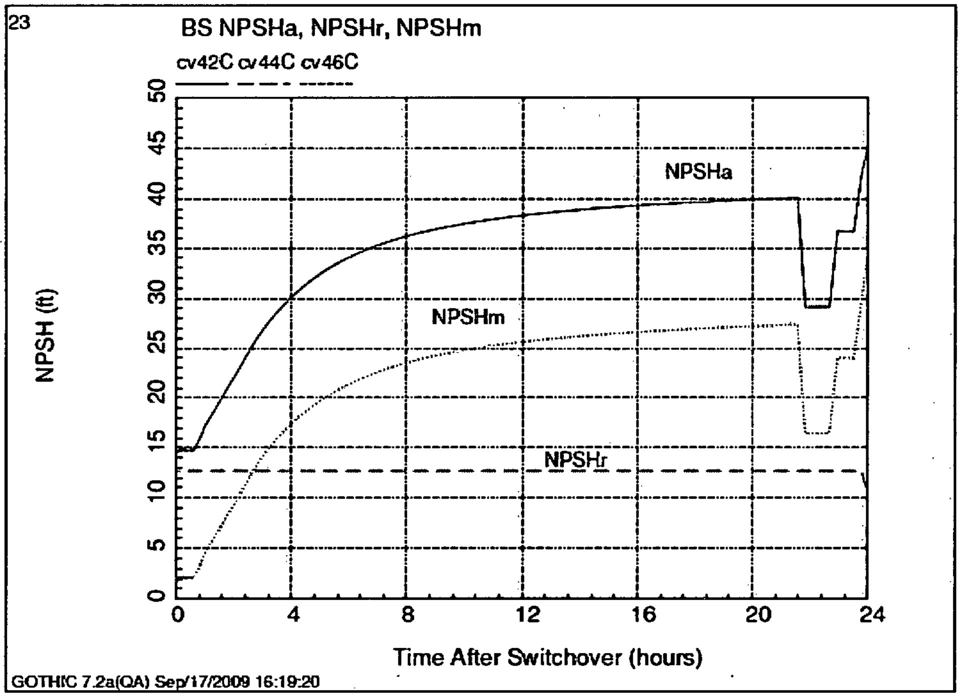


Figure 13: BS NPSH – EQ Reactor Building Response – Case I (Hours)

USNRC Question 8 (RAIs 17 and 19)

The staff requested that the licensee provide a discussion of how the single failure criterion was used in determining the bounding NPSH margin and why there is confidence that the worst-case single failure was identified and considered. The licensee's response to this item described a single failure of an LPI pump as being the worst-case single failure. Upon considering the NPSH margin results in Table 14 in the supplemental response, as well as the response to RAI 17 that indicates that maximizing reactor building cooling is considered a limiting condition, the staff questioned whether a configuration with one operating LPI pump and two operating BS pumps would be bounded by the results presented. For the case of two operating LPI pumps, having two operating BS pumps led to the minimum NPSH margin, but a corresponding case was not analyzed for single-train LPI operation. Please either (1) provide a basis for considering the configuration of one LPI pump and 2 BS pumps operating to be bounded by the cases analyzed or (2) provide a basis for concluding that this operating configuration will not be implemented following a LOCA (e.g., it would not be allowed by emergency procedures).

TMI, Unit 1 Response:

The TMI, Unit 1 NPSH Margin Analysis has been revised to add the additional case of a single LPI pump operating with both of the BS pumps operating. The minimum NPSH margin for this Case (Case V) was slightly lower than for Case IV as shown in the plots below. However, the minimum NPSH margin remains at 0.1 ft.

The five system configurations listed below have been evaluated with respect to LPI and BS pump NPSH and maximum strainer differential pressure:

- Case I represents two trains of LPI and two trains of BS in service. Each train of LPI is throttled to an indicated flow of 3000 gpm, with the BS pumps independently delivering 1180 gpm. The LPI system is configured with the cross-connect line (DH-V-38A/B) closed.

- Case II represents the same LPI configuration as described in Case I with both BS pumps secured. The LPI cross-connect line via DH-V-38A/B is closed.

- Case III represents a single LPI pump in operation feeding both trains of injection through DH-V-4A and DH-V-4B (i.e. DH-V-38A and DH-V-38B open). The total indicated flow is 2800 gpm. In this mode, the opposite train LPI pump minimum flow line is open and circulating water back to the DH pump suction. The BS pumps are not operating.

- Case IV represents the same LPI pump configuration as described in Case III with the corresponding train BS pump operating at 1180 gpm.

- Case V represents the same LPI pump configuration as described in Case III with both trains of BS independently operating at 1180 gpm.

Cases I through IV were included in the previous TMI, Unit 1 Response to Issue 3g.16 (Reference 1). Case V was added to evaluate the one LPI/ two BS pump combination. The limiting NPSH margin conditions occur during the first six hours of operation for EQ Cases IV and V as discussed below. The minimum margin of 0.1 ft occurs in EQ Case V during the first hour of sump recirculation due to the operation of two BS pumps. (Table IX, Attachment 5)

> **NOTE**: The TMI, Unit 1 NPSH Margin Analysis has undergone two revisions since the Supplemental Response to GL 2004-02 (Reference 1) was submitted to the USNRC. Both of these revisions to the NPSH Margin Analysis resulted in minor changes to Tables 14 and 15 of Reference 1. Supplemental information regarding the first revision was provided to the USNRC by Reference 4. The second revision to the NPSH Margin Analysis is discussed in Attachment 5 of this submittal.

A graph of NPSHa and NPSHr versus time for the first six hours of operation in the recirculation mode for EQ Case IV is provided below. The minimum margin for this case was listed as 0.1 ft in Table 14 (Reference 1). When the scale of the plot was expanded and compared to the result for Case V, it is evident that the NPSH margin for Case IV is initially slightly greater than the margin for Case V. The minimum margin for Case IV provided in the revised Table 14 (Attachment 5) is 0.2 ft based on the stable NPSH margin that exists after recirculation conditions are established.

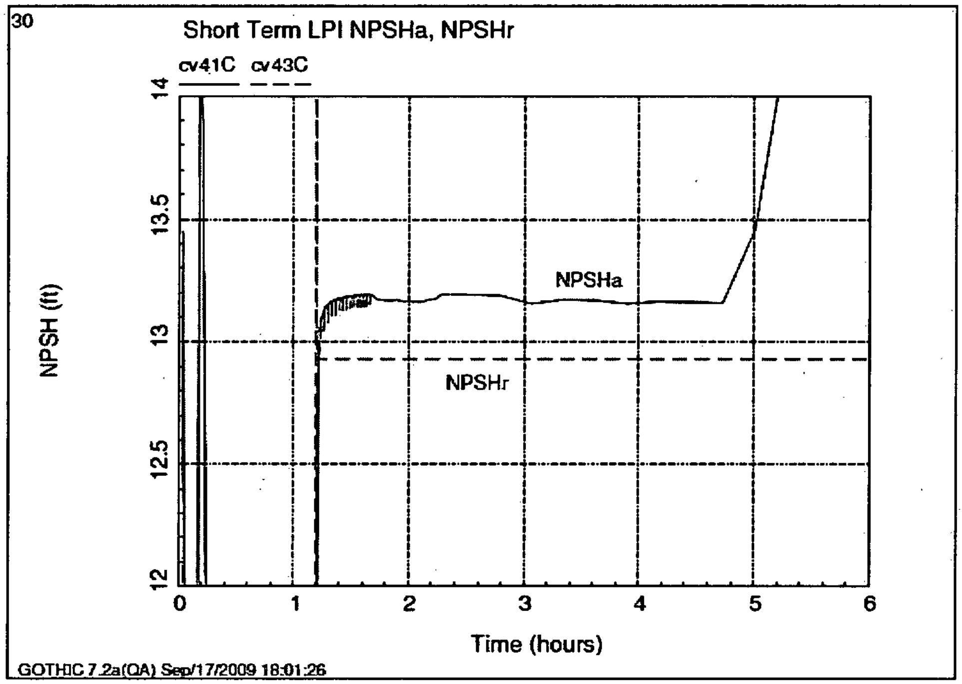


Figure 14: LPI NPSH – EQ Reactor Building Response – Case IV (Hours)

A graph of NPSHa and NPSHr versus time for the first six hours of operation in the recirculation mode for EQ Case V is provided below. The minimum stable NPSH margin for the first hour of operation is 0.1 ft. After 1 hour, the first BS pump is secured as described in the previous response to Issue 3f.10 (Reference 1). After the first BS pump is secured, the configuration is then equivalent to Case IV and the margin increases to 0.2 ft.

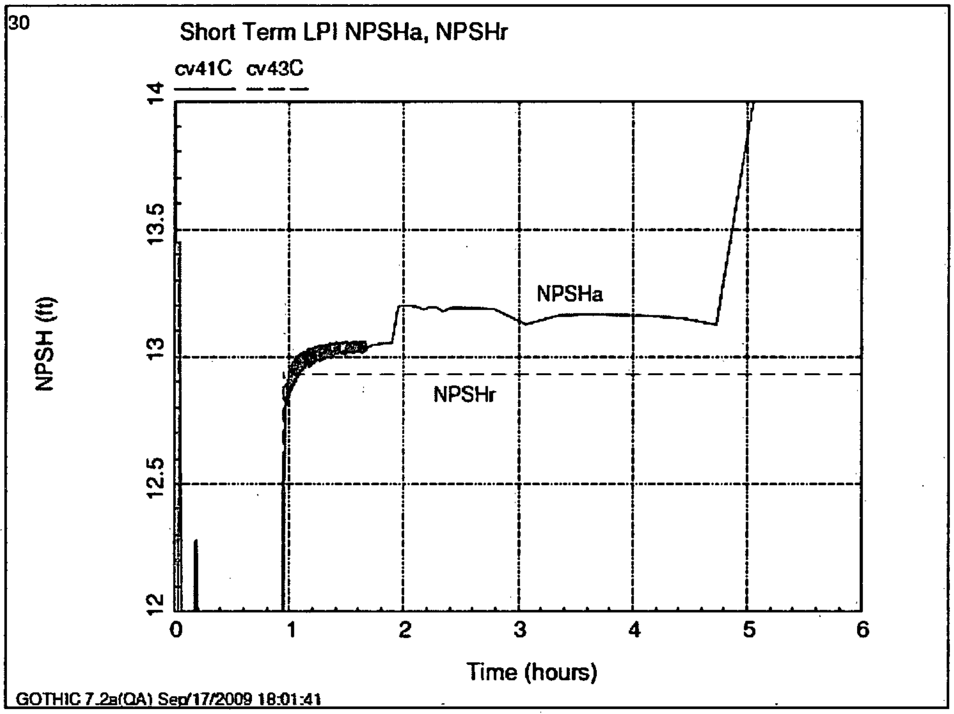


Figure 15: LPI NPSH – EQ Reactor Building Response – Case V (Hours)

The NPSH Margin Analysis uses a GOTHIC model to determine long term NPSH availability during the 30 day mission time for sump recirculation. The transition period from BWST injection to sump recirculation is not included in the GOTHIC model. As seen in the plot above, it appears as if the LPI pump is started at the initiation of sump recirculation at 0.9 hours as the NPSHr plot makes a step change to approximately 12.9 ft at that time. In actual conditions, the LPI pump will have been running prior to this time taking suction from the BWST. The curve of NPSHa would be decreasing from the value based on the BWST to the value based on the RB sump conditions. As the GOTHIC model does not include the transition time from the BWST to the sump, the minimum NPSH margin during recirculation is based on the stable region of the NPSHa curve when a steady state solution is obtained in the GOTHIC model.

USNRC Question 9

Please evaluate the potential for deaeration of the sump fluid to occur as it flows through the debris bed. The guidance in Regulatory Guide 1.82, Revision 3, Appendix A, states that entrained gas at the pump inlet can result in an increase in required NPSH. Please evaluate whether any adverse effect to pump performance could occur as a result of entrained gas at the pump inlets. If applicable, provide an evaluation of the effects on the pumps.

TMI, Unit 1 Response:

Response Summary:

An analysis has been performed to determine the air void fraction present in the post-LOCA fluid downstream of the sump strainer. The void fraction is 0% for Reactor Building sump water temperatures above 140°F due to the low debris head losses. At 140°F, the strainer head loss increases significantly due to the impact of the aluminum based precipitates. Based on the higher strainer head loss conditions, the average void fraction over the height of the strainer was calculated to be 1.30%.

For temperatures below 140°F when the void fraction at the strainer is greater than 0%, the void fraction at the pump was determined to be 0.97%. The Ideal Gas Law was applied to account for the increased static head and the resultant void compression at the lower elevation of the pump. For both the LPI and BS pumps, the NPSH margin remains greater than 5 ft after applying the RG 1.82 (Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident) adjustment factor to account for the potential effect of air ingestion on required NPSH.

Response Details:

The potential for air void formation downstream of the strainer was evaluated for the range of sump conditions as shown in Table VII below. Consistent with the NPSH analysis, above 208°F the RB pressure is set equal to the vapor pressure corresponding to the RB sump water temperature (as described in the Response to Issues 3g.1 and 3g.2 in Reference 1). Once the RB sump water temperature has decreased to where the vapor pressure is equal to or less than –1 psig, then a containment pressure equal to –1 psig is applied. For this initial evaluation, the void fraction is determined at the top of the strainer (1.3 ft submergence).

Table VII: Containment Void Fraction Parameters and Results

RB Sump Water Temp (°F)	RB Pressure (psia)	Strainer Flow Rate (gpm)	Screen Depth (ft)	Debris Head Loss (ft)	Vapor Pressure (psia)	Void Fraction (%)
260	42	8800	1.3	0.75	36.4	0.0
244	32	8800	1.3	0.79	27.4	0.0
208	13.7	8800	1.3	0.9	13.7	0.0
141	13.7	8800	1.3	1.32	2.9	0.0
140	13.7	8800	1.3	16.0	2.9	2.15

The containment pressure of 13.7 psia is the minimum pressure that can exist in containment prior to the event as discussed in the Response to Issue 3g.2 in Reference 1.

The RB sump void fraction is 0% at temperatures above 140°F. The head loss across the strainer increases significantly at 140°F due to the impact of the aluminum based chemical precipitates. The resulting void fraction at the strainer is 2.15%. Based on these initial results, a more detailed evaluation of the void fraction at 140°F was performed, including a determination of the void fraction at the pump.

To determine the void fraction at the elevation of the pump, an average void fraction along the height of the strainer top hat was calculated. The typical 83" tall top hat was divided into five equal segments and the void fraction was calculated for each segment. The average of these five values resulted in a void fraction of 1.30%. This void fraction was applied at the vertical midpoint of the top hat.

To extend the void fraction results to the pump inlet, the Ideal Gas Law was applied to account for the increased static head at the pump inlet and the resultant void compression. The resulting void fraction at the pump was determined to be 0.97%.

To evaluate the impact of air ingestion on NPSH margin, the Regulatory Guide (RG) 1.82 relationship was used to adjust the required NPSH for the LPI and BS pumps. The void fraction of 0.97% at the pump was rounded up to 1.0% in the evaluation of required NPSH. The minimum NPSH margin that occurred after the sump temperature reaches 140°F was determined for the LPI and BS pumps for all Cases. For the LPI pumps, the maximum cooldown Cases I and IV (described in the Response to NRC Question 7 (RAI 16), above) are the system configurations that resulted in the lowest NPSH margin at or below 140°F. Two LPI cases are evaluated due to the different LPI pump flows for the evaluated system configurations. For the BS pumps, the maximum cooldown Case I resulted in the lowest NPSH margin at or below 140°F. The BS pump flow is the same for all cases. The evaluations of the most limiting NPSH conditions at or below 140°F are provided in the Table below.

Table VIII : NPSH Margin Considering Air Ingestion

ECCS Pump	Case	Pump Flow (gpm)	NPSHr (ft)	β Per RG 1.82	Adjusted NPSHr (ft)	Minimum NPSHm (ft)	Adjusted Minimum NPSHm (ft)
LPI	Case I	3247	12.3	1.5	18.5	11.9	5.7
	Case IV	3351	13.7	1.5	20.6	20.1	13.2
BS	Case I	1180	13	1.5	19.5	13.6	7.1
		From Att. 5, Tables IX and X	From pump curve	β= 1+0.5(1.0%)	NPSHr x β	From Att. 5, Tables IX and X	= Min NPSHm – (adj. NPSHr – NPSHr)

Adequate NPSH margin exists for the ECCS pumps when the potential effects of air ingestion are included.

Minimum NPSH margins for sump temperatures above 140°F are discussed in the response to USNRC Question 7, above.

ATTACHMENT 3

Three Mile Island, Unit 1

Response to Request for Additional Information Related to

USNRC Generic Letter 2004-02

Questions Generic to Westinghouse Debris Generation Testing

Attachment 3
Three Mile Island Unit 1
Response to Request for Additional Information Related to Generic Letter 2004-02
Questions Generic to Westinghouse Debris Generation Testing

The set of 10 questions titled "Issues Generic to Westinghouse Debris Generation Testing," issued in the USNRC RAI to Exelon dated July 23, 2009 (Reference 2), applies to the TMI, Unit 1 credited debris generation testing. The PWROG is attempting to resolve all of the issues identified in these questions generically. The USNRC, the PWROG, and Westinghouse have been conducting regular meetings to reach a resolution of the USNRC issues. Furthermore, the PWROG approved the funding to conduct further jet impingement testing to provide data necessary to answer those USNRC RAIs for which a purely analytical approach has not proven acceptable. Due to the dependence on the PWROG and Westinghouse results and subsequent responses on these issues, TMI, Unit 1 is not able to respond to the 'Issues Generic to Westinghouse Debris Generation Testing' at this time.

TMI, Unit 1 hereby commits to report to the USNRC how it has addressed the set of 10 questions titled "Issues Generic to Westinghouse Debris Generation Testing," issued in the USNRC RAI to Exelon dated July 23, 2009 (Reference 2) within 90 days of issuance of the final USNRC decision on the acceptability of WCAP-16710-P (Reference 5), and its related supplemental information. The commitment is documented in Attachment 4 of this submittal.

In the interim, TMI, Unit 1 is evaluating contingency measures for the case where the PWROG and Westinghouse results do not adequately respond to the USNRC issues including potential removal of insulation (as discussed with the USNRC in the public meeting conducted August 11, 2009) in the TMI, Unit 1 Fall 2011 refueling outage.

ATTACHMENT 4

Three Mile Island, Unit 1

Response to Request for Additional Information Related to

USNRC Generic Letter 2004-02

Summary of Regulatory Commitments

Attachment 4
Three Mile Island Unit 1
Response to Request for Additional Information Related to Generic Letter 2004-02
Summary of Regulatory Commitments

The following table identifies commitments made in this document.

COMMITMENT	COMMITTED DATE OR "OUTAGE"	COMMITMENT TYPE	
		ONE-TIME ACTION (Yes/No)	PROGRAMMATIC (Yes/No)
TMI, Unit 1 hereby commits to report to the USNRC how it has addressed the set of 10 questions titled "Issues Generic to Westinghouse Debris Generation Testing," issued in the USNRC RAI to Exelon dated July 23, 2009.	Within 90 days of issuance of the final USNRC decision on the acceptability of WCAP-16710-P, and its related supplemental information.	Yes	No

ATTACHMENT 5

Three Mile Island, Unit 1

Response to Request for Additional Information Related to

USNRC Generic Letter 2004-02

Revised Tables 14 and 15

Attachment 5
Three Mile Island Unit 1
Response to Request for Additional Information Related to Generic Letter 2004-02
Revised Tables 14 and 15

The TMI, Unit 1 NPSH Margin Analysis has undergone two revisions since the Supplemental Response to GL 2004-02 (Reference 1) was submitted to the USNRC. Both of the revisions to the NPSH Margin Analysis resulted in minor changes to Tables 14 and 15 (Reference 1). Supplemental information regarding the first revision was provided to the USNRC by Reference 4. The second revision to the NPSH Margin Analysis is discussed, below.

A second revision to the NPSH Margin Analysis was recently completed to implement the following changes:

- Incorporate Case V to evaluate the operation of one LPI pump with two BS pumps as described in the Response to USNRC Question 8, Attachment 2.
- Incorporate a change in the flow rate from the Reactor Building Emergency Cooling (River Water) Pumps (shown in Figure 1 of the previous response to Issue 3f.1, Reference 1). This change was unrelated to GL 2004-02 and had minimal impact on the NPSH margin results.

Table IX: Updated Table 14, LPI Pump NPSH Results

Case	Reactor Building Cooling	Initial Indicated Train Flow (gpm)	Initial Pump Flow (gpm)	Initial Strainer Flow (gpm)	Minimum Excess NPSH (ft)
Case I	EQ	3000	3247	8582	0.4
Case II	EQ	3000	3247	6222	2.4
Case III	EQ	2800	3351	3076	2.0
Case IV	EQ	2800	3351	4256	0.2
Case V	EQ	2800	3351	5436	0.1
Case I	Maximum	3000	3247	8582	11.9
Case II	Maximum	3000	3247	6222	18.8
Case III	Maximum	2800	3351	3076	23.7
Case IV	Maximum	2800	3351	4256	20.1
Case V	Maximum	2800	3351	5436	20.1

NOTE: Table IX does not include the adjustment factor for air ingestion, as described in response to USNRC Question 9, above.

Apart from the addition of Case V, the updated Table 14 is the same as the Table provided in Reference 4 with the exception of the Minimum NPSH margin for EQ Case IV. As discussed in the response to USNRC Question 8, Attachment 2, when the scale of the plot of minimum margin for Case IV was expanded, the actual margin was determined to be 0.2 ft.

Table X: Updated Table 15, Building Spray Pump NPSH Results

Case	Reactor Building Cooling	Pump Flow (gpm)	Initial Strainer Flow (gpm)	Minimum Excess NPSH (ft)
Case I	EQ	1180	8582	2.0
Case IV	EQ	1180	4256	2.6
Case V	EQ	1180	5436	2.6
Case I	Maximum	1180	8582	13.6
Case IV	Maximum	1180	4256	22.4
Case V	Maximum	1180	5436	22.6

Apart from the addition of Case V, the updated Table 15 is the same as the Table provided in Reference 4 with the exception of the Minimum NPSH margin for EQ Case IV. The minimum margin for EQ Case IV increased slightly from 2.5 to 2.6 ft.

Additional Data Tables

The following additional tables are provided to support the information provided in the RAI responses. These tables are from the latest revision of the NPSH Margin Analysis and were not included in previous submittals to the USNRC.

Table XI: Transient Event Times – EQ Cases*

Event	Case I	Case II	Case III	Case IV	Case V
Time of Peak Sump Temperature (sec)	48.39	48.39	48.39	48.39	48.39
Time of Switchover to Recirculation (hr)	0.7	0.9	1.7	1.2	0.9
Time of Minimum Excess** LPI Pump NPSH (hr)	0.7	0.9	1.7	1.2	0.9
Time of Minimum Excess** BS Pump NPSH (hr)	0.7	n/a	n/a	1.2	0.9
Time When Sump Temperature Reaches 140 °F (hr)	22.3	24.5	133.4	133.4	133.4
Time When Strainer Pressure Drop Exceeds 10 ft (hr)	22.3	47.3	Never	Never	Never
Time of Maximum Pressure Drop across the Sump Strainer (hr)	23.3	47.3	720	720	720
Time When First Building Spray Pump is Secured (hr)	1.7	n/a	n/a	25.2	1.9
Time When Second Building Spray Pump Secured (hr)	24.7	n/a	n/a	n/a	24.9

* Event times are from the beginning of event
** Minimum Excess NPSH is determined after switchover operations are complete

Table XII: Key Transient Event Times – Maximum Cooldown Cases*

Event	Case I	Case II	Case III	Case IV	Case V
Time of Peak Sump Temperature (sec)	40.19	40.19	40.19	40.19	40.19
Time of Switchover to Recirculation (hr)	0.7	0.9	1.7	1.2	0.9
Time of Minimum Excess LPI Pump NPSH (hr)	1.1	1.4	5.6	3.9	3.9
Time of Minimum Excess BS Pump NPSH (hr)	1.1	n/a	n/a	3.9	3.9
Time When Sump Temperature Reaches 140 °F (hr)	1.1	1.4	5.6	3.9	3.9
Time When Strainer Pressure Drop Exceeds 10 ft (hr)	1.1	1.6	Never	Never	Never
Time of Maximum Pressure Drop across the Sump Strainer (hr)	1.7	2.6	720	25.2	24.9
Time When First Building Spray Pump is Secured (hr)	1.7	n/a	n/a	25.2	1.9
Time When Second Building Spray Pump Secured (hr)	24.7	n/a	n/a	n/a	24.9

* Event times are from the beginning of event

Table XIII: Maximum Strainer Head Loss

Case	Reactor Building Cooling	Initial Strainer Flow (gpm)	Maximum Head Loss (ft)
Case I	EQ	8582	12.1
Case II	EQ	6222	10.0
Case III	EQ	3076	4.2
Case IV	EQ	4256	4.2
Case V	EQ	5436	4.2
Case I	Maximum	8582	15.6
Case II	Maximum	6222	10.6
Case III	Maximum	3076	7.8
Case IV	Maximum	4256	8.4
Case V	Maximum	5436	7.8