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NL-09-138

November 19, 2009

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

SUBJECT: **Indian Point Nuclear Power Plants Unit 2 and 3**
Updated Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact Of Debris Blockage On Emergency Recirculation During Design Basis Accidents At Pressurized-Water Reactors"
Indian Point Units 2 and 3
Docket Nos. 50-247 and 50-286
License Nos. DPR-26 and DPR-64

REFERENCES:

1. NRC 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. NL-05-023, "90-Day 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 28, 2005.

3. NL-05-094, "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. NL-05-133, "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 15, 2005.

5. NL-08-025, "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 28, 2008.

6. NRC letter to Entergy Vice President of Operations, "Indian Point Nuclear Generating Unit Nos. 2 and 3 – Request for Additional Information Regarding Generic Letter 2004-02 (TAC Nos. MC4689 and MC4690)", dated November 19, 2008.

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7. NRC letter 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.

Dear Sir or Madam:

The purpose of this submittal is to provide Entergy's updated supplemental response to Generic Letter (GL) 2004-02 (Reference 1). The Nuclear Regulatory Commission (NRC) issued GL 2004-02 to request that addressees perform an evaluation of the Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) recirculation functions in light of the information provided in the GL and, if appropriate, take additional actions to ensure system function. Entergy responded to the GL in References 2, 3, 4 and, most recently, a supplemental response was provided in Reference 5. Based on an NRC review of Reference 5 the NRC staff determined that a request for additional information (RAI) was needed in order to conclude that there is reasonable assurance that GL 2004-02 has been satisfactory addressed for the Indian Point units (Reference 6).

The RAI addresses the supplemental response (Reference 5), however, since submitting that response, Entergy determined that an alternate approach to chemical effects testing would be pursued. The alternate approach involved not only chemical effects testing but also debris testing and substantial reanalysis. This submittal provides an updated response to the GL that incorporates the retesting and reanalysis results. Owing to the comprehensive changes made, this submittal supersedes Reference 5 in its entirety.

Attachment 1 provides the Entergy updated supplemental response to GL 2004-02. The response addresses the actions and methodologies used at Indian Point to resolve the issues identified in the GL and was prepared using NRC guidance provided in Reference 7.

Attachment 2 provides simplified Emergency Core Cooling System flow diagrams for both IP2 and IP3.

Attachment 3 provides Entergy's response to the NRC RAIs and, as applicable, the location in this response where the RAI is further discussed.

The final resolution of the industry issue regarding potential chemical and downstream effects within the reactor core is pending the issuance of the NRC Safety Evaluation Report (SER) on WCAP-16793-NP. Entergy will identify and report to the NRC any corrective actions that may apply to this issue, within 90 days of issuance of the SER.

No new commitments are being made in this submittal. If you have any questions or require additional information, please contact Mr. R. Walpole, Licensing Manager at 914-374-6710.

I declare under penalty of perjury that the foregoing is true and correct. Executed on 11/19

Sincerely,

JE Pollock

JEP/rw

Attachment 1: Indian Point Units 2 and 3, Updated Supplemental Response to NRC Generic Letter 2004-02

Attachment 2: Indian Point Units 2 and 3, Emergency Core Cooling System Flow Diagrams

Attachment 3: Indian Point Units 2 and 3, Responses to NRC Request for Additional Information Regarding Generic Letter 2004-02

cc: Mr. John P. Boska, Senior Project Manager, NRC NRR DORL
Mr. Samuel J. Collins, Regional Administrator, NRC Region 1
NRC Resident Inspector, IP2
NRC Resident Inspector, IP3
Mr. Paul Eddy, New York State Dept. of Public Service

ATTACHMENT 1 TO NL-09-138

INDIAN POINT UNITS 2 AND 3

UPDATED SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNITS 2 AND 3
DOCKETS 50-247 AND 50-286

Updated Supplemental Response to NRC Generic Letter 2004-02, Potential Impact Of Debris Blockage On Emergency Recirculation During Design Basis Accidents At Pressurized-Water Reactors

Entergy provided a comprehensive supplemental response to Generic Letter 2004-02 [Ref. 133] on February 28, 2008 (Reference 134), however, since submitting that response, Entergy determined that an alternate approach to chemical effects testing would be pursued. The alternate approach involved not only chemical effects testing but also debris testing and substantial reanalysis. This submittal provides an updated response to the GL that incorporates the retesting and reanalysis results. Owing to these comprehensive changes this submittal supersedes Reference 134 in its entirety.

Overall Compliance

USNRC Issue 1:

Provide information requested in GL 2004-02, "Requested Information." Item 2(a) regarding compliance with regulations. That is, provide confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis was updated to reflect the results of the analysis described above.

Entergy Response to Issue 1:

General Overview of Conservative Approach to GL 2004-02 Compliance

Entergy's approach to achieving compliance with the requirements of GL 2004-02 consists of a combination of (1) physical design changes, (2) licensing basis changes, and (3) administrative changes supported by (4) a conservative analytical approach, and (5) a conservative testing approach. Each aspect of the overall approach to compliance is described below, and taken together, provide reasonable assurance that the ECCS and CSS recirculation functions will be in compliance with the regulatory requirements of the GL once all corrective actions are complete.

1.1 Physical Design Changes

The following physical changes have been made:

1.1.1 Installation of passive strainer assemblies in the Internal Recirculation and Containment Sumps of both Indian Point units.

The modifications replaced the original grating and fine screen in the Internal Recirculation (IR) and Vapor Containment (VC) sumps with flow barriers and cylindrical (Top-Hat) type strainer assemblies made of 14 gauge Type 304 stainless steel perforated plate designed to accommodate the predicted increased post-accident debris loads. In order to increase the available strainer surface area the Unit 2 Containment sump strainer includes an extension outside the crane wall. The new strainers are sized to limit the head loss across them to ensure positive Net Positive Suction Head (NPSH) margin for the internal recirculation (IR) and residual heat removal (RHR) pumps. The passive strainer assemblies are sized for an acceptable head loss based on the bounding case debris load generated following a large break loss of coolant accident (LBLOCA) in order to ensure that high head safety injection (HHSI) pump, IR pump and RHR pump NPSH and system flow rate requirements are met. The design basis for the strainers includes providing sufficient flow area for the most limiting scenario to ensure that the design basis flow area is available to mitigate the consequences of a LOCA under post-LOCA design basis debris and chemical loading conditions.

The original Unit 2 IR and VC sump screens ($48ft^2$ and $14ft^2$, respectively) were replaced by strainer assemblies with effective areas of 3156 ft^2 and 1182 ft^2, respectively, and, the original Unit 3 IR and VC sump screens ($48ft^2$ and $32ft^2$, respectively) were replaced by strainer assemblies with effective areas of 3156 ft^2 and 1058 ft^2, respectively.

In addition to the significant increase in screen surface area the new strainers assemblies feature 3/32" diameter holes and a bypass eliminator. The bypass eliminator significantly reduces the amount of fiber that can pass through the strainers.

1.1.2 Installation of flow channeling barriers in both Indian Point units.

The flow channeling barriers are designed to route the post-LOCA water into the reactor sump and then up through the incore instrumentation tunnel to the VC annulus through openings in the crane wall before entering the IR sump or the VC sump. This flow path is credited so that a large quantity of the LOCA generated debris will settle in the reactor sump or elsewhere in the VC before reaching the IR or VC sump.

1.1.3 Installation of a trash rack over the refueling canal drain in both Indian Point units.

The trash racks are designed to minimize the potential for the drain to become blocked with debris. The trash rack thereby eliminates the potential for a significant holdup water volume and ensures the refueling cavity drains to the sumps.

1.1.4 Replacement of the Unit 2 tri-sodium phosphate (TSP) and Unit 3 sodium hydroxide (NaOH) pH buffers with sodium tetraborate (NaTB).

The replacement of the pH buffers by NaTB significantly reduces the predicted amount of chemical precipitants to an acceptable level. The accumulation of post LOCA debris and chemical precipitants at the sump strainers with the original buffers was such that the head loss across the strainers reduced pump NPSH margin to an unacceptable degree.

1.1.5 Removal of Kaowool from inside the Unit 3 crane wall.

The removal of Kaowool reduces the potential for the generation of fibrous debris and chemical precipitants. In the event of a LBLOCA it was estimated that 21.5 ft^3 of Kaowool would be destroyed as fines resulting in 100% transport to the sump strainer. Kaowool also contains aluminum that would contribute to chemical precipitant at the strainers.

In summary, significant physical changes have been made to the plants that increase the debris handling capabilities of the sump screens/strainers (increased area and reduced hole size), significantly reduce the predicted quantity of debris reaching the strainers (flow channeling), reduce the magnitude of strainer fiber bypass (bypass eliminator), and significantly reduce the predicted impact of chemical effects (buffer replacement).

1.2 Licensing Basis Changes

The following licensing basis changes have been made:

1.2.1 Licensing Basis Change Regarding the Containment Sump pH Buffering Agent (Units 2 and 3)

The benefits of these license amendments are as described above. The NRC approved these licensing basis changes through Technical Specification amendments 253 and 236 for Unit 2 and Unit 3, respectively.

1.2.2 Licensing Basis Change Regarding Passive Failure Analyses (Units 2 and 3)

Under the original licensing basis the original ECCS design incorporated redundancy of components such that neither a single active component failure during the injection phase nor an active or passive failure during the recirculation phase will degrade the ECCS function. The circumstances under which the recirculation pumps and associated piping would be unavailable was determined by a single failure analysis.

The single failure analysis included the loss of a flow path. Because a pipe or valve body rupture, at completion of the switchover to recirculation, were included in the original ECCS licensing basis, the system was arranged to allow either of the residual heat removal pumps to take over the recirculation function at that time.

The licensing basis change to the ECCS single failure analysis ensures that the design incorporates redundancy of components such that neither a single active component failure during the injection phase nor an active or passive failure during the long term recirculation phase will degrade the ECCS function. The principal change is that only active failures will be assumed to occur within the first 24 hours following the initiating event.

The single failure analysis continues to include the loss of a flow path. Because a pipe or valve body rupture is extremely unlikely, the system is now arranged to allow either of the residual heat removal pumps to take over the recirculation function, not at the completion of the switchover to recirculation, but 24 hours after event initiation. The change in the passive failure assumption effectively reduces the debris load on the VC sump.

The NRC approved these licensing bases changes through Technical Specification amendments 257 and 238 for Unit 2 and Unit 3, respectively.

1.2.3 Licensing Basis Change Regarding Emergency Core Cooling System Valve Surveillance Requirements (Unit 2 only)

The purpose of this change to the licensing basis is to add two ECCS motor operated valves (MOVs), 745A and 745B, to Technical Specification (TS) Surveillance Requirement (SR) 3.5.2.1 for checking valve position every 7 days. These two valves are located in series on the inlet pipe to the number 22 residual removal heat exchanger. The TS SR is designed to verify that ECCS valves whose single failure could cause the loss of the ECCS function are in the required position with ac power removed.

The NRC approved this licensing basis change through Technical Specification amendment No. 263.

In summary, licensing basis changes have been made to ensure that the predicted impact of chemical effects (buffer replacement) is significantly reduced and that the debris handling capability of the VC sump meets passive failure requirements.

1.3 Administrative changes

The following administrative changes have been made:

1.3.1 EN-MA-118 "Foreign Material Exclusion"

This procedure has been revised to identify the recirculation and containment sumps as FME Level 1 areas, the highest level of cleanliness control.

1.3.2 OAP-007 "Containment Entry and Egress"

This procedure has been revised to include specific Engineering inspections of the sump strainers and assemblies as well as critical features of the sump design that includes the flow barriers to ensure proper configuration. In addition, the procedure has been revised to ensure a thorough cleanup throughout Containment.

1.3.3 ENN-EE-S-010-IP2 "Electrical Separation Design Criteria"

This standard has been revised to phase out the use of vinyl cable tray tags, to exclude the use of new marinate and/or transite, to eliminate the use of new cable wrap for separation, and to require an Engineering evaluation should a deviation be necessary.

1.3.4 ENN-EE-S-008-IP "Electrical Installation Standard"

This standard has been revised to eliminate unqualified material such as vinyl tags, tape, and blankets in new installations.

1.3.5 Dust and Latent Debris Control

In order to ensure Containment dust, dirt, and latent debris does not exceed the analyzed quantities evaluated, a sampling program was initiated. The sampling uses the same methodology employed for the original walkdowns and is per NEI 04-07 methodology as amended by SER. Entries were made in the Work Control System that will automatically generate work orders to perform sampling activities on an appropriate recurring and periodic basis for each unit. Current FME and Housekeeping programs, as well as Containment cleaning efforts by Maintenance, Radiation Protection and Operations just prior to startup are performed to keep the loads within the bounds of the analysis.

1.3.6 Design Control:

Fleet design procedure EN-DC-115, "Engineering Change Development" is applicable to both units. This procedure has been revised to screen design changes for impact on GL 2004-02 compliance. Examples of specific screen items include any changes to: insulation, coatings, aluminum, and other metallic/non metallic debris sources.

1.3.7 Coatings Control:

Several enhancements to the existing Entergy Nuclear Northeast fleet procedure, ENN-DC-150, "Condition Monitoring of Maintenance Rule Structures", were made. These enhancements include a detailed inspection checklist for coatings. A PM (Preventative Maintenance) to visually inspect coating in the Indian Point Unit 2 and 3 Vapor Containment Buildings during all future refueling outages was created for GSI-191 employing guidance from ENN-DC-150. These changes have been incorporated in fleet procedure EN-DC-150, Rev. 0. The frequency of the PM inspection for GSI-191 is every two (2) years, or every cycle during the refueling outage. The process requires any degraded coatings be evaluated as acceptable, or repaired prior to exiting the outage.

All coating requests in the VC are evaluated by the coating engineer and only approved DBA qualified coatings are used.

In summary, procedural and programmatic controls have been established to ensure materials used in the Containments will not result in an increase of the debris loading beyond the analyzed values. This includes controls for foreign material exclusion, containment coatings, labels, insulation, and dust and latent debris.

1.4 Conservatisms in the analytical approach

Entergy has performed extensive analyses to determine the susceptibility of the ECCS and CSS recirculation functions to adverse effects of post-accident debris blockage and operation with debris-laden fluids. The analyses conform to the greatest extent practicable to the NEI 04-07 Guidance Report methodology (GR) as supplemented by the NRC Safety Evaluation Report (SER)[Ref. 3].

The major areas of conservatism include the application of the Nuclear Energy Institute (NEI) 04-07 methodologies in determining the amount and transportation of LOCA generated debris, deterministically calculated minimum sump water inventory, and applying the debris mix that exceeds the Indian Point design basis requirements in the debris head loss testing. The major conservatisms include:

1.4.1 Conservatisms in the Refueling Water Storage Tank and Containment Water Level

- Minimum RWST volumes credited – No credit is taken for the normal volume of fluid above the Technical Specification minimum water level in the tank. Volumes credited are minimums and do not credit fluid lost between reserved volumes to instrument inaccuracies. For LOCA scenarios in which containment spray actuates, the additional water that could be transferred would result in approximately 5 inches for IP2 and 3 inches for IP3 in Containment. Hold-up volumes are considered to ensure only the water injected or sprayed into Containment that reaches the lower 46 foot floor is counted toward Containment water level.

- Maximum RWST and Accumulator Temperatures – The temperatures for the RWST and four SI Accumulators was conservatively taken at the Technical Specification permitted maximum (110°F and 130°F, respectively). This minimizes fluid density for water level determinations and these are unlikely bulk tank fluid temperatures for most, if not all of the time at IPEC.

- Minimized Flood-up - Assumed hold up volumes in Containment were conservatively biased high to minimize water available for the Containment sump pool.

- Maximized Containment Open Volume – The Containment maximum water level analysis did not consider the increases in water level that would occur if all the equipment that occupied the lower Containment volume was included, i.e. many items below flood level were neglected.

- Full submergence – The Recirculation and Containment Sump strainers are located in pits and will be fully submerged. The IP2 Containment sump strainer has an extension outside the pit on the Containment floor to increase strainer area. These strainers were also shown to have complete submergence from the beginning of the event. Furthermore, vortex suppressors are to be installed to ensure no vortices can develop, eliminating the potential for air ingestion.

In summary, the conservatisms result in additional water level not credited in analysis that will directly increase NPSH available for the pumps, and also provide additional submergence margin for the vortex suppressors.

1.4.2 Conservatisms in the Debris Generation Evaluations

- Spherical Zone of Influence (ZOI) method employed – A spherical ZOI about the break location encompasses a large destruction zone in the relatively open design of the Indian Point Containments. This method takes no credit for energy lost in multiple reflections, which would reduce portions of the ZOI radius. All jet directions and break conditions are accounted for. This is recognized in the SER on the NEI Guidance document. This results in a conservatively large quantity of debris being generated, a key input to the GSI-191 analyses. Additionally, if the ZOI extended through any section of a line, the insulation surrounding the full circumference of the pipe was included in the destroyed insulation.

- Combination of Break Locations – Analysis was performed by combining the maximum amount of each type (fiber or particulate) of debris (from different break locations), not simply by selecting the case that produced the maximum debris quantity. This is significant in that no actual, single break location could result in this combined quantity of debris.

- All Un-Qualified Coatings Fail – All un-qualified coatings (regardless of location in Containment) are assumed to fail immediately and be available for transport to the Recirculation sump. This immediate and complete failure of all un-qualified coatings is unlikely. In the case of pool turnover for the Containment sump, all un-qualified coatings are then conversely assumed not to fail until the Containment sump is activated approximately 24 hours into the event. Water level and density will increase with time, raising the NPSH available.

- Additional Coatings Margin – An additional mass of coating material was included in the downstream analyses (including pumps). For Unit 2 an additional 31 lbs was included, and for Unit 3 an additional 352 lbs was included.

- Latent Debris Sampling – Numerous samples were taken throughout the Containment for each unit. The samples were taken while the plant was in a Refueling Outage when no special closeout cleanup efforts had been taken. Additional emphasis has since been placed on Containment cleanliness ensuring the samples represent bounding quantities.

In summary, the debris generation analysis conservatively maximized the quantity of debris generated for any LOCA. This then maximizes the head losses across the strainer, thereby minimizing NPSH, structural, and flow margins.

1.4.3 Conservatisms in the Debris Transport Evaluations

- Maximum Flow Rates Applied – The maximum system flow rates were determined with hydraulic system models with maximum "enhanced" pump curves, minimized system resistance, maximum Equipment Qualification flood levels all to maximize pump performance, and the results where then rounded up. No credit is taken for the significantly reduced flow rates both units would have after they are re-aligned for Hot-Leg recirculation about 7 hours into the accident. Transport models use lowest initial Containment water levels at start of recirculation, which conservatively increases velocities and turbulence, maximizing transport to the strainers. Flow barriers are assumed to be blocked instantly, increasing the velocity of the main flow path to the sumps, and hence transport. Considering this, the main flow path (under the reactor and through the In-core tunnel) is still a low velocity area, permitting settling.

- Transport Based on Velocity and TKE – Transport to the sumps are based simply on fluid velocity and Turbulent Kinetic Energy (TKE). The torturous path to the sumps and obstructions along the path, would result in much less debris than predicted reaching the sumps. The model does not predict agglomeration of debris during transport which can facilitate settling and trapping of smaller transportable debris. No credit was taken for settling of insulation particulates or fiber fines. It can be expected there will be quiescent areas in the pool where some debris will settle. The RCS break flow is assumed to fall directly to the pool, without impacting any obstructions, increasing turbulence and transport.

- Maximized Velocity, Minimizing Settling - The debris transport analysis conservatively modeled the vertical perforated surface of the flow barriers as being fully blocked during recirculation transport. This effectively maximized the velocity of the sump pool water flowing through the Reactor Cavity and In-core tunnel on the way to the sumps, increasing the velocity of the main flow path to the sumps, and hence transport. This conservatively minimizes the credit that can be taken for settling, thereby increasing the transport of debris.

- Debris Hold-up Not Credited – There was no credit taken for debris hold-up on Containment equipment or structural elements (e.g. Fuel Manipulator Crane, Polar Crane).

In summary, the debris transport analysis provided conservative values for transport of debris to both the IR and VC Sumps in excess of quantities that would be generated. It also conservatively discounted the expected capture of debris by the flow barriers and equipment within the Containment. Furthermore, the debris transport model conservatively maximized pool turbulence increasing the suspension of debris within the Containment pool.

1.4.4 Conservatisms in the NPSH Determination Evaluations

- No Containment Over Pressure – IPEC did not credit accident overpressure in the NPSH determinations. Note that Containment accident pressure, which contributes directly to the pump NPSH Available, is greatest at the start of recirculation when the water level and density is at a minimum.

- NPSH employed SBLOCA levels and LBLOCA Flows – All NPSH calculations were determined with the small break LOCA water level (minimizing NPSH Available) to the pump. Furthermore, potentially available RWST water levels mentioned in 1.4.1 above are not considered. Conversely, the maximum flow rates for the pumps are used. These are extreme flow rates and are reduced later in the event.

- Debris Head Loss Applied Immediately – Although LOCA generated debris will take time to wash down from upper levels of Containment, erode, and transport from dispersed locations to the sumps, the full head loss is applied to the strainer when the Containment water level and density is at the lowest, minimizing available NPSH.

- Vortex Suppressors – Indian Point will install vortex suppressors over all IR and VC sump strainers at or below the minimum water level. Rather than relying on testing or analysis, this installation ensures a vortex cannot develop regardless of the strainer loading conditions, eliminating the potential for air ingestion to the pumps.

In summary, the analyses maximized the debris loads and pump flow rates through the strainers, while minimizing the sump water level available. These conservatisms ensure margin in all plant recirculation operations.

1.4.5 Conservatisms in the Downstream Effects Evaluations

- All Particulate Bypasses Strainers – All particulate determined to reach the strainers was assumed to bypass into the system and contribute to wear. This includes asbestos, all failed coatings, and dust/dirt debris. This is conservative as testing demonstrates that the fiber debris bed on the strainer will capture particulates. An additional 31 pounds for IP2 and 352 pounds for IP3 were added into the respective analysis for margin. A maximum debris size of 0.14 inch, based on a larger strainer hole size of 1/8 inch was conservatively applied for blockage analysis while the actual strainer hole size is 3/32 of an inch.

- Max Flow Rates Employed - Typically, maximum calculated flow rates were applied in wear determinations. This is conservative since wear is proportional to the square of velocity. Note that IPEC flow rates of both units are significantly reduced (below 1350 GPM) from higher low head recirculation rates after the system is re-aligned for Hot-Leg recirculation, about 7 hours into the accident.

- Strainer Perforations Enlarged for Analysis - The maximum debris size was considered to be 50% larger (9/64" versus 3/32") than the actual maximum openings of the strainer modules (Top-Hats). This conservatively allows more bypass and increased wear and clogging of downstream components (excluding pumps).

- No Credit for Bed Filtration – For component wear evaluations, no credit was taken for particulate debris filtration by the strainer debris bed, or components in the flow path. This is significant since strainer array testing demonstrates the effectiveness of the debris bed at reducing the quantity of suspended particulates within the flow stream in a period of time substantially less than the mission time.

- Time Effect Not Considered – For the initial recirculation NPSH analysis, when flow rates are at the maximum and water level is at the minimum, no consideration is given to the fact that it will take time for the full debris load to transport to the strainers, while at the same time, water level will be increasing. The NPSH is determined at the minimum water level and with the full debris load assumed to be instantaneously transported at the strainer. Also, at 7 hours into the event/recirculation, flow rates and corresponding NPSH required values are significantly reduced.

In summary, the aforementioned conservatisms maximize the potential for wear and/or blockage of equipment downstream of the strainers and employ the high pump flow rates of low head recirculation.

1.5 Conservatisms in the testing approach:

The head loss across the installed sump screen has been determined via testing using a test for success testing methodology in the areas of debris head loss testing and chemical effects testing conducted in accordance with the March 2008 guidance [Ref. 129]. Conservatisms in the testing approach include:

- Strainer Testing with Fines - Entergy conservatively chose to retest using the newer NRC March 2008 protocol guidance, rather than justify earlier testing efforts. Several tests were done with fiber beds of 100% fines where the particulate was loaded in first. Careful preparation of the fines resulted in very good fiber separation, simulating true thin-bed condition tests. Remaining tests consisted of a minimum of 80% fines. Essentially no debris settling (near field settling) was permitted in the tank prior to reaching the strainers for all testing, and the debris was allowed to prototypically be drawn into the simulated strainer pit by the flow.

- Full WCAP Chemicals - The chemical loads added in testing are pre-prepared per the WCAP-16530 methodology. This is a conservative, single effect reaction approach to predict chemicals precipitants. No refinements were applied that could reduce the WCAP predicted quantities, (e.g. Silicon inhibition, protective oxidation on Aluminum surfaces, Aluminum solubility). Conservative inputs for the WCAP were used to produce the largest quantity of precipitants. The following program inputs were selected to maximize chemical precipitants: LOCA generated debris, spray time, sump pH, temperature, spray pH, Containment temperature, mass and surface area of aluminum, and area of concrete. Conservative logarithmic extrapolations were applied with all test data points bounded by the final curve.

- Bounding Flow Rates – The scaled testing was performed with bounding flow rates for multiple conditions and units (2 pump operation, recirculation spray, maximized flow conditions). These higher flow rates promote compression of the debris beds on the strainers, also resulting in higher particulate capture, and subsequently higher head losses than would be seen at lower flow rates. Note that IPEC flow rates of both units are significantly reduced (below 1350 GPM) after they are re-aligned for Hot-Leg recirculation, approximately 7 hours into the accident.

- Bounding Extrapolations for Head Losses - The head loss after each conventional debris and precipitate addition step was allowed to stabilize. Then, conservative logarithmic extrapolations were fitted to the test data, and then raised to bound the test points, to predict the head loss at 30 days. If a later test stage had a lower head loss (possibly due to a bed shift for instance), the higher previous value was applied.

In summary, conservative bounding flow rates were applied to analyses. Testing employed the March 2008 protocol with WCAP prepared precipitates and a high fraction of fines, even in full load tests. The extrapolations for the 30 day mission time were conservatively determined.

1.6 Overall Conclusion Regarding Conservatisms

The aforementioned conservatisms, in addition to the overall NEI methodology conservatisms applied throughout the mechanistic analyses for the Generic Letter resolution and numerous conservatisms not individually enumerated herein, will ensure successful ECCS pump operation at IP2 and IP3.

Regulatory Compliance

In order to achieve full compliance, the scheduled corrective actions discussed in the response to Issue 2 below must be completed. These corrective actions include the installation of vortex suppressors for both Units and the installation of an alternate source of power to the position indicators of Unit 2 MOVs 745A and 745B.

Entergy requested [Ref. 135] and received approval [Ref. 136] for an extension until spring 2010 to complete the installation of the Unit 2 vortex suppressors and the 745 valve modification. Entergy also requested [Ref. 135] an extension until spring 2011 to complete the installation of the Unit 3 vortex suppressors. The NRC approved a Unit 3 extension until May 31st, 2010 [Ref. 136].

Based on the scheduled corrective actions, Unit 2 will be in full compliance with the requirements of GL 2004-02 with the completion of the vortex suppressor installation and the 745 valve modification, and a revision to the licensing basis as described in the UFSAR to reflect the deterministic approach to sump screen blockage, including a 30 day ECCS mission time. However, Unit 3 will not achieve full compliance until spring 2011 with the installation of the vortex suppressors. Nevertheless, Entergy will revise the Unit 3 licensing basis to meet GL 2004-02 requirements by May 31st, 2010. An evaluation of the acceptability of the delay in installing the vortex suppressors for this interim period will be performed prior to May 31, 2020.

The UFSAR is submitted periodically (6 months after each refueling outage) to the NRC. The next Unit 2 refueling outage is scheduled for spring 2010 during which the final GL 2004-02 related modifications will be installed. Therefore, the UFSAR update including these changes will be submitted by fall 2010 for Unit 2. Similarly for Unit 3 the corresponding UFSAR changes will be submitted by fall of 2011.

General Description of and Schedule for Corrective Actions

USNRC Issue 2:

Provide a general description of actions taken or planned, and dates for each. For actions planned beyond December 31, 2007, reference approved extension requests or explain how regulatory requirements will be met as per "Requested Information" Item 2(b). That is provide a general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this generic letter. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If *all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.*

Entergy Response to Issue 2:

Completed Corrective Actions

Containment Walkdowns

1. Detailed containment walkdowns were conducted to identify and quantify the types and locations of potential debris sources. These walkdowns were conducted in accordance with the guidance in NEI 02-01.

Physical Design Corrective Actions

1. Installation of passive strainer assemblies in the Internal Recirculation (IR) and Containment sumps (VC) (Unit 2 spring 2006, Unit 3 spring 2007).

2. Installation of passive strainers outside the crane wall (Unit 2 spring 2008)

3. Installation of flow channeling barriers (Unit 2 spring 2006, Unit 3 spring 2007).

4. Installation of a debris trash rack over the refueling canal drain (Unit 2 spring 2006, Unit 3 spring 2007).

5. Replacement of the Unit 2 tri-sodium phosphate (TSP) pH buffer sodium tetraborate (NaTB)(spring 2008).

6. Replacement of the Unit 3 sodium hydroxide (NaOH) pH buffer by sodium tetraborate (NaTB)(summer 2008).

7. Removal of Kaowool from inside the Unit 3 crane wall (spring 2007).

Licensing Basis Corrective Actions

1. Replacement of the Unit 2 tri-sodium phosphate (TSP) pH buffer with sodium tetraborate (NaTB)(implemented spring 2008).

2. Replacement of the Unit 3 sodium hydroxide (NaOH) pH buffer with sodium tetraborate (NaTB)(implemented summer 2008).

3. Licensing basis change regarding passive failure analysis. (Unit 2 and 3)

4. Revision to Emergency Core Cooling System Valve Surveillance Requirements (issued by the NRC for implementation spring 2010)(Unit 2 only).

Administrative Corrective Actions

1. Procedural and programmatic controls have been established to ensure materials used in the Containments will not result in an increase of the debris loading beyond the analyzed values. This includes controls for foreign material exclusion, containment coatings, labels, insulation, and dust and latent debris. These procedural and programmatic controls are described in the response to Issue 1 and Issues 3h and 3i.

Analytical and Testing Corrective Actions

1. In order to achieve compliance with the requirements of GL 2004-02, Entergy implemented a plan that involves a debris and chemical head loss "test for success" methodology based on the NRC March 2008 guidance [Ref. 129]. The plan involved the development of a test protocol, NRC review of the protocol, "test for success" testing, preparation of the test report, and completion of analyses including strainer qualification. These actions were essentially completed by August 31st, 2009. However, in order to resolve certain NRC RAIs, Entergy recently completed revisions to a limited number of documents.

Scheduled Corrective Actions

1. Installation of vortex suppressors over the IR and VC sump strainers for both Indian Point units (Unit 2 spring 2010, Unit 3 spring 2011).

   The test for success testing determined the plant configuration needed to support strainer qualification, and what, if any, additional plant modifications would be required to resolve GL 2004-02. Entergy has recently completed this testing and it has been determined that additional plant modifications are required. During full flow testing with a thin bed and chemical precipitants a vortex was observed to form. In order to eliminate the potential for vortex formation a vortex suppressor was used in all subsequent testing. Therefore, in keeping with the test for success approach, vortex suppressors must be installed above the internal recirculation and containment sump strainers including the Unit 2 containment sump extension strainers.

   The vortex suppressors will be installed during the spring 2010 and spring 2011 refueling outages for Unit 2 and Unit 3, respectively. In addition, after April 30th, 2010, Entergy will also have plans in place to install the Unit 3 vortex suppressors during any forced outage requiring entry into Mode 5, of a long enough duration in that mode, to install the suppressors.

2. Installation of an alternate source of power to the position indicators of Unit 2 MOVs 745A and 745B associated with Technical Specification amendment 263 [Refs. 140 and 141](spring 2010).

   The amendment to the Unit 2 Technical Specifications adds two Emergency Core Cooling System (ECCS) valves to Surveillance Requirement (SR) 3.5.2.1. The purpose of the SR is to verify that ECCS valves whose single failure could cause loss of the ECCS function are in the required position with power removed so that the single failure could not occur. With normal ac power removed valve position indication would be lost.

The alternate source of power to the position indicators will be installed during the spring 2010 refueling outage.

3. Participation in a new 30-day fiber erosion test (December 2009 through April 2010).

   A new 30-day fiber erosion test will provide both 30-day results (percent change in weight for pre-test sample versus post-test sample) and time based data (measurement of collected eroded material at predetermined intervals throughout the 30-day test) to support the assumption of 10 percent fibrous debris erosion in the Containment pool over a 30-day period. The intent of this test is to fully address NRC RAI 2 and relevant parts of RAI 5 (see Attachment 3).

   The new 30-day fiber erosion test to be conducted by Alion is planned for December 2009 and a test report is scheduled to be available in April 2010. Should the test results not support the assumption of 10 percent fibrous debris erosion additional corrective actions may be required.

4. Review of NRC SER on WCAP-16793-NP.

   The final resolution of the industry issue regarding potential chemical and downstream effects within the reactor core is pending the issuance of the NRC Safety Evaluation Report (SER) on WCAP-16793-NP. Entergy will identify and report to the NRC any corrective actions that may apply to this issue, within 90 days of issuance of the SER.

In summary, substantial corrective actions have been made to enhance the recirculation functions of the ECCS and CSS. The scheduled corrective actions, when complete, will ensure full compliance with the regulatory requirements of GL 2004-02.

Specific Information Regarding Methodology for Demonstrating Compliance

USNRC Issue 3a:

Break Selection
The objective of the break selection process is to identify the break size and location that present the greatest challenge to post-accident sump performance.

1. *Describe and provide the basis for the break selection criteria used in the evaluation.*
2. *State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.*
3. *Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.*

Entergy Response to Issue 3a.1:

Common to both units

All methodologies, assumptions, calculations and results regarding Break Selections for Indian Point Units 2 and 3 are included in the Debris Generation Calculations [Refs. 1 and 2].

Indian Point evaluated a number of break locations and piping systems, and considered breaks that rely on recirculation to mitigate the event. The following break location criteria were considered:

Break Criterion No. 1 - Breaks in the RCS with the largest potential for debris;
Break Criterion No. 2 - Large breaks with two or more different types of debris;
Break Criterion No. 3 - Breaks with the most direct path to the sump;
Break Criterion No. 4 - Large breaks with the largest potential particulate debris to insulation ratio by weight; and
Break Criterion No. 5 - Breaks that generate a "thin-bed" - high particulate with 1/8" fiber bed.

This spectrum of breaks is consistent with that recommended in the SER [Ref. 3], and is also consistent with regulatory position 1.3.2.3 of Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," [Ref. 63].

The IR sump evaluations considered breaks in the primary coolant system piping having the potential for reliance on ECCS sump recirculation. The review determined that a primary coolant system piping Large Break Loss of Coolant Accident (LBLOCA) and certain primary coolant system piping Small Break LOCAs (SBLOCAs) would require ECCS sump recirculation. Indian Point considered other high energy line breaks (e.g., secondary side breaks) and determined that sump operation was not required.

The VC sump evaluations considered breaks in the primary coolant system piping having the potential for reliance on VC sump recirculation. There is no single active failure (pending IP-2 745 valve license amendment implementation), or single passive failure until 24 hours into the event, that would require the use of the VC sump.

The PRA model divides pipe break LOCAs into three categories based on equivalent size and associated failure frequency. The largest of these categories is a Large LOCA event, which is defined as a break within the Reactor Coolant System (RCS) of approximately 0.2 ft^2 or larger. This is equivalent to a 6 inch diameter break size. The Large LOCA event has a frequency of occurrence that is more than an order of magnitude lower than the Medium LOCA event (defined as 2" to 6" diameter equivalent size for PRA) and two orders of magnitude lower than Small LOCA events (defined as breaks up to 2" equivalent diameter for PRA) [Refs. 1 and 2].

An evaluation using the IP-2 and IP-3 Probabilistic Risk Assessment (PRA) models determined that assuming the VC sump was unavailable for external recirculation for LOCAs greater than 2 inch equivalent diameter would not result in a significant impact on overall core damage frequency (CDF)[Ref. 132]. However, the VC sump was qualified for 6 inch breaks or less for conservatism. Therefore, qualifying the VC sump for conventional and chemical debris loads associated with breaks of 6 inches or less limits the risk impact, primarily because breaks larger than 6 inches have a lower initiating event frequency [Refs. 1 and 2].

For small breaks in the GSI-191 analyses, both the IR and VC sump evaluations only consider piping that is 2 inches in diameter and larger. This is consistent with the Section 3.3.4.1 of the SER, which states that breaks less than 2 inches in diameter need not be considered. A detailed evaluation of the conditions present at Indian Point shows that this range may be extended to less than 3 inches. The evaluation demonstrates that the vortex analysis, NPSH values, and void fraction (deaeration/flashing) values documented for breaks of 3 inches and greater are bounding due to significantly lower debris loads, lower flow rates, and other mitigating factors associated with breaks less than 3 inches [Ref. 40].

LBLOCA (IR), 6 inch break LOCA (VC), and SBLOCA (IR and VC) cases are calculated with the conservative methodology described in NEI 04-07 Sections 3, 4, and 5 for debris generation, transport, and accumulation. Hence, the Alternate Methodology presented in Section 6 of the NEI 04-07 (Region I vs. Region II breaks) is not used for Indian Point's design basis.
Also, following a LBLOCA, the VC Sump is required for use 24 hours after event initiation [Ref. 102]. In this scenario, the IR Sump is operated for the first 24 hours following a LOCA. After this time, an ECCS passive failure may occur and cause the IR Sump to become inoperable, requiring the use of the VC Sump. During the first 24 hours in this scenario, the post LBLOCA generated debris settles out, is diverted by appropriate flow barriers, or is transported to the IR Sump strainers, thereby significantly reducing the debris load on the VC Sump [Ref. 102].

Entergy Response to Issue 3a.2:

Common to both units

Secondary line breaks were not considered because they do not lead to ECCS recirculation mode. Each Steam Generator has a fast closing stop valve and a check valve. These eight (8) valves prevent the blowdown of more than one (1) Steam Generator regardless of break location, thereby retaining three (3) Steam Generators for heat removal after the faulted Steam Generator has completed blowdown [Refs. 64 and 65].

Entergy Response to Issue 3a.3:

The Debris Generation Calculations [Refs. 1 and 2] identified break locations that provided limiting conditions for each of the 5 break selection criteria above. The possible break cases were identified according to the limiting cases for both the North and South compartments for large break and small break LOCAs. 6 inch break LOCA cases were also identified according to the same criteria for application to the VC sump. Section 3.3.5 of the NRC SER [Ref. 3] describes a systematic licensee approach to the break selection process which includes beginning at an initial location along a pipe and stepping in equal increments (5 ft increments per the SER), while considering breaks at each sequential location. However, for Indian Point, the use of spreadsheets allowed significantly smaller resolution such that the calculations consider all breaks along the length of the pipe, thereby, ensuring the selected break locations produced the largest amounts of debris. IP-2 used a maximum resolution of 2.1 ft with an average of 0.136 ft (1.63 inches), and IP-3 used a maximum resolution of 2.0 ft with an average of 0.195 ft (2.34 inches).

Unit 2

For SER break selection criterion No. 1, fourteen (14) possible break cases were identified at the following locations for generating the maximum quantities of fiber or particulate fines:

1. Case 1: LBLOCA at the Hot Leg near the #22 Steam Generator for generating the maximum mass of fiber fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, and 3)
2. Case 2: LBLOCA at the Cross-over Leg near the #22 RCP Nozzle for generating the maximum mass of particulate fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, 3, and 4)
3. Case 3: LBLOCA at the Cross-over Leg near the #24 Steam Generator for generating the maximum mass of fiber fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, and 3)

4. Case 4: LBLOCA at the Cross-over Leg near the #24 Steam Generator for generating the maximum mass of particulate fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, 3, and 4)
5. Case 9: SBLOCA at the Cross-over Leg near the #21 Steam Generator for generating the maximum mass of fiber fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
6. Case 10: SBLOCA at the RHR Loop #22 suction line for generating the maximum mass of particulate fines in the South Side Compartment (Line No. 10) (chosen to evaluate Break Criterion Nos. 1, 3, and 4)
7. Case 11: SBLOCA at the Hot Leg at the bottom of the #23 Steam Generator for generating the maximum mass of fiber fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
8. Case 12: SBLOCA at the Pressurizer Surge line for generating the maximum mass of particulate fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1, 3, and 4)
9. Case 13: LBLOCA Reactor Vessel nozzle break in the Reactor Cavity
10. Case 14: 6 inch break LOCA at the Cross-over Leg #22 for generating the maximum mass of fiber fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
11. Case 15: 6 inch break LOCA at the RHR Loop #22 suction line (Line No. 10) for generating the maximum mass of particulate fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1, 3, and 4)
12. Case 16: 6 inch break LOCA at the Hot Leg at the bottom of the #24 Steam Generator for generating the maximum mass of fiber fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
13. Case 17: 6 inch break LOCA at the Pressurizer Surge line (Line No. 63) for generating the maximum mass of particulate fines in the North Side Compartment (limiting break of Break Criterion Nos. 1, 3, and 4)
14. Case 19: 6 inch break LOCA Reactor Vessel nozzle break in the Reactor Cavity

These cases involved four large break cases, four 6-inch break cases, four small break cases, and two nozzle breaks within the Reactor Cavity (LBLOCA and 6 inch break LOCA). The results of the evaluation of insulation debris generation for Break Criterion No. 1 determined that all 14 breaks are limiting based on either the type or amount of debris generated. Note that five additional cases, Cases 5 through 8 and 18, were also identified in the IP-2 Debris Generation Calculation [Ref. 1] and evaluated for an alternate break size. However, the methodology associated with the alternate break size has been subsequently abandoned, and these cases are no longer needed. Therefore, these five additional cases are not included in any other evaluation.

It was determined that the debris generated by the four large break and the four 6 inch break limiting cases for Break Criterion No. 1 bounded the debris generated for Break Criterion No. 2 "large breaks with two or more different types of debris." The four large break limiting cases contained a mixture of Asbestos, Temp-Mat, Nukon™, Transco Blanket, and reflective metal insulation (RMI) and are limiting for the IP-2 IR Sump. The four 6 inch break limiting cases contained an identical mixture of insulation types and are limiting for the IP-2 VC Sump. The evaluation concluded that the four large break and the four 6 inch break cases generate the largest amount of debris, as well as the most limiting combinations of debris for the IP-2 IR Sump and IP-2 VC Sump, respectively.

For Break Criterion No. 3, "breaks with the most direct path to the sump," the most limiting case for the IP-2 IR Sump is a large break at the Hot Leg near the #22 Steam Generator as listed for Break

Criterion No. 1. Similarly, for Break Criterion No. 3, the most limiting case for the IP-2 VC Sump is a 6 inch break at the Cross-over Leg #22. Any pipeline closer to either sump is not large enough to produce a high energy line break (HELB) capable of producing large amounts of debris. Additionally, the IP-2 Debris Transport Calculation, Reference 41, determines a conservative set of transport fractions applicable to all breaks within the crane wall.

For Break Criterion No. 4, "large breaks with the largest potential particulate debris to insulation ratio by weight," the largest quantities of transportable particulate insulation are found on Line No. 10, the Pressurizer, and the Pressurizer Surge Line. To bound Break Criterion No. 4 for the IP-2 IR Sump, the large break cases in this area were evaluated to determine that Case 2 at the Cross-over Leg near the #22 RCP nozzle has the maximum particulate load. Likewise, to bound Break Criterion No. 4 for the IP-2 VC Sump, the 6-inch break cases in this area were evaluated to determine that Case 15 at the RHR Loop #22 suction line (Line No. 10) has the maximum particulate load. Consequently, both maximum particulate loads are evaluated for all possible fiber loads from no fiber, through thin bed thickness, and onto the maximum possible fiber load.

For Break Criterion No. 5, "breaks that generate a thin-bed," many possible HELBs can be postulated that would generate and transport the small quantity of fibrous debris needed to form a thin-bed. Therefore, all design case breaks could be susceptible to the thin-bed effect.

The Test Debris Amounts Calculation [Ref. 45] applied transport fractions and determined the scaled conventional and chemical debris quantities for the current (full) insulation configuration at Indian Point, as well as multiple configurations of incremental insulation removal. For the purposes of the Head Loss Calculation [Ref. 28], the following IP-2 full insulation analytical debris generation cases were investigated. These cases were chosen because the LBLOCA case bounds the smaller break sizes such as 6 Inch Break and Small Break cases for the IR Sump. Also, the 6 Inch Break LOCA is the largest debris generation case that needs to be evaluated for the VC Sump, and bounds all other VC sump debris generation cases.

- IP-2 IR Sump, LBLOCA with Full Insulation
- IP-2 IR Sump, Reactor Cavity LBLOCA with Full Insulation
- IP-2 VC Sump, 6 Inch Break LOCA with Full Insulation
- IP-2 VC Sump, Reactor Cavity 6 Inch Break LOCA with Full Insulation
- IP-2 VC Sump, LBLOCA after 24 hours of Pool Turnover with Full Insulation
- IP-2 VC Sump, Reactor Cavity LBLOCA after 24 hours of Pool Turnover with Full Insulation

Unit 3

For SER break selection criterion No. 1, fourteen (14) possible break cases were identified at the following locations for generating the maximum quantities of fiber or particulate fines:

1. Case 1: LBLOCA at the Cross-over Leg at the bottom of the #32 Steam Generator for generating the maximum mass of fiber fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, and 3)
2. Case 2: LBLOCA at the Cold Leg between the #31 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, and 3)
3. Case 3: LBLOCA at the Cross-over Leg at the bottom of the #34 Steam Generator for generating the maximum mass of fiber fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, and 3)

4. Case 4: LBLOCA at the Cold Leg between the #33 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1, 2, and 3)
5. Case 9: SBLOCA at the Cold Leg at the bottom of the #32 Reactor Coolant Pump for generating the maximum mass of fiber fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
6. Case 10: SBLOCA at the Cold Leg Return at the bottom of the #32 Reactor Coolant Pump for generating the maximum mass of particulate fines in the South Side Compartment (Line No. 10) (chosen to evaluate Break Criterion Nos. 1, 3, and 4)
7. Case 11: SBLOCA at the Cold Leg at the bottom of the #34 Reactor Coolant Pump for generating the maximum mass of fiber fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
8. Case 12: SBLOCA at Line No. 61 for generating the maximum mass of particulate fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1, 3, and 4)
9. Case 13: LBLOCA Reactor Vessel nozzle break in the Reactor Cavity
10. Case 14: 6 inch break LOCA at the Cold Leg at the bottom of the #32 Reactor Coolant Pump for generating the maximum mass of fiber fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
11. Case 15: 6 inch break LOCA at the Cold Leg between the #32 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the South Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
12. Case 16: 6 inch break LOCA at the Cold Leg at the #34 Reactor Coolant Pump for generating the maximum mass of fiber fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
13. Case 17: 6 inch break LOCA at the Cold Leg between the #33 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the North Side Compartment (chosen to evaluate Break Criterion Nos. 1 and 3)
14. Case 19: 6 inch break LOCA Reactor Vessel nozzle break in the Reactor Cavity

These cases involved four large break cases, four 6 inch break cases, four small break cases, and two nozzle break within the Reactor Cavity (LBLOCA and 6 inch break LOCA). The results of the evaluation of insulation debris generation for Break Criterion No. 1 determined that all 14 breaks are limiting based on either the type or amount of debris generated. Note that five additional cases, Cases 5 through 8 and 18, were also identified in the IP-3 Debris Generation Calculation [Ref. 1] and evaluated for an alternate break size. However, the methodology associated with the alternate break size has been subsequently abandoned, and these cases are no longer needed. Therefore, these five additional cases are not included in any other evaluation.

It was determined that the debris generated by the four large break and the four 6 inch break limiting cases for Break Criterion No. 1 bounded the debris generated for Break Criterion No. 2 "large breaks with two or more different types of debris." The four large break limiting cases contained a mixture of Calcium Silicate, Temp-Mat, Nukon™, fiberglass, Asbestos, and mineral wool, and are limiting for the IP-3 IR Sump. The four 6-inch break limiting cases contained an identical mixture of insulation types and are limiting for the IP-3 VC Sump. The evaluation concluded that the four large break and the four 6 inch break cases generate the largest amount of debris, and also the most limiting combinations of debris for the IP-3 IR Sump and the IP-3 VC Sump, respectively.

For Break Criterion No. 3, "breaks with the most direct path to the sump," the most limiting case for the IP-3 IR Sump is a large break at the Cross-over Leg at the bottom of the #32 Steam Generator as listed for Break Criterion No. 1. Similarly, for Break Criterion No. 3 the most limiting case for the

IP-3 VC Sump is a 6-inch break at the Cold Leg at the bottom of the #32 Reactor Coolant Pump. Any pipeline closer to either sump is not large enough to produce a HELB capable of producing large amounts of debris. Additionally, the IP-3 Debris Transport Calculation [Ref. 42] determines a conservative set of transport fractions applicable to all breaks within the crane wall.

For Break Criterion No. 4, "large breaks with the largest potential particulate debris to insulation ratio by weight," the largest quantities of transportable particulate insulation are found on the Cold Legs and the Pressurizer. To bound Break Criterion No. 4 for the IP-2 IR Sump, the large break cases in this area were evaluated to determine that Case 4 at the Cold Leg between the #33 Reactor Coolant Pump and the penetration to the Reactor has the maximum particulate load. Likewise, to bound Break Criterion No. 4 for the IP-2 VC Sump, the 6-inch break cases in this area were evaluated to determine that Case 17 at the Cold Leg between the #33 Reactor Coolant Pump and the penetration to the Reactor has the maximum particulate load. Consequently, both maximum particulate loads are evaluated for all possible fiber loads from no fiber, through thin bed thickness, and onto the maximum possible fiber load.

For Break Criterion No. 5, "breaks that generate a thin-bed," many possible HELBs can be postulated that would generate and transport the small quantity of fibrous debris needed to form a thin-bed. Therefore, all design case breaks could be susceptible to the thin-bed effect.

The Test Debris Amounts Calculation [Ref. 45] applied transport fractions and determined the scaled conventional and chemical debris quantities for the current (full) insulation configuration at Indian Point, as well as multiple configurations of incremental insulation removal. For the purposes of the Head Loss Calculation [Ref. 28], the following IP-3 full insulation analytical debris generation cases were investigated. These cases were chosen because the LBLOCA case bounds the smaller break sizes such as 6 Inch Break and Small Break cases for the IR Sump. Also, the 6 Inch Break LOCA is the largest debris generation case that needs to be evaluated for the VC Sump (at the beginning of recirculation), and bounds all other VC sump debris generation cases.

- IP-3 IR Sump, LBLOCA with Full Insulation
- IP-3 IR Sump, Reactor Cavity LBLOCA with Full Insulation
- IP-3 VC Sump, 6 Inch Break LOCA with Full Insulation
- IP-3 VC Sump, Reactor Cavity 6 Inch Break LOCA with Full Insulation
- IP-3 VC Sump, LBLOCA after 24 hours of Pool Turnover with Full Insulation
- IP-3 VC Sump, Reactor Cavity LBLOCA after 24 hours of Pool Turnover with Full Insulation

<u>*USNRC Issue 3b:*</u>

Debris Generation/Zone of Influence (ZOI) (excluding coatings)
The objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; and (2) the amount of debris generated by the break jet forces.

1. *Describe the methodology used to determine the ZOIs for generating debris. Identify which debris analyses used approved methodology default values. For debris with ZOIs not defined in the guidance report (GR)/safety evaluation (SE), or if using other than default values, discuss method(s) used to determine ZOI and the basis for each.*
2. *Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.*

3. *Identify if destruction testing was conducted to determine ZOIs. If such testing has not been previously submitted to the USNRC for review or information, describe the test procedure and results with reference to the test report(s).*
4. *Provide the quantity of each debris type generated for each break location evaluated. If more than four break locations were evaluated, provide data only for the four most limiting locations.*
5. *Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.*

Entergy Response to Issue 3b.1:

Common to both units

Indian Point applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SER [Ref. 3], which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated and the individual contributions from each debris type are summed to arrive at a total debris source term as described in the Debris Generation Calculations [Refs. 1 and 2].

The destruction pressures and ZOIs for the RMI, Nukon™ and Temp-Mat were obtained from a list of common PWR materials of potential debris contributors in Table 3-2 of the NRC SER [Ref. 3]. The destruction pressures and ZOIs for Transco blankets, fiberglass, and mineral wool insulation are assumed to be the same as Nukon™ due to their similar material properties. This assumption is supported by discussions in both the SER and the NEI-04-07 Guidance Report [Ref. 6].

No recommended destruction pressures or ZOIs are provided in the NRC SER or the NEI-04-07 Guidance Report [Ref. 6], for asbestos insulation. The asbestos insulation at Indian Point was examined using a scanning electron microscope, and the result indicates that the asbestos insulation is calcium silicate with asbestos fiber [Refs. 9 and 10]. The Alion Size Distribution Report [Ref. 11] conservatively uses an increased ZOI of 6.4D (compared to a SER suggested value of 5.5D) for calcium silicate insulation. Therefore, it is assumed that the asbestos and calcium silicate insulation with jacketing installed at Indian Point has the same destruction properties as calcium silicate listed in the Alion Report. The asbestos insulation without jacketing (asbestos with cloth) also is not listed in the SER or GR. Due to the minimal amount and dispersed location of asbestos within the crane wall [Refs. 1 and 2, Section 4.0a], the ZOI was increased from the value for jacketed asbestos insulation to the largest ZOI of the considered materials, 28.6D, with a destruction pressure of 2.4 psig.

Neither the GR nor the SER provides a destruction pressure or ZOI for Fiber (Marinite) Board. Marinite I is composed of 65-75% Calcium Silicate, 20 – 25% Calcium Metasilicate, 4 – 8% natural Organic Fiber and 0.1 – 2% Crystaline Silica. A request for material substitution approved the use of Marinite I for replacement of Transite when required. Transite is a cementatous product containing asbestos (41.2 to 45.5% asbestos and 54.5 to 58.8% Portland Type 1 cement) and is no longer available. Both materials are solid, self-supporting structural insulation materials. The GR Table 4-1 notes that Marinite board has a flexure strength (Modulus of Rupture) approximately 14 times that of typical calcium silicate insulation. Present day non-asbestos Transite has a flexure strength even greater than that of Marinite. Based on these properties and the recommendation by the GR that Marinite could conservatively be assumed to have the destruction pressure of calcium silicate insulation, it is assumed that both Transite and Marinite will have the same destruction pressure and ZOI as calcium silicate (ZOI = 6.4D).

Entergy Response to Issue 3b.2:

The ZOI is defined as a spherical volume about the break in which the jet pressure is larger than the destruction/damage pressure of insulation, coatings, and other materials impacted by the break jet. The use of spherical geometry constitutes a significant conservatism as the break flow would be directed to only some fraction of the sphere.

Unit 2

The ZOIs of each type of debris (excluding coatings) for Unit 2 are provided below:

Table 3b.2-1:
ZOI Radii for IP-2 Insulation (Excluding Coatings)

Debris Type	ZOI Radius (Radius/Break Diameter)	Reference
DPSC "Mirror" with Standard Bands (RMI)	28.6	NRC SER [Ref. 3]
Nukon™	17	NRC SER [Ref. 3]
Transco Blanket	17	Assume equal to Nukon™
Fiberglass	17	Assume equal to Nukon™
Temp-Mat	11.7	NRC SER [Ref. 3]
Asbestos with Cloth	28.6	Conservative Assumption
Asbestos with Jacket	6.4	Ref. 11 (Cal-Sil)

Unit 3

The ZOIs of each type of debris (excluding coatings) for Unit 3 are provided below:

Table 3b.2-2: ZOI Radii for IP-3 Insulation (Excluding Coatings)

Debris Type	ZOI Radius (Radius/Break Diameter)	Reference
DPSC "Mirror" with Standard Bands (RMI)	28.6	NRC SER [Ref. 3]
Nukon™	17	NRC SER [Ref. 3]
Fiberglass	17	Assumed to be equal to Nukon™
Temp-Mat	11.7	NRC SER [Ref. 3]
Mineral Wool with Jacket	17	Assumed to be equal to Nukon™
Asbestos with Jacket	6.4	Ref. 11
Calcium Silicate with Cloth	28.6	Conservative Assumption
Calcium Silicate with Jacket	6.4	Ref. 11
Fiber (Marinite) Board / Transite	6.4	Conservative Assumption

Entergy Response to Issue 3b.3:

Indian Point applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SER [Ref. 3], which allows the use of debris-specific spherical ZOIs. No new destruction testing was used to determine the ZOIs listed above. All destruction properties are based on published values.

Entergy Response to Issue 3b.4:

Using the ZOIs listed in this section and the size distributions provided in Section 3c, quantities of generated debris for each break case were calculated for each type of insulation. The quantities of debris generated for the most limiting break cases are listed below [Refs. 1 and 2]:

Unit 2

Table 3b.4-1:
Case 1: LBLOCA at the Hot Leg near the #22 Steam Generator for generating the maximum mass of fiber fines in the South Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed and Cloth)	283.41 Lb_m	74.79 (26.4 %)	54.96 (19.4 %)	153.66 (54.2 %)	
Temp-Mat	936.78 Lb_m	72.61 (7.7 %)	281.62 (30.1 %)	282.44 (30.2 %)	300.10 (32.0 %)
Nukon^{TM}	2449.83 Lb_m	365.65 (14.9 %)	1393.21 (56.9 %)	334.23 (13.6 %)	356.74 (14.6 %)
Transco Blanket	103.71 Lb_m	16.24 (15.7 %)	61.01 (58.8 %)	12.79 (12.3 %)	13.67 (13.2 %)
Fiberglass	2.54 Lb_m	0.20 (7.9 %)	0.18 (7.1 %)	1.04 (40.9 %)	1.12 (44.1 %)
RMI	7,762.12 ft^2	–	5,821.59 (75 %)	1,940.53 (25 %)	–

Table 3b.4-2:
Case 2: LBLOCA at the Cross-over Leg near the #22 RCP Nozzle for generating the maximum mass of particulate fines in the South Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed and Cloth)	760.41 Lb_m	180.41 (23.7 %)	121.20 (15.9 %)	458.80 (60.3 %)	
Temp-Mat	986.93 Lb_m	93.10 (9.4 %)	364.38 (36.9 %)	256.71 (26.0 %)	272.75 (27.6 %)
Nukon^{TM}	2035.09 Lb_m	251.38 (12.4 %)	759.75 (37.3 %)	494.30 (24.3 %)	529.66 (26.0 %)
Transco Blanket	80.50 Lb_m	11.42 (14.2 %)	39.12 (48.6 %)	14.47 (18.0 %)	15.49 (19.2 %)
RMI	7,762.12 ft^2	–	5,821.59 (75 %)	1,940.53 (25 %)	–

Table 3b.4-3:
Case 3: LBLOCA at the Cross-over Leg near the #24 Steam Generator for generating the maximum mass of fiber fines in the North Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed and Cloth)	340.75 Lb_m	83.91 (24.6 %)	58.29 (17.1 %)	198.54 (58.3 %)	
Temp-Mat	754.71 Lb_m	52.94 (7.0 %)	204.23 (27.1 %)	241.23 (32.0 %)	256.31 (34.0 %)
Nukon™	2405.34 Lb_m	354.25 (14.7 %)	1342.71 (55.8 %)	342.63 (14.2 %)	365.75 (15.2 %)
Transco Blanket	132.46 Lb_m	20.64 (15.6 %)	79.70 (60.2 %)	15.54 (11.7 %)	16.58 (12.5 %)
RMI	7,762.12 ft^2	–	5,821.59 (75 %)	1,940.53 (25 %)	–

Table 3b.4-4:
Case 4: LBLOCA at the Cross-over Leg near the #24 Steam Generator for generating the maximum mass of particulate fines in the North Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed and Cloth)	342.98 Lb_m	84.23 (24.6 %)	58.38 (17.0 %)	200.37 (58.4 %)	
Temp-Mat	754.71 Lb_m	52.94 (7.0%)	204.23 (27.1 %)	241.23 (32.0 %)	256.31 (34.0 %)
Nukon™	2397.49 Lb_m	351.61 (14.7 %)	1327.72 (55.4 %)	347.34 (14.5 %)	370.82 (15.5 %)
Transco Blanket	132.46 Lb_m	20.55 (15.5 %)	79.34 (59.9 %)	15.76 (11.9 %)	16.81 (12.7 %)
RMI	7,762.12 ft^2	–	5,821.59 (75 %)	1,940.53 (25 %)	–

Table 3b.4-5:
Case 14: 6 Inch Break LOCA at the Cross-over Leg #22 for generating the maximum mass of fiber fines in the South Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed)	–	–	–	–	
Temp-Mat	–	–	–	–	–
Nukon™	518.09 Lb_m	69.98 (13.5%)	229.15 (44.2%)	105.71 (20.4%)	113.25 (21.9%)
Transco Blanket	4.25 Lb_m	0.34 (8.0%)	0.30 (7.1%)	1.74 (40.9%)	1.87 (44.0%)
RMI	3,881.06 ft^2	–	2,910.80 (75 %)	970.27 (25 %)	–

Table 3b.4-6:
Case 15: 6 Inch Break LOCA at Line No. 10 for generating the maximum mass of particulate fines in the South Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed)	140.53 Lb_m	47.52 (33.8%)	40.79 (29.0%)	52.22 (37.2%)	
Temp-Mat	275.62 Lb_m	21.00 (7.6%)	81.38 (29.5%)	84.00 (30.5%)	89.25 (32.4%)
Nukon™	16.59 Lb_m	1.33 (8.0%)	1.16 (7.0%)	6.80 (41.0%)	7.30 (44.0%)
Transco Blanket	20.04 Lb_m	2.40 (12.0%)	7.43 (37.1%)	4.93 (24.6%)	5.28 (26.3%)
RMI	3,881.06 ft^2	–	2,910.80 (75 %)	970.27 (25 %)	–

Table 3b.4-7:
Case 16: 6 Inch Break LOCA at the Hot Leg at the bottom of the #24 Steam Generator for generating the maximum mass of fiber fines in the North Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed)	–	–	–	–	
Temp-Mat	22.11 Lb_m	1.55 (7.0%)	5.97 (27.0%)	7.07 (32.0%)	7.52 (34.0%)
Nukon™	374.85 Lb_m	59.03 (15.7%)	213.65 (57.0%)	49.34 (13.2%)	52.84 (14.1%)
Transco Blanket	7.00 Lb_m	0.56 (8.0%)	0.49 (7.0%)	2.87 (41.0%)	3.08 (44.0%)
RMI	3,881.06 ft^2	–	2,910.80 (75 %)	970.27 (25 %)	–

Table 3b.4-8:
Case 17: 6 Inch Break LOCA at Line No. 63 for generating the maximum mass of particulate fines in the North Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos (Jacketed)	101.69 Lb_m	38.65 38.0%)	35.04 (34.5%)	28.00 (27.5%)	
Temp-Mat	–	–	–	–	–
Nukon™	12.07 Lb_m	0.97 (8.0%)	0.85 (7.0%)	4.95 (41.0%)	5.31 (44.0%)
Transco Blanket	20.11 Lb_m	2.84 (14.1%)	10.93 (54.4%)	3.07 (15.3%)	3.27 (16.3%)
RMI	3,881.06 ft^2	–	2,910.80 (75 %)	970.27 (25 %)	–

The maximum quantity of debris results from a combination of break cases as shown in the IP-2 Debris Generation Calculation [Ref. 1]. The subsequent analysis for the resolution of GSI-191 was performed by selecting the fibrous debris types from the case that generates the maximum total fiber debris and selecting the particulate debris types from the case that generates the maximum total particulate debris (see Test Debris Amounts Calculation, Ref. 45). The use of these quantities represents a significant conservatism because no single break location exists that would generate this total quantity of debris.

Table 3b.4-9:
Unit 2 Maximum Insulation Debris Quantity for LBLOCA

Insulation Type	Total Amount Destroyed	% Fines	% Small Pieces	% Large Pieces	% Intact Blankets	Break Location*
Asbestos	760.41 Lb_m	23.7 %	15.9 %	60.3 %		Case 2
Temp-Mat	936.78 Lb_m	7.7 %	30.1 %	30.2 %	32.0 %	Case 1
Nukon^{TM}	2449.83 Lb_m	14.9 %	56.9 %	13.6 %	14.6 %	Case 1
Transco Blanket	103.71Lb_m	15.7 %	58.8 %	12.3 %	13.2 %	Case 1
Fiberglass	2.54 Lb_m	7.9 %	7.1 %	40.9 %	44.1 %	Case1
RMI	7,762.12 ft^2	–	75 %	25 %	–	Cases 1-4

* The break location case selected provides the maximum total fibrous, particulate, or RMI loads.

Table 3b.4-10:
Unit 2 Maximum Insulation Debris Quantity for 6 Inch Break LOCA

Insulation Type	Total Amount Destroyed	% Fines	% Small Pieces	% Large Pieces	% Intact Blankets	Break Location*
Asbestos	140.53 Lb_m	33.8 %	29.0 %	37.2 %		Case 15
Temp-Mat	–	–	–	–	–	Case 14
Nukon^{TM}	518.09 Lb_m	13.5 %	44.2 %	20.4 %	21.9 %	Case 14
Transco Blanket	4.25 Lb_m	0.34 %	0.30 %	40.9 %	44.0 %	Case 14
Fiberglass	–	–	–	–	–	Case 14
RMI	3881.06 ft^2	–	75 %	25 %	–	Cases 14-17

* The break location case selected provides the maximum total fibrous, particulate, or RMI loads.

Unit 3

Table 3b.4-11:
Case 1: LBLOCA at the Cross-over Leg at the bottom of the #32 Steam Generator for generating the maximum mass of fiber fines in the Southside Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	144.59 Lb_m	33.26 (23.0 %)	21.69 (15.0 %)	89.65 (62.0 %)	
Calcium Silicate	8.39 Lb_m	1.93 (23.0 %)	1.26 (15.0 %)	5.20 (62.0 %)	
Temp-Mat	1862.29 Lb_m	247.83 (13.3 %)	981.75 (52.7 %)	306.77 (16.5 %)	325.94 (17.5 %)
Mineral Wool	33.09 Lb_m	4.30 (13.0 %)	17.87 (54.0 %)	5.29 (16.0 %)	5.63 (17.0 %)
Nukon™	1881.94 Lb_m	268.77 (14.3%)	989.80 (52.6 %)	301.38 (16.0 %)	322.00 (17.1 %)
Fiberglass	124.19 Lb_m	19.79 (15.9 %)	73.95 (59.6 %)	14.71 (11.8 %)	15.73 (12.7 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-12:
Case 2: LBLOCA at the Cold Leg between the #31 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the Southside Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	468.34 Lb_m	215.72 (46.1 %)	210.26 (44.9 %)	42.36 (9.0 %)	
Calcium Silicate	8.39 Lb_m	1.93 (23.0 %)	1.26 (15.0 %)	5.20 (62.0 %)	
Temp-Mat	1310.22Lb_m	95.72 (7.3 %)	370.10 (28.2 %)	409.41 (31.2 %)	435.00 (33.2 %)
Mineral Wool	–	–	–	–	–
Nukon™	1752.94 Lb_m	204.63 (11.7 %)	597.19 (34.1 %)	459.18 (26.2 %)	491.93 (28.1 %)
Fiberglass	74.13Lb_m	10.08 (13.6 %)	35.84 (48.3 %)	13.63 (18.4 %)	14.57 (19.7 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-13:
Case 3: LBLOCA at the Cross-over Leg at the bottom of the #34 Steam Generator for generating the maximum mass of fiber fines in the Northside Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	–	–	–	–	
Calcium Silicate	311.89 Lb_m	71.73 (23.0 %)	46.78 (15.0 %)	193.37 (62.0 %)	
Temp-Mat	3058.71 Lb_m	331.44 (10.8 %)	1304.19 (42.6 %)	689.98 (22.6 %)	733.10 (24.0 %)
Mineral Wool	75.39 Lb_m	11.27 (15.0 %)	46.17 (61.2 %)	8.70 (11.5 %)	9.25 (12.3 %)
Nukon™	1996.74 Lb_m	288.44 (14.5 %)	1061.64 (53.2 %)	312.61 (15.7 %)	334.05 (16.7 %)
Fiberglass	101.82 Lb_m	14.79 (14.5 %)	58.17 (57.1 %)	13.98 (13.7 %)	14.89 (14.6 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-14:
Case 4: LBLOCA at the Cold Leg between the #33 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the Northside Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	342.78 Lb_m	171.39 (50.0 %)	171.39 (50.0 %)	–	
Calcium Silicate	274.39 Lb_m	63.11 (23.0 %)	41.16 (15.0 %)	170.12 (62.0 %)	
Temp-Mat	1393.29 Lb_m	102.23 (7.3 %)	395.34 (28.4 %)	434.29 (31.2 %)	461.43 (33.1 %)
Mineral Wool	18.39 Lb_m	1.47 (8.00 %)	1.29 (7.0 %)	7.54 (41.0 %)	8.09 (44.0 %)
Nukon™	1801.69 Lb_m	207.59 (11.5 %)	606.35 (33.7 %)	476.91 (26.5 %)	510.84 (28.4 %)
Fiberglass	41.83 Lb_m	6.25 (14.9 %)	24.15 (57.7 %)	5.53 (13.2 %)	5.90 (14.1 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-15:
Case 14: 6 Inch Break LOCA at the Cold Leg at the bottom of the #32 Reactor Coolant Pump for generating the maximum mass of fiber fines in the South Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	–	–	–	–	
Calcium Silicate	2.76 Lb_m	0.63 (22.9 %)	0.41 (14.9 %)	1.71 (62.2 %)	
Temp-Mat	1053.68 Lb_m	133.21 (12.6 %)	526.89 (50.0 %)	190.82 (18.1 %)	202.75 (19.2 %)
Mineral Wool	–	–	–	–	–
Nukon^{TM}	–	–	–	–	–
Fiberglass	21.63 Lb_m	2.32 (10.7 %)	6.51 (30.1 %)	6.18 (28.6 %)	6.62 (30.6 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-16:
Case 15: 6 Inch Break LOCA at the Cold Leg between the #32 Reactor Coolant Pump and penetration to the Reactor for generating the maximum mass of particulate fines in the South Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	213.45 Lb_m	73.06 (34.2 %)	63.08 (29.6 %)	77.30 (36.2 %)	
Calcium Silicate	2.76 Lb_m	0.63 (22.9%)	0.41 (14.9%)	1.71 (62.2%)	
Temp-Mat	141.69 Lb_m	9.92 (7.0 %)	38.26 (27.0 %)	45.34 (32.0 %)	48.17 (34.0 %)
Mineral Wool	–	–	–	–	–
Nukon^{TM}	–	–	–	–	–
Fiberglass	9.20 Lb_m	0.77 (8.4 %)	0.92 (10.0 %)	3.62 (39.3 %)	3.89 (42.3 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-17:
Case 16: 6 Inch Break LOCA at the Cold Leg at the #34 Reactor Coolant Pump for generating the maximum mass of fiber fines in the North Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	–	–	–	–	
Calcium Silicate	–	–	–	–	
Temp-Mat	885.22 Lb_m	112.04 (12.7 %)	443.16 (50.1 %)	160.01 (18.1 %)	170.01 (19.2 %)
Mineral Wool	10.71 Lb_m	0.99 (9.2 %)	1.98 (18.5 %)	3.74 (34.9 %)	4.01 (37.4 %)
Nukon™	73.1 Lb_m	8.85 (12.1 %)	25.61 (35.0 %)	18.65 (25.5 %)	19.99 (27.3 %)
Fiberglass	17.58 Lb_m	1.81 (10.3 %)	5.04 (28.7 %)	5.18 (29.5 %)	5.55 (31.6 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

Table 3b.4-18:
Case 17: 6 Inch Break LOCA at the Cold Leg between the #33 Reactor Coolant Pump and the penetration to the Reactor for generating the maximum mass of particulate fines in the North Side Compartment

Insulation Type	Total Amount Destroyed	Fines	Small Pieces	Large Pieces	Intact Blankets
Asbestos	213.45 Lb_m	73.06 (34.2 %)	63.08 (29.6 %)		77.30 (36.2 %)
Calcium Silicate	–	–	–		–
Temp-Mat	14.57 Lb_m	1.02 (7.0 %)	3.93 (27.0 %)	4.66 (32.0 %)	4.95 (34.0 %)
Mineral Wool	–	–	–	–	–
Nukon™	37.36 Lb_m	3.50 (9.4 %)	7.42 (19.9 %)	12.76 (34.2 %)	13.68 (36.6 %)
Fiberglass	0.10 Lb_m	0.01 (10.0 %)	0.01 (10.0 %)	0.04 (40.0 %)	0.05 (50.0 %)
RMI	–	–	–	–	–
Fiber Board* (Marinite)/Transite	–	–	–	–	–

* note that Fiber Board is used as a cable tray fire barrier

The maximum quantity of debris results from a combination of break cases as shown in the IP-3 Debris Generation Calculation [Ref. 2]. The subsequent analysis for the resolution of GSI-191 was performed by selecting the fibrous debris types from the case that generates the maximum total fiber debris and selecting the particulate debris types from the case that generates the maximum total particulate debris (see Test Debris Amounts Calculation, Ref. 45). The use of these quantities represents a significant conservatism because no single break location exists that would generate this total quantity of debris.

Table 3b.4-19:
Unit 3 Maximum Insulation Debris Quantity for LBLOCA

Insulation Type	Total Amount Destroyed	% Fines	% Small Pieces	% Large Pieces	% Intact Blankets	Break Location
Asbestos	342.78 Lb_m	50.0 %	50.0 %	–		Case 4
Calcium Silicate	274.39 Lb_m	23.0 %	15.0 %	62.0 %		Case 4
Temp-Mat	3058.71 Lb_m	10.8 %	42.6 %	22.6 %	24.0 %	Case 3
Mineral Wool	75.39 Lb_m	15.0 %	61.2 %	11.5 %	12.3 %	Case 3
Nukon™	1996.74 Lb_m	14.5 %	53.2 %	15.7 %	16.7 %	Case 3
Fiberglass	101.82 Lb_m	14.5 %	57.1 %	13.7 %	14.6 %	Case 3

Table 3b.4-20:
Unit 3 Maximum Insulation Debris Quantity for 6 Inch Break LOCA

Insulation Type	Total Amount Destroyed	% Fines	% Small Pieces	% Large Pieces	% Intact Blankets	Break Location
Asbestos	213.45 Lb_m	34.2 %	29.6 %	36.2 %		Case 15
Calcium Silicate	2.76 Lb_m	22.9 %	14.9 %	62.2 %		Case 15
Temp-Mat	1053.68 Lb_m	12.6 %	50.0 %	18.1 %	19.2 %	Case 14
Mineral Wool	–	–	–	–	–	Case 14
Nukon™	–	–	–	–	–	Case 14
Fiberglass	21.63 Lb_m	10.7 %	30.1 %	28.6 %	30.6 %	Case 14

Entergy Response to Issue 3b.5:

Unit 2

Ref. 1 documented 235.72 square feet of tags and labels that could potentially transport to the sump and obstruct strainer surface area. Refer to Section 3.d for details.

Unit 3

Ref. 2 documented 45.8 square feet of tags and labels that could potentially transport to the sump and obstruct strainer surface area. Refer to Section 3.d for details.

USNRC Issue 3c:

Debris Characteristics
The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to head loss. Provide the assumed size distribution for each type of debris.

1. *Provide the assumed size distribution for each type of debris.*
2. *Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris.*
3. *Provide assumed specific surface areas for fibrous and particulate debris.*
4. *Provide the technical basis for any debris characterization assumptions that deviate from USNRC-approved guidance.*

Entergy Response to Issue 3c.1:

Common to both units

The size distributions for the various types of insulation found within containment are listed below. The RMI insulation size distribution was obtained from the values published in the GR and SER [Refs. 3 and 6]. Nukon™, Temp-Mat, and Calcium Silicate insulation size distributions were obtained from the Alion Size Distribution Report [Ref. 11]. Transco blanket and fiberglass insulation are assumed to have the same destruction properties as Nukon™ due to their similar material properties (low density fiberglass). The particle diameter of latent particulate (Dirt/Dust) was assumed to be 17.3 μm [Ref. 1, Table 7.3-37] based on the specific surface area of 106,000 ft^{-1} for use in the NUREG/CR-6224 [Ref. 32] correlation as specified in the SER [Ref. 3]. Refer to the Coatings Evaluation (Section 3h) for the size distribution of all coatings.

The RMI debris size distribution at Indian Point Units 2 and 3 is shown in the table below and is consistent with the guidance in NEI 04-07 [Ref. 6] and Table 3-3 of the NRC staff's SER on NEI 04-07 [Ref. 3].

**Table 3c.1-1:
Size Distribution for Diamond Power Mirror (RMI) [Refs. 3 & 6]**

Size	≥2.4 psi ZOI (28.6 L/D)
Fines	-
Small Pieces	75%
Large Pieces	25%
Intact (covered) Blankets	-

For Nukon™, Thermal-Wrap™ and Mineral Wool LDFG, it was determined that the debris size distribution within the ZOI can be best defined using three sub-zones. The size distributions within each of these sub-zones are shown in the Table below. Note that the Alion size distribution defines fines as individual fibers, small pieces as those less than 6", and large pieces as those greater than 6".

**Table 3c.1-2:
Size Distribution for Nukon™, Thermal-Wrap™ (Transco Blanket), Mineral Wool, and Fiberglass (Mineral Wool and Fiberglass assumed the same as Nukon™) [Ref. 11]**

Size	>18.6 psi ZOI (7.0 L/D)	10.0 – 18.6 psi ZOI (11.9 – 7.0 L/D)	6.0 – 10.0 psi ZOI (17.0 – 11.9 L/D)
Fines	20%	13%	8%
Small Pieces	80%	54%	7%
Large Pieces	-	16%	41%
Intact (covered) Blankets	-	17%	44%

Latent fiber was assumed to be 100% Nukon™ fines in all subzones.

For Temp-Mat™ fiberglass, it was determined that the debris size distribution within the ZOI can best be defined using two sub-zones. The size distributions within each of these sub-zones are shown in the Table below.

**Table 3c.1-3:
Size Distribution for Temp-Mat™ [Ref. 11]**

Size	>45.0 psi ZOI (3.7 L/D)	10.2 – 45.0 psi ZOI (11.7 – 3.7 L/D)
Fines	20%	7%
Small Pieces	80%	27%
Large Pieces	-	32%
Intact (covered) Blankets	-	34%

Asbestos insulation is assumed to have the same destruction properties, including size distribution, as Calcium Silicate (see Debris Generation discussion). Asbestos was found to be identical to

Calcium Silicate using a scanning electron microscope [Refs. 1 and 2]. Since the ZOI for Asbestos was enlarged to 28.6 L/D, it was assumed that the size distribution for the 2.7D to 6.4D zone of destruction for Calcium Silicate is applicable out to the enlarged ZOI.

For Calcium Silicate insulation, it was determined that the debris size distribution within the ZOI can best be defined using two sub-zones. The size distributions within each of these sub-zones are shown in the Table below.

Table 3c.1-4:
Size Distribution for Cal-Sil [Asbestos assumed to be the same as Calcium Silicate, Reference 11]

	Jacket		Cloth	
Size	≥70 psi ZOI (2.7 L/D)	20-70 psi ZOI (6.4-2.7 L/D)	≥70 psi ZOI (2.7 L/D)	≥2.4 psi ZOI (28.6 L/D)
Fines	50 %	23 %	50 %	23 %
Small Pieces	50 % *	15 % *	50 % *	15 % *
Large Pieces/Intact	-	62 %*	-	62 %*

* Calcium-Silicate Chunk

Entergy Response to Issue 3c.2:

Common to both units (when applicable)

Below are the material and bulk densities and their references for the various types of debris.

Table 3c.2-1:
Debris Types and Properties

	Debris Type	Material Density (lbm/ft^3)	Bulk Density (lbm/ft^3)	Density Used in Calculation (lbm/ft^3)	Reference
Insulation	Nukon™	159.0	2.4	2.4	NEI-04-07 Vol. I [Ref. 6, Table 3-2]
	Temp-Mat	162.0	11.8	11.8	NEI-04-07 Vol. I [Ref. 6, Table 3-2]
	Mineral Wool	90.0	4, 6, 8, 10	10	NEI-04-07 Vol. I [Ref. 6, Table 3-2]
	Fiberglass[3]	159.0	2.4	2.4	See Note 3
	Fiber Board[1] (Marinite)	-	40-51	46	IP-3 Debris Generation Calculation [Ref. 2, Table 6.2-2]
	Fiber Board[1] (Transite)	-	90-100	100	IP-3 Debris Generation Calculation [Ref. 2, Table 6.2-2]

Debris Types and Properties

	Debris Type	Material Density (lbm/ft^3)	Bulk Density (lbm/ft^3)	Density Used in Calculation (lbm/ft^3)	Reference
	Transco Blanket	159.0	2.4	2.4	NEI-04-07 Vol. I [Ref. 6, Table 3-2]
	Cal-Sil (Asbestos)[2]	144.0	14.5	14.5	NEI-04-07 Vol. I [Ref. 6, Table 3-2]
Latent Debris	Latent Fiber	94.0	2.4 (assumed)	94.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-37]
	Dirt/Dust	169.0	-	169.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-37]
Coatings	Epoxy 6129 (Floor)	64.9	-	64.9	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	Epoxy 5000 (Floor)	88.0	-	88.0	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	Epoxy 4129 (Wall/Concrete)	70.8	-	70.8	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	Epoxy 4000 (Wall/Concrete)	114.5	-	114.5	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	Epoxy D-1 (Wall/Concrete)	92.2	-	92.2	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	Carbo Zinc 11 (Steel)	255.2	-	255.2	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	Carboline 890 (Steel)	108.0	-	108.0	IP-2 Debris Generation Calculation [Ref. 1, Section 7.3.2.1]
	195 Surfacer (Floor)	104.2	-	104.2	IP-3 Debris Generation Calculation [Ref. 2, Table 7.3-30]

Debris Types and Properties

	Debris Type	Material Density (lbm/ft^3)	Bulk Density (lbm/ft^3)	Density Used in Calculation (lbm/ft^3)	Reference
	195 Surfacer (Wall/Concrete)	104.2	-	104.2	IP-3 Debris Generation Calculation [Ref. 2, Table 7.3-30]
	Phenoline 305 (Floor)	86.1	-	86.1	IP-3 Debris Generation Calculation [Ref. 2, Table 7.3-35]
	Phenoline 305 (Wall/Concrete)	86.1	-	86.1	IP-3 Debris Generation Calculation [Ref. 2, Table 7.3-35]
	Epoxy 6548/7107 (Inside ZOI)	101.7	-	101.7	IP-3 Debris Generation Calculation [Ref. 2, Table 7.3-30]
	Epoxy E-1-7475 (Inside ZOI)	76.1	-	76.1	IP-3 Debris Generation Calculation [Ref. 2, Table 7.3-30]
	High Temp. Aluminum (Inside ZOI)	90.0	-	90.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	Epoxy/Epoxy Phenolic (Inside ZOI)	94.0	-	94.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	Alkyd Enamel (Inside ZOI)	98.0	-	98.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	High Temp. Aluminum (Outside ZOI)	90.0	-	90.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	Epoxy/Epoxy Phenolic (Outside ZOI)	94.0	-	94.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	White RTV / Black Poly Caulk	81.1	-	81.1	IP-2 Debris Generation Calculation [Ref. 1, Assumption 4.0 (g)]

Debris Types and Properties

	Debris Type	Material Density (lbm/ft^3)	Bulk Density (lbm/ft^3)	Density Used in Calculation (lbm/ft^3)	Reference
	Inorganic Zinc	457	-	457	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	Alkyd Enamel (Outside ZOI)	98.0	-	98.0	IP-2 Debris Generation Calculation [Ref. 1, Table 7.3-31]
	Instacote	56.0	-	56.0	IP-2 Debis Generation Calculation [Ref. 1, Table 7.3-36]

1 Fiber Board is used as cable tray fire barrier.
2 Asbestos is assumed to have the same properties as Cal-Sil (see Debris Generation discussion).
3 Fiberglass is assumed to have the same density as Nukon™ in the calculations.

Entergy Response to Issue 3c.3:

Common to both units

The particle diameter of latent particulate (Dirt/Dust) was assumed to be 17.3 μm [Refs. 1 and 2] based on the specific surface area of 106,000 ft^{-1} for use in the NUREG/CR-6224 [Ref. 32] correlation as specified in the SER [Ref. 3]. The diameter of latent fibers were assumed to be 7 μm [Ref. 6, Table 3-2, note that section 3.5.2.3 of Reference 6 did not provide characterization of the latent dust] based on a comparison to Nukon™ fibers and results in a specific surface area of 171,000 ft^{-1}. Since the head loss across the installed sump screen is determined via testing, the specific surface area of latent fiber and particulate was not used in the design basis for Indian Point. Therefore, these values are provided to fulfill the requested information but have no relevance in the qualification of the Indian Point ECCS strainers.

Entergy Response to Issue 3c.4:

Common to both units

A complete discussion of the technical basis for the deviation from NRC guidance on the size distributions of Nukon™, Temp-Mat™, and Calcium Silicate insulation is located in the Alion Size Distribution Report [Ref. 11]. For fibrous debris, the Alion Report uses that same air-jet impact tests (AJIT) as the SER. However, conservatism with respect to the size distributions is removed based on the data collected for the fraction of small fines at various jet pressures. In order to remain conservative, a 10% penalty was added to the small debris fraction calculated from this data. The fraction of fines versus small pieces is based on the Drywell Debris Transport Study (DDTS) [Ref. 66]. For Calcium Silicate insulation, the Alion Report uses the same Ontario Power Generation (OPG) testing as the SER and subdivides the ZOI to provide two size distributions.

The Alion Size Distribution Report [Ref. 11] outlines the methodology used to justify 4 distinct size categories of fiber glass. The 4 categories of size classification within each size distribution are consistent with the suggested refinements of the SER. The GR Section 3.4.3 recommends using a two category size distribution for insulation debris including: (1) small pieces (assumed to be the basic constituent of the material), and (2) large pieces (pieces greater than 4 inches). Although this size distribution is adequate for the baseline analysis, it allows for only limited benefit when computational fluid dynamics (CFD) analyses are used to refine the recirculation pool debris transport fractions. The NRC recognized this limitation in the SER. The SER Section 4.2.4 recommends a four category size distribution including: (1) fines that remain suspended (fines), (2) small piece debris that is transported along the pool floor (small pieces), (3) large piece debris with the insulation exposed to potential erosion (large pieces), and (4) large debris with the insulation still protected by a covering, thereby preventing further erosion (intact (covered) blankets). This is the basis for the four size categories used by Alion to classify the size distributions of each type of fibrous insulation.

<u>*USNRC Issue 3d:*</u>

Latent Debris
The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss.

1. *Provide the methodology used to estimate quantity and composition of latent debris.*
2. *Provide the basis for assumptions used in the evaluation.*
3. *Provide results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris as requested for other debris under c. above.*
4. *Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.*

<u>**Entergy Response to Issue 3d.1:**</u>

<u>Common to both units</u>

The evaluation for Latent Debris at Indian Point was performed in a manner consistent with the SER approved methodology. The total source term was determined through the collection of debris samples from multiple locations throughout the containment. Conservatism was added by sampling those areas that exhibited unusually large concentrations of dirt and dust. In addition to dirt and dust, foreign materials and other debris sources were surveyed and documented including tape, equipment labels, and fiberboard (cable tray fire protection).

Vertical, horizontal and equipment surfaces were sampled for dirt and dust by wiping with Masolin cloth. Sample areas were chosen by cognizant engineering personnel with the intent to produce bounding results. The containment was divided into categories from which a minimum of three samples were taken. Prior to collecting samples, the containment was surveyed through a series of walkdowns to locate desirable sample locations. Afterwards, maps and spreadsheets were constructed to assist in the collection effort. When possible, photographs of the sample site were taken before and after collection. Thirty five (35) to forty five (45) samples were taken throughout each containment, and the results are shown in tables in the Response to Issue 3d.3. The amount of latent debris collected from the samples was scaled by area to estimate the total amount of latent debris per area. From these samples and estimates of the total areas of various surface types, a calculation was performed to provide an estimate of the total amount of latent debris in containment. It was also noted that sample collection was conducted during a refueling outage and it appeared that no cleanup efforts had yet been instigated. Therefore, additional latent debris that would cleaned up by the end of the refueling outage was conservatively counted as latent debris that always remains in Containment. Further details of the sampling effort may be found in Refs. 17 and 23 for IP-2 and IP-3, respectively.

Entergy Response to Issue 3d.2:

Common to both units

The characterization of latent debris followed the guidance in section 3.5.2.3 of the SER [Ref. 3]. 15% of the mass of dirt/dust/lint was categorized as latent fiber, the characteristic size was assumed to be equal to Nukon™, 2.3E-5 ft (7.0 μm). Per the SER, a mean fiber density of 1.5 g/cm^3 (94 lbm/ft^3) was assumed, and the dirt/dust characteristic size was assumed to be 5.68E-5 ft (17.3 μm) with a density of 2.7 g/cm^3 (169 lbm/ft^3). Note that latent fiber debris was conservatively considered to be 100% small fiber fines for testing purposes, while latent particulate debris was conservatively considered to be debris fine particulate. Silicon carbide was used as a testing surrogate for the latent particulate debris and Nukon™ fines were used as a testing surrogate for the latent fiber debris.

Entergy Response to Issue 3d.3:

The results of the latent debris evaluation for IP-2 and IP-3, including the amount of latent debris types and physical data for the latent debris is provided in the following tables.

Unit 2 Final Latent Debris Values, Ref. 1:

Table 3d.3-1:
IP-2 Final Latent Debris Quantity

Latent Debris Type	Inside Crane Wall		Outside Crane Wall	Above Operating Deck
Tape and Equipment Labels	Metal 2.86 ft^2	Non-Metal 20.66 ft^2	211.13 ft^2	1.02 ft^2
Tie Wraps	South 1,693	North 1,090	14,800	--
Fiber Board Tags	--		0.05 ft^3	--

Latent Debris Type	Mass (lbm)	Density (lbm/ft^3)	Size
Dirt & Dust	164.9	169	5.68E-5 ft (17.3 μm)
Latent Fiber	29.1	94	2.3E-5 ft (7.0 μm)

Unit 3 Final Latent Debris Values, Ref. 2:

Table 3d.3-2:
IP-3 Final Latent Debris Quantity

Latent Debris Type	Inside Crane Wall		Outside Crane Wall	Above Operating Deck
Tape and Equipment Labels	13.81 ft^2		30.76 ft^2	1.21 ft^2
Tie Wraps	South 2,320	North 1,425	13,412	--
Fiber Board Tags	--		0.02 ft^3	--

Latent Debris Type	Mass (lbm)	Density (lbm/ft^3)	Size
Dirt & Dust	212.5	169	5.68E-5 ft (17.3 μm)
Latent Fiber	37.5	94	2.3E-5 ft (7.0 μm)

<u>Entergy Response to Issue 3d.4:</u>

Sacrificial strainer surface area for tags and labels was determined in Refs. 17 and 23. As suggested in NEI guidance [Refs. 3 and 6], all tags, tape, and labels that were determined to be transportable were assumed to arrive on the strainer intact and obstruct an area equivalent to 75% of the total original single-sided surface area. Ref.17 documented approximately 242 square feet of tags and labels that could potentially transport to the IP-2 sump and obstruct strainer surface area. However, the IP-2 Debris Generation Calculation [Ref. 1] noted that metal tags that are secured by metal straps or wire are assumed to be robust enough to prevent the failure of the tag when outside the ZOI. Based on this, the IP-2 Debris Generation Calculation assumes that there are 235.72 square feet of tags and labels that could potentially transport to the IP-2 sump and obstruct strainer surface area. Ref. 23 documented approximately 45.8 square feet of tags and labels that could potentially transport to the IP-3 sump and obstruct strainer surface area.

As stated in the Indian Point Debris Head Loss Calculation [Ref. 28], it is assumed that the impact of the tie wraps on the IP-2 and IP-3 strainer head loss is negligible, and that they are unable to form an appreciable bed on the strainer screens. Also, the NRC has previously accepted the general assumption that the tie wraps are not expected to transport to the sump and collect on the sump screen [Ref. 67]. Thus, no sacrificial strainer surface area is allotted for tie wraps.

USNRC Issue 3e:

Debris Transport
The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers.

1. *Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.*
2. *Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.*
3. *Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.*
4. *Provide a summary of, and supporting basis for, any credit taken for debris interceptors.*
5. *State whether fine debris was assumed to settle and provide basis for any settling credited.*
6. *Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.*

Entergy Response to Issue 3e.1:

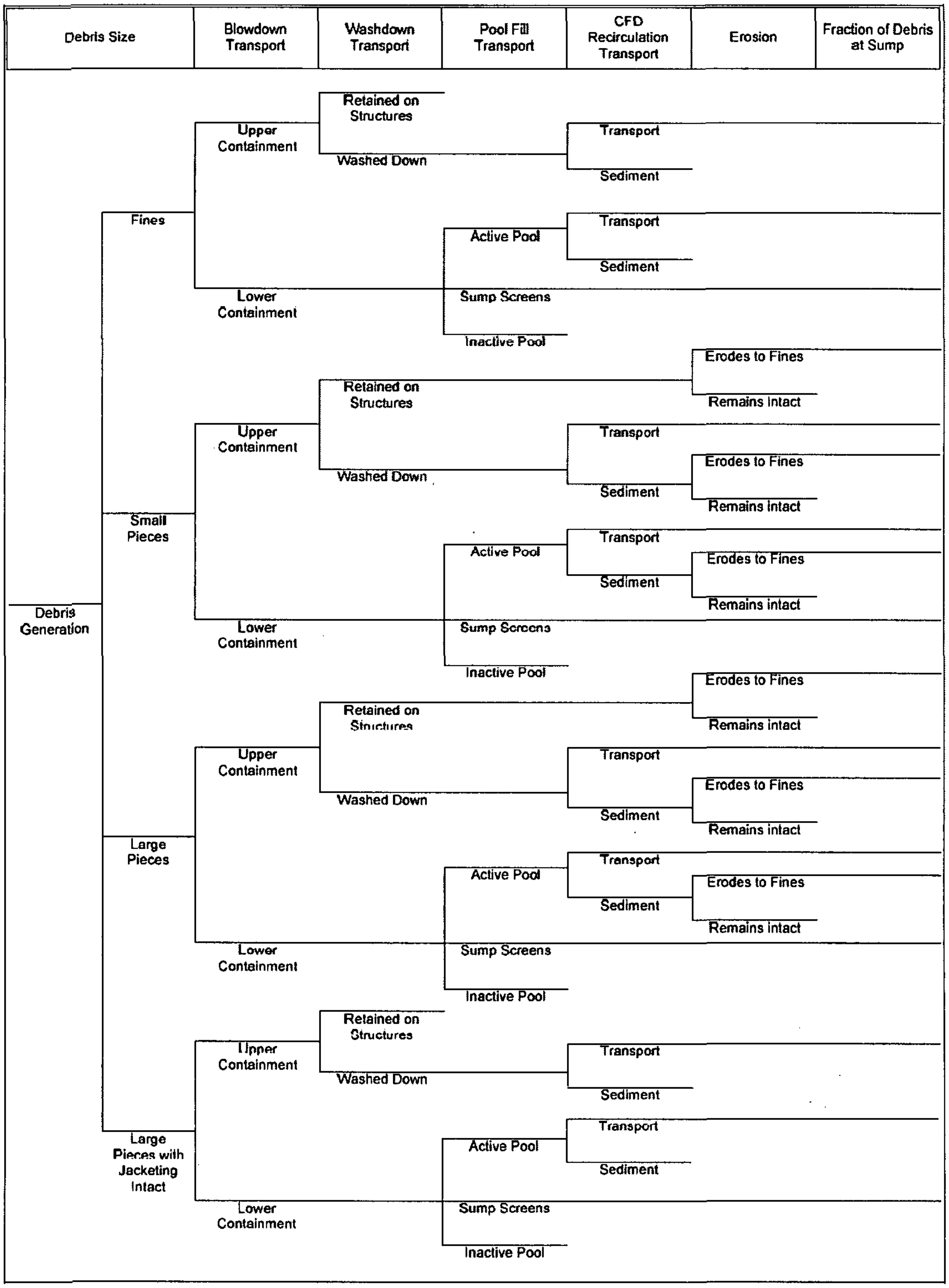
Common to both units

The methodology used in the transport analysis is based on the NEI 04-07 guidance report (GR) for refined analyses as modified by the NRC's safety evaluation report (SER), as well as the refined methodologies suggested by the SER in Appendices III, IV, and VI [Ref. 3]. The specific effect of each of four modes of transport was analyzed in the Debris Transport Calculations [Refs. 41 and 42] for each type of debris generated. These modes of transport are:

- *Blowdown transport* – the vertical and horizontal transport of debris to all areas of containment by the break jet.
- *Washdown transport* – the vertical (downward) transport of debris by the containment sprays and break flow.
- *Pool fill-up transport* – the transport of debris by break and containment spray flows from the refueling water storage tank (RWST) to regions that may be active or inactive during recirculation.
- *Recirculation transport* – the horizontal transport of debris from the active portions of the recirculation pool to the sump screens by the flow through the emergency core coolant system (ECCS).

The logic tree approach was then applied for each type of debris determined from the Debris Generation Calculation. The logic tree shown in Figure 3e.1-1 is slightly different than the baseline logic tree provided in the GR [Ref. 6]. This discrepancy was made to account for certain nonconservative assumptions identified by the SER including the transport of large pieces, erosion of small and large pieces, the potential for washdown debris to enter the pool after inactive areas have been filled, and the direct transport of debris to the sump screens during pool fill-up. Also, the generic logic tree was expanded to account for a more refined debris size distribution. (Note that some branches of the logic tree were not required for certain debris types).

**Figure 3e.1-1:
Generic debris transport logic tree**



The basic methodology used for the IR LBLOCA and VC 6 Inch Break LOCA cases in the Indian Point transport analyses [Refs. 41 and 42] is shown below:

1. Based on many of the containment building drawings, a three-dimensional model of lower containment was built using computer aided drafting (CAD) software.
2. A review of the drawings and CAD model was completed to determine transport flow paths. Potential upstream blockage points including screens, fences, grating, drains, etc. that could lead to water holdup were addressed.
3. Debris types and size distributions were gathered from the Debris Generation Calculations [Refs. 1 and 2] for each postulated break location.
4. The fraction of debris blown into upper containment and around flow barriers was determined based on the flow of steam during blowdown.
5. The quantity of debris washed down by spray flow was conservatively determined.
6. The quantity of debris transported to inactive areas or directly to the sump screens was calculated based on the volume of the inactive and sump cavities proportional to the water volume at the time these cavities are filled.
7. Using conservative assumptions, the locations of each type/size of debris at the beginning of recirculation was determined.
8. A CFD model was developed to simulate the flow patterns that would develop in the pool and the incore instrumentation tunnel during recirculation.
9. A graphical determination of the transport fraction of each type of debris was made using the velocity and total kinetic energy (TKE) profiles from the CFD model output, along with the determined initial distribution of debris.
10. The recirculation transport fractions from the CFD analysis were gathered to input into the logic trees.
11. The quantity of debris that could experience erosion due to the break flow or spray flow was determined.
12. The impact of Temp-Mat™ and mineral wool debris floating in the recirculation pool was analyzed.
13. The overall transport fraction for each type of debris was determined by combining each of the previous steps in logic trees.

For cases where the VC sump is initiated 24 hours after an accident, an additional step (after step 12) in the methodology was employed. The transient debris transport to the IR sump during the first 24 hours of the event was determined. Then, the remaining debris (with margin added for conservatism) is assumed to reach the VC sump.

3e.1.1 Blowdown Transport

<u>Common to both units</u>

Blowdown is considered to be omni-directional within lower containment, and after pressurizing the lower containment compartments, the blowdown would primarily relieve upward past the Steam Generators and Reactor Coolant Pumps to upper containment [Refs. 41 and 42]; some of this pressure would also be relieved to the annulus through the openings in the crane wall. Since the blowdown would relieve to all areas of the containment building, the fraction of blowdown flow to various regions was estimated using the relative volumes of containment. Fine debris can be easily suspended and carried by the blowdown flow. Small and large piece debris can also be carried by the high velocity blowdown flow in the vicinity of the break. However, in areas farther away from the break that are not directly affected by the blowdown, this debris would likely fall to the floor.

The volumes for the upper containment (including the refueling canal and areas above the Operating Deck) and for lower containment (including the open area inside the Steam Generator compartments and annulus below the Operating Deck) were determined using a laser scan CAD model of the containment building and relevant containment building drawings [Refs. 41 and 42]. The debris was assumed to be carried with the blowdown flow, and the flow split was assumed to be proportional to the containment volumes. This resulted in a transport fraction for the fine debris to upper containment of 79%.

The drywell debris transport study (DDTS) [Ref. 66] testing for BWRs showed that in a wetted, highly congested area, approximately 10% of small fiberglass debris would be trapped by miscellaneous structures, and approximately 25% would be trapped by grating. Also, 17% of small fiberglass debris was shown to be captured at 90° turns in a flow path. Although 90° turns might not have to be negotiated by debris blown to upper containment at Indian Point, significant bends would have to be made. Therefore, it was estimated that 5% of the small fiberglass debris blown upward would be trapped due to changes in flow direction. The openings in the Operating Deck at Indian Point are largely covered with grating, so the percentage of small fibrous debris that would be blown to upper containment is estimated to be 51% (= 0.79*(1.00 - 0.10)*(1.00 - 0.05)*(1.00 - 0.25)).

The boiling water reactor (BWR) utility resolution guide (URG) [Ref. 68] indicates that grating would trap approximately 65% of the small RMI debris blown toward it. This gives a blowdown transport fraction of small RMI debris to upper containment of 28% (= 0.79*(1.00 – 0.65)).

The large piece debris would be blown upward similar to the small piece debris. However, since this debris would not pass through the grating, the transport fraction to upper containment would be 0%.

<u>Unit 2</u>

Tables 3e.1-1 and 3e.1-2 (from Ref. 41) show the transport fractions for each type/size of debris to upper containment due to the blowdown forces for breaks inside the crane wall.

Table 3e.1-1:
IP-2 Blowdown transport fractions of debris to upper containment

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	79%	51%	0%	0%
Fiberglass	79%	51%	0%	0%
Temp-Mat™	79%	51%	0%	0%
Transco Blanket	79%	51%	0%	0%
Asbestos	79%	0%	0%	
RMI	NA	28%	0%	NA
Qualified Coatings Inside the ZOI	79%	NA	NA	NA
Unqualified Coatings Inside the ZOI	79%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	0%	NA	NA	NA

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	23%	NA	NA
Unqualified Alkyd Enamel Outside the ZOI	4%	NA	NA	NA
Unqualified Inorganic Zinc Outside the ZOI	1%	NA	NA	NA
White RTV/Black Caulk	0%	NA	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Table 3e.1-2:
IP-2 Blowdown transport fractions of debris over IR sump gates

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	1%	1%	0%	0%
Fiberglass	1%	1%	0%	0%
Temp-Mat™	1%	1%	0%	0%
Transco Blanket	1%	1%	0%	0%
Asbestos	1%	0%	0%	
RMI	NA	1%	0%	NA
Qualified Coatings Inside the ZOI	1%	NA	NA	NA
Unqualified Coatings Inside the ZOI	1%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	0%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	0%	NA	NA
Unqualified Alkyd Enamel Outside the ZOI	0%	NA	NA	NA
Unqualified Inorganic Zinc Outside the ZOI	0%	NA	NA	NA
White RTV/Black Caulk	0%	NA	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

Unit 3

Tables 3e.1-3 and 3e.1-4 (from Ref. 42) show the transport fractions for each type/size of debris to upper containment due to the blowdown forces for breaks inside the crane wall.

**Table 3e.1-3:
IP-3 Blowdown transport fractions of debris to upper containment**

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	79%	51%	0%	0%
Fiberglass	79%	51%	0%	0%
Temp-Mat™	79%	51%	0%	0%
Mineral Wool	79%	51%	0%	0%
Cal-Sil and Asbestos	79%	0%	0%	0%
RMI	NA	28%	0%	NA
Qualified Coatings Inside the ZOI	79%	NA	NA	NA
Unqualified Coatings Inside the ZOI	79%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	0%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	2%	NA	NA
Unqualified Alkyd Enamel Outside the ZOI	10%	NA	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

**Table 3e.1-4:
IP-3 Blowdown transport fractions of debris over IR sump gates**

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	1%	1%	0%	0%
Fiberglass	1%	1%	0%	0%
Temp-Mat™	1%	1%	0%	0%
Mineral Wool	1%	1%	0%	0%
Cal-Sil and Asbestos	1%	0%	0%	0%
RMI	NA	1%	0%	NA
Qualified Coatings Inside the ZOI	1%	NA	NA	NA
Unqualified Coatings Inside the ZOI	1%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	0%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	0%	NA	NA

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Unqualified Alkyd Enamel Outside the ZOI	0%	NA	NA	NA
Dirt/Dust	0%	NA	NA	NA
Latent Fiber	0%	NA	NA	NA

3e.1.2 Washdown Transport

Common to both units

During the washdown phase, debris in upper containment could be washed down by the containment sprays. For Indian Point, all of the debris blown to upper containment was determined to be fines and small pieces [Refs. 41 and 42]. It was conservatively assumed that all of this debris would be washed back to lower containment, with the exception of any small piece debris held up on the 95' and 68' elevation gratings as it is washed down. It was also assumed that failed coatings in upper containment would be washed down by the containment sprays.

The debris blown to upper containment was assumed to be scattered around on the Operating Deck (95' elevation) and in the Refueling Canal; therefore, a reasonable approximation of the quantity of debris washing to specific locations was made based on the spray flow split to the various areas [Refs. 41 and 42]. Inside the crane wall, the spray flow split was estimated to be 11% to the Steam Generator compartments inside the Steam Generator bio-shield walls, 21% to the Refueling Canal drain, and 30% to the miscellaneous grated openings on the Operating Deck. Debris transported to the gratings in the annulus includes 26% for both the 95' and 68' elevation gratings, and 12% to the annulus to the 95' elevation grating through openings around the support columns.

The results of the DDTS testing [Ref. 66] showed that approximately 40-50% of small fiberglass debris landing on grating would be washed through the grating due to spray flows. If the only hold up of small piece debris that is credited is for grating at the 95' elevation and the 68' elevation, the transport fraction for small pieces of fiberglass washed down to the annulus would be 13% (= 0.26*(1.00-0.50)*(1.00-0.50)+0.12*(1.00-0.50)). The transport fraction for small pieces of fiberglass washed down to the Steam Generator compartments would be 47% (= 0.11+0.21+0.30*(1.00-0.50)). Additional justification for 40% retention of small fiberglass debris on gratings in upper containment is provided in Response to RAI 1 provided below following the response to 3e.6.

The BWR URG indicates that the retention of small RMI debris on gratings is approximately 29% [Ref. 68]. Therefore, the washdown transport fraction for small RMI to the annulus and to the Steam Generator compartments is 22% (= .26*(1.00-0.29)*(1.00-0.29)+0.12*(1.00-0.29)) and 53% (= 0.11+0.21+0.30*(1.00-0.29)), respectively.

Unit 2

Tables 3e.1-5 and 3e.1-6 (from Ref. 41) show the transport fractions for each type/size of debris due to the washdown forces for breaks inside the crane wall.

Table 3e.1-5:
IP-2 Washdown transport fractions of debris from upper containment to the annulus

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	38%	13%	NA	NA
Fiberglass	38%	13%	NA	NA
Temp-Mat™	38%	13%	NA	NA
Transco Blanket	38%	13%	NA	NA
Asbestos	38%	NA	NA	NA
RMI	NA	22%	NA	NA
Qualified Coatings Inside the ZOI	38%	NA	NA	NA
Unqualified Coatings Inside the ZOI	38%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	38%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	38%	NA	NA
Unqualified Alkyd Enamel Outside the ZOI	38%	NA	NA	NA
Unqualified Inorganic Zinc Outside the ZOI	38%	NA	NA	NA
White RTV/Black Caulk	38%	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Table 3e.1-6:
IP-2 Washdown transport fractions of debris from upper containment to the Steam Generator compartments

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	62%	47%	NA	NA
Fiberglass	62%	47%	NA	NA
Temp-Mat™	62%	47%	NA	NA
Transco Blanket	62%	47%	NA	NA
Asbestos	62%	NA	NA	
RMI	NA	53%	NA	NA
Qualified Coatings Inside the ZOI	62%	NA	NA	NA
Unqualified Coatings Inside the ZOI	62%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	62%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	62%	NA	NA

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Unqualified Alkyd Enamel Outside the ZOI	62%	NA	NA	NA
Unqualified Inorganic Zinc Outside the ZOI	62%	NA	NA	NA
White RTV/Black Caulk	62%	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

Unit 3

Tables 3e.1-7 and 3e.1-8 (from Ref. 42) show the transport fractions for each type/size of debris due to the washdown forces for breaks inside the crane wall.

Table 3e.1-7:
IP-3 Washdown transport fractions of debris from upper containment to the annulus

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	38%	13%	NA	NA
Fiberglass	38%	13%	NA	NA
Temp-Mat™	38%	13%	NA	NA
Mineral Wool	38%	13%	NA	NA
Cal-Sil and Asbestos	38%	NA	NA	NA
RMI	NA	22%	NA	NA
Qualified Coatings Inside the ZOI	38%	NA	NA	NA
Unqualified Coatings Inside the ZOI	38%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	38%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	38%	NA	NA
Unqualified Alkyd Enamel Outside the ZOI	38%	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

**Table 3e.1-8:
IP-3 Washdown transport fractions of debris from upper containment to the Steam Generator compartments**

Debris Type	Fines	Small Pieces	Unjacketed Large Pieces	Jacketed Large Pieces
Nukon™	62%	47%	NA	NA
Fiberglass	62%	47%	NA	NA
Temp-Mat™	62%	47%	NA	NA
Mineral Wool	62%	47%	NA	NA
Cal-Sil and Asbestos	62%	NA	NA	NA
RMI	NA	53%	NA	NA
Qualified Coatings Inside the ZOI	62%	NA	NA	NA
Unqualified Coatings Inside the ZOI	62%	NA	NA	NA
Unqualified High Temp Aluminum Outside the ZOI	62%	NA	NA	NA
Unqualified Epoxy/Epoxy Phenolic Outside the ZOI	NA	62%	NA	NA
Unqualified Alkyd Enamel Outside the ZOI	62%	NA	NA	NA
Dirt/Dust	NA	NA	NA	NA
Latent Fiber	NA	NA	NA	NA

3e.1.3 Pool Fill-up Transport

Common to both units

During pool fill-up, the flow of water transports insulation debris from the break location to all areas of the recirculation pool. Some of the debris was assumed to transport to inactive areas of the pool, while other debris was assumed to transport directly to the sump screens as the emergency sump cavities are filled.

Assuming that fine debris is uniformly distributed in the pool, and the water entering the pool from the break and sprays is clean (i.e. washdown of debris in upper containment occurs after inactive cavities have been filled), the transport to each of the inactive cavities was calculated. (Note that the assumption that debris washdown occurs after inactive cavities have been filled is consistent with the requirements of the SER Section 3.8 [Ref. 3].)

3e.1.4 Recirculation Transport Using CFD

Common to both units

The recirculation pool debris transport fractions were determined through CFD modeling. To accomplish this, a three-dimensional CAD model was imported into the CFD model, flows into and out of the pool were defined, and the CFD simulation was run until steady-state conditions were reached. The result of the CFD analysis is a three-dimensional model showing the turbulence and fluid velocities within the pool. By comparing the direction of pool flow, the magnitude of the turbulence and velocity, the initial location of debris, and the specific debris transport metrics (i.e. the minimum velocity or turbulence required to transport a particular type/size of debris), the recirculation transport of each type/size of debris to the sump screens was determined. Two CFD simulations were run for each of the Indian Point units to model the flow to the IR sumps and the VC sumps.

A diagram showing the significant parts of the CFD model is shown below in Figure 3.e.1-2. The sump mass sink, the modeled break location, the refueling canal drain mass source, and the modeled spray drainage are highlighted.

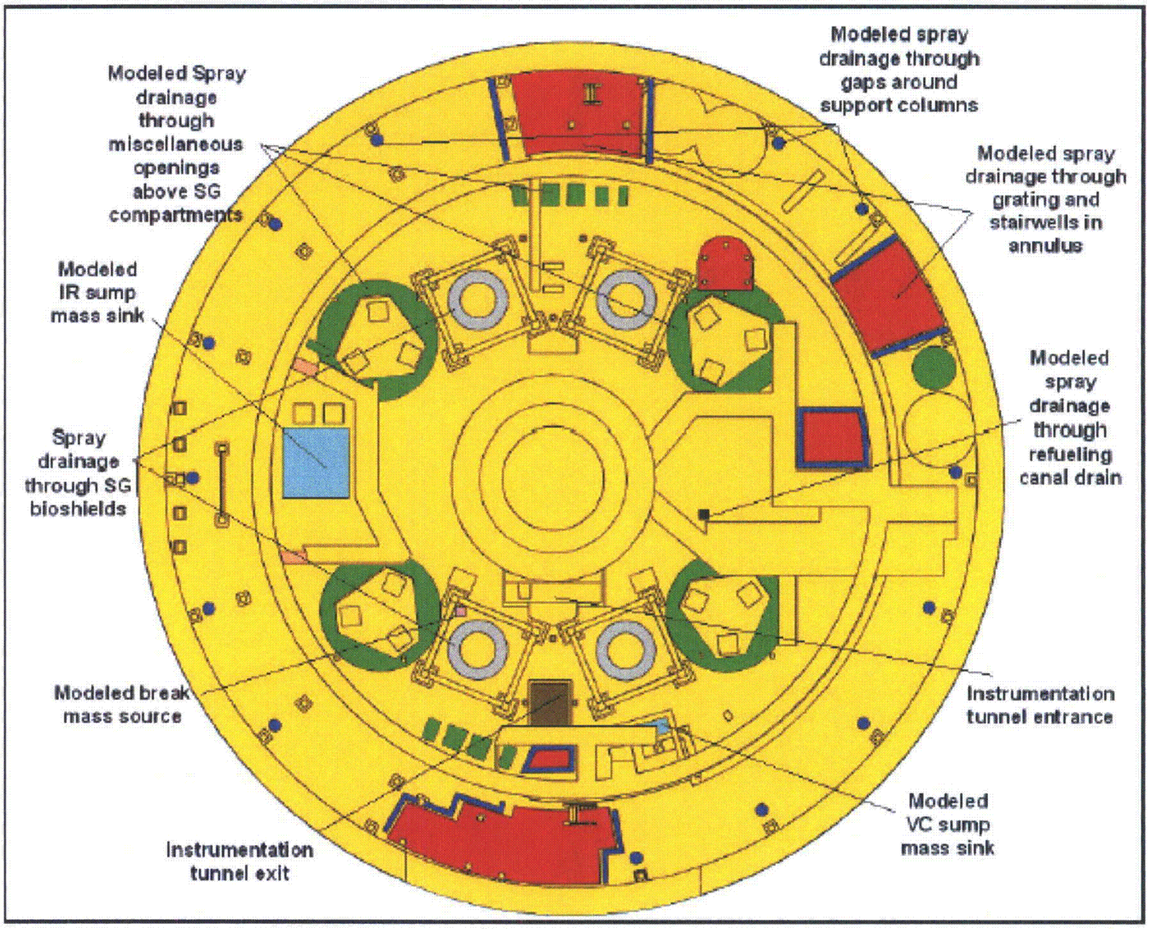


Figure 3e.1-2:
Diagram of significant features modeled (Figure is for IP-2. IP-3 has the same features and is nearly identical)

Flow-3D® Version 9.0 developed by Flow Sciences, Incorporated, with an Alion-modified subroutine was used for the CFD modeling. The key CFD modeling attributes/considerations included the following:

<u>Computational Mesh:</u>
A rectangular mesh was defined in the CFD model that was fine enough to resolve important features, but not so fine that the simulation would take prohibitively long to run. For the main portion of the model, 4"×4" mesh spacing was used in the x-y directions, and 3" to 6" mesh spacing was used in the z direction. For the tunnel portion of the model, a linked mesh with 6"×6"×6" mesh spacing was used.

Modeling of Containment Spray Flows:
From consideration of various containment drawings, it was judged that spray water would drain to the pool through the following pathways:

- The grated openings and stairwells in the annulus
- The gaps in the toe plates around support columns in the annulus
- The 4-inch refueling canal drain
- The openings around the Steam Generators
- The grated hatches above the Reactor Coolant Pumps
- The opening above the Pressurizer
- Other miscellaneous openings on the Operating Deck

Note that no drainage through the annular space around the vessel in the refueling cavity to the Reactor Cavity was credited.

Assuming that spray flow is uniform across containment, the fraction of spray landing on any given area can be calculated using the ratio of that area to the overall area. Also, for sprays landing on a solid surface, such as the Operating Deck, the runoff flow split to different regions, such as the annulus grating and refueling canal, can be reasonably approximated using the ratios of open perimeters where water could drain off.

The spray flow splits were estimated as follows:

- Spray drainage through the Steam Generator bioshields: 11.0%
- Spray drainage through refueling canal: 21.3%
- Spray drainage through miscellaneous grated areas into Steam Generator compartments: 29.4%
- Spray drainage through both 95' elevation and 68' elevation gratings in annulus: 26.0%
- Spray drainage through 95' elevation grating and openings around support beams: 12.3%

Modeling of Break Flow:
The water stream falling from the postulated break would introduce momentum into the containment pool that would influence the flow dynamics. This break stream momentum is accounted for by introducing the break flow to the pool at the velocity a freefalling object would have if it fell the vertical distance from the location of the break to the surface of the pool.

The break stream was introduced in the CFD model by defining a flow region populated with mass source particles and setting the flow rate and velocity similar to the containment spray sources. The break source was situated near the postulated break location, below the surface of the pool. This was done to avoid the splashing (which would drastically increase the calculation run time) that would occur if the source was above the pool surface. Splashing is considered to be a negligible mode of transport for all types of debris.

Emergency Sumps:
Indian Point has two sumps - the IR sump and the VC sump. Since these sumps are in different locations and have different flow rates, separate CFD models were run for the two sumps. The IR sump supplies the internal recirculation pumps, and the VC sump supplies the RHR pumps. Mass sinks used to pull flow from the CFD model were defined for the IR sump and for the VC sump as shown in Figure 3e.1-2.

A negative flow rate was set for the IR sump mass sink (IP-2 = 7,100 gpm and IP-3 = 5,400 gpm) and for the VC sump mass sink (3,700 gpm). Each of these flow rates are based upon the maximum low head pump flow and the maximum spray pump flow for each sump at each unit. This tells the CFD model to draw the specified amount of water from the pool over the entire exposed surface area of the mass sink obstacle. This flow rates represent the maximum recirculation flow for the respective unit which eventually decrease as the time after the accident progresses. These maximum flow rates are conservatively used as steady-state conditions for the CFD model. These flows maximize the turbulent kinetic energy (TKE) and velocities, consequently maximizing the debris transport fractions.

Turbulence Modeling:
Several different turbulence modeling approaches can be selected for a Flow-3D® calculation. The approaches are (ranging from least to most sophisticated): Prandtl mixing length, Turbulent energy model, Two-equation k-ε model, Renormalized group theory (RNG) model, and Large eddy simulation model. From these, the RNG turbulence model was judged to be the most appropriate for this CFD analysis due to the large spectrum of length scales that would likely exist in a containment pool during emergency recirculation. Sensitivity calculations have shown that Flow-3D® Containment Pool calculations utilizing the RNG and Large eddy turbulence models yield results with only slight differences [Refs. 41 and 42].

Steady State Metrics:
The CFD models were started from a stagnant state at a pool depth of 1.44 ft for IP-2 and 1.19 ft for IP-3, then run long enough for steady-state conditions to develop. The pool depths are less than the minimum containment water levels (in the latest calculations; Refs. 33 and 34) that are present at the beginning of recirculation, which maximizes the turbulent kinetic energy (TKE) and velocities. This is conservative because the water level in containment will increase with time and result in lower TKE and velocities. A plot of mean kinetic energy was used to determine when steady-state conditions were reached. Checks were also made of the velocity and turbulent energy patterns in the pool to verify that steady-state conditions were reached.

Debris Transport Metrics:
Metrics for predicting debris transport have been adopted or derived from data. The specific metrics are the turbulent kinetic energy (TKE) necessary to keep debris suspended, and the flow velocity necessary to tumble sunken debris along a floor or lift it over a curb.

The metrics utilized in the Indian Point transport analysis originate from:

- NUREG/CR-6772 Tables 3.2, 3.5, or C.19(a) [Ref. 12]
- NUREG/CR-6808 Table 5-3 [Ref. 7]
- NUREG/CR-6916 [Ref. 69] or
- Stokes' Law.

Graphical Determination of Debris Transport Fractions:
The following steps were taken to determine what percentage of a particular type of debris could be expected to transport through the containment pool to the emergency sump screens.

- Colored contour velocity and TKE maps indicating regions of the pool through which a particular type of debris could be expected to transport were generated from the Flow-3D® results in the form of bitmap files.
- The bitmap files were overlaid on the initial debris distribution plots and imported into AutoCAD® with the appropriate scaling factor to convert the length scale of the color maps to feet.

- For the uniformly distributed debris, closed polylines were drawn around the contiguous areas where velocity or TKE was high enough that debris could be carried in suspension or tumbled along the floor to the sump screens.
- The areas within the closed polylines were determined utilizing an AutoCAD ® querying feature.
- The combined area within the polylines was compared to the debris distribution area.
- The percentage of a particular debris type that would transport to the sump screens was estimated based on the above comparison.

Plots showing the TKE and the velocity magnitude in the pool were generated for each case to determine areas where specific types of debris would be transported. The limits on the plots were set according to the minimum TKE or velocity metrics necessary to move each type of debris. Regions where the debris would be suspended were specifically identified in the plots as well as regions where the debris would be tumbled along the floor. Color coded TKE portions of the plots is a three-dimensional representation of the TKE. The velocity portion of the plots represents the velocity magnitude just above the floor level (1.5 inches), where tumbling of sunken debris could occur. Directional flow vectors were also included in the plots to determine whether debris in certain areas would be transported to the sump screens or transported to quieter regions of the pool where it could settle to the floor.

The following figures (3e.1-3 through 3e.1-8, from Refs. 41 and 42) are presented as an example of the way in which the transport analysis was performed for a single debris type – small pieces of fiberglass in the pool. This same approach was utilized for other debris types analyzed at Indian Point.

Unit 2

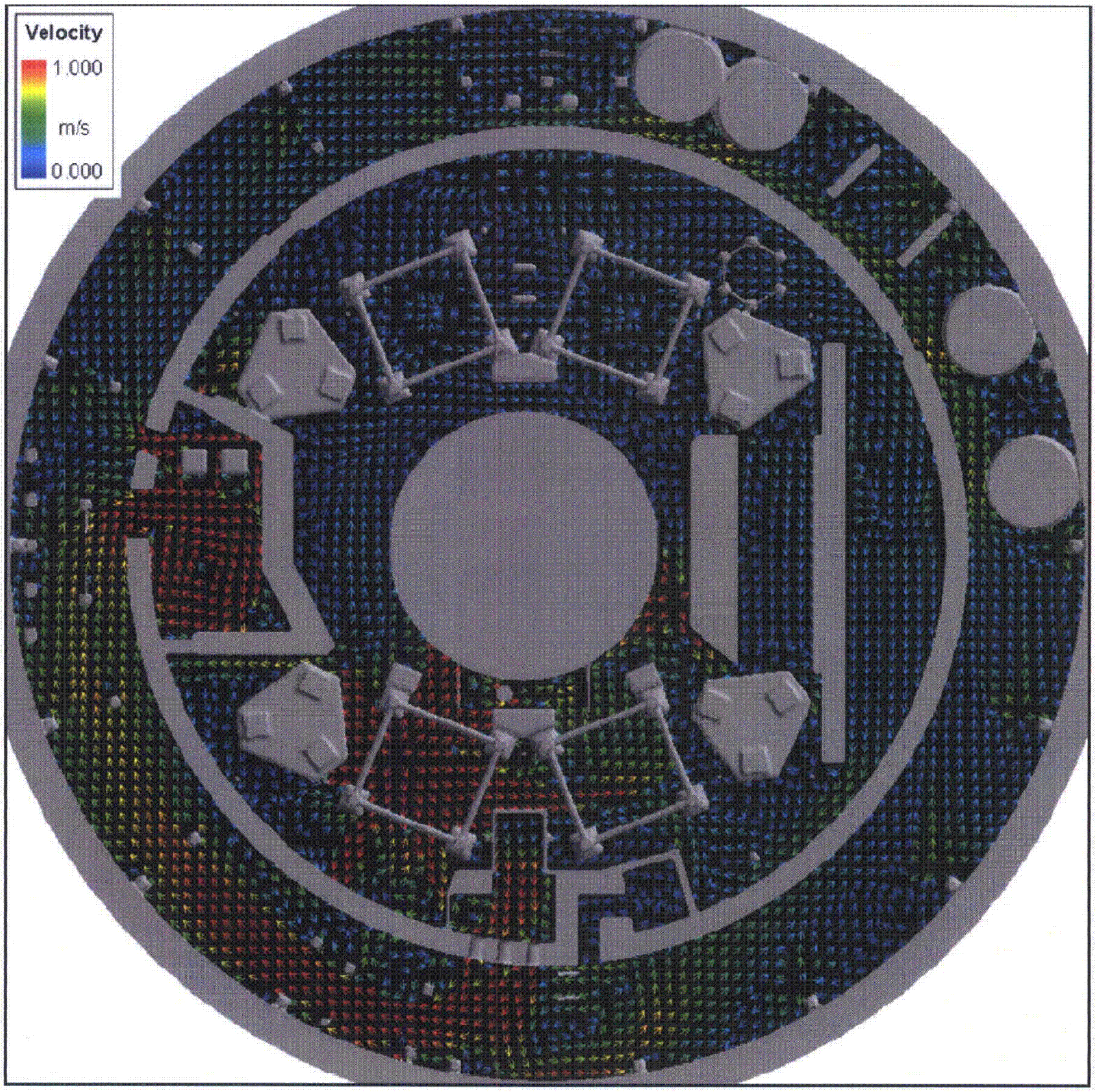


Figure 3e.1-3:
Vectors showing pool flow direction on the IP-2 containment floor (IR sump run)

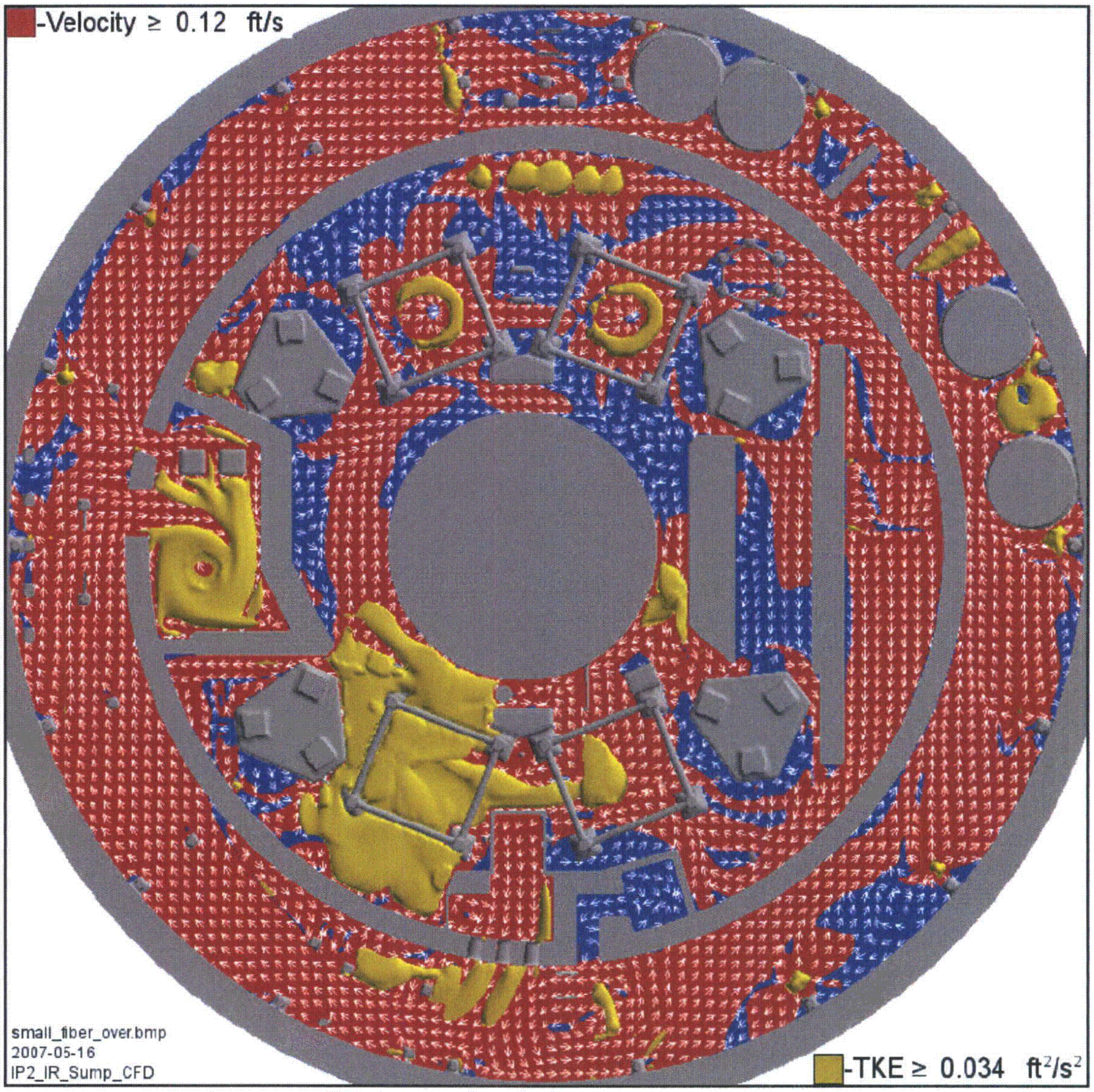


Figure 3e.1-4:
TKE and velocity with limits set at suspension/tumbling of small pieces of fiberglass in the IP-2 pool (IR sump run)

The annulus washdown distribution area was overlaid on top of the plot showing tumbling velocity and flow vectors to determine the recirculation transport fraction, Figure 3e.1-5

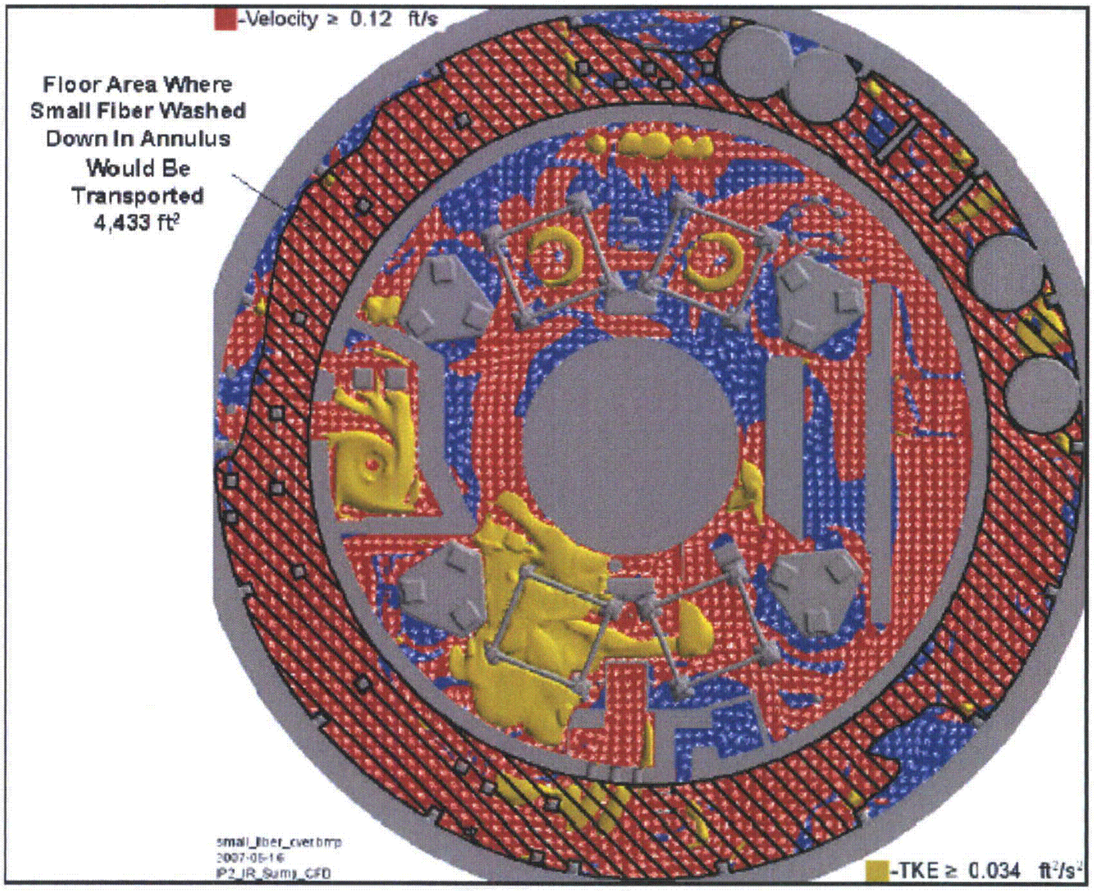


Figure 3e.1-5:
Floor area where small fiberglass would transport to the IP-2 sump (IR sump run)

This same analysis was applied for each debris type (grouped as applicable) evaluated at IP-2. Recirculation pool transport fractions were identified for each debris type associated with the location of its original distribution. This includes a transport fraction for debris: 1) not originally blown into upper containment, 2) debris washed down inside the secondary shield wall, and 3) debris washed down into the annulus.

Unit 3

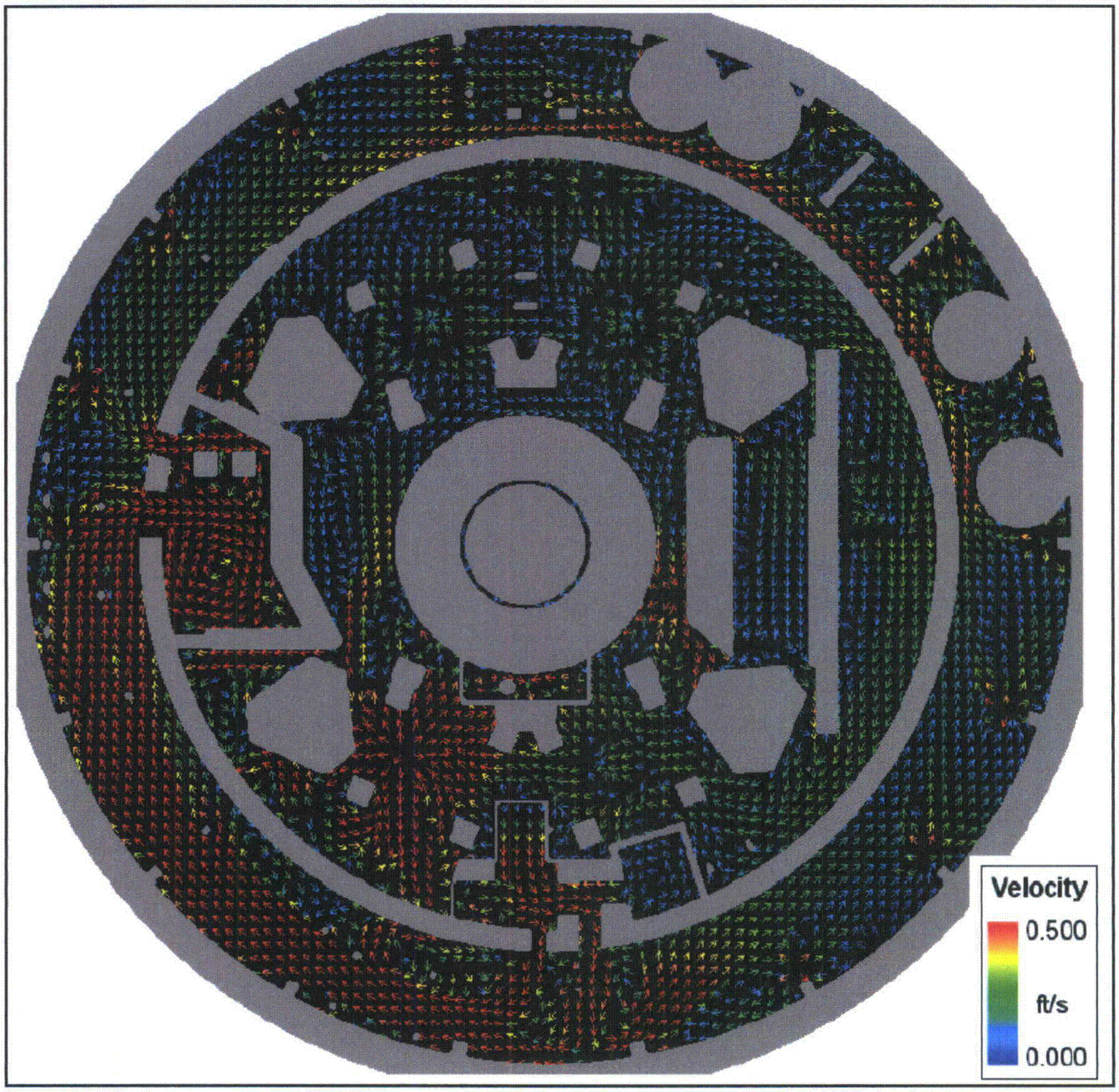


Figure 3e.1-6:
Vectors showing pool flow direction on the IP-3 containment floor (IR sump run)

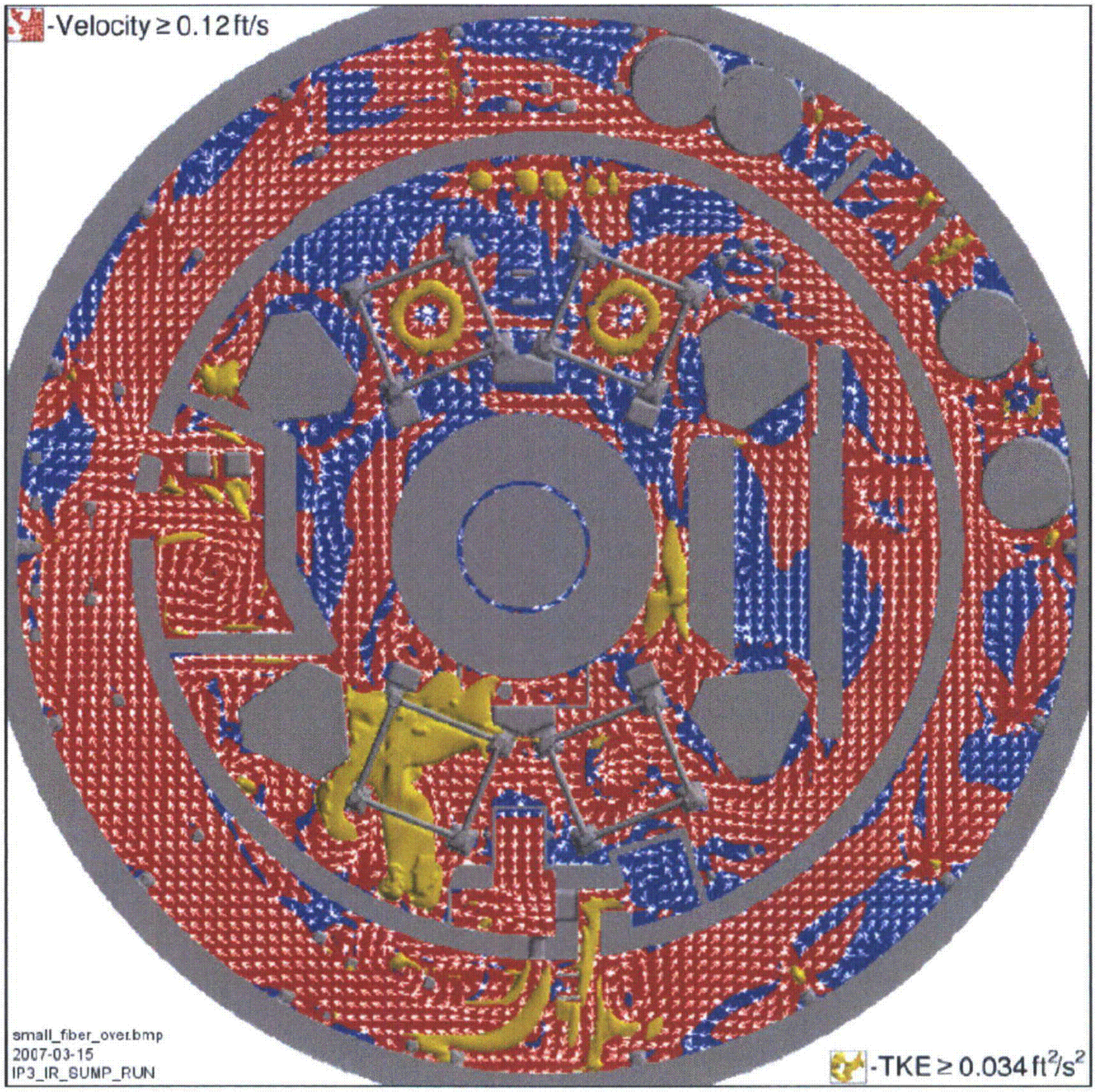


Figure 3e.1-7:
TKE and velocity with limits set at suspension/tumbling of small pieces of fiberglass in the IP-3 pool (IR sump run)

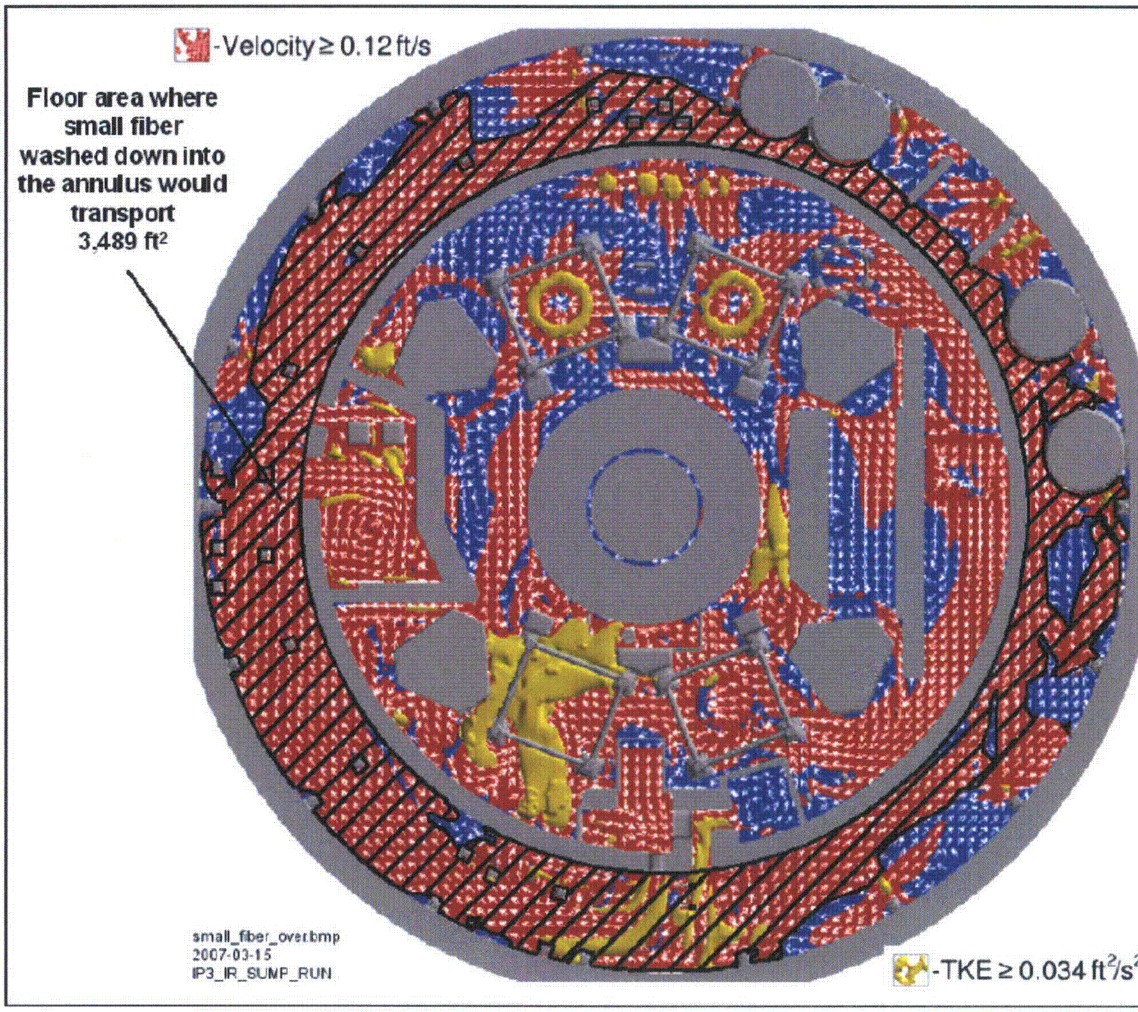


Figure 3e.1-8:
Floor area where small fiberglass would transport to the IP-3 sump (IR sump run)

Pool Turnover Methodology:

For an accident scenario where the IR sump strainer is operated for 24 hours before recirculation flow is switched over to the VC sump strainer, a large portion of the transportable debris in the recirculation pool would be transported to the IR sump and therefore would not be available for transport to the VC sump. In the Debris Transport Calculation [Refs. 41 and 42], the fraction of debris that would be transported to the IR sump was calculated based on the number of pool turnovers that would occur in 24 hours. This analysis conservatively used the maximum pool volume and minimum sump flow rate since these parameters give the longest pool turnover time and would result in the lowest quantity of debris transporting to the IR sump during this period (leaving more debris available to transport to the VC sump). Note that the pool turnover approach is appropriate for fine debris that is in the pool at the beginning of recirculation and is readily transported.

Entergy Response to Issue 3e.2:

Common to both units

Some types of insulation debris could erode when subjected to the continuing forces of break or spray flows and pool turbulence. If the debris breaks down into smaller pieces, it would transport more easily and cause a larger head loss across the sump strainer.

Stainless steel RMI is assumed not to break down into smaller pieces following the initial generation at the beginning of the LOCA. The other insulation debris types with the potential for erosion at Indian Point are Nukon™, fiberglass, Transco Blanket, Temp-Mat™, Cal-Sil, and asbestos. The individual fibers and Cal-Sil/asbestos fines would not be subject to further erosion, and the intact pieces of fiberglass are still covered by the original jacketing and therefore would also not be subject to erosion [Refs. 3 and 6]. This leaves the small and large pieces of fiberglass (Nukon™, generic fiberglass, Transco Blanket, and Temp-Mat™) and the chunks of Cal-Sil and asbestos.

Debris erosion rates within the debris transport analysis deviate from the regulatory guidance. The guidance specifies that an erosion fraction of 90% should be used for fiberglass debris. However, an erosion fraction of 10% was used for fiberglass debris in the recirculation pool [Refs. 41 and 42]. A justification for this deviation is provided below.

Tests performed as a part of the BWR drywell debris transport study (DDTS) [Ref. 66] have indicated that the erosion of fibrous debris is significantly different for debris directly impacted by containment sprays versus debris directly impacted by break flow. The erosion of large pieces of fibrous debris by containment sprays was found to be less than 1%, whereas the erosion due to the break flow was much higher. Due to differences in the design of PWR nuclear plants compared to the boiling water reactor (BWR) nuclear plants, the results of the erosion testing in the DDTS are only partially applicable. In a BWR plant, a LOCA accident would generate debris that would be held up below the break location on grating above the suppression pool. In the Indian Point plants, however, the break would generate debris that would either be blown to upper containment or blown out away from the break. Most of the debris would not be hung up directly below the break flow where it would undergo the high erosion rates suggested by the DDTS. Any debris blown to upper containment that is not washed back down, however, would be subject to erosion by the sprays. Based on the results of the DDTS testing, a 1% erosion factor was applied for small and large piece fibrous debris held up in upper containment. This is consistent with the approach taken for the pilot plant in the SER (Appendix VI) [Ref. 3]. The erosion mechanism for debris in the pool is somewhat different than what was tested in the DDTS.

To quantify the recirculation pool erosion fractions for IP-2, 30 day erosion testing was performed. Based on this testing an erosion fraction of 10% was used for the fiberglass (Nukon™, generic fiberglass, Transco Blanket, and Temp-Mat™) debris [Ref. 122].

As discussed in the Debris Generation Calculations [Refs. 1 and 2], the chunks of Cal-Sil and Asbestos are not subject to dissolution in the recirculation pool. This is supported by the IP-2 Material Dissolution Report [Ref. 104], which states that (based on testing) large scale dissolution did not occur with IP-2 Cal-Sil specimens. The IP-2 Calcium Silicate Material Characterization Report [Ref. 9] and the IP-3 Plant Material Characterization Report [Ref. 10] state that on a microscopic level the IP-2 and IP-3 Cal-Sil compared quite similar to PCI and IIG materials. Therefore, the results, which verify that IP-2 Cal-Sil does not dissolve in the recirculation pool environment, apply to both IP-3 Asbestos and Cal-Sil. These results indicate that the 100%

destruction of Cal-Sil as "small fines" [Ref. 6] is overly conservative; the NRC guidance assumes "small fines" as being the basic constituent of the material for fibrous blankets (i.e., individual fibers) and pigments for coatings.

Also, the Debris Generation Calculations [Refs. 1 and 2] assumed that Cal-Sil and Asbestos would have the debris distribution shown in Table 3c.1-4 instead of 100% "small fines" as indicated by NRC guidance [Ref. 6]. Based on testing, the erosion fraction for Asbestos is conservatively approximated as 14% (IP-2 and IP-3) and the erosion fraction for Cal-Sil is conservatively approximated as 15% (IP-3 only) in the Debris Transportation Calculations [Refs. 41 and 42]. Plant materials were compared to industry erosion testing [Ref. 105] to result in the erosion fractions. Again, these erosion factors indicate that the industry guidance of 100% "small fines" is conservative.

Entergy Response to Issue 3e.3:

Common to both units

See response to 3e.1.4 for a discussion of the methodology and results used in the CFD model. However, in addition to the discussion in 3e.1.4, the following assumptions were identified in the Debris Transportation Calculations [Refs. 41 and 42] specifically for the CFD model:

- It was assumed that the screens installed as flow barriers in the crane wall doorways, in the crane wall penetrations, and around the VC and IR sumps would be blocked with debris forcing all break flow through the incore instrumentation tunnel. This is a conservative assumption since any flow through the doorways would decrease the flow through the tunnel and increase the potential for debris to settle in the tunnel.
- The water falling from the reactor coolant system (RCS) breach was assumed to do so without encountering any structures before reaching the containment pool. This is a conservative assumption since any impact with structures would dissipate the momentum of the water and decrease the turbulent energy in the pool.
- For the CFD model, it was assumed that potential upstream blockage points (with the exception of the flow barriers, which are designed to be blocked) would not inhibit the flow of water through these areas. This is conservative because it promotes transport of debris to the strainer.

Entergy Response to Issue 3e.4:

Common to both units

Debris interceptors are not integrated into the Indian Point debris transport analysis. However, flow barriers are designed to force flow down into the Reactor Cavity (where larger pieces of debris will be retained), through the in-core instrumentation tunnel, and then flow to the annulus through a set of crane wall holes next to the VC sump. These are explained in the Upstream Effects Section 3l of this document under the name "flow barrier". The flow barriers are assumed to be fully blocked so that the velocity through the incore instrumentation tunnel is maximized and consequently the debris transport would also be maximized. This represents a significant conservatism as some fraction of flow would pass through the flow barriers. The amount of debris caught by these flow barriers was not credited for a decreased debris amount at the sump. This represents a significant conservatism as large pieces and intact blankets would likely collect on the coarse screens that make up the barriers.

Entergy Response to Issue 3e.5:

Common to both units

One hundred percent (100%) of fine debris was assumed to transport to the sump, as can be seen by the transport fractions [Refs. 41 and 42]. This represents a conservatism as some fraction of fine debris would settle in stagnant areas of the pool.

Entergy Response to Issue 3e.6:

Transport logic trees were developed for each size and type of debris generated [Refs. 41 and 42]. These trees were used to determine the total fraction of debris that would reach the sump screen in each of the postulated cases.

The transport fractions, along with the debris generated for miscellaneous breaks, are used to determine the total quantities of each type of debris transported to the strainers. Note, for each break case presented in the Test Debris Amounts Calculation [Ref. 45], there are four potential break scenarios, except for Reactor Cavity break scenarios, which only has one break scenario. A break scenario is defined as a break that generates either the maximum total particulate debris amount in the North Compartment of the Containment, the maximum total fibrous debris amount in the North Compartment of Containment, the maximum total particulate debris amount in the South Compartment of Containment, or the maximum total fibrous debris amount in the South Compartment of Containment. Then, for each break case, the maximum of each fibrous debris type is conservatively chosen from the larger maximum total fiber break scenario, and the maximum of each particulate debris type is chosen from the larger maximum total particulate break scenario. Thus, the break cases developed in the Test Debris Amounts Calculation are conservative combinations of multiple break scenarios that maximize debris. The following tables summarize the total quantity of debris that is transported to the strainers for the 3 break bounding cases evaluated for each unit in the Test Debris Amounts Calculation [Ref. 45], the IR Sump Large Break LOCA (IR LBLOCA), the VC Sump 6 Inch Break LOCA (VC 6 Inch LOCA), and the VC Sump Large Break LOCA after 24 hours of IR Sump Operation (VC LB24 LOCA). This information has been extracted from the appendices in the Test Debris Amounts Calculation [Ref. 45]; however, the same information can be derived from the Debris Generation and Debris Transport Calculations [Refs. 41 and 42]. The tables below provide the debris transport fractions and the total quantities of each type of debris transported to the strainers.

Unit 2

**Table 3e.6-1:
IP-2 IR LBLOCA Debris Transport to Strainers Summary Table**

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	365.65	100	365.65	lbm
Nukon™ (small pieces)	1393.21	15	208.98	lbm
Nukon™ (large pieces)	334.23	10	33.42	lbm
Nukon™ (intact pieces)	356.74	0	0.00	lbm
Nukon™ Total	**2449.83**	**--**	**608.05**	**lbm**
Thermal-Wrap (fines)	16.24	100	16.24	lbm
Thermal-Wrap (small pieces)	61.01	15	9.15	lbm
Thermal-Wrap (large pieces)	12.79	10	1.28	lbm
Thermal-Wrap (intact pieces)	13.67	0	0.00	lbm
Thermal-Wrap Total	**103.71**	**--**	**26.67**	**lbm**
Temp-Mat (fines)	72.61	100	72.61	lbm
Temp-Mat (small pieces)	281.62	15	42.24	lbm
Temp-Mat (large pieces)	282.44	10	28.24	lbm
Temp-Mat (intact pieces)	300.10	0	0.00	lbm
Temp-Mat Total	**936.77**	**--**	**143.10**	**lbm**
Asbestos (fines)	180.41	100	180.41	lbm
Asbestos (small pieces)	121.20	14	16.97	lbm
Asbestos (large pieces)	458.80	0	0.00	lbm
Asbestos Total	**760.41**	**--**	**197.38**	**lbm**
Fiberglass (fines)	0.20	100	0.20	lbm
Fiberglass (small pieces)	0.18	15	0.03	lbm
Fiberglass (large pieces)	1.04	10	0.10	lbm
Fiberglass (intact pieces)	1.12	0	0.00	lbm
Fiberglass Total	**2.54**	**--**	**0.33**	**lbm**
Coatings Inside ZOI	**608.32**	**100**	**608.32**	**lbm**
UQ Epoxy	**394.92**	**39**	**154.02**	**lbm**
UQ Non Epoxy	**208.68**	**100**	**208.68**	**lbm**
Additional UQ Epoxy (lbs)[1]	**0.57**	**100**	**0.57**	**lbm**
Additional UQ Enamel (lbs)[1]	**15.88**	**100**	**15.88**	**lbm**
Additional 2R17 UQ Coatings[2]	**8.40**	**100**	**8.40**	**lbm**
UQ IOZ	**191.83**	**100**	**191.83**	**lbm**
Dirt/Dust	**164.90**	**100**	**164.90**	**lbm**
Latent Fiber	**29.10**	**100**	**29.10**	**lbm**
Fiber Tags	**0.12**	**100**	**0.12**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-015, and conservatively assumed to transport 100% in the IP-2 Debris Transport Calculation, ALION-CAL-ENT-2833-01.

2. Also, additional UQ coatings were identified during the 2R17 outage and are assumed to transport 100% in this calculation.

**Table 3e.6-2:
IP-2 IR Reactor Cavity LBLOCA Debris Transport to Strainers Summary Table**

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	100	0.00	lbm
Nukon™ (small pieces)	0.00	15	0.00	lbm
Nukon™ (large pieces)	0.00	10	0.00	lbm
Nukon™ (intact pieces)	0.00	0	0.00	lbm
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Thermal-Wrap (fines)	0.00	100	0.00	lbm
Thermal-Wrap (small pieces)	0.00	15	0.00	lbm
Thermal-Wrap (large pieces)	0.00	10	0.00	lbm
Thermal-Wrap (intact pieces)	0.00	0	0.00	lbm
Thermal-Wrap Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	45.43	100	45.43	lbm
Temp-Mat (small pieces)	180.05	15	27.01	lbm
Temp-Mat (large pieces)	53.85	10	5.39	lbm
Temp-Mat (intact pieces)	57.21	0	0.00	lbm
Temp-Mat Total	**336.54**	**--**	**77.82**	**lbm**
Asbestos (fines)	0.00	100	0.00	lbm
Asbestos (small pieces)	0.00	14	0.00	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**0.00**	**--**	**0.00**	**lbm**
Fiberglass (fines)	0.00	100	0.00	lbm
Fiberglass (small pieces)	0.00	15	0.00	lbm
Fiberglass (large pieces)	0.00	10	0.00	lbm
Fiberglass (intact pieces)	0.00	0	0.00	lbm
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**546.65**	**100**	**546.65**	**lbm**
UQ Epoxy	**423.21**	**39**	**165.05**	**lbm**
UQ Non Epoxy	**201.42**	**100**	**201.42**	**lbm**
Additional UQ Epoxy (lbs)[1]	**0.57**	**100**	**0.57**	**lbm**
Additional UQ Enamel (lbs)[1]	**15.88**	**100**	**15.88**	**lbm**
Additional 2R17 UQ Coatings[2]	**8.40**	**100**	**8.40**	**lbm**
UQ IOZ	**191.83**	**100**	**191.83**	**lbm**
Dirt/Dust	**164.90**	**100**	**164.90**	**lbm**
Latent Fiber	**29.10**	**100**	**29.10**	**lbm**
Fiber Tags	**0.12**	**100**	**0.12**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-015, and conservatively assumed to transport 100% in the IP-2 Debris Transport Calculation, ALION-CAL-ENT-2833-01.

2. Also, additional UQ coatings were identified during the 2R17 outage and are assumed to transport 100% in this calculation.

Table 3e.6-3:
IP-2 VC 6 Inch LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	69.98	100	69.98	lbm
Nukon™ (small pieces)	229.15	9	20.62	lbm
Nukon™ (large pieces)	105.71	10	10.57	lbm
Nukon™ (intact pieces)	113.25	0	0.00	lbm
Nukon™ Total	**518.09**	**--**	**101.17**	**lbm**
Thermal-Wrap (fines)	0.34	100	0.34	lbm
Thermal-Wrap (small pieces)	0.30	9	0.03	lbm
Thermal-Wrap (large pieces)	1.74	10	0.17	lbm
Thermal-Wrap (intact pieces)	1.87	0	0.00	lbm
Thermal-Wrap Total	**4.25**	**--**	**0.54**	**lbm**
Temp-Mat (fines)	0.00	100	0.00	lbm
Temp-Mat (small pieces)	0.00	14	0.00	lbm
Temp-Mat (large pieces)	0.00	10	0.00	lbm
Temp-Mat (intact pieces)	0.00	0	0.00	lbm
Temp-Mat Total	**0.00**	**--**	**0.00**	**lbm**
Asbestos (fines)	47.52	100	47.52	lbm
Asbestos (small pieces)	40.78	14	5.71	lbm
Asbestos (large pieces)	52.22	0	0.00	lbm
Asbestos Total	**140.52**	**--**	**53.23**	**lbm**
Fiberglass (fines)	0.00	100	0.00	lbm
Fiberglass (small pieces)	0.00	9	0.00	lbm
Fiberglass (large pieces)	0.00	10	0.00	lbm
Fiberglass (intact pieces)	0.00	0	0.00	lbm
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**63.97**	**100**	**63.97**	**lbm**
UQ Epoxy	**423.12**	**3**	**12.69**	**lbm**
UQ Non Epoxy	**209.50**	**100**	**209.50**	**lbm**
Additional UQ Epoxy (lbs)[1]	**0.57**	**100**	**0.57**	**lbm**
Additional UQ Enamel (lbs)[1]	**15.88**	**100**	**15.88**	**lbm**
Additional 2R17 UQ Coatings[2]	**8.40**	**100**	**8.40**	**lbm**
UQ IOZ	**191.83**	**100**	**191.83**	**lbm**
Dirt/Dust	**164.90**	**100**	**164.90**	**lbm**
Latent Fiber	**29.10**	**100**	**29.10**	**lbm**
Fiber Tags	**0.12**	**100**	**0.12**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-015, and conservatively assumed to transport 100% in the IP-2 Debris Transport Calculation, ALION-CAL-ENT-2833-01.

2. Also, additional UQ coatings were identified during the 2R17 outage and are assumed to transport 100% in this calculation.

Table 3e.6-4:
IP-2 VC Reactor Cavity 6 Inch LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	100	0.00	lbm
Nukon™ (small pieces)	0.00	9	0.00	lbm
Nukon™ (large pieces)	0.00	10	0.00	lbm
Nukon™ (intact pieces)	0.00	0	0.00	lbm
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Thermal-Wrap (fines)	0.00	100	0.00	lbm
Thermal-Wrap (small pieces)	0.00	9	0.00	lbm
Thermal-Wrap (large pieces)	0.00	10	0.00	lbm
Thermal-Wrap (intact pieces)	0.00	0	0.00	lbm
Thermal-Wrap Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	11.36	100	11.36	lbm
Temp-Mat (small pieces)	45.02	14	6.30	lbm
Temp-Mat (large pieces)	13.46	10	1.35	lbm
Temp-Mat (intact pieces)	14.30	0	0.00	lbm
Temp-Mat Total	**84.14**	**--**	**19.01**	**lbm**
Asbestos (fines)	0.00	100	0.00	lbm
Asbestos (small pieces)	0.00	14	0.00	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**0.00**	**--**	**0.00**	**lbm**
Fiberglass (fines)	0.00	100	0.00	lbm
Fiberglass (small pieces)	0.00	9	0.00	lbm
Fiberglass (large pieces)	0.00	10	0.00	lbm
Fiberglass (intact pieces)	0.00	0	0.00	lbm
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**1.31**	**100**	**1.31**	**lbm**
UQ Epoxy	**423.21**	**3**	**12.70**	**lbm**
UQ Non Epoxy	**235.21**	**100**	**235.21**	**lbm**
Additional UQ Epoxy (lbs)[1]	**0.57**	**100**	**0.57**	**lbm**
Additional UQ Enamel (lbs)[1]	**15.88**	**100**	**15.88**	**lbm**
Additional 2R17 UQ Coatings[2]	**8.40**	**100**	**8.40**	**lbm**
UQ IOZ	**191.83**	**100**	**191.83**	**lbm**
Dirt/Dust	**164.90**	**100**	**164.90**	**lbm**
Latent Fiber	**29.10**	**100**	**29.10**	**lbm**
Fiber Tags	**0.12**	**100**	**0.12**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-015, and conservatively assumed to transport 100% in the IP-2 Debris Transport Calculation, ALION-CAL-ENT-2833-01.

2. Also, additional UQ coatings were identified during the 2R17 outage and are assumed to transport 100% in this calculation.

Table 3e.6-5:
IP-2 VC LB24 LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	365.65	5	18.28	**lbm**
Nukon™ (small pieces)	1393.21	1	13.93	**lbm**
Nukon™ (large pieces)	334.23	1	3.34	**lbm**
Nukon™ (intact pieces)	356.74	0	0.00	**lbm**
Nukon™ Total	**2449.83**	**--**	**35.56**	**lbm**
Thermal-Wrap (fines)	16.24	5	0.81	**lbm**
Thermal-Wrap (small pieces)	61.01	1	0.61	**lbm**
Thermal-Wrap (large pieces)	12.79	1	0.13	**lbm**
Thermal-Wrap (intact pieces)	13.67	0	0.00	**lbm**
Thermal-Wrap Total	**103.71**	**--**	**1.55**	**lbm**
Temp-Mat (fines)	72.61	5	3.63	**lbm**
Temp-Mat (small pieces)	281.62	1	2.82	**lbm**
Temp-Mat (large pieces)	282.44	1	2.82	**lbm**
Temp-Mat (intact pieces)	300.10	0	0.00	**lbm**
Temp-Mat Total	**936.77**	**--**	**9.27**	**lbm**
Asbestos (fines)	180.41	5	9.02	**lbm**
Asbestos (small pieces)	121.2	14	16.97	**lbm**
Asbestos (large pieces)	458.8	0	0.00	**lbm**
Asbestos Total	**760.41**	**--**	**25.99**	**lbm**
Fiberglass (fines)	0.2	5	0.01	**lbm**
Fiberglass (small pieces)	0.18	1	0.00	**lbm**
Fiberglass (large pieces)	1.04	1	0.01	**lbm**
Fiberglass (intact pieces)	1.12	0	0.00	**lbm**
Fiberglass Total	**2.54**	**--**	**0.02**	**lbm**
Coatings Inside ZOI	**608.32**	**5**	**30.42**	**lbm**
UQ Epoxy	**394.92**	**3**	**11.85**	**lbm**
UQ Non Epoxy	**208.68**	**100**	**208.68**	**lbm**
Additional UQ Epoxy (lbs)[1]	**0.57**	**100**	**0.57**	**lbm**
Additional UQ Enamel (lbs)[1]	**15.88**	**100**	**15.88**	**lbm**
Additional 2R17 UQ Coatings[2]	**8.40**	**100**	**8.40**	**lbm**
UQ IOZ	**191.83**	**100**	**191.83**	**lbm**
Dirt/Dust	**164.90**	**5**	**8.25**	**lbm**
Latent Fiber	**29.10**	**5**	**1.46**	**lbm**
Fiber Tags	**0.12**	**100**	**0.12**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-015, and conservatively assumed to transport 100% in the IP-2 Debris Transport Calculation, ALION-CAL-ENT-2833-01.

2. Also, additional UQ coatings were identified during the 2R17 outage and are assumed to transport 100% in this calculation.

Table 3e.6-6:
IP-2 VC Reactor Cavity LB24 LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	5	0.00	**lbm**
Nukon™ (small pieces)	0.00	1	0.00	**lbm**
Nukon™ (large pieces)	0.00	1	0.00	**lbm**
Nukon™ (intact pieces)	0.00	0	0.00	**lbm**
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Thermal-Wrap (fines)	0.00	5	0.00	**lbm**
Thermal-Wrap (small pieces)	0.00	1	0.00	**lbm**
Thermal-Wrap (large pieces)	0.00	1	0.00	**lbm**
Thermal-Wrap (intact pieces)	0.00	0	0.00	**lbm**
Thermal-Wrap Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	45.43	5	2.27	**lbm**
Temp-Mat (small pieces)	180.05	1	1.80	**lbm**
Temp-Mat (large pieces)	53.85	1	0.54	**lbm**
Temp-Mat (intact pieces)	57.21	0	0.00	**lbm**
Temp-Mat Total	**336.54**	**--**	**4.61**	**lbm**
Asbestos (fines)	0	5	0.00	**lbm**
Asbestos (small pieces)	0	14	0.00	**lbm**
Asbestos (large pieces)	0	0	0.00	**lbm**
Asbestos Total	**0.00**	**--**	**0.00**	**lbm**
Fiberglass (fines)	0	5	0.00	**lbm**
Fiberglass (small pieces)	0	1	0.00	**lbm**
Fiberglass (large pieces)	0	1	0.00	**lbm**
Fiberglass (intact pieces)	0	0	0.00	**lbm**
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**546.65**	**5**	**27.33**	**lbm**
UQ Epoxy	**423.21**	**3**	**12.70**	**lbm**
UQ Non Epoxy	**201.42**	**100**	**201.42**	**lbm**
Additional UQ Epoxy (lbs)[1]	**0.57**	**100**	**0.57**	**lbm**
Additional UQ Enamel (lbs)[1]	**15.88**	**100**	**15.88**	**lbm**
Additional 2R17 UQ Coatings[2]	**8.40**	**100**	**8.40**	**lbm**
UQ IOZ	**191.83**	**100**	**191.83**	**lbm**
Dirt/Dust	**164.90**	**5**	**8.25**	**lbm**
Latent Fiber	**29.10**	**5**	**1.46**	**lbm**
Fiber Tags	**0.12**	**100**	**0.12**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-015, and conservatively assumed to transport 100% in the IP-2 Debris Transport Calculation, ALION-CAL-ENT-2833-01.

2. Also, additional UQ coatings were identified during the 2R17 outage and are assumed to transport 100% in this calculation.

Unit 3

Table 3e.6-7:
IP-3 IR LBLOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	288.44	100	288.44	lbm
Nukon™ (small pieces)	1061.64	13	138.01	lbm
Nukon™ (large pieces)	312.61	10	31.26	lbm
Nukon™ (intact pieces)	334.05	0	0.00	lbm
Nukon™ Total	**1996.74**	--	**457.71**	**lbm**
Temp-Mat (fines)	331.44	100	331.44	lbm
Temp-Mat (small pieces)	1304.19	15	195.63	lbm
Temp-Mat (large pieces)	689.98	10	69.00	lbm
Temp-Mat (intact pieces)	733.10	0	0.00	lbm
Temp-Mat Total	**3058.71**	--	**596.07**	**lbm**
Cal-Sil (fines)	63.11	100	63.11	lbm
Cal-Sil (small pieces)	41.16	15	6.17	lbm
Cal-Sil (large pieces)	170.12	0	0.00	lbm
Cal-Sil Total	**274.39**	--	**69.28**	**lbm**
Asbestos (fines)	171.39	100	171.39	lbm
Asbestos (small pieces)	171.39	14	23.99	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**342.78**	--	**195.38**	**lbm**
Fiberglass (fines)	14.79	100	14.79	lbm
Fiberglass (small pieces)	58.17	13	7.56	lbm
Fiberglass (large pieces)	13.98	10	1.40	lbm
Fiberglass (intact pieces)	14.89	0	0.00	lbm
Fiberglass Total	**101.83**	--	**23.75**	**lbm**
Mineral Wool (fines)	11.27	100	11.27	lbm
Mineral Wool (small pieces)	46.17	15	6.93	lbm
Mineral Wool (large pieces)	8.70	10	0.87	lbm
Mineral Wool (intact pieces)	9.25	0	0.00	lbm
Mineral Wool Total	**75.39**	--	**19.07**	**lbm**
Coatings Inside ZOI	**534.59**	**100**	**534.59**	**lbm**
UQ Epoxy	**799.35**	**28**	**223.82**	**lbm**
UQ Non Epoxy	**37.03**	**100**	**37.03**	**lbm**
Additional UQ Epoxy[1]	**14.22**	**100**	**14.22**	**lbm**
Additional UQ Enamel[1]	**5.92**	**100**	**5.92**	**lbm**
Dirt/Dust	**212.50**	**100**	**212.50**	**lbm**
Latent Fiber	**37.50**	**100**	**37.50**	**lbm**
Fiber Tags	**0.05**	**100**	**0.05**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-010, and conservatively assumed to transport 100% in the IP-3 Debris Transport Calculation, ALION-CAL-ENT-2833-03.

Table 3e.6-8:
IP-3 IR Reactor Cavity LBLOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	100	0.00	lbm
Nukon™ (small pieces)	0.00	13	0.00	lbm
Nukon™ (large pieces)	0.00	10	0.00	lbm
Nukon™ (intact pieces)	0.00	0	0.00	lbm
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	45.43	100	45.43	lbm
Temp-Mat (small pieces)	180.05	15	27.01	lbm
Temp-Mat (large pieces)	53.85	10	5.39	lbm
Temp-Mat (intact pieces)	57.21	0	0.00	lbm
Temp-Mat Total	**336.54**	**--**	**77.82**	**lbm**
Cal-Sil (fines)	0.00	100	0.00	lbm
Cal-Sil (small pieces)	0.00	15	0.00	lbm
Cal-Sil (large pieces)	0.00	0	0.00	lbm
Cal-Sil Total	**0.00**	**--**	**0.00**	**lbm**
Asbestos (fines)	0.00	100	0.00	lbm
Asbestos (small pieces)	0.00	14	0.00	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**0.00**	**--**	**0.00**	**lbm**
Fiberglass (fines)	0.00	100	0.00	lbm
Fiberglass (small pieces)	0.00	13	0.00	lbm
Fiberglass (large pieces)	0.00	10	0.00	lbm
Fiberglass (intact pieces)	0.00	0	0.00	lbm
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Mineral Wool (fines)	0.00	100	0.00	lbm
Mineral Wool (small pieces)	0.00	15	0.00	lbm
Mineral Wool (large pieces)	0.00	10	0.00	lbm
Mineral Wool (intact pieces)	0.00	0	0.00	lbm
Mineral Wool Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**389.45**	**100**	**389.45**	**lbm**
UQ Epoxy	**828.25**	**28**	**231.91**	**lbm**
UQ Non Epoxy	**29.73**	**100**	**29.73**	**lbm**
Additional UQ Epoxy[1]	**14.22**	**100**	**14.22**	**lbm**
Additional UQ Enamel[1]	**5.92**	**100**	**5.92**	**lbm**
Dirt/Dust	**212.50**	**100**	**212.50**	**lbm**
Latent Fiber	**37.50**	**100**	**37.50**	**lbm**
Fiber Tags	**0.05**	**100**	**0.05**	**lbm**

1. After the initial containment walkdowns, additional UQ coatings were identified in letter IP-DE-08-010, and conservatively assumed to transport 100% in the IP-3 Debris Transport Calculation, ALION-CAL-ENT-2833-03.

Table 3e.6-9:
IP-3 VC 6 Inch LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	100	0.00	lbm
Nukon™ (small pieces)	0.00	8	0.00	lbm
Nukon™ (large pieces)	0.00	10	0.00	lbm
Nukon™ (intact pieces)	0.00	0	0.00	lbm
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	133.21	100	133.21	lbm
Temp-Mat (small pieces)	526.89	14	73.76	lbm
Temp-Mat (large pieces)	190.82	10	19.08	lbm
Temp-Mat (intact pieces)	202.75	0	0.00	lbm
Temp-Mat Total	**1053.68**	**--**	**226.06**	**lbm**
Cal-Sil (fines)	0.63	100	0.63	lbm
Cal-Sil (small pieces)	0.41	15	0.06	lbm
Cal-Sil (large pieces)	1.71	0	0.00	lbm
Cal-Sil Total	**2.76**	**--**	**0.70**	**lbm**
Asbestos (fines)	73.06	100	73.06	lbm
Asbestos (small pieces)	63.08	14	8.83	lbm
Asbestos (large pieces)	77.30	0	0.00	lbm
Asbestos Total	**213.45**	**--**	**81.89**	**lbm**
Fiberglass (fines)	2.32	100	2.32	lbm
Fiberglass (small pieces)	6.51	8	0.52	lbm
Fiberglass (large pieces)	6.18	10	0.62	lbm
Fiberglass (intact pieces)	6.62	0	0.00	lbm
Fiberglass Total	**21.63**	**--**	**3.46**	**lbm**
Mineral Wool (fines)	0.00	100	0.00	lbm
Mineral Wool (small pieces)	0.00	14	0.00	lbm
Mineral Wool (large pieces)	0.00	10	0.00	lbm
Mineral Wool (intact pieces)	0.00	0	0.00	lbm
Mineral Wool Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**60.15**	**100**	**60.15**	**lbm**
UQ Epoxy	**828.25**	**2**	**16.57**	**lbm**
UQ Non Epoxy	**37.85**	**100**	**37.85**	**lbm**
Additional UQ Epoxy[1]	**14.22**	**100**	**14.22**	**lbm**
Additional UQ Enamel[1]	**5.92**	**100**	**5.92**	**lbm**
Dirt/Dust	**212.50**	**100**	**212.50**	**lbm**
Latent Fiber	**37.50**	**100**	**37.50**	**lbm**
Fiber Tags	**0.05**	**100**	**0.05**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-010, and conservatively assumed to transport 100% in the IP-3 Debris Transport Calculation, ALION-CAL-ENT-2833-03.

Table 3e.6-10:
IP-3 VC Reactor Cavity 6 Inch LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	100	0.00	lbm
Nukon™ (small pieces)	0.00	8	0.00	lbm
Nukon™ (large pieces)	0.00	10	0.00	lbm
Nukon™ (intact pieces)	0.00	0	0.00	lbm
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	11.36	100	11.36	lbm
Temp-Mat (small pieces)	45.02	14	6.30	lbm
Temp-Mat (large pieces)	13.46	10	1.35	lbm
Temp-Mat (intact pieces)	14.30	0	0.00	lbm
Temp-Mat Total	**84.14**	**--**	**19.01**	**lbm**
Cal-Sil (fines)	0.00	100	0.00	lbm
Cal-Sil (small pieces)	0.00	15	0.00	lbm
Cal-Sil (large pieces)	0.00	0	0.00	lbm
Cal-Sil Total	**0.00**	**--**	**0.00**	**lbm**
Asbestos (fines)	0.00	100	0.00	lbm
Asbestos (small pieces)	0.00	14	0.00	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**0.00**	**--**	**0.00**	**lbm**
Fiberglass (fines)	0.00	100	0.00	lbm
Fiberglass (small pieces)	0.00	8	0.00	lbm
Fiberglass (large pieces)	0.00	10	0.00	lbm
Fiberglass (intact pieces)	0.00	0	0.00	lbm
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Mineral Wool (fines)	0.00	100	0.00	lbm
Mineral Wool (small pieces)	0.00	14	0.00	lbm
Mineral Wool (large pieces)	0.00	10	0.00	lbm
Mineral Wool (intact pieces)	0.00	0	0.00	lbm
Mineral Wool Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**1.31**	**100**	**1.31**	**lbm**
UQ Epoxy	**828.25**	**2**	**16.57**	**lbm**
UQ Non Epoxy	**63.52**	**100**	**63.52**	**lbm**
Additional UQ Epoxy[1]	**14.22**	**100**	**14.22**	**lbm**
Additional UQ Enamel[1]	**5.92**	**100**	**5.92**	**lbm**
Dirt/Dust	**212.50**	**100**	**212.50**	**lbm**
Latent Fiber	**37.50**	**100**	**37.50**	**lbm**
Fiber Tags	**0.05**	**100**	**0.05**	**lbm**

1. After the initial containment walkdowns, additional UQ coatings were identified in letter IP-DE-08-010, and conservatively assumed to transport 100% in the IP-3 Debris Transport Calculation, ALION-CAL-ENT-2833-03.

Table 3e.6-11:
IP-3 VC LB24 LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	288.44	5	14.42	lbm
Nukon™ (small pieces)	1061.64	1	10.62	lbm
Nukon™ (large pieces)	312.61	1	3.13	lbm
Nukon™ (intact pieces)	334.05	0	0.00	lbm
Nukon™ Total	**1996.74**	--	**28.16**	**lbm**
Temp-Mat (fines)	331.44	5	16.57	lbm
Temp-Mat (small pieces)	1304.19	1	13.04	lbm
Temp-Mat (large pieces)	689.98	1	6.90	lbm
Temp-Mat (intact pieces)	733.10	0	0.00	lbm
Temp-Mat Total	**3058.71**	--	**36.51**	**lbm**
Cal-Sil (fines)	63.11	5	3.16	lbm
Cal-Sil (small pieces)	41.16	15	6.17	lbm
Cal-Sil (large pieces)	170.12	0	0.00	lbm
Cal-Sil Total	**274.39**	--	**9.33**	**lbm**
Asbestos (fines)	171.39	5	8.57	lbm
Asbestos (small pieces)	171.39	14	23.99	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**342.78**	--	**32.56**	**lbm**
Fiberglass (fines)	14.79	5	0.74	lbm
Fiberglass (small pieces)	58.17	1	0.58	lbm
Fiberglass (large pieces)	13.98	1	0.14	lbm
Fiberglass (intact pieces)	14.89	0	0.00	lbm
Fiberglass Total	**101.83**	--	**1.46**	**lbm**
Mineral Wool (fines)	11.27	5	0.56	lbm
Mineral Wool (small pieces)	46.17	1	0.46	lbm
Mineral Wool (large pieces)	8.70	1	0.09	lbm
Mineral Wool (intact pieces)	9.25	0	0.00	lbm
Mineral Wool Total	**75.39**	--	**1.11**	**lbm**
Coatings Inside ZOI	**534.59**	**5**	**26.73**	**lbm**
UQ Epoxy	**799.35**	**2**	**15.99**	**lbm**
UQ Non Epoxy	**37.03**	**100**	**37.03**	**lbm**
Additional UQ Epoxy[1]	**14.22**	**100**	**14.22**	**lbm**
Additional UQ Enamel[1]	**5.92**	**100**	**5.92**	**lbm**
Dirt/Dust	**212.50**	**5**	**10.63**	**lbm**
Latent Fiber	**37.50**	**5**	**1.88**	**lbm**
Fiber Tags	**0.05**	**100**	**0.05**	**lbm**

1. After the initial containment walkdowns, additional unqualified (UQ) coatings were identified in letter IP-DE-08-010, and conservatively assumed to transport 100% in the IP-3 Debris Transport Calculation, ALION-CAL-ENT-2833-03.

Table 3e.6-12:
IP-3 VC Reactor Cavity LB24 LOCA Debris Transport to Strainers Summary Table

Debris Type (size)	Debris Generated	Transport Fraction (%)	Debris at Sump	Units
Nukon™ (fines)	0.00	5	0.00	lbm
Nukon™ (small pieces)	0.00	1	0.00	lbm
Nukon™ (large pieces)	0.00	1	0.00	lbm
Nukon™ (intact pieces)	0.00	0	0.00	lbm
Nukon™ Total	**0.00**	**--**	**0.00**	**lbm**
Temp-Mat (fines)	45.43	5	2.27	lbm
Temp-Mat (small pieces)	180.05	1	1.80	lbm
Temp-Mat (large pieces)	53.85	1	0.54	lbm
Temp-Mat (intact pieces)	57.21	0	0.00	lbm
Temp-Mat Total	**336.54**	**--**	**4.61**	**lbm**
Cal-Sil (fines)	0.00	5	0.00	lbm
Cal-Sil (small pieces)	0.00	15	0.00	lbm
Cal-Sil (large pieces)	0.00	0	0.00	lbm
Cal-Sil Total	**0.00**	**--**	**0.00**	**lbm**
Asbestos (fines)	0.00	5	0.00	lbm
Asbestos (small pieces)	0.00	14	0.00	lbm
Asbestos (large pieces)	0.00	0	0.00	lbm
Asbestos Total	**0.00**	**--**	**0.00**	**lbm**
Fiberglass (fines)	0.00	5	0.00	lbm
Fiberglass (small pieces)	0.00	1	0.00	lbm
Fiberglass (large pieces)	0.00	1	0.00	lbm
Fiberglass (intact pieces)	0.00	0	0.00	lbm
Fiberglass Total	**0.00**	**--**	**0.00**	**lbm**
Mineral Wool (fines)	0.00	5	0.00	lbm
Mineral Wool (small pieces)	0.00	1	0.00	lbm
Mineral Wool (large pieces)	0.00	1	0.00	lbm
Mineral Wool (intact pieces)	0.00	0	0.00	lbm
Mineral Wool Total	**0.00**	**--**	**0.00**	**lbm**
Coatings Inside ZOI	**389.45**	**5**	**19.47**	**lbm**
UQ Epoxy	**828.25**	**2**	**16.57**	**lbm**
UQ Non Epoxy	**29.73**	**100**	**29.73**	**lbm**
Additional UQ Epoxy[1]	**14.22**	**100**	**14.22**	**lbm**
Additional UQ Enamel[1]	**5.92**	**100**	**5.92**	**lbm**
Dirt/Dust	**212.50**	**5**	**10.63**	**lbm**
Latent Fiber	**37.50**	**5**	**1.88**	**lbm**
Fiber Tags	**0.05**	**100**	**0.05**	**lbm**

1. After the initial containment walkdowns, additional UQ coatings were identified in letter IP-DE-08-010, and conservatively assumed to transport 100% in the IP-3 Debris Transport Calculation, ALION-CAL-ENT-2833-03.

NRC RAIs 1, 2, 3, 4 and 6 concern Debris Transport, the subject of the current NRC Issue (3e). The RAIs were identified in an NRC letter to Entergy, dated November 19, 2007 [Ref. 119]. Responses to RAIs 1, 3 and 4 are provided below. Responses to RAIs 2 and 6 may be found in Attachment 3.

RAI 1:

An adequate technical basis was not provided to support the assumption that 40% of small pieces of fibrous debris will be captured on gratings in the upper containment. Please provide a justification for this assumption or revise it as determined appropriate. (Audit Open Item)

Response to RAI 1:

The IP-2 and IP-3 Debris Transport Calculations (Refs. 41 and 42) were revised to include an appendix that provides additional justification for 40 percent hold up of small pieces on structures. The content in Appendix 5 of the IP-2 Debris Transport Calculation (Ref. 41) is included below. Appendix 6 of the IP-3 Debris Transport Calculation (Ref. 42) is identical except where unit specific values or rates are used. All references have been updated to correspond with this document.

APPENDIX 5 of IP-2 Debris Transport (Ref. 41):

Background
As discussed in the IP-2 Debris Transport Calculation (Ref. 41), a portion of the fiberglass debris that is generated by a high energy line break would be blown toward upper containment. Some of the small pieces of fiberglass that are blown upward, however, would be trapped by grating and other miscellaneous structures before reaching upper containment. This debris was conservatively assumed to fall back to the pool at the end of the blowdown phase. The small pieces of fiberglass that reach upper containment would be scattered around and could be held up on grating, the concrete operating deck, the refueling canal, or other locations in upper containment.

In the IP-2 Debris Transport Calculation (Ref. 41), drywell debris transport study (DDTS) test data was used to take credit for small pieces of fiberglass being held up on grating as discussed in NUREG/CR-6369 (Ref. 66). In the NUREG/CR-6369 testing, 1.5" pieces of fiberglass (obtained directly from blast testing) were placed on 1" x 4" grating and subjected to containment sprays with a flow rate per unit area of 5 gpm/ft^2 for a total of 30 minutes (Ref.66). Additional explanation for use of test data (not included in Appendix 5): If you look at NUREG/CR-6369 Conclusion 1 by itself, it appears that 100% of both fine and small piece debris would be washed down off of grating whether it is exposed to either break flow or spray flow. However, if you look at the table showing the results of the testing, you can see that the small piece debris would only have a 100% washdown fraction if it is exposed to <u>break</u> flow. For every test where the small piece debris was exposed to <u>spray</u> flow, the washdown fraction was less than 50%. This is the basis for Indian Point assumption of 50% holdup on grating.

The results of the testing showed a washdown fraction between 38% and 47%. For IP-2, the grating size is approximately the same (1-¼" x 3/16" bearing bars with cross bars on 4" centers (Ref. 130)), and the maximum spray flowrate is approximately 5,574 gpm (Ref. 120) (this maximum spray flow rate is for an SBLOCA and occurs for approximately 38 minutes during the injection phase). Since the total area for IP-2 is approximately 14,300 ft^2, the average spray flow rate per unit area is less than 0.4 gpm/ft^2, which is significantly less than the flow rate used for the NUREG/CR-6369 washdown tests. Therefore, it was considered to be reasonable and conservative to use a washdown fraction of 50% for small fiberglass through grating. Note that the

40% retention of small fiberglass debris is a result of the methodology presented in Section 5.5 of the Transport Calculation which uses the 50% holdup of small fiberglass on grating as an input. The fiberglass fines were conservatively assumed to have 100% transport with no retention on structures, grating, or inactive cavities.

An onsite audit of the IP-3 GSI-191 analyses was conducted by the NRC from December 3, 2007 through December 6, 2007 (Ref. 67). During the audit, the NRC verbally expressed concerns regarding the applicability of using the NUREG/CR-6369 test data for crediting hold up of small pieces of fiberglass on grating. Specifically, they questioned, 1) the applicability of the test results for long term spray operation at IP-3 since the tests were terminated after 30 minutes, 2) the applicability of the test results for debris washed from a concrete floor over the edge of a grated opening since the spray flow would be more concentrated in the regions where spray flow spills over the edge of a concrete floor, and 3) whether debris washed through an upper level of grating would be captured with the same efficiency by a second level of grating as it is washed down.

These concerns are addressed in the following analysis.

Applicability of Tests Results for Long Term Spray Operation
It is possible that some additional washdown could occur after 30 minutes. However, NUREG/CR-6369 states that based on visual observation, the majority of the washdown occurred within the first 15 minutes. Given this observation, it is not likely that a significantly larger quantity of debris would have been washed down if the test was run longer than 30 minutes. To account for some uncertainty in the testing, however, the observed washdown of 38% to 47% was conservatively rounded up to 50%. Note that the containment spray erosion of fiberglass debris that is retained on grating was addressed separately and included as an additional transport term in the logic trees.

Applicability of Test Results for Debris Washed off of a Concrete Floor through Grating
At the end of the blowdown phase, some of the debris blown to upper containment would land on the grating in upper containment, and some of the debris would land on the concrete operating deck. As the containment sprays pool up and run off the edges of the operating deck, the debris on the operating deck could potentially be transported over the edges of the grating in a higher flow concentration than the direct spray resulting in a higher washdown transport fraction.

In the Indian Point debris transport calculation, debris landing on the operating deck inside the crane wall was conservatively assumed to be washed to the various steam generator compartment hatches and the refueling canal (see Section 5.5 of Ref. 41). In reality, however, much of the debris would likely be retained on the operating deck floor as discussed later in this appendix. Note also that debris retention in the polar crane rail and manipulator crane rail trenches was conservatively neglected. The total spray flow draining from the operating deck to the grated hatches was calculated to be approximately 578 gpm at IP-2 based on a recirculation spray flow rate of 2,600 gpm (see Appendix 1 of Ref. 41). Scaling this flow rate up to account for the higher injection phase spray flow rate of 5,574 gpm, the flow rate to the grated hatches would be approximately 1,239 gpm. Since the total perimeter of all of the grated hatches inside the crane wall is 415 ft at IP-2 (see Appendix 1 of Ref. 41), and the water level on the operating deck is approximately 0.025 ft (Ref. 33), the approach velocity at any of the grated openings would be approximately 0.3 ft/s. Based on engineering judgment it is likely that a significant fraction of the small fiberglass debris would be captured by the grating as the water spills past the grating.

Similar to the grated hatches inside the crane wall, the approach velocities to the grated openings in the intermediate floor (68' elevation) in the annulus can be calculated. The total spray flow draining from the concrete floor to the grated openings would be approximately 487 gpm at IP-2 based on a recirculation spray flow rate of 2,600 gpm (see Appendix 1 of Ref. 41). Scaling this flow rate up to account for the higher injection phase spray flow rate of 5,574 gpm, the flow rate to the grated hatches would be approximately 1,044 gpm. Since the total perimeter around these openings is approximately 124 ft at IP-2 (see Appendix 1 of Ref. 41), and the water level on the 68' elevation annulus floor is approximately 0.047 ft, the approach velocity at any of the grated openings would be approximately 0.4 ft/s. Although this velocity is higher than the approach velocity to the grated hatches inside the crane wall, based on engineering judgment it is still expected that a significant fraction of the small fiberglass debris would be captured by the grating.[1]

Note that the uncertainty associated with the engineering judgment is offset by the conservatisms in the debris transport analysis discussed later in this appendix.

Debris Capture as it is Washed through a Second Level of Grating
A portion of the small piece debris that is washed down through the first level of grating at the 95' elevation could pass directly through the second level of grating at the 68' elevation if it happens to be lined up correctly. However, a significant portion of the small fiberglass debris washed onto the 68' elevation grating would be likely to land on and be caught by the bars of the grating. Although the NUREG/CR-6369 washdown tests did not specifically test the capture efficiency of a second level of grating, due to the highly conservative flow rates in the testing compared to Indian Point (5 gpm/ft^2 versus less than 0.4 gpm/ft^2), the actual retention fraction of debris on the grating at Indian Point would likely be significantly higher than 50%. Therefore, even if some of the small pieces fall directly through the second level of grating at the 68' elevation, the washdown fraction through this level of grating is still considered to be conservative.

Conservatisms in the Debris Transport Analysis
Although the Indian Point grating retention fractions are considered to be a very conservative application of the NUREG/CR-6369 washdown tests, it is acknowledged that there is some uncertainty due to the limited amount of test data available. However, when other conservatisms in the transport analysis are taken into consideration, it can be seen that the uncertainty in the grating retention fractions is easily offset by these conservatisms. The following items were considered: 1) BWROG washdown testing, 2) retention of debris on the concrete floors, 3) retention of debris that has been impinged on walls and structures inside the steam generator compartments.

Limiting Fiberglass Break Cases
The limiting break cases with respect to the fiber debris generated were taken from the debris generation calculation Table 7.3-7 for IP-2 (Ref. 1).

At IP-2, the total quantity of Nukon, Transco Blanket, and fiberglass generated was determined to be 2,556 lb_m (1,065 ft^3). The average size distribution for this debris was determined to be approximately 15% fines, 57% small pieces, 14% large pieces, and 14% intact blankets (Ref. 1). The blowdown transport fractions for fiberglass are 79% for fines, 51% for small pieces, and 0% for large and intact pieces (see Section 5.4 of Ref. 41). Multiplying the blowdown transport fractions by the size distributions shows that a total of approximately 440 ft^3 of fiberglass debris would be blown to upper containment with a distribution of 29% fines and 71% small pieces.

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[1] Note that the annulus floor at the 95' elevation is mostly grating with some intermittent lengths of checkered plate. The runoff flow from the checkered plate floors would be similar to the runoff flow from the concrete floors. However, since the lengths of checkered plate floor at the 95' elevation are shorter than the lengths of concrete floor on the 68' elevation, the water accumulation and subsequent runoff flow on the 95' elevation is bounded by the runoff flow on the 68' elevation.

<u>BWROG Washdown Testing</u>
In order to determine the appropriate blowdown and washdown fractions for the BWR ECCS strainer blockage resolution, the BWR owner's group (BWROG) sponsored testing to measure blowdown and washdown fractions for various scenarios and containment configurations (Ref. 66). For the small fiberglass testing, the debris was generated by shredding pieces of fiberglass and then further breaking it down by exposing the pieces to a steam jet. As discussed in the Utility Resolution Guide (URG) (Ref. 66), this resulted in a fibrous debris size much finer than expected following a LOCA (up to 67% fines). A comparison with the size distributions above shows that the URG distribution is conservative with respect to the IP-2 distribution (67% fines for the BWROG washdown testing versus 29% fines in upper containment for the IP-2 case discussed in Ref. 41). The individual test results are shown in Volume 3, Appendix E of the URG. Tables 1 and 2 in this appendix show that the average washdown fraction of the debris remaining after the blowdown for a Mark II containment configuration is approximately 43%. Tables 3 and 4 show that the average washdown fraction for a Mark I containment configuration is approximately 70%[2] (Ref. 66).

Using the more conservative Mark I washdown fraction of 70% and applying it to Indian Point for the fines and small pieces in upper containment shows that the current debris transport results are essentially the same as the alternate approach of applying the BWROG washdown test results (See Figure 1-1 and 1-2). This is a significant finding considering the statement in the URG that the BWROG test results were very conservative (Ref. 66). The current debris transport washdown methodology is discussed in Section 5.5 of Ref. 41.

[2] The washdown fractions are calculated by dividing the washdown transport (% of initial mass) by 100% minus the blowdown transport (% of initial mass). The debris not transported during the blowdown in these tests is the remaining debris available for washdown.

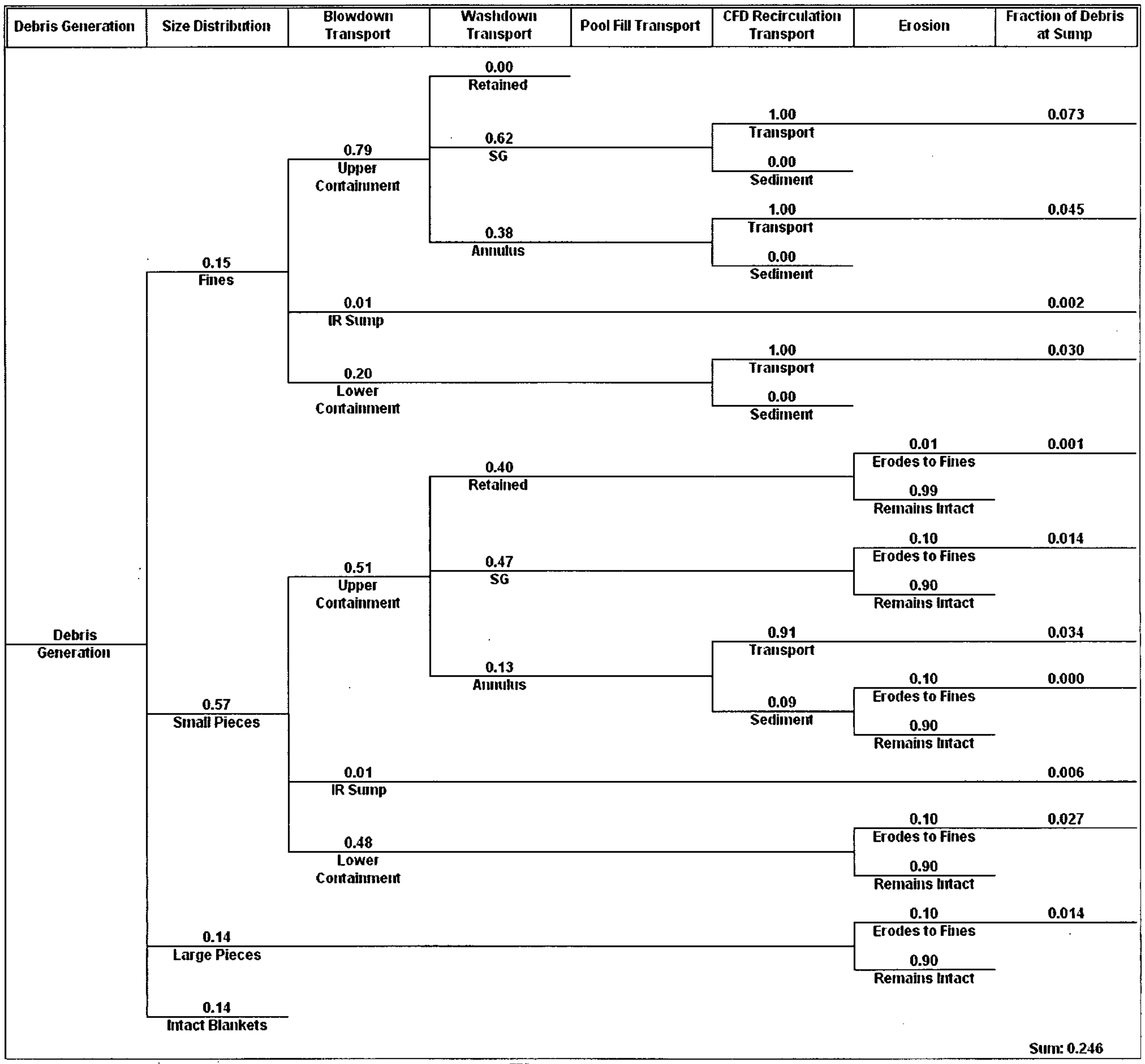

Figure 1-1:
Combined fiberglass logic trees with existing transport fractions for IP-2

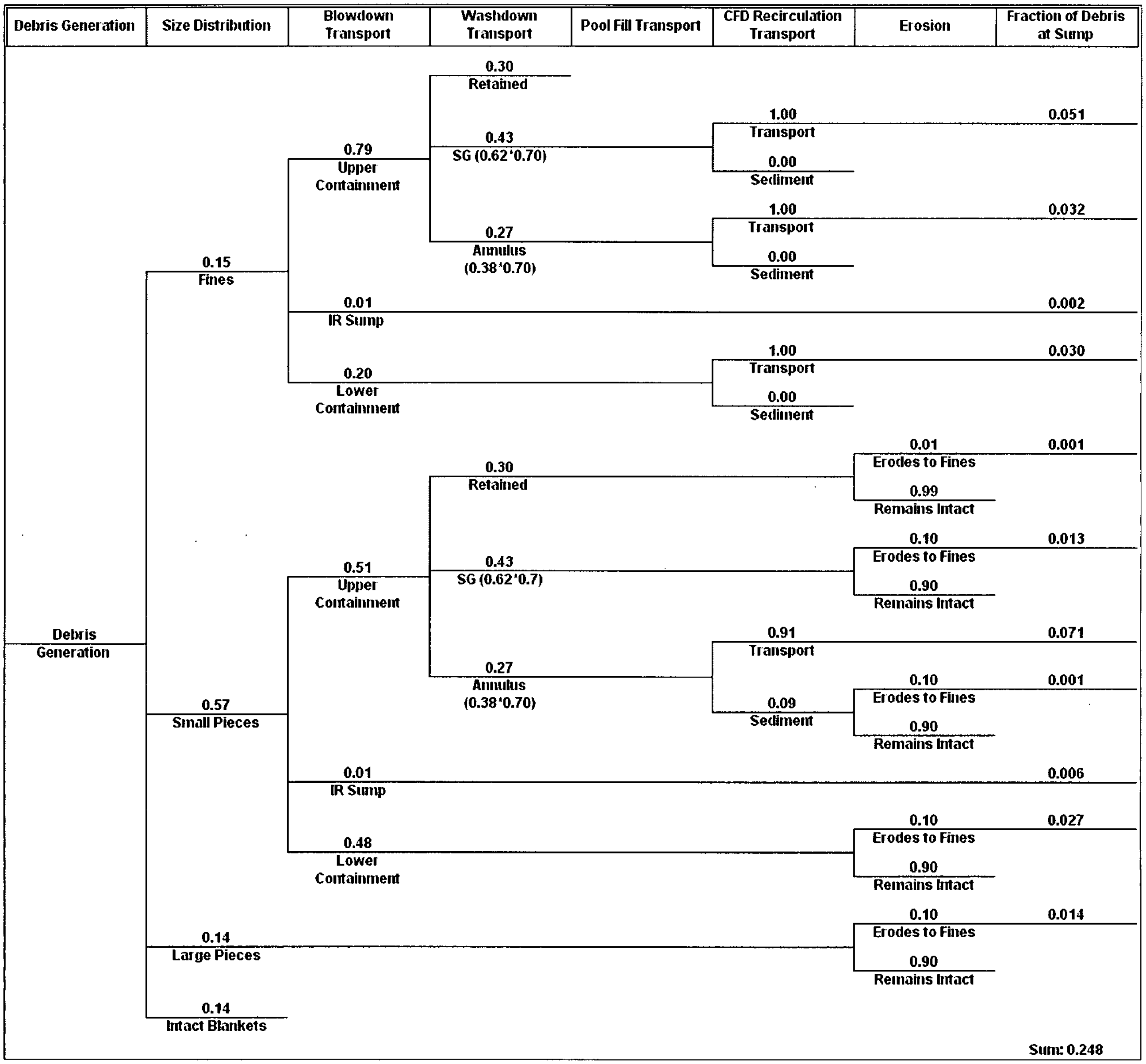

Figure 1-2:

Combined fiberglass logic trees with alternate BWROG washdown transport fractions for IP-2

Retention of Debris on Concrete Floors

One of the significant conservatisms in the Indian Point debris transport analysis is the assumption that all debris in upper containment would be washed down to the pool with the exception of a portion of small piece debris held up on grating (i.e. all debris is washed to the various grated hatches and openings without being held up on the concrete floors). As discussed previously, the average spray flow velocities on the operating deck would be approximately 0.3 ft/s and the average flow on the concrete floor in the annulus at Elevation 68' would be approximately 0.4 ft/s.

The incipient tumbling velocity for small pieces of fiberglass is 0.12 ft/s (Ref. 12). However, since this tumbling velocity is for 1 inch clumps of fiberglass completely submerged in water, the velocity required to tumble clumps of fiberglass sitting on the operating deck at Indian Point would be somewhat different since the pieces would not be fully submerged. Assuming that the small pieces of fiberglass on the operating deck are 1 inch clumps with dimensions of approximately 1" × 1" × ½", the clumps would be approximately half submerged in the ¼" water level on the operating deck. As shown in the following calculations, the difference in the submergence level has a significant impact on the transportability of the fiberglass pieces.

The bulk density of Nukon fiberglass is 2.4 lbm/ft^3, and the material density is 159 lbm/ft^3 (Ref. 6). Using the porosity equation shown in Section 5.8.8 of Ref. 41 (Equation 1-1) of the debris transport calculation, along with an air density of 0.075 lbm/ft^3 (Ref. 131) gives the following porosity for Nukon:

$$\phi = \frac{159\,lb_m/ft^3 - 2.4\,lb_m/ft^3}{159\,lb_m/ft^3 - 0.075\,lb_m/ft^3} = 0.985 \qquad \text{Equation 1-1}$$

When saturated with water[3] at 265°F (density of 58.4 lb_m/ft^3), the bulk density of the fiberglass would be:

$$\rho_b = 159\,lb_m/ft^3 - 0.985 \cdot (159\,lb_m/ft^3 - 58.4\,lb_m/ft^3) = 59.9\,lb_m/ft^3 \qquad \text{Equation 1-2}$$

The horizontal forces acting on the piece of fiberglass include the drag from the water flow (a function of the water velocity and the cross sectional area of fiberglass), and the friction force between the fiberglass and concrete. The friction force is directly proportional to the normal force which is equal to the weight of the piece of fiberglass minus the buoyancy.

$$\sum F_{horizontal} = F\{velocity, area\} - Friction = 0 \qquad \text{Equation 1-3}$$

$$Friction = \mu \cdot N \qquad \text{Equation 1-4}$$

$$N = Weight - Buoyancy \qquad \text{Equation 1-5}$$

$$Weight = V \cdot \rho_b \cdot g \qquad \text{Equation 1-6}$$

$$Buoyancy = V_{submerged} \cdot \rho_{water} \cdot g \qquad \text{Equation 1-7}$$

Since the pieces of fiberglass on the operating deck at Indian Point would only be half submerged:

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[3] As discussed in NUREG/CR-6770 (see Figure 12, page 55), the pieces of debris generated would be wetted by the initial two-phase jet blast. Given the fact that small pieces of fiberglass will readily absorb water at room temperature conditions (and even more quickly at elevated temperatures), the small pieces of fiberglass that are blown to upper containment and land on the operating deck would be exposed to containment sprays and fully saturated very quickly.

$$V_{submerged} = 1/2 \cdot V \qquad \text{Equation 1-8}$$

$$N_{Half\ Submerged} = V \cdot \rho_b \cdot g - 1/2 \cdot V \cdot \rho_{water} \cdot g = V \cdot \left(\rho_b - 1/2 \cdot \rho_{water}\right) \cdot g \qquad \text{Equation 1-9}$$

And the ratio of the normal forces on a half submerged piece of fiberglass versus a fully submerged piece would be:

$$\frac{N_{Half\ Submerged}}{N_{Fully\ Submerged}} = \frac{V \cdot \left(\rho_b - 1/2 \cdot \rho_{water}\right) \cdot g}{V \cdot \left(\rho_b - \rho_{water}\right) \cdot g} = \frac{59.9\, lb_m/ft^3 - 1/2 \cdot 58.4\, lb_m/ft^3}{59.9\, lb_m/ft^3 - 58.4\, lb_m/ft^3}$$
$$= 20 \qquad \text{Equation 1-10}$$

Therefore, since the coefficient of friction between fiberglass and concrete would be constant, and the reduced cross-sectional area for a partially submerged piece of fiberglass can be conservatively neglected, a 20 times higher flow velocity would be required to tumble a piece of fiberglass that is half submerged compared to a piece of fiberglass that is fully submerged. Since the incipient tumbling velocity for a fully submerged piece of fiberglass is 0.12 ft/s, a velocity of approximately 2.4 ft/s would be required to tumble the small pieces of fiberglass on the operating deck at Indian Point. Since this is significantly higher than the actual water velocity on the operating deck, most of the small fiberglass debris on the operating deck would not transport to the grated openings.

Since the water level on the 68' elevation annulus floor is slightly higher than half an inch, the small pieces of fiberglass could be fully submerged and the measured tumbling velocity of 0.12 ft/s is assumed to be applicable. As discussed previously, the maximum approach velocity to the grated openings on this floor would be approximately 0.4 ft/s. This would also be true for the flow draining through the gaps in the toe plate next to the steel support beams. However, since the velocity of the water would increase as the spray flow collects and moves toward the openings in the floor, at points farther away from the openings, the velocities would be significantly lower. If it is conservatively assumed that the approach path to each opening is linear (in reality the approach path would be very non-linear, especially the flow draining through the toe plate gaps), 75% of the floor area would have velocities higher than 0.1 ft/s and 25% would have lower velocities. Therefore, approximately 25% of the debris washed down in the annulus would be held up on the concrete floor at Elevation 68'.

As shown in Figure 1-1, this results in only a slightly higher transport fraction than currently predicted for the limiting fiberglass cases at IP-2, even if the hold up of fiberglass on the grating at the 68' and 95' elevations is completely neglected.

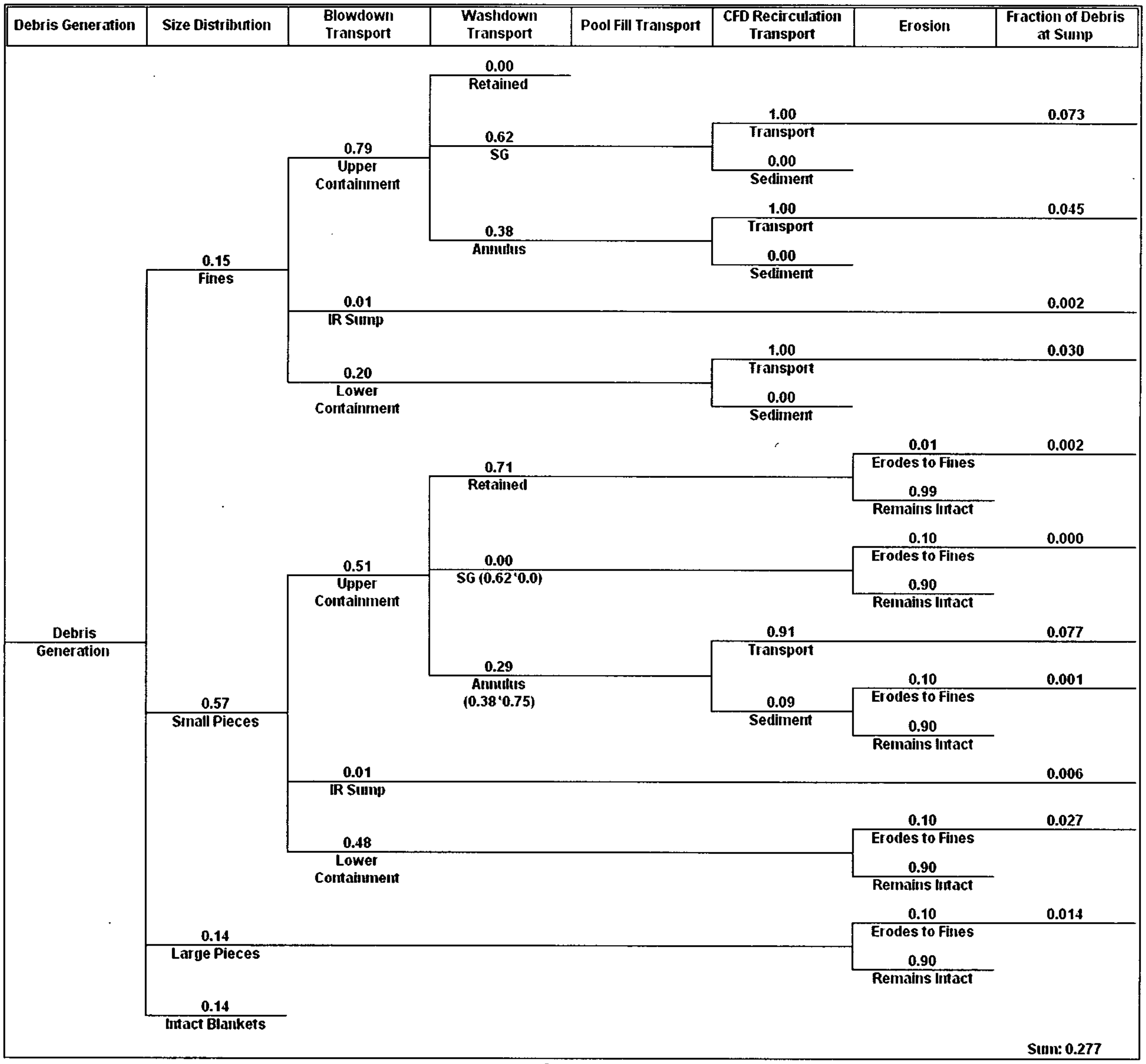

Figure 1-3:
Combined fiberglass logic trees with alternate concrete floor washdown transport fractions for IP-2

<u>Retention of Debris Impinged on Walls and Structures during Blowdown</u>
Another significant conservatism in the Indian Point debris transport analysis is assuming that all debris that is not blown to upper containment would be washed back to the recirculation pool. As discussed in Appendix VI of the SER, approximately 17% of fiberglass fines and small pieces would be captured when the flow makes a 90-degree bend (Ref. 6). Additional debris would also be captured by miscellaneous structures and grating. In the IP-2 debris transport analysis, 11% of small fiberglass debris was determined to be captured on walls and miscellaneous structures in the steam generator compartments (see Section 5.4 of Ref. 41). Although fiberglass fines would be captured similar to the small pieces, no credit was taken for this capture and all of the small pieces not blown to upper containment were conservatively assumed to be washed back to the containment pool. Since most of the walls and structures in the steam generator compartments are shielded from the containment sprays, the majority of the debris captured on the walls and structures would be retained. Taking credit for this would reduce the overall transport fraction for

fiberglass fines from 100% to 89%, as well as a slight reduction in the erosion transport for the small pieces of fiberglass. For the limiting fiberglass debris generation cases, the reduction in fiberglass fines transport would result in a reduction of approximately 18 ft^3 at the strainer.

Conclusions (Updated from Appendix 5)
Although there is uncertainty in any debris transport analysis, Indian Point used a methodology that is based on the guidance in the appendices to the SER, and includes a number of conservatisms to ensure that the overall debris load on the strainer is bounding.

The assumption that small pieces are approximately 1" clumps, similar to the DDTS small pieces, is conservative since larger (3 - 4 inch) clumps would be less likely to transport.

Even if debris is only partially wetted by the LOCA blast, the small clumps of fiber that are blown to upper containment would be quickly saturated by the containment sprays, and many of them would not be transported to the grated openings.

The NUREG/CR-6369 washdown testing is directly applicable and conservative for small pieces of fiberglass that are blown to upper containment and land on top of grating in upper containment. Although the NUREG/CR-6369 grating washdown testing is not directly applicable for small pieces landing on a second level of grating or for small pieces washed off a concrete floor through grating, based on the conservatisms in the analysis, even if no small pieces are assumed to be held up on grating, the actual debris retention would be higher than the value credited.

RAI 3:

The testing performed for Indian Point 2 (IP-2) calcium silicate with asbestos, that is also being applied to Indian Point 3 (IP-3), was not performed for a sufficiently long period to give high confidence of no erosion of the material, as opposed to a small erosion rate that could lead to a significant fraction of erosion over a 30-day period (the post-LOCA mission time of the containment sumps). Please provide justification for its conclusions about erosion of this material. (Audit Open Item)

Response to RAI 3:

This RAI is directed to the applicability of the results of the dissolution testing reported in ALION-REP-IP2-2833-01 entitled "Indian Point 2 Material Dissolution Report" [Ref. 104]. These were the only tests performed with Cal-Sil containing asbestos. The dissolution testing was performed by Alion at the Westinghouse test facilities located in Pittsburgh, PA. This laboratory was selected in that it was capable of handling radioactive contaminated asbestos Cal-Sil removed from IP-2. Alion has not performed any other dissolution or erosion testing with Cal-Sil containing asbestos fibers other than those testing reported in ALION-REP-IP2-2833-01. Erosion was not intended to be addressed in the ALION-REP-IP2-2833-01 report.

Test Background

Cal-Sil debris generation testing conducted by Ontario Hydro indicated that a significant fraction of the debris were pieces ranging in size from small to large. In early 2005 there was very little experimental data available addressing the integrity of pieces of Cal-Sil debris in a large pool of water. How small and large pieces of Cal-Sil material behaves in water or in a moving body of water is important in understanding if this material can potentially disintegrate further and thus, be regarded as highly transportable debris fines. There are three basic phenomena that could result in disintegration of small and large pieces of Cal-Sil debris in a post DBA pool of water.

The phenomenon that needed to be quantified is the dissolution of pieces of Cal-Sil debris. A material that is normally intact in a dry ambient environmental condition could become soluble in a hot liquid environment, especially with other ionic species present such as sodium hydroxide or boric acid as found in a post-DBA pool. Dissolution of a material would cause the dissolved material be placed in solution with the rest of the chemical constituents. A dissolved material does not behave as a particulate, rather as a chemical element. The testing conducted by Alion reported in Alion ALION-REP-IP2-2833-01 was aimed at addressing the dissolution issue.

<u>IP-2 Asbestos Cal-Sil Dissolution Tests</u>

The dissolution phenomena for potential material degradation can be evaluated with relatively short term tests. Alion performed dissolution tests by taking pieces of actual IP-2 Cal-Sil debris of several sizes and subjecting them to borated water baths at different temperatures. The purpose of the testing addressed in the ALION-REP-IP2-2833-01 report was to document the macroscopic density and the dissolution measurement of the IP-2 CalSil material. Two dissolution tests were conducted, one with deionized water and one in borated/neutralized water (at approx. 2570 ppm boron, with TSP). The report concludes that dissolution did not occur with the IP-2 specimens (approximately 1 inch size) in either deionized or borated/neutralized water solutions. The formation of any precipitants from chemical reactions was not visually observed in the borated/neutralized water solution.

<u>Cal-Sil Background</u>

In his document *Summary of Calcium Silicate Insulation Types Used Inside Containment at US Nuclear Plants,* [Ref. 117] Gordon H. Hart, P.E., describes that over the past 50 years or so of nuclear power plant construction and operation, several different types of calcium silicate pipe and block insulation have been used. The summary prepared by Hart was based upon information provided by Tom Whitaker of Technical Support at Industrial Insulation Group, LLC, (IIG), currently the only North American manufacturer of Cal-Sil. Hart summarizes as follows:

- Type I, which contains asbestos fibers as a reinforcement and is a post autoclave process:
- Type II, which is free of asbestos fibers and is made by a filter press, pre-autoclave process (sometimes referred to as the Johns-Manville process); and
- Type III, which is free of asbestos fibers and is made in a pour and mold process known as the Pabco process, also a post autoclave process.

Due to the recognition of health hazards associated with asbestos, since 1972 the manufacture of Type I, asbestos-based Cal-Sil was discontinued in North America. At the time, however, there remained large quantities of this Type I insulation in warehouses, so Type I Cal-Sil was still installed on many projects where asbestos-containing material was still allowed [Ref. 116].

The predominant Cal-Sil available between 1972 and 1998-2000 were Type II and Type III, while the predominant Cal-Sil produced from 2000 to the present is/was Type III [Ref. 116].

According to IIG, Calcium Silicate pipe and block insulation as manufactured by the Pabco, Precision Mold, Post-Autoclave process (Type III) is more friable than calcium silicate made by the Johns Manville, Filter Press, Pre-Autoclave process (Type II). The precision molded, post autoclave (Type III) product is softer and will most likely erode faster in a moving fluid than products made by the filter press, pre-autoclaved process (Type II). Further according to IIG, "To my (Tom Whitaker's) knowledge, there is no published information related to erosion rates of any of these products. The comparison of the erosion rates is based on personal experience in the Calcium Silicate business since 1972." In summary, the relative erosion fractions should be Type I < Type II < Type III [Ref. 116].

Evaluation

Alion performed flume erosion testing to measure the weight loss of non-asbestos Cal-Sil insulation debris. The overall objective of the Alion Cal-Sil erosion test program was to establish sufficient erosion data at various times to enable development of estimates of erosion fractions at 30 days of exposure to a flow comparable to the incipient tumbling velocity of Cal-Sil debris. The Test Report [Ref. 105] presents the results and evaluations of flow erosion tests of unjacketed Cal-Sil insulation material. Alion also produced a report to compare the test materials and conditions to those present in the Indian Point containment building. More details concerning the applicability of test data to 30 day values for IP-2 and IP-3 are included in Alion's "CalSil Erosion Fractions for IP2 and IP3" [Ref. 116].

Based on knowledge of the manufacturing process, the asbestos Cal-Sil at IP-2 and IP-3 is expected to have lower erosion fractions than the materials used in the Alion flume erosion flume tests. The IP-2 Debris Transport Calculation [Ref. 41] conservatively uses 14% erosion for the IP-2 asbestos Cal-Sil insulation. The IP-3 Debris Transport Calculation [Ref. 42] developed a conservative erosion fraction of 15% to account for the presence of non-asbestos Cal-Sil present in IP-3.

RAI 4:
Please provide a justification for the use of erosion data from the IP-2 calcium silicate tests with asbestos for the IP-3 calcium silicate material without asbestos. (Audit Open Item)

Response to RAI 4:

The Response to RAI 3 provides justification for the use of erosion testing data for Indian Point. The following Section provides additional justification, based on the similarities between IP-2 and IP-3 asbestos based Cal-Sil.

Applicability of IP-2 Asbestos Cal-Sil Dissolution Test Results to IP-3 Asbestos Cal-Sil:

The IP-2 dissolution testing [Ref. 104] can be applied to IP-3 since the asbestos Cal-Sil material in IP-3 is the same as the Cal-Sil material of IP-2 and will not dissolve. The assertion that the asbestos Cal-Sil at both plants is the same is based on the following arguments:

The debris source term walkdown documents the presence of "calcium silicate with asbestos fiber" in the IP-2 Containment Building. IP-2's period of construction from 1966 to commercial operation in 1974 is consistent with the period of use and phase-out of asbestos Cal-Sil. As previously noted, the Asbestos/CalSil samples from IP-2 used in the dissolution tests were shown to be calcium silicate with asbestos fiber, and were shown not to dissolve in water solutions.

Asbestos-based Cal-Sil at IP-3:
During construction, both IP-2 and IP-3 were owned by Consolidated Edison. A comparison of IP-2 and IP-3 original insulation specifications concluded that similar asbestos is used in both IP-2 and IP-3. Based upon the similarity of insulation specifications between both units, the likelihood that procurement would be from the same source for both units, and the similar construction to operation timeframes for both units (IP-2 construction from 1966 to Commercial operation in 1974, versus IP-3 construction from 1969 to Commercial operation in 1976), it is logical to conclude that IP-3 asbestos-based Cal-Sil is the same as the asbestos used in IP-2.

USNRC Issue 3f:

Head Loss and Vortexing
The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

1. *Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS).*
2. *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SB LOCA) and large-break loss-of-coolant accident (LB LOCA) conditions.*
3. *Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.*
4. *Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions.*
5. *Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.*
6. *Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.*
7. *Provide the basis for the strainer design maximum head loss.*
8. *Describe significant margins and conservatisms used in the head loss and vortexing calculations.*
9. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.*
10. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.*
11. *State whether the sump is partially submerged or vented (i.e., lacks a complete water seal over its entire surface) for any accident scenarios and describe what failure criteria in addition to loss of net positive suction head (NPSH) margin were applied to address potential inability to pass the required flow through the strainer.*
12. *State whether near-field settling was credited for the head-loss testing and, if so, provide a description of the scaling analysis used to justify near-field credit.*
13. *State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed.*
14. *State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.*

Entergy Response to Issue 3f.1:

Schematics of the Safety Injection System are included in Attachment 2.

Entergy Response to Issue 3f.2:

Unit 2

The IR and VC sump strainers, including the VC strainer extension (located inside the containment annulus), are fully submerged under a large break loss-of-coolant accident (LBLOCA). As shown in the response to the Issue 3g.1, the minimum LBLOCA water level is 47.87 ft [Ref. 33]. The elevation of the highest Top Hat screen for the VC strainer extension is 47.21 ft [Ref. 24]. Taking the 0.5 inch drawdown into consideration [Ref. 26], the minimum submergence of the VC strainer extension is about 0.62 ft. Note that the submergence of the VC extension is conservatively taken to be the minimum submergence of the VC strainer since it is less than (and therefore bounding for) that of the VC sump portion of the strainer. For the IR strainer, the elevation of the highest Top Hat screen is 45.39 ft. The minimum submergence of the IR strainer is therefore 2.28 ft considering a drawdown of 0.2 ft.

The IR and VC sump strainers, including the extension are also fully submerged under a small break loss-of-coolant accident (SBLOCA). As shown in the response to the Issue 3g.1, the minimum SBLOCA water level is 47.54 ft [Ref. 33]. Using the drawdown values and Top Hat elevations presented above, the minimum submergences of the VC and IR strainers are 0.28 ft and 1.95 ft, respectively.

The minimum submergences for the SBLOCA cases were used in the IP-2 Void Fraction Calculation [Ref. 26] since these submergences are bounding for those of the LBLOCA and 6 Inch Break LOCA cases. It should also be noted that the drawdown values used above are conservative for LBLOCA, 6 Inch Break LOCA, and SBLOCA cases because they were determined using flow rates higher than calculated for the ECCS pumps [Ref. 24].

<u>Unit 3</u>

The IP-3 IR and VC strainers are fully submerged under a LBLOCA [Ref. 25]. Since the strainers are fully below the floor level (i.e., 46' El.), the strainer submergence for both the IR and VC sumps is conservatively taken to be the minimum LBLOCA water level above the floor, 1.22 ft [Ref. 25]. The drawdown was included when determining the water levels. Note that due to rounding, the minimum strainer submergence for the VC strainer was calculated as 1.23 ft; the minimum submergence of 1.22 ft will be conservatively used in place of this value.

Also, the IP-3 IR and VC strainers are fully submerged under a SBLOCA [Ref. 25]. Since the strainers are fully below the floor level (i.e., 46' El.), the strainer submergence for both the IR and VC sumps is conservatively taken to be the minimum SBLOCA water level above the floor, 0.97 ft [Ref. 25]. Note that the water levels used in the IP-3 Hydraulic Analysis [Ref. 25] included drawdown.

The minimum submergences for the SBLOCA cases were used in the IP-3 Void Fraction Calculation [Ref. 27] since these submergences are bounding for those of the LBLOCA and 6 Inch Break LOCA cases. It should also be noted that the drawdown values used to determine the minimum water levels above are conservative for LBLOCA, 6 Inch Break LOCA, and SBLOCA cases because they were determined using flow rates higher than calculated for the ECCS pumps [Ref. 25].

<u>Entergy Response to Issue 3f.3:</u>

<u>Common to both units</u>

The sump strainers for IP-2 and IP-3 consist of Top Hats installed horizontally. The strainers are designed such that they remain fully submerged under the minimum water level that will occur in the containment during a LOCA. When the water depth above the Top Hats is small, vortices may form by swirling water that creates a free air path to the suction line. Consequently, entrained air may reach the emergency core cooling system (ECCS) recirculation pumps. Because the suction lines are encased in the plenum box and are not exposed to open water, air ingestion through vortexing could only occur at the Top Hats. To prevent vortex formation, Indian Point has elected to install vortex suppression gratings for all Top Hats within IP-2 and IP-3. The Vortex Suppressor Evaluation Report [Ref. 70] addresses the hydraulic requirements and configuration of the vortex suppressor design.

The Vortex Suppressor Evaluation Report [Ref. 70] determined the vortex suppression elevation using the lowest static water level for the SBLOCA with sprays case at the start of recirculation with the reduction in water level due to "drawdown" considered. In addition, a margin of 0.04 ft or 0.03 ft was applied to account for uncertainty. As shown in the table below, the maximum vortex suppressor elevations were calculated for the following locations: IP-2 IR Sump, IP-2 VC Sump, IP-2 VC Sump Extension, IP-3 IR Sump, and IP-3 VC Sump. In addition, the report determined the dimensions of grating and/or vortex suppression devices that are required to prevent vortex formation at the IP-2 and IP-3 sump strainers. The report also showed that the drawdown and head loss associated with the vortex suppression grating are negligible.

The report [Ref. 70] recommends that the vortex suppression gratings are installed with the top edge at or below the following maximum elevations for the various locations of the IP-2 and IP-3 strainers. It was also concluded, based on industry testing and previous Top Hat vortex testing results, that submerged floor grating with a minimum height of 1 inch and spacing of 1 to 2 inches should be effective to prevent the formation of vortices for the sump strainers at Indian Point. The design drawings show that the grating height is identical or similar to that used in chemical effects array testing, either 1 inch or 1 ¼ inch with a spacing of 1 3/8 inches [Refs. 110 - 114].

Table 3f.3-1:
Summary of IP-2 Vortex Suppressor Elevations

	SBLOCA Water Level with drawdown (ft)	Margin (ft)	Max. Grating Elevation (ft)
IR Sump	47.38	0.04	47.34
VC Sump	47.35	0.04	47.31
VC Sump Annulus	47.53	0.04	47.49

Table 3f.3-2:
Summary of IP-3 Vortex Suppressor Elevations

	SBLOCA Water Level with Drawdown (ft)	Margin (ft)	Max. Grating Elevation (ft)
IR Sump	46.97	0.03	46.94
VC Sump	46.97	0.04	46.93

No assumptions were made in the Vortex Suppressor Evaluation Report [Ref. 70].

Entergy Response to Issue 3f.4:

Common to both units

The objective of the Indian Point strainer prototypical head loss testing [Ref. 37] was to obtain conventional and chemical debris head loss data on a strainer array that was prototypical of the strainers that are installed at the plant. The head loss testing follows the March 2008 guidance

[Ref. 129]. Head loss was measured for a range of conventional (fibrous and particulate) and chemical precipitate debris loads at various flow rates, which are representative of the predicted post-accident conditions.

The technical approach implemented in this test was to:

- Measure the head loss associated with conventional debris for a range of debris loads based upon achievable plant condition(s), including thin bed and full load conditions;
- Measure the resulting conventional plus chemical debris head loss by adding a quantity of chemical debris (ranging from zero to the full debris loads predicted by the WCAP-16530 methodology) to the conventional debris bed in each test.

The testing results therefore provided a matrix of head loss data for the various combinations of conventional and chemical debris loads.

The strainer module that was tested is dimensionally similar to a portion of the strainer that is installed at Indian Point. The module contains a 3×3 array of Top-Hats with a double-annulus design developed by Enercon Services, Inc. The Top Hats consist of hollow concentric cylinders made of stainless steel perforated plates that are mounted on a square base plate. The Debris Bypass Eliminators, which consist of stainless steel knitted wire meshes, are inserted into the Top Hats to reduce the quantity of fiber that passes through the Top Hats.

The test array of Top-Hats were horizontally mounted to a flow plenum. The array was placed near the middle of a testing tank which is capable of flow recirculation. Walls were constructed surrounding the Top Hat array inside the tank to simulate the front, back, and side walls of the sump pit or adjacent Top-Hats inside the actual pit. The gross and net surface areas of the array are 135.9 ft^2 and 114.1 ft^2, respectively [Ref. 45].

The amount of each debris component is determined in the Array Test Debris Amounts Calculation [Ref. 45], which employs a conservative approach to obtain a debris load and mix to yield the maximum head loss. The debris generated from the five break criteria recommended in volume II of the NEI 04-07 [Ref. 6] are considered. The many different debris types are categorized into fiber, particulate (or microporous insulation), and coatings. The maximum amount of each debris category determined for the five different break criteria is used as input to the test. Therefore, the debris scenario reflected in the test is not a single break, but a combination of breaks to ensure a maximum head loss result.

Fiber fines preparation consisted of double shredding fiber blankets and boiling for 10 minutes. Then, ¼ lb of the boiled fiber was added to a bucket with 4 gallons of water and beat with a paint stirrer for 4 minutes [Ref. 37]. The resulting mixture had the appearance of a well dispersed slurry of individual fibers and very few clumps which were no larger than ¼" as shown in the representative photograph (see Figure 3f.4-1).

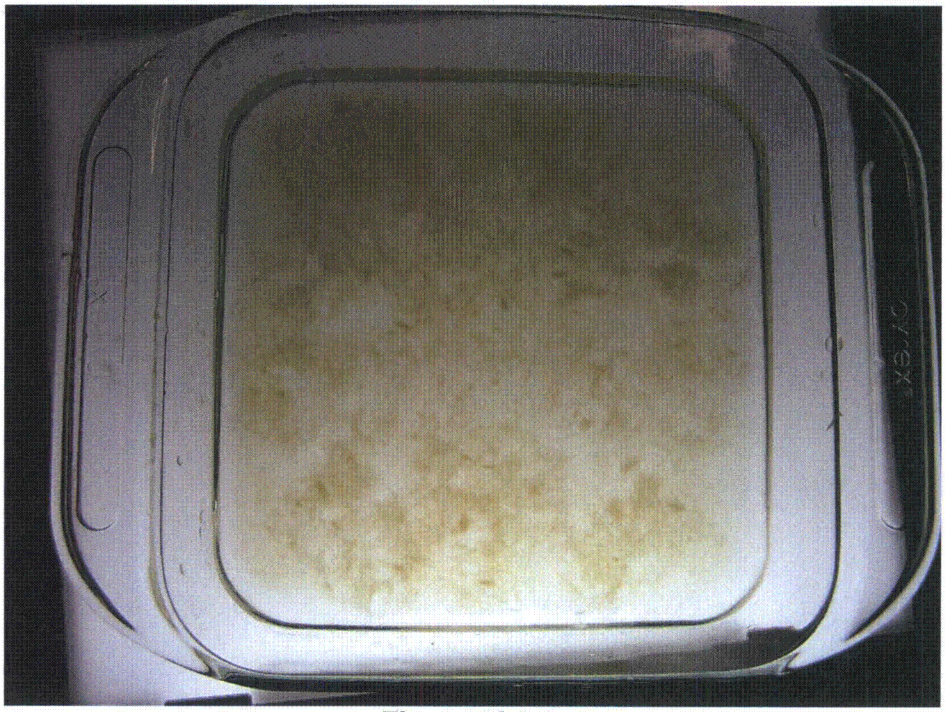

Figure 3f.4-1:
Representative photograph of prepared fines in a 9"x9" glass dish

The NRC Staff observed one of the tests and noted the following in a Trip Report dated February 10, 2009 [Ref. 118]:

> *When the debris was added to the flume it was apparent that it was well dispersed in the water and had not agglomerated in the bucket or when added to the flume. The additions resulted in clouds of debris disbursing slowly throughout the tank which was evidence of the fineness of the debris. In particular the fine Nukon behaved as would be expected for fine fiber. It is estimated that 90% of the fine fiber met the definition of Class 1 to 3 fibers with 10% slightly larger. The fine Thermal Wrap fiber was also broken down into relatively small pieces, but appeared to be coarser due to the physical properties of the fiber. The Thermal Wrap fibers were longer, coarser, and straighter than the Nukon, but were well separated.*

Therefore, the testing was conducted with sufficiently fine fibers and complies with the March 2008 Staff Guidance on Head Loss.

The 3x3 array test strainer was in a simulated pit configuration within a larger tank. Debris was added off to the side of the pit and carried into the pit by the flow, simulating the plant configuration and operation. Any debris added to the tank that did not immediately flow into the strainers was subjected to constant turbulence from the pump return line. A motorized agitator, and manual stirring (when needed), prevented settling of debris outside the strainer array pit ensuring the debris reached the strainers. Per test protocol for thin beds, after particulates were circulated in the tank, fines were then added incrementally until full screen coverage by fibrous debris was achieved. Per test protocol for full debris loads, fines were added to the tank with particulates before addition of small pieces. Due to these methods, agglomeration was avoided, and conservative transport of the debris to the strainer array was ensured.

The testing for Indian Point was conducted to accommodate 12 predicted debris loads that required mitigation from the IP-2 and IP-3 ECCS system. Eight (8) tests were completed in order to obtain bounding thin bed and full load data points for these 12 predicted loads (see Table 3f.4-6). The following Tests meet the suspendable fibers requirement by utilizing 100% fines and ensuring a prototypical/conservative debris mix:

- Test A (thin-bed)
- Test A1 (thin-bed)
- Test E (thin-bed)
- Test F (thin-bed)
- Test G (IP-2 VC LB24/RCLB24)

The remainder of tests conducted for Indian Point used a debris mix size distribution based on the Debris Generation [Refs. 1 and 2] and Debris Transport Calculations [Refs. 41 and 42]. The results are determined in the Test Debris Amounts Calculation [Ref. 45] and shown in Tables 3f.4-1 and 3f.4-2. The different breaks are abbreviated as follows:

LB = Large break loss of coolant accident
RCLB = Reactor cavity large break loss of coolant accident
6" = 6 inch break loss of coolant accident
LB24 = Large break loss of coolant accident where VC sump operation is initiated at 24 hours (IR sump is operated up to 24 hours)
RCLB24 = Large break loss of coolant accident where VC sump operation is initiated at 24 hours (IR sump is operated up to 24 hours)

Table 3f.4-1:
IP-2 Percent Fiber Transported to Sumps as Fines

			Total Surrogate Amounts for Test (lbs)					
Unit	Sump	Break	Nukon™ (lbs)	Nukon™ Fines (%)	Temp-Mat (lbs)	Temp-Mat Fines (%)	Min. Wool (lbs)	Min. Wool Fines (%)
IP-2	IR	LB	25.19	84%	5.43	85%	0.00	N/A
IP-2	IR	RCLB	1.10	100%	2.95	82%	0.00	N/A
IP-2	VC	6"	15.13	98%	0.00	N/A	0.00	N/A
IP-2	VC	RC 6"	3.37	100%	2.20	85%	0.00	N/A
IP-2	VC	LB24	4.47	100%	1.07	100%	0.00	N/A
IP-2	VC	RCLB24	0.18	93%	0.53	100%	0.00	N/A

* Note that all the remaining fiber that transports to the sump, transports as small pieces.

Table 3f.4-2:
IP-3 Percent Fiber Transported to Sumps as Fines

			Total Surrogate Amounts for Test (lbs)					
Unit	Sump	Break	Nukon™ (lbs)	Nukon™ Fines (%)	Temp-Mat (lbs)	Temp-Mat Fines (%)	Min. Wool (lbs)	Min. Wool Fines (%)
IP-3	IR	LB	18.94	88%	21.75	83%	0.70	82%
IP-3	IR	RCLB	1.37	100%	2.84	82%	0.00	N/A
IP-3	VC	6"	4.76	100%	26.20	85%	0.00	N/A
IP-3	VC	RC 6"	4.36	100%	2.20	85%	0.00	N/A
IP-3	VC	LB24	3.66	98%	4.23	100%	0.13	100%
IP-3	VC	RCLB24	0.23	98%	0.53	100%	0.00	N/A

* Note that all the remaining fiber that transports to the sump, transports as small pieces.

Test B was conducted to bound the IP-2 IR sump LBLOCA/RCLBLOCA. The Test Procedure [Attachment F of Ref. 37] specified the debris mix shown in Table 3f.4-3. Comparing the information in Tables 3f.4-1 and 3f.4-3 demonstrates that Test B was conducted with a debris mix that bounds that predicted to arrive at the sump.

**Table 3f.4-3:
Test B Debris Mixture (Bounding for IP-2 IR LBLOCA)**

	Nukon 25.19 (lbs)		Temp-Mat 5.43 (lbs)	
Size Distribution	Fines (lbs)	Smalls (lbs)	Fines (lbs)	Smalls (lbs)
	84%	16%	85%	15%
100% Quantity	21.16	4.03	4.62	0.81

Test C was conducted to bound the IP-3 IR sump LBLOCA/RCLBLOCA. The Test Procedure [Attachment F of Ref. 37] specified the debris mix shown in Table 3f.4-4. Comparing the information in Tables 3f.4-2 and 3f.4-4 demonstrates that Test C was conducted with a debris mix that bounds that predicted to arrive at the sump. This test was also used as bounding for the IP-3 VC sump 6"/RC 6" LOCA (see Table 3f.4-6). The total amount of fines (Nukon™ + Temp-Mat) in the test exceeded the specified amount in Table 3f.4-2. Therefore, the methodology of using a bounding debris load is considered conservative.

**Table 3f.4-4:
Test C Debris Mixture (Bounding for IP-3 IR LBLOCA)**

	Nukon 18.94 lbs		Temp-Mat 21.75 lbs		Min. Wool 0.70 lbs	
Size Distribution	Fines (lbs)	Smalls (lbs)	Fines (lbs)	Smalls (lbs)	Fines (lbs)	Smalls (lbs)
	88%	12%	83%	17%	82%	18%
100% Quantity	16.67	2.27	18.05	3.70	0.57	0.13

Test D was conducted to simulate the IP-3 VC sump LBLOCA after approximately 24 hours of IR sump operation. Table 3f.4-2 specifies the expected fiber size distribution for each case. Table 3f.4-5 in the Test Procedure [Attachment F of Ref. 37] documents the size distribution used in Test D. Review of the information reveals that the Nukon™ and Temp-Mat "fines" percentage in the test was less than that specified by the analysis. The Test Report body notes that the Mineral Wool was actually prepared as 100% fines due to practical issues [Ref. 37].

Test D was conducted as a full debris load test using homogeneous fiber and particulate addition as opposed to a thin-bed test. This was appropriate because previous tests had shown that the fiber load of 7.89 lb_m was not expected to fully cover the screen and was validated at the end of the test when significant clean screen was observed. When clean screen is present head losses are typically lower, therefore it is important to verify that full screen coverage is not possible. Thin-bed tests that utilized higher particulate loads, higher approach velocities, and 100% fines (all of which promote thin-bed effect) showed that fiber masses of at least 13.54, 15.13, 14.25, 8.55 lb_m are required to achieve full screen coverage with those conditions. Given these factors, increasing the percentage of fines for Nukon™ (from 88% to 98%) and Temp-Mat (from 83% to 100%) would not lead to complete screen coverage. It should be reiterated that the full fiber mass was introduced into the test, traveled to the screen, and was able to contribute to head loss. Therefore, the fiber size distribution used in Test D was acceptable.

Other mitigating factors include:

- The Nukon™ and Temp-Mat "smalls" amounts inherently contain some portion of "fines" which would compensate for a portion of the discrepancy.

- The Debris Generation Calculation classifies "small pieces" as being less than 6 inch. The debris preparation of "smalls" for the test ensured that there were no pieces of debris and all agglomerations were less than 1 inch.

Table 3f.4-5:
Test D Debris Mixture (Bounding for IP-3 VC LBLOCA 24 hour)

	Nukon (3.66 lbs)		Temp-Mat (4.23 lbs)		Min. Wool (0.13 lbs)	
Size	**Fines (oz)**	**Smalls (oz)**	**Fines (oz)**	**Smalls (oz)**	**Fines (oz)**	**Smalls (oz)**
Distribution	**88%**	**12%**	**83%**	**17%**	**82%**	**18%**
100% Quantity	51.53	7.03	56.17	11.51	1.71	0.37

The methodology of WCAP-16530-NP-A was implemented into a spreadsheet model and used to predict the quantities of the three different chemical precipitates that could form. The inputs to the model were treated in a conservative fashion to produce greater amount of precipitates. For example, the pH and temperature values interpolated from the pH and temperature profiles are conservatively rounded up to maximize the amount of chemical precipitates. Refinements to the determination of the chemical precipitates were released as WCAP-16785-NP, which included refinements to aluminum corrosion rates due to silica inhibition and aluminum and calcium precipitates solubility. For conservatism, however, no credit was taken for any of the WCAP-16785-NP refinements.

For each test, the following measurements were conducted:

- An initial clean screen flow sweep, which covers the maximum approach velocity predicted in the Hydraulic Analyses [Refs. 24 and 25], was carried out at the plant minimum submergence.
- Batches of particulate and fibrous conventional debris were added to the testing tank. When the final fiber addition had met the steady head loss criteria, addition of chemical precipitates was accomplished in batches. The head loss stabilization criteria were ensured to be met after the addition of each batch of chemical precipitates and before the introduction of the next batch of chemical. Note that the head loss was considered to be stable when the variation in head loss was less than 1% per hour for head loss values ≥ 2 ft-water or less than 0.25" change per hour for head loss values < 2 ft-water.
- A final flow sweep with a debris and chemical precipitate-laden screen was conducted. During the testing, the flow rate, differential pressure and fluid temperature were recorded.

The basic approach to testing includes the following inherent assumptions:

- In the testing, Silicon Carbide powder, instead of Sil-Co-Sil, was used as a surrogate for the coating debris due to its highly controlled size distribution. The Silicon Carbide Powder has a mean particle diameter of approximately 10 μm and is consistent with industry guidance for the size distribution of coating debris.
- The performance of the reduced (3 × 3) strainer array is assumed to be representative or conservative when compared with the full strainer array. This is reasonable because the debris tends to be loaded more non-uniformly for a larger array, resulting in potentially more open strainer area and consequently lower total head loss.
- The testing performed using tap water at room temperature (80-100°F) can be scaled appropriately to various temperatures of the actual reactor coolant. This is a reasonable assumption as temperature effects on head loss are well documented (*e.g.* NUREG/CR-6224, Ref. 32), and tap water and reactor coolant water have essentially identical physical

properties (*e.g.*, density, viscosity). The head losses will eventually be scaled to the minimum sump temperature of 70°F for comparison to the structural limit. To compensate for bed compression at lower temperatures, the tests were conducted at approach velocities higher (~2x) than those in the plant when the sump fluid cools to 70°F.

- Results of short-term testing can be used to predict the performance of the sump over a longer mission time. This assumption is reasonable since during each test step, the debris was given sufficient time to collect on the screen until the head loss was stabilized, as stated above. Data extrapolation was used to obtain the conventional plus chemical debris head loss 30 days after an accident.

The test program consisted of 8 tests so that every scenario for the IR and VC sump at both units is bounded by at least one full load and one thin-bed test [Ref. 28]. A summary of the bounding tests for each scenario is presented in the table below; note that only testing performed in accordance with the March 2008 guidance [Ref. 129] (conducted in 2009) was used to quantify debris head losses and qualify the strainer [Ref. 28] .

Table 3f.4-6:
Summary of Bounding Tests

	Bounding Chemical Effects Test	
Scenario	Thin-bed	Full Load
IP-2 IR (LBLOCA and RC LBLOCA)	Test E	Test B
IP-2 VC (6" LOCA and 6" RC LOCA)	Test E	Test A1
IP-2 VC (LBLOCA 24hr and RC break)	Test G	Test G
IP-3 IR (LBLOCA and RC LBLOCA)	Test E	Test C
IP-3 VC (6" LOCA and 6" RC LOCA)	Test E	Test C
IP-3 VC (LBLOCA 24hr and RC break)	Test D	Test D

The raw head loss data obtained from the prototypical testing is listed below (temperature and flow adjusted values are located in Response to Issue 3f.10). Note that the WCAP chemicals were added in batches into the test tank and the cumulative amounts of the chemical are shown in the tables below. For the conventional debris, although the debris was also batched into the test tank, only the total debris amount and the head loss after all conventional debris was added into the tank are presented.

Table 3f.4-7:
Test A - Thin Bed Test Load[1]

	Nukon[2] (lbs)	**Temp -Mat (lbs)**	**Min. Wool (lbs)**	**Cal-Sil (lbs)**	**SiC (lbs)**	**Dirt (lbs)**	**Cumulative WCAP $NaAlSi_3O_8$ (lbs)**	**Flow (gpm)**	**Head Loss (ft)**
Conventional Debris	13.54	0.00	0.00	9.66	97.07	15.57	0.00	395.92	1.41[3]

[1] The test was terminated before the WCAP Step 1 stabilized.
[2] Nukon™ were 100% fines.
[3] This head loss is the cumulative conventional debris head loss.

Table 3f.4-8:
Test A1 – IP-2 VC 6 Inch Break Test Load

	Nukon[1] (lbs)	Temp -Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	Cumulative WCAP $NaAlSi_3O_8$ (lbs)	Flow (gpm)	Head Loss (ft)
Conventional Debris	15.13	0.00	0.00	9.66	97.07	15.57	0.00	396.84	0.75[2]
WCAP Step 1	0.00	0.00	0.00	0.00	0.00	0.00	2.72	392.02	2.84
WCAP Step 2	0.00	0.00	0.00	0.00	0.00	0.00	3.12	390.72	2.75
WCAP Step 3	0.00	0.00	0.00	0.00	0.00	0.00	3.74	395.92	3.23
WCAP Step 4	0.00	0.00	0.00	0.00	0.00	0.00	5.11	398.70	4.59
WCAP Step 5	0.00	0.00	0.00	0.00	0.00	0.00	5.87	390.55	5.03
WCAP Step 6	0.00	0.00	0.00	0.00	0.00	0.00	6.54	397.08	6.17
WCAP Step 7	0.00	0.00	0.00	0.00	0.00	0.00	9.51	150.78	6.91
WCAP Step 8	0.00	0.00	0.00	0.00	0.00	0.00	11.87	154.45	10.16
WCAP Step 9	0.00	0.00	0.00	0.00	0.00	0.00	13.65	149.25	11.85

[1] Nukon™ were 100% fines.
[2] This head loss is the cumulative conventional debris head loss.

Table 3f.4-9:
Test B – IP-2 IR Large Break Full Insulation Test Load

	Nukon (lbs)		Temp-Mat (lbs)		Min. Wool (lbs)	Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	Cumulative WCAP $NaAlSi_3O_8$ (lbs)	Flow (gpm)	Head Loss (ft)
	Fines	Smalls	Fines	Smalls							
Conventional Debris	21.16	4.03	4.62	0.81	0.00	7.49	86.99	6.26	0.00	402.20	1.16[1]
WCAP Step 1	0.00		0.00		0.00	0.00	0.00	0.00	2.86	395.09	3.61
WCAP Step 2	0.00		0.00		0.00	0.00	0.00	0.00	3.12	395.82	3.90
WCAP Step 3	0.00		0.00		0.00	0.00	0.00	0.00	3.38	393.86	4.19
WCAP Step 4	0.00		0.00		0.00	0.00	0.00	0.00	6.54	396.37	6.44
WCAP Step 5	0.00		0.00		0.00	0.00	0.00	0.00	7.52	396.57	7.56

[1] This head loss is the cumulative conventional debris head loss.

Table 3f.4-10:
Test C – IP-3 IR Large Break Full Insulation Test Load

	Nukon (lbs)		Temp-Mat (lbs)		Min. Wool (lbs)		Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	Cumulative WCAP $NaAlSi_3O_8$ (lbs)	Flow (gpm)	Head Loss (ft)
	Fines	Smalls	Fines	Smalls	Fines	Smalls						
Conventional Debris	16.67	2.27	18.05	3.70	0.57	0.13	9.66	61.62	7.75	0.00	395.15	2.30[1]
WCAP Step 1	0.00		0.00		0.00		0.00	0.00	0.00	3.38	392.29	4.04
WCAP Step 2	0.00		0.00		0.00		0.00	0.00	0.00	3.52	390.30	4.12
WCAP Step 3	0.00		0.00		0.00		0.00	0.00	0.00	3.74	389.93	4.14
WCAP Step 4	0.00		0.00		0.00		0.00	0.00	0.00	6.49	397.68	4.70
WCAP Step 5	0.00		0.00		0.00		0.00	0.00	0.00	7.46	389.42	5.39

[1] This head loss is the cumulative conventional debris head loss.

Table 3f.4-11:
Test D – IP-3 VC Large Break 24 hour Full Insulation Test Load

	Nukon (lbs)		Temp-Mat (lbs)		Min. Wool (lbs)		Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	Cumulative WCAP $NaAlSi_3O_8$ (lbs)	Flow (gpm)	Head Loss (ft)
	Fines	Smalls	Fines	Smalls	Fines	Smalls						
Conventional Debris	3.221	0.439	3.512	0.719	0.107	0.023	4.85	19.61	1.21	0.00	151.41	0.10[1]
WCAP Step 1	0.00		0.00		0.00		0.00	0.00	0.00	9.33	150.78	2.70
WCAP Step 2	0.00		0.00		0.00		0.00	0.00	0.00	10.73	148.55	3.04
WCAP Step 3	0.00		0.00		0.00		0.00	0.00	0.00	11.17	147.81	3.21
WCAP Step 4	0.00		0.00		0.00		0.00	0.00	0.00	11.87	146.39	3.30
WCAP Step 5	0.00		0.00		0.00		0.00	0.00	0.00	12.46	143.14	3.79

[1] This head loss is the cumulative conventional debris head loss.

**Table 3f.4-12:
Test E - Thin-Bed Test Load**

	Nukon[1] (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	Cumulative WCAP $NaAlSi_3O_8$ (lbs)	Flow (gpm)	Head Loss (ft)
Conventional Debris	14.25	0.00	0.00	9.66	97.07	15.57	0.00	393.44	0.87[2]
WCAP Step 1	0.00	0.00	0.00	0.00	0.00	0.00	2.72	389.55	6.31
WCAP Step 2	0.00	0.00	0.00	0.00	0.00	0.00	3.12	392.99	7.32
WCAP Step 3	0.00	0.00	0.00	0.00	0.00	0.00	3.74	404.36	8.43
WCAP Step 4	0.00	0.00	0.00	0.00	0.00	0.00	5.87	397.88	11.38
WCAP Step 5	0.00	0.00	0.00	0.00	0.00	0.00	6.54	395.32	13.27
WCAP Step 6	0.00	0.00	0.00	0.00	0.00	0.00	9.51	154.43	11.93
WCAP Step 7	0.00	0.00	0.00	0.00	0.00	0.00	10.47	148.98	13.44

[1] The Nukon™ are 100% fines.
[2] This head loss is the cumulative conventional debris head loss.

**Table 3f.4-13:
Test F – IP-3 VC 6 Inch Thin Bed Test Load**

	Nukon[1] (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	Cumulative WCAP $NaAlSi_3O_8$ (lbs)	Flow (gpm)	Head Loss (ft)
Conventional Debris	8.55	0.00	0.00	9.57	28.18	24.63	0.00	391.67	2.42[2]
WCAP Step 1	0.00	0.00	0.00	0.00	0.00	0.00	2.72	385.01	6.86
WCAP Step 2	0.00	0.00	0.00	0.00	0.00	0.00	3.12	394.26	7.18
WCAP Step 3	0.00	0.00	0.00	0.00	0.00	0.00	3.74	389.30	7.47
WCAP Step 4	0.00	0.00	0.00	0.00	0.00	0.00	5.87	387.79	9.97
WCAP Step 5	0.00	0.00	0.00	0.00	0.00	0.00	6.54	396.96	10.98
WCAP Step 6	0.00	0.00	0.00	0.00	0.00	0.00	9.51	145.26	9.62
WCAP Step 7	0.00	0.00	0.00	0.00	0.00	0.00	11.87	155.44	13.59
WCAP Step 8	0.00	0.00	0.00	0.00	0.00	0.00	13.65	152.09	16.14

[1] The Nukon™ are 100% fines.
[2] This head loss is the cumulative conventional debris head loss.

Table 3f.4-14:
Test G – IP-2 Large Break 24 Hour Full Insulation Test Load

	Nukon[1] (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	SiC (lbs)	Dirt (lbs)	WCAP $NaAlSi_3O_8$ (ltr)	Flow (gpm)	Head Loss (ft)
Conventional Debris	2.85	0.00	0.00	3.01	88.41	0.95	0.00		
Fiber Add 2	1.62	1.07	0.00	0.00	0.00	0.00	0.00	161.19	0.08[2]
WCAP Step 1	0.00	0.00	0.00	0.00	0.00	0.00	6.84	154.28	2.72
WCAP Step 2	0.00	0.00	0.00	0.00	0.00	0.00	8.72	159.70	4.75
WCAP Step 3	0.00	0.00	0.00	0.00	0.00	0.00	9.19	156.81	5.42
WCAP Step 4	0.00	0.00	0.00	0.00	0.00	0.00	9.51	154.65	5.70
WCAP Step 5	0.00	0.00	0.00	0.00	0.00	0.00	9.99	151.13	6.57

[1] The Nukon™ are 100% fines.
[2] This head loss is the cumulative conventional debris head loss.

Entergy Response to Issue 3f.5:

Common to both units

As stated in the response to the Issue 3f.4, the head loss testing used a 3 × 3 array of Top Hats which is representative of the actual strainer. The ability of the strainer design to accommodate a certain volume of debris, and avoid circumferential loading, can be characterized by the Open Volume Value, which is discussed below.

The Open Volume Value is defined as the total interstitial volume in the pit divided by the total gross strainer surface area. The total interstitial volume is the total pit volume minus the volume of the strainers and waterbox. The total gross surface area is the sum of the gross strainer surface areas of all perforated and non-perforated surface areas on each type of top hat module multiplied by the number of Top-Hats with all the types finally added together. It should be noted that a lower Open Volume Value indicates that the strainer is more confined while a higher value indicates that the strainer is more open.

The chemical effects array testing used the maximum volume of debris predicted to arrive at the sump (scaled based on strainer surface area). Visual observations during the test, as documented in photographs, indicate that the array did not become circumferentially loaded [Ref. 37]. The Open Volume Values were calculated for the test facility and different portions of the IP-2 and IP-3 strainers in the Debris Head Loss Calculation (Appendix D, Ref. 28). The results are compared in Table 3f.5-1.

Table 3f.5-1:
Open Volume Values for Array Test and Sump Pits

Structures	Open Volume (ft^3/ft^2)
Test Facility	0.177
IP-2 VC Pit	0.193
IP-2 IR	0.194
IP-3 VC	0.309
IP-3 IR	0.194

As shown in the table, the test facility has an Open Volume Value lower than those of the IP-2 and IP-3 strainers. This indicates that the actual strainers are more open than the Top Hat array used in the tests and will be able to accommodate more than the predicted amount of debris expected to arrive at the screen. The test, therefore, conservatively models the debris loading for the IP-2 and IP-3 strainers considering that the amounts of debris for the testing are determined by scaling the maximum debris amounts in the actual plant conditions based on the surface areas of the actual strainers and the testing array. In addition, the more confined testing array suggests that, in the testing, the debris is pushed closer to the strainer surface where it is more likely to contribute to higher head loss. Following an actual LOCA, it is expected that the debris bed on the strainer is more likely to be non-uniformly loaded, resulting in potentially more open strainer area and a not as densely packed debris bed. Note that the actual non-uniform loading will lead to lower head losses than the uniformly loaded debris bed in the testing.

Entergy Response to Issue 3f.6:

Common to both units

The "thin-bed effect" is defined as the relatively high head losses that occur across a uniform thin bed of fibrous debris, which can sufficiently filter particulate debris to form a dense particulate debris bed. The Prototype Array Head Loss Test [Ref. 37] included testing for both thin-bed effects and full debris load. For the thin-bed testing, the full particulate load was first added into the testing tank. Batches of fiber were then added in 1/8" equivalent bed thicknesses. Strainer array head loss (differential pressure) was recorded throughout the duration of the testing. In the Head Loss Calculation [Ref. 28], the head losses measured for the thin-bed and full-load testing are compared and the greater value is used to calculate the final head loss. Thus, the thin-bed effects are accounted for in the final head loss results and the strainer is demonstrated to be able to accommodate thin bed formation.

Entergy Response to Issue 3f.7:

Common to both units

For each unit, head losses for the following 6 bounding accident categories were analyzed:

- LBLOCA with IR Sump Operation
- Reactor Cavity (RC) LBLOCA with IR Sump Operation
- 6 Inch Break LOCA with VC Sump Operation
- RC 6 Inch Break LOCA with VC Sump Operation
- LBLOCA with VC Sump Operation after 24 hours of Pool Turnover
- RC-LBLOCA with VC Sump Operation after 24 hours of Pool Turnover

In the Certification Calculation [Ref. 40], the ability of the strainer to sustain the head loss, for each of the above six accident categories, was assessed through fulfillment of the acceptance criteria based on:

- Pump maximum (NPSH) performance
- Minimum flow performance
- Structural limit requirements

It should be noted that since the Chemical Precipitate Timing Report [Ref. 46] showed that chemical precipitate will not occur until at least 7 hours after an accident, the conventional debris head loss (*i.e.*, head loss due to fibrous and particulate debris only) is considered prior to the 7-

hour time mark while the conventional plus chemical debris head loss is evaluated after the 7-hour time mark.

Entergy Response to Issue 3f.8:

Common to both units

As summarized in the response to Issue 3f. 3, the installation of vortex suppression gratings for the IP-2 and IP-3 strainers will prevent vortex formation. In the Vortex Suppressor Evaluation Report [Ref. 70], the minimum water level for all break sizes, which is the water level at the start of recirculation for a SBLOCA with spray case, was conservatively used to determine the maximum elevation of the grating. The vortex suppressor design specifies grating dimensions [Refs. 110 - 114] which have been demonstrated to be effective through testing [Ref. 70].

The Head Loss Calculation [Ref. 28] determined the total head loss under various post-accident operating conditions by considering the calculated clean screen head losses and tested debris head losses. Major assumptions and conservatisms for the Clean Screen Head Loss Calculations will be discussed in the response to the Issue 3f.9. The conservatisms used in the Head Loss Calculation are summarized below.

- The total head loss is calculated by the summation of head losses due to each debris component. Per NRC and industry testing, this approach is conservative. The method has been endorsed in the Safety Evaluation Report [Ref. 3].
- To account for the effects of air entrainment due to void fraction (which includes flashing/deaeration), when scaling the head losses, the surface area of the strainer was reduced by 3%, which corresponds to the void fraction acceptance limit as specified in Attachment V-1 of Ref. 3. This is conservative because the maximum void fractions are determined to be 0.31% and 0.67% for the IR and VC sumps, respectively for IP-2 and 0.41% and 0.60% for the IR and VC sumps, respectively for IP-3 [Refs. 26 and 27].
- When calculating head losses for comparison criteria other than NPSH (*e.g.*, structural limit and minimum flow performance), the head losses are scaled from the testing temperatures to 70°F [Ref. 28] which corresponds to the lowest temperature for both normal and post-accident operation of the Component Cooling Water System at IP-2 and IP-3. This method results in conservatively higher head losses since the head losses increase as water temperature decreases due to higher water viscosity. Note that the purpose of evaluating the minimum flow cases is to ensure that the strainer head loss does not reduce the pump flow rate below the minimum performance required for accident mitigation.
- Tested debris head losses were scaled from the testing conditions to the actual plant conditions using conservative correction equations. This is discussed further in the response to the Issue 3f.13.
- Instrument accuracy noted in the Prototype Test Report [Ref. 37] was either added or subtracted from the data presented in the report to produce conservatively higher head losses. Instrument accuracy is added to the measured head loss and temperature data obtained from the test report, while it is subtracted from the measured flow rate data in the report.
- For test stages with chemical loads, head losses measured in the Prototype Testing [Ref. 37] were curve fitted to a function of time, which is extrapolated to determine the head loss at 30 days in the Head Loss Calculation [Ref. 28]. The logarithmic curve that resulted in the most conservative head loss was chosen for the extrapolation. If a bed shift occurred during a test, head losses measured both before and after the bed shift were fitted and extrapolated to obtain the 30-day head loss. The greater value from the bed shift

extrapolations was conservatively chosen to be the final head loss. This was done because bed shifts often result in exposed strainer area, which reduces head loss.

- In the prototype testing, WCAP chemicals were cumulatively added into the testing tank in multiple stages. If a certain test stage had an extrapolated head loss that was lower than that of the preceding stage, the head loss of that stage is replaced by the higher head loss value of the previous test stage for conservatism.

Entergy Response to Issue 3f.9:

Common to both units

All methodologies, assumptions, calculations and results regarding the clean strainer head loss (CSHL) are included in the Hydraulic Analyses [Refs. 24 and 25]. To calculate the CSHL, the following basic steps were followed:

- The strainer effective surface area is first determined.
- The head loss through a single Top Hat module is calculated using the correlation between the measured Top Hat head loss and the Top Hat annulus flow velocity obtained from testing.
- The head loss due to the flow traveling through the support structure of the Top Hats is calculated in the following way: Flow through the support structure (referred to as channel or manifold depending on the situation) is broken down into nodes and the appropriate junctions are modeled according to their hydraulic configuration as Wyes, elbows, flow contractions, expansions and obstructions such as I-beams. The length between nodes is used to calculate the wall friction. Flow entering the manifold from the individual Top Hats is modeled as a 90 degree elbow at the initial node point and as a Wye intersection for the subsequent Top Hats along the channel. If more than one Top Hat is attached to the same nodal point, the combined flow is modeled as one junction. Major obstructions are considered and significant changes in cross-sectional area are modeled as sudden expansions and/or contractions.
- In order to estimate head loss through the manifold, a hydraulic diameter is calculated for each section that has a unique cross-sectional area and configuration. In some cases, the flow channel through the manifold is constantly changing. In these cases the most conservative attributes are used.
- The largest head losses experienced by a Top-Hat and its associated channels and manifolds are summed to produce the most conservative clean strainer head loss.

Important assumptions in the clean strainer head loss include:

- Steady, incompressible flow is assumed. By definition, the system is water-solid and single-phase.
- The lowest sump water temperature is assumed to be constant at 60°F. This is conservative since water at higher temperatures (characteristic of post-accident sump temperatures) would exhibit lower viscosity while a conservatively low water temperature would result in lower Reynolds numbers, and consequently higher friction factors and head losses.
- It is assumed for this analysis that the containment pressure is 14.7 psia. This assumption is reasonable because the water properties associated with this pressure are not significantly affected by the pressure term.
- The head loss across the strainer Top Hat Modules, including the knitted wire mesh bypass eliminator feature, is determined based on the correlation between the Top Hat head loss and the Top-Hat annulus velocity obtained from testing [Refs.24 and 25]. This approach is

conservative since, in addition to the head loss associated with the flow inside the Top Hat, the measured head loss includes additional losses due to flow turning and merging at the intersection of the Top Hat exit and the plenum.

- The flow is assumed to be uniformly distributed over the whole strainer. Under this assumption, a Top Hat strainer approach velocity, defined as the ratio between the total flow rate and the net surface area of the strainer, was applied to all of the Top Hat modules within the strainer for the CSHL Calculation. This approach is conservative because it results in higher flow rates for those Top Hats far from the suction lines, forcing more flow (than would actually occur) traveling the full length of the strainer. It should be noted that in reality, the flow would follow the path of least resistance and the Top Hats nearest the suction lines have the highest flow rates.

The IR and VC sump clean strainer head loss values are shown in the tables below for both IP-2 [Ref. 24] and IP-3 [Ref. 25]:

Unit 2

Table 3f.9-1:
IP-2 Clean Strainer Head Loss

IR Sump		VC Sump	
Flow (gpm)	Head Loss (ft)	Flow (gpm)	Head Loss (ft)
1000	0.039	1000	0.130
1350	0.044	1350	0.209
2500	0.071	2000	0.417
2625	0.075	2834	0.798
2750	0.079	3000	0.890
2875	0.084	3528	1.215
3000	0.088	3700	1.332
3125	0.093	4000	1.549
3250	0.098	4500	1.984
3375	0.103	4749	2.164
3500	0.108	5000	2.393
3958	0.129	5500	2.885
4000	0.131	6000	3.423
4300	0.146	-	-
4428	0.153	-	-
5565	0.223	-	-
6000	0.254	-	-
7086	0.341	-	-
7200	0.351	-	-

Unit 3

Table 3f.9-2:
IP-3 Clean Strainer Head Loss

IR Sump		VC Sump	
Flow	Head Loss	Flow Rate	Head Loss
(gpm)	(ft)	(gpm)	(ft)
1000	0.043	1000	0.076
1350	0.052	1350	0.114
2000	0.075	2000	0.211
2600	0.104	2500	0.312
3000	0.127	3000	0.434
3342	0.150	3700	0.646
3530	0.164	4000	0.748
4000	0.201	4500	0.937
4300	0.228	4749	1.041
5000	0.296	5000	1.147
5400	0.340	5500	1.384
6000	0.413	6000	1.639

Entergy Response to Issue 3f.10:

Common to both units

The total head loss was determined in the Head Loss Calculation [Ref. 28] by summing the calculated Clean Screen Head Loss (CSHL), tested debris head losses (conventional plus chemical debris) and RMI debris head loss. Per NRC and industry testing, this approach is conservative and has been previously endorsed in the Safety Evaluation Report [Ref. 3].

The methodology, assumptions and conservatisms used in the CSHL calculation are summarized in the response to Issue 3f. 9. It was shown that the head loss associated with the RMI debris is orders of magnitude smaller than other head loss components and has a negligible effect on the total head loss. Therefore, the head loss due to the maximum amount of RMI debris that will be transported to the strainer was calculated and used for all cases within each accident category for conservatism [Ref. 28].

Prototypical array testing was conducted to measure the head loss for flow through the debris bed [Ref. 37]. For each test, the conventional debris (the fiber and particulate mixes) was first added into the testing tank. After the head loss stabilization criteria was met, chemical precipitates were then batched in. The head loss was recorded through the duration of the testing. Furthermore, the debris head loss was measured for both the thin-bed and full debris loads. The maximum head loss of the two was used in the final head loss calculation.

The methodology used to calculate the total strainer head loss is summarized below [Ref. 28]:

- The head loss test data based upon the results of the Prototype Test Report [Ref. 37] was analyzed. This includes curve fitting and extrapolating the measured head losses from chemical addition stages to obtain the head loss after a 30 day period.

- Measured head losses are normalized from test temperatures and flow rates to 70°F and 155 gpm or 400 gpm (whichever is applicable) to facilitate test stage matching (see next bullet).
- For each of the accident categories discussed in the response to the Issue 3f.7, a matching test stage is selected such that the test stage best represents the scaled debris composition and amounts and flow of the accident category.
- The measured head loss for each analytical test case was adjusted from the test conditions to the actual plant conditions to account for the differences in temperature and flow rate.
- Total strainer head loss is finally calculated by summation of the CSHL, tested debris head loss (conventional plus chemical debris), and RMI debris head loss.

As discussed earlier, chemical precipitate effects have been shown as being negligible during the initial 7-hours following a LOCA [Ref. 46]. The general methodology used to determine head loss before and after this time are summarized below [Ref. 28]:

Prior to 7-hours post-LOCA

- The NPSHa, NPSHr, and minimum flow performance values are found in the Westinghouse hydraulic performance evaluations which use a fathom model.
- The NPSHa is adjusted based on water level so that it bounds both LBLOCAs and SBLOCAs.
- The corrected conventional debris head loss value for each break case/scenario, as documented in the Head Loss Calculation [Ref. 28], is compared to the NPSH margin, minimum flow performance limit, and structural integrity limit for each flow alignment. All break cases/scenarios are shown to meet the head loss limits.

After 7-hours post-LOCA

- The NPSHa and NPSHr are found in the Westinghouse hydraulic performance evaluations which use a fathom model.
- The NPSHa is adjusted based on water level so that it bounds both LBLOCAs and SBLOCAs.
- The corrected conventional plus chemical debris head loss value (extrapolated to 30 days) for each break case/scenario, as documented in the Head Loss calculation [Ref. 28], is compared to the NPSH margin and structural integrity limit for each flow alignment. All break cases/scenarios are shown to meet the head loss limits.

Major assumptions used in the Head Loss Calculation [Ref. 28] include:

- The break cases developed for testing are conservative combinations of multiple break scenarios that maximize debris. Therefore, the debris amount is larger than can be produced by any one break location.
- It is assumed that the total head loss due to a mixture of debris materials can be determined by summation of head losses due to each debris component. For the purpose of this calculation, the head loss consists of contributions from the RMI debris, the fibrous/particulate debris, the chemical precipitant debris, and the clean strainer head loss. Per NRC and industry testing, this approach is conservative and has been previously endorsed in the Safety Evaluation Report [Ref. 3].
- All failed tape, tag, and label debris that is determined to be transportable are assumed to arrive at the sump strainers intact and obstruct an area equivalent to 75% of the total original single-sided surface area, as stated in NEI 04-07 [Ref. 6]. This is predicated upon the fact that all unqualified tape, tags, and labels (miscellaneous debris) in the containment fails and contributes to the debris source term, as stated in the Debris Generation Calculations [Refs. 1 and 2].

- It is assumed that the impact of the tie wraps on the IP-2 and IP-3 strainer head loss is negligible. Due to the geometrical characteristics of the tie wraps in containment, they are unable to form an appreciable debris bed on the strainer screens, and therefore, can be neglected in the head loss analysis. Also, the NRC has previously accepted the general assumption that the tie wraps are not expected to transport to the sump and collect on the sump screen [Ref. 90]. Thus, no sacrificial strainer surface area is allotted for tie wraps.
- To account for the effects of air entrainment due to void fraction (which includes flashing/deaeration), when scaling the head losses, the surface area of the strainer was reduced by 3%, which corresponds to the maximum acceptable void fraction as specified in Attachment V-1 of Ref. 3. This is conservative because the maximum void fractions are determined to be 0.31% and 0.67% for the IR and VC sumps, respectively for IP-2 and 0.41% and 0.60% for the IR and VC sumps, respectively for IP-3 [Refs. 26 and 27].
- For some of the analytical cases that were chosen for testing, the coatings surrogate amounts in the Test Debris Amounts Calculation [Ref. 45] are slightly larger than the tested coating surrogate amounts [Ref. 37]. The difference in the calculated amount and tested amount of coatings will be referred to as the incremental particulate amount. It is determined in Ref. 28 that even though this incremental particulate amount was not included in the tested coatings surrogate amounts, due to the range of particulate amounts tested and the conservatism in the methodology used to match an analytical case to a test stage, the selected conventional and chemical head losses for the analytical test cases are bounding and conservative for most cases. The remaining cases exhibited clean screen area during the testing; therefore, head losses in these tests are less likely to be impacted by the incremental particulate amount since any additional particulate would pass through the open screen area. However, the head losses for these remaining cases were increased by a ratio of the total particulate amount to the tested particulate amount. The incremental particulate amount ranges between 6% to 21% of tested particulate amount for these tests.
- It is assumed that it is conservative to correct head loss to 204.7°F for NPSH margin determination. At the minimum containment pressure of -2 psig, the corresponding sump pool saturation temperature is 204.7°F. At temperatures greater than 204.7°F, it is assumed that the vapor pressure at the sump pool temperature is equal to the containment pressure. This is reasonable since if the containment pressure were to be lower than the vapor pressure, boiling (flashing) would occur at the pool surface until the pressures are equalized. For temperatures below 204.7°F, it is assumed that the containment pressure will remain at the minimum containment pressure of -2 psig. Since the vapor pressure decreases as the sump temperature decreases, at temperatures below 204.7°F, the containment pressure of -2 psig is always greater than the vapor pressure. This is illustrated below in Figure 3f.10-1.

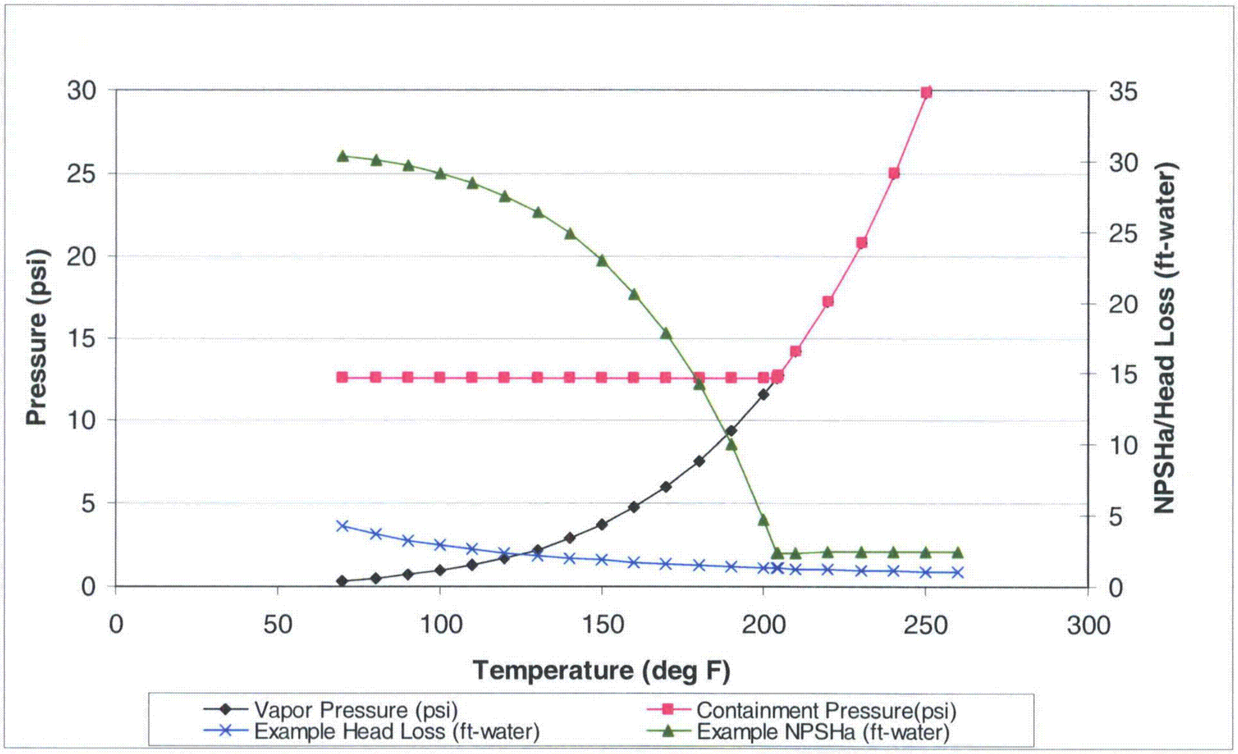

Figure 3f.10-1:
Comparison between the containment pressure and vapor pressure at various sump temperatures for IP-2 and IP-3.

For Net Positive Suction Head calculations, the following equation is applicable:

$NPSH_a = h_{atm}+h_{z(s)}-h_{f(s)}-h_{vp}$

where,

h_{atm}	=	Atmospheric (Containment) Pressure
$h_{z(s)}$	=	The head due to the height of liquid above pump suction
$h_{f(s)}$	=	Head Loss due to Friction
h_{vp}	=	Vapor Pressure Head

Based on this equation and the above assumptions, the $NPSH_a$ reaches a minimum at a pool temperature of 204.7°F and remains constant at temperatures greater than 204.7°F. At sump pool temperatures below 204.7°F, additional $NPSH_a$ is gained due to the decrease in the vapor pressure of water. This is shown in Figure 3f.10-1 as the green curve with triangle markers.

It should be noted that when the head loss is scaled to a lower temperature, the head loss value increases due to the higher viscosity at the lower temperature. It can be shown, however, that this increase in head loss is always less than the additional gain in $NPSH_a$ as stated above. For example, a head loss of 1.0 ft at 260°F was scaled (conservatively using 100% laminar fractions) to the values at temperatures as low as 70°F, as plotted in Figure 3f.10-1 (represented by the blue curve with 'x' markers). It can be clearly seen that as temperature decreases there is only a slight increase in head loss (~ 4.2 ft at 70°F) while there is a significant gain in $NPSH_a$ (~ 26 ft at 70°F). It is therefore reasonable to assume that correcting head losses to 204.7°F is conservative for NPSH margin evaluations since the $NPSH_a$ reaches a minimum at 204.7°F while conditions below

204.7°F result in additional gain in $NPSH_a$ which exceeds the temperature effects on the debris bed head loss.

The 6 Analytical Debris Generation Cases for each unit (12 total) identified in Section 3f.7 were matched to a test stage/s in order to determine the applicable head loss. The methodology described in the Debris Head Loss Calculation [Ref. 28] is applied here to each case.

Analytical Debris Generation Case Load to Test Load matching is performed to determine the experimental head loss for each case. The Analytical Debris Generation Case Load refers to the analytically determined debris loads for each of the 6 Analytic Debris Generation Cases under consideration for each unit (as listed in Section 3f.7). Analytical Debris Generation Case Loads were calculated based on transport fractions and prototype surface area [Ref. 45]. Test Load refers to the debris loads that were used for each test stage (conventional or conventional and chemical).

A discussion of test selection for each case using the above approach is presented below. It should be noted that the total particulate load refers to the summation of the mass contribution of Cal-Sil, Sil-Co-Sil and dirt, while the total fiber load refers to the summation of the mass contribution of Nukon™, Temp-Mat and Mineral Wool.

<u>IP-2 IR Sump LBLOCA (IP-2 IR Sump RC LBLOCA)</u>

Two thin bed tests (Tests A1 and E) and a full load test (Tests B) were completed to investigate the head losses for this case. Additionally, the head losses from the Test F are considered since these tests resulted in higher measured head losses.

The test particulate load for Tests A1 and E (105.72 lbs = 9.66 lbs+ 80.49 lbs + 15.57 lbs) are greater than this Analytical Debris Generation Case particulate load (87.35 lbs = 7.49 lbs + 73.6 lbs + 6.26 lbs), however, the particulate load from Test B (85.88 lbs = 7.49 lbs + 72.13 lbs + 6.26 lbs) is slightly less than this case due to the incremental particulate amount of 1.47 lbs (73.60 – 72.13 lbs).

The full insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 3f.10-1.

Table 3f.10-1:
Bounding Debris Loads for IP-2 IR Sump LB LOCA from Test Debris Amounts Calculation with Applicable Test Stage Head Losses

	Test Debris Loads							**Measured Head Loss		
	Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
A1-2 (Thin Bed)	15.13	0.00	0.00	9.66	80.49	15.57	3.12	0.96	4.06	4.94
*B-2	25.19	5.43	0.00	7.49	72.13	6.26	3.12	1.38	5.17	7.32
E-2 (Thin Bed)	14.25	0.00	0.00	9.66	80.49	15.57	3.12	1.10	9.71	11.37
F-2 (Thin Bed)	8.55	0.00	0.00	9.57	23.37	24.63	3.12	3.07	9.37	10.17
	Analytical Debris Generation Case							Matched Test Stages		
IP-2 IR Sump LB LOCA	25.19	5.43	0	7.49	73.60	6.26	3.12	F	E-2	E-2

* Extrapolation from B-1 is shown for conservatism.

** Measured Head Losses are scaled to 400 gpm or 155 gpm (which ever is applicable) and 70°F.

The lower particulate test, Test F, resulted in a higher conventional debris head loss of 3.07 ft-water than the high particulate tests, Tests B and E (1.38 and 1.10 ft-water, respectively) due to the higher Cal-Sil to Sil-Co-Sil ratio in Test F. Cal-Sil is less dense and has a smaller mass to volume ratio than Sil-Co-Sil, which would result in a higher head losses. Because a full range of particulate loads were tested, it is considered acceptable and conservative to use the bounding head losses from Test F to quantify the conventional head loss for this case.

The chemical effects head loss from the second chemical add in Test E (which included a conservative particulate amount of 105.72 lbs) is bounding for this case since the chemical effects head losses are larger than the than the head losses for the other tests listed in Table 3f.10-1. The minor particulate discrepancy for Test B (1.47 lbs) is inconsequential since the results from this test are not used as the bounding.

Table 3f.10-2 shows that the debris loads for IP-2 IR Sump RC LBLOCA analytical debris generation case are fully bounded by the IP-2 IR Sump LBLOCA analytical debris generation case in Table 3f.10-1, therefore the head losses from the selected test stages in Table 3f.10-1 will be bounding for this RC case.

Table 3f.10-2:
Bounding Debris Loads for IP-2 IR Sump RC LB from Test Debris Amounts Calculation

IP-2 IR RCLB LOCA Full Insulation Load						
Nukon	Temp-Mat	Min. Wool	Cal-Sil	Sil-Co-Sil	Dirt	WCAP Debris
(lbs)			(lbs)			(lbs)
1.10	2.95	0.00	0.00	69.73	6.26	3.02

<u>IP-2 VC Sump 6 Inch Break LOCA (IP-2 VC Sump 6 Inch Break RC LOCA)</u>

Two thin bed tests (Tests A1 and E) were completed to investigate the head losses for this Analytical Debris Generation Case. The particulate load for Tests A1 and E (105.72 lbs = 9.66 lbs + 80.49 lbs + 15.57 lbs) no longer bound the particulate load for this case (110.57 lbs = 6.16 lbs + 85.34 lbs + 19.07 lbs) due to the incremental particulate amount. Additionally, the head losses from the Test F are considered since these tests resulted in higher measured head losses. The full insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 3f.10-3.

Table 3f.10-3:
Bounding Debris Loads for IP-2 VC 6 Inch Break LOCA from Test Debris Amounts Calculation with Applicable Test Stage Head Losses

		Test Debris Loads							**Measured Head Loss		
		Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
Tests	A1-5 (Thin Bed)	15.13	0.00	0.00	9.66	80.49	15.57	5.87	0.96	7.19	8.93
	E-4 (Thin Bed)	14.25	0.00	0.00	9.66	80.49	15.57	5.87	1.10	15.87	20.60
	F-4 (Thin Bed)	8.55	0.00	0.00	9.57	23.37	24.63	5.87	3.07	13.98	19.89
	Analytical Debris Generation Case								Matched Test Stages		
	IP-2 VC 6" LOCA	15.13	0	0	6.16	85.34	19.07	5.87	F	E-4	E-4

* Measured Head Losses are scaled to 400 gpm or 155 gpm (which ever is applicable) and 70°F.

As shown in Table 3f.10-3, the conventional head loss measured in Test F is bounding for this case. Because a full range of particulate loads were tested, it is considered acceptable and conservative to use the bounding head losses from Test F to quantify the conventional head loss for this case.

The chemical effects head losses from Test E are chosen as bounding for this case. This is acceptable because Test E contained 3.5 lbs (9.66 – 6.16 lbs) more Cal-Sil than needed. Since Cal-Sil has a density of 14.5 lb-m/ft^3 which is much smaller than that of Dirt (169 lb-m/ft^3) and Sil-Co-Sil (165 lb-m/ft^3), the differences in the Sil-Co-Sil (4.85 lbs = 85.34 – 80.49 lbs) and Dirt (3.5 lbs) amounts will be more than compensated for by the larger volume of the excess in Cal-Sil amount. It is generally accepted that Cal-Sil, with its larger volume to mass ratio than Dirt and Sil-Co-Sil, creates higher head losses than the equivalent mass of coatings and dirt particulate. The results from Test E can therefore be used to quantify the chemical head losses for this case.

The IP-2 VC Sump 6 Inch RC LBLOCA analytical debris generation case is bounded by the IP-2 VC Sump 6 Inch LBLOCA analytical debris generation case for conventional loads only; therefore, the chemical effects head losses need further examination since the RC break debris mix results in a larger chemical load. The normalized head losses from the applicable chemical effects stages are shown in Table 3f.10-4.

Table 3f.10-4:
Valid Chemical Test Stage Head Losses for the IP-2 VC Sump 6 Inch Break RC LOCA

		Test Debris Loads							**Measured Head Loss		
		Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
Test	A1-6 (Thin Bed)	15.13	0.00	0.00	9.66	80.49	15.57	6.54	1.83	8.54	9.98
	E-5 (Thin Bed)	14.25	0.00	0.00	9.66	80.49	15.57	6.54	1.10	18.45	21.88
	F-5 (Thin Bed)	8.55	0.00	0.00	9.57	23.37	24.63	6.54	3.07	14.73	19.02
		Analytical Debris Generation Case							***Matched Test Stages		
	IP-2 VC RC 6" LOCA	3.37	2.2	0	0	77.82	19.07	6.54	F	E-5	E-5

** Measured Head Losses are scaled to 400 gpm or 155 gpm (which ever is applicable) and 70°F

*** Head losses for the matched test stages, which are used in subsequent calculations are obtained from Table A1, Appendix A of Reference 28.

The total fibrous debris load and particulate load for this case is fully bounded by Tests A1 and E. As shown in the table, the chemical effects head losses measured in Test E are bounding for this case. Note that Tests A1 and E included a bounding particulate amount (105.72 lbs vs. 96.89 lbs for this Reactor Cavity case) by including Cal-Sil. As stated above, Cal-Sil is generally accepted to result in higher head losses than an equivalent mass of coatings particulate or dirt mixture. Therefore, the results from Tests E are conservative for this RC case.

IP-2 VC Sump LB LOCA after 24 Hours of Pool Turnover (IP-2 VC Sump RC LB LOCA 24 Hours of Pool Turnover)

Test G was completed to investigate the head losses for this case. The full insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage is shown in Table 3f.10-5.

Table 3f.10-5:
Bounding Debris Loads for IP-2 VC Sump LB LOCA after 24 Hours of Pool Turnover from the Test Debris Amounts Calculation with Applicable Test Stage Head Losses

		Test Debris Loads							**Measured Head Loss		
		Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
Test	G-4	4.47	1.07	0.00	3.01	73.30	0.95	9.51	0.10	7.56	8.10
		Analytical Debris Generation Case							***Matched Test Stages		
	IP 2 VC LBLOCA 24 HRS	4.47	1.07	0	3.01	78.17	0.95	9.51	N/A	G-4	G-4

** Measured Head Losses are scaled to 400 gpm or 155 gpm (which ever is applicable) and 70°F

*** Note that these head losses will be increased by 6.64 % prior to correcting head losses to scaled plant flow rates and temperatures.

Note that only conventional plus chemical head losses are need for this case. The VC sump start-up for this Analytical Debris Generation Case is at 24 hours after a LOCA, while it has been shown that precipitation will not occur until after the switchover to hot leg recirculation, at approximately 7 hours.

The particulate debris amount in Test G (77.26 lbs = 3.01 lbs + 78.17 lbs +0.95 lbs) no longer bounds this case due to the incremental particulate amount. However, Test G demonstrated that the debris load for this case will leave open screen areas. It is likely that any additional particulate would pass through the clean screen areas with the majority of the flow rather than embedding in the fiber covered areas. Therefore, it is unlikely that the incremental particulate amount would have resulted in increased head losses. However, for conservatism, a correction factor will be applied to increase the chemical effects head loss for this case and compensate for the incremental particulate amount. The correction factor to be applied is the ratio of the incremental particulate amount (4.87 lbs = 78.17 lbs – 73.30 lbs) of Sil-Co-Sil to the amount of Sil-Co-Sil used in the test (73.30 lbs). Therefore, the measured and extrapolated chemical effects head loss will be increased by the correction factor for this case of 6.64% (4.87/73.30*100%).

Table 3f.10-6 shows that the debris loads for IP-2 VC RC LBLOCA, after 24 Hours of pool turnover, is bounded by the debris loads for the IP-2 VC Sump Large Break LOCA after 24 Hours of pool turnover; therefore, the selected test stage head losses in Table 3f.10-5 with the applied 6.64% increase will be bounding for this RC case.

Table 3f.10-6:
Bounding Debris Loads for IP-2 VC Sump RC LB w/24 Hr IR Sump Operation from Test Debris Amounts Calculation

IP-2 VC Large Break 24 Hour LOCA Full Insulation Load						
Nukon	Temp-Mat	Min. Wool	Cal-Sil	Sil-Co-Sil	Dirt	WCAP Debris
(lbs)			(lbs)			(lbs)
0.18	0.53	0.00	0.00	76.24	0.95	9.19

<u>IP-3 IR Sump LBLOCA Full Insulation (IP-3 IR Sump RC LBLOCA)</u>

A thin bed test (Tests E) and a full load insulation test (Test C) were completed to investigate the head losses for this case.

The test particulate load for Test E (105.72 lbs = 9.66 lbs+ 80.49 lbs + 15.57 lbs) is greater than the Debris Generation Particulate Load of 69.67 lbs (9.66 lbs + 52.26 lbs + 7.75 lbs); however, the particulate debris from Test C (68.50 lbs = 9.66 lbs + 51.09 lbs + 7.75 lbs) no longer bounds this case due to the incremental particulate amount of 1.17 lbs (52.26 lbs - 51.09 lbs). Since this incremental particulate amount is small, head losses from Test C are still considered for the full load.

Additionally, the head loss for Test F, that included less debris, is considered since this test resulted in higher measured head loss.

The debris loads for this case together with the applicable test debris loads and normalized head losses for each applicable test stage are shown in Table 3f.10-7.

**Table 3f.10-7:
Bounding Debris Loads for IP-3 IR Sump LB LOCA from Test Debris Amounts Calculation with Applicable Test Stage Head Losses**

		Test Debris Loads							**Measured Head Loss		
		Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
Test	C-3	18.94	21.75	0.70	9.66	51.09	7.75	3.74	2.80	5.28	6.65
	E-3 (Thin Bed)	14.25	0.00	0.00	9.66	80.49	15.57	3.74	1.10	10.91	12.32
	*F-3 (Thin Bed)	8.55	0.00	0.00	9.57	23.37	24.63	3.74	3.07	10.02	10.78
	Analytical Debris Generation Case								Matched Test Stages		
	IP-3 IR Sump LB LOCA	18.94	21.75	0.70	9.66	52.26	7.75	3.74	F	E-3	E-3

* Bed shift occurred for this test stage - extrapolating data prior to bed shift resulted in a more conservative head loss.

** Measured Head Losses are scaled to 400 gpm or 155 gpm (which ever is applicable) and 70°F

The table above shows that Test F resulted in a higher conventional head loss (3.07 ft-water) than the high particulate tests, Test E (1.10 ft-water). Because a full range of particulate loads were tested and the thin-bed load is clearly bounding, it is considered acceptable and conservative to use the bounding head losses from Test F to quantify the conventional head loss for this case.

The bounding chemical effects head loss in Test E (which included a conservative particulate amount) is bounding for this case. The particulate discrepancy for Test C is inconsequential since the head losses from this test are not used.

Table 3f.10-8 shows that the debris loads for the IP-3 IR Sump RC LBLOCA analytical debris generation case are fully bounded by the debris loads for the IP-3 IR Sump LBLOCA analytical debris generation case in Table 3f.10-7, therefore, the head losses from the selected test stages will be bounding for this RC case. It should be noted that both the selected test stages have greater total fiber loads, total particulate loads and total chemical loads than this analytical RC debris generation case.

**Table 3f.10-8:
Bounding Debris Loads for IP-3 IR Sump RC LB LOCA from Test Amounts Calculation**

IP-3 IR Sump RC LB LOCA Full Insulation Load						
Nukon	Temp-Mat	Min. Wool	Cal-Sil	Sil-Co-Sil	Dirt	WCAP Debris
(lbs)			(lbs)			(lbs)
1.37	2.84	0.00	0.00	42.99	7.75	2.76

<u>IP-3 VC Sump 6 Inch Break LOCA Full Insulation (IP-3 VC Sump 6 Inch Break RC LOCA)</u>

A thin bed test (Tests E) and a full load test (Test C) were completed to investigate the head losses for this case.

The test particulate loads for Test E (105.72 lbs = 9.66 lbs + 80.49 lbs +15.57 lbs) and Test B (85.88 lbs = 7.49 lbs + 72.13 lbs +6.26 lbs) bound the Debris Generation Case particulate load of 61.62 lbs (9.57 lbs + 27.42 lbs + 24.63 lbs). Additionally, the head losses from the tests that included less conventional debris (Test B and Test F) are considered since these tests resulted in higher measured head losses. Tests B, C, E, and F cover a large range of particulate loads, including a bounding particulate load for Debris Generation Case. The full insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 3f.10-9.

Table 3f.10-9:
Bounding Debris Loads for IP-3 VC Sump 6 Inch Break LOCA from Test Debris Amounts Calculation with Applicable Test Stage Head Losses

		Test Debris Loads							**Measured Head Loss		
		Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
Test	B-4	25.19	5.43	0.00	7.49	72.13	6.26	6.54	1.38	8.78	11.73
	C-4	18.94	21.75	0.70	9.66	51.09	7.75	6.49	2.80	5.80	7.36
	E-5 (Thin Bed)	14.25	0.00	0.00	9.66	80.49	15.57	6.54	1.10	18.45	21.88
	*F-5 (Thin Bed)	8.55	0.00	0.00	9.57	23.37	24.63	6.54	3.07	14.73	19.02
		Analytical Debris Generation Case							***Matched Test Stages		
	IP 3 VC 6" LOCA	4.76	26.20	0.00	9.57	27.42	24.63	6.49	F	F-5	F-5

* Extrapolation from F-4 is shown for conservatism since the extrapolation from F-4 resulted in higher head losses than the extrapolation from F-5.

** Measured Head Losses are scaled to 400 gpm or 155 gpm (which ever is applicable) and 70°F

The low particulate test (Test F) resulted in a higher conventional head loss of 3.07 ft-water compared to the high particulate tests (B, C and E). Test E which included a bounding particulate load resulted in a higher chemical head loss of 18.45 ft-water. Therefore, since a full range of particulate loading was tested, it is considered acceptable and conservative to use the bounding head losses from Tests F to quantify the conventional head loss and Test E to quantify the chemical head losses for this case.

Table 3f.10-10 shows that the debris loads for the IP-3 VC Sump 6 Inch RC LOCA analytical debris generation case are fully bounded by the debris loads for the IP-3 VC 6 Inch LOCA analytical debris generation case in Table 3f.10-9, therefore, the head losses from the selected test stages in Table 3f.10-9 will be bounding for this RC case. It should be noted that both the selected test cases have greater total fiber loads, total particulate loads and total chemical loads than this RC debris generation case.

Table 3f.10-10:
Bounding Debris Loads for IP-3 VC Sump 6 Inch Break RC LOCA from Test Debris Amounts Calculation

IP 3 VC 6" RC LOCA Full Insulation Load						
Nukon	Temp-Mat	Min. Wool	Cal-Sil	Sil-Co-Sil	Dirt	WCAP Debris
(lbs)			(lbs)			(lbs)
4.36	2.20	0.00	0.00	20.66	24.63	6.42

IP-3 VC Sump LBLOCA w/24 Hour IR Sump Operation (IP-3 VC Sump RC LBLOCA w/24 Hour IR Sump Operation)

Test D was completed to investigate the head losses for this case. The full insulation debris loads for this case together with the applicable debris loads and the normalized head losses from each test stage are shown in Table 3f.10-11.

Table 3f.10-11:
IP-3 VC Sump 24 Hour LB LOCA Debris Loads from the Test Debris Amounts Calculation with Applicable Test Stage Debris Loads and Head Losses

		Test Debris Loads							**Measured Head Loss		
		Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Conventional (ft-water)	Conventional & Chemical (ft-water)	Extrapolated Conventional & Chemical (ft-water)
Test	D-4	3.66	4.23	0.13	4.85	16.26	1.23	11.87	0.13	4.57	5.80
		Analytical Debris Generation Case							***Matched Test Stages		
	IP 3 VC LBLOCA 24 HRS	3.66	4.23	0.13	4.85	20.33	1.23	11.87	N/A	D-4	D-4

** Measured Head Losses are scaled to 400 gpm or 155 gpm which ever is applicable and 70°F

*** Note that these head losses will be increased by 20.02% prior to correcting head losses to scaled plant flow rates and temperatures.

Note that only conventional plus chemical head losses are need for this case. The VC sump start-up for this Analytical Debris Generation Case is at 24 hours after a LOCA, while it has been shown that precipitation will not occur until after the switchover to hot leg recirculation, at approximately 7 hours.

The particulate debris in Test D (22.34 lbs = 4.85 lbs + 16.26 lbs + 1.23 lbs) no longer bounds this debris generation case particulate load (26.41 lbs = 4.85 lbs + 20.33 lbs +1.23 lbs) due to the incremental particulate load of 4.07 lbs. Test D demonstrated that the test debris load will leave open screen areas. It is likely that any additional particulate would pass through the clean screen areas with the majority of the flow rather than embedding in the fiber covered areas to increase head loss. Therefore, it is unlikely that the incremental particulate amount of 4.07 lbs (26.41 lbs – 22.34 lbs) would have resulted in significantly increased head losses.

However, for conservatism, a correction factor will be applied to the head losses from Test D to increase the chemical effects head loss for this case and compensate for the incremental particulate amount. The correction factor to be applied is the ratio of the incremental particulate amount (4.07 lbs) of Sil-Co-Sil to the amount of Sil-Co-Sil used in the test (20.33 lbs). The correction factor for this case is 20.02% (4.07 lbs/20.33 lbs * 100%). Therefore, the measured and extrapolated chemical effects head loss will be increased by 20.02%.

Table 3f.10-12 shows that the debris loads for IP-3 VC RC LBLOCA w/24 Hour IR Sump operation, are fully bounded by the IP-3 VC Sump LBLOCA w/24 Hour IR Sump analytical debris generation case in Table 3f.10-11, therefore, the head losses from the selected test stages in Table 3f.10-11, with the applied correction factor of 20.02%, will be bounding for this RC case. It should be noted that Test D has greater total fiber loads, particulate loads and chemical loads than this RC case.

Table 3f.10-12: Bounding Debris Loads for IP-3 VC Sump RC LBLOCA w/24 Hr IR Sump Operation from Test Debris Amounts Calculation

IP 3 VC Large Break 24 Hour LOCA Full Insulation Load						
Nukon	Temp-Mat	Min. Wool	Cal-Sil	Sil-Co-Sil	Dirt	WCAP Debris
(lbs)			(lbs)			(lbs)
0.23	0.53	0.00	0.00	17.50	1.23	8.75

The following table shows the calculated total head losses for various plant flow configurations for IP-2 [Ref. 40].

Table 3f.10-13: Total Head Losses for Various IP-2 Plant Flow Configurations

Sump	LOCA Break Cases	Plant Flow Rate	Conventional Debris Head Loss (70°F)	Conventional Debris Head Loss (204.7°F)	Chemical & Conventional Debris Head Loss (70°F)	30 Day Extrapolated Chemical & Conventional Debris Head Loss (70°F)
		(gpm)	(ft-water)	(ft-water)	(ft-water)	(ft-water)
IR Sump[1]	LBLOCA or RC-LBLOCA	7086	2.45	1.71	7.07	8.21
IR Sump[1]	LBLOCA or RC-LBLOCA	6615	2.27	1.57	6.58	7.65
IR Sump[1]	LBLOCA or RC-LBLOCA	5565	1.88	1.26	5.50	6.41
IR Sump[1]	LBLOCA or RC-LBLOCA	5115	1.72	1.13	5.05	5.88
IR Sump[1]	LBLOCA or RC-LBLOCA	3984	1.32	0.83	3.91	4.56
IR Sump[2]	LBLOCA or RC-LBLOCA	3588	1.18	0.73	3.52	4.10
IR Sump[2]	LBLOCA or RC-LBLOCA	3568	1.18	0.72	3.50	4.08
IR Sump[1]	LBLOCA or RC-LBLOCA	3127	1.03	0.61	3.06	3.57
IR Sump[2]	LBLOCA or RC-LBLOCA	2452	0.80	0.46	2.40	2.80
IR Sump[1, 2]	LBLOCA or RC-LBLOCA	1350	0.45	0.23	1.33	1.55
VC Sump[1]	6"-Break LOCA	3528	4.46	3.45	18.21	23.28
VC Sump[2]	6"-Break LOCA	3221	3.87	2.95	16.11	20.60
VC Sump[1]	6"-Break LOCA	2835	3.30	2.46	14.07	18.03
VC Sump[2]	6"-Break LOCA	2198	2.45	1.75	10.80	13.87
VC Sump[1, 2]	6"-Break LOCA	1350	1.40	0.91	6.53	8.41
VC Sump[1]	6" RC LOCA	3528	4.46	3.45	20.92	24.59
VC Sump[2]	6" RC LOCA	3221	3.87	2.95	18.42	21.66
VC Sump[1]	6" RC LOCA	2835	3.30	2.46	16.11	18.96
VC Sump[2]	6" RC LOCA	2198	2.45	1.75	12.38	14.59
VC Sump[1, 2]	6" RC LOCA	1350	1.40	0.91	7.50	8.86
VC Sump[1, 2]	24 HR LBLOCA or 24 HR RC LBLOCA	1350	N/A	N/A	8.60	9.27

[1] Flow rate corresponds to a maximum performance (NPSH) case [2] Flow rate corresponds to a minimum flow performance case

Unit 3

The following table shows the calculated total head losses for various plant flow configurations at Indian Point Unit 3 [Ref. 40].

Table 3f.10-14:
Total Head Losses for Various IP-3 Plant Flow Configurations

Sump	LOCA Break Cases	Plant Flow Rate	Conventional Debris Head Loss (70°F)	Conventional Debris Head Loss (204.7°F)	Chemical & Conventional Debris Head Loss (70°F)	30 Day Extrapolated Chemical & Conventional Debris Head Loss (70°F)
		(gpm)	(ft-water)	(ft-water)	(ft-water)	(ft-water)
IR Sump[1]	LBLOCA or RC LBLOCA	5263	1.82	1.24	5.79	6.49
IR Sump[1]	LBLOCA or RC LBLOCA	4149	1.40	0.91	4.52	5.08
IR Sump[2]	LBLOCA or RC LBLOCA	3517	1.17	0.73	3.81	4.28
IR Sump[1]	LBLOCA or RC LBLOCA	2484	0.81	0.47	2.68	3.01
IR Sump[2]	LBLOCA or RC LBLOCA	1402	0.46	0.24	1.51	1.70
IR Sump[1, 2]	LBLOCA or RC LBLOCA	1350	0.44	0.23	1.46	1.64
VC Sump[1]	6" LOCA or 6" RC LOCA	3586	3.85	2.84	20.25	23.91
VC Sump[2]	6" LOCA or 6" RC LOCA	3367	3.46	2.53	18.40	21.72
VC Sump[1]	6" LOCA or 6" RC LOCA	2312	2.28	1.57	12.54	14.82
VC Sump[1, 2]	6" LOCA or 6" RC LOCA	1350	1.29	0.80	7.28	8.61
VC Sump[2]	6" LOCA or 6" RC LOCA	1226	1.17	0.71	6.61	7.82
VC Sump[1, 2]	24 HR LBLOCA or 24 HR RC LBLOCA	1350	N/A	N/A	5.50	7.12

[1] Flow rate corresponds to a maximum performance (NPSH) case
[2] Flow rate corresponds to a minimum flow performance case

Entergy Response to Issue 3f.11:

Common to both units

For both IP-2 and IP-3 during a LBLOCA or a SBLOCA, no vents or other penetrations exist in the strainer control surfaces that might connect the strainer's internal volume to the containment atmosphere above the containment minimum water level.

However, vortex suppressors must be installed in order to prevent air ingesting vortices from forming, which have the potential to create breaks in the water seal. The following table summarizes the minimum water elevations in both IP-2 and IP-3. These water elevations include drawdown and an additional ½" margin for conservatism; the elevations are developed in the Vortex Report [Ref. 70] as minimum water levels for vortex suppressor grating that is fully submerged with a ½" margin. The vortex suppressor design elevations are found in the Certification Calculation [Ref. 40].

Table 3f.11-1:
Water Elevations and Vortex Suppressor Design Elevations

	IP-2		IP-3	
	Minimum Water Elevation (ft)	Vortex Suppressor Design Elevation (ft)	Minimum Water Elevation (ft)	Vortex Suppressor Design Elevation (ft)
IR Sump (ft)	47.34	46.92	46.94	46.94
VC Sump (ft)	47.31	47.25	46.93	46.92
VC Sump Annulus	47.49	47.39	N/A	N/A

This table shows that the vortex suppressor design elevations are at or below the minimum water elevations. Therefore, the vortex suppressors will prevent the formation of air ingesting vortices.

Entergy Response to Issue 3f.12:

Common to both units

No near-field settling was credited or allowed in head loss testing. Sufficient turbulence was provided in the tank to facilitate essentially all debris reaching the test strainer, while not disturbing the debris bed formation. Additionally, manual stirs were utilized to eliminate any settled debris caused by eddies [Ref. 37]. This is conservative because the turbulence in the testing tank was much higher than in most areas of the actual sump pool where some amount of near field settling will occur.

Entergy Response to Issue 3f.13:

Common to both units

Tested debris head losses were scaled from testing conditions to the actual plant conditions using conservative correction equations [Ref. 28]. When correcting the head losses upward for increasing flow rate and/or temperature, a correction equation with case-specific laminar-to-turbulent split was used. Note that only minor corrections were done to adjust to higher flow rates due to flow rate variability in the testing (±10 gpm). The split was determined based on the case-specific Top Hat approach velocities and a polynomial equation (relating the Top Hat approach velocity and head loss) obtained from flow sweep data [Ref. 37]. Flow sweep was performed after each test, resulting in several polynomial equations. The most conservative equation was used in determining the laminar and turbulent split. It should also be noted that the flow sweeps were conducted at approach velocities between 0.006 ft/s and 0.008 ft/s [Ref. 37], which are higher than those actually present in the IR and VC Sump [Refs. 24 and 25]. Since the turbulent fraction decreases as approach velocity decreases, the turbulent fraction obtained using this flow sweep data is conservatively higher, which adds additional conservatisms to the scaled head loss values. When correcting the head loss downward for decreasing flow rate and temperature, a 100% laminar equation was used [Ref. 28]. This methodology is conservative because it results in a higher head loss for either decreasing flow or temperature adjustments.

The results from flow sweeps which were conducted during tests were used to develop semi-empirical equations based on Indian Point specific conditions, as discussed above. Boreholes and/or differential pressure induced effects are most likely to occur during the flow sweeps due to the high velocities, and consequently high head losses, present. Therefore, any debris-bed morphology effects are inherently included in the head loss corrections [Ref. 28] and are less likely to form at the lower design flow rates. It should be noted that boreholes were not observed during post test inspection of the Indian Point debris beds.

Entergy Response to Issue 3f.14:

Common to both units

The void fraction analyses (which includes flashing/deaeration) [Refs. 26 and 27] contain the complete methodology used to calculate the volume of air bubbles and associated water vapor (steam voids) present in the water downstream of the strainer surface. The NRC SER [Ref. 3] suggests a maximum void fraction of 3% to prevent cavitation problems within the sump pumps. Containment accident pressure was credited in evaluating the extent of flashing across the strainer surface. The results show that at times up to 10,000,000 seconds (115.74 days) after an accident, the containment pressure is always higher than the vapor pressure at the corresponding sump temperature. Therefore, flashing will not occur at the surface of the containment pool.

The Void Fraction Calculations also reported the lowest containment pressure that would result in a void fraction less than 3% for various times up to 10,000,000 seconds after an accident. The results are shown in the figures below as the solid lines. It was verified that even these low containment pressure limits are well above the vapor pressure at the corresponding sump temperature [Refs. 26 and 27]. Therefore the margins in the containment pressure to prevent flashing from occurring are bigger than the pressure margin available for maintaining void fractions lower than 3% as shown in the figures below.

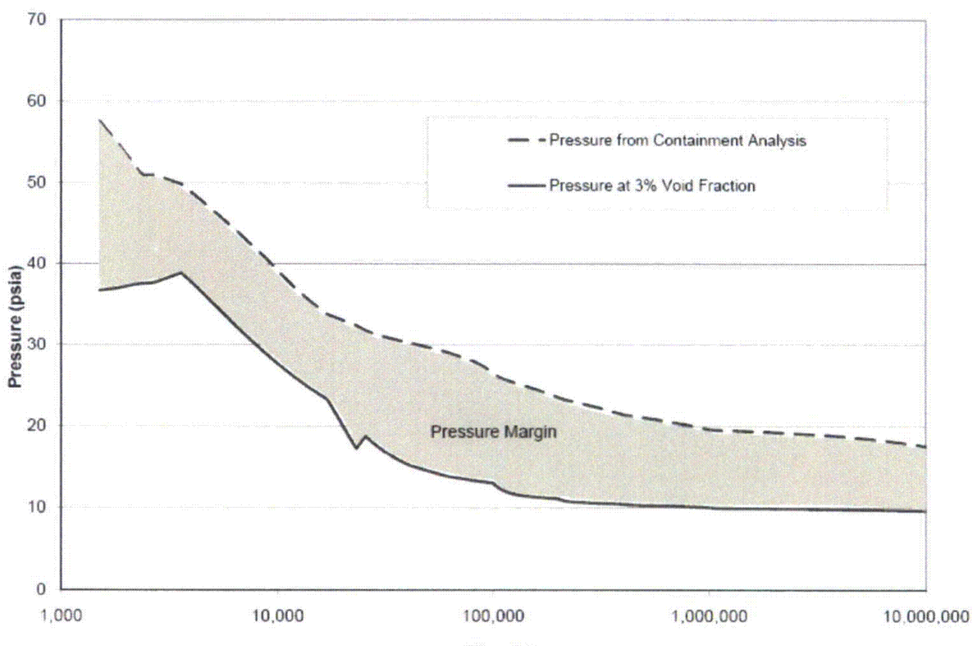

Figure 3f.14-1:
Calculated pressure margin in the containment pressure to maintain an acceptable void fraction (< 3%) in the IP-2 IR sump.

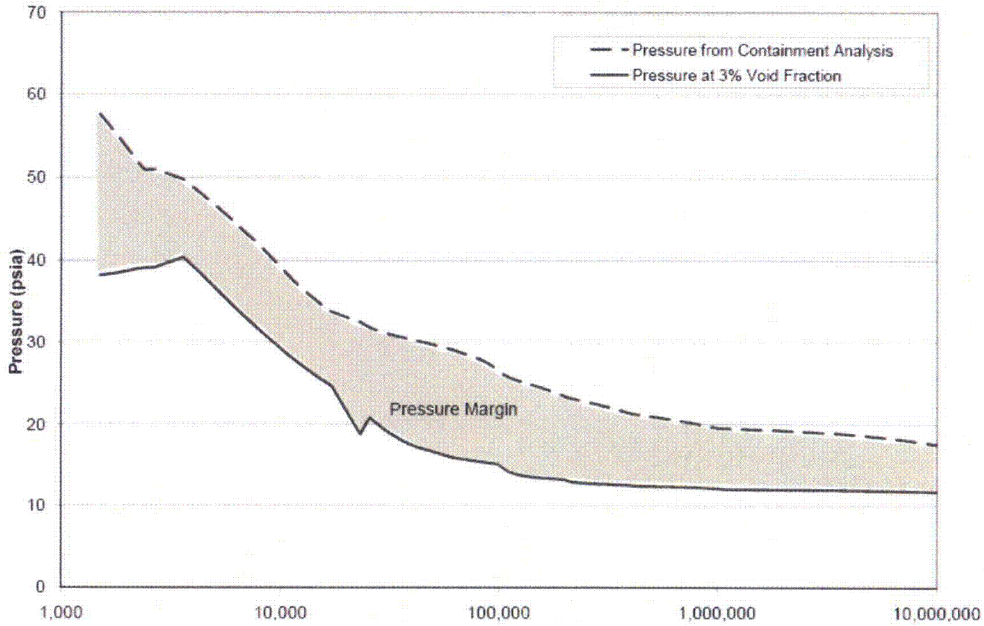

Figure 3f.14-2:
Calculated pressure margin in the containment pressure to maintain an acceptable void fraction (< 3%) in the IP-2 VC sump.

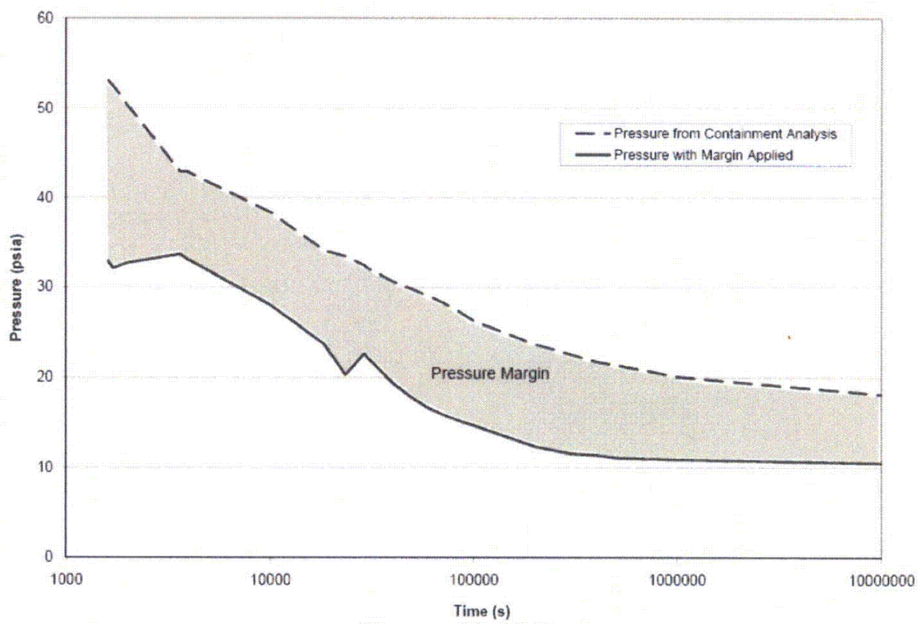

Figure 3f.14-3:
Calculated pressure margin in the containment pressure to maintain an acceptable void fraction (< 3%) in the IP-3 IR sump.

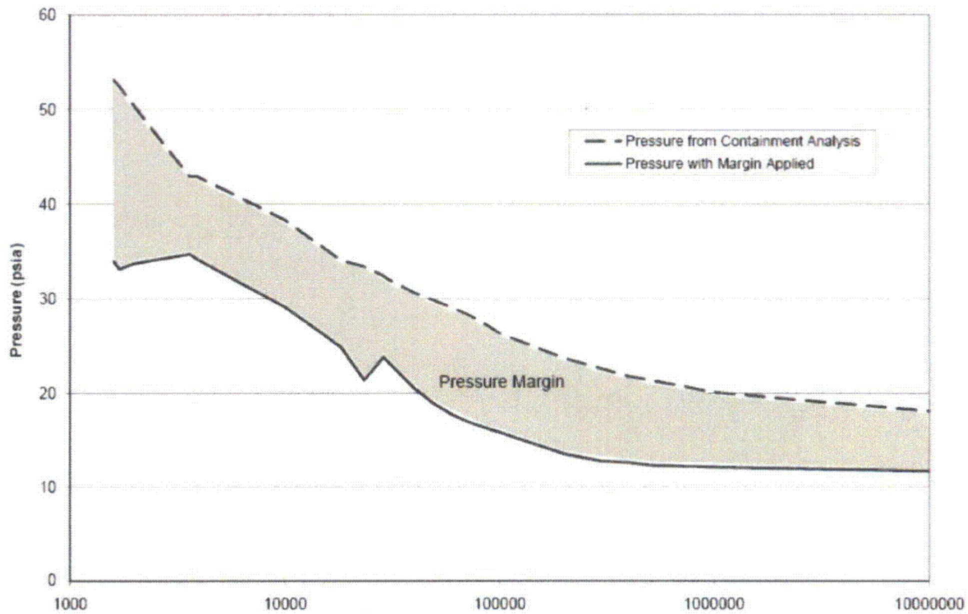

Figure 3f.14-4:
Calculated pressure margin in the containment pressure to maintain an acceptable void fraction (< 3%) in the IP-3 VC sump.

NRC RAIs 5, 7, 8, 9, 10, 11, 12, 13, and 14 concern Head Loss and Vortexing, the subject of the current NRC Item (3f). The RAIs were identified in an NRC letter to Entergy, dated November 19, 2007 [Ref. 119]. The response to RAI 5 is provided below. Responses to the other RAIs may be found in Attachment 3.

RAI 5:

The licensee plans to credit time-dependent debris transport for qualification of the VC sump. The licensee should provide adequate technical justification to demonstrate that the time-dependent model is conservative, considering the issues raised in Section 3.5.4.6 of the audit report (ADAMS Accession No. ML082050446). The areas that require justification in connection with the time-dependent debris transport for qualification of the VC sump are blowdown, pool fill, and washdown transport directly to the VC sump, erosion of debris, IR strainer filtering efficiency, potential release of material from the IR strainer when the pumps are secured, potential delay of transport to the VC sump strainer due to flotation, and the formation of chemical precipitates. (Audit Open Item)

Response to RAI 5:

The IP2 and IP3 Debris Transport Calculations [Refs. 41 and 42] were revised to include an appendix that provides additional justification for the conservative nature of the time-dependent model. The response below is based on Appendix 7 of the IP3 Debris Transport Calculation [Ref. 42]. Appendix 6 of the IP2 Debris Transport Calculation [Ref. 41] is similar except where unit specific volumes and flow rates are used. All references have been updated to correspond with this document.

Based on APPENDIX 7 of IP3 Debris Transport [Ref. 42]:

This appendix contains additional information to justify the transient recirculation debris transport during 24-hour IR sump operation in response to an additional open item identified by the NRC after the IP-3 GSI-191 audit.

Among the most significant approximations made by the licensee which are either inadequately justified or non-conservative with respect to the design of the VC sump are the following:

1. Washdown of debris into the containment pool would be completed prior to the switchover to containment sump recirculation. In fact, a significant fraction of washdown is expected to occur after switchover.
2. Essentially all erosion of fibrous debris in containment would cease after 24 hours, and the vast majority of the eroded fines would erode and transport very quickly. While erosion rates have been demonstrated to decrease with time, the staff has not seen evidence that they reach zero after 24 hours. In addition, gradual blockage at debris interceptor barriers in containment and the assumed transfer from the IR sump to the VC sump after 24 hours may cause changes in the containment pool flow pattern. As a result of the changing flow pattern in the pool, some debris formerly exposed to low velocities may be exposed to increased velocities, which could temporarily increase local erosion rates.
3. The IR sump strainer has a capture efficiency of 100% for fine debris. Although, based on the design of the downstream filters, a high capture efficiency is expected for all fibrous debris other than fine, short strands, prior to the formation of a contiguous debris bed on the IR sump strainer, the filtration efficiency for fine particulate debris would be expected to be significantly less than 100%.
4. Securing the IR pumps after 24 hours of IR sump operation would not temporarily result in reverse flow through the strainer or the release of trapped gas that could cause some of the debris accumulated on the strainers to be resuspended in the containment pool. Although, as a result of its location in a pit, it is unlikely that reverse flow or trapped air could cause major quantities of debris to be resuspended in the containment pool, it is not clear that this effect is negligible.
5. Floatation would not significantly delay the progress of debris sinking in the containment pool. Any debris that is floating will be delayed in transporting to the sump strainers or being eroded. Such delays would increase the quantity of debris remaining in the containment pool after 24 hours of IR sump operation, which would subsequently be available for transport to the VC sump.
6. Pool-fill and blowdown transport would not result in any debris being transported directly to the VC sump. As discussed above in Sections 3.5.1 and 3.5.3, transport to the VC sump through these two mechanisms was neglected for cases that did not include time dependent modeling, which the staff considered acceptable based in part on other conservatisms associated with those cases. However, those conservatisms do not apply to the time-dependent modeling of the VC sump. Although pool-fill and blowdown transport percentages to the VC sump are not expected to be large, the licensee did not provide sufficient information to justify zero transport.
7. No chemical precipitates would accumulate on the debris bed covering the IR sump strainers within 24 hours of the LOCA. The licensee's analysis did not include any discussion of the formation and accumulation of chemical precipitates in the debris bed. If chemical precipitates were to accumulate in the debris bed within the first 24 hours of the LOCA or soon thereafter, it is not clear that the licensee's time-dependent analysis for the VC sump would be valid.

Background

For an accident scenario where the IR sump strainer is operated for 24 hours before recirculation flow is switched over to the VC sump strainer, a large portion of the transportable debris in the recirculation pool would be transported to the IR sump and therefore would not be available for transport to the VC sump. In the IP3 debris transport calculation, the fraction of debris that would be transported to the IR sump was calculated based on the number of pool turnovers that would occur in 24 hours. This analysis conservatively used the maximum pool volume and minimum sump flow rate since these parameters give the longest pool turnover time and would result in the lowest quantity of debris transporting to the IR sump during this period (leaving more debris available to transport to the VC sump). Note that the pool turnover approach is appropriate for fine debris that is in the pool at the beginning of recirculation and is readily transported. However, other factors must be considered for transportable debris that does not meet these criteria, including the following:

- Debris in upper containment that is washed down by the containment sprays (which may not wash down immediately)
- Small pieces of fiberglass (which would not transport as quickly as the fine debris)
- Unqualified paint chips both in the pool and washed down from upper containment (which could fail at some time later in the event and would also not transport as quickly as the fine debris)
- Fines generated due to the erosion of the unjacketed fiberglass and Cal-Sil/Asbestos debris (which could occur gradually)

The delayed transport for debris washed down from upper containment, small pieces of fiberglass in the pool, and fines generated due to erosion were determined to have only a small impact in reducing the transport to the IR sump during the first 24 hours [see Section 5.13 of Ref. 42]. Therefore, the transport fraction to the IR sump for the transportable debris generated inside the ZOI was decreased from 99% to 95% to account for the potentially slower transport of some of the debris [see Section 5.14.3 of Ref. 42]. Since erosion testing indicates that the majority of Cal-Sil and Asbestos erosion could occur after 24 hours, the transport fraction for Cal-Sil/Asbestos erosion fines to the IR sump was conservatively assumed to be 0% [see Section 5.14.3 of Ref. 42]. Also, since the unqualified coatings could potentially fail later in the event (after 24 hours), the transport fraction for the unqualified coatings to the IR sump was conservatively assumed to be 0% [see Section 5.14.3 of Ref. 42].

At the time of the NRC's onsite audit of the IP-3 GSI-191 analyses conducted from December 3, 2007 through December 6, 2007, Entergy was not planning to implement the pool turnover methodology. Therefore, the NRC staff did not review the methodology in detail at that time. After the audit, however, when Entergy identified that they may need to implement the pool turnover methodology after all, the NRC reviewed it and identified seven potential areas of concern. These concerns are addressed in the following analysis.

Item 1: Washdown Occurring Later in the Event

NUREG/CR-6369 states that based on visual observation during containment spray washdown testing for small pieces of fiberglass retained on grating, the majority of the washdown occurred within the first 15 minutes. Fine debris can be expected to washdown even faster since it is more readily transportable.

The minimum volume of water injected from the RWST prior to switchover to recirculation is

204,216 gal [Ref. 34]. Using the maximum injection phase spray flow rate of 5,590 gpm [Ref. 120], along with the maximum injection phase 2 pump RHR flow of 6,045 gpm and 3 pump HHSI flow of 1,435 gpm [Ref. 74], the maximum total RWST drawdown flow rate would be 13,070 gpm. This gives a total time to the beginning of recirculation of 15.6 minutes. Since most debris would be washed down in 15 minutes, it is reasonable to assume that essentially all fine debris and the majority of small fiberglass debris washed down from upper containment would reach the pool prior to the beginning of recirculation. Note, however, that even if it takes up to 4 hours for some of the debris to wash down from upper containment, that would still leave 20 hours of IR sump operation. Editing Equation 25 and Equation 26 [Section 5.13 of Ref. 42] with a start time at 4 hours yields the fraction of debris remaining in the pool at the time of switchover to VC sump operation.

Fraction of debris remaining in the pool after 5.5 hours:

$$x(t_{4-5.5hr}) = 1.0 \cdot \exp\left[-\frac{1.5\text{hr} \cdot 60\frac{\text{min}}{\text{hr}} \cdot 1{,}402\text{gpm} \cdot 0.1337\frac{\text{ft}^3}{\text{gal}}}{49{,}998\ \text{ft}^3}\right] = 0.714 \qquad \text{Equation 25}$$

Fraction of debris remaining in the pool after 24 hours:

$$x(t_{5.5-24hr}) = 0.714 \cdot \exp\left[-\frac{18.5\text{hr} \cdot 60\frac{\text{min}}{\text{hr}} \cdot 1{,}000\text{gpm} \cdot 0.1337\frac{\text{ft}^3}{\text{gal}}}{49{,}998\ \text{ft}^3}\right] = 0.037 \qquad \text{Equation 26}$$

Since the original analysis, based on a wash down time of 15 minutes, showed that the fraction debris remaining in the pool following 24 hours would be 0.01 [Ref. 42], a delay in the washdown for fine debris of up to 4 hours after the beginning of recirculation would only slightly increase the fraction transported to the VC sump to 0.037. Note also that if the small pieces of fiberglass are washed down after the switchover to recirculation, the transport fraction to the VC sump would not be significantly increased since the pieces washed down inside the crane wall would not transport through the tunnel, and the pool velocities are low enough during VC sump operation that only a small portion of the fiberglass washed down in the annulus could potentially transport to the VC sump [see Figure 5.9.27 of the Ref. 42].

Note also that although it is conservatively assumed in the Indian Point debris transport analysis that sprays would operate for the entire mission time, based on plant procedures the containment sprays would be secured after 4 hours as long as the containment pressure is lower than 16 psig or the containment fan cooler units are operating [Ref. 121]. Any debris that is in upper containment after the sprays are secured is expected to remain in upper containment, and would not transport to the VC sump.

Item 2: Fiberglass Erosion Occurring Later in the Event

Testing was performed to determine the erosion rate for pieces of fiberglass debris submerged in the recirculation pool [Ref. 122]. This testing showed that the majority of erosion occurs within the first 24 hours. Also, as shown in Figure 3f.15-1, the erosion rate decreases over time. The highest percentage of erosion fines are generated early in the event (within approximately 4 hours), and would have time to transport almost completely to the IR sump. Even the very small quantity of erosion fines generated at approximately 20 hours would still have a transport fraction of roughly 50% to the IR sump during the 4 hours prior to switchover to VC sump operation, as shown in the following equation:

$$x(t_{20-24hr}) = 1.0 \cdot \exp\left[-\frac{4\text{hr} \cdot 60\frac{\text{min}}{\text{hr}} \cdot 1{,}000\text{gpm} \cdot 0.1337\frac{\text{ft}^3}{\text{gal}}}{49{,}998\,\text{ft}^3} \right] = 0.526 \qquad \text{Equation 7-3}$$

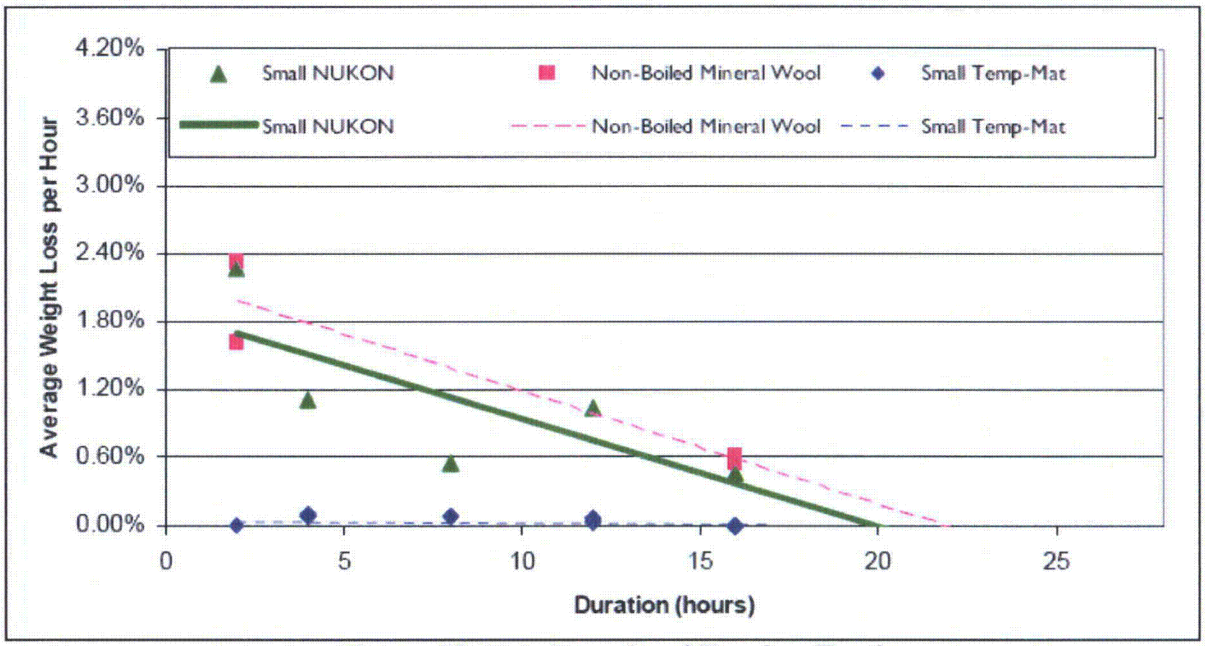

Figure 3f.15-1: Results of Erosion Testing

It is possible that flow patterns will change somewhat during the course of the event as debris accumulates on the flow barriers and redirects flow through the tunnel. However, based on the velocity vectors, shown in Figures 3f.15-2 and 3f.15-3 below, the fraction of debris that is exposed to low flow conditions initially and later exposed to higher flows is judged to be negligible. Note also that if the flow velocity exceeds the tumbling velocity of the debris, the entire piece of debris would be transported to a lower velocity region. The CFD run for the IR sump, based on a maximum total sump flow rate of 7,100 gpm, shows that a significant portion of the pool inside the crane wall would have relatively high velocity, resulting in the majority of debris transporting to the reactor cavity. Additionally, the majority of area outside the crane wall would have a velocity sufficient to transport small pieces to the sump. The CFD run for the VC sump, based on a maximum total sump flow rate of 3,700 gpm, shows that the velocities and flow patterns inside the crane wall are very similar to the IR sump run. The almost identical flow fields inside the crane wall are expected because the fluid in both cases is flowing from the break to the reactor cavity entrance. The flow patterns in the reactor cavity and tunnel, where the majority of erodible debris will be located, will be very similar due to the flow entrance and exit are not dependent on which sump is operating. The fluid velocities in the reactor cavity and tunnel will be reduced because of the much lower flow rate during VC sump operation. Meanwhile, the velocities outside the crane wall (as indicated by less red colored area in Figure 3f.15-3) will be much less during VC sump operation, but this is inconsequential because essentially all of the erodible debris would have already transported to the IR sump. It is important to note that the velocities for the VC sump will be significantly less than shown in Figure 3f.15-3 because the flow rates after the switch from IR sump to VC sump operation will be less than 1,350 gpm, compared to the 3,700 gpm used to develop the figure. In conclusion, the velocity vectors show that there is not a significant change in containment pool flow pattern, and velocities are reduced after switchover from IR sump operation to VC sump operation. Therefore, any additional erosion of the insulation after 24 hours is unlikely.

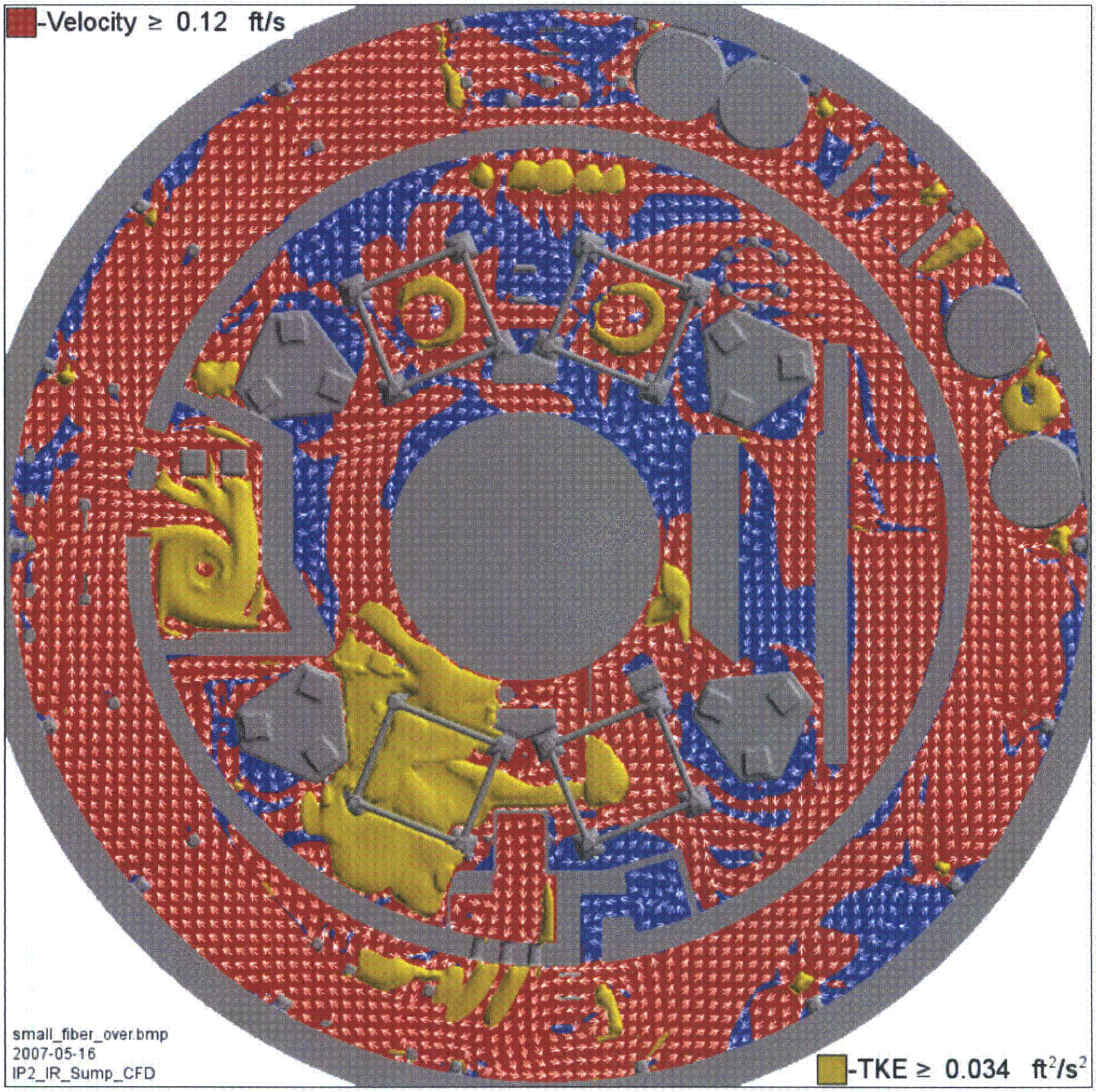

Figure 3f.15-2: TKE and velocity with limits set at suspension/tumbling of small pieces of fiberglass in the pool (IR sump run). Note: red or yellow shading indicates an area where debris will transport.

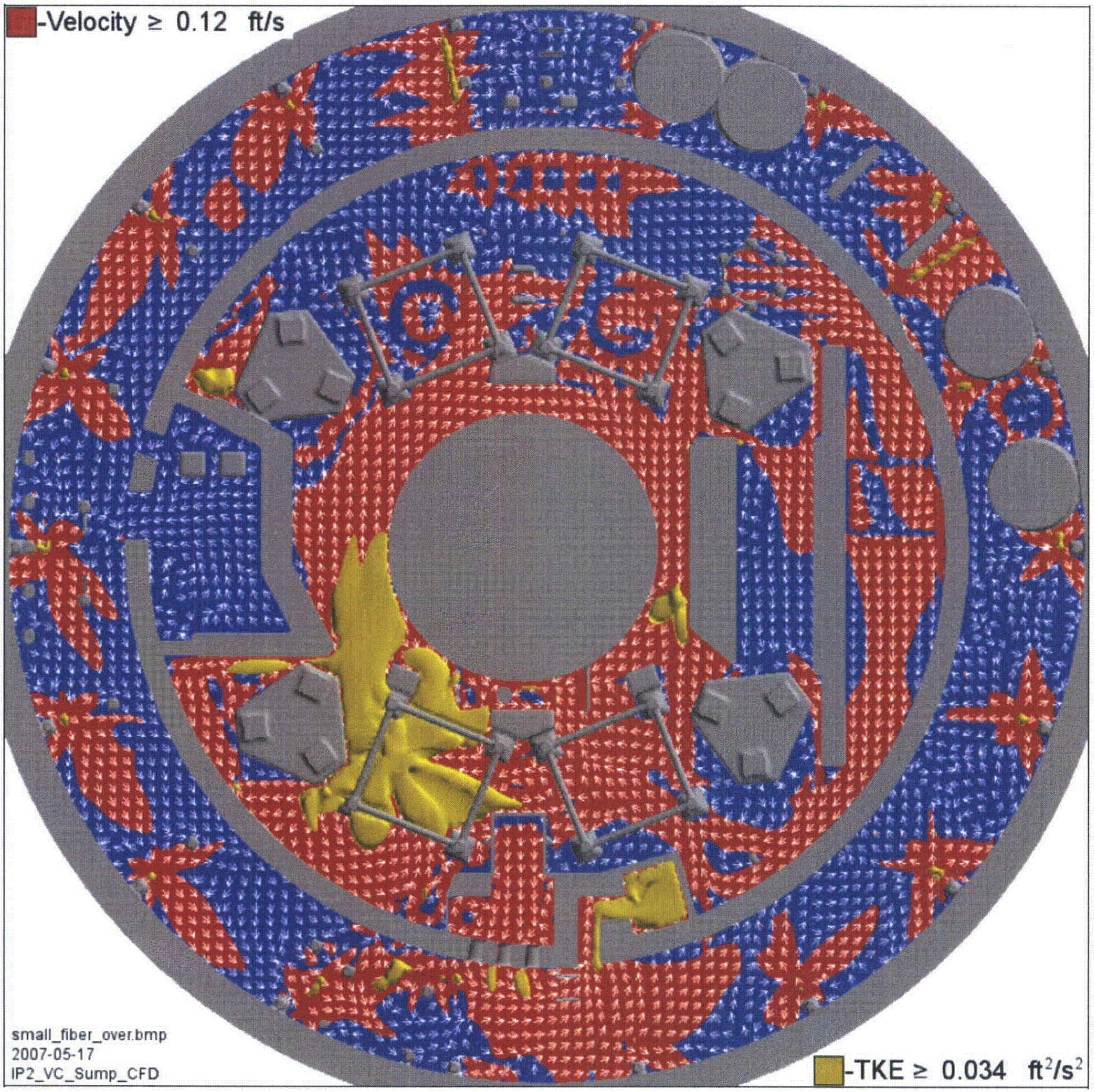

Figure 3f.15-3: TKE and velocity with limits set at suspension/tumbling of small pieces of fiberglass in the pool (VC sump run). Note: red or yellow shading indicates an area where debris will transport.

Item 3: IR Sump Strainer Debris Capture Efficiency

The replacement strainers designed for Indian Point were Enercon's Double Top-Hat strainers with bypass eliminators installed. The bypass eliminators significantly reduce the quantity of fiberglass debris that can be washed through the strainers. Debris bypass testing has been performed for these strainers. The results of the testing showed that the fiber bypass would be only 2.84 lb_m/1000 ft^2 [Ref. 84], at a bounding average approach velocity for IP2 and IP3 (0.0058 ft/s). Since the IR sump strainer at IP-3 has a net screen area of 3,156 ft^2 [Ref. 25], the fiberglass debris bypass would be equivalent to approximately 9 lb_m[4,5]. However, bypass test data is not available for the particulate debris. All un-qualified coatings (outside the ZOI) and all fines due to erosion of Cal-Sil/Asbestos are not included in the time-dependent debris transport analysis and are not assumed to be depleted by the IR sump [Refs. 41 and 42]. As the strainer loads with debris, the capture efficiency of the strainer will increase, and the fiberglass will filter out the qualified coatings and dirt/dust particulate that is present at the beginning of an event; this will reduce the amount of qualified coatings and dirt/dust particulate in the sump pool. In the Indian Point testing, the water in the tank was observed to clear up as particulate collected on the strainer. This was also shown by the decrease in measured turbidity in the IP-3 tests [Ref. 37][6]. As discussed in Response to RAI 1, the limiting break has 2,121 lb_m of Nukon™ and fiberglass generated where 15% (approximately 320 lb_m) of the fiberglass debris is fines. As shown in Figure 5.13.1 of the Debris Transport Calculation [Ref. 42], after 4 hours of IR sump operation, approximately 80% (260 lb_m) of this debris would transport to the strainer (neglecting the transport of small pieces of fiberglass, fiberglass erosion fines, and the mineral wool and Temp- Mat fiberglass debris). Using a density of 2.4 lb_m/ft^3, 260 lb_m gives an equivalent debris bed thickness of almost ½ inch on the IR sump strainer. Indian Point's prototypical testing demonstrated that only 0.31 inches (8.55 lb_m in test) is required to fully cover the screen area so that the debris bed can effectively filter most of the particulate debris [Ref. 37]. Most of the fiberglass and particulate debris that bypasses the strainer and circulates back into the recirculation pool before this debris bed forms would still have sufficient time to transport back to the IR sump before switchover to VC sump operation occurs (see Equation 5-1).

Item 4: Resuspension of Accumulated Debris when IR Sump Pumps are Secured

In the head loss testing for Indian Point Units 2 and 3 [Ref. 37], very little debris bed movement was observed when the pumps were secured. Note that there are check valves in close proximity to the recirculation pumps at both units that would prevent reverse flow into the strainers [Refs. 123 and 124]. As fiberglass and particulate debris accumulates on the strainer it agglomerates into a thick debris bed that would not be easily broken back down into the individual constituents of fibers and particles that could be subsequently transported to the VC sump. Also, debris on the IR sump strainer would not easily transport to the VC sump since the IR strainer is located in a pit, and the pit is enclosed within the IR sump room. As shown in Figure 3f.15-3, the pool velocities in the IR sump room are very low during VC sump operation. Figure 3f.15-4 shows that the turbulence in the middle of the IR sump room, in the area of the strainer, is insufficient to suspend individual fibers. When you consider the turbulence values in Figure 3f.15-4 are based on a flow rate of 3,700 gpm compared to an actual flow rate of less than 1350 gpm after 24 hours, it indicates that even individual fibers released as the pump is shut down would settle back into the pit, rather than transport to the VC sump. As shown in Figure 3f.15-4, the IR and VC sumps are roughly 90 degrees apart in containment, and the VC sump entrance is adjacent to the flow path from inside the crane wall (in-core instrumentation tunnel exit). Therefore, the majority of the flow will not pass by the IR sump to draw any debris out of the IR room.

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[4] Note that given a net area of 3,156 ft^2 and a sump flow rate of 5,400 gpm, the average approach velocity would be 0.004 ft/s, which is bounded by the approach velocity used in the bypass testing.
[5] Taking the limiting break case discussed in Appendix 6, and the transport results in Section 6, the overall transport of Nukon and fiberglass at the end of the IR sump operation is 2,121 $lb_m \cdot (15\%_{fines}\ 95\%_{24\,hr} \cdot 100\%_{IR\,transport} + 54\%_{small} \cdot 95\%_{24\,hr} \cdot 13\%_{IR\,transport} + 15\%_{large} \cdot 95\%_{24\,hr} \cdot 10\%_{IR\,transport} + 16\%_{intact} \cdot 95\%_{24\,hr} \cdot 0\%_{IR\,transport}) = 474\ lb_m$. Since only 9 lbm would bypass the strainer, this gives an overall fiberglass capture efficiency of 98%. Note that this is a conservative estimate of the capture efficiency since it excludes the mineral wool and Temp-Mat fiberglass.
[6] Note that turbidity was not measured in the IP-2 testing.

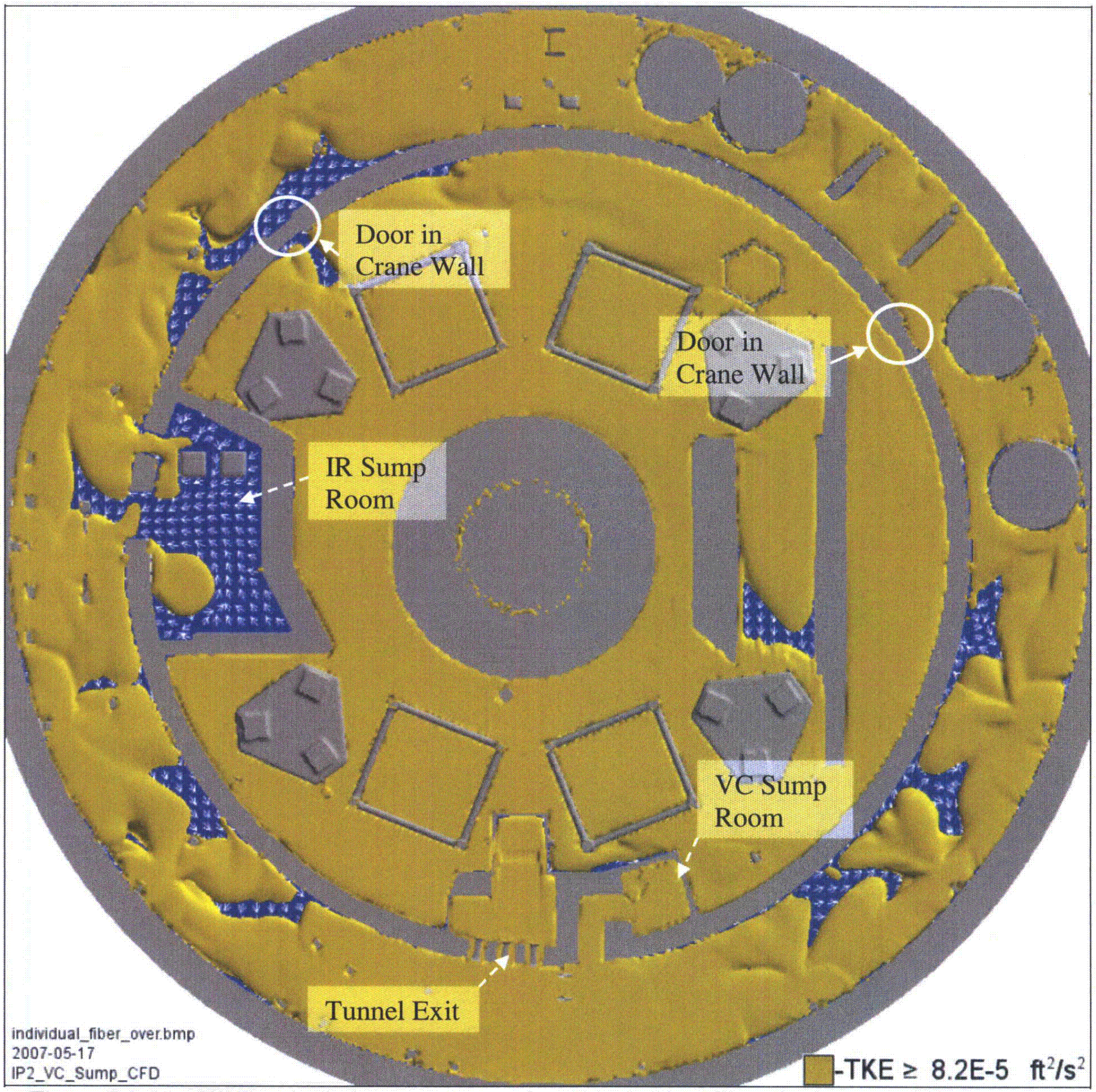


Figure 3f.15-4: TKE with limits set at suspension of individual fibers in the pool (VC sump run)

Item 5: Reduction in Transport to IR Sump Due to Debris Floatation

In the Indian Point Debris Transport Analyses [Refs. 41 and 42], pieces of mineral wool and Temp-Mat were conservatively assumed to float in the recirculation pool. These debris types have been observed to initially float when placed in water since they are higher density than Nukon™, which inhibits water from being as readily absorbed. Mineral wool is not predicted to be destroyed in IP2, and it represents a very small fraction (~1.2%) of the total debris load in IP3 [Refs. 1 and 2]. During the "VUEZ" testing, debris was observed to float during introduction to the chemical test loops. This was resolved by baking the Temp-Mat for a relatively short period of time. The result was debris that quickly became submerged and formed a debris bed in the loops [Ref. 125]. Since the insulation in Indian Point's containment that has been destroyed has been in contact with reasonably hot pipes for a period of time and the resulting LOCA generates a pool of near boiling water with considerable agitation (Note also that the initial break flow and spray flow would tend to saturate the pieces of debris), it is expected that the small pieces and many of the large pieces of Temp-Mat would sink early in the event. Testing, documented in NUREG/CR-6808, has shown that only large, jacketed pieces of fiberglass float for an extended period of time. However, this size of fiberglass debris is not subject to erosion [Ref. 3]. Small pieces of fibrous debris also absorb water and sink more quickly than large pieces due to the higher surface area to volume ratio of the small pieces. The NUREG/CR-6808 testing showed that small and large pieces of fiberglass insulation readily absorb water at 120°F and sink in 20 – 30 seconds. This is a conservative floatation time since the sump pool is at much higher temperatures that promote sinking due to the reduced viscosity and enhanced absorption of hot water. Therefore, all fiberglass debris which is subject to erosion at Indian Point would likely sink in the containment pool, before recirculation begins.

The erosion of large pieces of mineral wool and Temp-Mat due to debris floatation is expected to be minimal. The negligible amount of floating debris pieces would transport with the flow of water until they reach a stagnant region of the pool or a higher flow velocity area where they can no longer transport horizontally (e.g. the entrance to the incore instrumentation tunnel—since the flow entering the tunnel is vertical, and pieces of floating debris would only transport horizontally, floating debris would remain on the surface of the pool above the tunnel entrance). The transport time for these large pieces would be significantly less than 24 hours since floating debris would transport at essentially the same velocity as the water. The pieces that transport to a stagnant region of the pool would not be likely to experience any significant erosion after sinking given the low flow velocities in those locations. In contrast, the pieces that transport to a higher velocity area would likely be eroded by the flowing water in similar amounts and on a similar time scale as pieces submerged in the pool. Debris erosion is based on maximum sump flow rates early in the event. Indian Point is procedurally driven to shut off sprays and switch to the HHSI pumps at or before 6.5 hours [Ref. 126]. This significantly reduces the sump flow rates to less than 1,350 gpm, which would also reduce the erosion during VC sump operation. The reduced flow rate validates the assumption that negligible erosion occurs during VC sump operation.

Since floating debris was determined not to transport through the in-core instrumentation tunnel [see Section 5.12 of Reference 42], the only pieces of mineral wool and Temp-Mat that could transport to either strainer would be the small pieces washed down to the annulus from upper containment. These pieces would be soaked by the containment sprays in addition to the factors discussed previously. While the amount of mineral wool is negligible, the small pieces of Temp-Mat washing down in the annulus would sink within minutes (see test data above) and accumulate on the IR sump strainer during the 24 hours of IR sump operation similar to the small pieces of low density fiberglass.

<u>Item 6: Transport Directly to the VC Sump During the Blowdown and Pool Fill-up Phases</u>

The Debris Transport analysis performed for the blowdown phase assumes a uniform distribution of debris due to the chaotic blowdown flow and pressure wave. It is reasonable to assume that the sump pit rooms are not a preferential location for debris to accumulate during the blowdown phase considering that the containment building is relatively open. Approximately 30% of the area above the RCS piping is open to upper containment. Additionally, both sumps are surrounded by flow barriers that prevent the transport of small and large debris, and there are two openings in the crane wall in the IR sump room and one door in the VC sump flow barrier enclosure that allow the blowdown flow to exit the sump rooms. There are also two additional openings through the crane wall on the 46 foot elevation (see Figure 3f.15-4). Therefore the blowdown phase debris distribution was based on the relative containment volumes, which indicates that a negligible quantity of debris would be transported to the vicinity of the VC sump.

The entrance to the IR and VC sump pits are located on the 46-foot elevation. The flow of water from a LOCA is first directed into the reactor cavity, below the 46-foot elevation, where debris will most likely settle. The water must travel up through the in-core instrumentation tunnel, outside the crane wall, and to the sumps. Therefore, the reactor cavity and tunnel are filled first during the pool fill-up phase of an accident. The volume of the VC sump pit (conservatively neglecting the strainer and strainer support structures) is only 496 ft^3 (8'×8'×7'9") [Ref. 127] versus the combined volume of 12,642 ft^3 for the reactor cavity and tunnel [Ref. 34]. Although some fine debris could be transported to the VC sump during the initial pool fill-up period, the pit volume is small (~4%) compared to the volume below the 46 foot elevation, which results in a low transport fraction of the fine debris in the pool to the pit. Also, the VC sump and IR sump cavities would be filled simultaneously early in the event [see Section 5.6 of Ref. 42]. At this time, a large percentage of the fine debris would be in upper containment, so the fraction of fines in the pool that are available to transport to the VC sump and IR sump during the pool fill-up phase is small. Before recirculation begins, the total pool volume increases to at least 26,078 ft^3 [Ref. 34] so that the pit volume is only 2% of the total. Since the fraction of fines available to transport to the VC sump during pool fill-up is small, the ratio of cavity volume to pool volume is small, and the pool fill-up debris transport would be split between the IR and VC sumps, the overall transport to the VC sump during pool fill-up would be negligible.

Item 7: Formation of Chemical Precipitants in the IR Sump Strainer Debris Bed

The accumulation of debris on the IR sump strainer is determined using flow requirements that as a minimum must be met in order to qualify the IR strainer. Therefore, debris accumulation is conservatively modeled as if the IR strainer is qualified. Since the IR sump strainer must be qualified to handle the full debris loads including chemical precipitants over the entire mission time, the formation of chemical precipitants in the IR strainer debris bed during the first 24 hours is irrelevant to the transient debris transport analysis and subsequent transport of debris to the VC sump.

Conclusions

Based on this analysis, the relative effect of each area of concern identified by the NRC is quite small. Using very conservative inputs of minimum flow rates and a maximum pool volume for the transient debris transport analysis, it was calculated that a fraction of only 0.007 (0.7%) [IP2: 0.005 (0.5%)] of the debris in the recirculation pool would remain in the pool at the end of 24 hours [see Section 5.13 of Reference 42]. If the pool volume is lower or the flow rate is higher, this fraction would be reduced even more. However, to take into account the uncertainties in transient debris transport, the transport fraction to the VC sump was conservatively increased from 0.7% to 5% [IP2: 0.5% to 5%] for the majority of debris generated inside the ZOI, 100% for the Cal-Sil and Asbestos fines generated due to erosion, and 100% for unqualified coatings outside the ZOI [see Section 5.14.3 of Reference 42]. Some of the 7 items in this RAI were justified as having a small impact, while others were non-quantifiable (but essentially negligible). Therefore, it is judged that the cumulative effects of the 7 items are enveloped by the 5% transport fraction to the VC sump.

The VC sump has also been qualified to maintain adequate NPSH for a 6 inch break conventional debris load [Ref. 40]. This is important because it demonstrates that the time dependent debris transport cases have significant margin which compensates for any uncertainties remaining in the seven items discussed above. The 6 inch fibrous debris loads are equivalent to raising the time-dependent transport fraction of fine fibrous debris to 15% for IP-2 and 21% for IP-3 (from 5% in both units). The 6 inch breaks contain more particulate debris at the sump which is equivalent to raising the time dependent transport fractions Cal-Sil and coatings between 2% to 6%. The latent dirt and dust mass is the equal for all breaks, but the 6 inch breaks assume a transport of 100% compared to the 5% assumption for the time dependent transport cases. This information demonstrates that the conventional debris transport fractions could be increased beyond the assumed 5% (to 15% for IP-2 and 21% for IP-3) without challenging the NPSH margin. (It should be noted that the time dependent debris transport cases have a higher precipitate load because of the LBLOCA debris amounts that are subjected to the sump fluid. The VC sump has not been shown to maintain adequate NPSH margin with a combination of a 6 inch conventional debris load and the LBLOCA chemical precipitate quantities.) Indian Point's prototypical array testing also demonstrated that significant clean screen remained for the time-dependent transport cases such that doubling the amount of fibrous debris would likely have an insignificant effect on head loss [Ref. 37].

<u>USNRC Question 3g:</u>

Net Positive Suction Head (NPSH)
The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a loss-of-coolant accident (LOCA) considering a spectrum of break sizes.

1. *Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.*
2. *Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.*
3. *Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion.*
4. *Describe how friction and other flow losses are accounted for.*
5. *Describe the system response scenarios for LB LOCA and SB LOCAs.*
6. *Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.*
7. *Describe the single failure assumptions relevant to pump operation and sump performance.*
8. *Describe how the containment sump water level is determined.*
9. *Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*
10. *Describe whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why.*
11. *Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*
12. *Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.*
13. *If credit is taken for containment accident pressure in determining available NPSH, provide description of the calculation of containment accident pressure used in determining the available NPSH.*
14. *Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.*
15. *Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.*

16. Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.

Entergy Response to Issue 3g.1:

Unit 2

Pump and Sump Flow Rates

The sump flow rates were determined in the Westinghouse 106 Calculation [Ref. 35] for Indian Point Unit 2 under various flow configurations. The following table shows the various cases examined in Ref. 35 for both the IR sump and VC sump. Note that the miniflow line flow rates are included in the IR sump flow rates, but are excluded from the VC sump flow rates in the following tables. Also, note that the Hot-Leg Recirculation alignment flow rate will always be less than the analyzed High Head Safety Injection (HHSI) maximum system flow (1350 gpm).

Table 3g.1-1:
IP-2 NPSH Determination

Sump	Alignment	Pumps	Sump Flow Rate *Q* (gpm)
IR	Start of Recirculation	1 Pump (1 RHR-HX)	3127
IR	Start of Recirculation	2 Pumps (2 RHR-HXs)	5565
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (1 RHR-HX)	5115
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (2 RHR-HXs)	6615
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3984
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (2 RHR-HXs)	7086
IR	HHSI – max	2 Pumps	1350
VC	Start of Recirculation	1 Pump (1 RHR-HX)	2835
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3528
VC	HHSI – max	2 Pumps	1350

In addition to the NPSH margin cases shown above, the minimum flow performance cases were also examined. The purpose of evaluating the minimum flow cases is to ensure that the strainer head loss does not reduce the pump flow rate below the minimum performance required for accident mitigation. The cases are summarized below.

Table 3g.1-2:
IP-2 Minimum Performance

Sump	Alignment	Pumps	Sump Flow Rate *Q* (gpm)
IR	Start of Recirculation	1 Pump (1 RHR-HX)	2452
IR	Full Recirculation (with Recirculation Spray)	1 Pump	3568

		(1 RHR-HX)	
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3568
IR	HHSI-min	2 Pumps	1350
VC	Start of Recirculation	1 Pump (1 RHR-HX)	2198
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3221
VC	HHSI-min	2 Pumps	1350

Minimum Water Level

The minimum water levels for various accident scenarios were determined in the Indian Point Unit 2 Water Level Calculation [Ref. 33]. The following table summarizes the results of this calculation. A summary of key assumptions can be found in the response to the Issue 3g.9.

Table 3g.1-3:
IP-2 Post-LOCA Containment Water Level Results

Break Location	Case	Water Level (feet EL.)
Large Break Loss-of Coolant Accident Double-Ended Pump Suction Break	At Start of SI Recirculation	48.04
	At Start of Recirculation Spray	48.87
	After Recirculation Spray is Secured	48.23
	End-of-Event	48.35
Large Break Loss-of-Coolant Accident Double-Ended Pressurizer Surge Line Break	At Start of SI Recirculation	47.87
	At Start of Recirculation Spray	48.69
	After Recirculation Spray is Secured	48.40
Small Break Loss-of-Coolant Accident	At Start of SI Recirculation – No Sprays	47.78
	End-of-Event – No Sprays	47.69
	At Start of SI Recirculation – Sprays	47.54
	At Start of Recirculation Spray	48.37

Sump Temperature

In the strainer certification assessments, conventional debris head losses are corrected to a sump temperature of 204.7°F when compared to the NPSH [Ref. 40] since at this temperature, the NPSHa (and therefore the NPSH margin) reaches a minimum. Further justification for the use of 204.7°F is in the Response to Issue 3g.14. The conventional debris head losses are corrected to a sump temperature of 70°F when compared to the minimum performance or structural criteria [Ref. 40].

Unit 3

Pump and Sump Flow Rates

The sump flow rates were determined in the Westinghouse 107 Calculation [Ref. 36] for Indian Point Unit 3 under various flow configurations. The following table shows the sump flow rates for various cases examined in Ref. 36 for both the IR sump and VC sump. Note that the miniflow line flow rates are included in the IR sump flow rates, but are excluded from the VC sump flow rates in the following tables. Also, note that the Hot-Leg Recirculation alignment flow rate will always be less than the analyzed High Head Safety Injection (HHSI) maximum system flow (1350 gpm).

Table 3g.1-4:
IP-3 NPSH Determination

Sump	Alignment	Pumps	Sump Flow Rate *Q* (gpm)
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (2 RHR-HXs)	5263
IR	Start of Recirculation	1 Pump (2 RHR-HXs)	2484
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	4149
IR	HHSI – max	2 Pumps	1350
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3586
VC	Start of Recirculation	1 Pump (1 RHR-HX)	2312
VC	HHSI - max	2 Pumps	1350

In addition to the NPSH margin cases shown above, the minimum flow performance cases were also examined. The purpose of evaluating the minimum flow cases is to ensure that the strainer head loss does not reduce the pump flow rate below the minimum performance required for accident mitigation. The cases are summarized below.

Table 3g.1-5:
IP-3 Minimum Performance

Sump	Alignment	Pumps	Sump Flow Rate *Q* (gpm)
IR	Start of Recirculation	1 Pump (1 RHR-HX)	1402
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3517
IR	HHSI - min	2 Pumps	1350
VC	Start of Recirculation	1 Pump (1 RHR-HX)	1226
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3367
VC	HHSI - min	2 Pumps	1350

Minimum Water Level

The minimum water levels for various accident scenarios are determined in the Indian Point Unit 3 Water Level Calculation [Ref. 34]. The following table summarizes the results of this calculation. A complete list of assumptions is located in Ref. 34, and a summary of key assumptions can be found in the response to the Issue 3g.9.

Table 3g.1-6:
IP-3 Post-LOCA Containment Water Level Results

Break Location	Case	Water Level (feet EL.)
Large Break Loss-of Coolant Accident Double-Ended Pump Suction Break	At Start of SI Recirculation	47.51
	At Start of Recirculation Spray	48.74
	After Recirculation Spray is Secured	48.12
	End-of-Event	48.19
Large Break Loss-of-Coolant Accident Double-Ended Pressurizer Surge Line Break	At Start of SI Recirculation	47.32
	At Start of Recirculation Spray	48.55
	After Recirculation Spray is Secured	48.28
Small Break Loss-of-Coolant Accident	At Start of SI Recirculation – No Sprays	47.20
	End-of-Event – No Sprays	47.19
	At Start of SI Recirculation – Sprays	47.06
	At Start of Recirculation Spray	48.17

Sump Temperature

In the strainer certification assessments, conventional debris head losses are corrected to a sump temperature of 204.7°F when compared to the NPSH [Ref. 40] since at this temperature, the NPSHa (and therefore the NPSH margin) reaches a minimum. Further justification for the use of 204.7°F is in the Response to Issue 3g.14. The conventional debris head losses are corrected to a sump temperature of 70°F when compared to the minimum performance or structural criteria [Ref. 40].

Entergy Response to Issue 3g.2:

Unit 2

Pump and Sump Flow Rates

The sump flow rates for various post-accident scenarios are determined in the Westinghouse 106 Calculation [Ref. 35] for Indian Point Unit 2. The following assumptions are used in this calculation:

- The sump screen loss is neglected for the maximum performance cases, which is conservative since it maximizes flow. Also, if the actual screen loss is less than the values determined in this calculation, the results of this calculation are still bounding.
- The unblocked nozzles spray ring header resistance is used for the minimum recirculation spray performance cases.
- A system "overpressure" of 37.6 psia is assumed for the model boundary conditions since the maximum sump (at the time of switchover) temperature of 264.4°F is used. This overpressure is applied so that the fluid in the Fathom model remains single-phase (Fathom is not capable of modeling two-phase flows).
- NPSH for the Recirculation and RHR pumps was evaluated at both hot and cold sump screen head loss conditions (while still using the conservative hot, no-screen-loss flow conditions for the pump NPSHr) to bound both conditions at the plant. The calculation determined the maximum allowable sump screen head loss based on maximum flows assuming no screen loss at hot conditions because: 1) Hot conditions are more limiting for determining NPSH available (NPSHa) since the saturation pressure is greater at a higher temperature; 2) The change in suction piping head loss (for the larger suction lines, where applicable) due to temperature is small. To bound both the hot or cold conditions at the plant, the final cold (or end of transient) sump screen head loss was applied to the maximum allowable screen loss based on hot conditions determined in this calculation.

Minimum Water Level

The minimum water levels for various accident scenarios are determined in the Indian Point Unit 2 Water Level Calculation [Ref. 33]. A summary of key assumptions can be found in the response to the Issue 3g.9.

Sump Temperature

Strainer certification assessments [Ref. 40] for the conventional debris head losses of the maximum performance cases are performed at a sump temperature of 204.7°F since at this temperature, the NPSHa (and therefore the NPSH margin) reaches a minimum. Further justification for the use of 204.7°F is in the Response to Issue 3g.14.

Unit 3

Pump and Sump Flow Rates

The sump flow rates for various post-accident scenarios are determined in the Westinghouse 107 Calculation [Ref. 36] for Indian Point Unit 3. The following assumptions are used in this calculation:

- The sump screen loss is neglected for the maximum performance cases (maximum sump level), which is conservative since it maximizes the flow. Also, if the actual screen loss is less than the values determined in this calculation, the results of this calculation are still bounding.

- Due to the temperature of the system being modeled above 212°F, the boundary pressure of the system had to be raised above the vapor pressure at 242.8°F to prevent the water from forming into steam. Therefore, the systems boundary pressure was raised to 26.1 psia in Fathom.
- NPSH for the Recirculation and RHR pumps was evaluated at both hot and cold sump screen head loss conditions (while still using the conservative hot, no-screen-loss flow conditions for the pump NPSHr) to bound both conditions at the plant. The calculation determined the maximum allowable sump screen head loss based on maximum flows assuming no screen loss at hot conditions because: 1) Hot conditions are more limiting for determining NPSH available (NPSHa) since the saturation pressure is greater at a higher temperature; 2) The change in suction piping head loss (for the larger suction lines, where applicable) due to temperature is small. To bound both the hot or cold conditions at the plant, the final cold (or end of transient) sump screen head loss was applied to the maximum allowable screen loss based on hot conditions determined in this calculation.

Minimum Water Level

The minimum water levels for various accident scenarios are determined in the Indian Point Unit 3 Water Level Calculation [Ref. 34]. A summary of key assumptions is located in the response to the Issue 3g.9.

Sump Temperature

Strainer certification assessments [Ref. 40] for the conventional debris head losses of the maximum performance cases are performed at a sump temperature of 204.7°F since at this temperature, the NPSHa (and therefore the NPSH margin) reaches a minimum. Further justification for the use of 204.7°F is in the Response to Issue 3g.14.

Entergy Response to Issue 3g.3:

Net Positive Suction Head (NPSH) margins were calculated in Ref. 40 for various post-accident flow configurations. More specifically, the pump NPSH margins were determined by subtracting the NPSHr and the head loss through the ECCS strainer and debris bed from the NPSHa.

The NPSHr values for the IP-2 and IP-3 Internal Recirculation (IR) pumps were determined by vendor testing using the current IP-2 three-stage pump. The IP-2 test data provided a bounding NPSHr curve for both the IP-2 and IP-3 IR pumps. For the RHR pumps, the NPSHr curves were provided by vendor testing of the specific RHR pumps currently installed at IP-2 and IP-3. The NPSHa values were determined by modeling system alignments consistent with the UFSAR and plant procedures for the ECCS sump recirculation. Using AFT Fathom 6.0 software, various flow configurations were modeled and analyzed in the Westinghouse 106 and 107 Calculations [Refs. 35 and 36].

Entergy Response to Issue 3g.4:

Common to both units

All methodologies, calculations and results regarding the Net Positive Suction Head (NPSH) are included in the "Westinghouse 106 and 107 Calculations": CN-SEE-05-106 (Indian Point Unit 2 SI Recirculation (LSHI and HHSI) Performance for the Containment Sump Program, Ref. 35) and CN-SEE-05-107 (Indian Point Unit 3 SI Recirculation (LHSI and HHSI) Performance for the Containment Sump Program, Ref. 36).

Various cases corresponding to different system alignment configurations were analyzed using the Fathom models, which accounted for the friction and other pipe losses in the flow network. The pump and sump flow rates and NPSH values were determined for each case.

When determining the maximum pump and sump flow rates, the system resistances were minimized and maximum water levels were used. This approach is conservative since it gives conservatively higher flow rates and therefore higher NPSHr.

Entergy Response to Issue 3g.5:

Common to both units

The Engineered Safety Feature (ESF) systems include two separate sumps, the Internal Recirculation Sump (IR Sump) and the Vapor Containment Sump (VC Sump) for collecting liquid discharged during a design basis accident. After the injection operation, coolant spilled from the break and water collected from the containment spray are cooled and returned to the Reactor Coolant System (RCS) by the recirculation system.

When the break is large, depressurization occurs due to the large rate of mass and energy loss through the break, to containment. In the event of a large break, the recirculation flow path is initially within the containment. The system is arranged so that the Recirculation Pumps take suction from the IR Sump in the containment floor and deliver spilled reactor coolant and borated refueling water back to the core through the residual Heat Exchangers.

The system is also arranged to allow either of the Residual Heat Removal (RHR) Pumps to take over the recirculation function. The RHR Pumps would only be used if backup capability to the IR sump loop is required after 24 hours from the accident [Ref. 102]. The VC sump could also be used to mitigate a 6 inch or smaller LOCA from the beginning of the accident. For the purposes of head loss analysis, the cases that will produce the highest head loss are always examined. Generally, the highest flow rate would produce the highest head loss. During an LBLOCA, at 6.5 hours after the break [Refs. 71 and 72], the system is aligned for Hot Leg recirculation. This entails the use of the Recirculation Pumps to provide suction to the High Head Safety Injection (HHSI) Pumps. These pumps then provide cooling flow to both the Cold Legs and the Hot Legs of the RCS.

For small breaks, the depressurization of the reactor coolant system is augmented by steam dump from and auxiliary feedwater addition to the Steam Generators. For the smaller breaks in the reactor coolant system where recirculated water must be injected against higher pressures for long-term cooling, the system is arranged to deliver the water from residual heat removal Heat Exchangers to the high-head safety injection pump suction and by this external recirculation route to the reactor coolant loops. If this flow path is unavailable, an alternate flow path is also provided.

The alternate flow path includes the VC sump, the RHR pumps, and the middle HHSI pump. It bypasses the RHR Heat Exchangers with core/VC cooling provided by the Containment Fan Cooler Units and the recirculation spray (if available). Thus, if depressurization of the reactor coolant system proceeds slowly, the safety injection pumps may be used to augment the flow-pressure capacity of the recirculation pumps in returning the spilled coolant to the reactor. In this system configuration, the recirculation pump (or residual heat removal pump) provides flow and net positive suction head to the operating safety injection pumps. At IP-2, to prevent safety injection pump flow in excess of its maximum allowable (i.e., runout) limit, variable flow orifices are installed at the discharge of the safety injection pumps and the hot and Cold Leg motor-operated isolation valves are preset with mechanical stops based on data from operational flow testing to limit system maximum flow capability. At IP-3, to prevent excess pump flow, manual throttling valves were installed and set in specified positions in selected cold and Hot Leg branch lines.

Entergy Response to Issue 3g.6:

There are seven pumps employed for RCS LOCA accident mitigation where the use of the Containment Building sump(s) is required. The seven ECCS pumps are the two Recirculation Pumps within the Containment, three High Head Safety Injection Pumps and two Residual Heat Removal Pumps in the Primary Auxiliary Building (PAB). There are also two Containment Spray Pumps in the PAB which only draw fluid from the RWST.

Prior to the recirculation phase is the injection phase. Provided power is available and no failures occur, the three HHSI Pumps, two RHR Pumps, and two Containment Spray Pumps (provided a hi-hi containment pressure signal is generated) will be delivering flow from the RWST.

For Recirculation Phase, the three HHSI Pumps and two RHR pumps are ultimately secured during the switchover process to the Recirculation Pumps. The Containment Spray pumps, if actuated, can continue drawing down the RWST to its low level cut off point in part to satisfy the minimum spray time for dose reduction and to increase the Containment flood level above the sumps. The Recirculation pumps will be started to initiate low head recirculation. If this cannot be accomplished due to high RCS backpressure or other reasons, the Recirculation Pump's discharge will then be routed to the HHSI pump(s) to provide additional head. If continued containment Spray is required and the RWST is exhausted (thereby preventing use of the Containment Spray pump which only draws from the RWST), part of the recirculation flow can be diverted off to the spray headers. If both of the recirculation pumps are or become unavailable, either of the two RHR Pumps can be aligned to draw from the Containment sump to provide Low head recirculation, or feed into the HHSI Pumps as needed in place of the Recirculation Pumps.

Entergy Response to Issue 3g.7:

The basic single failure assumptions with regard to the ECCS and CSS are identical at Unit 2 and Unit 3. At both Units these systems are currently required to fulfill their safety-related functions with a single active failure during the injection phase of the post-accident period or with an active or passive failure during the recirculation phase (assuming no active failure has occurred during injection). A License Amendment Request (LAR) was requested and approved by the NRC to change the Unit 2 / Unit 3 Licensing Basis concerning the timing of the passive failure. Previously, the passive failure was postulated to occur immediately at recirculation initiation; the LAR changed this occurrence time to a minimum of 24 hours into the accident scenario.

A single failure re-evaluation of Unit 2 and Unit 3 ECCS and CSS was performed in light of GSI-191. Currently, for certain single failures (either active or passive) during any portion of recirculation, a switchover from the IR sump to the VC sump must be implemented to maintain core / VC cooling. At Unit 2, an active failure was identified that would disable the IR sump as a source of coolant for Hot Leg recirculation. For Small size LOCAs (6" and under), this would not represent a problem since the debris load could be adequately handled by the VC sump (i.e., RHR Pump NPSH margin and strainer structural integrity maintained) at any time during the entire recirculation phase. For a LB LOCA, it was demonstrated by analysis that the debris removed and retained at the IR sump prior to switching over to the VC sump (at approximately the Hot Leg recirculation switchover time) was sufficient to permit the latter sump to function as required. At Unit 3, no single active failure was identified that would require a switchover from the IR sump to the VC sump. With the approval of the LAR for the change in passive failure timing (24 hours into the event), the single failure re-evaluation has concluded that both at Unit 2 and Unit 3, the ECCS and CSS could fulfill their safety functions with a passive failure.

Entergy Response to Issue 3g.8:

Common to both units

The post-LOCA minimum containment flood water is determined in the IP-2 and IP-3 Minimum Water Level Calculations [Refs. 33 and 34] using the following methodology:

1. A correlation was first developed for the relationship between the containment water level and the water volume. This correlation is based on the IP-2 and IP-3 Free Volume Calculations [Refs. 38 and 39].
2. The quantity of water added to containment from the Refueling Water Storage Tank (RWST), SI Accumulators and the Reactor Coolant System (RCS) was calculated for each of the breaks: LBLOCA and SBLOCA.
3. The quantity of water that is diverted from the containment sump by the following effects was evaluated:
   - Steam holdup in the containment atmosphere
   - Water volume required to fill the Safety Injection, Residual Heat Removal and Containment Spray Piping that is empty prior to the LOCA
   - Additional mass of water that must be added to the RCS due to the increase in the water density at the lower sump water temperature (versus the RCS temperature prior to the LOCA)
   - Condensation on surfaces
   - Water volume required to fill the RCS steam space
   - Water in transit from the Containment Spray nozzles and the break to the Containment Sump
   - ECCS leakage outside of containment
   - Holdup within the Refueling Cavity
   - Miscellaneous holdup volumes throughout containment
4. Given the net mass of water added to the containment floor based on items 2 and 3 listed above, the post-LOCA containment water level is calculated using the correlation developed in item 1.

The containment water level is calculated for the following breaks:
LBLOCA – Double-Ended Guillotine Break of Reactor Coolant System (RCS) Loop Piping
SBLOCA – RCS Break less than or equal to 3 inches

These breaks were chosen in order to encompass a wide range of potential breaks. The containment water level was calculated for large and small breaks because the Emergency Core

Cooling System (ECCS) flow requirements from the Internal Recirculation (IR) sump and the Vapor Containment (VC) sump and the potential debris generated following a LOCA will be distinctly different for each scenario.

The time after the LOCA also has impact on the containment water level. Among other things, the time after the LOCA will impact the volume of water transferred from the Refueling Water Storage Tank (RWST) to the containment, accumulation of water in various holdup volumes in containment, RCS shrinkage and water held up in the containment atmosphere. For this reason, the containment water level is determined for the time that SI recirculation begins (Low-Low RWST water level), the time that Containment Spray (CS) is switched over to Recirculation Spray (Low-Low-Low RWST level), the time that Recirculation Spray is secured, and end-of-event LBLOCA and SBLOCA scenarios.

Entergy Response to Issue 3g.9:

Common to both units

The following assumptions provided the basis to ensure that minimum (conservative) containment water levels are calculated in the IP-2 and IP-3 Water Level Calculations [Refs. 33 and 34]:

- Since it is conservative to maximize the hold up of steam in the containment atmosphere, the highest containment temperature for the specific point of an analyzed scenario is employed in the determination of the VC water level. These temperatures are either directly obtained from the Power Uprate Project LOCA Containment Integrity Evaluation and SBLOCA analysis, or are conservatively estimated from information contained in these References and other relevant documentation.
- Portions of Engineered Safety Feature (ESF) piping are assumed to not be filled with water prior to emergency operation. This is conservative because filling the drained portions of these systems will divert water from the containment sumps, resulting in lower containment water level.
- To conservatively minimize the mass of water within the SI accumulators that could spill into the containment, the temperature is assumed to be equal to the maximum initial containment air temperature consistent with the accident analysis of 130°F. This approach is conservative because the density of water decreases with increasing temperature.
- For non-flowing condensation, a conservative film thickness of 0.003 inch was assumed for all break cases. The use of a 0.003-inch non-flowing film thickness for all containment surfaces, except for the containment walls (in which a thicker flowing film thickness is used), is conservative because it is expected that many of these surfaces will not support any film due to the turbulence that is expected inside containment.
- For conservatism when calculating holdup of water due to water-in-transit, all of the containment spray flow is assumed to originate from the upper ring of containment spray nozzles, maximizing the fall time. In addition, all of the injection flow is assumed to flow from a break at the top of the Pressurizer Surge line. This is the highest potential break elevation in the RCS that could allow full ECCS flow through the break.
- For a break in the RCS loop piping, it is conservatively assumed that the Reactor Vessel (up to the top elevation of the hot and Cold Leg piping), RCS loop piping (including reactor coolant pump internals), and Pressurizer Surge line are refilled with ECCS inventory at the time of ECCS switchover to recirculation.
- The refueling cavity hold up assumes all flow goes through the drain, not through the annular space around the Reactor Vessel. This represents a significant volume that does not contribute to the water level. Also, the spray flow value is conservatively high, as is the

friction factor for flow through the drain. This maximizes the volume contained in the refueling cavity.

Additional assumptions are made that result in conservative VC levels, but these are minor contributors as compared to the assumptions cited above.

LBLOCA water levels, with estimated drawdown values, were used in the Westinghouse 106 and 107 calculations [Refs. 35 and 36] to determine the sump flow rate and NPSH. To ensure that the NPSH margins bound accidents of any break sizes, the minimum post-LBLOCA water levels originally used in the Westinghouse 106 calculation were replaced by those of SBLOCA with spray cases, as shown in Response to issue 3g.1, to adjust the NPSHa values (and therefore NPSH margins) in the Certification Calculation [Ref. 40]. This ensures that the adjusted NPSH margins bound accidents of all break sizes.

Entergy Response to Issue 3g.10:

See Responses to Issues 3g.8, 3g.9 and 3g.12

Entergy Response to Issue 3g.11:

The volumes occupied by structures, equipment and equipment supports, etc. will displace water and result in a higher pool level. Examples of such equipment include concrete walls, accumulator tanks and piping, curbs, and supports for the major RCS components. These volumes were calculated in the IP-2 and IP-3 Free Volume Calculations [Refs. 38 and 39] and subtracted from the available volume at each elevation in containment to obtain the net free volume at each level. The correlation between the net free volume and elevation can then be used to determine the water level.

For both IP-2 and IP-3, all assumptions used in these calculations [Refs. 38 and 39] were designed to minimize the volumes occupied by the equipment and maximize the free volume at each level. This is to provide a conservatively lower water level for evaluating NPSHa values for the ECCS pumps.

Entergy Response to Issue 3g.12:

Unit 2

The following design inputs provided the basis for water sources and their volumes to determine the minimum containment water level for IP-2 [Ref. 33]:

- The net water volume to fill containment to elevations of 46' and 49' 6" is 96,355 and 380,923 gallons, respectively.
- The minimum water volume maintained in the RWST is greater than or equal to 345,000 gallons. This level includes allowances for instrument accuracy, margin and the unusable volume in the RWST.
- The manual process of switchover to recirculation is initiated after the RWST LOW LOW level alarm setpoint is reached which is maintained between 74,200 gallons and 99,000 gallons. During and after switchover to recirculation, water continues to be drawn from the RWST for accident mitigation. Water level setpoints provide a minimum water volume of 246,000 gallons during the injection phase and 60,000 gallons during and after the transition to the recirculation phase. Additionally a sufficient quantity of water is allowed for

instrument inaccuracies, additional margin and water that is unavailable from the bottom of the tank. These are conservatively not credited.

- The maximum RWST temperature of 110°F is used in the Water Level Calculation. The specific volume of water at this temperature is 1.6167×10^{-2} ft^3/lbm.
- There are four SI accumulators that have a minimum volume of 723 ft^3 and are maintained at a nitrogen cover pressure between 598 and 685 psig. The total accumulator volume includes the average accumulator line volume (47 ft^3); therefore volume of 770 ft^3 for each accumulator was used.
- The Containment average air temperature is maintained > 50 °F and ≤ 130 °F.
- The Pressurizer minimum level for Stretch Power Uprate (SPU) was very conservatively assumed to be 30%, which gives the Pressurizer total volume of 1800 ft^3, instrument span of 1666.1 ft^3 and the liquid volume at 30% of span of 499.8 ft^3. In the Water Level Calculation, a realistically conservative Pressurizer level of 50% was used, which is conservative as it minimizes the mass of water added to the containment sump at the time of a postulated break. This relates to a volume of 833 ft^3.
- The minimum RCS volume is 11,151 ft^3 based on a 50% Pressurizer level.

Table 3g.12-1:
IP-2 RCS Volumes

RCS Component	Volume (ft^3)
Reactor Vessel	4,628
Hot Legs	320
Pressurizer Surge Line	51
Pressurizer (Full)	1800
Pressurizer (50%)	833
Steam Generators (Primary Side)	3,696
Cross-over Legs	516
Reactor Coolant Pumps	768
Cold Legs	339
Total RCS (Pressurizer Full)	12,118
Total RCS (Pressurizer 50%)	11,151

Unit 3

The following design inputs provided the basis for water sources and their volumes to determine the minimum containment water level for IP-3 [Ref. 34]:

- The net water volume to fill containment to elevations of 46' and 49' is approximately 94,564 and approximately 345,186 gallons, respectively.
- The minimum water level maintained in the RWST is 35.4' which corresponds to a water volume of approximately 342,200 gallons. This level includes allowances for instrument accuracy, margin and the unusable volume in the RWST.
- The manual process of switchover to recirculation is initiated after the RWST LOW level alarm setpoint is reached which is maintained between 10.5' and 12.5'. During and after switchover to recirculation, one Containment Spray pump continues to draw from the RWST until the water level reaches the LOW-LOW level alarm setpoint at 1.5'. The maximum setpoint instrument uncertainties are ±1.18' (35.4' setpoint), ±0.93' (11.5' setpoint) and ±1.23' (1.5' setpoint). The RWST volume per unit height is 9372 gal/ft. The additional quantity of water that is allowed for the instrument uncertainties is conservatively not credited.

- The maximum RWST temperature of 110°F is used in the Water Level Calculation. The specific volume of water at this temperature is 1.6167x 10^{-2} ft^3/lbm.
- There are four SI accumulators that have a minimum water volume of 775 ft^3 and are maintained at a nitrogen cover pressure between 600 and 700 psig. The accumulator injection lines contain a minimum of 32.2 ft^3 per accumulator.
- The Containment average air temperature during normal plant operation is maintained > 50°F and ≤ 130°F.
- The worst-case Pressurizer level, the Hot Zero Power value of 23.1%, was very conservatively used in the Stretch Power Uprate (SPU) analysis, which gives a Pressurizer total volume of 1800 ft^3, an instrument span of 1666.1 ft^3, and a liquid volume of 383.2 ft^3 at 23.1% of span. In the containment Water Level Calculation, a realistically conservative Pressurizer level of 44% in a span of 1678.88 ft^3 was used. This equates to a liquid volume of 738.7 ft^3.
- The minimum RCS volume is 11,071 ft3 based on a 44% Pressurizer level.

Table 3g.12-2:
IP-3 RCS Volumes

RCS Component	Volume (ft^3)
Reactor Vessel	4,642
Hot Legs	320
Pressurizer Surge Line	51
Pressurizer (Full)	1800
Pressurizer (44%)	739
Steam Generators Primary Side	3,696
Cross-over Legs	516
Reactor Coolant Pumps	768
Cold Legs	339
Total RCS (Pressurizer Full)	12,132
Total RCS (Pressurizer 44%)	11,071

<u>Common to both units</u>

The post-LOCA containment water levels are based on a minimum break size of 3 inches, resulting in accumulator injection. An evaluation was completed to show that due to significantly lower debris loads, lower flow rates, and other mitigating factors, breaks less than 3 inches are bounded by this methodology [Ref. 40].

The water levels are the lowest for the SBLOCA where the RCS does not fully depressurize and sprays are activated (see Tables 3g.1-3 and 3g.1-6). The minimum level occurs at the start of SI recirculation. For the SBLOCA case with No Spray, some of the RWST inventory that is actually available for injection into Containment is not credited since the sprays will not be activated. This is conservative since even when Containment Spray is not activated, the High Head Safety Injection (HHSI) pumps are taking suction on the RWST through the SI Recirculation switchover process, and depending on the size of the SBLOCA, these pumps may inject a significant volume of water into the Containment prior to their shutoff. It should also be pointed out that the water level for the SBLOCA cases is conservatively determined using the containment analysis for a large break LOCA since the containment analysis was not performed for a SBLOCA. This is conservative because the steam hold up in the containment atmosphere and the holdup due to containment shrinkage are greater for the higher temperatures associated with the LBLOCA.

Entergy Response to Issue 3g.13:

Common to both units

The NPSHa values were calculated using assumptions consistent with the guidance in NEI 04-07 and its associated SER for minimizing the effect of containment over-pressure on the NPSH results. For the minimum NPSH margin case, no containment accident overpressure was credited (*i.e.*, the containment pressure was assumed to be equal to the saturation pressure at the sump water temperature; see Figure 3f.10-1).

Unit 2

Due to the temperature of the system being modeled above 212°F, the boundary pressure of the system had to be raised to the vapor pressure at 264.4°F [Ref. 35] to prevent the water from forming into steam. Therefore, the system's boundary pressure was raised to 37.6 psia in Fathom since the computer code can only handle single-phase fluids. In examining the potential for release of gas from the fluid as it passes through the ECCS strainer, it was assumed that the containment dry air pressure remained constant; however, no credit was taken for an elevated containment pressure resulting from post-LOCA heating of the air. This approach is consistent with the guidance of NEI 04-07.

Unit 3

Due to the temperature of the system being modeled above 212 °F, the boundary pressure of the system had to be raised above the vapor pressure at 242.8°F [Ref. 36] to prevent the water from forming into steam. Therefore, the system's boundary pressure was raised to 26.1 psia in Fathom since the computer code can only handle single-phase fluids. In examining the potential for release of gas from the fluid as it passes through the ECCS strainer, it was assumed that the containment dry air pressure remained constant; however, no credit was taken for an elevated containment pressure resulting from post-LOCA heating of the air. This approach is consistent with the guidance of NEI 04-07.

Entergy Response to Issue 3g.14:

Common to both units

Regulatory Position 1.3.1.2 of Regulatory Guide 1.82 [Ref. 63] allows for the use of some containment pressure, if needed. Section 6.4.7.3 of NEI 04-07 [Ref. 6] provides generally acceptable assumptions for a more realistic calculation of NPSH available. These two pieces of guidance resulted in the following methodology for minimizing the containment pressure:

The IP-2 and IP-3 Technical Specifications limit the minimum containment pressure under normal operation to -2 psig which corresponds to a temperature of 204.7°F. At post-LOCA sump pool temperatures below 204.7°F, the containment pressure is assumed to never drop below -2 psig. Since the vapor pressure of water decreases as the temperature decreases, the vapor pressure at a temperature lower than 204.7°F is less than its corresponding value at 204.7°F; this difference between the containment pressure and the lower vapor pressure provides additional NPSH margin. This assertion can be verified in any set of standard engineering steam tables. At pool temperatures greater than 204.7°F, the NPSH margin remains the same, for otherwise constant conditions, since it is assumed that the vapor pressure of the sump pool is always equal to the containment pressure at temperatures higher than 204.7°F. It can therefore be concluded that the

NPSH margin reaches a minimum at 204.7°F for the IR and Residual Heat Removal (RHR) pumps (see Figure 3f.10-1). Given that the debris head loss decreases as the temperature increases due to the lower sump water viscosity at the higher temperature, it is conservative to conduct the strainer Certification Calculation at 204.7°F to compare the debris head loss with the minimum NPSH margins for the Indian Point recirculation pumps.

Unit 2

When determining the NPSHa, it is assumed that the containment pressure is equal to the vapor pressure of water at the given sump temperature. It can be shown that this assumption is very conservative. For example, at the maximum sump temperature after start of recirculation, 252.68°F, assuming minimum safeguards [Ref. 26], the vapor pressure is 30.9 psia and the containment pressure predicted in Ref. 73 is 49.79 psia. Given the above assumption, when calculating the NPSHa, the vapor pressure 30.9 psia (instead of 49.79 psia) is used and this approach therefore gives conservatively lower NPSHa and therefore NPSH margin.

The Indian Point Unit 2 Void Fraction Calculation [Ref. 26] determined the containment pressure margins that maintain 3% or lower void fractions for various times up to 10,000,000 seconds (115.74 days) after an accident. The results show that, compared with the containment pressures predicted in the LOCA Containment Integrity Analysis Report [Ref. 73], the minimum margins are 7.92 psi and 5.80 psi for the IR sump and VC sump, respectively.

Unit 3

When determining the NPSHa, it is assumed that the containment pressure is equal to the vapor pressure of water at the given sump temperature. It can be shown that this assumption is very conservative. For example, at 3899 seconds after an accident (recirculation starts at 1623.8s), the sump temperature is 241.71°F assuming minimum safeguards [Ref. 27]. The vapor pressure at this sump temperature is 25.9 psia and the containment pressure predicted in Ref. 82 is 42.88 psia. Given the above assumption, when calculating the NPSHa, the vapor pressure 25.9 psia (instead of 42.88 psia) is used and this approach therefore gives conservatively lower NPSHa and therefore NPSH margin.

The Indian Point Unit 3 Void Fraction Calculation [Ref. 27] determined the containment pressure margins that maintain 3% or lower void fractions for various times up to 10,000,000 seconds (115.74 days) after an accident. The results show that, compared with the containment pressures predicted in the LOCA Containment Integrity Analysis Report [Ref. 74], the minimum margins are 7.55 psi and 6.40 psi for the IR sump and VC sump, respectively.

Entergy Response to Issue 3g.15:

Common to both units

At pool temperatures greater than 204.7°F, it is assumed that the containment accident pressure is equal to the vapor pressure of water at the sump temperature. At pool temperatures below 204.7°F, it is assumed that the containment pressure never drops below the minimum containment pressure of -2 psig [Ref. 40] (see Figure 3f.10-1).

Entergy Response to Issue 3g.16:

The NPSH margins for various flow configurations at both IP-2 and IP-3 are provided in the tables below [Ref. 40]. The final margins include the total strainer head losses contributed by the strainer structures (CSHL) and various conventional debris components. At 160°F, there is an increase of at least 18.4 ft in the NPSH margin (compared to 204.7°F), as shown in the Certification Calculation [Ref. 40]. Since the structural design differential pressure limits for both IP-2 and IP-3 are less than 12 ft, the structural limit of the strainer (instead of the NPSH margin) becomes the most restrictive requirement. The chemical effects methodology demonstrated that chemical precipitation does not occur until after sprays are secured and recirculation flow is aligned through the High Head Safety Injection (HHSI) pumps [Ref. 46]. Tables 3g.16-1 to 3g.16-4 represent the conditions present before the onset of chemical precipitation. NPSH margins with chemical effects is addressed separately below.

Table 3g.16-1:
IP-2 NPSH and Conventional Debris Head Loss Margins

Sump	Alignment	Pumps	Sump Flow Rate Q (gpm)	NPSHa – NPSHr (ft)	Total Strainer Head Loss $h_{L,Total}$ (ft)	Final NPSH Margin (ft)
IR	Start of Recirculation	1 Pump (1 RHR-HX)	3127	2.52	0.61	**1.91**
IR	Start of Recirculation	2 Pumps (2 RHR-HXs)	5565	3.02	1.26	**1.76**
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (1 RHR-HX)	5115	3.86	1.13	**2.73**
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (2 RHR-HXs)	6615	2.86	1.57	**1.29**
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3984	1.36	0.83	**0.53**
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (2 RHR-HXs)	7086	2.56	1.71	**0.85**
IR	HHSI – max	2 Pumps	1350	3.17	0.23	**2.94**
VC	Start of Recirculation	1 Pump (1 RHR-HX)	2835	11.78[1]	3.30	**8.48**
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3528	8.85	3.45	**5.40**
VC	HHSI – max	2 Pumps	1350	11.78[1]	1.40	**10.38**

[1]The value shown is the structural design limit because it is most limiting for these cases.

Table 3g.16-2:
IP-3 NPSH and Conventional Debris Head Loss Margins

Sump	Alignment	Pumps	Flow Rate Q (gpm)	NPSHa - NPSHr (ft)	Total Strainer Head Loss $h_{L,Total}$ (ft)	Final NPSH Margin (ft)
IR	Full Recirculation (with Recirculation Spray)	2 Pumps (2 RHR-HXs)	5263	3.67	1.24	**2.43**
IR	Start of Recirculation	1 Pump (2 RHR-HXs)	2484	2.92	0.47	**2.45**
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	4149	0.92	0.91	**0.01**
IR	HHSI – max	2 Pumps	1350	3.17	0.23	**2.94**
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3586	9.06	2.84	**6.22**
VC	Start of Recirculation	1 Pump (1 RHR-HX)	2312	11.53[1]	2.28	**9.25**
VC	HHSI - max	2 Pumps	1350	11.53[1]	1.29	**10.24**

[1] The value shown is the structural design limit because it is most limiting for these cases.

The Final NPSH Margins shown in the table above represent a series of conservatisms that were combined, but will not occur simultaneously. These conservatisms include: the minimum water levels from SBLOCA cases were assumed for NPSH calculations for LBLOCA flows, even though those water levels increase after the pumps start up; the maximum water level was assumed to obtain the maximum flow rates; full debris loading on the strainers was assumed at the start of recirculation, however the strainers do not become fully loaded with debris this early; the debris load has been conservatively comprised of the worst combined maximum debris types from multiple break locations; and no accident overpressure is credited. The combination of all of these conservatisms will not occur during an actual accident scenario, but nonetheless, all these conservatisms have been used to determine the Final NPSH Margins.

Note that the SBLOCA NPSH margins will be bounded by LBLOCA cases. The Strainer Certification Calculation [Ref. 40] reduces the NPSHa values given in the Westinghouse System Hydraulic Calculations [Refs. 35 and 36] to account for the difference in water level and bound both the LBLOCA and SBLOCA cases. This is very conservative for the SBLOCA cases because the small break flow rates and related NPSHr will be much lower. The Strainer Certification Calculation also demonstrates that the head loss for a SBLOCA is bounded by prototypical testing for a LBLOCA. Also, the Debris Generation Calculations [Refs. 1 and 2] show that the SBLOCA debris loads are less than the LBLOCA debris loads. These results indicate that the SBLOCA NPSH margins will be bounded by LBLOCA cases.

In addition to the NPSH margin analyses shown above, the minimum flow performance cases were also evaluated for both IP-2 and IP-3. The purpose of evaluating the minimum flow cases is to ensure that the strainer head loss does not reduce the pump flow rate below the minimum performance required for accident mitigation. The results are summarized below. Note that since these minimum performance cases are not related to the NPSH requirements, the head loss margins are shown in the tables.

Table 3g.16-3:
IP-2 Minimum Performance with Conventional Debris

Sump	Alignment	Pumps	Sump Flow Rate Q (gpm)	Min Flow Criteria (ft)	Total Strainer Head Loss $h_{L,Total}$ (ft)	Final Head Loss Margin (ft)
IR	Start of Recirculation	1 Pump (1 RHR-HX)	2452	4.00	0.80	3.20
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3568	2.50	1.18	1.32
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3568	1.70	1.18	0.52
IR	HHSI-min	2 Pumps	1350	8.52	0.45	8.07
VC	Start of Recirculation	1 Pump (1 RHR-HX)	2198	7.00	2.45	4.55
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3221	7.00	3.87	3.13
VC	HHSI-min	2 Pumps	1350	11.78	1.40	10.38

Table 3g.16-4:
IP-3 Minimum Performance with Conventional Debris

Sump	Alignment	Pumps	Sump Flow Rate Q (gpm)	Min Flow Criteria (ft)	Total Strainer Head Loss $h_{L,Total}$ (ft)	Final Head Loss Margin (ft)
IR	Start of Recirculation	1 Pump (1 RHR-HX)	1402	2.5	0.46	2.04
IR	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3517	4.01	1.17	2.84
IR	HHSI - min	2 Pumps	1350	9.47	0.44	9.03
VC	Start of Recirculation	1 Pump (1 RHR-HX)	1226	2.00	1.17	0.83
VC	Full Recirculation (with Recirculation Spray)	1 Pump (1 RHR-HX)	3367	7.00	3.46	3.54
VC	HHSI - min	2 Pumps	1350	11.53	1.29	10.24

The chemical effects methodology demonstrated that chemical precipitation does not occur until after sprays are secured and recirculation flow is aligned through the High Head Safety Injection (HHSI) pumps [Ref. 46]. The Strainer Certification Calculation [Ref. 40] shows that, at the HHSI flow rates, the structural limit becomes the critical criteria. Therefore, the head losses associated with conventional debris plus chemical effects at the HHSI flow rates of 1350 gpm are compared to the structural limit in Tables 3g.16-5 and 3g.16-6.

Table 3g.16-5:
IP-2 NPSH and Conventional and Chemical Debris Head Loss Margins

Sump	Alignment	Pumps	Sump Flow Rate Q (gpm)	Structural Limit (ft)	Total Strainer Head Loss $h_{L,Total}$ (ft)	Final Head Loss Margin (ft)
IR	HHSI	2 Pumps	1350	8.52	1.55	**6.97**
VC	HHSI	2 Pumps	1350	11.78	8.86	**2.92**
VC	HHSI – after 24 hours of IR sump operation	2 Pumps	1350	11.78	9.27	**2.51**

Table 3g.16-6:
IP-3 NPSH and Conventional and Chemical Debris Head Loss Margins

Sump	Alignment	Pumps	Sump Flow Rate Q (gpm)	Structural Limit (ft)	Total Strainer Head Loss $h_{L,Total}$ (ft)	Final Head Loss Margin (ft)
IR	HHSI	2 Pumps	1350	9.47	1.64	**7.83**
VC	HHSI	2 Pumps	1350	11.53	8.61	**2.92**
VC	HHSI – after 24 hours of IR sump operation	2 Pumps	1350	11.53	7.12	**4.41**

Section 3a.3 presents 6 break cases that require certification of adequate NPSH margin. A summary of the head losses and final margins for these 6 break cases, at the most limiting flow conditions, is shown in Table 3g.16-7 and Table 3g.16-8 for IP-2 and IP-3, respectively.

Table 3g.16-7:
Summary of Debris Head Loss and Head Loss Margin for IP-2 (For Each Accident Category, Results of the Case with the Minimum Margin are Shown).

Accident Category	Sump	Flow Rate Q	Acceptance Criteria h_C	Head Loss				Margin $h_C - h_L$
Conventional Debris Head Loss								
				Debris	RMI	CSHL	Total* h_L	
		(gpm)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
LBLOCA or RC-LBLOCA	IR	3568	1.70	1.06	2.37 $\times 10^{-7}$	0.111	1.18	0.52
6 Inch or RC-6 Inch Break LOCA	VC	3221	7.00	2.84	0.00	1.026	3.87	3.13
LBLOCA or RC-LBLOCA after 24 Hour Pool Turnover	VC	N/A						
Conventional Plus Chemical Debris Head Loss								
Accident Category	Sump	Flow Rate Q	Acceptance Criteria h_C	Head Loss				Margin $h_C - h_L$
				Debris	RMI	CSHL	Total* h_L	
		(gpm)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
LBLOCA or RC-LBLOCA	IR	1350	8.52	1.50	2.37 $\times 10^{-7}$	0.044	1.55	6.97
6 Inch Break	VC	1350	11.78	8.20	0.00	0.209	8.41	3.37
RC-6 Inch Break LOCA	VC	1350	11.78	8.64	0.00	0.209	8.86	2.92
LBLOCA or RC-LBLOCA after 24 Hour Pool Turnover	VC	1350	11.78	9.05	0.00	0.209	9.27	2.51

* Note that the total head loss is conservatively rounded up.

Table 3g.16-8:
Summary of Debris Head Loss and Head Loss Margin for IP-3 (For Each Accident Category, Results of the Case with the Minimum Margin are Shown).

Conventional Debris Head Loss

Accident Category	Sump	Flow Rate Q	Acceptance Criteria h_C	Head Loss				Margin $h_C - h_L$
				Debris	RMI	CSHL	Total* h_L	
		(gpm)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
LBLOCA or RC-LBLOCA	IR	4149	0.92	0.69	0.00	0.214	0.91	0.01
6 Inch or RC-6 Inch Break LOCA	VC	1226	2	1.06	0.00	0.101	1.17	0.83
LBLOCA or RC-LBLOCA after 24 Hour Pool Turnover	VC	N/A						

Conventional Plus Chemical Debris Head Loss

Accident Category	Sump	Flow Rate Q	Acceptance Criteria h_C	Head Loss				Margin $h_C - h_L$
				Debris	RMI	CSHL	Total* h_L	
		(gpm)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
LBLOCA or RC-LBLOCA	IR	1350	9.47	1.58	0.00	0.052	1.64	7.83
6 Inch or RC-6 Inch Break LOCA	VC	1350	11.53	8.49	0.00	0.114	8.61	2.92
LBLOCA or RC-LBLOCA after 24 Hour Pool Turnover	VC	1350	11.53	7.00	0.00	0.114	7.12	4.41

* Note that the total head loss is conservatively rounded up.

NRC RAIs 16, 17, 18 and 19 concern NPSH, the subject of the current NRC Issue (3g). The RAIs were identified in an NRC letter to Entergy, dated November 19, 2007 [Ref. 119]. The responses to these RAIs may be found in Attachment 3.

USNRC Issue 3h:

Coatings Evaluation
The objective of the coatings evaluation section is to determine the plant-specific ZOI and debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

1. *Provide a summary of type(s) of coating systems used in containment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat.*
2. *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*
3. *Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris.*
4. *Provide bases for the choice of surrogates.*
5. *Describe and provide bases for coatings debris generation assumptions. For example, describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings.*
6. *Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*
7. *Describe any ongoing containment coating condition assessment program.*

Entergy Response to Issue 3h.1:

Unit 2

The types and amounts of coatings used in the IP-2 containment are included in the IP-2 Debris Generation Calculation, Ref. 1. The types of coating systems used in containment are presented below:

Qualified Coatings:

Keeler & Long 6129
Keeler & Long 4129
Keeler & Long 4000
Keeler & Long 6548/7107
Keeler & Long 5000
Keeler & Long D-1

Unqualified / Unacceptable Coatings:

Inorganic Zinc
High Temperature Aluminum
Alkyd Enamel
Epoxy/Epoxy Phenolic
White RTV / Black Polysilicone Caulk
Instacote

Unit 3

The types and amounts of coatings used in the IP-3 containment are included in the IP-3 Debris Generation Calculation, Ref. 2. The types of coating systems used in containment are presented below:

Qualified Coatings:

Carboline 195
Carboline 890
K&L 6548/7107
K&L E-1-7475
Phenoline 305

Unqualified / Unacceptable Coatings:

High Temperature Aluminum
Alkyd Enamel
Epoxy/Epoxy Phenolic

Entergy Response to Issue 3h.2:

Common to both units

The following assumptions related to fine particulate debris, including paint chips, were made in the debris transport analysis [Refs. 41 and 42]:

a. It was assumed that the settling velocity of fine particulate debris (insulation, dirt/dust, and paint particulate) can be calculated using Stokes' Law.

   Basis: This is a reasonable assumption since the particulate debris is generally spherical and would settle slowly (within the applicability of Stokes' Law).

b. It was assumed that the fines generated by the LOCA blast would be transported to upper containment in proportion to the volume of upper containment compared to the entire volume.

   Basis: This is a reasonable assumption since fine debris generated by the LOCA jet would be easily entrained and carried with the blowdown flow.

c. It was assumed that the debris washed down from upper containment by the spray flow would remain in the general vicinity of the location where it is washed down until recirculation begins.

   Basis: This is a reasonable assumption since there is no preferential pool flow direction during pool fill-up after the in-core instrumentation tunnel/Reactor Cavity and the sump cavities have been filled. Also, this assumption is somewhat conservative since the local turbulence caused by the sprays would increase the potential for debris to transport from these locations.

d. It was assumed that the fine debris that is not blown to upper containment would be uniformly distributed in the recirculation pool at the beginning of recirculation.

   Basis: This is a reasonable assumption, since the flow during pool fill-up would carry the fine debris to all regions of the pool.

e. It was assumed that the unqualified coatings outside the ZOI would be distributed based on their applied locations.

   Basis: This is a reasonable assumption since the unqualified coatings would fail gradually and fall into the pool in the location where they are applied (or the locations to which coatings in upper containment would be washed down).

f. In accordance with the GR [Ref. 6, Section 3.4.3.3.4] and endorsed by the SER, unqualified coatings outside the ZOI that are under intact insulation are not considered to fail. Unqualified coatings that are under insulation that becomes debris (i.e. insulation within the ZOI) are assumed to fail.

   Basis: This is a reasonable assumption because the coatings would be captured and retained by the intact insulation.

g. Epoxy / Epoxy Phenolic unqualified coatings outside of the ZOI are assumed to fail as chips. The size of chips or flakes is assumed to be equivalent to the smallest applied coating thickness as reported in Attachment E in Report No. CON032-RPT-001 [Ref. 17], which corresponds to 6 mil (153 μm). To be conservative, all other unqualified coatings outside of the Coatings ZOI are assumed to fail as 10 μm particles.

   Basis: This assumption is reasonable because autoclave test data [Ref. 75] gathered by BWROG Containment Coating Committee to simulate LOCA exposure and gain insight into post-LOCA failure mechanisms, showed that coatings outside the ZOI fail as chips. Likewise, Report No. CON041-002-PR-01 Rev. 0 [Ref. 76] confirms the applicability of the test data presented in the Keeler & Long PPG High Performance Coatings Report No. 06-0413 [Ref. 77] to Indian Point Units 2 & 3. The test data on unqualified coatings under DBA conditions indicated that the phenolic topcoat was non-transportable debris and that the epoxy coatings failed as chips with no degradation of the thickness. Report No. 06-0413 and Report No. CON041-002-PR-01 Rev. 0 [Ref. 76] also indicate that all other coatings fail as 10 μm particles or larger; meaning that the particle sizes cannot be smaller, but can be larger. Smaller particle sizes have the potential to transport more easily to the sump and to cause higher sump screen head losses. Therefore, choosing the smallest possible particle size is conservative.

h. It was conservatively assumed that the additional unqualified coatings identified after the initial walkdowns and documented in design input letters IP-DE-08-010 and IP-DE-08-015 would have a transport fraction of 100%.

   This is a reasonable assumption because the sump transport of the coatings debris discussed in letters IP-DE-08-010 and IP-DE-08-015 is being maximized. In an actual accident scenario, it is likely that some portion of the failed coatings will be held up on miscellaneous pieces of equipment or other structures.

Entergy Response to Issue 3h.3:

Common to both units

Silicon Carbide (SiC) was the surrogate material used in suction strainer head loss testing to simulate the mechanical behavior of both qualified and unqualified coatings debris [Ref. 37]. Details of head loss testing as it relates to DBA qualified and unqualified coatings are located in Response to Issue 3f.4 and 3f.5.

Entergy Response to Issue 3h.4:

Common to both units

The Silicon Carbide (SiC) particulate debris surrogate material was selected based on a comparison of the microscopic densities of the plant materials. Epoxy and alkyd coatings densities at plants range from 94 lb/ft^3 to 98 lb/ft^3 per the NEI Guidance Report [Ref. 6]. Inorganic zinc coatings used at Indian Point have a density on the order of 457 lb/ft^3 [Ref. 1]. The surrogate (SiC) material's specific gravity is 3.2 [Ref. 37], which corresponds to a microscopic density of 199.5 lb/ft^3. The critical parameter for selecting the surrogate material is the volume of the material in the debris mix. The particulate material occupies a certain volume in the fibrous debris space that results in increasing resistance to flow and higher head loss. The surrogate material volume was adjusted to match the volume of the coatings particulate for coatings that are less dense than the SiC (e.g. alkyds and epoxies) [Ref. 37]. Sufficient turbulence was maintained within the test tank to prevent near field settling of debris. Therefore, the difference in density does not have an effect on the final test head loss values. During testing, the particle size for all coatings (epoxy, alkyd, and inorganic zinc) was simulated by 10 μm spheres; this is a conservative treatment of unqualified epoxy outside of the ZOI, which fails as 6-mil chips. The Silicon Carbide surrogate material is a spherical particulate with a mean particulate diameter of approximately 10 μm.

Entergy Response to Issue 3h.5:

Common to both units

As described in Section 3.4 of the GR [Ref. 6], all qualified and unqualified coatings within the ZOI are assumed to fail. All unqualified and degraded (unacceptable) coatings outside the coating ZOI are assumed to fail. All DBA qualified coatings that are not subjected to the break jet are assumed to remain intact in the post HELB environment. Also, unqualified coatings that are under intact insulation are not considered to contribute to the debris load.

A ZOI of 4D for DBA-qualified/acceptable epoxy coating systems was used for the coating Debris Generation Calculation [Refs. 1 and 2]. These destruction properties of the DBA-qualified/acceptable coating systems were obtained from testing performed by Westinghouse [Ref. 78]. The coating systems applied at Indian Point were stated in an evaluation by Westinghouse [Ref. 79] to be consistent in composition and application as the coatings used in testing.

The latest NRC review guidance for coatings references WCAP-16568-P [Ref. 78], which recommends using a 5D ZOI for un-topcoated in-organic zinc (IOZ) paint. However, the coatings on structural steel were conservatively assumed to be epoxy with a 15 mil thickness and a ZOI of 4D. Debris loads were calculated for a 100% in-organic zinc system applied to the structural steel with a ZOI of 5D for the break location with the maximum structural steel surface area (6703 ft^2) and were compared to debris loads calculated for a 100% epoxy system applied to the structural steel with a 4D ZOI for the same break location (4256 ft^2). A comparison of the results showed that the total amount of coatings generated from the epoxy system was greater (5.32 ft^3 vs. 1.68 ft^3). Therefore, it is concluded that due to the applied thicknesses and densities of the various Indian Point coating systems, the current approach of 100% Epoxy at 4D is bounding with respect to other 5D cases [Ref.107].

Coatings walkdowns were performed to identify DBA qualified/acceptable, unqualified, and degraded coatings and to quantify the amount of debris that would be generated by them. These walkdowns are summarized in Appendix E of the Walkdown Reports [Refs. 17 and 23]. This technique identified coatings based upon experience and previous work at other nuclear facilities. Each coating area was estimated by breaking down the applied surfaces into simple geometric shapes with easily determined surface areas. The thickness of each coating was either recorded from station records or determined based upon previous experience at other facilities.

The maximum quantities of coatings debris for all breaks, except the Reactor Cavity breaks, are presented in Tables 3h.5-1 and 3h.5-5 for Unit 2 and Unit 3, respectively [Refs. 1 and 2].

The maximum quantities of coatings debris for Reactor Cavity breaks are presented in Tables 3h.5-2 and 3h.5-6 for Unit 2 and Unit 3, respectively [Refs. 1 and 2].

Additional Unqualified Coatings were identified for both Unit 2 and Unit 3 that were not included in the earlier walkdowns. These additional coatings are discussed in the Debris Generation Calculations [Refs. 1 and 2], and are summarized in Tables 3h.5-3, 3h.5-4, and 3h.5-7. Since these coatings are unqualified, they are all assumed to fail.

Table 3h.5-1:
Unit 2 Maximum Coating Debris Quantity – All breaks except the Reactor Cavity Break

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Qualified Coatings (Inside ZOI)	Epoxy 6129, Epoxy 4129, Epoxy 4000, Epoxy 6548/7107, Epoxy 5000, Epoxy D-1	579.04	10	LB
Unqualified Coatings (Inside ZOI)	High Temp. Aluminum, Epoxy/Epoxy Phenolic, Inorganic Zinc, Alkyd Enamel	29.51	10	LB
Unqualified Coatings (Outside ZOI)	Inorganic Zinc	191.60	10	LB, SB, 6"
Unqualified Coatings (Outside ZOI)	High Temp. Aluminum	8.25	10	SB, 6"
Unqualified Coatings (Outside ZOI)	Alkyd Enamel	32.29	10	LB, SB, 6"
Unqualified Coatings (Outside ZOI)	Epoxy/Epoxy Phenolic	423.12	153 *	SB, 6"
Unqualified Coatings (Outside ZOI)	White RTV Caulk / Black Polysilicone Caulk	168.96	10	LB, SB, 6"

* Chip or flake thickness (6 mils = 153 μm)

** Additional 30 ft^2 of Unqualified Coatings identified during Outage 2R17 are not included in this table. See Table 3h.5-4.

***Also, additional Unqualified Coatings identified during Outage 2R18 are not included in this table. See Table 3h.5-3.

Table 3h.5-2:
Unit 2 Maximum Coating Debris Quantity – Reactor Cavity Break

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Qualified Coatings (Inside ZOI)	Epoxy 6129, Epoxy 4129, Epoxy 4000, Epoxy 5000, Epoxy D-1	511.55	10	LB
Unqualified Coatings (Inside ZOI)	High Temp. Aluminum	35.10	10	LB
Unqualified Coatings (Outside ZOI)	Inorganic Zinc	191.83	10	LB, SB, 6”
Unqualified Coatings (Outside ZOI)	High Temp. Aluminum	34.77	10	SB
Unqualified Coatings (Outside ZOI)	Alkyd Enamel	32.46	10	LB, SB, 6”
Unqualified Coatings (Outside ZOI)	Epoxy/Epoxy Phenolic	423.21	153 *	LB, SB, 6”
Unqualified Coatings (Outside ZOI)	White RTV Caulk / Black Polysilicone Caulk	168.96	10	LB, SB, 6”

* Chip or flake thickness (6 mils = 153 μm)

** Additional 30 ft^2 of Unqualified Coatings identified during Outage 2R17 are not included in this table. See Table 3h.5-4.

***Also, additional Unqualified Coatings identified during Outage 2R18 are not included in this table. See Table 3h.5-3.

Table 3h.5-3:
Unit 2 Additional Unqualified Coatings Identified During Outage 2R18

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Unqualified Coatings (Outside ZOI)	Epoxy/Epoxy Phenolic	0.57	153	LB, SB, 6”
Unqualified Coatings (Outside ZOI)	Alkyd Enamel	15.88	10	LB, SB, 6”

*These coatings amounts are applicable to all breaks.

Table 3h.5-4:
Additional Unqualified Coatings Identified During Outage 2R17

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Unqualified Coatings (Outside ZOI)	Instacote	8.4	10	LB, SB, 6”

*The unqualified coatings amounts listed are applicable to all breaks.

Table 3h.5-5:
Unit 3 Maximum Coating Debris Quantity – All breaks except the Reactor Cavity Break

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Qualified Coatings (Inside ZOI)	195 Surfacer, Carboline 890, Epoxy 6548/7107, Epoxy E-1-7475	504.72	10	LB
Unqualified Coatings (Inside ZOI)	High Temp. Aluminum, Epoxy/Epoxy Phenolic, Alkyd Enamel	29.87	10	LB
Unqualified Coatings (Outside ZOI)	High Temp. Aluminum	8.25	10	SB, 6”
Unqualified Coatings (Outside ZOI)	Epoxy/Epoxy Phenolic	828.25	153 *	SB, 6”
Unqualified Coatings (Outside ZOI)	Alkyd Enamel	29.60	10	LB, SB, 6”

* Chip or flake thickness (6 mils = 153 μm)

**Additional Unqualified Coatings identified during Outage 3R14 are not included in this table. See Table 3h.5-7.

Table 3h.5-6:
Unit 3 Maximum Coating Debris Quantity – Reactor Cavity Break

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Qualified Coatings (Inside ZOI)	195 Surfacer, Carboline 890	354.35	10	LB
Unqualified Coatings (Inside ZOI)	High Temp. Aluminum	35.10	10	LB
Unqualified Coatings (Outside ZOI)	Epoxy/Epoxy Phenolic	828.25	153 *	LB, SB, 6”
Unqualified Coatings (Outside ZOI)	Alkyd Enamel	29.73	10	LB, SB, 6”

* Chip or flake thickness (6 mils = 153 μm)

**Also, additional Unqualified Coatings identified during Outage 3R14 are not included in this table. See Table 3h.5-7.

3h.5-7:
Unit 3 Additional Unqualified Coatings Identified During Outage 3R14

Coating Type	Type	Weight (lbs)	Analysis Size (μm)	Break Type
Unqualified Coatings (Outside ZOI)	Epoxy/Epoxy Phenolic Identified	18.03	153	LB, SB, 6"
	Epoxy/Epoxy Phenolic Removed	3.81		
	Total Additional Epoxy/Epoxy Phenolic	**14.22**		
Unqualified Coatings (Outside ZOI)	Total Additional Alkyd Enamel	**5.92**	10	LB, SB, 6"

*These coatings amounts are applicable to all breaks.

Entergy Response to Issue 3h.6:

Common to both units

All coatings inside the ZOI will have a 10 μm particle coating debris size, per SER recommendation [Ref. 3]. Epoxy / Epoxy Phenolic unqualified coatings outside of the ZOI are assumed to fail as chips. As demonstrated by testing described and confirmed in the Indian Point specific coatings evaluation [Ref. 76], the size of chips or flakes is assumed to be equivalent to the smallest applied coating thickness, which corresponds to 6 mil (153 μm) as reported in Attachment E of the Walkdown Reports [Refs. 17 and 23]. All other unqualified coatings outside of the Coatings ZOI are assumed to fail as 10 μm particles.

Entergy Response to Issue 3h.7:

Several enhancements to the existing Entergy Nuclear Northeast fleet procedure, ENN-DC-150, "Condition Monitoring of Maintenance Rule Structures", were made. These enhancements include a detailed inspection checklist for coatings. A PM to visually inspect coating in the Indian Point Unit 2 and 3 Vapor Containment Buildings during all future refueling outages was created for GSI-191 employing guidance from ENN-DC-150. These changes have been incorporated in fleet procedure EN-DC-150, Rev. 0. The frequency of the PM inspection for GSI-191 is every two (2) years, or every cycle during the refueling outage. The process requires any degraded coatings be evaluated as acceptable, or repaired prior to exiting the outage.

All coating requests in the VC are evaluated by the coating engineer and only approved DBA qualified coatings are used.

NRC RAI 20 concerns Coating Evaluation, the subject of the current NRC Issue (3h). This RAI was identified in an NRC letter to Entergy, dated November 19, 2007 [Ref. 119]. The response this RAI may be found in Attachment 3.

USNRC Issue 3i:

i. Debris Source Term
The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions.
Provide the information requested in GL 04-02 Requested Information Item 2.(f) regarding programmatic controls taken to limit debris sources in containment.
GL 2004-02 Requested Information Item 2(f)
A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, A *Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," to the extent that their responses address these specific foreign material control issues.*

In responding to GL 2004 Requested Information Item 2(f), provide the following:

1. *A summary of the containment housekeeping programmatic controls in place to control or reduce the latent debris burden. Specifically for RMI/low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.*
2. *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment.*
3. *A description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46 and related regulatory requirements.*
4. *A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.*

If any of the following suggested design and operational refinements given in the guidance report (guidance report, Section 5) and SE (SE, Section 5.1) were used, summarize the application of the refinements.

5. *Recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers*
6. *Any actions taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers*
7. *Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers*
8. *Actions taken to modify or improve the containment coatings program*

Entergy Response to Issue 3i.1:

In general, it is plant policy to leave an area better than when you first entered it. Existing plant procedures support this concept in practice. Besides maintenance/construction following good housekeeping practices, the Radiation Protection group has a keen interest in ensuring good housekeeping is enforced to help reduce the spread of contamination and general area dose reductions.

Plant procedure OAP-007, "Containment Entry and Egress" is applicable to both units. This procedure requires various inspections before exiting an outage. It was revised to include specific Engineering inspections of the sump strainers and assemblies, as well as critical features of the sump design, like the flow barriers, to ensure proper configuration. This procedure is already sensitive to the Foreign Material Exclusion (FME) issue. A required Pre-job brief includes covering FME. The VC closeout checklist includes a detailed listing of unacceptable items such as: combustible materials, debris, non secured plastic bags/film/sheets, shoe covers, paper, fibrous materials, rags, wood, tape/rope, damaged insulation, non-metal signage. At the end of each outage, personnel will perform walkthroughs to catch and remove any extraneous materials. See also the response to item 3i.2 and the dust and latent debris control response described in 3i.3.

<u>It should be noted that Unit 2 and Unit 3 are not considered lower fiber plants and therefore the strainers are not especially sensitive to latent fiber.</u>

<u>Entergy Response to Issue 3i.2:</u>

Entergy Fleet procedure EN-MA-118, "Foreign Material Exclusion" is applicable to both units. It establishes specific requirements for physical controls to prevent foreign material from entering systems and components. This procedure is applicable whenever maintenance, modifications, repairs, inspections, and operating activities are performed.

Additionally, the procedure identifies the recirculation and containment sumps as FME Level 1 areas, the highest level of cleanliness control, and both sumps are treated as such at Indian Point.

Procedure IP-SMM-RW-103; "Radioactive Waste Volume reduction Program" is applicable to both Units. While the purpose is reduction of radioactive waste, this procedure has several points which support Containment cleanliness. The procedure requires that non-essential materials (e.g. packaging) not be brought into Containment, only the amount of consumables require be taken in, and in general to minimize material brought into Containment.

Procedure IP-SMM-HU-102; "Pre-Job Briefing and Post Job Critiques" are performed to refresh workers of important aspects of the job about to be worked. This procedure contains a standard checklist in which FME and Housekeeping are discussed.

Additionally, inspections in the Containment building for reasons other than GL 2004-02 related provide an opportunity to capture potential adverse conditions. Procedure 2-PT-Q092 for Unit 2, and 3-PT-Q137 for Unit 3; both entitled "Containment Building Inspection" direct the personnel performing the inspections to identify any suspect FME concerns to Operations for disposition. These procedures are performed quarterly, thereby providing an opportunity to observe conditions in-between refueling outages.

<u>Entergy Response to Issue 3i.3:</u>

To maintain the required configuration of containment that supports the inputs and assumptions utilized to perform the mechanistic evaluation of the recirculation function, Indian Point has implemented programmatic and process controls as described below.

Plant procedures, programs, and design requirements were reviewed to determine those that could impact the analyzed containment or recirculation function configuration. These reviews resulted in the identification of those documents that required revision or development of new documents to ensure continued compliance with the regulatory requirements of GL 2004-02 as follows:

- Electrical Control

  Engineering Standard ENN-EE-S-010-IP2 (Unit 2), Electrical Separation Design Criteria was revised and specifically:
  - Phases out the use of vinyl cable tray tags. When, and as required, such tags will be replaced by DBA qualified tags.
  - Excludes the use of new marinate and/or transite used for cable tray separation barriers.
  - Eliminates use of new cable wrap for separation.
  - Requires Engineering evaluation should a deviation be necessary.

- Engineering Standard ENN-EE-S-008-IP, "Electrical Cable Installation Standard" is applicable to both units and was revised to eliminate unqualified material such as vinyl tags, tape, and blankets in new installations. An Engineering evaluation would be required should a deviation be necessary.

- Design Control

  Fleet design procedure EN-DC-115, "Engineering Change Development" is applicable to both units. This procedure screens changes for impact on GL 2004-02 compliance. Examples of specific screen items include any changes to: insulation, coatings, aluminum, and other metallic/non metallic debris sources.

  Fleet design procedure EN-DC-141, "Design Inputs" is applicable to both units. This procedure also contains numerous screening items to consider when developing designs.

- Aluminum Control

  Use of Aluminum is typically restricted in PWR containments due to potential for post accident Hydrogen production and GSI concerns reinforce its restriction. Both the Unit 2 and 3 insulation specifications prohibit the use of aluminum in containment (Unit 2 – MM92-250, "Specification for Insulations (Thermal/Acoustic)", Unit 3 - TS-MS-003, "Specification for Piping and Equipment Insulation").

  Plant procedure OAP-007, "Containment Entry and Egress" is applicable to both units and requires the removal of any aluminum brought into Containment that has not been evaluated by Engineering.

- Coatings Control

  See Response to 3h.7.

- Insulation Control

  Plant procedure 0-SYS-404-GEN, "Installation of Insulating Materials for All Plant Piping and Equipment" is applicable to both units. It was created to maintain thermal insulation configuration control. The procedure works with the new INSUL series of plant drawings, which were created for each unit from plant walk downs of the piping systems in Containment, and document the current analyzed insulation. The procedure requires evaluation for the installation of any new insulation, or replacement that is not identical to the existing material.

- Tagging Control

  Plant procedure OAP-044, "Plant Labeling Program", is applicable to both units. This procedure indicates that labels/tagging to be installed in the Containment Building shall be stainless steel.

- Containment Entry Control

  Refer to item 3.i.1 & 3.i.2.

- Maintenance FME Control

  Refer to item 3.i.1 & 3.i.2.

- Dust and Latent Debris Control

  In order to ensure Containment dust, dirt, and latent debris does not exceed the analyzed quantities evaluated; a sampling program was initiated. The sampling uses the same methodology employed for the original walkdown and is per NEI 04-07 methodology as amended by SER. Entries were made in the Work Control System that will automatically generate work orders to perform sampling activities on an appropriate recurring and periodic basis for each unit. Current FME and Housekeeping programs, as well as Containment cleaning efforts by Maintenance, Radiation Protection and Operations just prior to startup are expected to keep the loads within the bounds of the analysis.

Entergy Response to Issue 3i.4:

Maintenance activities including temporary changes are subject to the provisions of 10 CFR 50.65(a)(4) as well as the Technical Specifications. The Entergy fleet procedures provide guidance on 50.59 review process, which provides details and guidance on maintenance activities and temporary alterations; the on-line work control process procedure, which establishes the administrative controls for performing on-line maintenance of systems, structures and components to enhance overall plant safety and reliability; and the temporary modification procedure, which establishes the overall requirements for such changes.

Entergy Response to Issue 3i.5:

There are no insulation changeouts currently planned for the Indian Point units.

Entergy Response to Issue 3i.6:

Refer to Item 3.i.5 above.

Entergy Response to Issue 3i.7:

Refer to Section 3.j.2 for descriptions of other modifications performed relative to the GSI effort.

Entergy Response to Issue 3i.8:

See Response to 3h.7.

USNRC Issue 3j:

Screen Modification Package
The objective of the screen modification package section is to provide a basic description of the sump screen modification.

1. *Provide a description of the major features of the sump screen design modification.*
2. *Provide a list of any modifications, such as reroute of piping and other components, relocation of supports, addition of whip restraints and missile shields, etc., necessitated by the sump strainer modifications.*

Entergy Response to 3j.1:

The existing grating and fine screen in the IR and VC sumps were replaced with flow barriers and basket (Top-Hat) type strainer assemblies designed to accommodate the increased post-accident debris loads. In addition, an extension strainer assembly is connected to the Unit 2 VC sump strainer assembly. The new strainers are sized to limit the head loss across them to ensure positive NPSH margin for the IR and RHR pumps. The Top-Hat type strainers are made of 14 gauge Type 304 stainless steel plate perforated with 3/32" diameter holes. These Top-Hat assemblies are configured as four concentric cylinders (arranged in a double set) attached at one end to a rectangular plate. Two wire mesh filter elements are inserted between each set of cylinders with a woven steel mesh Debris Bypass Eliminator situated in the annulus of the concentric cylinders of the Top-Hat modules. The strainers are mounted to a water box that channels flow to the IR pit or RHR pump suction piping.

The new strainers significantly increase the effective surface area of strainer in the IR sump (~3156 ft^2 for each Unit) and VC sump (~1182 ft^2 for Unit 2 and ~1058 ft^2 for Unit 3). The new strainers will prevent particles greater than 3/32" in diameter from entering the IR Pump suction. The maximum water velocity through the sump screen remains less than one foot per second.

Flow channeling barriers are designed to route the post-LOCA water into the reactor cavity and then up through the incore instrumentation tunnel to the VC annulus through openings in the crane wall before entering the IR sump or the VC sump/extension (see details in section 3.j.2). These changes are intended to reduce debris transport to the ECCS sumps by minimizing the flow velocities and turbulent energy of the recirculating fluid as it flows back to the sump(s). The low velocities and torturous path will maximize debris settlement and sedimentation. The reactor sump/incore tunnel offers an expansive area free from turbulence that produces the low velocities allowing for the settling out of small and large debris. Consequently, only small pieces, fines, and particulate matter are transportable to the ECCS sumps.

Structural steel and flow barriers were installed around the VC sumps as part of the flow channeling design. Perforated plate was placed on the floor of the RHR Heat Exchanger room above the IR sump enclosure, and also over the trenches leading to the IR sump, to prevent large particles from being washed down directly into the sump. In order to install the strainer assemblies, certain equipment had to be relocated to alleviate interferences.

Internal Recirculation Sump Strainer:

The internal recirculation sump strainers at Indian Point are located inside the crane wall and surrounded by a concrete barrier. The internal recirculation sump strainer consists of two (2) plenum frames and a collector plenum that communicates with the IR pump compartment. Top Hats are mounted on either side of the vertically mounted plenum frame. The plenum frames are anchored to the sump walls utilizing concrete anchors. Thermal releases are provided through use of sliding connections and slotted holes.

Sketches showing the existing and modified sump strainer assemblies for IP-2 and IP-3 are provided in Attachments A and B, respectively.

Vapor Containment Sump Strainer:

<u>Unit 2</u>

The VC sump strainer consists of two sections, the sump mounted strainer inside the crane wall and the strainer extension in the annulus between the crane wall and the containment wall. The two strainer sections are connected via a rectangular plenum that is routed through an existing penetration in the crane wall. The sump mounted strainer consists of a single vertically mounted plenum frame with Top Hats mounted on one side of the plenum frame. The plenum frame is anchored to the sump walls utilizing concrete anchors. Thermal releases are provided through use of sliding connections and slotted holes. The suction pipe connects directly to the plenum frame.

The extension strainer is located in the annular region outside the crane wall and is connected to the sump mounted strainer via duct type rectangular plenums. The extension strainer consists of plenums (rectangular cross-section) mounted directly on the containment floor. A series of Top Hats are mounted on either side of the plenums.

<u>Unit 3</u>

The VC sump strainer at IP-3 consists of a sump mounted strainer inside the crane wall consisting of a single vertically mounted plenum frame with Top Hats mounted on one side of the plenum frame. The plenum frame is anchored to the sump walls utilizing concrete anchors. Thermal releases are provided through use of sliding connections and slotted holes. The suction pipe connects directly to the plenum frame.

<u>Entergy Response to 3j.2:</u>

<u>Both Units</u>

Physical changes were implemented to ensure required flow channeling. These included the following [Refs. 94 and 95]:

- Permanently removed grating at the entrance to the reactor sump and incore tunnel.
- Permanently removed the vertical grating on the south side of the incore tunnel.
- Modified the access ladder to the reactor sump

- Reduced the curb height on the south end of the incore tunnel to 1". Also reduced the curb height around the reactor sump.
- Modified the reactor sump platform.
- Installed the incore tunnel flow channeling barriers.
- Cut three flow channel openings in the crane wall (Unit 2).
- Cut flow channel openings in the crane wall and through the VC sump labyrinth wall (Unit 3).
- Installed flow channeling barriers at appropriate crane wall penetrations.
- Installed personnel gates at applicable IR sump, VC sump, and crane wall openings.
- Installed flow barriers around VC sumps
- Removed the perforated plate strainer on the fuel transfer canal drain and installed a debris trash rack.
- Grating with perforated plate was placed on a section of the VC sump trench inside the crane wall (Unit 2).

These changes are intended to reduce debris transport to the ECCS sumps by minimizing the flow velocities and turbulent energy of the recirculating fluid as it flows back to the sump(s).

Vortex suppression grating is scheduled to be installed over all portions of the VC and IR sump strainers, including the IP-2 VC extension, during Spring 2010 (IP-2) and Spring 2011 (IP-3) outages.

Indian Point Unit 2

The interaction of accident-generated debris with borated water, aluminum, and the pH buffer has the potential to form chemical precipitates. The accumulation of these chemical precipitates along with the more conventional fibrous and particulate debris could impact the head loss across the strainers and reduce the pump NPSH margin to an unacceptable level. It has been predicted through generic testing and chemical analysis that the calcium silicate-bearing insulation debris in Unit 2 could react with the boric acid, if a Tri-sodium Phosphate (TSP) buffer is present in the containment sump water, to yield chemical precipitates and yield a greater head loss across the strainers. Therefore, the TSP pH buffer was replaced with Sodium Tetraborate (NaTB) using the existing baskets on the 46' elevation in the Spring 2008 Refueling Outage [Ref. 96]. This eliminates the possibility of phosphate based precipitates.

Indian Point Unit 3

The IR pumps were replaced during the spring 2007 refueling outage [Ref. 97] with a double inlet suction style pump. Due to the predicted increased sump screen debris load determined by GL 2004-02 related analyses, the head losses through the IR sump are also predicted to increase. Based on hydraulic and NPSH Calculations, due to the increased debris loads the original pumps would not have been able to fulfill their safety functions. The replacement pumps are demonstrated to have the capability to operate without cavitation at the required flow rates assuming maximum anticipated sump screen head losses.

Previously, the containment spray system included NaOH injection. This system was replaced with solid NaTB buffer maintained in specially designed baskets located in the VC (46' elevation). This pH buffer replacement was completed in 2008 [Ref. 98], and the existing NaOH storage tank was functionally eliminated.

<u>USNRC Issue 3k:</u>

Sump Structural Analysis
The objective of the sump structural analysis section is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces. Provide the information requested in GL 2004-02 Requested Information Item 2(d)(vii). GL 2004-02 Requested Information Item 2(d)(vii) Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions.

1. *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*
2. *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*
3. *Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable).*
4. *If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.*

<u>Entergy Response to Issue 3k.1:</u>

<u>Common to both units</u>

The sump structural analyses comply with plant specific design criteria. Within these requirements, the Manual for Steel Construction by the American Institute for Steel Construction (AISC) [Ref. 100] constitutes the primary design code.

<u>Sump Strainers</u>

The evaluations are performed utilizing finite element analysis, supplemented by hand calculations. The evaluations follow the requirements of the plant specific design requirements. The strainer structure is designed for the following loads, and the stresses are maintained within the material elastic yield stresses under the most adverse loading conditions

A summary of the methodology, design inputs, the loadings, load combinations used in the strainer structural analysis is provided in References 49 - 51 and 55 - 57.

- Deadweight: The deadweight loading includes the self weight of the strainer components. No credit is taken for buoyancy effects following post-LOCA submergence of the strainer structure.

- Seismic Loads: Seismic analysis of the strainer is performed using dynamic modal analysis. Modal and directional responses are combined consistently with plant specific design specifications. Hydrodynamic mass (virtual mass) effects resulting from post-LOCA submergence of the strainer are included in the modal analysis.

- Differential Pressure Load: The strainer structure may be subjected to differential pressure loading during ECCS pump operation following a LOCA as a result of debris accumulation. The design of the strainer structure includes a differential pressure loading applied to all external surfaces, including perforated surfaces. No reduction in differential pressure loading is credited for the perforations.

- Thermal Effects: The strainer structure is designed to allow unrestrained thermal growth through use of sliding connections and slotted bolt holes. These thermal releases are included in the analysis model and are considered for all loads, including seismic loading. The design provides adequate thermal releases to accommodate the full range of thermal expansion movements associated with the maximum design temperature based on post-LOCA containment environmental and pool temperatures. Effects of elevated post-LOCA temperatures on the allowable material stresses are also considered in the design of the strainer structure.

Vortex Suppressors

The VC sump vortex suppressor is attached to the existing VC sump flow barrier structure and analyzed as a single structural model. For the Unit 2 VC sump strainer extension, the vortex suppressor is attached below the existing trash rack and analyzed as single structural model. An individual vortex suppressor frame is used above the IR sump area. The evaluations are performed utilizing finite element analysis, supplemented by hand calculations. The evaluations follow plant specific design requirements. The vortex suppressor structure is designed for the following loads, and the stresses are maintained within the material elastic yield stresses under the most adverse loading conditions.

A summary of the methodology, design inputs, the loadings, load combinations used in the vortex suppressor structural analysis is provided in References 52, 53, 58 and 62.

- Deadweight: The deadweight loading includes the self weight of the vortex suppressor components. No credit is taken for buoyancy effects following post-LOCA submergence of the structure.

- Live Load: A 100 pound per square foot live load is considered to be acting on the structure during an outage. During plant operation, a 50 pound per square foot live load is consider to be acting in conjunction with the deadweight and seismic loading. However, the IP-2 VC sump strainer extension live load is not considered on the vortex suppressor; this is because the vortex suppressor is located beneath the existing trash rack grating, and therefore, no live load can be directly placed on the vortex suppressor in this area.

- Seismic Loads: A seismic analysis of the structure is performed using dynamic modal analysis. Modal and directional responses are combined consistently with plant specific design specifications. Hydrodynamic mass (virtual mass) effects resulting from post-LOCA submergence of the strainer are included in the modal analysis.

- Thermal Effects: The vortex suppressor structure is designed to allow unrestrained thermal growth through use of sliding connections and slotted bolt holes. These thermal releases are included in the analysis model and are considered for all loads, including seismic loading. The design provides adequate thermal releases to accommodate the full range of thermal expansion movements associated with the maximum design temperature based on post-LOCA containment environmental and pool temperatures. Effects of elevated post-LOCA temperatures on the allowable material stresses are also considered in the design of the strainer structure.

Flow Barrier Structures

Common to both units

The design includes reactor cavity/in-core tunnel exit flow barriers, a VC sump flow barrier, and gates (two openings through the Crane wall for access, and two openings into the compartment where the IR sump is located) act as flow barriers.

The evaluations are performed by hand calculations or utilizing computer analysis (GTSTRUDL), supplemented by hand calculations. The evaluations follow the plant specific design requirements. The flow barriers/gates are designed for the following loads, and the stresses are maintained within the material elastic yield stresses under the most adverse primary loading conditions [Refs. 53 – 54 and 58 – 61].

- Deadweight: The deadweight loading includes the self weight of the components. No credit is taken for buoyancy effects following post-LOCA submergence of the flow barriers/gates.

- Seismic Loads: Modal and directional responses are combined consistent with plant specific design specifications.

  Unit 2
  Seismic analysis of the flow barriers/gates is performed using static analysis with peak acceleration. The seismic design uses a damping value of up to 1%. The flow barriers/gates are considered "Bolted Steel structures" and a damping value of 7% for SSE can be used per Regulatory Guide 1.61 [Ref. 101]. Consequently, use of lower damping value signifies considerable conservatism in the design.

  Unit 3
  Seismic analysis of the flow barriers/gates is performed using static analysis with peak acceleration or dynamic modal analysis. The seismic design uses a damping value of 0.5%. The flow barriers/gates are considered "Bolted Steel structures" and a damping value of 7% for SSE can be used per Regulatory Guide 1.61 [Ref.101]. Consequently, use of lower damping value signifies considerable conservatism in the design.

- Pressure Load: The flow barriers/gates that may be subjected to sub-compartment pressurization due to their location within the containment building are designed to withstand the expected differential pressure loading. Sub-compartment pressurization loading occurs during the initial phase of LOCA blowdown and consequently is not considered concurrent with the seismic loading and thermal effects.

- Thermal Effects: The flow barriers/gates are bolted structures which allow adequate thermal relief at the bolted connections under post-LOCA containment pool temperature. Effects of elevated post-LOCA temperatures on the material stress allowables are also considered in the design of the flow barriers/gates.

Entergy Response to Issue 3k.2:

Common to both units

Design Conservatism:

- The sump structural analyses comply with plant specific design criteria. Within these requirements, Manual for Steel Construction by American Institute for Steel Construction (AISC) [Ref. 100] constitutes the primary design code. AISC code methodology includes inherent design conservatisms that not have been specifically quantified here.

- Structural anchorages utilizing concrete expansion anchors incorporates minimum safety factor of four.

- Material stress allowables are limited to 90% of elastic yield strength which is considerably lower than the ultimate strength of the material.

Sump Strainers

Structural qualifications for the sump strainers were performed in the following calculations:

Indian Point Unit 2:
- CON034-CALC-001, Analysis of Recirculation Sump Strainer Structure [Ref. 49]
- CON034-CALC-002, Analysis of VC Sump Strainer and Extension Strainer Structure [Ref. 50]
- CON034-CALC-003, Analysis of Sump Strainer Top-Hat [Ref. 51]

Indian Point Unit 3:
- CON035-CALC-001, Analysis of Recirculation Sump Strainer Structure [Ref. 55]
- CON035-CALC-002, Analysis of VC Sump Strainer Structure [Ref. 56]
- CON035-CALC-003, Analysis of Sump Strainer Top-Hat [Ref. 57]

Design Conservatism:

- The design of strainer structures has used a seismic damping value of 0.5%. The structures are considered "Bolted Steel structures", and a damping value of 7% for SSE can be used per Regulatory Guide 1.61 [Ref. 101]. Consequently, use of lower damping value (0.5%) signifies considerable conservatism in the design.

- Material allowables considered in the sump strainer structural designs are conservatively based on the maximum temperature. No credit is taken for increased material allowables at lower temperatures when high viscosity and chemical effects result in higher differential pressure values.

- The following table provides margin in the design differential pressure loading associated with a fully debris loaded strainer, including chemical effects.

Table 3k.2-1:
Differential Pressure Design Margins

Unit	Component[3]	Differential Pressure Loading (ft)			Available Structural Margin
		Actual	Design	Margin	
IP-2	IR Sump Weir Wall	1.71	8.52	6.81	398.2%
IP-2	IR Sump Strainer	1.71	9.65[4]	7.94	464.3%
IP-2	VC Sump Strainer	9.27[1]	11.78	2.51	27.0%
IP-3	IR Sump Strainer[2]	1.64[1]	9.47	7.83	477.4%
IP-3	VC Sump Strainer	8.61[1]	11.53	2.92	33.9%

1 Chemical effects contribute to the maximum differential pressure loading
2 IR Sump Weir Wall for IP-3 is not a limiting component, therefore not listed.
3 Top Hat, which is designed for 23.1 ft of Differential Pressure Loading, is not a limiting component, therefore not listed.
4 The IR Sump Strainer is designed for 9.65 ft of Differential Pressure Loading; however, a limiting value of 8.52 ft is used in the Certification Calculation.

<u>Trash Rack and or Vortex Suppressors</u>

Structural qualifications for the Trash Rack and or Vortex Suppressors were performed in the following calculations:

Indian Point Unit 2:
- CON034-CALC-005, Evaluation of VC Sump annulus Trash Rack, IR Sump and VC Sump annulus vortex suppressor [Ref. 52]
- CON034-CALC-006, Containment Building Flow Barrier [Ref. 53]

Indian Point Unit 3:
- CON035-CALC-04, Analysis of VC Sump Flow Barrier / Vortex Suppressor [Ref. 58]
- CON048-CALC-04, IR Sump Vortex Suppressor frame evaluation for IP-3 [Ref. 62]

Vortex suppressor structures for both units were found to be within acceptable plant design criteria and are thus qualified structurally to withstand deadweight, seismic loads and thermal effects at the design temperature. The structural design includes 50 pounds per square foot live load in conjunction with the deadweight and seismic loading during normal operation. The live loads are included to provide additional robustness for any unanticipated loading due to falling items and debris accumulation.

Design Conservatism:

- The design of strainer structures has used a seismic damping value of 0.5%. The structures are considered "Bolted Steel structures", and a damping value of 7% for SSE can be used per Regulatory Guide 1.61 [Ref. 101]. Consequently, use of lower damping value (0.5%) signifies considerable conservatism in the design.

<u>Flow Barrier Structures</u>

Structural qualifications for the Flow barriers were performed in the following calculations:

Indian Point Unit 2:
- CON034-CALC-006, Containment Building Flow Barrier [Ref. 53]

- CON034-CALC-007, Crane Wall Access Gates and Sump Strainer Access Gates Inside Crane Wall [Ref. 54]

Indian Point Unit 3:

1. CON035-CALC-04, Analysis of VC Sump Flow Barrier / Vortex Suppressor [Ref. 58]
2. CON035-CALC-05, Analysis of In-Core South Barrier Structure [Ref. 59]
3. CON035-CALC-06, Analysis of In-Core Tunnel North Flow Barrier [Ref. 60]
4. CON035-CALC-07, Qualification of Containment Building Gates and Misc. Barriers [Ref. 61]

Flow barrier structures are found to be within acceptable plant design criteria and thus qualified structurally to withstand deadweight, seismic loads (including the hydrodynamic mass effects), differential pressure loads, and thermal effects at the design temperature.

Design Conservatism:

- Seismic damping

  <u>Unit 2</u>

  Seismic analysis of the flow barriers/gates is performed using static analysis with peak acceleration. The seismic design uses a damping value of up to 1%. The flow barriers/gates are considered "Bolted Steel structures" and a damping value of 7% for SSE can be used per Regulatory Guide 1.61 [Ref. 101]. Consequently, use of lower damping value signifies considerable conservatism in the design.

  <u>Unit 3</u>

  Seismic analysis of the flow barriers/gates is performed using static analysis with peak acceleration or dynamic modal analysis. The seismic design uses a damping value of 0.5%. The flow barriers/gates are considered "Bolted Steel structures" and a damping value of 7% for SSE can be used per Regulatory Guide 1.61, [Ref. 101]. Consequently, use of lower damping value signifies considerable conservatism in the design.

<u>Entergy Response to Issue 3k.3:</u>

Evaluations of dynamic effects associated with high-energy line breaks for the IR and VC sumps are included below.

Internal Recirculation Sump Strainer:

The Internal Recirculation Sump is located inside the crane wall and is surrounded by the concrete that extends to the operating floor. Therefore, the high-energy lines outside of this barrier will not impact the IR Sump. There are high-energy lines inside this barrier; however none of these line breaks require the post-LOCA recirculation operation of the ECCS system. Therefore, internal recirculation sump does not need to be evaluated for jet impingement or pipe whipping force [Refs. 92 and 93].

Vapor Containment Sump Strainer:

The Vapor Containment Sump Strainer is located inside the crane wall. A number of high energy lines are located within the crane wall. The isolation points on these lines were reviewed. An isolation point (generally a closed valve) is the location on the high energy line beyond which a pipe break would not require ECCS system to operate in the recirculation mode. It was determined that the isolation points are located entirely within the crane wall and away from the VC sump. Therefore, vapor containment sump strainer, including the extension strainer does not need to be evaluated for jet impingement or piping whipping force [Refs. 92 and 93].

Vortex Suppressor and Flow Barrier Structures:
Postulated high energy line breaks including pipe whip, jet impingement and postulated internal missiles were reviewed. The review indicated that the postulated pipe breaks are not located in close proximity of the Flow Barriers / Vortex Suppressor structures are consequently not subjected to the dynamic effects associated with high energy line breaks.

Entergy Response to Issue 3k.4:

Common to both units

No backflushing strategy is credited for ECCS Sump performance.

USNRC Issue 3l.

Upstream Effects
The objective of the upstream effects assessment is to evaluate the flowpaths upstream of the containment sump for holdup of inventory, which could reduce flow to and possibly starve the sump. Therefore, provide a summary of the upstream effects evaluation including the information requested in GL 2004-02, "Requested Information," Item 2(d)(iv) including the basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

1. *Summarize the evaluation of the flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.*
2. *Summarize measures taken to mitigate potential choke points.*
3. *Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.*
4. *Describe how potential blockage of reactor cavity and refueling cavity drains was evaluated, including likelihood of blockage and amount of expected holdup.*

Entergy Response to Issue 3l.1:

Common to both units

Indian Point evaluated water inventory available for the ECCS or CSS recirculation. The Minimum Post-LOCA Containment Water Level Calculations, Refs. 33 and 34, analyzes water transferred from the RWST to the containment, accumulation of water in various holdup volumes in containment, RCS shrinkage, and water held up in the containment atmosphere and in transit (also see section 3g).

In addition to the Water Level Calculation, Indian Point evaluated the transportability of various debris in the Debris Transport Calculations, Refs. 41 and 42. The Debris Transport Calculations used Computational Fluid Dynamics (CFD) to model the containment pool flow paths and velocities. A three-dimensional computer aided drafting (CAD) model of the Indian Point containment building floors (El. 46' and below) and in-core instrumentation tunnels were developed and used for input to the CFD model. Refs. 41 and 33 evaluate the IP-2 containment for upstream blockage concerns. References 42 and 34 evaluate the IP-3 containment for upstream blockage concerns. The lower containment (46' elevation) at Indian Point is basically made up of two compartments—the area inside the crane wall (the Steam Generator compartments), and the area outside the crane wall (the annulus). The Steam Generator compartments are connected to the annulus by doors that have perforated plate flow barriers installed. These flow barriers are designed to allow flow to pass through until they are blocked by debris that would collect on the screens. This forces flow down, as intended, into the Reactor Cavity, then up through the in-core instrumentation tunnel where it can flow to the annulus through a set of crane wall holes next to the VC sump. The entrance to the in-core instrumentation tunnel is nominally 3.5 ft by 16 ft [Refs. 108 and 109], the tunnel itself is nominally 6 ft square [Refs. 108 and 109], and the holes in the crane wall/labyrinth wall are nominally 2 ft by 2 ft [Refs. 24 and 25]. Given the size of the in-core instrumentation tunnel entrance and exit, this is not a significant concern for upstream blockage.

A potential upstream blockage point is the 4-inch refueling canal drain line. Any sprays falling directly in the refueling canal must flow through the refueling canal drain, which runs to the floor of lower containment [Refs. 33 and 34]. If this drain were to become clogged with debris, a large amount of water could be held up in the refueling canal. However, a large trash rack was installed over the refueling canal drain (as described in Response to Issue 3l.2 below) to mitigate this choke point.

Entergy Response to Issue 3l.2:

Common to both units

To mitigate potential choke points, flow barriers and walls were installed to direct flow through areas that are much larger than the largest estimated debris size [Ref. 45]. Hence, as the flow travels from the break location, through the in-core instrumentation tunnel and out the crane wall holes, all flow areas are significantly larger than any of the postulated debris sizes.

To preclude the refueling canal drain from clogging with debris, a large trash rack has been designed for the refueling canal drain (approximately 3ft x 9ft x 1ft). The spacing between the trash rack grating bars is sized such that any small pieces of debris that pass through the trash rack would also readily pass through the 4-inch drain. Also, large debris is not expected to be blown to upper containment since it will not pass through the grating in the loop compartments. Therefore, plugging of the canal drain is prevented by the trash rack. However, holdup above in the refueling canal may still be possible due to the hydraulic head needed to overcome the drain line frictional losses and as described in Responses to Issue 3g.9. This volume is only held up in the refueling canal during the operation of containment sprays, subsequently the canal would drain completely to the sump pool.

Entergy Response to Issue 3l.3:

Common to both units

Once containment spray begins, a portion of the water will fall and be retained on the Operating Deck (El. 95'). This holdup is due to the hydraulic head of water required to push the containment spray water off of the Operating Deck. Flow across the Operating Deck is approximated by assuming weir flow over a weir opening of a length equal to the length of the openings through which water can flow off of the floor [Refs. 33 and 34].

Since much of the 68' elevation of the annular region is concrete slab, water will be retained there. As was done for the Operating Deck, flow across the floor is approximated by assuming weir flow over a weir opening of a length equal to the length of the openings through which water can flow off the floor [Refs. 33 and 34].

To account for miscellaneous holdup volumes not specifically quantified in the Water Level Calculation, a miscellaneous holdup quantity of 500 ft^3 is included for the LBLOCA non-End-of-Event cases and SBLOCA with sprays cases. For the LBLOCA End-of-Event case, a miscellaneous holdup quantity of 250 ft^3 is included. A volume of 125 ft^3 is included for the end-of-event and SBLOCA - no sprays cases [Refs. 33 and 34]. Additional curbs were built and/or left in place to ensure that during normal operation (power and shutdown) any incidental leakage would be channeled to the desired section of the VC sump. These curbs are considered to have insignificant effects on water hold-up or flow patterns during the post-LOCA timeframe.

No debris interceptors are installed at Indian Point and therefore do not present a potential for water hold up.

Entergy Response to Issue 3l.4:

Common to both units

See response to 3l.2 regarding the refueling cavity drain.

The Reactor Cavity is the lowest elevation in the containment and does not have a drain line. Under LOCA conditions, water will fill the Reactor Cavity, which is considered in the minimum Water Level Calculations [Refs. 33 and 34]. In general, the containment was designed to facilitate free drainage to the 46 foot elevation without choke points.

Potential hold-up above the refueling canal drain due to hydraulic head to overcome drain line frictional losses is evaluated and included as a hold-up volume in the Minimum Sump Water Level Calculations [Refs. 33 and 34] and described in the Responses to Issues 3g.9 and 3l.2.

USNRC Issue 3m:

Downstream effects - Components and Systems

The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams.

Provide the information requested in GL 04-02, "Requested Information," Item 2.(d)(v) and 2.(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the sump by explaining the basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface. For GL 2004-02, Item 2(d)(vi) provide verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

GL 2004-02 Requested Information Item 2(d)(v)
The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

GL 2004-02 Requested Information Item 2(d)(vi)
Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

1. *If USNRC-approved methods were used (e.g., WCAP-16406-P with accompanying USNRC SE) briefly summarize the application of the methods.*
2. *Provide a summary and conclusions of downstream evaluations.*
3. *Provide a summary of design or operational changes made as a result of downstream evaluations.*

Entergy Response to Issue 3m.1:

Common to both units
Debris blockage of flow restrictions in the ECCS and CSS flow paths downstream of the sump screen is addressed within the Downstream Effects Reports [Ref. 19 and 20]. The adequacy of the sump screen's mesh spacing (or strainer hole size) is conservatively addressed by applying a 0.14" (9/64") particle size as described in step 3.e of the Downstream Effects Reports methodology below. In addition, the strainer was manufactured to ensure that no gaps or openings between connected parts of the strainer are greater than 3/32" in diameter (Section 6.5.2 of 6.6.2 Refs. 80 and 81 respectively). Also, slots (or non-circular openings) within the strainer assembly shall be less than 1/16" height, and the fabricator shall strive to have no gaps, slots or openings to the greatest extent possible. Therefore, the strainer hole size and adverse gaps or breaches are conservatively bounded by the blockage evaluations performed using a 0.14" particle size as described in step 3.e below.

The following methodology was employed in this Downstream Effects Reports [Refs. 19 and 20].

1. **Debris Concentrations** - NUREG-0897 [Ref. 82] and NUREG/CR-2792 [Ref. 83] estimate that volumetric concentrations of less than 1% abrasive and soft, fibrous material could be contained in the process fluid downstream of the containment building sump screens. The WOG Downstream Effects Report [Ref. 21] states that the volumetric concentration of debris in the recirculation fluid that passes through the sump screens is taken to be equal to or less than 0.1%. Ref. 21 also states that it is expected that plant licensees will confirm this debris concentration as part of the downstream effects evaluation. Within the Safety Evaluation of WCAP-16406-P-A [Ref. 106], the NRC discusses utilization of the plant-specific profile for downstream analysis. Thus, the Downstream Effects Report takes into consideration the plant-specific containment sump filter effluent profiles and associated filter efficiency factor which were determined utilizing the results of prototype filter testing performed at ALION laboratories, with the effluent examined with scanning electron microscopy (SEM) and optical microscopy to determine the outlet fiber sizing profile [Refs. 84, 85, and 3].

The strainer modules are covered by vortex suppression grating which has been shown through testing [Ref. 86] to be effective at eliminating vortices. Therefore, there is not a concern with an air core vortex causing a portion of the strainer to maintain clear strainer area leading to additional fiber bypass.

Using the Debris Generation and Debris Transport Calculation results [Refs. 1, 2, 41, and 42] and the results of the strainer bypass testing [Ref. 86], the maximum debris concentration was determined (IP-2 = 822.1 ppm; IP-3 = 818.6 ppm), and the individual mass fractions were calculated per the guidance contained within WCAP-16406-P-A, Revision 1 [Ref. 21]. An additional 31.4 pounds of unqualified coatings for IP-2 and 352.4 pounds for IP-3 are included within these concentrations to provide margin. Note that this margin is based on the most limiting components (i.e., Cage Valves FE-6454, 6456, 6457, and 6458 for IP-2 and Globe Valves SI-1877A,B for IP-3) approaching their respective wear limits without failing.

Further, the wear analyses for some components were performed under the conservative conditions of a constant, more concentrated debris profile (IP-2 = 1143 ppm; IP-3 = 1528 ppm). These analyses provided wear results which were well below the acceptance criteria of less than 3% change in flow and/or area. Specific guidance on orifice wear evaluation to account for bell-mouthing on sharp edges was provided with the issuance of WCAP-16406-P-A, Revision 1, and was incorporated into this analysis.

2. **Flow Paths and Alignments Review** - The Cold Leg recirculation and Hot Leg recirculation alignments for the Safety Injection System (SIS) which includes Internal Recirculation (IR), Residual Heat Removal (RHR), High Head Safety Injection (HHSI) flow paths and portions of the Containment Spray System (CSS) were reviewed to ensure that all of the flow paths and components impacted by the debris passing through the sump screens are considered. Further, return pathways to the sump such as pool drains, cavities, isolated containment compartments, and any constricted drainage paths, as well as the containment spray itself were also assessed for potential obstruction.

3. **Component Blockage and Wear Evaluations** - A detailed methodology was developed to evaluate whether the system valves, piping, instrument tubing and Heat Exchangers could be susceptible to blockage or wear from the debris that passes through the sump strainer:

    a. Review the safety function of the containment heat removal systems and the emergency core cooling systems that use the Recirculation and Containment sump as the source for system cooling water.
    b. Identify the systems required for supporting the safety functions of the containment heat removal systems and the emergency core cooling systems by reviewing the UFSAR and Design Bases Documents.
    c. Identify the flow paths for each system used during recirculation mode (including failures) following a design basis accident (DBA).
    d. Review flow diagrams, piping and instrumentation drawings (P&ID), vendor drawings, vendor manuals, and other available plant documentation to determine the size of the flow passages in each component in the flow path. Determine the internal materials of construction for components of concern for wear and abrasion. Determine whether or not the component is located within a stagnant branch line (i.e., an instrument line).
    e. Compare the size of the flow passageways to the size of debris that could enter the process fluid through the sump screen openings. Conservatively, blockage

evaluations were performed using a particle size of 0.14" (9/64"), larger than the strainer hole size of 3/32" [Refs. 19 and 20].

f. All downstream valves were screened according to Section 8.2.3 of WCAP-16406-P-A to identify those susceptible to wear. Then, all downstream components including identified valves were evaluated for wear according to WCAP-16406-P-A Sections 7 and 8 as detailed in Refs. 19 and 20.

The evaluation for blockage, wear effects (abrasion and erosion) from the debris laden recirculation flow through the Internal Recirculation, RHR, and HHSI Pumps can be found in the Flowserve Debris Ingestion Evaluations [Ref. 99 and 103]. These evaluations utilized the bounding debris concentration data taken from the IP2 and IP3 Downstream Effects Reports [Ref. 19 and 20] as a primary input. Flowserve, owner of the legacy pump brands and models installed at IPEC, performed the analysis based on the information and guidance in revision 1 of WCAP-16406-P [Ref. 21] with modifications made specifically to IPEC operations.

As discussed in the WCAP, the conditions for packing type wear (Archard Model) will not develop for debris concentrations of less than 920PPM; and therefore, this method of analysis is not necessary at IPEC since debris concentrations are less than 920PPM. Erosion by particles being dragged by flow was shown to be of minor importance compared to three-body abrasion, as shown in the analyses performed.
Modifications to the abrasive wear model were made because of: 1) differences in the pressure drops across the pump running clearances from in the tests of "the Hanson Bowman Paper" (ASME publication 80-C2/PVP-30) which the WCAP model is based, and 2) differences between the IPEC debris characterization and that of the WCAP.

Modifications made to the WCAP wear model for IPEC include factors that multiply with the wear rate model providing an increase of diametral clearance of the bearing, namely: 1) head drop across close clearance parts, and 2) for average damaging particle size. For item 1, from the Hanson-Bowman testing, it is noted that a higher differential across a bearing drives a higher flow through it bringing in fresh debris and results in increased wear. The flow through the bearing is conservatively assumed to be laminar and varies directly with the pressure head drop across it. For items 1 and 2, the wear model is adjusted based on factors for the difference in the differential head in the WCAP and the IPEC pump, as well as the WCAP particle size and that of the damaging IPEC particles.

Erosive wear is evaluated based on the erosive wear model in Appendix F of the WCAP. It is seen to be several orders of magnitude less than abrasive wear, generates negligible wear, and is not a cause for concern.

<u>The following applies only to the Internal Recirculation Pumps</u>

Flowserve developed a rotor-dynamic model specifically for the IPEC Internal Recirculation pump/motor assembly. A rotor-dynamic analysis was performed specifically to evaluate and demonstrate stability during pump operation with the calculated increased clearances within the assembly.

The WCAP provides data for generic, plain Carbon bearing material; however, the Recirculation pumps at IPEC utilize an improved wear resistant Nickel-Carbon bearing material. IPEC commissioned testing by the bearing manufacturer, through Flowserve, to obtain comparison data to develop a specific factor for the Nickel-Carbon material to use in the wear model. The Nickel-

Carbon was conservatively shown to be at least twice as resistant to wear as the plain Carbon material.

All the various types of mechanical pump seals for the RHR and HHSI pumps were evaluated separately by MPR Associates, Inc [Ref. 142]. The Recirculation Pump has a leak off packing arrangement that is not subject to wear. Considering the debris laden fluid and the internal design of the various seals, it was concluded all the seals would survive the 30-day mission time.

Entergy Response to Issue 3m.2:

Common to both units

With the following exceptions and limitations, all of the ECCS/SIS components can accommodate 0.14" (9/64") diameter particulate and fibrous debris (which are greater than the as-built screen hole size of 3/32") without blockage occurring and have acceptable cumulative wear and abrasion effects for a mission time of 30 days:

The results of the Flowserve pump analyses [Refs. 99 and 103] are presented below.

The Recirculation Pumps are a 3-stage, vertical centrifugal pump. They can experience a wear of up to 0.047 inches for IP2 and 0.024 inches for IP3 diameterally at the head bearing, which experiences the highest wear. Pumps were shown to be below the maximum allowable clearances provided by the parametric rotor-dynamic analysis performed for the 30-day mission time. In addition, Flowserve has stated that the pumps will operate beyond the 30-day mission time with the debris laden fluid before critical clearances are reached. No physical modifications to the pumps were necessary to achieve these results.

The RHR pumps are a single stage, vertical centrifugal pump. Considering the debris laden fluid, the total wear of the impeller wear rings was calculated to be 0.0018 inch. The pumps will be rotor-dynamically stable for the 30-day mission time, and considering the minimal wear, the pumps can be expected to operate beyond the 30-day period calculated.

The HHSI pumps are multi-stage, horizontal high pressure pumps. Considering the debris laden fluid, the total wear calculated for the impeller wear rings was 0.0005 inch, and the wear calculated for the bushings was 0.0002 inch. The pumps will be rotor-dynamically stable for the 30-day mission time, and considering the minimal wear, the pumps can be expected to operate beyond the 30-day period calculated.

Unit 2

- Attachment 4 of Ref. 19 contains the summary of the SPX Process Equipment evaluation of the flow opening and cage holes for the HHSI pump 2-1/2" discharge flow restricting valves FE-6454 / 6456 / 6457 / 6458 assuming a sump screen hole size of 3/32". The Cv reduction of 2.7, 4.0% of valve capacity, due to partial clogging of the cage has already been factored into the system hydraulic analysis [Ref. 24].

The debris loading presented in the IP-2 Downstream Effects report [Ref. 19] includes an additional 31.4 pounds of unqualified coatings to provide additional margin for possible, unidentified debris loads not accounted for in the report. Table 3m.2-1 below provides a summary of the wear evaluation results for a mission time of 30 days and an extended period of operation time of 1 year to illustrate potential margin [Table 7.1 of Ref. 19].

Table 3m.2-1:
IP-2 Summary of Wear Evaluation for each ECCS/CIS Component

Component ID(s)	Type	Acceptance Criteria	30 Day Current Value	30 Day Pass?	365 Day Current Value	365 Day Acceptance ?
HCV-638, 640	Butterfly Valve	ΔA/A≤3%	1.5%	Yes	14.7%	No
FE-6454, 6456, 6457, 6458	Cage Valve	ΔQ/Q≤3%	2.95%	Yes	32.78%	No
SI-743	Globe Valve	ΔA/A≤3%	0.035%	Yes	0.345%	Yes
SI-1817A, B	Globe Valve	ΔA/A≤3%	2.547%	Yes	26.207%	No
SI-1870	Globe Valve	ΔA/A≤3%	0.070%	Yes	0.697%	Yes
SI-856A	Globe Valve	ΔA/A≤3%	0.085%	Yes	0.845%	Yes
SI-856B	Globe Valve	ΔA/A≤3%	0.041%	Yes	0.400%	Yes
SI-856C	Globe Valve	ΔA/A≤3%	0.465%	Yes	4.624%	No
SI-856D	Globe Valve	ΔA/A≤3%	1.074%	Yes	10.798%	No
SI-856E	Globe Valve	ΔA/A≤3%	0.136%	Yes	1.350%	Yes
SI-856F	Globe Valve	ΔA/A≤3%	0.041%	Yes	0.400%	Yes
Containment Spray Nozzles	Nozzle	ΔQ/Q≤10%	0.071%	Yes	0.716%	Yes
FE-642	Orifice	ΔQ/Q≤3%	0.026%	Yes	0.262%	Yes
FE-924	Orifice	ΔQ/Q≤3%	0.041%	Yes	0.413%	Yes
FE-924A	Orifice	ΔQ/Q≤3%	0.043%	Yes	0.436%	Yes
FE-925	Orifice	ΔQ/Q≤3%	0.045%	Yes	0.450%	Yes
FE-926	Orifice	ΔQ/Q≤3%	0.041%	Yes	0.416%	Yes
FE-926A	Orifice	ΔQ/Q≤3%	0.045%	Yes	0.456%	Yes
FE-927	Orifice	ΔQ/Q≤3%	0.041%	Yes	0.415%	Yes
FE-945A, B	Orifice	ΔQ/Q≤3%	0.001%	Yes	0.012%	Yes
FE-946A, B, C, D	Orifice	ΔQ/Q≤3%	0.008%	Yes	0.079%	Yes
RHR Heat Exchanger	Heat Exchanger	delta t≤0.0314"	Not Evaluated	N/A	0.0035”	Yes
RHR Seal Water Heat Exchanger	Heat Exchanger	delta t≤0.0353"	0.0003”	Yes	0.0027”	Yes
SI Seal Water Heat Exchanger	Heat Exchanger	delta t≤0.0168"	Not Evaluated	N/A	0.0035”	Yes

Unit 3

The debris loading presented in the IP-3 Downstream Effects report, Ref. 20, includes an additional 352.4 pounds of unqualified coatings to provide additional margin for possible, unidentified debris loads not accounted for in this report. The table below provides a summary of the wear evaluation results for the mission time of 30 days and an extended period of operation time of 1 year to illustrate potential margin [Table 7.1 of Ref. 20].

Table 3m.2-2:
IP-3 Summary of Wear Evaluation for each ECCS/CIS Component

Component ID(s)	Type	Acceptance Criteria	30 day Current Value	30 Day Pass?	365 day Current Value	365 Day Acceptance ?
SI-638, 640	Butterfly Valve	ΔA/A≤3%	0.04%	Yes	0.41%	Yes
SI-2165	Cage Valve	ΔQ/Q≤3%	1.17%	Yes	12.05%	No
SI-2166	Cage Valve	ΔQ/Q≤3%	1.17%	Yes	12.05%	No
SI-2168	Cage Valve	ΔQ/Q≤3%	0.63%	Yes	6.40%	No
SI-2169	Cage Valve	ΔQ/Q≤3%	2.04%	Yes	21.50%	No
SI-2170	Cage Valve	ΔQ/Q≤3%	1.77%	Yes	18.45%	No
SI-2171	Cage Valve	ΔQ/Q≤3%	1.17%	Yes	12.05%	No
SI-2172	Cage Valve	ΔQ/Q≤3%	1.17%	Yes	12.05%	No
AC-841	Globe Valve	ΔA/A≤3%	0.060%	Yes	0.593%	Yes
AC-842	Globe Valve	ΔA/A≤3%	0.046%	Yes	0.454%	Yes
AC-1870	Globe Valve	ΔA/A≤3%	1.165%	Yes	11.751%	No
SI-856G	Globe Valve	ΔA/A≤3%	0.177%	Yes	1.760%	Yes
SI-856H	Globe Valve	ΔA/A≤3%	0.064%	Yes	0.631%	Yes
SI-1803	Globe Valve	ΔA/A≤3%	0.050%	Yes	0.494%	Yes
SI-1877A, B	Globe Valve	ΔA/A≤3%	2.978%	Yes	30.858%	No
Boron Injection Tank Inlet Nozzles	Nozzle	ΔQ/Q≤3%	0.005%	Yes	0.052%	Yes
Containment Spray Nozzles	Nozzle	ΔQ/Q≤10%	0.077%	Yes	0.778%	Yes
FE-642	Orifice	ΔQ/Q≤3%	0.015%	Yes	0.153%	Yes
FE-945A,B	Orifice	ΔQ/Q≤3%	0.003%	Yes	0.026%	Yes
FE-946A	Orifice	ΔQ/Q≤3%	0.003%	Yes	0.028%	Yes
FE-946B	Orifice	ΔQ/Q≤3%	0.005%	Yes	0.049%	Yes
FE-946C	Orifice	ΔQ/Q≤3%	0.003%	Yes	0.028%	Yes
FE-946D	Orifice	ΔQ/Q≤3%	0.005%	Yes	0.049%	Yes
FE-984, 985	Orifice	ΔQ/Q≤3%	0.006%	Yes	0.064%	Yes
FE-924A, 925, 926A, 927	Orifice	ΔQ/Q≤3%	0.038%	Yes	0.381%	Yes
FE-924B	Orifice	ΔQ/Q≤3%	0.018%	Yes	0.180%	Yes
FE-926, 980, 981, 982	Orifice	ΔQ/Q≤3%	0.034%	Yes	0.347%	Yes

FE-983	Orifice	ΔQ/Q≤3%	0.016%	Yes	0.159%	Yes
SIPFE 31, 32, 33	Orifice	ΔQ/Q≤3%	0.059%	Yes	0.600%	Yes
RHR Heat Exchanger	Heat Exchanger	delta t≤0.0314"	Not Evaluated	N/A	0.0047"	Yes
RHR Seal Water Heat Exchanger	Heat Exchanger	delta t≤0.0353"	0.000266"	Yes	0.0027"	Yes
SI Seal Water Heat Exchanger	Heat Exchanger	delta t≤0.0168"	Not Evaluated	N/A	0.0047"	Yes

Entergy Response to Issue 3m.3:

Common to both units

No design or operational changes were performed as a result of the debris blockage or wear evaluations of downstream components excluding pumps.

Additionally, system piping along the flow paths subjected to debris-laden ECCS Recirculation was evaluated for post-accident wear. Using the methodology described in WCAP-16406-P-A [Ref. 21] Sections 7 and 8 for wear of Heat Exchanger tubes, all system piping with recirculating fluid after an accident is considered to have an acceptable amount of wear for the entire mission time [Attachment 14 of Ref. 19 and Attachment 15 of Ref. 20].

Heat Exchangers were also evaluated for wear with the added condition of 30% tube plugging. Using the methodology described in WCAP-16406-P-A [Ref. 21] Sections 7 and 8 for wear of Heat Exchanger tubes, all Heat Exchangers with recirculating fluid after an accident are considered to have an acceptable amount of wear for an extended period of operation of 1 year with 30% of the tubes plugged [Attachment 18 of Ref. 19 and Attachment 19 of Ref. 20].

NRC RAI 21 concerns Downstream Effects – Components and Systems, the subject of the current NRC Issue (3m). This RAI was identified in an NRC letter to Entergy, dated November 19, 2007 [Ref. 119]. The response to this RAI may be found in Attachment 3.

USNRC Issues 3.n

Downstream Effects - Fuel and Vessel

The objective of the downstream effects, fuel and vessel section is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on core cooling.

1. *Show that the in-vessel effects evaluation is consistent with, or bounded by, the industry generic guidance (WCAP-16793), as modified by USNRC comments on that document. Provide a basis for any exceptions.*

Entergy Response to Issue 3n.1

Common to both units

The methodology presented below is one approach to resolving Fuel and Vessel downstream effects concerns. However, a new industry methodology is expected to be finalized after the issuance of this submittal. Therefore, the following methodology may need to be supplemented or replaced with the new industry-wide methodology, once the NRC has reviewed and approved it.

Westinghouse has performed evaluations [Refs. 87 and 88] for Indian Point of the downstream impact of sump debris on the Reactor Vessel and nuclear fuel following a loss of coolant accident (LOCA). The downstream effects evaluations were performed in accordance with the methodology presented in WCAP-16406-P-A [Ref. 21]. The evaluations consider the effect of debris ingested through the containment sump screen on the following components deemed to be required to operate:

- Reactor Vessel internals
- Nuclear fuel

Reactor Vessel Internals
It was found that all dimensions of the essential flow paths through the reactor internals are adequate to preclude plugging by sump debris. The smallest flow clearances found in the Reactor Vessel internals evaluations are 0.46 inches, which is almost twice the maximum debris dimension (0.25 inches) for either deformable or non-deformable debris with a sump screen hole size of 0.125 inches. The as-built sump strainer design incorporated a 3/32 inch (0.094 inches) sump screen hole size. Therefore, retaining the original assumption of a 0.125 inches sump screen hole size is conservative for downstream evaluations.

Nuclear Fuel
In the event of a HELB, a small amount of the fibrous debris generated and transported to the sump will be ingested into the ECCS and CSS flow paths and be carried through the RCS, possibly affecting downstream components. A portion of this fibrous debris in the ECCS flow path may collect on the underside of the fuel bottom nozzle.

Once a fiber bed of approximately 1/8th inch thickness is formed, and if there is also particulate debris in the recirculating flow, a thin bed may occur.

For the evaluation of the cold-leg break, although there is a high rate of bypass flow around the core, the fiber bed builds to approximately 0.09 inch thickness for IP-2 and to approximately 0.08 inch thickness for IP-3 in 10 hours.

For the evaluation of the hot-leg break, the thickness of the fibrous bed forming on the bottom of the core is calculated to reach a 0.125-inch thickness within minutes, regardless of the sensitivity case.

For hot-leg recirculation following a cold-leg or hot-leg break, the fiber concentration is depleted enough that essentially no fiber deposits on the top nozzle.

The acceptance criteria defined in the Westinghouse evaluations [Refs. 87 and 88] states that core cooling is maintained if a fiber bed of <1/8 inch is formed at the core inlet. For Indian Point, a fiber volume of < 1 ft^3 at the core inlet will result in a continuous fiber bed of <1/8 inch. To determine a sump screen capture efficiency that will prevent the core inlet acceptance criteria from being exceeded, a slight simplification of the model used in the calculation can be employed. The model assumes a 95% fiber capture efficiency at the fuel and assumes the remaining 5% returns to the sump. A conservative simplification would assume 100% capture efficiency at the fuel.

Employing this simplification for Indian Point, a conservative screen capture efficiency can be calculated. Unit 2, with a total fiber load of 213.1 ft^3 and assuming 100% capture efficiency at the core inlet, a sump screen efficiency of >99.531% is required to prevent 1 ft^3 from depositing at the core inlet. Unit 3, with a total fiber load of 237.8 ft^3 and assuming 100% capture efficiency at the core inlet, a sump screen efficiency of >99.580% is required to prevent 1 ft^3 from depositing at the core inlet.

(1 – 1/213.1) x 100 = 99.531% (Unit 2)
(1 – 1/237.8) x 100 = 99.580% (Unit 3)

Also note that, the potential for particulate debris, in and of itself, to impede flow into and through the core has been generically considered as described in Ref. 89. Based on the guidance in Ref. 6, the deposition of particulates of sufficient size and number on fuel elements such that particulate debris, by itself, will impede flow through the fuel is unlikely.

The quantity of fiber passing through the Debris Bypass Eliminator within the new Top Hat modules for Indian Point was conservatively determined in the Summary Bypass Report [Ref. 86]. The total quantity of fiber that could bypass through the Debris Bypass Eliminator and collect at the top or bottom of the nuclear reactor core is 0.188 ft^3. This is not sufficient to develop a "thin bed" debris bed thickness of 1/8". Since the total quantity of fiber is not sufficient to develop a 1/8" thick debris bed, the quantity of fiber is not expected to provide the required structure to bridge over the passageways at the bottom and top of the nuclear fuel assemblies. Therefore, blockage of the post-LOCA flow through the nuclear fuel assemblies is not expected based on the debris types documented in the Debris Generation Calculations [Refs. 1 and 2].

Plant specific cladding temperatures were calculated in accordance with the guidance in WCAP-16793-NP and as qualified by the conditions and limitations of the draft NRC safety evaluation of WCAP-16793-NP. The maximum clad temperature for IP2 was 419.92°F and for IP3 was 384.15°F [Ref. 143].

USNRC Issues 3.o

Chemical Effects
The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

1. *Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.*
2. *Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425).*
   - 2.1 *Sufficient 'Clean' Strainer Area*
     - i. *Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.*
   - 2.2 *Debris Bed Formation*
     - i. *Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects was based on break location 2.*
   - 2.3 *Plant Specific Materials and Buffers*
     - i. *Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.*
   - 2.4 *Approach to Determine Chemical Source Term (Decision Point)*
     - i. *Licensees should identify the vendor who performed plant-specific chemical effects testing.*
   - 2.5 *Separate Effects Decision (Decision Point)*
     - i. *State which method of addressing plant-specific chemical effects is used.*
   - 2.6 *AECL Model*
     - i. *Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.*
     - ii. *Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.*
   - 2.7 *WCAP Base Model*
     - i. *For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425)], justify any deviations from the WCAP base model spreadsheet (i.e., any plant specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.*

ii. List the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

2.8 WCAP Refinements: State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

2.9 Solubility of Phosphates, Silicates and Al Alloys

i. Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.

ii. For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.

iii. For any attempts to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amount of chemical precipitate can produce significant increases in head loss.

iv. Licensees should list the type (e.g., AlOOH) and amount of predicted plant specific precipitates.

2.10 Precipitate Generation (Decision Point)

i. State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.

2.11 Chemical Injection into the Loop

i. Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.

ii. For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.

iii. Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100 percent 140 percent).

2.12 Pre-Mix in Tank

i. Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.

2.13 Technical Approach to Debris Transport (Decision Point)

i. State whether near-field settlement is credited or not.

2.14 Integrated Head Loss Test with Near-Field Settlement Credit

i. Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.

ii. Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.

2.15 Head Loss Testing Without Near Field Settlement Credit

i. Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable.

   ii. *Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).*

2.16 *Test Termination Criteria*
   i. *Provide the test termination criteria.*

2.17 *Data Analysis:*
   i. *Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.*
   ii. *Licensees should explain any extrapolation methods used for data analysis.*

2.18 *Integral Generation (Alion)*

2.19 *Tank Scaling / Bed Formation*
   i. *Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.*
   ii. *Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant specific evaluation.*

2.20 *Tank Transport*
   i. *Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions.*

2.21 *30-Day Integrated Head Loss Test*
   i. *Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.*
   ii. *Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.*

2.22 *Data Analysis Bump Up Factor*
   i. *Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.*

Entergy Response to Issue 3o.1

The chemical effects strategy for Indian Point includes quantification of chemical precipitates with WCAP-16530, inclusion of those pre-prepared precipitates in prototypical array testing, applying an Argonne National Laboratory (ANL) correlation to determine formation temperature/timing, a time-based determination of acceptable head losses, and extrapolation of the resulting head losses to 30 days.

As discussed in Response to Item 3a.3 Indian Point has 12 break cases/scenarios that must be evaluated. The amount/mass of chemical precipitates is quantified individually for each of these cases with WCAP-16530 using the maximum amount of LOCA generated debris for that respective case. Other plant specific inputs such as pH, temperature, aluminum amount and spray times are chosen to maximize the generated amount. These amounts are used as input into a prototypical array testing program, and the amounts are scaled based on a ratio of test strainer surface area to plant strainer surface area. Before the test, the sodium aluminum silicate is prepared according to the WCAP-16530 "recipe" and verified to meet the settling criteria within 24 hours of the test. During the test, a fibrous and particulate debris bed is established on the strainer surfaces, the stabilization criteria is satisfied, and then the pre-prepared precipitates are added to the test tank in batches. The resulting head loss data is used as the basis for a logarithmic regression which forecasts the 30 day head loss.

Entergy Response to Issue 3o.2.1.i

All twelve (12) break cases/scenarios were bounded by eight (8) prototypical array tests (with WCAP precipitates). The VC sump LBLOCA cases after 24 hours of IR sump operation (VC LB24) have very low fiber loads and demonstrated through testing that it was insufficient to cover the screen. This is corroborated by the fact that the fiber loads are lower than those required to cover the screen in thin-bed tests. However, Indian Point is not crediting clean strainer area to perform a simplified chemical effects analysis.

Entergy Response to Issue 3o.2.2.i

In general, NEI 04-07 was used to determine the plant-specific debris characteristics (see Response to Issue 3b for details). The Array Test Debris Amounts Calculation [Ref. 45] employs a conservative approach, as explained below, to test a debris load and mix which yields the maximum head loss.

The debris generated from the five break criteria recommended in the SER [Refs. 3 and 6] are considered. The many different debris types are categorized into fiber, particulate (or microporous insulation), and coatings. The maximum amount of each category is used as input to the test. Therefore, the debris scenario reflected in the test is not a single break, but a combination of breaks to ensure a maximum head loss result.

In all tests, the conventional debris bed (fiber, microporous insulation, and coatings debris) was formed before the introduction of chemical precipitates. In the case of thin-bed tests, all particulate was added to the tank before the addition of 1/8" equivalent fiber batches. Once full bed coverage was verified and the stabilization criterion was satisfied, batches of chemical precipitates were added to the tank. In the case of full load tests, batches of fiber, microporous insulation, and coatings debris were added simultaneously to the test tank. Once the full debris load was added and the stabilization criterion was satisfied, batches of chemical precipitates were added to the tank.

Entergy Response to Issue 3o.2.3.i

The WCAP-16530-NP-A chemical model requires a number of plant-specific inputs. Each input is chosen to maximize the prediction of the chemical precipitates. Indian Point has completed a sump pool buffer change in each unit so they both units now use sodium tetraborate. Tables 3o.2.3-1 and 3o.2.3-2 show the maximum sump pH and temperatures. The spray pH is assumed to be equivalent to the sump pH while the sprays are active.

Unit 2

Table 3o.2.3-1:
Unit 2 pH and Temperature Inputs for WCAP-16530 Chemical Model [Ref. 45]

Time (sec)	Sump pH	Sump Temp. (°F)	Steam or Spray pH	Containment Temp. (°F)
6	4.62	233	4.62	232
30	4.62	253	4.62	256
60	4.62	247	4.62	256
120	4.62	247	4.62	255
180	4.62	247	4.62	253
200	4.62	247	4.62	253
400	4.62	248	4.62	259
600	4.62	251	4.62	262
800	4.62	254	4.62	264
1000	4.62	256	4.62	266
1200	4.62	258	4.62	267
1500	4.62	249	4.62	263
1800*	7.3	249	7.3	259
2354	7.3	251	7.3	252
3600	7.3	253	7.3	250
5200	7.3	246	7.3	243
6400	7.3	241	7.3	239
7600	7.3	237	7.3	235
8800	7.3	233	7.3	231
10400	7.3	229	7.3	226
11600	7.3	227	7.3	223
12240	7.3	225	7.3	221
14800	7.29	221	7.29	216
17200	7.29	218	7.29	212
23200	7.29	197	7.29	208
41600	7.29	171	-	-
85600	7.29	156	-	-
159000	7.29	133	-	-
276000	7.28	121	-	-
354000	7.28	120	-	-
432000	7.27	117	-	-
783000	7.26	115	-	-
1855000	7.25	107	-	-
2592000	7.24	107	-	-

*Start of recirculation

Unit 3

**Table 3o.2.3-2:
Unit 3 pH and Temperature Inputs for WCAP-16530 Chemical Model [Ref. 45]**

Time (sec)	Sump pH	Sump Temp. (ºF)	Steam or Spray pH	Containment Temp. (ºF)
6	4.62	233	4.62	227
30	4.62	253	4.62	255
60	4.62	244	4.62	252
120	4.62	244	4.62	254
180	4.62	245	4.62	254
200	4.62	245	4.62	254
400	4.62	250	4.62	258
600	4.62	254	4.62	258
800	4.62	257	4.62	259
1000	4.62	259	4.62	260
1200	4.62	258	4.62	260
1380	4.62	249	4.62	258
1600	4.62	241	4.62	255
2200*	7.3	241	7.3	248
2820	7.3	242	7.3	243
3900	7.3	242	7.3	235
4600	7.3	241	7.3	234
8800	7.3	233	7.3	226
10000	7.3	231	7.3	224
10200	7.29	231	7.29	223
12420	7.29	228	7.29	220
18300	7.29	219	7.29	211
21600	7.29	212	7.29	210
50000	7.29	183	-	-
90000	7.29	166	-	-
200000	7.28	140	-	-
300000	7.28	128	-	-
400000	7.27	127	-	-
500000	7.27	121	-	-
600000	7.26	120	-	-
700000	7.25	119	-	-
1000000	7.25	118	-	-
2000000	7.24	117	-	-
2592000	7.23	117	-	-

*Start of recirculation

The values for sump pool volume, Al surface area, Al mass, spray duration, and concrete area are maximized to result in a conservative amount of chemical precipitates. The specific values for each unit are shown in Table 3o.2.3-3.

Table 3o.2.3-3:
Inputs for WCAP-16530 Chemical Model

Input	IP-2	IP-3
Maximum Sump Pool Volume (ft^3)	59682	59592
Submerged Al Surface Area for Reactor Cavity breaks (ft^2)	2890	2890
Submerged Al Mass for Reactor Cavity breaks (lb_m)	4.406	4.406
Submerged Al Surface Area for all other breaks (ft^2)	1100	1100
Submerged Al Mass for all other breaks (lb_m)	0.77	0.77
Unsubmerged Al Surface Area (ft^2)	1100	1100
Unsubmerged Al Mass (lb_m)	4100	4100
Spray Duration (hr)	6	6
Concrete Area (ft^2)	388.88	387.68

The LOCA generated debris loads are different for each break size and location. The same maximum values used as test input for the conventional debris loads are used as input to the WCAP-16530 model and shown in Tables 3o.2.3-4 and 3o.2.3-5. Each Unit at Indian Point, requires six cases to be qualified. Because a LBLOCA generates the same amount of debris (and hence chemical load generated) regardless of the sump that the load is being applied to, the IR LBLOCA and the VC LBLOCA after 24 hours use the same inputs for the WCAP-16530 model. Hence, only four sets of inputs are shown in the Tables 3o.2.3-4 to 3o.2.3-6.

Table 3o.2.3-4:
Indian Point Break Cases and Associated Chemical Inputs

Break Case	Chemical Inputs Used
IR LBLOCA	LBLOCA
VC LBLOCA after 24 hours	
IR Reactor Cavity LBLOCA	Reactor Cavity LBLOCA
VC Reactor Cavity LBLOCA after 24 hours	
VC 6" LOCA	6" LOCA
VC Reactor Cavity 6" LOCA	Reactor Cavity 6" LOCA

Table 3o.2.3-5:
IP-2 LOCA Generated Debris Inputs for WCAP-16530 Chemical Model

		IP-2 LBLOCA	IP-2 Reactor Cavity LBLOCA	IP-2 6" LOCA	IP-2 Reactor Cavity 6 Inch Break LOCA
Asbestos	lb_{mass}	760.41	0.00	234.47	0.00
	Density (lb_m/ft^3)	14.5	14.5	14.5	14.5
	Volume Input (ft^3)	52.44	0.00	16.17	0.00
	Reference	Reference 1, Design Case 2	Reference 1, Design Case 13	Reference 1, Design Case 6	Reference 1, Design Case 19
Fiberglass	lb_{mass}	2.54	0.00	1.92	0.00
	Density (lb_m/ft^3)	2.4	2.4	2.4	2.4
	Volume Input (ft^3)	1.06	0.00	0.80	0.00
	Reference	Reference 1, Design Case 1	Reference 1, Design Case 13	Reference 1, Design Case 5	Reference 1, Design Case 19
Nukon	lb_{mass}	2449.83	0.00	659.99	0.00
	Density (lb_m/ft^3)	2.4	2.4	2.4	2.4
	Volume Input (ft^3)	1020.76	0.00	275.00	0.00
	Reference	Reference 1, Design Case 1	Reference 1, Design Case 13	Reference 1, Design Case 5	Reference 1, Design Case 19
Temp Mat	lb_{mass}	936.78	336.54	503.87	84.14
	Density (lb_m/ft^3)	11.8	11.8	11.8	11.8
	Volume Input (ft^3)	79.39	28.52	42.70	7.13
	Reference	Reference 1, Design Case 1	Reference 1, Design Case 13	Reference 1, Design Case 5	Reference 1, Design Case 19
Thermal Wrap (Transco Blanket)	lb_{mass}	103.71	0.00	42.46	0.00
	Density (lb_m/ft^3)	2.4	2.4	2.4	2.4
	Volume Input (ft^3)	43.21	0.00	17.69	0.00
	Reference	Reference 1, Design Case 1	Reference 1, Design Case 13	Reference 1, Design Case 5	Reference 1, Design Case 19

Table 3o.2.3-6:
IP-3 LOCA Generated Debris Inputs for WCAP-16530 Chemical Model

		IP-3 LBLOCA	IP-3Reactor Cavity LBLOCA	IP-3 6" LOCA	IP-3 Reactor Cavity 6 Inch Break LOCA
Calcium Silicate	lb_{mass}	274.39	0.00	0.00	0.00
	Density (lb_m/ft^3)	14.5	14.5	14.5	14.5
	Volume Input (ft^3)	18.92	0.00	0.00	0.00
	Reference	Reference 2, Design Case 4	Reference 2, Design Case 13	Reference 2, Design Case 6	Reference 2, Design Case 19
Asbestos	lb_{mass}	342.78	0.00	410.02	0.00
	Density (lb_m/ft^3)	14.5	14.5	14.5	14.5
	Volume Input (ft^3)	23.64	0.00	28.28	0.00
	Reference	Reference 2, Design Case 4	Reference 2, Design Case 13	Reference 2, Design Case 6	Reference 2, Design Case 19
Fiberglass	lb_{mass}	101.82	0.00	60.46	0.00
	Density (lb_m/ft^3)	4	4	4	4
	Volume Input (ft^3)	25.46	0.00	15.12	0.00
	Reference	Reference 2, Design Case 3	Reference 2, Design Case 13	Reference 2, Design Case 5	Reference 2, Design Case 19
Nukon	lb_{mass}	1996.74	0.00	460.79	0.00
	Density (lb_m/ft^3)	2.4	2.4	2.4	2.4
	Volume Input (ft^3)	831.98	0.00	192.00	0.00
	Reference	Reference 2, Design Case 3	Reference 2, Design Case 13	Reference 2, Design Case 5	Reference 2, Design Case 19
Temp Mat	lb_{mass}	3058.71	336.54	1391.71	84.14
	Density (lb_m/ft^3)	11.8	11.8	11.8	11.8
	Volume Input (ft^3)	259.21	28.52	117.94	7.13
	Reference	Reference 2, Design Case 3	Reference 2, Design Case 13	Reference 2, Design Case 5	Reference 2, Design Case 19
Mineral Wool	lb_{mass}	75.39	0.00	15.19	0.00
	Density (lb_m/ft^3)	10	10	10	10
	Volume Input (ft^3)	7.54	0.00	1.52	0.00
	Reference	Reference 2, Design Case 3	Reference 2, Design Case 13	Reference 2, Design Case 5	Reference 2, Design Case 19

Entergy Response to Issue 3o.2.4.i

Alion performed the chemical effects testing for both Indian Point Units.

The total chemical source term was determined using the WCAP-16530 model. One refinement was credited for the chemical effects evaluation. An ANL empirical equation, based on a compilation of data from the various experiments, was developed to predict the aluminum solubility as a function of pH and temperature [Ref. 128]. The equation can be used to predict the post-LOCA aluminum precipitation temperature for Indian Point. Based on plant-specific aluminum concentrations and pH, aluminum is predicted to precipitate at 118°F for IP-2 and 121°F for IP-3 [Ref. 46]. The minimum possible temperature at 7 hours after a LOCA is 110°F and 116°F for IP-2 and IP-3, respectively [Ref. 48]. `While the temperatures shown above for the minimum containment temperature and the predicted precipitation temperature indicate that there is only a small amount of margin, both values contain significant conservatisms that make the actual margin larger than the calculated margin. The minimum containment temperature is based on a model which used simplifying assumptions to minimize temperature rather than a model using refined inputs to achieve an exact result. These assumptions include maximum performance of the fan cooler units, non-degraded RHR heat exchanger performance, maximum performance RHR flow rates, minimum ambient temperatures, and minimum CCW temperatures [Ref. 48]. The ANL equation also results in a conservative approximation of the precipitation temperature. ANL's own empirical evidence suggests that the ANL correlation may be overly conservative and predict higher precipitation temperatures for systems whose aluminum concentrations are lower than the concentrations used to derive the correlation (40 – 120 ppm). Therefore, it is considered conservative for use at Indian Point, where the maximum aluminum concentration is 2.9 ppm [Ref. 46].Therefore, it is concluded that precipitation would not occur at Indian Point in the first 7 hours following a LOCA. Temperature dependent aluminum precipitate formation is credited to allow the higher chemical related head losses quantified in array testing to be compared to the acceptance criteria later in the event, when temperatures and flows through the strainers are lower.

Entergy Response to Issue 3o.2.5.i

Indian Point is quantifying the chemical source term using the WCAP-16530 model [Ref. 43]. Therefore, the plant is relying on single variable test measurements for one material acting independently with one pH-adjusting chemical at an elevated temperature; this single effects type testing is considered a conservative approach to chemical generation.

Entergy Response to Issue 3o.2.6.i

Indian Point is not using the AECL model.

Entergy Response to Issue 3o.2.7.i

Indian Point is not deviating from the WCAP Base model to calculate 30-day chemical precipitate quantities, and all inputs were chosen to maximize the predicted amount of precipitates. These inputs are described in Response to Item 3o.2.3 above. Additionally, the timing of the chemical precipitates is not based on the WCAP release rates. Timing is evaluated using an ANL empirical equation with plant specific inputs which is discussed in Response to Item 3o.2.4. The types and amounts of chemical precipitates as predicted by the WCAP model are listed in Tables 3o.2.7-1 and 3o.2.7-2 [Ref. 45].

Table 3o.2.7-1:
IP-2 WCAP-16530 Predicted Chemical Precipitates [Ref. 45]

Unit	Break Type	Chemical Precipitate		
		$NaAlSi_3O_8$ lb_m	AlOOH lb_m	Total lb_m
IP-2	LBLOCA	82.28	0.00	82.28
IP-2	Reactor Cavity LBLOCA	79.49	0.00	79.49
IP-2	6 Inch Break LOCA	50.72	0.00	50.72
IP-2	Reactor Cavity 6 Inch Break LOCA	51.31	5.21	56.52

Table 3o.2.7-2:
IP-3 WCAP 16530 Predicted Chemical Precipitates [Ref. 45]

Unit	Break Type	Chemical Precipitate		
		$NaAlSi_3O_8$ lb_m	AlOOH lb_m	Total lb_m
IP-3	LBLOCA	102.40	0.00	102.40
IP-3	Reactor Cavity LBLOCA	75.52	0.00	75.52
IP-3	6 Inch Break LOCA	56.02	0.00	56.02
IP-3	Reactor Cavity 6 Inch Break LOCA	51.31	4.11	55.42

Entergy Response to Issue 3o.2.8.i

Indian Point is not crediting any refinements to the WCAP-16530 [Ref. 43] model to reduce the predicted 30-day chemical precipitate amounts (WCAP-16785 [Ref. 44] refinements were not used).

Entergy Response to Issue 3o.2.9.i

Indian Point did not credit the passivation of aluminum by phosphate, silica, or any other substances in order to maintain conservatism in the overall chemical effects assessment.

Entergy Response to Issue 3o.2.10.i

Indian Point only utilized surrogate precipitate, generated in a separate mixing tank, in the chemical effects strategy. The prototypical strainer array head loss tests used sodium aluminum silicate precipitate prepared according to the methodology outlined in WCAP-16530 [Ref. 43].

Entergy Response to Issue 3o.2.11.i

Indian Point did not utilize chemical injection into the loop in the chemical effects methodology.

Entergy Response to Issue 3o.2.12.i

The chemical effects array head loss tests employed the pre-mixed chemical surrogate methodology. The WCAP-16530 precipitate formation methodology was followed with no exceptions. The surrogate precipitate was not used after its defined shelf life and the settling properties were measured within 24 hours of every addition to the tank [Ref. 37].

Entergy Response to Issue 3o.2.13.i

Indian Point chemical effects testing utilized agitation and turbulence in the test tank to ensure that essentially all debris analyzed to reach the strainer in the plant reached the strainer in head loss testing. A scaling factor was used to compensate for the different surface areas in the plant versus the test [Ref. 37]. Indian Point did not credit any near field settlement in head loss testing [Ref. 37].

Entergy Response to Issue 3o.2.14.i

This item is not applicable to Indian Point (see Response to Item 3o.2.13.i).

Entergy Response to Issue 3o.2.15.i

Indian Point chemical effects testing utilized agitation and turbulence in the test tank to ensure that essentially all debris analyzed to reach the strainer in the plant reached the strainer in head loss testing. A sparger was attached to the return flow line and located on one end of the tank to prevent settling of debris in the edge and corners on that side of the tank. A mechanical mixer was located on the opposite side of the tank to eliminate settling adjacent to and behind the plenum. Additionally, manual stirring was utilized outside of the simulated pit walls to eliminate settling in all other areas. These measures effectively eliminated any settling of chemical precipitates. Any fiber or particulate traces that remained outside of the pit walls were deemed to be insignificant by the test engineer before proceeding to the next step of the test. No debris was allowed to settle after introduction into the test tank without multiple efforts to re-suspend it [Ref. 37]. Furthermore, these materials were provided multiple pool turnovers to deposit on the strainers. Each test was maintained for a minimum of 10 pool turnovers before the addition of chemical precipitates, and all tests required longer time periods due to the head loss stabilization criteria.

The chemical precipitate was prepared in accordance with Alion's internal procedure which follows the WCAP-16530-NP-A methodology [Refs. 37 and 43]. The 1-hour settling rate for each batch of chemical precipitates was determined at the time that the batch was produced and was required to be 6 ml or greater for a 10 ml volume. The chemical precipitate settling rate was measured within 24 hours of the time it will be used in testing. For a 10mL sample of the precipitate solution, at a concentration less than 11 g/L, the 1-hour settled volume was 6 ml or greater for sodium aluminum silicate [Ref. 91]. These measurements were conducted during testing and confirmed to be within the limits. The batch number of each load was recorded as it was added. It should be noted that only sodium aluminum silicate was used in the array tests.

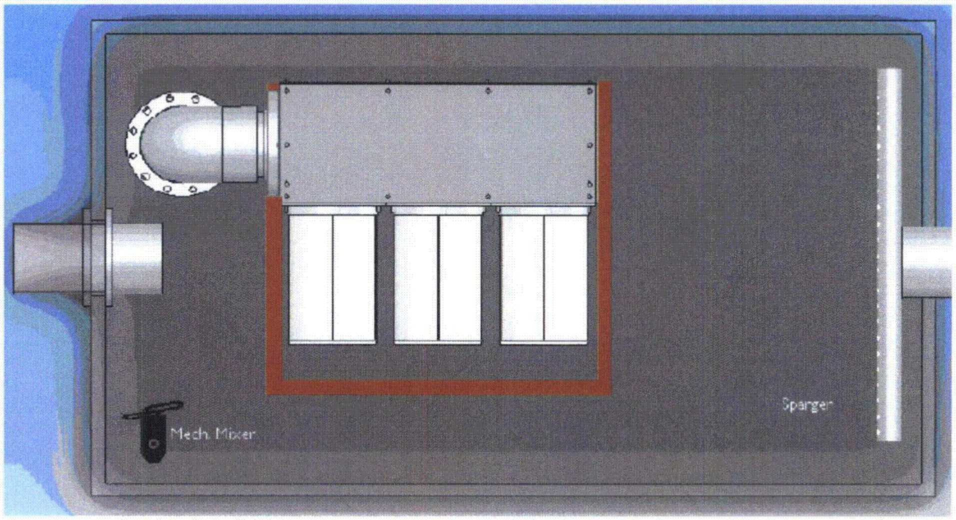


Figure 3o.2.15-1:
Test Tank Setup

Entergy Response to Issue 3o.2.16.i

Each chemical addition, or test step, was considered stable when the head loss was calculated to be less than 1% change per hour for head loss values ≥ 2 ft-water or less than 0.25 inch (0.02 ft) change per hour for head loss values < 2 ft-water. This was calculated by comparing two moving average windows: the previous 5 minutes compared to the 5 minute window from 65 minutes to 60 minutes in the past [Ref. 37].

Each chemical addition was allowed to circulate in the test tank for a long period of time (average of ~8 hours) until the head loss was essentially stable. Test observations and turbidity measurements show that when the test resulted in full coverage of the strainer surfaces, the test fluid cleaned up and became less turbid. This information results in a high confidence that transport of the chemical precipitates to the screen was complete.

Entergy Response to Issue 3o.2.17.i

The head loss for each chemical addition was extrapolated to the 30-day mission time for the plant. The raw test data from the applicable chemical addition is used as the basis for regression analysis. A logarithmic curve fit was chosen because it provides a reasonably good fit for each data set. It results in an equation of the form:

$\Delta H = b \ln t + a$

where:
ΔH = Head Loss (ft-water)
t = Time (s)
a,b = Constants

A second series is then plotted on the same graph using the equation obtained for the fitted curve. The value of the constant a is adjusted until it is visually confirmed that the raw data is bounded by the adjusted curve fit in the region of stabilization. The resulting "bounding curve" is used to predict the head loss for a 30 day mission time [Ref. 28].

A copy of the head loss curve for each chemical addition for each test is included below along with the extrapolation curve. Note that only those chemical additions that represent design quantities and are needed for qualification of the sump strainers are included.

Test A1: 2nd Chemical Add

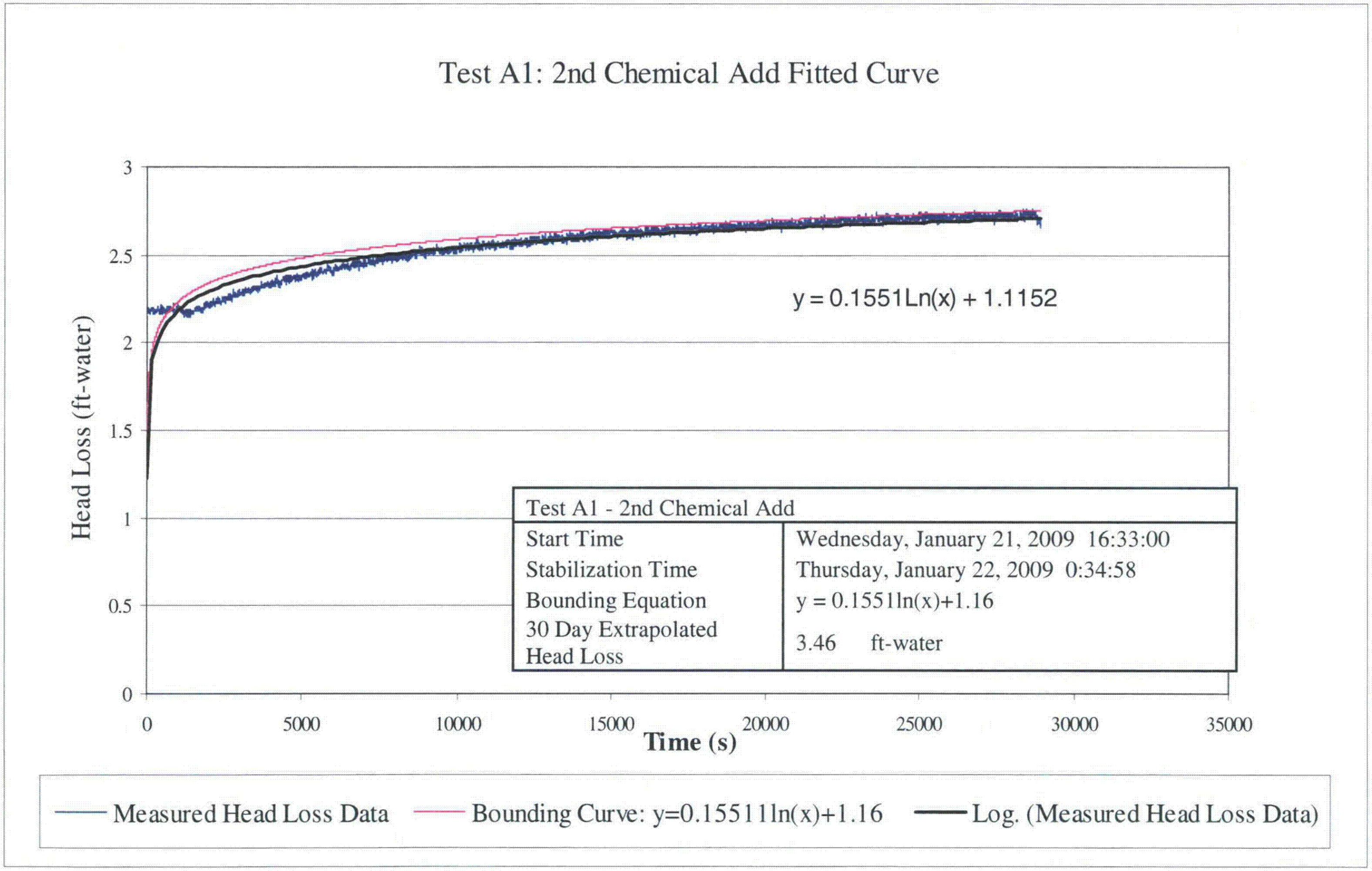


Figure 3o.2.17-1:
Figure showing the Curve Fitting and Extrapolation for the Data from the 2nd Chemical Add of Test A1

Test A1: 3rd Chemical Add

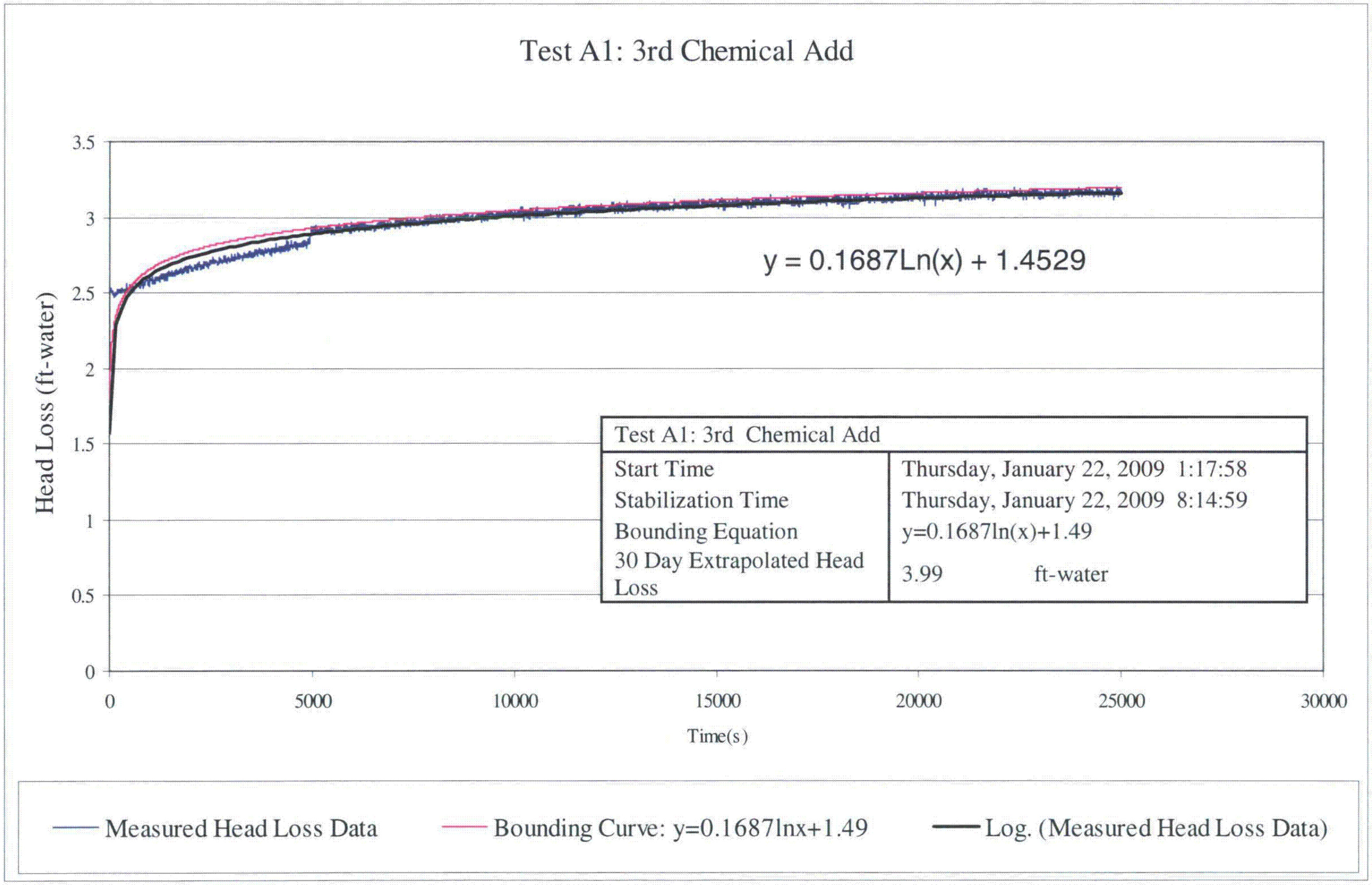
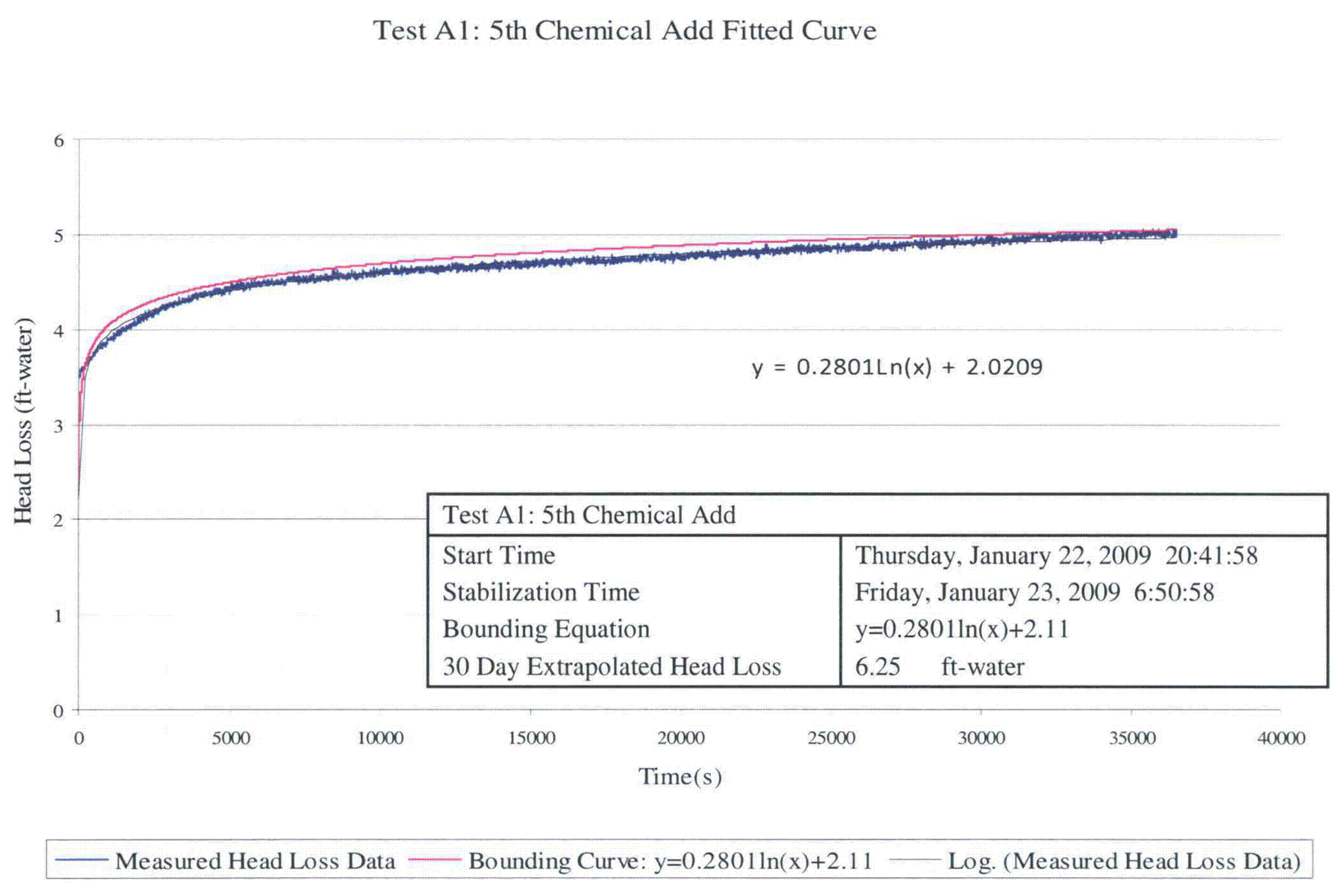


Figure 3o.2.17-2:
Figure showing the Curve Fitting and Extrapolation for the Data from the 3rd Chemical Add of Test A1

Test A1: 5th Chemical Add



Test A1: 5th Chemical Add	
Start Time	Thursday, January 22, 2009 20:41:58
Stabilization Time	Friday, January 23, 2009 6:50:58
Bounding Equation	y=0.2801ln(x)+2.11
30 Day Extrapolated Head Loss	6.25 ft-water

Figure 3o.2.17-3:
Figure showing the Curve Fitting and Extrapolation for the Data from the 5th Chemical Add of Test A1

Test A1: 6th Chemical Add

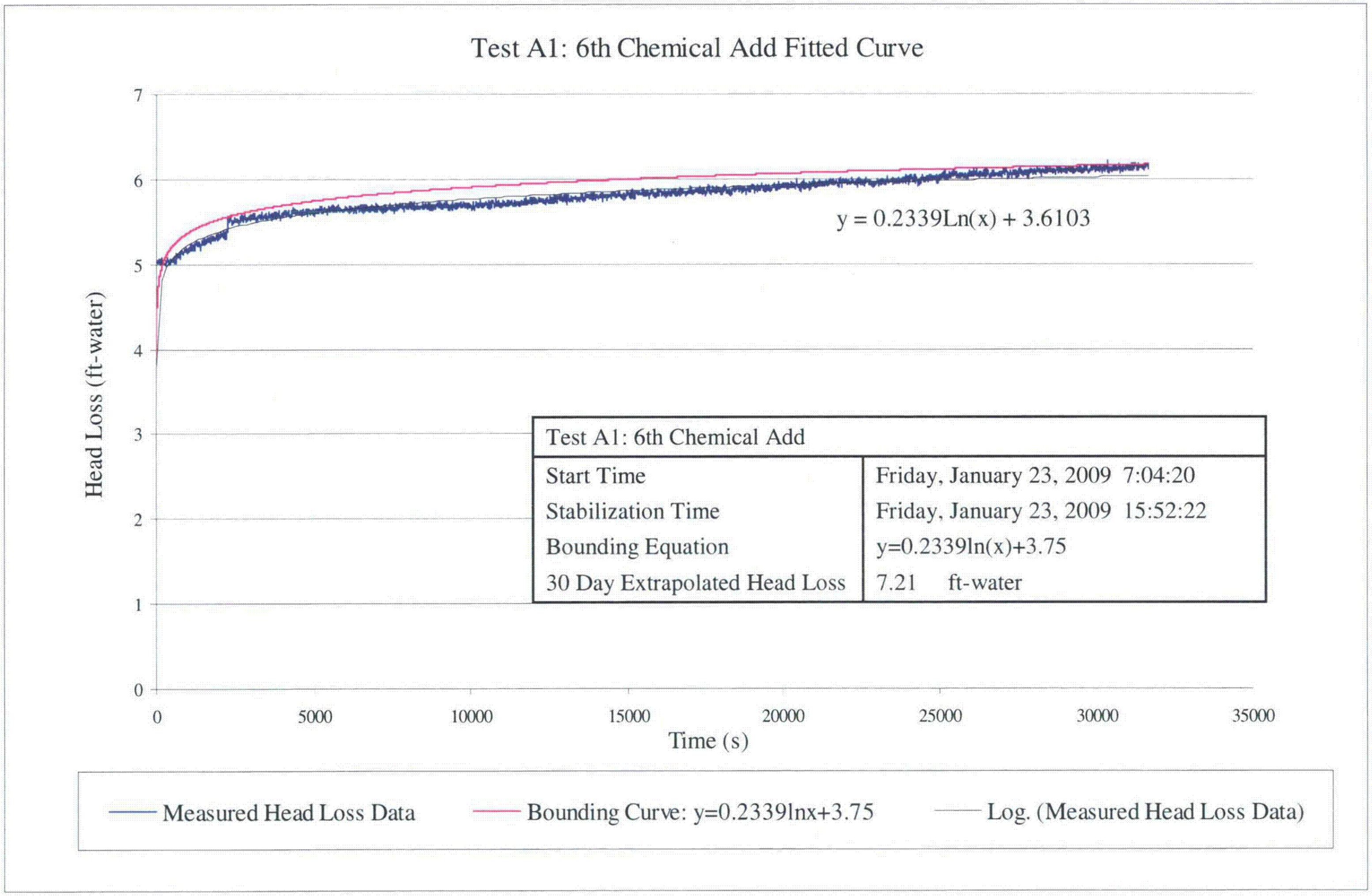
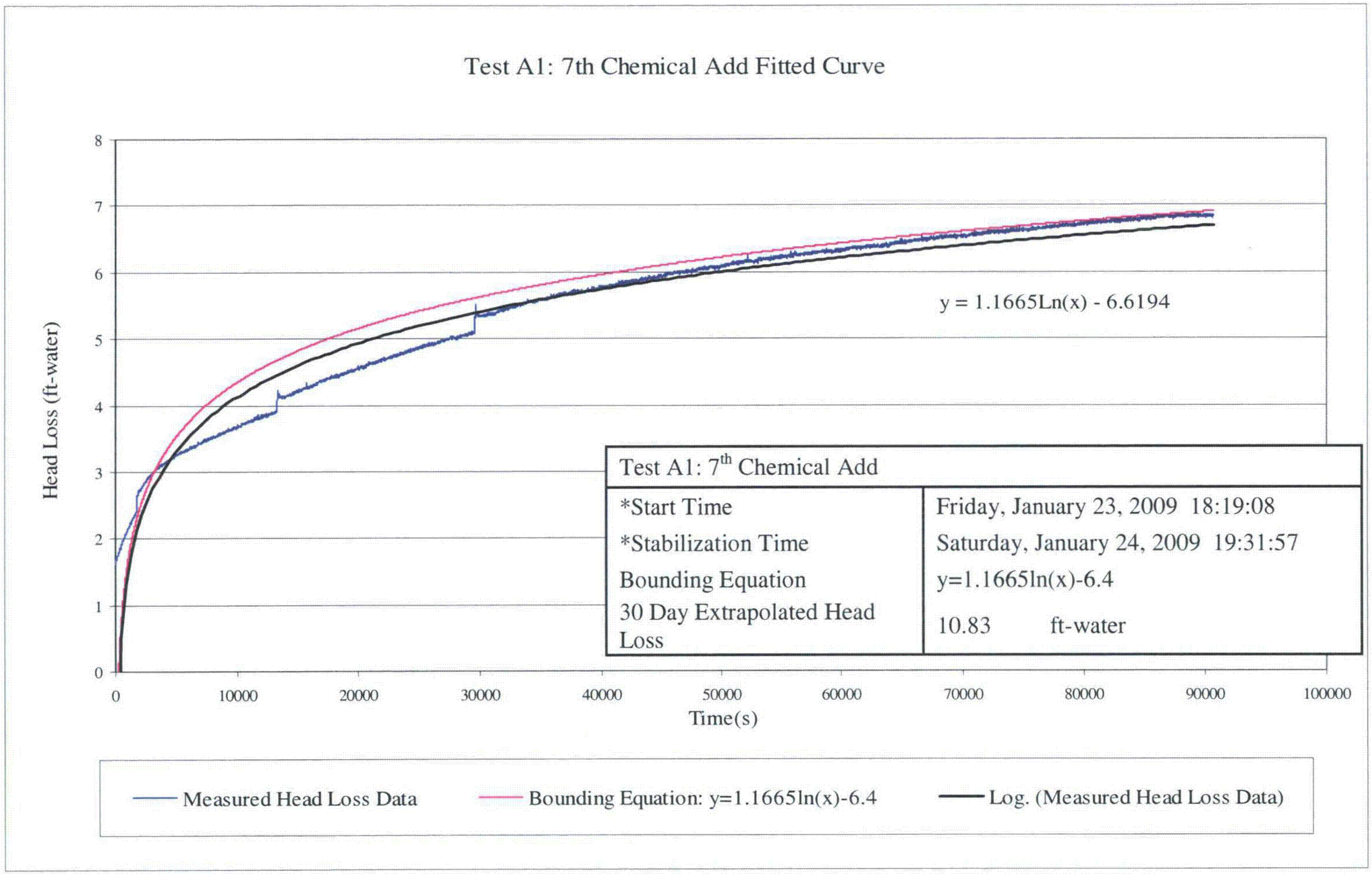


Figure 3o.2.17-4:
Figure showing the Curve Fitting and Extrapolation for the Data from the 6th Chemical Add of Test A1

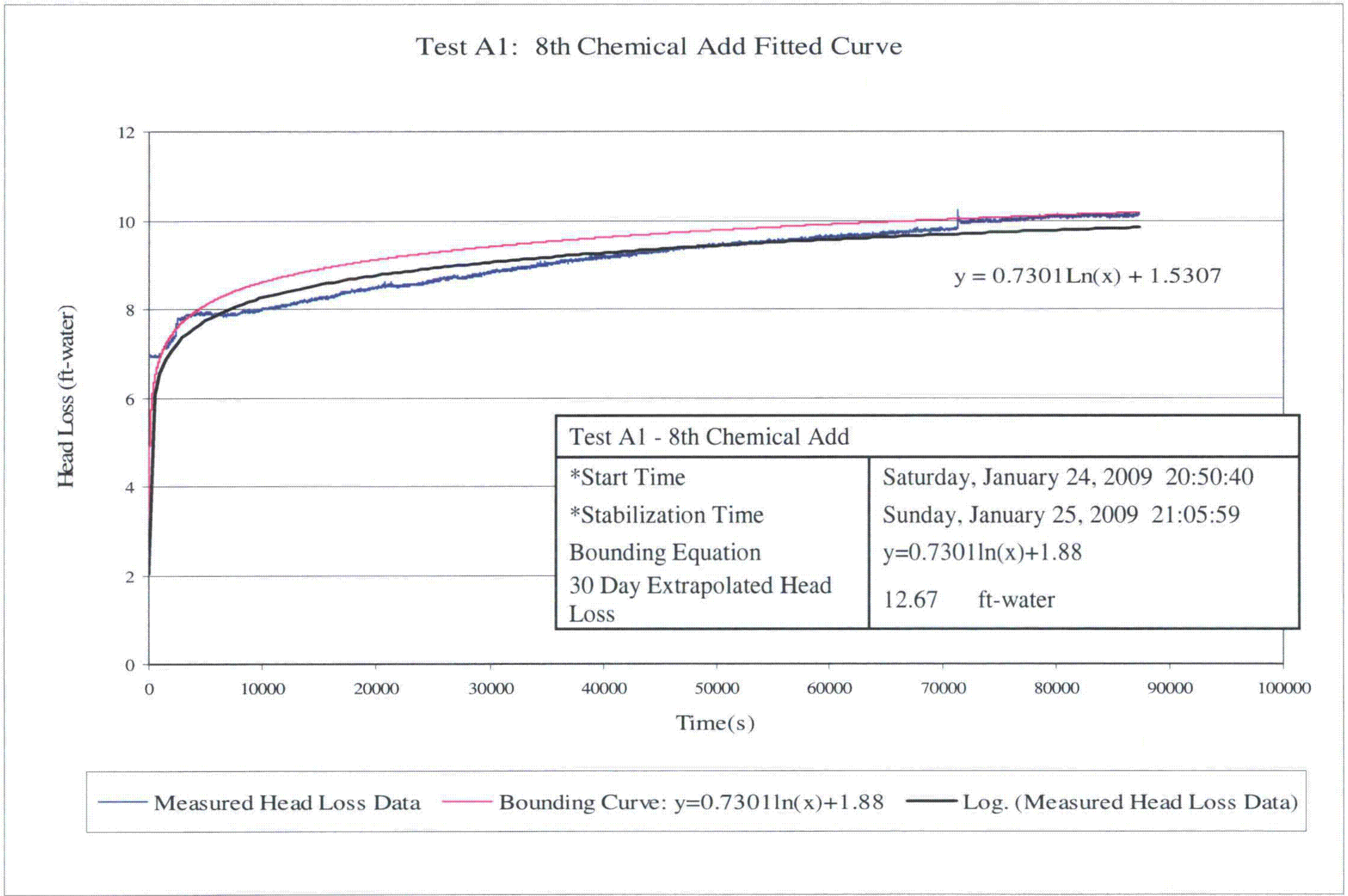
Test A1: 7th Chemical Add



*Due to the length of this test, every other data point was used for the curve fit. This is reasonable since the data set has sufficient resolution to produce the same result as every data point.

Figure 3o.2.17-5.
Figure showing the Curve Fitting and Extrapolation for the Data from the 7th Chemical Add of Test A1

Test A1: 8th Chemical Add



*Due to the length of this test, every other data point was used for the curve fit. This is reasonable since the data set has sufficient resolution to produce the same result as every data point.

Figure 3o.2.17-6.
Figure showing the Curve Fitting and Extrapolation for the Data from the 8th Chemical Add of Test A1

Test B: 1st Chemical Add

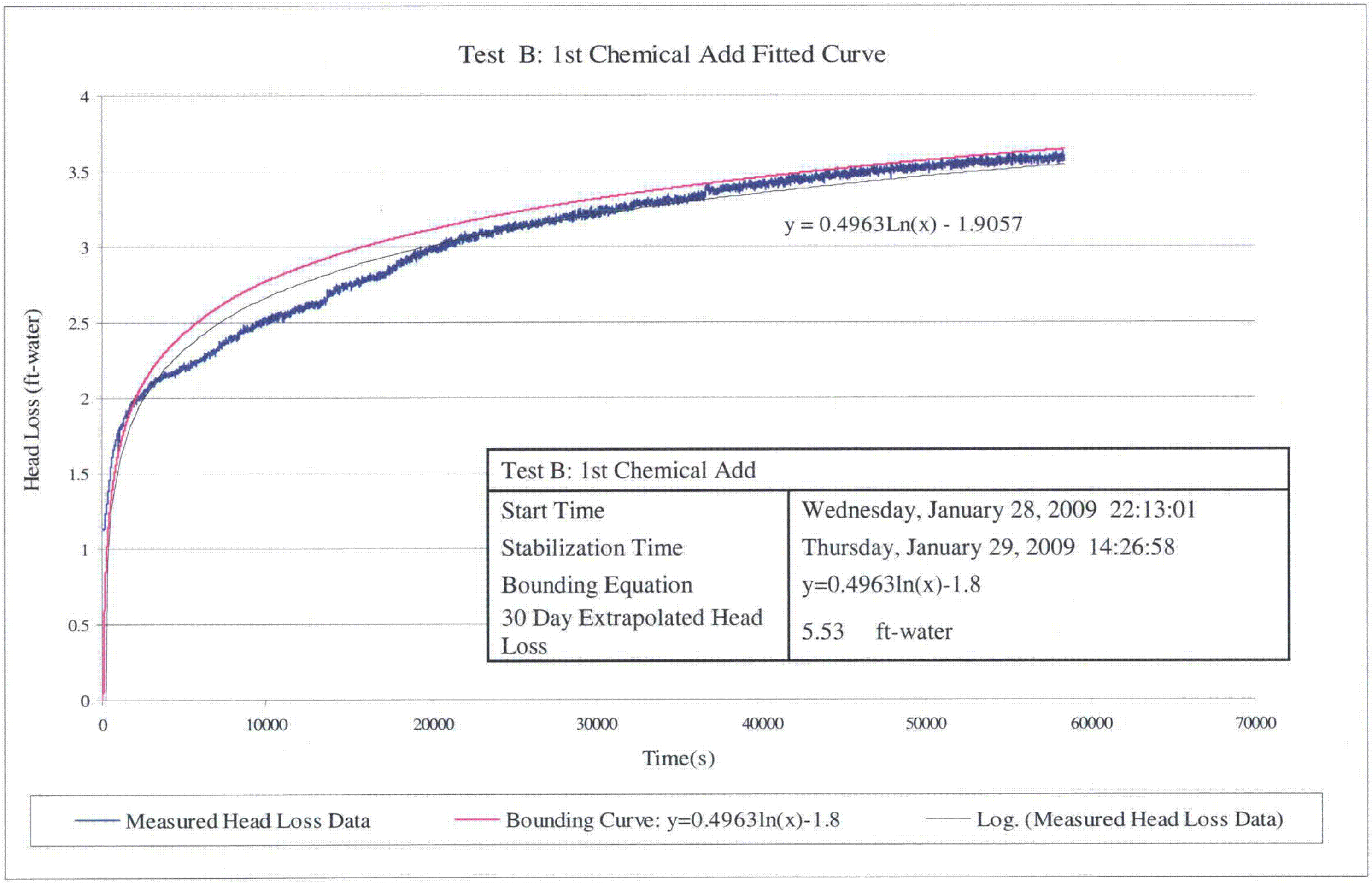
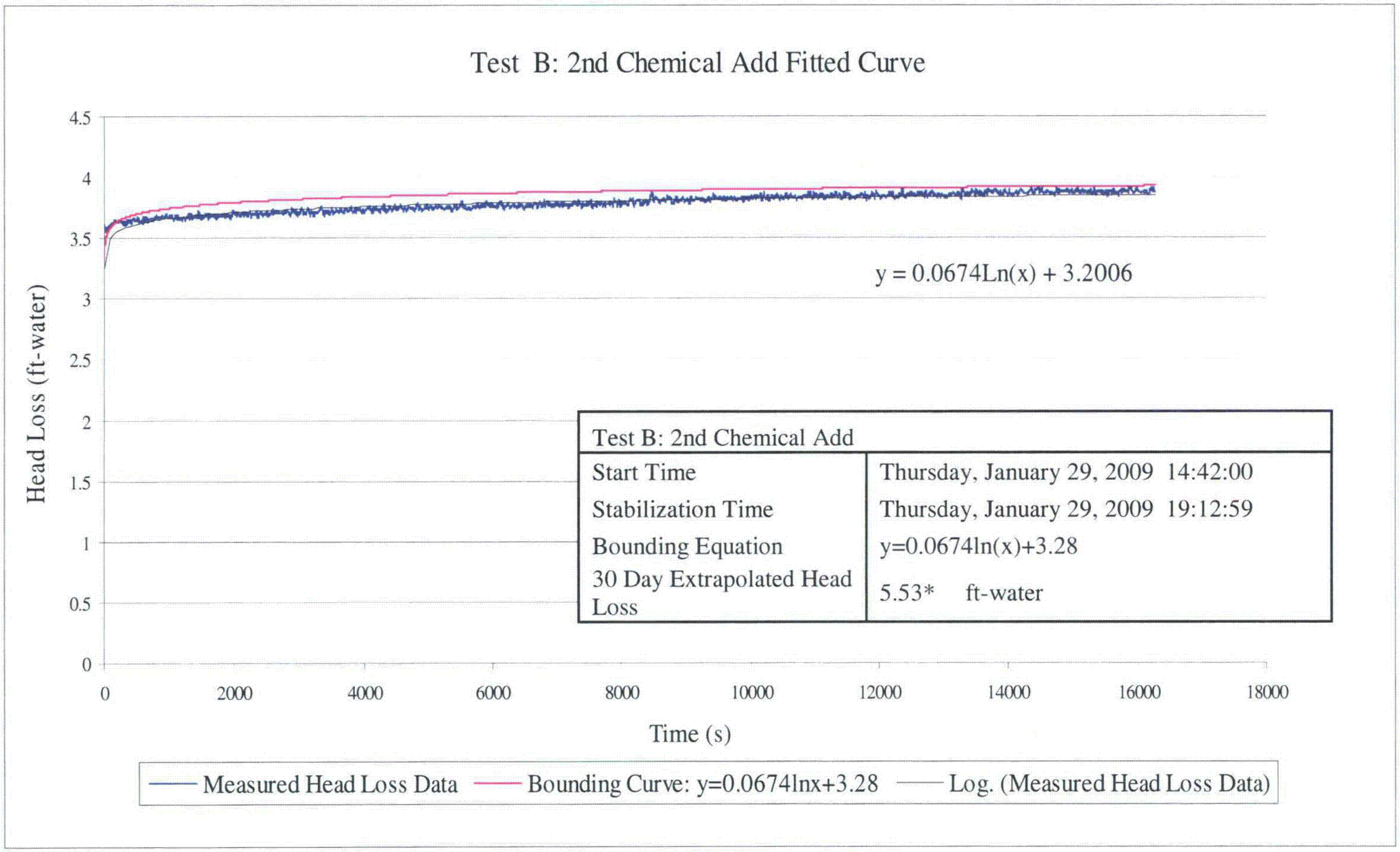


Figure 3o.2.17-7:
Figure showing the Curve Fitting and Extrapolation for the Data from the 1st Chemical Add of Test B

Test B: 2nd Chemical Add



* The extrapolated head loss from the 1st chemical add resulted in a higher head loss (5.53 ft-water) than that from the 2nd chemical add (4.28 ft-water). For added conservatism the extrapolated head loss from the 1st chemical add is used.

Figure 3o.2.17-8:
Figure showing the Curve Fitting and Extrapolation for the Data from the 2nd Chemical Add of Test B

Test B: 4th Chemical Add

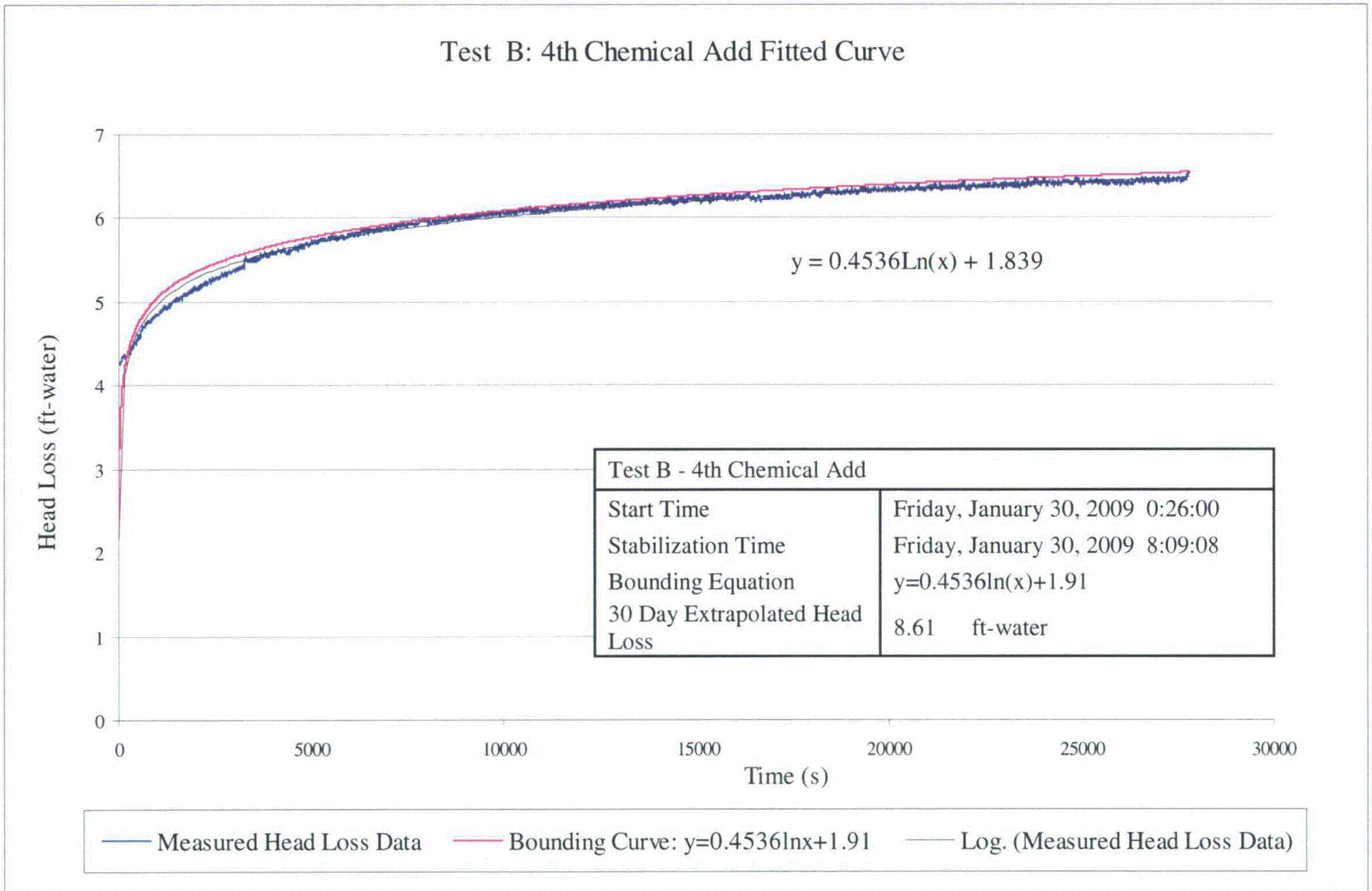
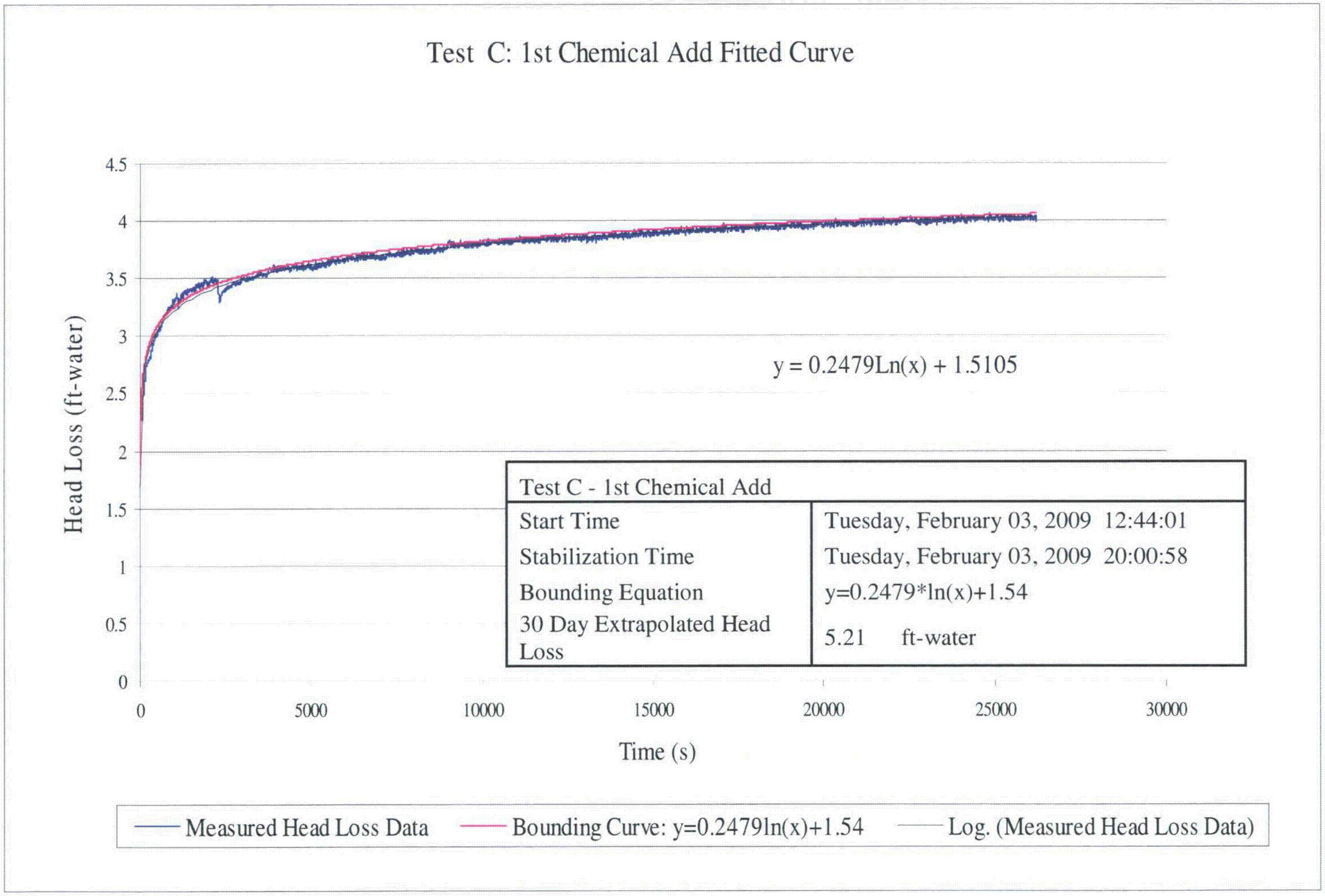


Figure 3o.2.17-9:
Figure showing the Curve Fitting and Extrapolation for the Data from the 4th Chemical Add of Test B

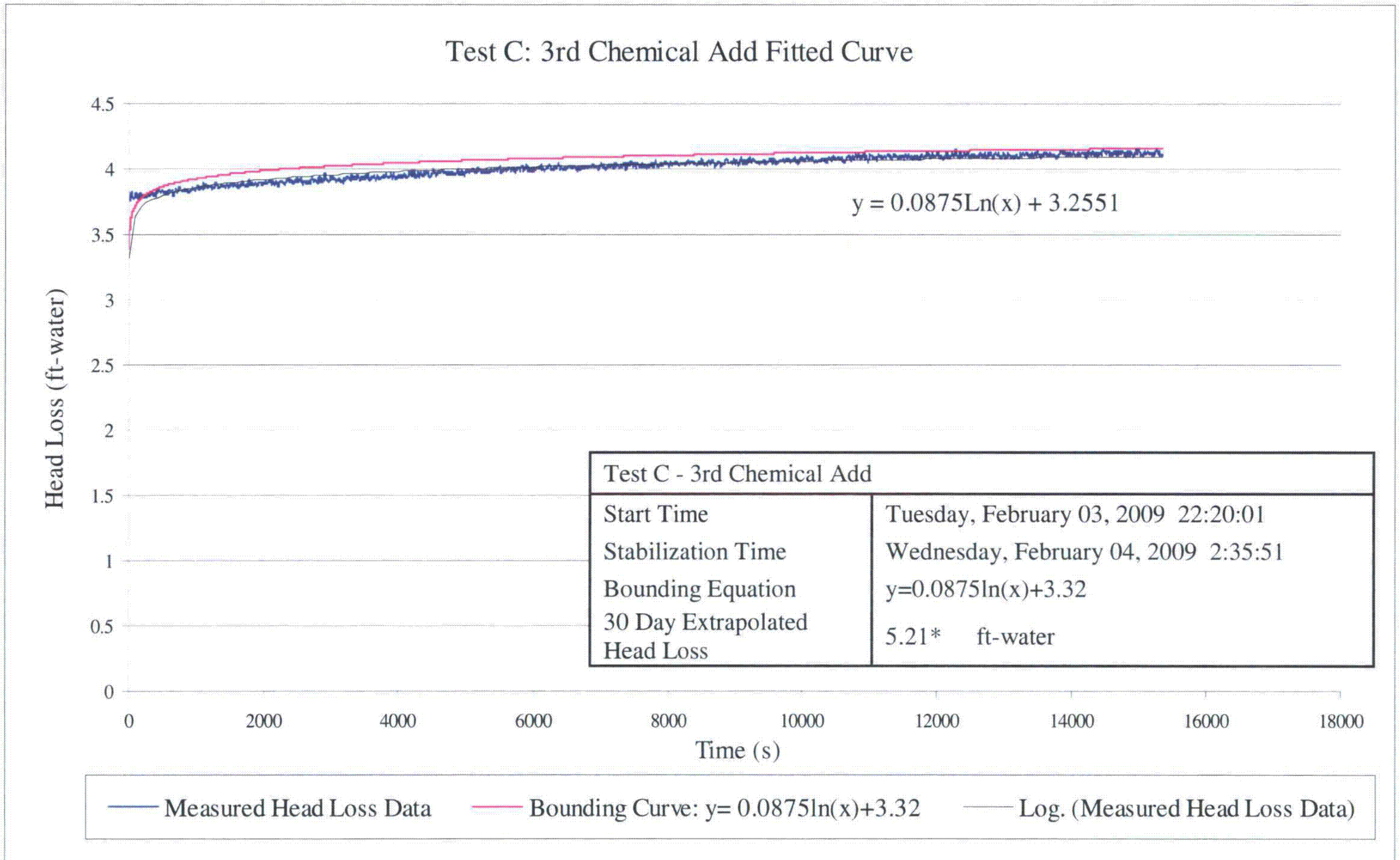
Test C: 1st Chemical Add



Test C - 1st Chemical Add	
Start Time	Tuesday, February 03, 2009 12:44:01
Stabilization Time	Tuesday, February 03, 2009 20:00:58
Bounding Equation	y=0.2479*ln(x)+1.54
30 Day Extrapolated Head Loss	5.21 ft-water

Figure 3o.2.17-10:
Figure showing the Curve Fitting and Extrapolation for the Data from the 1st Chemical Add of Test C

Test C: 3rd Chemical Add

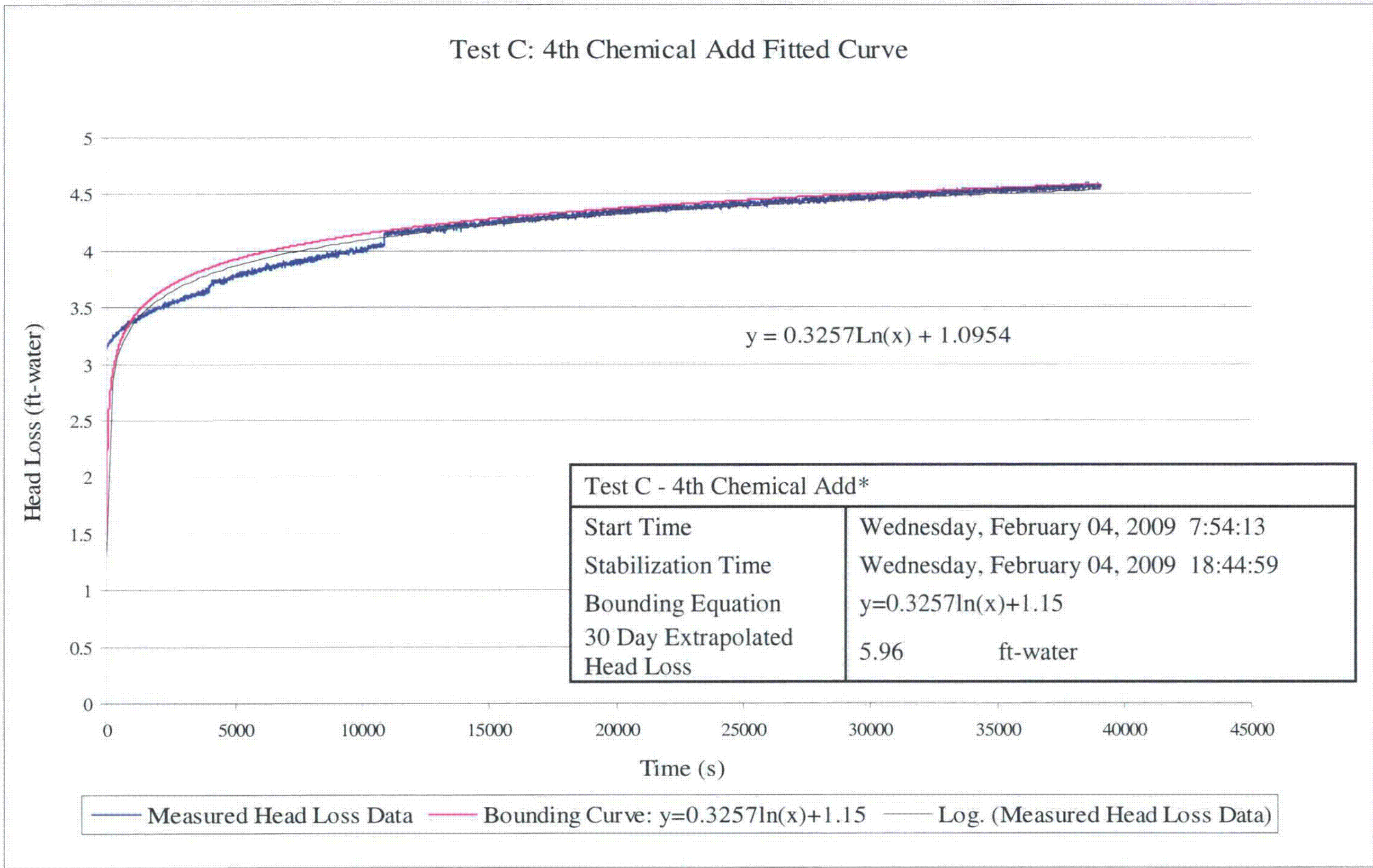


Test C - 3rd Chemical Add	
Start Time	Tuesday, February 03, 2009 22:20:01
Stabilization Time	Wednesday, February 04, 2009 2:35:51
Bounding Equation	y=0.0875ln(x)+3.32
30 Day Extrapolated Head Loss	5.21* ft-water

* The extrapolated head loss from the 1st chemical add resulted in a higher head loss (5.21 ft-water) than that from the 3rd chemical add (4.62 ft-water). For added conservatism the extrapolated head loss from the 1st chemical add is used.

Figure 3o.2.17-11:
Figure showing the Curve Fitting and Extrapolation for the Data from the 3rd Chemical Add of Test C

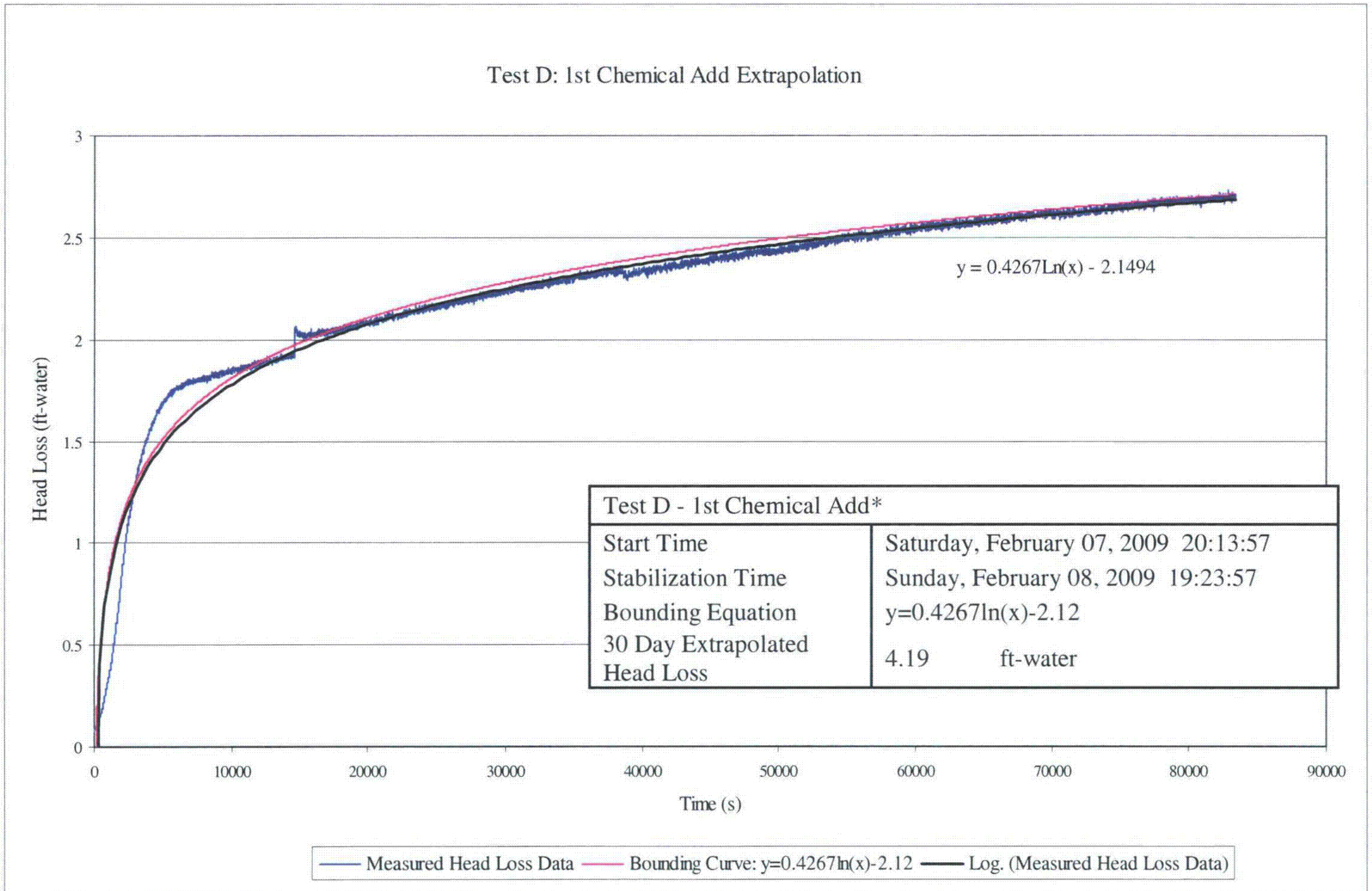
Test C: 4th Chemical Add



*Data was analyzed after bed shift (not shown) since this resulted in a larger head loss which is more conservative.

Figure 3o.2.17-12:
Figure showing the Curve Fitting and Extrapolation for the Data from the 4th Chemical Add of Test C

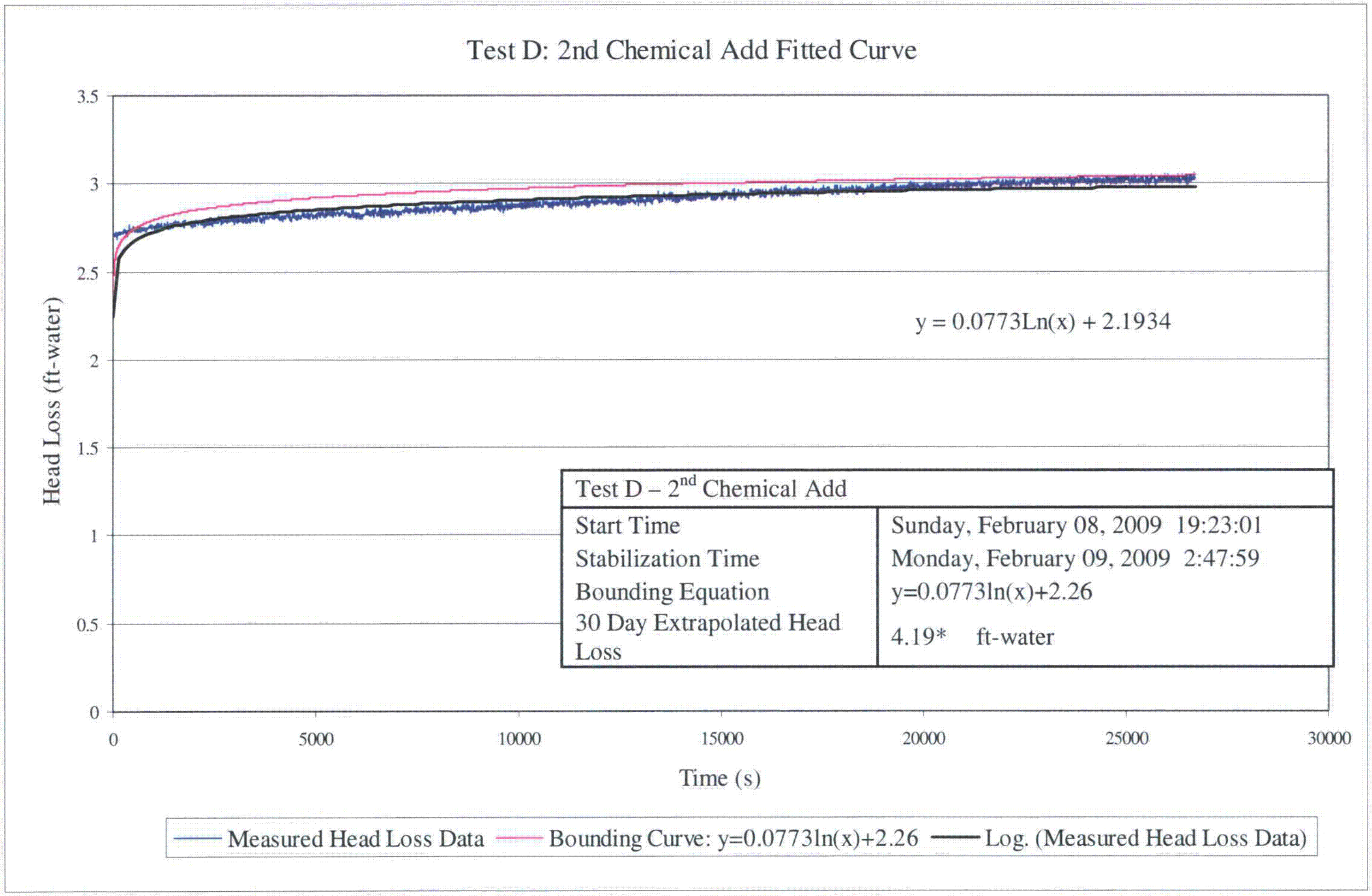
Test D: 1st Chemical Add



*Due to the length of this test, every other data point was used for the curve fit. This is reasonable since the data set has sufficient resolution to produce the same result as every data point.

Figure 3o.2.17-13:
Figure showing the Curve Fitting and Extrapolation for the Data from the 1st Chemical Add of Test D

Test D: 2nd Chemical Add

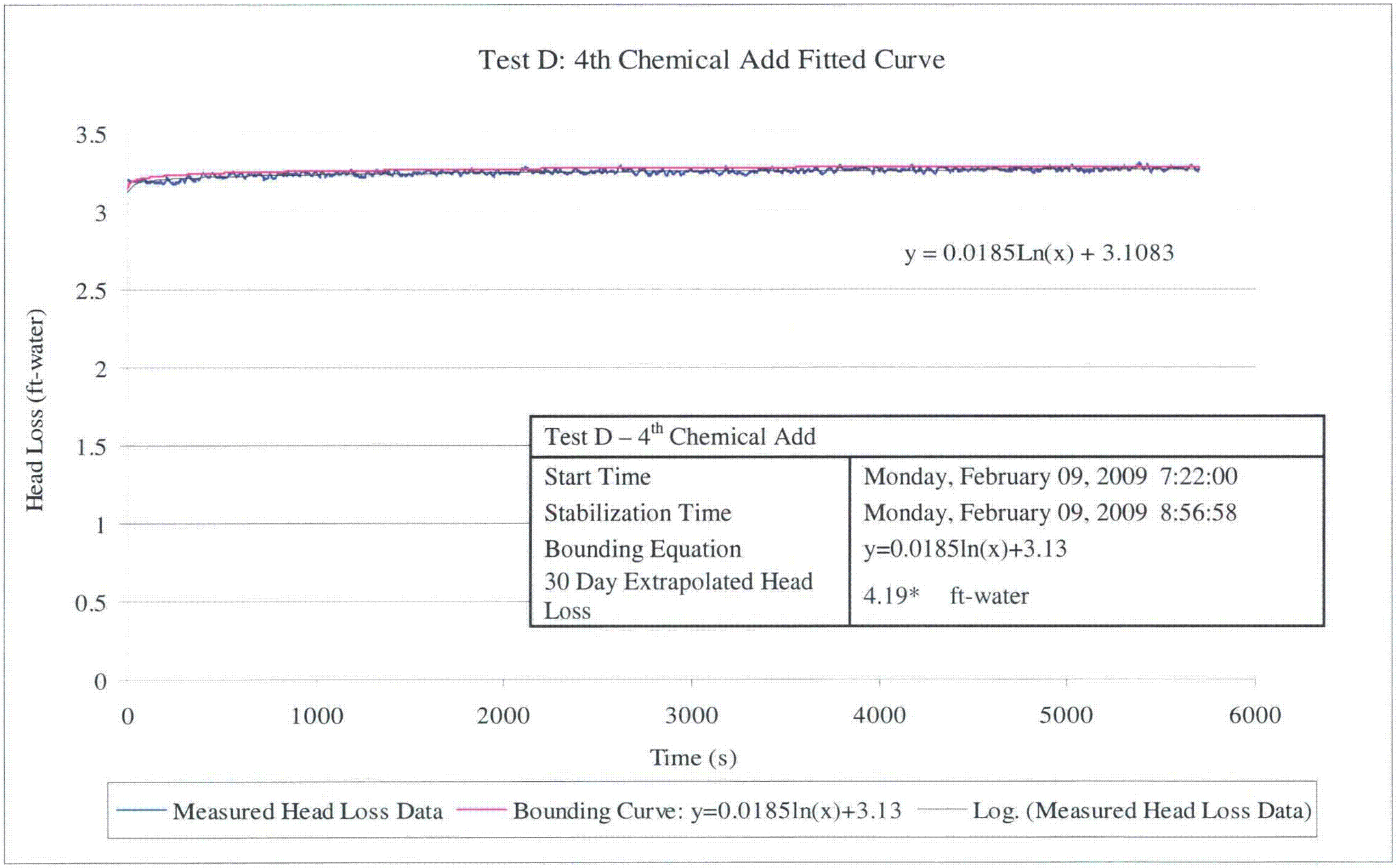


Test D – 2nd Chemical Add	
Start Time	Sunday, February 08, 2009 19:23:01
Stabilization Time	Monday, February 09, 2009 2:47:59
Bounding Equation	y=0.0773ln(x)+2.26
30 Day Extrapolated Head Loss	4.19* ft-water

* The extrapolated head loss from the 1st chemical add resulted in a higher head loss (4.19 ft-water) than that from the 2nd chemical add (3.41 ft-water). For added conservatism the extrapolated head loss from the 1st chemical add is used.

Figure 3o.2.17-14:
Figure showing the Curve Fitting and Extrapolation for the Data from the 2nd Chemical Add of Test D

Test D: 4th Chemical Add



* The extrapolated head loss from the 1st chemical add resulted in a higher head loss (4.19 ft-water) than that from the 2nd chemical add (3.41 ft-water) and 4th chemical add (3.41 ft-water). For added conservatism the extrapolated head loss from the 1st chemical add is used.

Figure 3o.2.17-15:
Figure showing the Curve Fitting and Extrapolation for the Data from the 4th Chemical Add of Test D

Test E: 2nd Chemical Add

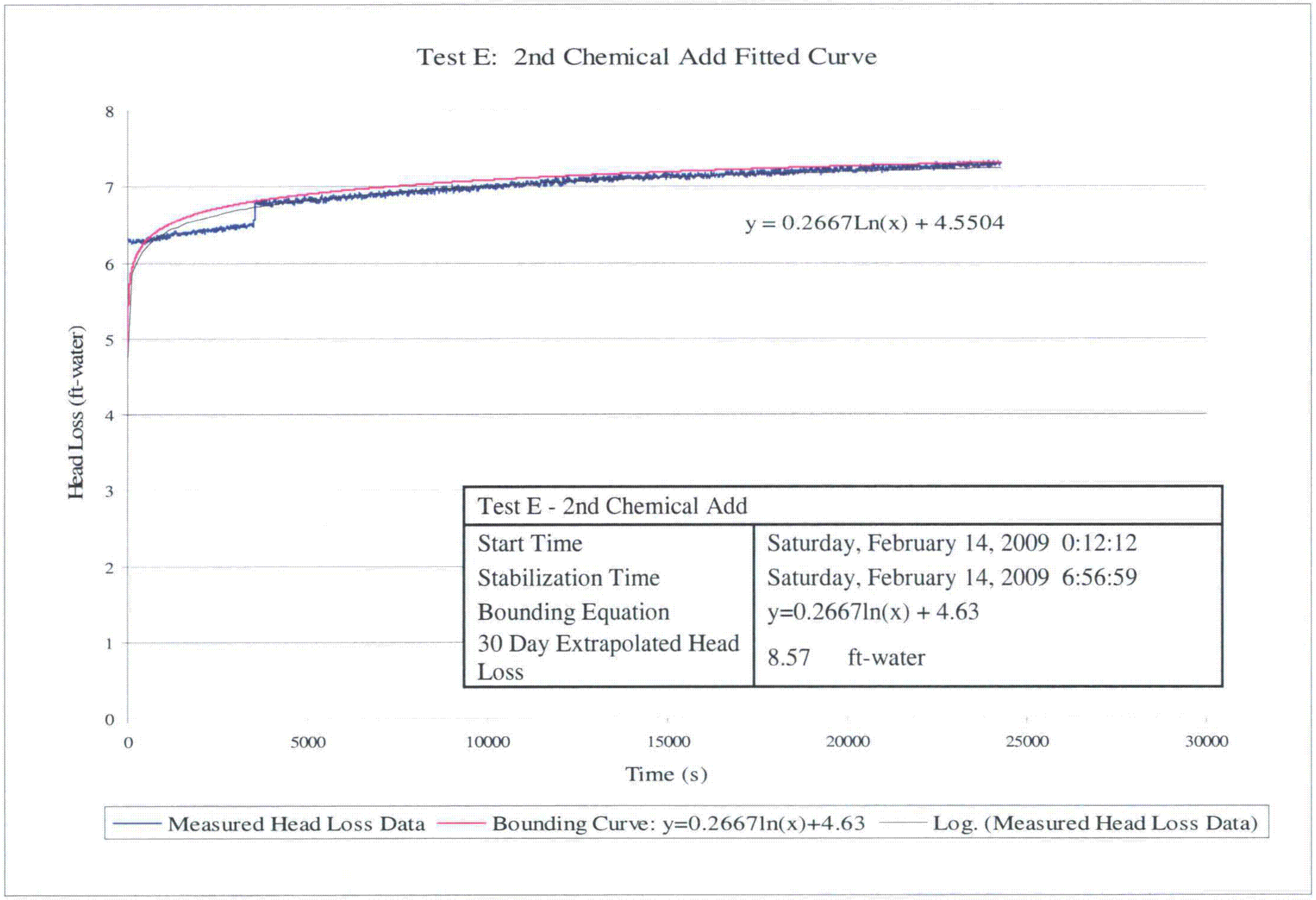
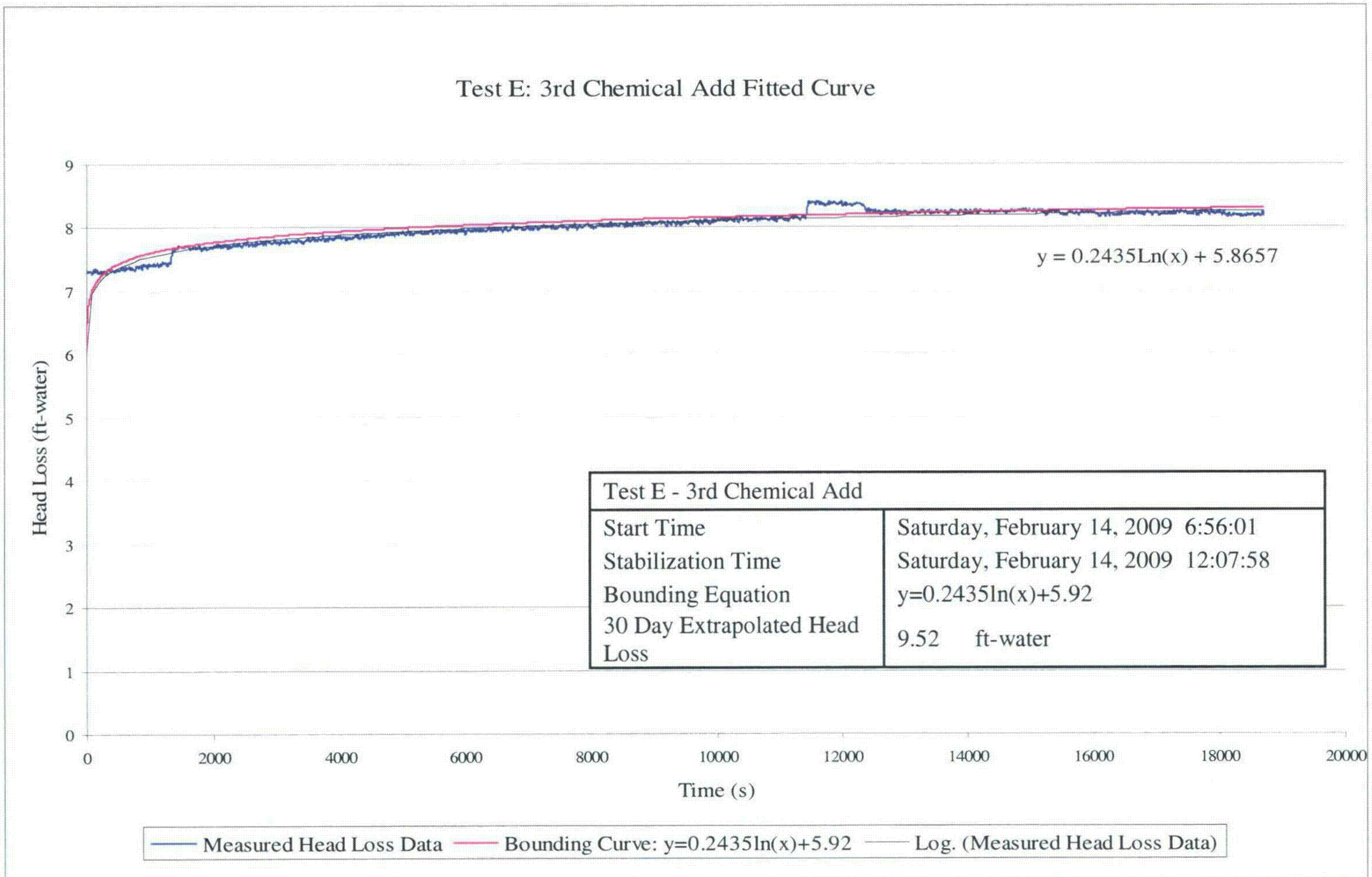


Figure 3o.2.17-16:
Figure showing the Curve Fitting and Extrapolation for the Data from the 2nd Chemical Add of Test E

Test E: 3^{rd} Chemical Add

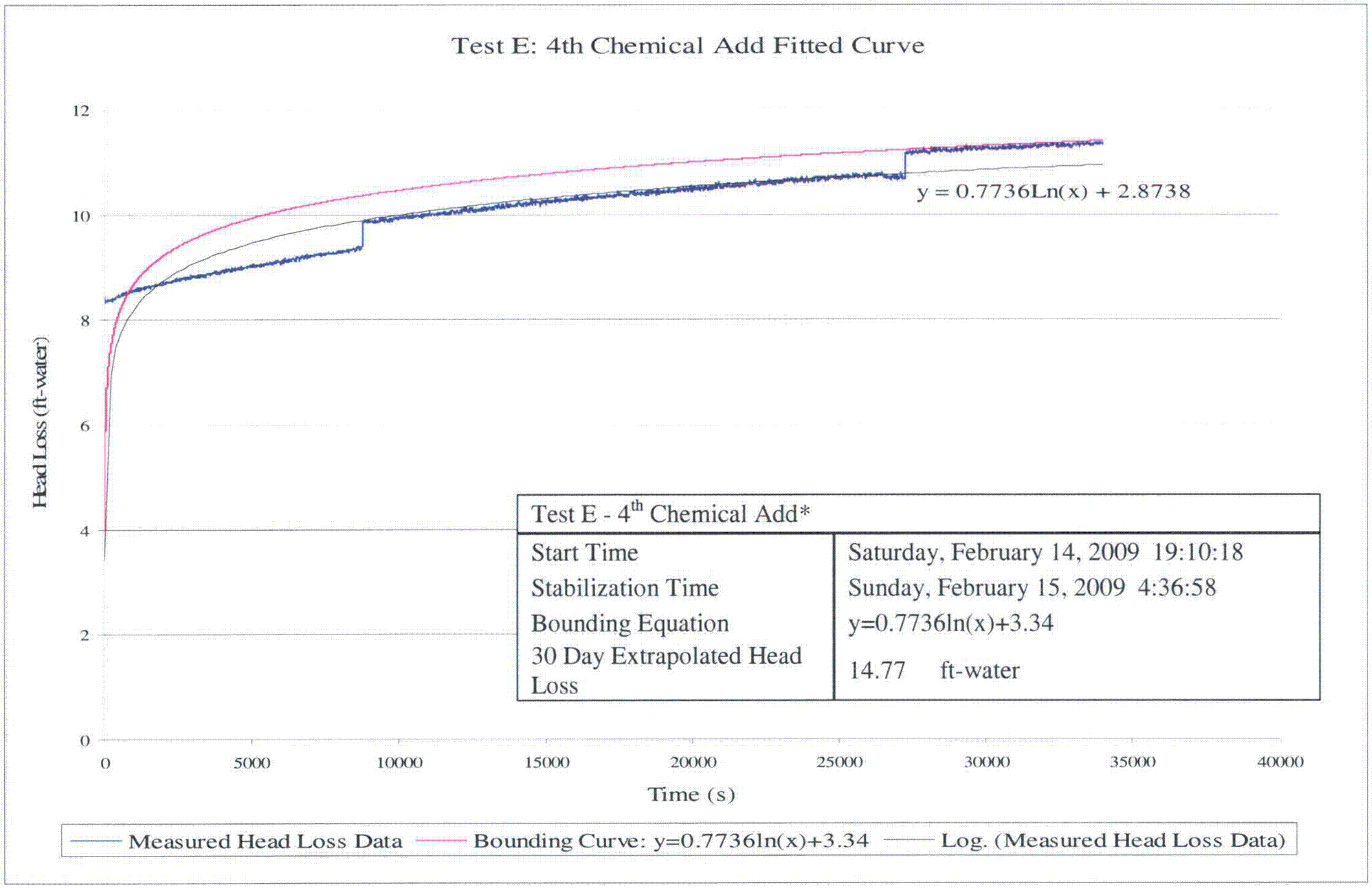


Note that the sudden increase in Head Loss at approximately 11000 seconds occurred because the Low Differential Pressure cells stopped working; their range ends around 8 ft of differential pressure. As the Head Loss began to increase, the Low DP cells were replaced with High DP cells. At that point, the Head Loss measurement started to come down once again. As seen in the figure, the Bounding Curve bounds all the data, except the momentary increase due to malfunctioning of the equipment.

Figure 3o.2.17-17:

Figure showing the Curve Fitting and Extrapolation for the Data from the 3^{rd} Chemical Add of Test E

Test E: 4th Chemical Add



Test E - 4th Chemical Add*	
Start Time	Saturday, February 14, 2009 19:10:18
Stabilization Time	Sunday, February 15, 2009 4:36:58
Bounding Equation	y=0.7736ln(x)+3.34
30 Day Extrapolated Head Loss	14.77 ft-water

* Extrapolation was performed after bed shift (not shown) since extrapolated head loss after the bed shift (14.77 ft-water) is more conservative than extrapolated data prior to the bed shift (14.03 ft-water).

Figure 3o.2.17-18:
Figure showing the Curve Fitting and Extrapolation for the Data from the 4th Chemical Add of Test E

Test E: 5th Chemical Add

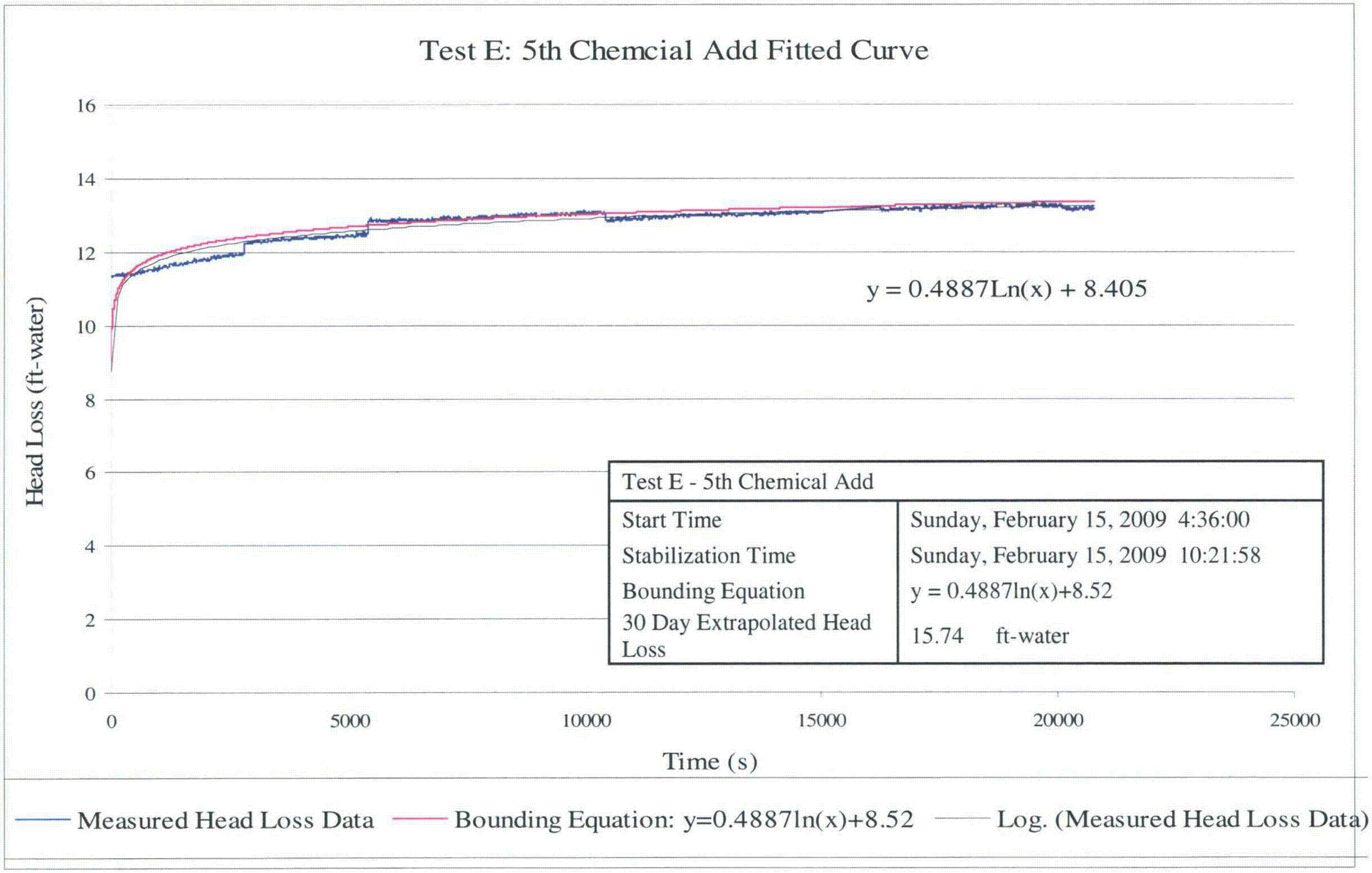
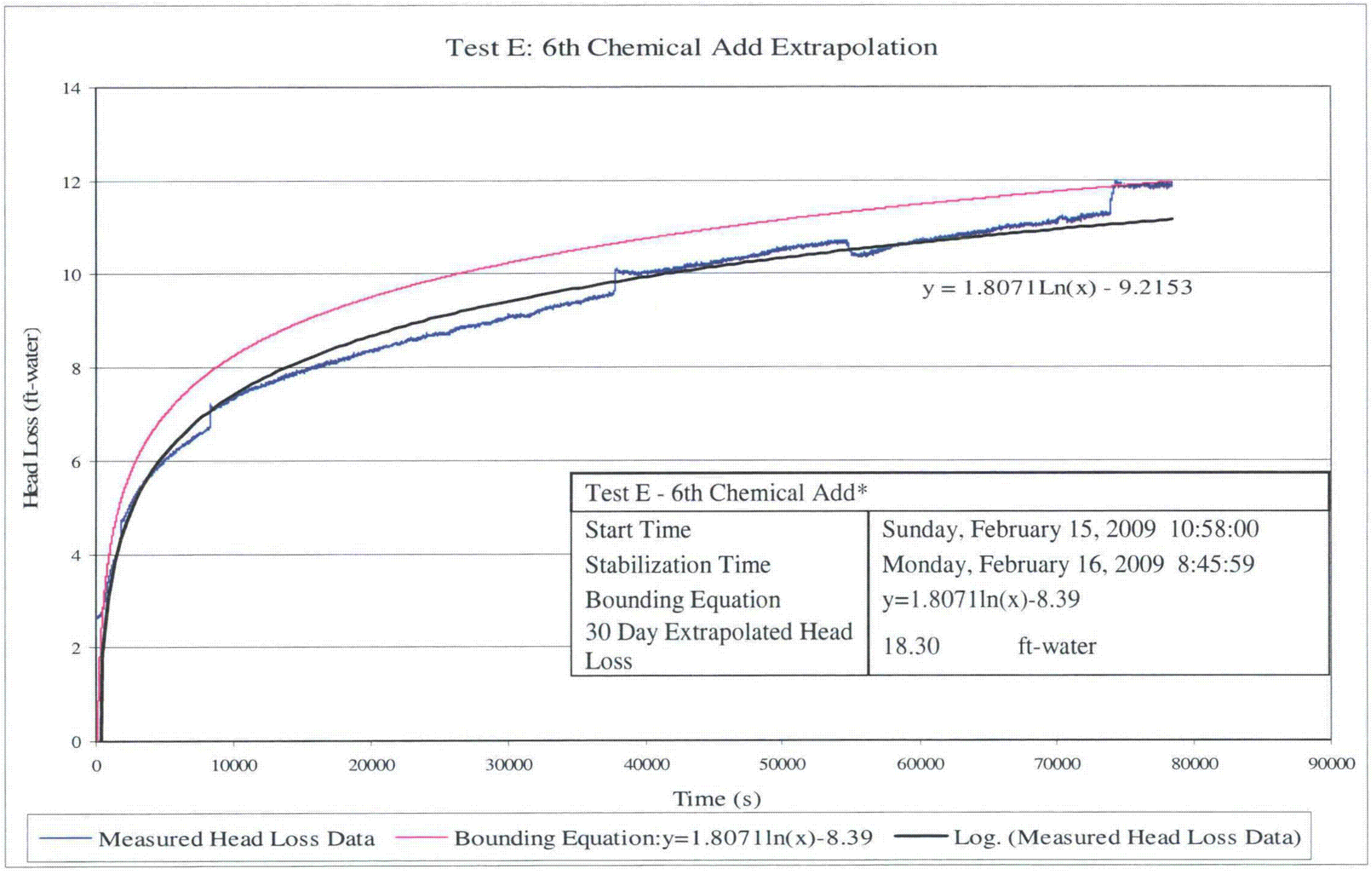


Figure 3o.2.17-19:
Figure showing the Curve Fitting and Extrapolation for the Data from the 5th Chemical Add of Test E

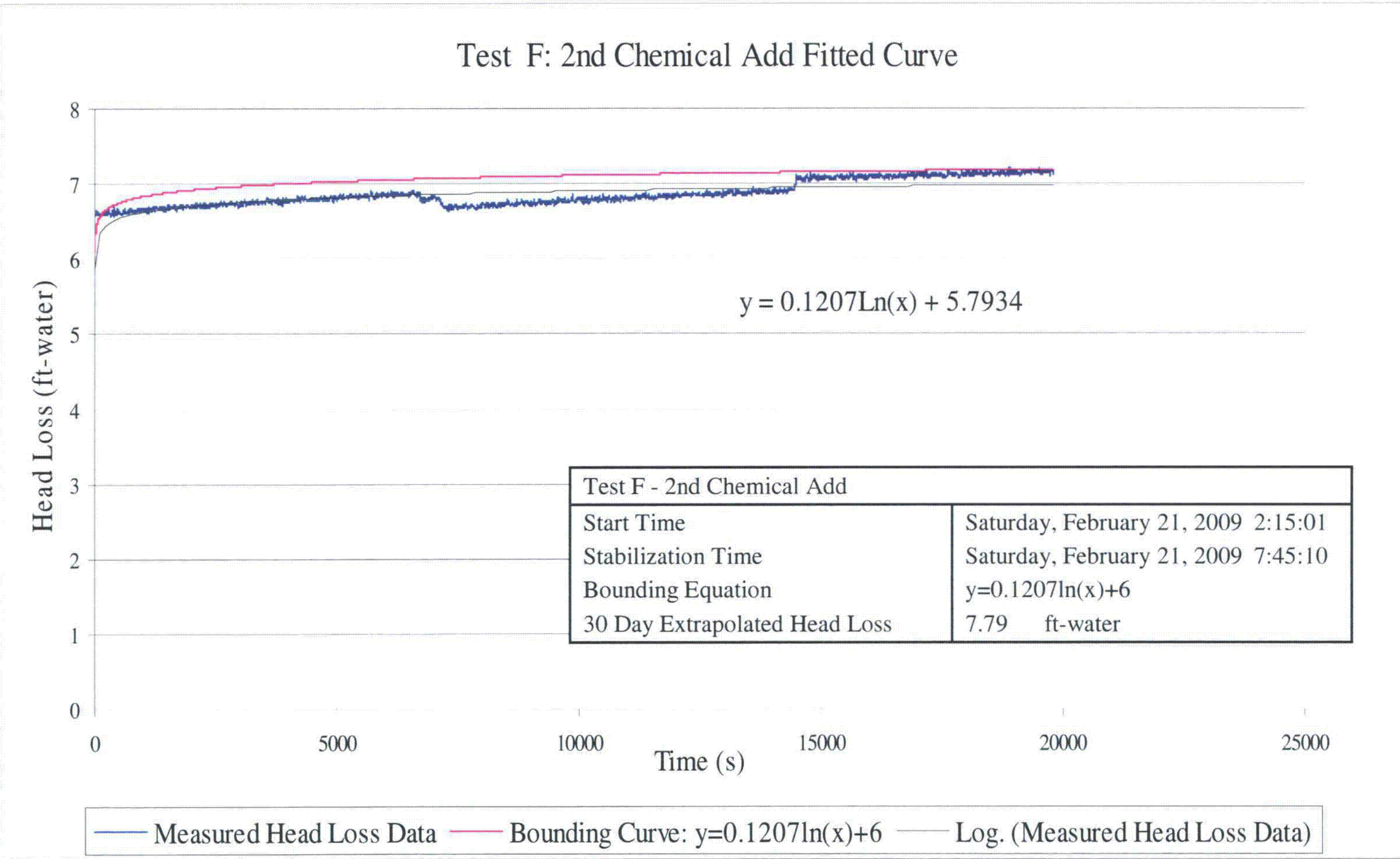
Test E: 6th Chemical Add



*Due to the length of this test, every other data point was used for the curve fit. This is reasonable since the data set has sufficient resolution to produce the same result as every data point.

Figure 3o.2.17-20:
Figure showing the Curve Fitting and Extrapolation for the Data from the 6th Chemical Add of Test E

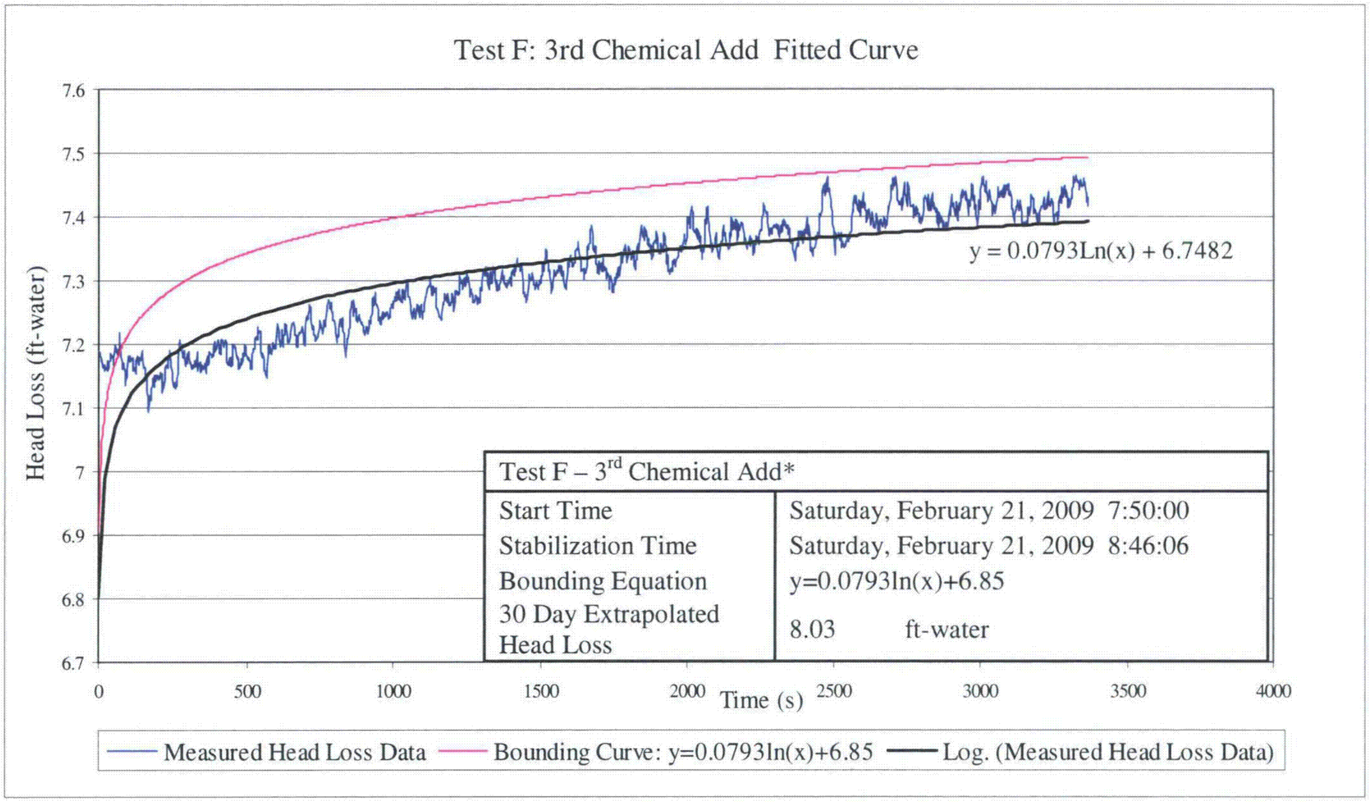
Test F: 2nd Chemical Add



Test F - 2nd Chemical Add	
Start Time	Saturday, February 21, 2009 2:15:01
Stabilization Time	Saturday, February 21, 2009 7:45:10
Bounding Equation	y=0.1207ln(x)+6
30 Day Extrapolated Head Loss	7.79 ft-water

Figure 3o.2.17-21:
Figure showing the Curve Fitting and Extrapolation for the Data from the 2nd Chemical Add of Test F

Test F: 3rd Chemical Add

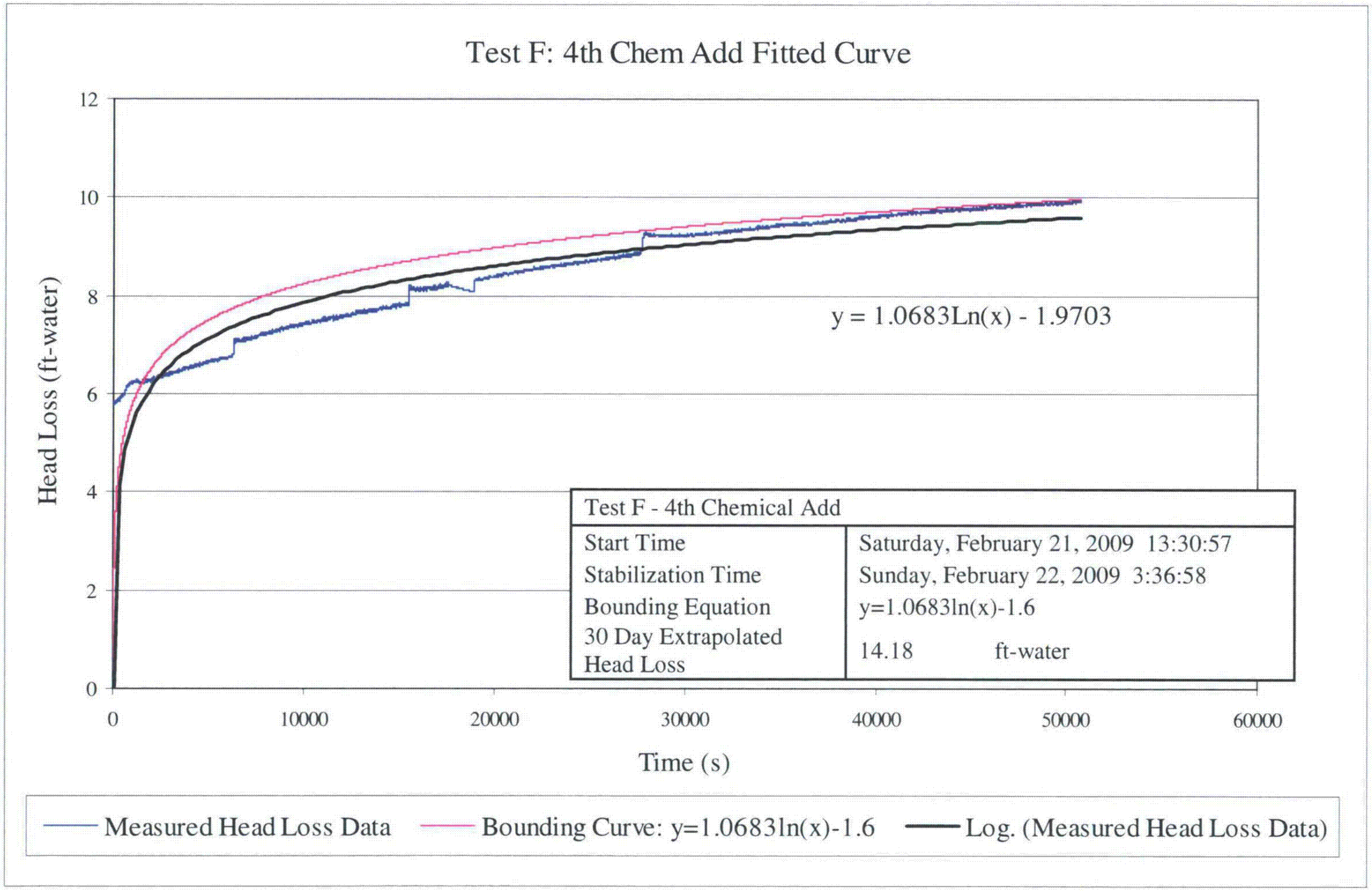


*Extrapolation performed on data prior to bed shift (not shown) since this results in a more conservative head loss.

Figure 3o.2.17-22:
Figure showing the Curve Fitting and Extrapolation for the Data from the 3rd Chemical Add of Test F

A bed shift occurred soon after the chemical load was added for this test stage and once stabilization was reached the head loss did not recover to what it had been prior to the bed shift. The data was extrapolated both before and after the bed shift and it was found that the extrapolated head loss was larger prior to the bed shift. Therefore, the data prior to the bed shift is selected for extrapolation since a more conservative head loss results.

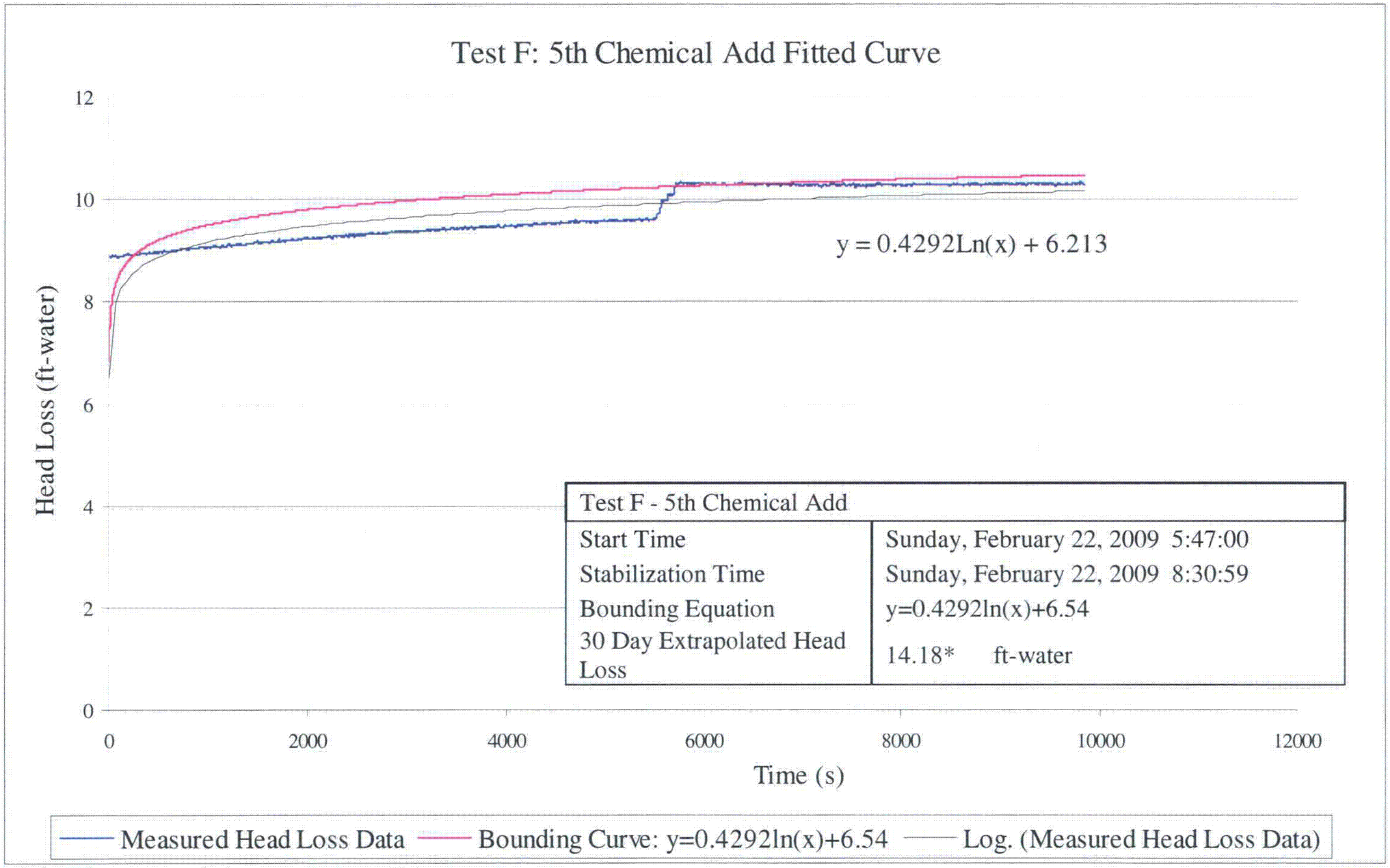
Test F: 4th Chemical Add



Test F - 4th Chemical Add	
Start Time	Saturday, February 21, 2009 13:30:57
Stabilization Time	Sunday, February 22, 2009 3:36:58
Bounding Equation	y=1.0683ln(x)-1.6
30 Day Extrapolated Head Loss	14.18 ft-water

Figure 3o.2.17-23:
Figure showing the Curve Fitting and Extrapolation for the Data from the 4th Chemical Add of Test F

Test F: 5th Chemical Add



Test F - 5th Chemical Add	
Start Time	Sunday, February 22, 2009 5:47:00
Stabilization Time	Sunday, February 22, 2009 8:30:59
Bounding Equation	y=0.4292ln(x)+6.54
30 Day Extrapolated Head Loss	14.18* ft-water

* The extrapolated head loss from the 4th chemical add resulted in a higher head loss (14.18 ft-water) than that from the 5th chemical add (12.88 ft-water). For added conservatism the extrapolated head loss from the 4th chemical add is used.

Figure 3o.2.17-24:
Figure showing the Curve Fitting and Extrapolation for the Data from the 5th Chemical Add of Test F

Test F: 6th Chemical Add

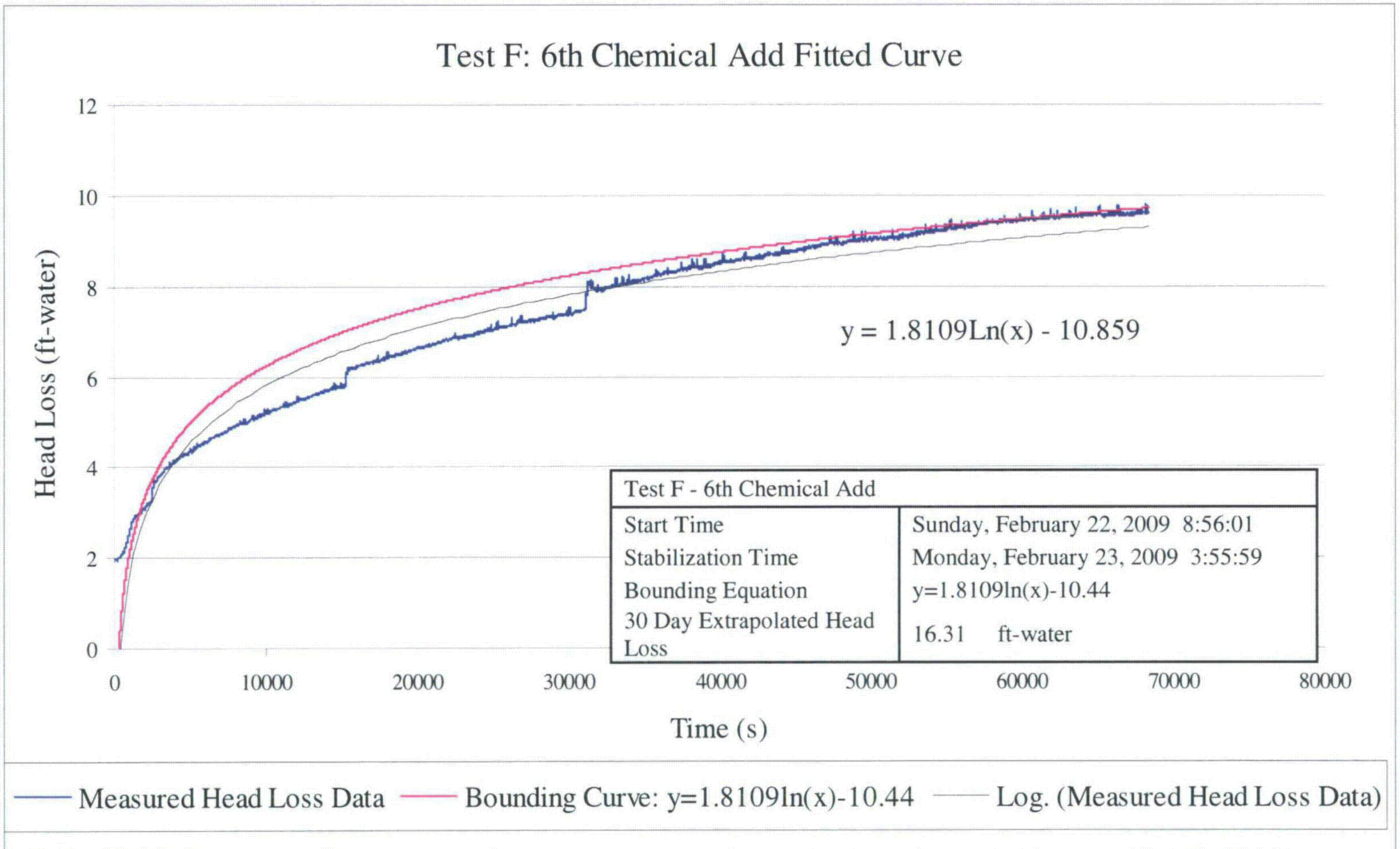
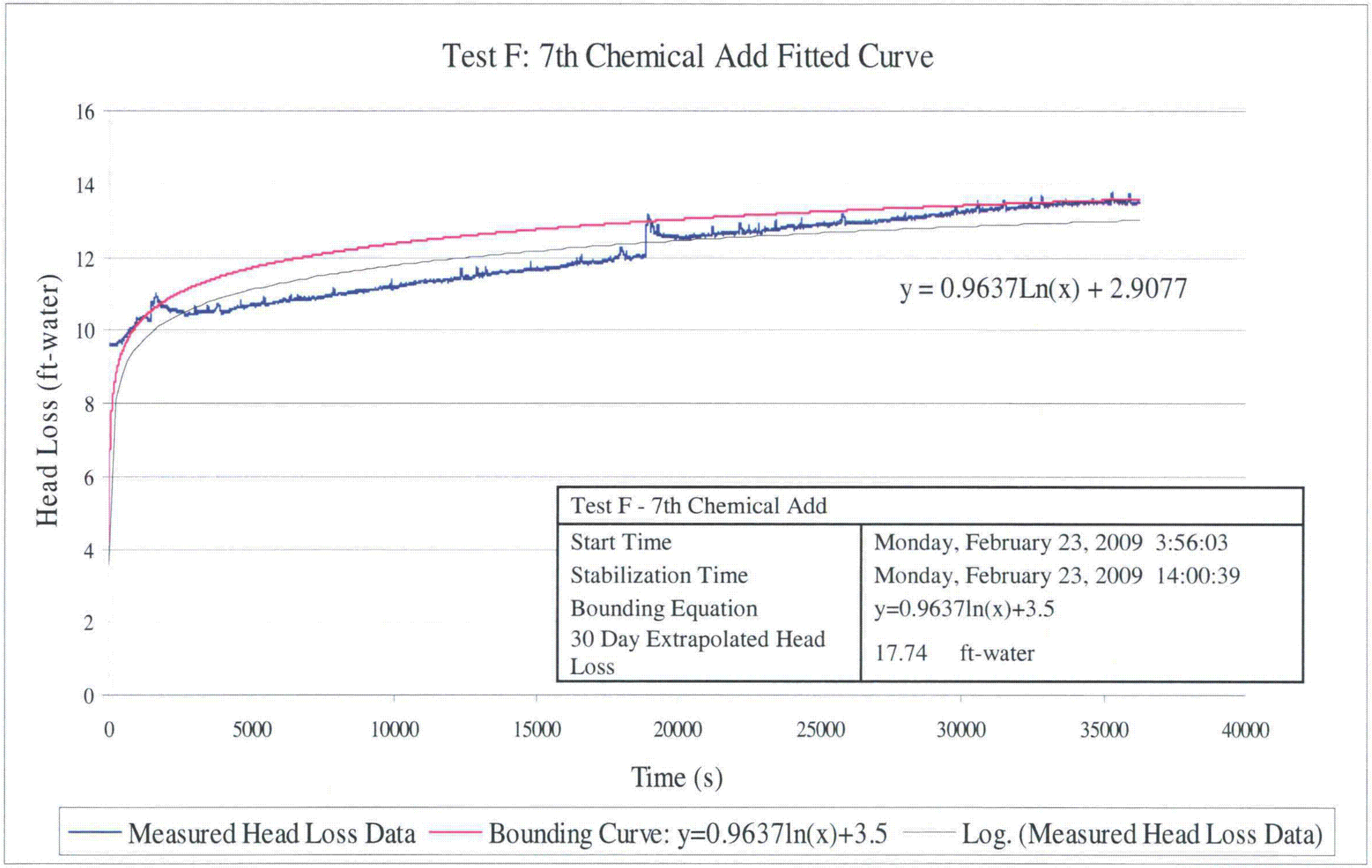


Figure 3o.2.17-25:
Figure showing the Curve Fitting and Extrapolation for the Data from the 6th Chemical Add of Test F

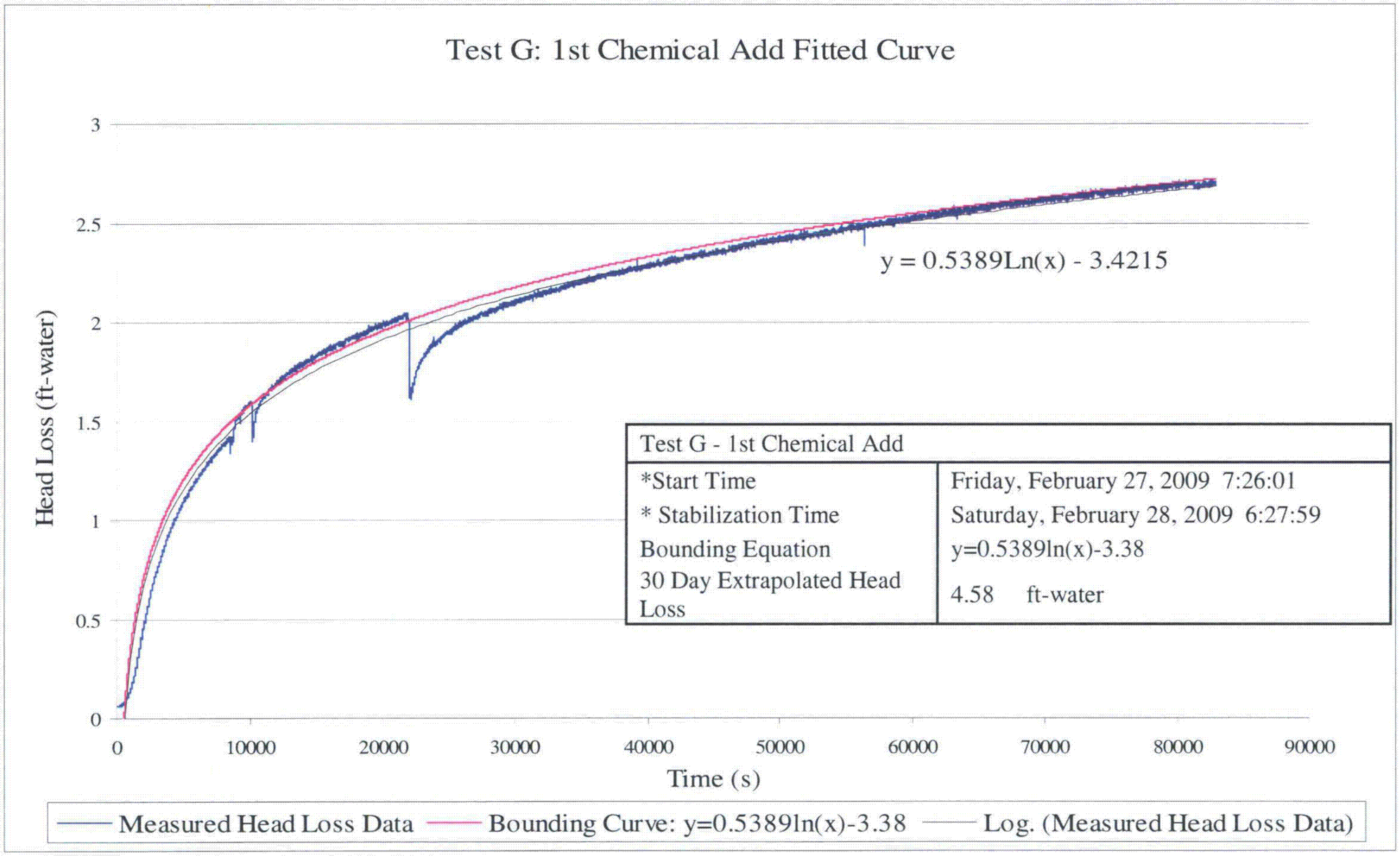
Test F: 7th Chemical Add



Test F - 7th Chemical Add	
Start Time	Monday, February 23, 2009 3:56:03
Stabilization Time	Monday, February 23, 2009 14:00:39
Bounding Equation	y=0.9637ln(x)+3.5
30 Day Extrapolated Head Loss	17.74 ft-water

Figure 3o.2.17-26:
Figure showing the Curve Fitting and Extrapolation for the Data from the 7th Chemical Add of Test F

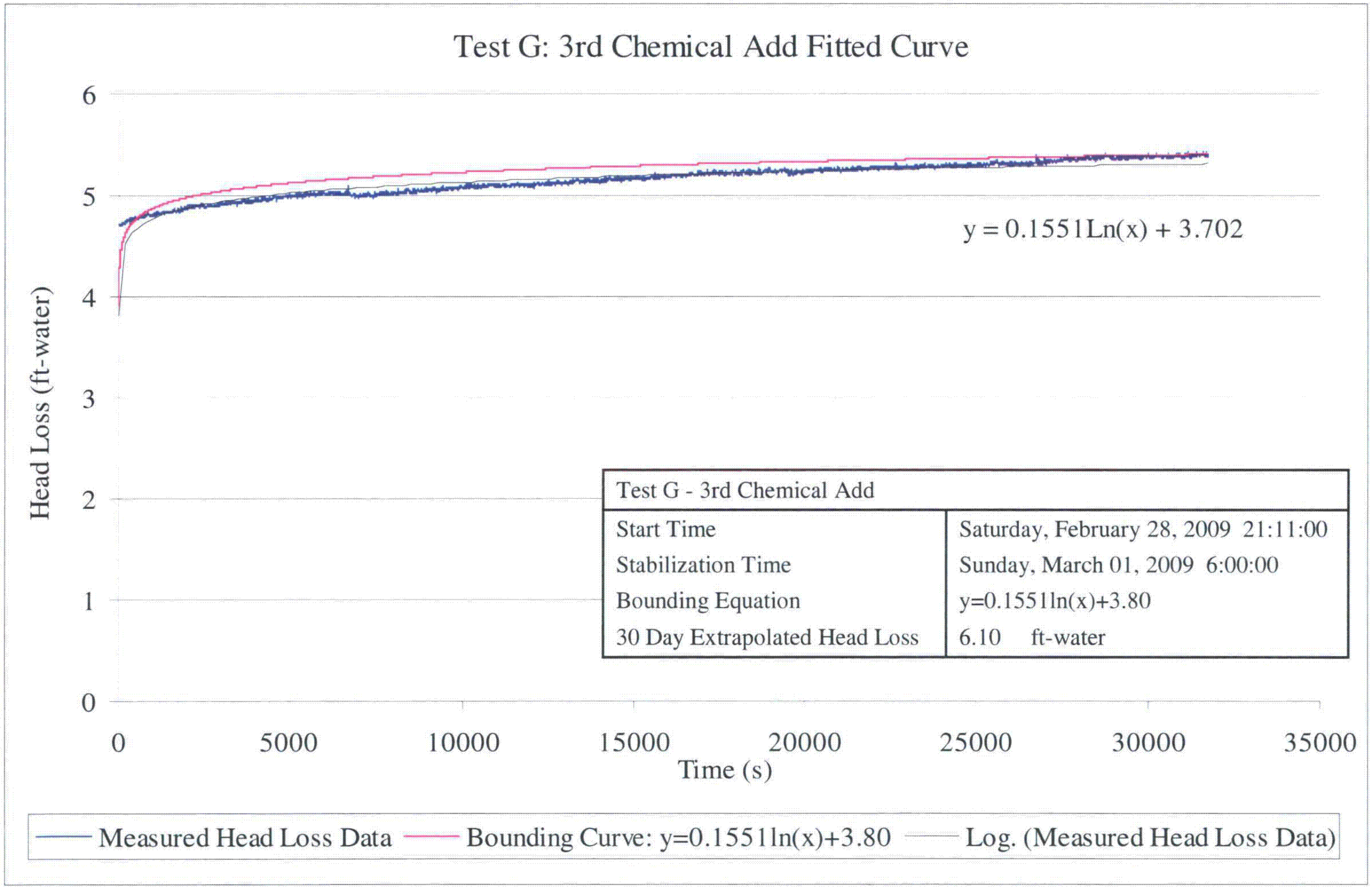
Test G: 1st Chemical Add



*Due to the length of this test, every other data point was used for the curve fit. This is reasonable since the data set has sufficient resolution to produce the same result as every data point.

Figure 3o.2.17-27:
Figure showing the Curve Fitting and Extrapolation for the Data from the 1st Chemical Add of Test G

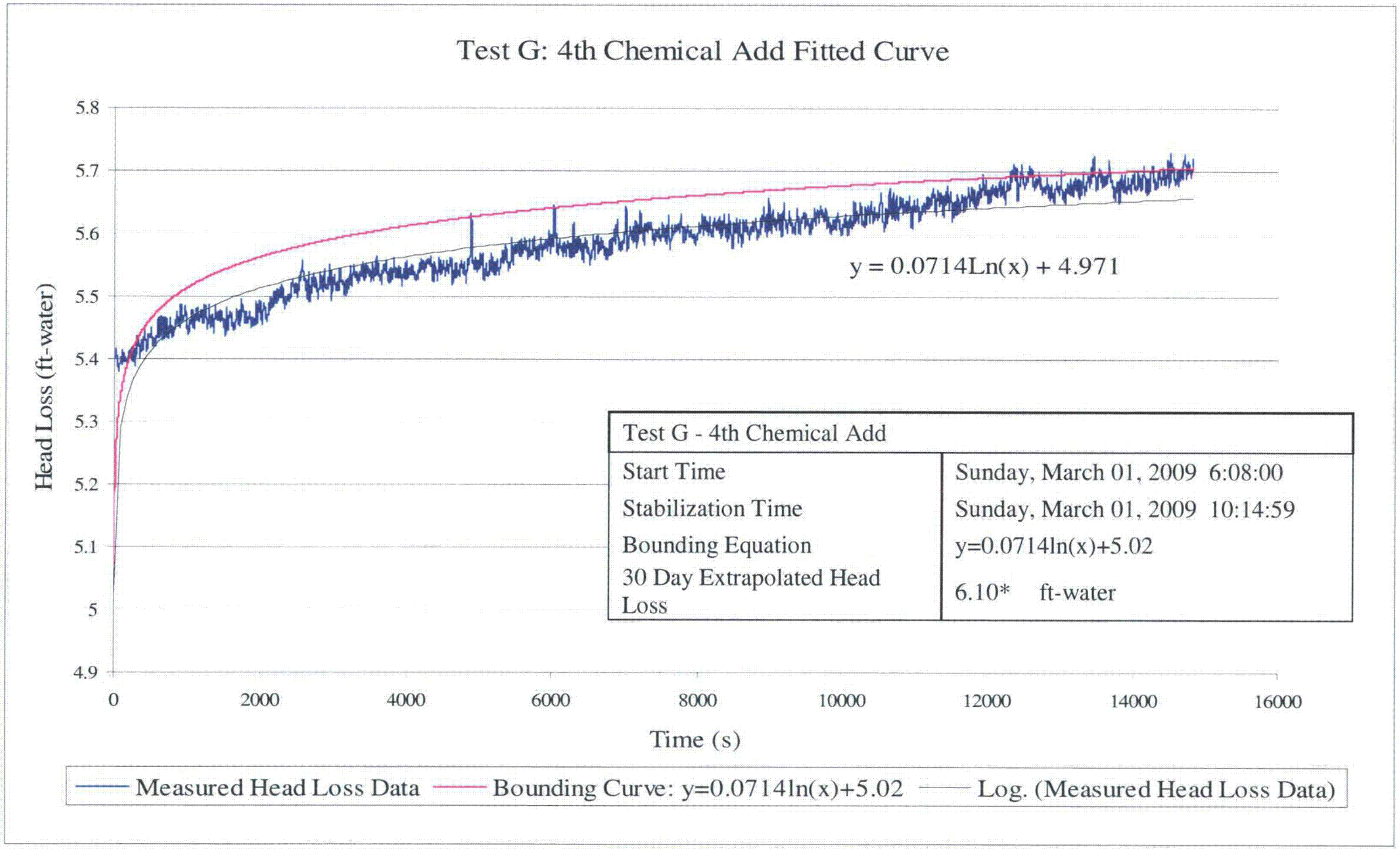
Test G: 3rd Chemical Add



Test G - 3rd Chemical Add	
Start Time	Saturday, February 28, 2009 21:11:00
Stabilization Time	Sunday, March 01, 2009 6:00:00
Bounding Equation	y=0.1551ln(x)+3.80
30 Day Extrapolated Head Loss	6.10 ft-water

Figure 3o.2.17-28:
Figure showing the Curve Fitting and Extrapolation for the Data from the 3rd Chemical Add of Test G

Test G: 4th Chemical Add



* The extrapolated head loss from the 3rd chemical add resulted in a higher head loss (6.10 ft-water) than that from the 4th chemical add (6.08 ft-water). For added conservatism the extrapolated head loss from the 3rd chemical add is used.

Figure 3o.2.17-29:
Figure showing the Curve Fitting and Extrapolation for the Data from the 4th Chemical Add of Test G

Entergy Response to Issue 3o.2.18.i

Indian Point is not employing integral generation of chemical effects.

Entergy Response to Issue 3o.2.19.i

The chemical effects array testing utilized full size Top Hats (21" in length) as compared to the IR sump in both units. While the VC sump Top Hats range from 15 inches to 43 inches in length, the diameter of the perforated tubes was equivalent. The debris sizes used in the testing were also equivalent to those predicted to be present in the plant post-LOCA. The test utilized an array with a smaller number of Top Hats compared to the plant; therefore, scaling for debris amounts and flow rate was completed based on a ratio of the surface areas. The approach velocities in the test equaled the maximum value expected in the plant. The equation for the debris scaling factors (DSF), and the corresponding values for each sump are summarized below:

$$\mathrm{DSF} = \frac{\text{Test Strainer Gross Area}}{\text{Sump Strainer Gross Area - } 0.75 \times \text{Tape \& Equipment Label Area}}$$

$$\text{IP-2 IR Sump: DSF} = \frac{135.9\,\mathrm{ft}^2}{\left(3759\,\mathrm{ft}^2 - 235.67\,\mathrm{ft}^2 \cdot 0.75\right)} = 0.038$$

$$\text{IP-2 VC Sump: DSF} = \frac{135.9\,\mathrm{ft}^2}{\left(1352\,\mathrm{ft}^2 - 235.67\,\mathrm{ft}^2 \cdot 0.75\right)} = 0.116$$

$$\text{IP-3 IR Sump: DSF} = \frac{135.9\,\mathrm{ft}^2}{\left(3759\,\mathrm{ft}^2 - 45.78\,\mathrm{ft}^2 \cdot 0.75\right)} = 0.036$$

$$\text{IP-3 VC Sump: DSF} = \frac{135.9\,\mathrm{ft}^2}{\left(1207\,\mathrm{ft}^2 - 45.78\,\mathrm{ft}^2 \cdot 0.75\right)} = 0.116$$

Entergy Response to Issue 3o.2.19.ii

Representative bed formation was achieved as described in Response to Item 3o.2.20.i.

Entergy Response to Issue 3o.2.20.i

The 3x3 array test strainer was in a simulated pit configuration within a larger tank. Debris was added off to the side of the pit and carried into the pit by the flow, simulating the plant configuration, operation, and bed formation. Any debris added to the tank that did not immediately flow into the strainers was subjected to constant turbulence from the pump return line. A motorized agitator, and manual stirring (when needed), prevented settling of debris outside the strainer array pit ensuring the debris reached the strainers. Due to these methods, agglomeration and settling was avoided, and conservative transport of the debris to the strainer array was ensured. These methods are also discussed in previous responses.

Entergy Response to issue 3o.2.21

Indian Point is not employing the 30-day integrated head loss test methodology.

Entergy Response to Issue 3o.2.22.i

Indian Point is not employing a Data Analysis Bump Up Factor methodology.

The NRC RAIs 15 and 23 concern Chemical Effects, the subject of the current NRC Issue (3o). The RAIs were identified in an NRC letter to Entergy, dated November 19, 2007 [Ref. 119]. The responses these RAIs may be found in Attachment 3.

USNRC Issue 3p:

Licensing Basis
The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications. Provide the information requested in GL 04-02, "Requested Information," Item 2.(e) regarding changes to the plant licensing basis. That is, provide a general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.

Entergy Response to Issue 3p:

To ensure compliance with the regulatory requirements listed in the GL licensing basis changes regarding the Unit 2 and Unit 3 containment buffering agents, ECCS passive failure requirements, and ECCS valve surveillance requirements have been approved by the NRC. These licensing basis changes are summarized below.

Licensing Basis Change Regarding Containment Sump Buffering Agent (Unit 2)

Due to the potential interaction of accident-generated debris with a combination of certain materials in the VC, borated water, and the previously existing pH buffer (Trisodium Phosphate (TSP)), the quantity and physical nature of that debris is ultimately affected. The accumulation of the modified debris at the sump strainers could have been such that the head loss across the strainers reduce pump NPSH margin to an unacceptable degree. It had been predicted through testing and chemical analysis that specific Unit 2 calcium silicate-bearing insulation debris could react negatively with the boric acid and previously existing TSP in the VC water to yield a greater head loss across the strainers.

On February 7, 2008, the NRC approved and issued Amendment No. 253 [Ref. 137] to the Facility Operating License changing the containment buffering agent from TSP to sodium tetraborate (NaTB). The TSP buffer was replaced by NaTB during the spring 2008 refueling outage.

Licensing Basis Change Regarding Containment Sump Buffering Agent (Unit 3)

Due to the potential interaction of accident-generated debris with a combination of certain materials in the VC, borated water, and the previously existing pH buffer (Sodium Hydroxide (NaOH)), the quantity and physical nature of that debris is ultimately affected. The accumulation of the modified debris at the sump strainers could have been such that the head loss across the strainers reduce pump NPSH margin to an unacceptable degree. It had been predicted through testing and chemical analysis that specific Unit 3 calcium silicate-bearing insulation debris could react negatively with the boric acid and NaOH in the VC water to yield a greater head loss across the strainers.

On June 9, 2008, the NRC approved and issued Amendment No. 236 [Ref. 138] to the Facility Operating License changing the containment buffering agent from NaOH to sodium tetraborate (NaTB). The NaOH buffer was replaced by NaTB in June 2008.

<u>Licensing Basis Change Regarding Passive Failure Analyses (Units 2 and 3)</u>

The purpose of this change to the licensing basis is to establish the following basis for passive failures:

1. Revise the ECCS single passive failure analysis such that passive failures are assumed to occur 24 hours or greater after event initiation.

2. Revise the Unit 2 CCWS single passive failure analysis such that passive failures are assumed to occur 24 hours or greater after event initiation.

3. Revise the recirculation phase backup capability such that the residual heat removal pumps would be used if backup capacity to the internal recirculation loop is required in the event of an ECCS or CCWS (Unit 2 only) passive failure 24 hours after event initiation.

On December 4, 2008, the NRC approved and issued Technical Specification amendment Nos. 257 and 238 for Unit 2 and Unit 3, respectively, [Ref. 139] to the Facility Operating License changing the requirements for single passive failure.

<u>Licensing Basis Change Regarding Emergency Core Cooling System Valve Surveillance Requirements (Unit 2 only)</u>

The purpose of this change to the licensing basis is to add two ECCS MOVs, 745A and 745B, to Technical Specification (TS) Surveillance Requirement (SR) 3.5.2.1 for checking valve position every 7 days. These two valves are located in series on the inlet pipe to the number 22 residual removal heat exchanger. The TS SR is designed to verify that ECCS valves whose single failure could cause the loss of the ECCS function are in the required position with ac power removed.

On October 29, 2009, the NRC approved and issued Technical Specification amendment No. 263 for Unit 2, [Ref. 141] to the Facility Operating License revising the ECCS valve surveillance requirements to include the 745 valves to be implemented by spring 2010.

<u>Licensing Basis Changes Performed Pursuant to 10 CFR 50.59</u>

The UFSAR is submitted periodically (6 months after each refueling outage) to the NRC. The sump strainer, flow channeling and attendant modifications were evaluated under 10 CFR 50.59 and are included in the current revisions of the UFSAR (Unit 2 Revision 21, Unit 3 Revision 03). The next Unit 2 refueling outage is scheduled for spring 2010 during which the final GL 2004-02 related modifications will be installed. Therefore, the UFSAR update including these changes will be submitted by fall 2010. Similarly for Unit 3 the corresponding UFSAR changes will be submitted by fall of 2011.

Based on the scheduled corrective actions Unit 2 will be in full compliance with the requirements of GL 2004-02 with the completion of the vortex suppressor installation and the 745 valve modification, and a revision to the licensing basis as described in the UFSAR to reflect the deterministic approach to sump screen blockage including a 30 day ECCS mission time. However, Unit 3 will not achieve full compliance until spring 2011 with the installation of the vortex suppressors. Nevertheless, Entergy will revise the Unit 3 licensing basis to meet GL 2004-02 requirements by May 31st, 2010. An evaluation of the acceptability of the delay in installing the vortex suppressors for this interim period will be performed prior to May 31, 2020.

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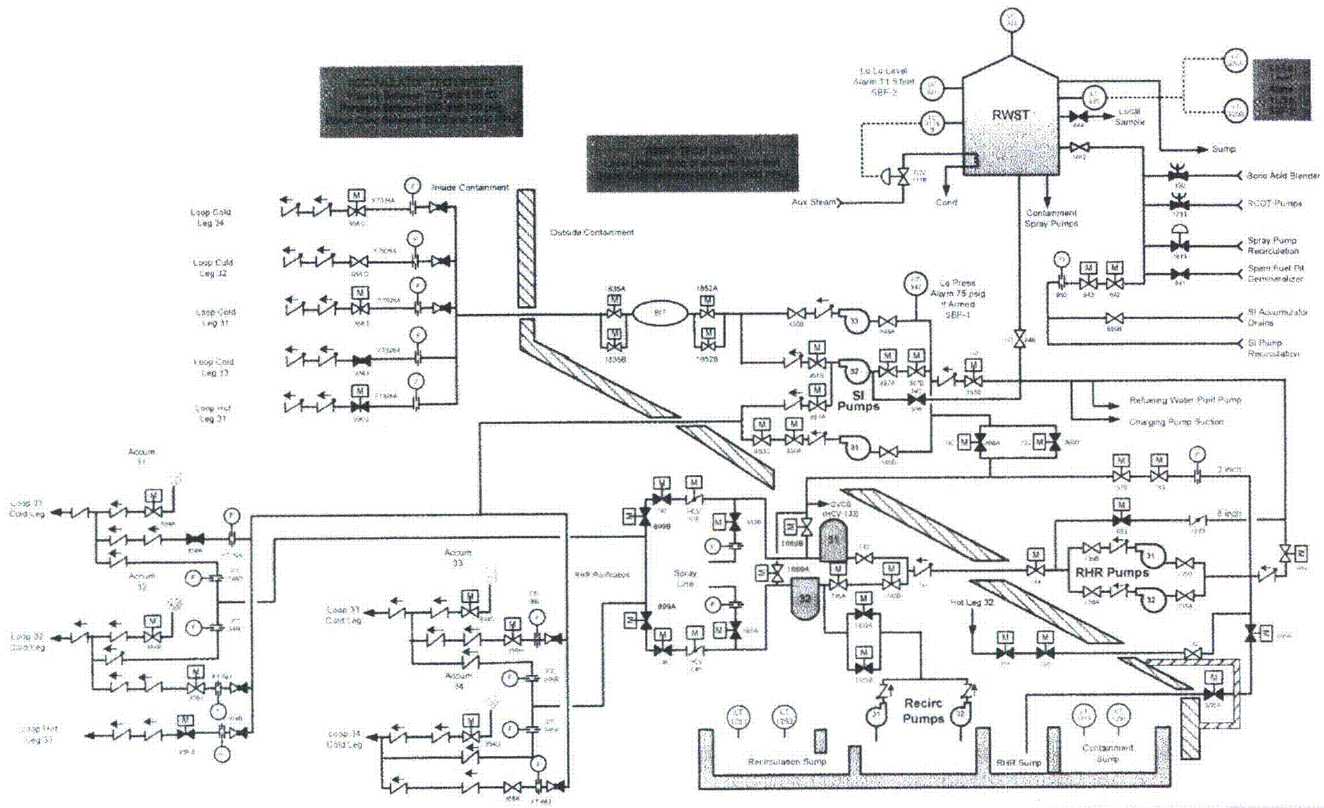
ATTACHMENT 2 TO NL-09-138

INDIAN POINT UNITS 2 and 3

Emergency Core Cooling System Flow Diagrams[1]

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNITS 2 AND 3
DOCKETS 50-247 AND 50-286

[1] Note – These drawings are simplified for illustrative purposes and not controlled



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Rev. 4	Date: 10/18/2005
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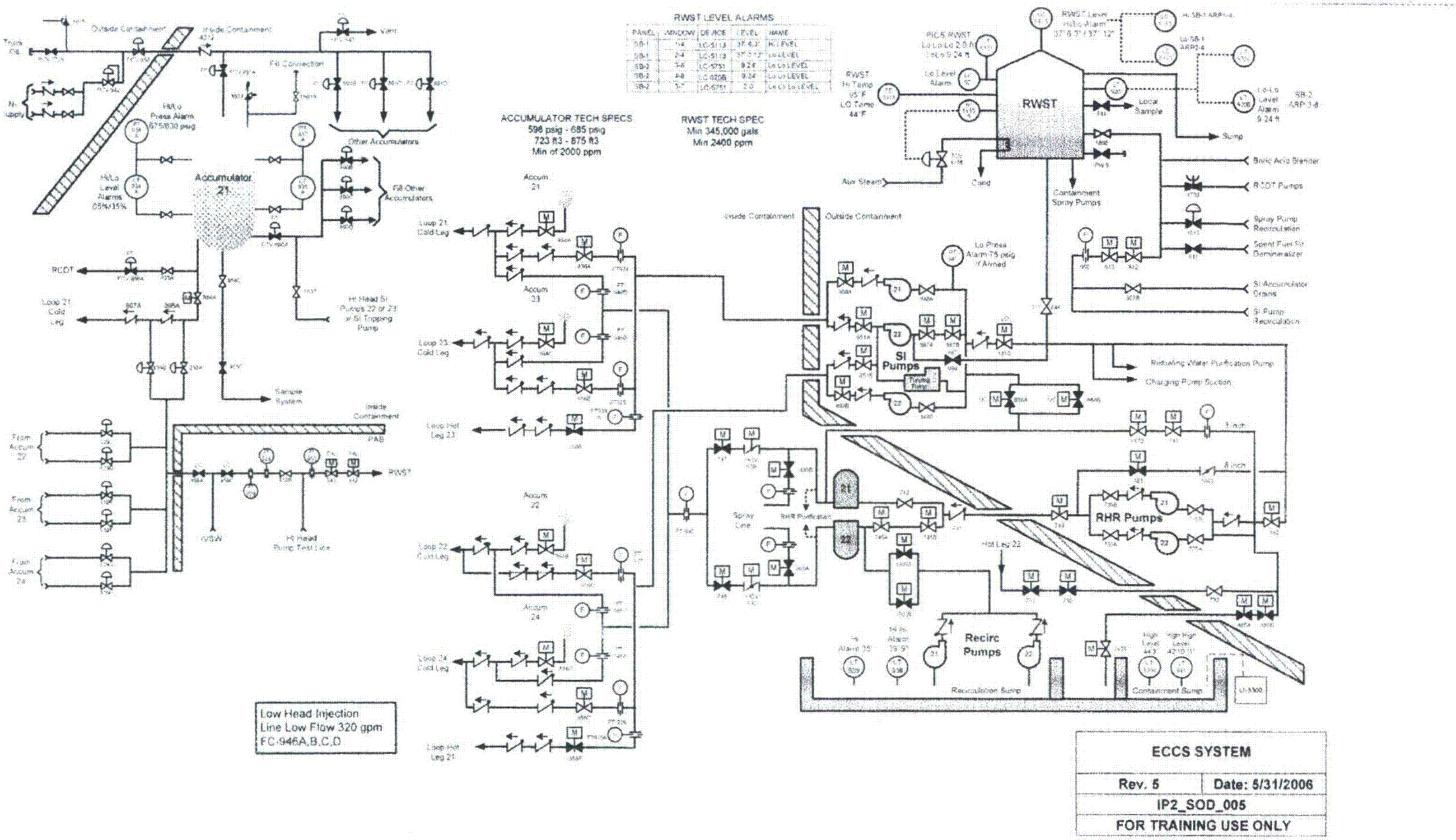
FOR TRAINING USE ONLY	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ACCUMULATOR TECH SPECS
596 psig - 685 psig
723 ft3 - 875 ft3
Min of 2000 ppm
RWST TECH SPEC
Min 345,000 gals
Min 2400 ppm
Accumulator 21
RWST
SI Pumps
RHR Pumps
Recirc Pumps
Low Head Injection
Line Low Flow 320 gpm
FC-946A,B,C,D
ECCS SYSTEM
Rev. 5
Date: 5/31/2006
IP2_SOD_005
FOR TRAINING USE ONLY

ATTACHMENT 3 TO NL-09-138

INDIAN POINT UNITS 2 AND 3

Responses to NRC Request for Additional Information Regarding Generic Letter 2004-02

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNITS 2 AND 3
DOCKETS 50-247 AND 50-286

Responses to NRC Request for Additional Information Regarding Generic Letter 2004-02
(This table identifies the location of information provided in Attachment 1 that addresses the issues identified in the NRC letter to Entergy, dated November 19, 2007, Ref. 119)

RAI #	RAI	Response/Summary of Response	Location within Attachment 1
1	An adequate technical basis was not provided to support the assumption that 40 percent of small pieces of fibrous debris will be captured on gratings in the upper containment. Please provide a justification for this assumption or revise it as determined appropriate. (Audit Open Item)	**Summary of Response:** Note that the 40% retention of small fiberglass debris is a result of the methodology presented in Section 5.5 of the Transport Calculation which uses the 50% holdup of small fiberglass on grating as an input. In the IP-2 Debris Transport Calculation, drywell debris transport study (DDTS) test data was used to take credit for small pieces of fiberglass being held up on grating as discussed in NUREG/CR-6369 (Ref. 66). For every test where the small piece debris was exposed to spray flow, the washdown fraction was less than 50%. The NUREG/CR-6369 washdown testing is directly applicable and conservative for small pieces of fiberglass that are blown to upper containment and land on top of grating in upper containment. Note that fiberglass fines were conservatively assumed to have 100% transport with no retention on structures, grating, or inactive cavities.	Following response to 3e.6
2	An adequate technical basis (e.g., test data) was not provided to support the assumption of 10 percent fibrous debris erosion in the containment pool over a 30-day period. Please provide a justification for this assumption or revise it as determined appropriate. (Audit Open Item)	**Summary of Response:** In this submittal, 10% fibrous erosion is assumed and a justification for this reasonable assumption is provided. However, in order to further support this assumption, Entergy is participating in a supplemental 30-day fibrous debris erosion test scheduled to start in December 2009 at Alion's Warrenville facility. The final test report is expected April, 2010.	3e.2

Note: Cited reference numbers are from Attachment 1

RAI #	RAI	Response/Summary of Response	Location within Attachment 1
3	The testing performed for Indian Point 2 (IP2) calcium silicate with asbestos, that is also being applied to Indian Point 3 (IP3), was not performed for a sufficiently long period to give high confidence of no erosion of the material, as opposed to a small erosion rate that could lead to a significant fraction of erosion over a 30-day period (the post-LOCA mission time of the containment sumps). Please provide justification for its conclusions about erosion of this material. (Audit Open Item)	**Summary of Response:** The only tests performed with Cal-Sil containing asbestos were the tests reported in ALION-REP-IP2-2833-01 entitled "Indian Point 2 Material Dissolution Report". A dissolved material does not behave as a particulate, rather as a chemical element. The testing conducted by Alion reported in Alion ALION-REP-IP2-2833-01 was aimed at addressing the dissolution issue. Based on knowledge of the manufacturing process, the asbestos Cal-Sil at IP2 and IP3 is expected to have lower erosion fractions than the materials used in the Alion flume erosion flume tests. The IP2 and IP3 Debris Transport Calculations conservatively use a 14% erosion fraction for Asbestos Cal-Sil insulation, and a 15% erosion fraction for non-Asbestos Cal-Sil.	Following response to 3e.6
4	Please provide a justification for the use of erosion data from the IP2 calcium silicate tests with asbestos for the IP3 calcium silicate material without asbestos. (Audit Open Item)	**Summary of Response:** During construction, both IP2 and IP3 were owned by Consolidated Edison. A comparison of IP-2 and IP3 original insulation specifications concluded that similar asbestos is used in both IP2 and IP3. Based upon the similarity of insulation specifications between both units, the likelihood that procurement would be from the same source for both units, and the similar construction to operation timeframes for both units (IP2 construction from 1966 to Commercial operation in 1974, versus IP3 construction from 1969 to Commercial operation in 1976), it is logical to conclude that IP3 asbestos-based Cal-Sil is the same as the asbestos used in IP2.	Following response to 3e.6

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5	The licensee plans to credit time-dependent debris transport for qualification of the VC sump. The licensee should provide adequate technical justification to demonstrate that the time-dependent model is conservative, considering the issues raised in Section 3.5.4.6 of the audit report (ADAMS Accession No. ML082050446). The areas that require justification in connection with the time-dependent debris transport for qualification of the VC sump are blowdown, pool fill, and washdown transport directly to the VC sump, erosion of debris, IR strainer filtering efficiency, potential release of material from the IR strainer when the pumps are secured, potential delay of transport to the VC sump strainer due to flotation, and the formation of chemical precipitates. (Audit Open Item)	**Summary of Response:** Based on this analysis, the relative effect of each area of concern identified by the NRC is quite small. It was calculated that only a small fraction of the debris would remain in the pool at the end of 24 hours (0.5% for IP2 and 0.7% for IP3). However, to take into account the uncertainties in transient debris transport, the transport fraction to the VC sump was conservatively increased to 5% for the majority of debris generated inside the ZOI, 100% for the Cal-Sil and Asbestos fines generated due to erosion, and 100% for unqualified coatings outside the ZOI. Some of the 7 items in this RAI were justified as having a small impact, while others were non-quantifiable (but essentially negligible). Therefore, it is judged that the cumulative effects of the 7 items are enveloped by the 5% transport fraction to the VC sump.	Following response to 3f.14
6	The amounts of LOCA generated debris listed in the debris generation section of the supplemental response (Table 3b.4-10) differed from the debris generation amounts listed in the transport section (Tables 3e.6-9 and 3e6-10) [Ref. 1]. Please provide an explanation for the differences between the values in the tables.	**Response:** The debris generation amounts listed in Tables 3e.6-9 and 3e.6-10 of the previous Supplemental Response to NRC Generic Letter 2004-02 (Ref. 1, February 28, 2008) were based on earlier information. The Debris Generation Calculations were revised to include insulation and coatings debris generated from a 6 inch break LOCA, to refine the methodology, calculation, and summary of results and conclusions for the destruction of debris within the Reactor Cavity, and to incorporate additional unqualified coatings that were previously unaccounted for. This revised Supplemental Response shows that the transport fractions were applied to the full amounts of the debris generated. See new data presented in Sections 3b for debris generation and 3e for debris transport.	Contained within response to 3b and 3e

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RAI #	RAI	Response/Summary of Response	Location within Attachment 1
7	The analysis techniques used in the strainer certification calculation for IP2 used the NUREG-6224 head loss correlation to adjust the test data. Please demonstrate that a test was conducted that bounds applicable scenarios, or should justify its present approach of extrapolating head loss data based on a correlation. The main area of concern for this issue is extrapolation of test data to different debris loads or different flow velocities. Please provide the raw test data and any extrapolation methodology should be clearly explained and shown to be conservative. (Audit Open Item)	**Response:** New tests were conducted in the first quarter of 2009 using the "Test-for-Success" methodology which incorporated the staff's March 2008 guidance [Ref. 37]. The debris load for each plant scenario was bounded by at least one test, eliminating the need for a correlation to extrapolate to a different debris load. See new data presented in Section 3f.	Contained within response to 3f
8	Please show that testing was conducted using a debris mix that matches its transport calculation or should show its existing method is conservative. The main points of this issue are to ensure that testing is conducted with the amounts of fine (suspendable) fiber predicted to reach the strainer, and to ensure that the fiber is prepared as true fines. In addition, the introduction of the debris should allow prototypical or conservative transport to the strainer (e.g., agglomeration should be avoided). For thin bed testing, only fine fibers should be introduced until the entire fine fiber load has been added incrementally. For example, supplemental response 3f.6 concludes that no thin bed will result. However, the testing that justifies this conclusion should be shown to be appropriately conducted with fine fiber. (Audit Open Item)	**Response:** New prototypical head loss tests were conducted in the first quarter of 2009 using the "Test-for-Success" methodology to address the concerns raised in the March 2008 Staff Guidance on Head Loss. A draft test protocol was developed by the test vendor and reviewed by the NRC staff. After several interactions with the staff and incorporation of comments, an Indian Point specific test plan was developed. Of the 8 tests conducted, 5 were with 100% fines, while the remaining tests were conducted with at least 80% fines. See new data presented in Section 3f.4.	Contained within response to 3f.4
9	Test procedures and test results concentrated on the VC sump and did not provide clear traceability to show that these tests bounded the internal recirculation sump conditions. Please provide a summary of the testing and analysis results applicable to the internal recirculation sump. (Audit Open Item)	**Response:** New tests were conducted in the first quarter of 2009 using the "Test-for-Success" methodology which incorporated the staff's March 2008 guidance [Ref. 37]. The test program consisted of 8 tests so that every scenario for the IR and VC sump at both units is bounded by at least one full load and one thin-bed test [Ref. 28]. See new data presented in Section 3f.4.	Contained within response to 3f.4

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RAI #	RAI	Response/Summary of Response	Location within Attachment 1
10	The methodology used to qualify the IP2 VC sump strainers for vortex formation/air ingestion was not clear. The supplemental response stated that a vortex evaluation using the submergence Froude number, and consideration of design limits recommended in Regulatory Guide (RG) 1.82, was completed. Please provide the methodology, assumptions, and the bases for the assumptions in this evaluation.	**Response:** The approach to the GL 2004-02 resolution was modified to include the installation of vortex suppression grating above the IR and VC sumps for IP2 and IP3. Because the suppressors will be located below the minimum water level for each sump, vortex formation will be precluded. Design details for the vortex suppressor are contained in Section 3f.3 and References 70, 110-114.	Contained within response to 3f.3
11	It was not clear that the debris loading for the IP2 VC sump strainer for a small-break LOCA with partial submergence was adequately considered. With partial submergence, less strainer area is available to collect debris and the velocity through the submerged portion of the strainer is higher. The methodology for evaluation of this condition was not provided. The supplemental response states that the VC sump strainer can sustain 1688 gpm flow while only 1350 gpm is required for the small break case. Please provide the methodology, assumptions, and bases for the assumptions for this analysis.	**Response:** The Minimum Water Level Calculation was revised to show that the IP2 VC sump strainer is fully submerged for all breaks.	Contained within response to 3f.11
12	The test results presented in tables 3f.10-1 and 2 [of the supplement response, Ref. 1] could not be traced by the NRC staff to head loss testing results. Please provide the raw test data and test conditions, and please show how the head loss results were derived from the test data. Please include any assumptions used for this analysis. Please ensure that a clear explanation of how the strainer head loss was determined for each net positive suction head (NPSH) margin case is provided.	**Response:** New tests were conducted in the first quarter of 2009 using the "Test-for-Success" methodology which incorporated the staff's March 2008 guidance [Ref. 37]. Hence, all test data and analysis has been updated (see Reports ALION-REP-IPEC-7338-001 and CON048-CALC-02). Eight tests were conducted to evaluate the bounding debris and chemical loading conditions for the 12 analytical debris generation cases under consideration. Each of these 8 tests included multiple debris loads called stages. At the completion of testing, it was confirmed that sufficient data was obtained to evaluate the 12 debris generation cases/scenarios. See new data presented in Section 3f.10.	Contained within response to 3f.10

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RAI #	RAI	Response/Summary of Response	Location within Attachment 1
13	The supplemental response did not include information on a test case for time-delayed transport to the VC sump strainer. Note that this strategy has been proposed, and the NRC has received a license amendment request to revise the Updated Final Safety Analysis Report to change the assumptions regarding failures of the IR sump. Please provide the results of the analysis that calculates the VC sump strainer head loss considering delayed transport of debris to the sump. Please include the methodology used, any assumptions made, and the bases for the assumptions in the response to this issue.	**Response:** The methodology for calculating debris loads for the 24 hour VC sump initiation scenario is similar to the other scenarios. The debris loads are determined in the Debris Generation Calculations [Refs. 1 and 2], the fractions that reach the sump are determined in the Debris Transport Calculations [Refs. 41 and 42], the amounts of debris that reaches the sump are determined and scaled for the test in the Array Test Debris Amounts Calculation [Ref. 45], and the results are summarized in the Indian Point ECCS Sump Strainer Head-Loss Calculation [Ref. 28]. See new data presented in Section 3f.4.	Contained within response to 3a.3, 3b.4, 3e.1, 3e.6, 3f.4
14	The basis for the minimum sump level inputs to the void fraction calculation could not be determined. The flood levels in the void fraction calculation did not appear to match the minimum flood levels provided in the supplemental response. Please provide information that justifies the use of the levels that were included in the void fraction calculation.	**Response:** The Minimum Water Level Calculations [Refs. 33 and 34] and the Void Fraction Calculations [Refs. 26 and 27] have been revised since the supplemental GL-response was submitted in February 2008. The latest water levels used in the Void Fraction calculations either match, or are conservative, compared to the Minimum Water Level calculations. The Void Fraction calculations also account for drawdown of water level above the sump pits. See new data presented in Section 3f.2.	Contained within response to 3f.2, 3f.14
15	The licensee's original plan was to use separate chemical effects testing to extrapolate the test results to the emergency core cooling system (ECCS) mission time. It is currently unclear how chemical effects will be addressed by the licensee. Please include information that shows that the test termination criteria and extrapolation of the data to the ECCS mission time were conducted to result in prototypical or conservative results.	**Response:** New tests were conducted in the first quarter of 2009 using the "Test-for-Success" methodology [Ref. 37], which incorporated the staff's March 2008 Guidance [Ref. 129]. The test program consisted of adding pre-prepared chemical precipitates to the test tank after the formation of particulate and fibrous debris bed. The chemical precipitates were quantified by and prepared in accordance with WCAP 16530. The test or test step was terminated when the head loss was calculated to be less than 1% change per hour for head loss values ≥ 2 ft-water or less than 0.25" change per hour for head loss values < 2 ft water. During post-test data analysis, a logarithmic curve was fit to the raw test data. Then curve fit was adjusted up to "bound" the data, and extrapolated out to a 30 day mission time. See new data presented in Sections 3o.2.16 and 3o.2.17.	Contained within response to 3o

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16	Please provide a justification for the application of data from single-stage testing to the three-stage IP3 internal recirculation pumps (Audit Open Item 3.7-1).	**Response:** The single stage testing is no longer applied to the three-stage recirculation pumps. The NPSHr values for the IP2 and IP3 Internal Recirculation (IR) pumps were determined by vendor testing using the current IP2 three-stage pump. The IP2 test data provided a bounding NPSHr curve for both the IP2 and IP3 IR pumps.	Contained within response to 3g.3
17	Please provide the NPSH margin for a single IP3 IR pump at full recirculation (4124 gallons per minute).	**Response:** The revised ECCS System Hydraulic Calculation results in a full recirculation flow rate of 4149 gpm for a single IP3 IR pump. The margin available for head loss for the recirculation pump at 4149 gpm is 0.92 ft-H_2O, the total strainer head loss is 0.91 ft-H_2O, and the final NPSH margin is 0.01 ft-H_2O. See new data presented in Section 3g.16.	Contained within response to 3g.16
18	Please provide information that shows that the small-break LOCA NPSH margins are bounded by the large break cases. Alternatively, please provide the NPSH margins for the small-break LOCA cases.	**Response:** The ECCS Sump Strainer Certification Calculation reduces the NPSHa values given in the ECCS System Hydraulic Calculations to account for the difference in water level and bound both the LBLOCA and SBLOCA cases. This is very conservative because the SBLOCA flow rates, and consequently NPSHr, will be much lower. See new data presented in Section 3g.16.	Contained within response to 3g.16
19	Please provide an NPSH margin evaluation for the hot-leg recirculation case, or show this case to be bounded by other cases that were evaluated.	**Response:** The NPSH margin for the hot-leg recirculation cases are bounded by the High Head Safety Injection alignment (HHSI maximum case/1350 gpm). See new data presented in Section 3g.16.	Contained within response to 3g.16

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20	The latest NRC review guidance for coatings (ADAMS Accession No. ML080230112, Enclosure 2) references WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings", that recommends using a 5D ZOI for un-topcoated in-organic zinc (IOZ) paint. Please provide the rationale for using a 4.28D ZOI for un-topcoated IOZ paint. This question was also listed as Open Item 3.8-1 in the audit report (ADAMS Accession No. ML080870246).	**Response:** It should be first noted that per a Westinghouse analysis, 4.28 diameters "is an appropriate and defensible estimate of the ZOI for untopcoated IOZ." The Westinghouse analysis is an Indian Point specific report which evaluates the coatings systems used at Indian Point. Secondly, it should be noted that the Westinghouse analysis evaluated damage to the coatings, and reported average losses on the order of 0.3 mils for untopcoated IOZ. The Indian Point Debris Generation Calculations conservatively assume total destruction of any coatings within the assumed ZOI. Effectively, a 15 mil thick coating is completely destroyed even at the outermost locations of the ZOI, while the test data indicates this is unlikely. As a result, the 4.28 diameters ZOI has been evaluated and design verified, and this data is conservatively applied. See new data presented in Sections 3h.5.	Contained within response to 3h.5
21	Please provide the results of the wear analyses for the internal recirculation (IR) pumps, residual heat removal (RHR) pumps, and high head safety injection (HHSI) pumps, when completed.	**Response:** The ECCS pumps required for recirculation mode (IR, RHR, and HHSI) were evaluated for the downstream effects of sump fluid by Flowserve (OEM). The basic methodology found in WCAP-16406-P was employed for pump evaluation, with some justified changes for plant specific conditions. The mechanical pump seals were individually evaluated by MPR Associates, Inc based on the principles of seal operation and fluid conditions. All the pumps and associated mechanical seals were found to function acceptably in the worst case debris laden fluid and will operate for the required 30 day mission time.	Contained within response to 3m.2
22	Please confirm that calculated fuel cladding temperature will not exceed 800°F when calculating cladding temperature in accordance with the guidance in WCAP-16793-NP and as qualified by the conditions and limitations of the draft NRC safety evaluation of WCAP-16793-NP.	**Response:** Plant specific cladding temperatures were calculated in accordance with the guidance in WCAP-16793-NP and as qualified by the conditions and limitations of the draft NRC safety evaluation of WCAP-16793-NP. The maximum clad temperature for IP2 was 419.92°F and for IP3 was 384.15°F [Ref. 143].	Contained within response to 3n.1

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23	The NRC staff understands that Indian Point has changed their test approach to evaluate chemical effects. Please submit the revised chemical effects test results and analyses to the NRC when they become available.	**Response:** Entergy has revised the approach to chemical effects testing and no longer credits the Vuez approach or test results. The revised approach employs WCAP-16530 [Ref. 43] chemical precipitate quantities added into a prototypical debris bed during testing. The approach also credits no precipitate induced head loss before 7 hours post-LOCA. See new data presented in Section 3o.	3o

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