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NL-10-074

July 27, 2010

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

SUBJECT: **Response to Request for Additional Information Regarding Generic Letter 2004-02**
Indian Point Units 2 and 3
Docket Nos. 50-247 and 50-286
License Nos. DPR-26 and DPR-64

REFERENCES:

1) NRC letter to Indian Point Vice President of Operations, 4/29/10, "Indian Point Nuclear Generating Unit Nos. 2 and 3 – Request for Additional Information Regarding Generic Letter 2004-02 (TAC Nos. MC4689 and MC4690)"

2) Entergy letter NL-09-138, 11/19/09, "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""

3) Summary of June 9, 2010, Conference Call with Entergy on their Proposed Response to a Request for Additional Information on Generic Letter 2004-02 (TAC Nos. MC4689 and MC4690), dated June 18, 2010

Dear Sir or Madam:

On April 29, 2010, the NRC issued a request for additional information (RAI) (Reference 1) regarding Entergy Nuclear Operations, Inc (Entergy) updated supplemental response (Reference 2) to Generic Letter (GL) 2004-02. The NRC staff was previously provided draft RAI responses to facilitate discussion during the June 9, 2010, Category 1 public meeting. As discussed during the public meeting (Reference 3), Entergy's formal RAI responses are provided in the Attachment to this letter.

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There are no new commitments being made in this submittal.

Should you have any questions or require additional information, please contact Mr. R. Walpole, Manager, Licensing at (914) 734-6710.

I declare under penalty of perjury that the foregoing is true and correct. Executed on 7-27-10.

Sincerely,

Patrick W. Conroy, Acting Site Vice President for JEP

JEP/rmw

Attachment: 1. Response to Request for Additional Information Regarding Generic Letter 2004-02

cc: Mr. John P. Boska, Senior Project Manager, NRC NRR DORL
Mr. M. Dapas, Acting Regional Administrator, NRC Region 1
NRC Resident Inspector, IP2
NRC Resident Inspector, IP3
Mr. Robert Callender, Vice President, NYSERDA
Mr. Paul Eddy, New York State Dept. of Public Service

ATTACHMENT 1 TO NL-10-074

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

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOs. 2 and 3
DOCKET NO. 50-247 and 50-286

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

The U.S. Nuclear Regulatory Commission (NRC) staff has requested responses to the following questions, which relate to the November 19, 2009, supplemental submittal, in order to continue its review of the Entergy's response to GL 2004-02:

NRC Request 1

Head Loss and Vortexing

In RAI 12 of the staff's letter dated November 19, 2008 (ADAMS Accession No. ML083230054), the staff requested information that provides traceability between the test results presented as final values in the supplemental response and the raw test data. The RAI requested that the licensee provide the methodology for deriving the final values and the assumptions used in the evaluation. In its response letter dated November 19, 2009, the licensee provided descriptions of the tests that linked each break case to one or more tests that were used to evaluate the strainer performance for each particular scenario. This answered the staff's question regarding the ability to determine how each break was covered by the test program. However, the staff could not determine how the test cases were extrapolated to the plant conditions listed in Tables 3f.10-13 and 14. Please provide the methodology (the equations used) and assumptions used to extrapolate the test cases to each plant case listed in Tables 3f.10-13 and 14.

Entergy Response

Page # in parenthesis refer to the November 19, 2009 Entergy response.

The Entergy updated supplemental response shows total head losses for a variety of Emergency Core Cooling System (ECCS) alignments (Tables 3f.10-13 for IP-2 (pg 119) and 3f.10-14 for IP-3 (pg 120)). As a point of clarification, only certain of these alignments are permitted and supported by the Emergency Operating Procedures (EOPs). Due to the requirement for both units to initiate Hot-Leg recirculation by 6.5 hours, the only applicable alignments after that time are those with an analyzed maximum ECCS flow of 1350 gpm. In contrast to the aforementioned Tables, Tables 3g.16-7 (pg 156) and 3g.16-8 (pg 157) provide the minimum margin head loss results, and only for alignments permitted and supported by the EOPs.

The NRC staff requested information on how the results in Total Head Loss Tables 3f.10-13 and 3f.10-14 provided in response to question 3f.10 were obtained. The following explains the adjustments made using the 1st case listed (IP-3 / IR SUMP LBLOCA or RC LBLOCA / 5263 GPM) in table 3f.10-14 (page 120) as a representative example. All the cases would follow the same methodology.

All the Alion test data is normalized from the specific test conditions to: 70°F and/or 204.7°F, and either 400 GPM or 155 GPM, depending on which is applicable for the plant sump flow rate being considered. (The lower 155 GPM flow is typically applied to analyses for the low flow cases of VC Sump LBLOCA & RC-LBLOCA case after 24-hours of Recirculation Sump operation.) Normalizing places all the data on a relative basis so the various test head losses can be compared to select the bounding cases. The resulting head losses of this 1st normalization are provided in the last three columns of Tables 3f.10-1, -3, -4, -5, -7, -9, and -11.

After matching up the applicable debris loads (C-3, E-3, & F-3), from the relevant available test cases data, the highest normalized head loss values are selected from each table for: Conventional, Conventional & Chemical, and 30 Day Extrapolated Conventional & Chemical debris loads. These are depicted as the highlighted values in the last 3 columns of Table 3f.10-7 (page 116), specifically: 3.07 ft, 10.91 ft, and 12.32 ft. These particular values will not be used after this point since they were only to allow a *relative comparison* between all the test cases.

Actual test data is taken from the IPEC scaled prototypical strainer array testing performed by Alion in accordance with the 2008 protocol. The data selected from the applicable tests for the above case for "Conventional" (Test F), and "Conventional & Chemical" (Test E-3) debris loads were: 2.42 ft, and 8.43 ft, respectively. Testing instrument inaccuracy is already conservatively accounted for (added or subtracted as applicable) in these reported values. The "30 Day Extrapolated Conventional & Chemical" value of 9.52 ft is based on the curve fit formula as applied to the test data and further explained in 3o.2.17.i (pages 203 & 204). For the example case being discussed here: the test data, the extrapolation formula, and resulting value of 9.52 ft is presented in Figure 3o.2.17-17 from Test E - 3rd Chemical Addition (page 221).

In making adjustments from raw test data to the normalized values, the laminar/turbulent fraction of the flow is considered, and variations in the test flow rate are adjusted for. For further discussion on the adjustments, see the response to question 3f.13 (page 121-122). For the values presented in the final tables, the raw test data is adjusted to the specific plant conditions using the equations below. The various equations were used to ensure conservative corrections:

Decreased flow and temperature case:

$$\Delta H_2 = \Delta H_1 \frac{Q_2 \mu_2}{0.97 Q_1 \mu_1}$$

Increased flow and decreased temperature case

$$\Delta H_2 = \Delta H_1 \frac{\mu_2}{\mu_1}\left[L_{frac} \frac{Q_2}{0.97 \times Q_1} + T_{frac} \frac{Q_2^2}{(0.97)^2 Q_1^2} \right]$$

Decreased flow and increased temperature case

$$\Delta H_2 = \Delta H_1 \frac{Q_2}{0.97 \times Q_1}\left[L_{frac} \frac{\mu_2}{\mu_1} + T_{frac} \frac{\rho_2}{\rho_1} \right]$$

Increased flow and increased temperature case

$$\Delta H_2 = \Delta H_1 \left[L_{frac} \frac{\mu_2}{\mu_1} \frac{Q_2}{0.97 \times Q_1} + T_{frac} \frac{\rho_2}{\rho_1} \frac{Q_2^2}{(0.97)^2 Q_1^2} \right]$$

Note: The 0.97 value in the denominator is a reduction in screen area to compensate for an assumed void fraction of 3%.

Additionally, the viscosity of water at various temperatures was calculated using the following equation:

$\mu = 0.074T^{-1.1085}$

Where:

μ = Absolute (dynamic) viscosity (lb-m/ft/s)

T = Temperature (°F)

For this case, the calculated maximized plant accident flow rate of 5263 gpm through the Recirculation Sump Strainer (~3121 sq-ft surface area) compares to a scaled flow rate of ~192 gpm through the Test Array Strainer (~114 sq-ft surface area) based on a ratio of the full and scale strainer areas.

Note: CSHL = Clean Strainer Head Loss and is given as 0.325 feet in the sections below.

<u>For the Conventional Debris Load only (Test F data)</u>

The measured head loss (2.42 ft), at measured flow rate (391.67 gpm), and a temperature of 83.67°F are used to arrive at the corrected head Loss at 70°F (1.49 ft). The equation for decreasing temperature and flow rate is used (note that the equation is based on an assumption of 100% laminar flow for conservatism):

$$\text{HL at 70°F} = 2.42\,\text{ft}\frac{192\,\text{gpm}\left(6.66\cdot 10^{-4}\,\frac{\text{lb}_\text{m}}{\text{ft}\cdot\text{s}}\right)}{0.97(391.97\,\text{gpm})\left(5.47\cdot 10^{-4}\,\frac{\text{lb}_\text{m}}{\text{ft}\cdot\text{s}}\right)} = 1.49\,\text{ft}$$

Then, the total head loss is determined by summing:

- corrected head loss at 70F + RMI head loss + CSHL = (1.49) + (0.0) + (0.325) = 1.815 ⇒ **<u>1.82 ft-water</u>**

The test parameters outlined above, the laminar & turbulent fractions (0.37% & 0.63%), and the equation for increasing temperature and decreasing flow rate was used to obtain a corrected head loss at 204.7°F (0.91 ft).

$$\text{HL at 204.7°F} = 2.42\,\text{ft}\frac{192\,\text{gpm}}{0.97(391.97\,\text{gpm})}\left[(0.37)\frac{2.03\cdot 10^{-4}\,\frac{\text{lb}_\text{m}}{\text{ft}\cdot\text{s}}}{5.47\cdot 10^{-4}\,\frac{\text{lb}_\text{m}}{\text{ft}\cdot\text{s}}} + 0.63\frac{59.99\,\text{lb}_\text{m}/\text{ft}^3}{62.19\,\text{lb}_\text{m}/\text{ft}^3}\right] = 0.91\,\text{ft}$$

Densities where obtained from ASME steam tables (1967).

Then, the total head loss is determined by summing:

- corrected head loss at 204.7F + RMI head loss + CSHL = (0.91) + (0.0) + (0.325) =1.235 ⇒ **<u>1.24 ft-water</u>**

<u>For the Conventional & Chemical Debris Load (Test E-3 data)</u>

The measured head loss (8.43 ft), at measured flow rate (404.36 gpm), and a temperature of 89.92°F are used to arrive at the corrected head Loss at 70°F (5.46 ft). The equation for decreasing temperature and flow rate is used (note that the equation is based on an assumption of 100% laminar flow for conservatism).

Then, the total head loss is determined by summing:

- corrected head loss at 70F + RMI head loss + CSHL = (5.46) + (0.0) + (0.325) = 5.785 ⇒ **5.79 ft-water**

For the 30 Day Extrapolated Conventional & Chemical Debris Load (Test E-3 data extrapolated)
The measured head loss (8.43 ft) was extrapolated (9.52 ft), and then using measured flow rate (404.36 gpm), and a temperature of 89.92°F are used to arrive at the corrected head Loss at 70°F (6.16 ft). The equation for decreasing temperature and flow rate is used (note that the equation is based on an assumption of 100% laminar flow for conservatism).

Then, the total head loss is determined by summing:

- corrected head loss at 70F + RMI head loss + CSHL = (6.16) + (0.0) + (0.325) = 6.485 ⇒ **6.49 ft-water**

NRC Request 2

Head Loss and Vortexing

Please provide the results of an evaluation of the potential effect of voids (possibly resulting from deaeration of coolant) on the pumps' net positive suction head required (NPSHR) values as discussed in Regulatory Guide 1.82, Appendix A, and adjust the NPSHR values as described in that guidance. Please explain how the results of the evaluation affect the NPSH margin calculation.

Entergy Response

In Entergy's updated supplemental response to GL 2004-02, the void fraction values were provided in response to issue 3f.8 (page 104). The maximum void fractions downstream of the strainers were reported as:

- 0.31% and 0.67% for the IR and VC sumps, respectively for IP-2
- 0.41% and 0.60% for the IR and VC sumps, respectively for IP-3

These maximum values are reached during recirculation after extended periods of time (approximately 115 days), well beyond the GL 2004-02 mission time of 30 days. The void fraction varies over the 30 day time period and is often zero, or significantly below the maximum values quoted for long periods of time.

For conservatism, the above void fractions were calculated:

- from the top surface of the top screens in the assembly.

  The lower screens and an increasing water level above them would result in lower calculated void fractions; therefore, the true overall void fractions would be less than those reported above.

- assuming a constant minimum small break LOCA water level throughout the transient.

The small break water level is bounding and as safety injection and containment spray continue to draw down the RWST, containment water level will increase above this minimum level.

Re-evaluation of Void Fractions

Regulatory Guide 1.82, Appendix A, provides guidance on an adjustment to NPSHR based on % void fraction at inlet to the Emergency Core Cooling System pumps that perform the recirculation function. The void fractions reported in the supplemental response are too conservative for application at pump suction. Therefore, in order to obtain more realistic void fraction values for input into the NPSHR adjustment, credit was taken for:

- the smaller void fractions generated by strainers in the lower elevations of the sump
- the compression of voids, in accordance with the ideal gas law, between sump outlet and pump inlet

In determining the gas absorption into the fluid before it passes through the strainer, the void fraction calculation conservatively considers the pressure and temperature conditions of the sump fluid and the atmosphere above it. The void fractions just downstream of the strainer elements have been calculated for each level of the strainer assemblies and then averaged to obtain the overall value of the assembly. Lower levels of the strainers have a greater static head of water above them, thus reducing the overall void fraction.

The IP-2 and IP-3 IR and VC Sump strainers all consist of only horizontally mounted Top-Hat cylinder strainer elements connected to plenum boxes. The IP-2 and IP-3 IR strainer assemblies have nine levels of Top-Hats in a sump pit.

The IP-2 VC Sump strainers are horizontally mounted on one side of a plenum box. The strainer extension (outside of the sump pit) has a plenum leading to and then connecting to the plenum in the VC Sump pit. The strainers in the VC sump pit are stacked in levels with one removed in the top level due to the extension connection. The extension is about 1-3/4 feet above the sump pit plenum connection point and about 15 feet away.

The IP-3 VC Sump strainers are horizontally mounted and connected on both sides of a plenum box. The strainers in the VC sump pit are stacked in levels with the lower two rows on one side shortened for interferences and four removed for the connection to the suction line. There is no extension for IP-3 outside the sump pit.

In calculating the void fraction, the water level above the strainer appropriate for the time and applicable event was employed. In some cases, instead of applying the maximum structural limit of the strainer, actual strainer head loss values were used.

Any void bubbles that may develop as flow passes through the individual Top-Hat strainers would flow into the plenum assembly of the strainer. There they will have an opportunity to rise in the plenum and exit the strainer assembly through multiple high point vent holes, however, no credit is taken for release through high point vents. If the void bubbles continue downward towards the pump, there will be additional pressure head that will reduce the void size by compression.

The re-evaluated void fractions are provided in Table 1. These are the maximum void fraction values. At other times during the 30 day mission time the values are less, and are sometimes zero.

Table 1
Void Fractions

Unit	Sump	Void Fractions %: As Reported(1)	Void Fractions %: Strainer Assembly Average(2)	Void Fractions %: Pump Suction(2)
IP-2	IR	0.31	0.0	0.0
	VC	0.67	0.098	0.064
IP-3	IR	0.41	0.087	0.084
	VC	0.60	0.134	0.114

1. Maximum values attained after 115 days of recirculation
2. Maximum values during the 30 day mission time at the specified location

The void fractions, after compression due to available head at the suction of the pumps, are minimal and will have a negligible impact on pump performance as demonstrated below.

Regulatory Guide 1.82 Evaluation

Applying the guidance from Regulatory Guide 1.82, Appendix A, the following adjusted NPSHR values were determined.

Table 2
RG 1.82 Evaluation

Unit	Sump	As Reported NPSH Margin(1) ft	RG 1.82 Evaluation: As Reported NPSHR ft	RG 1.82 Evaluation: β	RG 1.82 Evaluation: RG 1.82 NPSHR ft	RG 1.82 Evaluation: RG 1.82 NPSH Margin ft
IP-2	IR(2)	-	-	-	-	-
	VC	2.51	10	1.032	10.32	2.19
IP-3	IR	0.01	9.25	1.042	9.64	-0.38
	VC	0.83	10	1.057	10.57	0.26

1. Minimum NPSH margin cases
2. Not applicable, β=1 due to a zero void fraction.

Table 2 shows that there is adequate NPSH margin to accommodate the adjusted NPSHR values for the IP-2 IR and VC sumps and the IP-3 VC sump. The IP-3 IR sump calculated

NPSH margin is -0.38 feet. However, the IP-3 IR pump is operable based on the following considerations.

IP-3 IR Pump Performance Capabilities

In support of IR pump performance capabilities the vendor and manufacturer of the IR pumps (Flowserve) reported that these pumps are low energy pumps, (i.e. impellor tip speed less than 60 ft/sec). Flowserve concluded that pump reliability will not be affected by resulting cavitation in the short term (limited to 7 days) while operating under deficient available NPSH conditions for flows greater than 3000 gpm due to the self limiting capability of the pump. For flows less than 3000 gpm, a 1 foot deficiency in NPSHA could be sustained for long-term operation without damage.

For flows greater than 3000 gpm the pump reliability is determined by the predicted reduction in developed head, not by a specific NPSH deficiency limitation. The vendor supports a reduction in developed head of up to 20%, which is ultimately controlled by the reduced NPSH that is available. A 1 foot deficiency in NPSHA would not result in a reduction greater than 20% developed head, therefore, short and long term vendor restrictions are bounded.

The 0.38 ft NPSH deficit, as a result of void fraction considerations, occurs prior to switchover at a pump flow rate 4149 gpm. This flow rate would occur for no more than 4 hours, after which the flow is reduced via termination of recirculation containment spray, and then to switchover to hot leg recirculation at 6.5 hours after the break. The 0.38 ft deficit is momentary and will be less than this value at all other times due to changing containment conditions. The 0.38 ft deficit is well below the 1 foot deficit described above for short and long periods of pump operation.

While deaeration is admittedly a somewhat different phenomenon, cavitation is assumed to be a more severe condition to operate a pump under. Therefore, any intermittent periods of time where a small void fraction potentially exists do not present a challenge to pump performance. Additionally, the IR pump is a vertical pump with the suction on the bottom, discharge on the top. This configuration for the IR pump does not support air collection in the pumps.

Regulatory Guidance

In addition to the guidance provided in RG 1.82 additional regulatory guidance is provided as follows.

NUREG-0897

NUREG-0897, Revision 1 describes typical pumps configurations for PWRs in section 2.1 as single stage centrifugal of low specific speed generally rated at 3000 GPM and heads of 300 feet, and requires about 20 feet of NPSH. The IR pump has a design point of 3000 GPM, a corresponding head of about 350 feet, and require less than 20 feet of NPSH at the design point. The pumps are constructed of stainless steel, and although the IR pump is a 3-stage vertical pump, it is a low specific speed design. The IR pumps operate under 1200 RPM. Therefore, the following NUREG-0897 statements apply to IPEC's pumps:

- "Pump impeller materials are generally highly resistant to erosion, corrosion, and cavitation damage."

- "...pumping performance is only slightly degraded when air ingestion is less than 2%. This value would be a conservative estimate for acceptable performance..."

NUREG-0897 supports the reliability of these pumps under conditions significantly worse than would be postulated with the minimal void fractions reported above.

Generic Letter 2004-02

The NRC Safety Evaluation related to NRC GL 2004-02 (Reference 1, below), in Section 6.4.6 states the following "... for Region II analyses, the GR states that limited operation without an NPSH margin is acceptable if it can be shown that the pumps reasonably be expected to survive during the time period of inadequate available NPSH. The suggested technical justification for this statement would include vendor information in the form of test data or engineering judgment derived from test and/or operational events". Although IPEC does not currently apply the less restrictive Region II allowances, the methodology is relevant. Region II includes LBLOCA events and therefore encompasses the IP-3 LBLOCA IR pump limiting NPSH case evaluated.

The Region II methodology supports the use of a vendor assessment of reliability of the IR pumps under inadequate available NPSH conditions.

Generic Letter 2008-01

Generic Letter 2008-01 – "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems", requires that the impact of gas voids on ECCS recirculation pump performance be evaluated. In Revision 2 to NRC staff criteria for gas movement in suction lines and pump response to gas (draft) (ML090900136) up to a 1% void would be well within the capability of pumps to accept and pass without detriment to the pump. There is no upstream piping for the IR pumps as they are located adjacent to the strainer plenum. The sump and strainer are a low point and self vent as the Containment floods up from the break flow. Therefore, there can be no existing gas voids present prior to the accident. The calculated void, for the IP-3 IR pump due to deaeration (0.084%) is well below the staff accepted 1% void fraction for not jeopardizing pump operability. In addition, the GL 2008-01 criteria document referred to above discusses the RG 1.82 NPSHR correlation and refers to the correlation as including substantial conservatism.

Conclusion

As reported in the Entergy supplemental response of November 19th, 2009, void fractions were conservatively determined immediately downstream of the top strainer and no credit for strainers at lower elevations, nor void compression due to the elevation head between this point and the suction point of the IR or RHR pumps was taken.

A new evaluation shows that the additional static head, minus any applicable frictional losses, reduce any voids to a point where they would be expected to travel through the pump without affect. There is adequate NPSH margin to accommodate the adjusted NPSHR values for the IP-2 IR and VC sumps and the IP-3 VC sump. The adjusted NPSHR value for the limiting IP-3 IR sump results in a negative NPSH margin.

The IP-3 IR sump calculated void fraction is considered to be negligible at 0.084% and the RG 1.82 NPSHR adjustments are considered to be overly conservative for void fractions of this magnitude. Nevertheless, even with the RG 1.82 NPSHR adjustments made, the pump vendor supports operation of the IR pumps under these conditions. In addition to RG 1.82 other regulatory guidance is available. NUREG 0897, the NRC SER on GL 2004-02 (Region II analysis), and NRC guidance on GL 2008-01, all support pump operation with limited void fractions that envelope the predicted plant void fractions evaluated in this response.

In summary adequate NPSH margin is available to accommodate the adjusted NPSHR values for the IP-2 IR and VC sumps and the IP-3 VC sump. The IP-3 IR sump can also accommodate the adjusted NPSHR values when credit is taken for pump performance capabilities under the predicted gas void conditions.

It is important to note that IPEC currently does not credit any Containment accident over pressure in performing NPSH calculations. This very pressure, which is considered in the void creation, represents margin that is not credited in void mitigation, but by necessity would be present during the postulated event.

Reference

1. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report (Proposed Document Number NEI 04-07), "Pressurized Water Reactor Sump Performance Evaluation Methodology," Issued December 6, 2004 NRC Bulletin 2003-01, “Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized Water Reactors,” dated June 9, 2003

NRC Request 3

Coatings

In RAI 20 the staff asked the licensee to provide the rationale for using a 4.28 diameter (D) zone of influence (ZOI) for inorganic zinc (IOZ). In attachment 3 of the response, the licensee response noted the 4.28D ZOI has been evaluated, design verified, and the data (new data presented in response) conservatively applied. However, in Section 3h.5, the licensee response noted 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 the IOZ 5D cases. It is unclear to the staff which approach the licensee is using (4.28D for IOZ or a bounding 4D epoxy case). In addition, the staff has become aware of issues with the testing intended to support a 5D ZOI for IOZ (WCAP-16568P). Westinghouse provided revised ZOI analyses for both epoxy and untopcoated inorganic zinc coatings in a letter dated March 24, 2010 (Accession Number ML100880023). The staff has not accepted the Westinghouse-sponsored confirmatory testing and analysis for untopcoated inorganic zinc coatings. Therefore, the NRC staff no longer finds a 5D ZOI acceptable for untopcoated inorganic zinc. This conclusion will be documented in a near-term revision to the staff's review guidance on this subject. Instead, licensees may rely on the staff's prior acceptance of a 10D ZOI for untopcoated inorganic zinc as documented in its SE for NEI 04-07. Please clarify and justify the ZOI for untopcoated IOZ without the use of the WCAP-16568P reduction, or describe impacts on strainer performance as a result of a decision to use a larger ZOI.

Entergy Response

The current Debris Generation calculations, as reported in Entergy's updated supplemental response, used the following design inputs: 4D ZOI for Epoxy coatings and 4.28D ZOI for untopcoated Inorganic Zinc (IOZ). However, the calculation notes that using a 4D ZOI consisting of an Epoxy only system results in a greater volume of coatings debris because the thickness of the Epoxy coatings is much greater than the thickness of the IOZ coatings. The bounding values for the 4D ZOI Epoxy system were reported in the calculation and used in subsequent analysis and testing.

Subsequent to Entergy's updated supplemental response, the NRC no longer endorsed the 5D ZOI from WCAP-16568-P and recommended the use of a 10D ZOI as noted above (ML100880023).

Entergy has evaluated the impact of applying the 10D ZOI by revisiting the debris generation calculation. Because walkdown documentation indicates the presence of Epoxy and untopcoated IOZ, a 4D ZOI for Epoxy coatings and the NRC recommended 10D ZOI for the untopcoated IOZ were applied. The new calculations determined the volume of coating debris for the applicable surface areas of untopcoated IOZ and Epoxy coating systems by utilizing more realistic, yet still conservative, quantities of the different coating systems.

The results of the bounding RCS loop break case which includes the coatings of the Pressurizer supports are presented below for the original and revised coating debris volumes:

Unit	Original quantities in Debris Generation (4D Epoxy)	Revised quantities in Debris Generation (4D Epoxy and 10D IOZ)
IP-2	5.32 ft^3	5.20 ft^3
IP-3	4.67ft^3	4.63 ft^3

These results illustrate that the original 4D Epoxy coating debris volumes are still bounding and conservative. The Debris Generation calculations will be updated to address the issue raised by this RAI, however, the strainer qualification calculations remain bounding.

NRC Request 4

Chemical Effects

In RAI 23 the staff asked the licensee to submit the revised chemical effects test results and analyses. The licensee responded that chemical precipitates would not occur for the first seven hours following a loss-of-coolant accident (LOCA) at Indian Point Units 2 and 3. This conclusion is based, in part, on the following statements from this letter (page 200 of 243):

> *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 122°F and 123 °F for IP-2 and IP-3, respectively. 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.

Since the minimum containment temperatures are lower than the calculated threshold temperature for precipitation based on an equation developed by Argonne National Laboratory, the staff does not understand how the temperatures shown above demonstrate any margin. Additional statements indicated that the post-LOCA temperatures will not reach the stated minimum values; however, there is no discussion to quantify how these assumptions result in unreasonably low calculated minimum temperatures. Please justify the conclusion of no precipitation during the first seven hours following a LOCA.

Entergy Response

In Entergy's updated supplemental response to GL 2004-02, the values for the minimum possible temperature of the post-LOCA containment sump pool provided for IP-2 and IP-3 were incorrectly listed as 110°F and 116°F, respectively. The following sentence taken from page 200 of 243 of Entergy letter NL-09-138, dated November 19, 2009 is revised below to indicate the correct temperatures:

"The minimum possible temperature at 7 hours after a LOCA is 122°F and 123°F for IP-2 and IP-3, respectively [Ref. 48]."

Based on the corrected temperatures above, the precipitation point temperatures (118°F for IP-2 and 121°F for IP-3) are below the minimum calculated sump pool temperatures; therefore, precipitation is not expected to occur earlier than 7 hours into the LOCA for either unit.

	IP-2	**IP-3**
Precipitation Point Temperature	118°F	121°F
Minimum Sump Pool Temperature	122°F	123°F

The minimum sump pool temperatures were determined in calculation IP-CALC-09-00128, "IP Maximum Post-LOCA Containment Cooling Prior to Hot Leg Recirculation for Units 2 and 3", that was prepared to obtain a conservatively low temperature in the post-LOCA sump pool at 7 hours into the accident. These calculated temperatures were compared to the results of the conservative Argonne Nation Laboratory (ANL) method for determining a precipitation point temperature to show precipitation would not occur prior to the switchover to hot leg recirculation, which is required to be completed no later than 6.5 hours into the LOCA timeframe. After the procedurally required switch to the hot leg recirculation pathway, the pump flow rate is significantly reduced, and consequentially, so are the head losses for the strainers.

This calculation, together with the associated assumptions, was formulated to result in the maximum cool down rate of the post-LOCA sump pool to conservatively determine if the precipitation point is reached within 7 hours.

The following conservative assumptions were made in the cooldown calculation:

- Containment Fan Cooler Units (CFCUs) operating at maximum performance capabilities.
  The CFCUs directly cool and condense the air and steam atmosphere of post-LOCA containment on metal tube and fin coils cooled directly by the Service Water System (Hudson River water). The heat transfer data is taken from a calculation in which a fouling factor of zero is assumed for the coils. The CFCUs are normally in operation throughout the year as the primary means of cooling the Containment. Some degree of tube fouling would be expected from the river water, reducing the predicted maximum cooling performance used in the calculation.

- Containment Fan Cooler Units operating with maximum heat transfer rate
  CFCU performance was taken from existing Westinghouse Peak Clad Temperature (PCT) analyses which are designed to maximize heat removal at the units and apply minimal Service Water temperatures. Any increase in Service Water temperature directly reduces the delta T for the CFCUs, and therefore, decreases overall transfer rate and quantity of heat removed from Containment.

- Heat transfer through the Containment wall only considers concrete and steel liner resistance
  The sump pool fluid, in addition to the cooldown provided by the Residual Heat Removal Heat Exchangers (RHRHXs), transfers heat to the its surroundings. The Containment wall starting just below the concrete floor at 46 foot elevation, and going up to at least the 68 foot elevation (and higher in some locations), has rigid thermal insulation with a metal jacket against and attached to the wall to reduce the transfer of post-LOCA sump pool heat into the concrete. The insulation protects the concrete by forming a thermal barrier between the sump fluid and the Containment steel liner and concrete. Therefore, the insulation directly reduces heat transfer from the hot sump fluid at this critical location. The effect of the Containment liner insulation is not considered in the calculation; therefore, the magnitude of the cool down rate is conservatively increased.

- Heat transfer through Containment uses larger outer building diameter
  Outside dimensions were applied in calculating the heat losses through the Containment wall to maximize the area and heat transfer to the outside environment. This over predicts the heat transfer since the actual heat input into the walls is physically on a smaller surface area based on inside dimension of the Containment.

- Entire outer surface of Containment assumed equal to minimum design basis external air temperature
  This assumption is conservative because the Containment Reactor Cavity, and much of the Containment Building below 46 foot elevation, where the sump fluid is, is either below ground or shielded. Sub-surface ground temperatures are generally constant and would be expected to be closer to 40 to 50°F, well above the postulated minus 5°F ambient air design value applied. Some of the lower portions of the containment are also shielded by and adjacent to heated structures (e.g. Primary Auxiliary Building, Auxiliary Feed Pump/Steam Bridge, and Fuel Storage Building) that reduce the temperature differential and heat transfer to the assumed minus 5°F outside air temperature.

- The Component Cooling Water System temperature is assumed to be at, and remains at, its lowest possible value of 70°F
  The CCWS is a closed loop cooling system that accepts heat from the Residual Heat Removal Heat Exchanges (RHRHXs) (and other plant loads), and then rejects it to the Service Water System (SWS), and ultimately to the Hudson River. The CCWS loop temperature is procedurally maintained between a minimum of 70°F and 110°F for other equipment served by the loop and as part of the implementation for the resolution to GL 2004-02. As discussed in the Ultimate Heat Sink Analyses for IP-2 and IP-3, during abnormally high system heat loads, which occur in a LOCA where the RHRHXs are the primary means for sump pool fluid temperature reduction, the CCWS will initially increase above this defined minimum temperature (70°F) during recirculation mode. The CCWS may also be at a higher temperature before the accident, as 70°F is a minimum value. The increase in CCWS temperature would reduce the heat transfer effectiveness (delta T) and consequently the sump cooldown rate.

- Sump fluid density assumed to be at 125°F for RHRHX calculations throughout analysis
  The density of the sump fluid was assumed to be at a low temperature of 125°F (as opposed to the high end temperature, or a more realistic average of the range) in the RHRHX heat transfer calculations throughout the entire duration of the accident. This higher applied fluid density effectively maximizes the heat removal performance of the RHRHXs by increasing mass flow rate in the tubes, and results in a larger Logarithmic Mean Temperature Difference (LMTD) between the hot (tube) side and cold (shell) sides. In implementing this conservatism, the heat capacity (c_p) is taken at the same temperature (125°F). This is reasonable, since it will vary only by about 2% from the range of interest (125°F to 250°F) and has a negligible net effect on sump temperature.

- Maximized flow applied during recirculation spray mode (suction from sump)
  Flow rates for this period of post-LOCA recirculation spray operation for IP-2 use a beyond design basis condition of two spray headers in operation. An extra spray header in operation during this time increases sump and RHRHXs flow rates, thereby increasing heat transfer and Containment cooling. Additionally, both the IP-2 and IP-3 cool down evaluations use flow rates which are from hydraulic calculations which purposely maximized flow. This was done by selecting enhanced pump performance curves, minimizing system resistances, and maximizing Containment water level. The resultant flows are conservatively high, thus increasing heat transfer in the RHRHXs and the cool down rate.

- Minimum sump temperature calculated for 7 hours into the event
  Hot-leg recirculation, and the associated beneficially reduced flow rates through the strainers, is procedurally initialized at no later than 6.5 hours. The final temperature results presented are calculated for a 7 hour heat removal period, 1/2 hour longer than permitted. This is conservative because the additional time allows further cool down of the sump fluid.

- Refueling Water Storage Tank (RWST) temperature is taken at Technical Specification minimum
  The Technical Specification minimum temperature for the RWST fluid is 40°F for IP-2 and 35°F for IP-3. Both storage tanks have a steam coil heating system to ensure the temperature is maintained above these minimum values during colder periods. Although IP-3 has a lower allowable, the heating system is set to, and capable of maintain at least a minimum 40°F temperature. These heating systems will typically maintain a higher

temperature to cover instrument inaccuracy, and for the majority of the year during warmer periods (spring/summer/fall), the RWST will be closer to outdoor ambient temperatures, which are above the 40°F temperature. Since the injected/sprayed fluid (over 300,000 gallons) from the RWST forms a majority of the fluid in the sump pool; this is an additional, unaccounted for heat load in the calculation that must be removed.

Conclusion

Based on the above conservatisms, coupled with the ANL methodology that is a known conservative predictor of precipitation point temperatures for the IP conditions, it can be concluded that there is a larger margin between the precipitation and sump pool temperatures than provided in the corrected response above.

NRC Request 5

Debris Transport

In RAI 1, the NRC staff asked the licensee to provide an adequate technical basis to support the assumption that some percentage of small pieces of fibrous debris will be captured on gratings in the upper containment. The licensee's response stated that the retention percentage assumed 50 percent holdup of small pieces on grating as an input. This assumption in turn was based on drywell debris transport study information (NUREG/CR 6369) which showed for each test case the washdown fraction was less than 50 percent. The response continued with a detailed discussion of associated assumptions, testing, and plant-specific information. The staff considers the licensee response did not adequately address this issue for the following reasons:

a. *For boiling water reactors (BWRs), most debris may be blown downward to the suppression pool and captured on the upper surface of gratings, whereas in pressurized water reactors (PWRs), most debris may be blown upward and captured on the underside of gratings. Washdown occurs more readily when debris is captured on the underside of gratings. Thus, the BWR washdown capture data likely overestimates the PWR condition.*
b. *A substantial fraction of the debris blown to the upper containment may be blown through gratings. This is unlike the BWR configuration, wherein debris subject to washdown may be blown downward and trapped on the upper side of grating without having first passed through other grating. The licensee stated that this effect is conservatively accounted for by assuming debris trapped on the underside of gratings would fall back to the containment pool. However, there are additional considerations. The staff would expect that full consideration of this design difference would have resulted in significantly fewer small pieces being blown to upper containment than assumed by the licensee (59 percent). In addition, NUREG/CR-6369 shows that debris that passes through one or more levels of grating during blowdown is more like fines that would tend not to be retained by gratings than like small pieces. Thus, the BWR retention data cited by the licensee for the small pieces in the upper containment of a PWR would not be applicable to a significant fraction of these pieces that would be significantly smaller. The staff expects that washdown for PWR debris would be significantly higher than the BWR washdown data, due to the fact that the pieces that reached upper containment would likely be smaller and more like fines.*

c. *Blowdown testing has shown that substantially less capture is observed on the second grating in a series due to the smaller debris size distribution. The licensee's model lacked consideration of this factor when crediting the second grating in series, instead having a capture fraction equal to the first.*
d. *Debris in the NUREG/CR-6369 washdown and erosion testing was piled up and packed together much more than the NRC staff would expect for the PWR case, which would not blow down directly onto gratings to the same extent. It is not clear that such packing would exist for the PWR configuration, except at boundaries where debris is washed off of solid floors or surfaces and is exposed to concentrated flow. More washdown will occur for a less-packed debris configuration or with the presence of concentrated flow.*
e. *Concentrated drainage was not considered in the Indian Point evaluation. The licensee determined a flow flux of 0.4 gpm/ft^2, apparently assuming uniform drainage across the containment cross section. This value is significantly lower than the value used in the BWR testing. However, the Indian Point containment drainage would likely be more concentrated at locations where large debris masses are trapped on gratings, since water and debris typically transport together during washdown. Solid flooring and obstacles will lead to significant non-uniformity in the debris and water drainage distribution that includes flow through gratings. The staff questions the conservatism of the licensee's assumption of 50% pass through of small pieces through grating since neither testing nor evaluation has adequately considered the effect of non-uniform drainage. It is unclear that a low uniform dispersed flow represents potential plant conditions in that local conditions where washdown and erosion would occur are not accounted for.*
f. *Of all the tests done with sprays, only tests of 30 minutes were done for small pieces, with one 60-minute test for medium pieces. NUREG/CR-6369 concludes that a transport fraction of 1.0 is appropriate for debris smaller than gratings for either break or spray flows. The licensee's assumption of 50 percent small piece retention on gratings is inconsistent with the conclusions of the document from which the data is taken.*
g. *Although the licensee correctly stated that NUREG/CR-6369 indicates that the majority of washdown occurred during the first 15 minutes of testing, it is clear that the NUREG did not conclude that washdown ceases after this time. Without having run tests prototypical of plant conditions (finer debris that is more spread out and potentially lower spray flows), the staff does not agree with the licensee's determination that washdown will effectively cease after 15 or 30 minutes.*
h. *The Utility Resolution Guidance indicates transport fractions of 1.0 for Mark I and Mark III BWR containments; the corresponding SE modified the Utility Resolution Guidance position to recommend a 1.0 transport fraction for Mark II containments as well. Therefore, no hold up credit for gratings was permitted by the approved analysis methodology used by the BWRs. The staff notes that the licensee's discussion (response Page 80) using the BWR Owners Group washdown data relied on a method the staff did not consider acceptable for BWRs. The staff did not consider the BWR Owners Group washdown testing conservative for its intended use. This also supports the staff's interpretation that NUREG/CR-6369 concluded that no retention should be credited under spray-only conditions.*
i. *The licensee's discussion on gratings in series does not appear to account for the reason the debris was washed down. The NRC staff considers that debris in the washdown tests did not pass through the gratings because it lined up correctly with the openings in the grating; the debris was piled up on top of the gratings more or less randomly. The more likely reason it passed through the gratings was due to the flow*

interacting with, or breaking up, or realigning, or forcing the debris through the openings. Therefore, the staff does not consider it appropriate to credit multiple gratings in series with the same capture fraction based on a simplified geometric argument that does not address the size distribution changes discussed above, nor the associated mechanisms by which the debris could pass through the initial grating.

j. *The licensee considered debris retention on solid floors an uncredited conservatism. Although the predicted flow velocities on such floors typically would exceed the incipient tumbling velocity for certain fibrous small pieces, the licensee considers that the debris pieces would be saturated with water and thus transport via partially submerged tumbling. However, the NRC staff's view is that, at more than several linear L/D from the break, debris pieces, while wetted, would not likely be fully saturated with water by the jet. The staff does not consider it conservative to assume debris pieces will be soaked when determining transport across containment floors. Pieces of fiber would likely still be partially floating, particularly in cooler spray water that would constitute the water on solid floors in upper containment. This latter effect was not considered by the licensee and could significantly increase transport. Even if the debris were not floating, there would still be no way to assess whether the debris continued to house trapped air that would change significantly the frictional force felt by the tumbling debris per the licensee's analytical methodology. The staff considers it appropriate for the licensee to consider limiting fluid thermodynamic conditions when assessing debris wetting and saturation with water. The staff considers the licensee's analytical derivation of transport metrics for fully liquid saturated debris transporting under partially submerged conditions to lack adequate justification. The licensee took significant credit for this unvalidated methodology, deriving incipient tumbling metrics 20 times higher than the accepted measured values for submerged conditions. Measurements of actual debris transport velocities would be needed to validate the licensee's analytical methodology. Therefore, the staff did not consider this analysis to show a significant conservatism.*

k. *The licensee stated that retention of inertially captured debris would realistically occur but was conservatively not credited. The staff considers it unlikely that a significant mass of inertially captured debris will be retained in the long term. Whether by sprays, condensate, or gravity, much of this debris will release from vertical surfaces or the underside of horizontal surfaces.*

l. *The uncertainty with blowdown and washdown transport is very high due to a lack of testing. The behavior of debris in response to these mechanisms is not well understood, as is discussed in NUREG/CR-6369.*

Please address the above issues to justify the holdup credited, or otherwise consider the impact of reduced holdup of small debris on gratings and other features above the containment pool.

<u>Entergy Response</u>

This response will evaluate the impact of revising the debris transport methodology to use a higher washdown fraction for small fiberglass debris.

<u>Debris Transport Fractions for 100% Washdown</u>

To obtain the "revised" debris transport fractions for small fiberglass pieces due to 100% washdown from upper containment, the debris transport logic trees from the Debris Transport

Calculations were modified. The IP2 debris transport logic tree for Nukon to the IR sump is shown below as an example. The original logic trees for each sump and each debris type required a few changes. The value shown in Figure 1 for "Retained on Structures" under "Washdown Transport" (0.40) was changed to zero, while the "Washed Down Annulus" value was increased to 0.53. Those values were then carried forward through the logic (to the right on the tree) to obtain the revised transport fractions. A summary of the results is shown in Table 1. The revised transport fractions for small fiberglass pieces are approximately twice the original values.

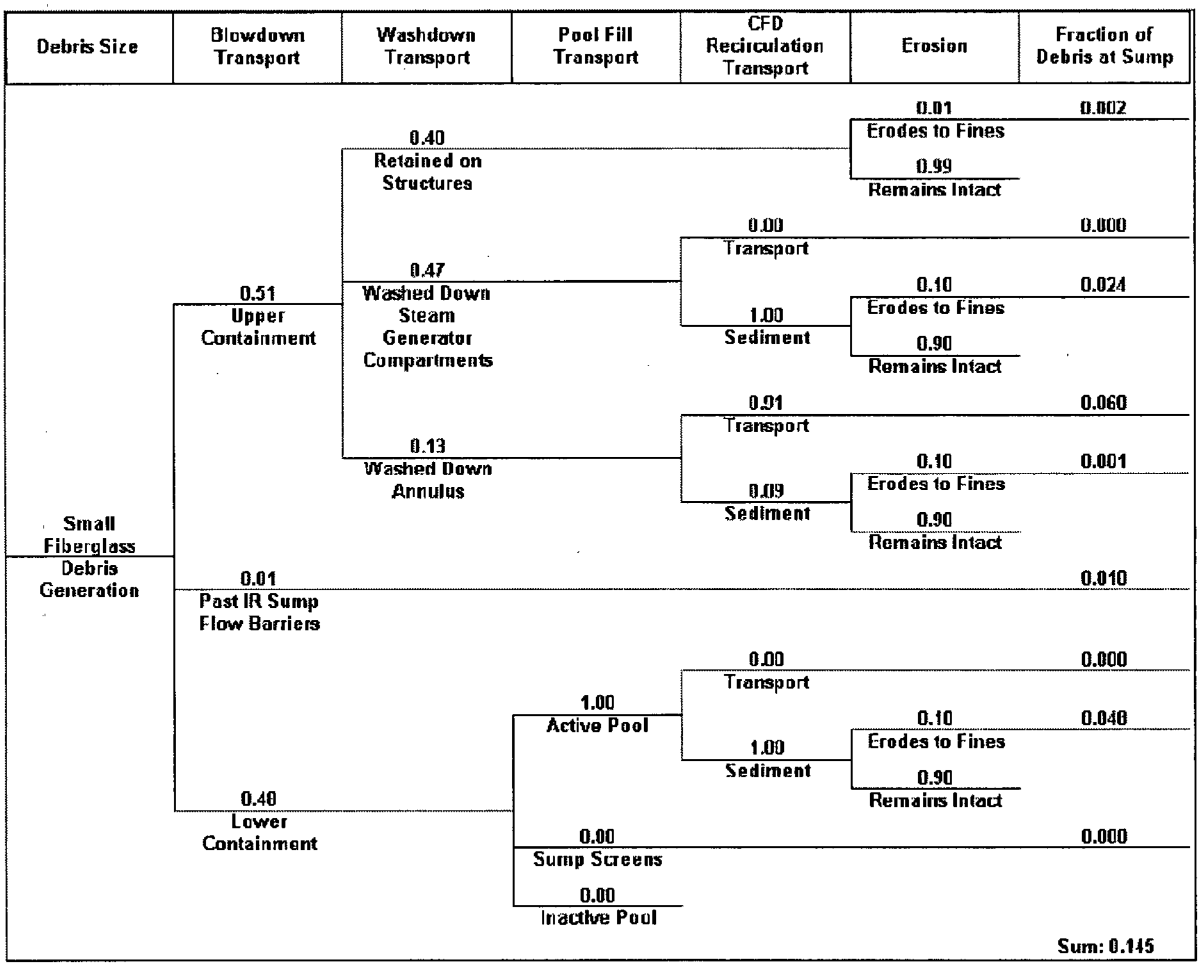

Figure 1: Original IP2 Nukon, Transco Blanket, and fiberglass small pieces debris transport logic tree (IR sump)

Table 1: Small Piece Debris Transport Fractions

	Original, 50% Washdown from Upper Containment	Revised, 100% Washdown from Upper Containment
IP2 IR Sump Nukon	0.15	0.330
IP2 IR Sump Temp-Mat	0.15	0.352
IP2 VC Sump Nukon	0.09	0.115
IP2 VC Sump Temp-Mat	0.14	0.343
IP3 IR Sump Nukon	0.13	0.284
IP3 IR Sump Temp-Mat	0.15	0.352
IP3 VC Sump Nukon	0.08	0.107
IP3 VC Sump Temp-Mat	0.14	0.343

Debris Load Comparisons for 100% Washdown

To determine the “revised debris load” at the sump, the debris generation values for a LBLOCA, a reactor cavity LBLOCA, a 6 inch LOCA, and a reactor cavity 6 inch LOCA (4 cases for each unit), are multiplied by the transport fractions. Then, for comparison to the existing test inputs, the bounding debris load at the sump was determined and multiplied by the test scaling factor according to the methodology documented in the Test Debris Amounts Calculation. A summary of the revised test debris loads is shown in Tables 2 and 3. It should be noted that only the fiber loads are affected by this change in methodology.

Table 2: IP2 Revised Test Debris Loads

			Total Surrogate Amounts for Test (lbs)						
Unit	**Sump**	**Break**	**Nukon (lbs)**	**Temp-Mat (lbs)**	**Min. Wool (lbs)**	**Cal-Sil (lbs)**	**Sil-Co-Sil (lbs)**	**Dirt (lbs)**	**WCAP (NaAlSi)**
IP-2	**IR**	**LB**	35.12	7.59	0.00	7.49	73.60	6.26	3.12
IP-2	**IR**	**RCLB**	1.10	4.33	0.00	0.00	69.73	6.26	3.02
IP-2	**VC**	**6"**	15.79	0.00	0.00	6.16	85.34	19.07	5.87
IP-2	**VC**	**RC 6"**	3.37	3.25	0.00	0.00	77.82	19.07	6.54

Table 3: IP3 Revised Test Debris Loads

Unit	Sump	Break	Total Surrogate Amounts for Test (lbs)						
			Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (NaAlSi)
IP-3	IR	LB	25.23	31.36	1.04	9.66	52.26	7.75	3.74
IP-3	IR	RCLB	1.37	4.17	0.00	0.00	42.99	7.75	2.76
IP-3	VC	6"	4.78	38.59	0.00	9.57	27.42	24.63	6.49
IP-3	VC	RC 6"	4.36	3.26	0.00	0.00	20.66	24.63	6.42

As shown in the table above, all of the revised debris loads for the Reactor Cavity breaks have a fiber mass of less than 8 lbs (after assuming 100% washdown from upper containment), which is less than that required to form a thin-bed (see Table 4). Therefore, the full load for these Analytical Debris Generation Cases are bounded by the thin-bed tests and do not require further evaluation.

In the sections below, each Analytical Debris Generation Case (non-reactor cavity) will be discussed individually. The revised debris (fiber) load is compared to the prototypical array test data collected in Spring 2009 using the "Test-for-Success" methodology and conforming to the requirements of the March 2008 Guidance. This methodology is similar to that performed in the original Strainer Head Loss Calculation to determine the bounding head loss for each Analytical Debris Generation Case.

Indian Point's GSI-191 analysis is based on no chemical precipitation prior to 7 hours into the accident. The head losses for conventional debris and conventional plus chemical debris are evaluated independently below because they have different acceptance criteria. The conventional debris head losses are evaluated against the NPSH margins and the minimum flow criteria prior to 7 hours when the sump pool temperature and flow rates are relatively high. The conventional plus chemical debris head loss is compared to the NPSH margins and structural limit after 7 hours when the sump pool is cooler and the flow rates are lower. Both head losses are presented below because it is important to evaluate the margins for both time periods.

IP2 IR Sump LBLOCA

The revised transport fraction results in a total fiber load for the IP2 IR sump of 42.71 lbs. Test C was conducted with a total of 41.39 lbs of fiber and produced a conventional head loss that was 0.27 ft (9%) lower than the thin bed head loss for conventional debris and 4.86 ft (43%) lower than the thin bed head loss with chemical effects. The final head loss margin for this Analytical Debris Generation Case is 0.52 ft (44%) for conventional debris (prior to 7 hours) and 6.97 ft (450%) for conventional plus chemical debris (after 7 hours). This results in an "effective" margin of 53% for prior to 7 hours and 493% after 7 hours. Since the revised fiber load is 3.2% higher than Test C and the effective head loss margin is approximately 53%, it is not expected that the full load for this Analytical Debris Generation Case will challenge the NPSH margin.

The revised insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 4. The highlighted cells indicate the bounding tests that were used to determine the final head loss margins (NPSH, minimum flow, or structural margins).

Table 4: Debris Loads for IP2 IR Sump LBLOCA and Prototypical Tests 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 Stage	C-1	18.94	21.75	0.70	9.66	51.09	7.75	3.38	2.80	5.05	6.51
	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		
	IP2 IR Sump LBLOCA	35.12	7.59	0.00	7.49	73.60	6.26	3.12	F	E-2	E-2

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

IP2 VC Sump 6 Inch Break LOCA

The revised transport fraction results in a total fiber load for the IP2 IR sump of 15.79 lbs. This revised load can be compared to Test A1 which contained approximately 5% less total fiber. The 5% difference in fiber amount is unlikely to cause a significant head loss increase for the revised load because it is equivalent to a 1/32" increase in debris bed thickness. Additionally, Tests B and C were conducted with drastically greater fiber loads and did not produce bounding head losses. Therefore, it is concluded that the revised debris loads would not cause the full load to become limiting for this Analytical Debris Generation Case.

The revised insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 5. The highlighted cells indicate the bounding tests that were used to determine the final head loss margins (NPSH, minimum flow, or structural margin).

Another mitigating factor that provides assurance that this case will not challenge the operation of the recirculation pumps is the final head loss margin. The margin for the conventional debris head loss is 3.13 ft (81%), while the margin for the chemical effects head loss is 2.92 ft (33%).

Table 5: Debris Loads for IP2 VC 6 Inch Break LOCA and Prototypical Tests 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 Stage	A (Thin Bed)	13.54	0.00	0.00	9.66	80.49	15.57		1.83		
	A1-5 (Thin Bed)	15.13	0.00	0.00	9.66	80.49	15.57	5.87	0.96	7.19	8.93
	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-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		
	IP2 VC 6" LOCA	15.79	0.00	0.00	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

IP3 VC Sump 6 Inch Break LOCA

The revised transport fraction results in a total fiber load for the IP3 VC sump of 43.37 lbs. Test C was conducted with a total of 41.39 lbs of fiber and produced a conventional head loss that was 0.27 ft (9%) lower than the conventional debris thin bed head loss and 14.52 ft (66%) lower than the chemical effects thin bed head loss. The final head loss margin for this Analytical Debris Generation Case is 0.83 ft (71%) for conventional debris (prior to 7 hours) and 2.92 ft (34%) for chemical effects (after 7 hours). This results in an "effective" head loss margin of 80% prior to 7 hours and 100% after 7 hours. Since the revised fiber load is 4.8% higher than Test C and the effective head loss margin is 80%, it is not expected that the full load for this Analytical Debris Generation Case will challenge the NPSH margin.

The revised insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 6. The highlighted cells indicate the bounding tests that were used to determine the final head loss margins (NPSH, minimum flow, or structural margin).

Table 6: Debris Loads for IP3 VC Sump 6 Inch Break LOCA and Prototypical Tests 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 Stage	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	4.78	38.59	0.00	9.57	27.42	24.63	6.49	F	E-5	E-5

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

IP3 IR Sump LBLOCA

The revised transport fraction results in a total fiber load for the IP3 IR sump of 57.63 lbs. Since the revised fiber load is 39.2% higher than Test C, the prototypical array test data from 2009 cannot be used to evaluate this case, but it is evaluated using previous head loss testing below. The revised insulation debris loads for this case together with the applicable debris loads and normalized head losses from each test stage are shown in Table 7. The highlighted cells indicate the bounding tests that were used to determine the final head loss margins (NPSH, minimum flow, or structural margin).

Table 7: Debris Loads for IP3 IR Sump LBLOCA and Prototypical Tests 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 Stage	B-4	25.19	5.43	0.00	7.49	72.13	6.26	6.54	1.38	8.78	11.73
	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		
	IP3 IR Sump LBLOCA	25.23	31.36	1.04	9.66	52.26	7.75	3.74	F	E-3	E-3

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

IP3 IR Sump LBLOCA Comparison to Previous Head Loss Testing

Indian Point conducted prototypical array testing in the Fall of 2007, prior to the release of the March 2008 Guidance. Test #1 of the series was conducted to bound the full debris load for the various sumps and Analytical Debris Generation Cases. As shown in Table 8, Test Step #1D included debris amounts that bound the revised loads for the IP3 IR Sump LBLOCA break case. Therefore, this test data can be used to estimate the head loss resulting from the 100% washdown assumption. The stabilized head loss from Test Step #1D was 2.05 ft-water at 398 gpm and 82.5°F. For comparison to the head losses presented in the section above, the head loss for Test #1D is normalized to 400 gpm and 70°F. The flow sweeps for Test #1 indicate that the maximum turbulent fraction is 6.3%, but 10% is used in the normalization for conservatism. The methodology developed in the Strainer Head Loss Calculation and data given in Table 9 is used for normalization as presented below.

Table 8: Debris Loads for IP3 IR Sump LBLOCA and Test #1D

	Test Debris Loads							
	Nukon (lbs)	Temp-Mat (lbs)	Min. Wool (lbs)	Cal-Sil (lbs)	Sil-Co-Sil (lbs)	Dirt (lbs)	WCAP (lbs)	Normalized Conventional Head Loss (ft-water)
Test #1D	26.42	39.00	1.04	16.20	57.98	24.00	N/A	2.56
Analytical Debris Generation Case								
IP3 IR Sump LBLOCA	25.23	31.36	1.04	9.66	52.26	7.75	3.74	

Table 9: Data for Normalized Head Loss Correction

	Test Data	Normalized Data
Flow Rate (gpm)	398	400
Temperature (°F)	82.5	70
Water Viscosity (lb_m/ft/s)	$5.56*10^{-4}$	$6.67*10^{-4}$
Turbulent Fraction	10%	N/A

Equation for Increased flow and decreased temperature case (note the conservatism in evaluating the head loss as fully laminar for the temperature decrease and partially turbulent for the increased flow):

$$\Delta H_2 = \Delta H_1 \frac{\mu_2}{\mu_1}\left[L_{frac}\frac{Q_2}{0.97\times Q_1} + T_{frac}\frac{Q_2^2}{(0.97)^2 Q_1^2}\right]$$

$$\Delta H_2 = 2.05\,\text{ft}\,\frac{6.67\cdot 10^{-4}}{5.56\cdot 10^{-4}}\left[0.9\frac{400\,\text{gpm}}{0.97\times 398\,\text{gpm}} + 0.1\frac{(400\,\text{gpm})^2}{(0.97)^2(398\,\text{gpm})^2}\right] = 2.56\,\text{ft}$$

The normalized head loss for Test #1D (Fall 2007) is calculated to be 2.56 ft, which is less than the head losses measured in the most recent tests for thin-bed (Test F: 3.07 ft) and full load (Test C: 2.80 ft) (see Table 7). Test #1D was conducted with only minor differences in debris preparation of fine debris as compared to Tests C and F. The fine debris preparation described in the March 2008 guidance is more critical for thin bed tests, while the increase in debris discussed here only applies to full debris loads. Therefore, Test #1D is considered acceptable to evaluate head loss for the IP3 IR Sump LBLOCA case, and the comparison indicates that the revised debris loads will not have an adverse effect on the full load head loss. Because the debris loads and conventional debris head loss for Test #1D were similar to those of Test C, it is expected that the effects of chemical precipitates would also be similar. The extrapolated chemical effects head loss for Test C is 6.65 ft, which is 5.67 ft lower than the thin-bed test (Test E: 12.32 ft) that was used to qualify the strainer. Therefore, it is reasonable to assume that the revised full load would not become bounding for conventional or chemical debris head losses. Additionally, the final head loss margin for chemical effects head loss for the IP3 IR LBLOCA is 7.83 ft. (477%), which provides further confidence that the revised debris load would not adversely affect operation of the recirculation pumps.

Alternate Methodology: Determination of Limiting Washdown Fraction

An alternate method of evaluating the impact of a higher washdown fraction is to determine the maximum washdown fraction while maintaining a total fiber load less than Test C (41.39 lbs), which is the maximum fiber tested in 2009. The fractions for the four Analytical Debris Generation Cases are determined by iterating the methodology described above, and a summary of the results is shown in Table 10. The IP3 IR Sump LBLOCA case resulted in no change in washdown fraction because the highest fiber load test (Test C) was designed to contain the exact debris load for this case based on 50% washdown (see previous section for evaluation of this case).

Table 10: Maximum Washdown Fractions to be Bounded by 2009 Prototypical Head Loss Testing

	IP2	IP3
IR Sump LBLOCA	95.5%	50%
VC Sump 6" LOCA	100%	93.5%

Conclusions

The washdown fraction used in the Debris Transport Calculation was intended to include debris that is captured on equipment, piping, walls, floors, grating, inactive areas, and other miscellaneous items. The justification used for the washdown value was based on testing conducted with small fiberglass pieces on grating with flow rates that were significantly higher than Indian Point's flow rate. The test results should be conservative when considering only the grating as a debris transport restriction and certainly conservative when considering the upper containment area as a whole. RAI 5 focuses solely on washdown through gratings, but does not consider that the debris must also transport to the grating past equipment, piping, walls, floors, inactive areas, and other miscellaneous items before it can be washed down. Therefore, the 100% washdown assumption evaluated above is an extremely conservative methodology. It is difficult to imagine that nothing would be captured in the upper containment area and it would be completely fiber-free following a LBLOCA.

The transport fractions used to determine debris loads in this evaluation contain considerable conservatism. The erosion fraction is assumed to be 10%, which was demonstrated to be conservative based on the March 2010 erosion test results. As discussed above, the 100% washdown fraction is very conservative. Finally, the recirculation transport is based on maximum flow rates for the beginning of recirculation, 3,700 gpm for the VC sumps, 7,100 gpm for the IP2 IR sump, and 5,400 gpm for the IP3 IR sump. The alignment is switched to the HHSI pumps no later than 6.5 hours and the flow rate is reduced to 1,350 gpm (or less) for the remainder of the 30 days.

As shown in the sections above, the 100% washdown assumption for small fiberglass pieces from upper containment has a significant effect on the debris loads that are predicted to arrive at the sump. However, for each of the four Analytical Debris Generation Cases, test data exists for comparable fiber loads which indicate that the thin-bed debris loads would continue to produce the bounding head losses rather than the revised full debris load amounts determined in this analysis. Note that only four cases are evaluated because the 24 hour time-dependent cases are evaluated in a separate response, and the reactor cavity cases are completely bounded by the thin-bed tests and don't require further analysis.

The alternate methodology shows that 3 of the 4 Analytical Debris Generation Cases can use a washdown fraction near (or exactly) 100% to obtain a fiber quantity that is bounded by the latest "Test-for-Success" data. The other case, using the 100% washdown fraction, is bounded by a previous test that was conducted prior to the March 2008 Guidance. In summary, using a 100% washdown fraction for debris from upper containment versus the 50% does not change the bounding debris head loss and the existing analysis used to certify the strainer is valid.

Finally, each case has other mitigating factors, including final head loss margin, that provide confidence that adequate NPSH will be maintained for the recirculation pumps (see Table 11).

Table 11: Mitigating Factors for Each Analytical Debris Generation Case

	IP2	IP3
IR Sump LBLOCA	Significant conventional and chemical effects head loss margin.	Bounded by previous Test #1D. Significant chemical effects head loss margin.
VC Sump 6" LOCA	Bounded by Tests B and C. Significant conventional and chemical effects head loss margin.	Significant conventional and chemical effects head loss margin.

<u>NRC Request 6</u>

Debris Transport

In RAI 2, the staff asked the licensee to provide an adequate technical basis to support its assumption of ten percent fibrous debris erosion in the containment pool. The response stated that this was a reasonable assumption and provided justification. To further support the assumption, the licensee is participating in an industry program to generate additional erosion test results, with a report expected in April 2010. Please provide a description of the test and the test results once completed in order to demonstrate the adequacy of the assumed erosion percentage.

Entergy Response

Entergy participated in the Alion testing program to determine an erosion fraction for small pieces of Low Density Fiberglass (LDFG). After a 5 day pre-test was completed, the primary test was performed for 30 days on prepared LDFG samples, and then a follow-up confirmatory test was performed for 13 days on a second group of samples. The latter test provided information on repeatability and to confirm that the erosion rate tapers off early on during the recirculation phase. The LDFG test samples were arranged in the test flume such that the velocity and turbulent kinetic energy (TKE) values of the flow stream bounded the values in the IP-2 and IP-3 Containment Debris Transport models.

The 30 day test determined an erosion fraction value of 6.19%, while the confirmatory 13 day test determined an erosion fraction of 4.91%. Although the resultant tested values are less than the currently assumed 10% erosion fraction, the report concludes that a conservative value of 10% should be used for both small and large pieces of LDFG. As 10% is the erosion fraction that was applied in the IPEC analyses prior to this confirmatory testing, no changes to Debris Generation or other design bases analyses are required.

A copy of the Alion test report: ALION-REP-ALION-I006-04, Revision 0: "Erosion Testing of Small Pieces of Low Density Fiberglass Debris - Test Report," is available for NRC staff review, see NRC ADAMS Accession Number ML101090490.

NRC Request 7

The licensee is crediting time-dependent debris transport for qualification of the vapor containment (VC) sump. In RAI 5, the NRC staff asked the licensee to provide adequate technical justification that the time-dependent model is conservative. The response provided an analysis that noted the effect of each staff concern was quite small, and that only a small fraction of the debris would remain in the pool after one day (0.5 percent for IP2 and 0.7 percent for IP3). After reviewing this information, the staff still has questions concerning the adequacy of the head loss test assumption of less than 5 percent fiber transport to the VC sump. The staff considers that the licensee's response did not adequately address this issue for the following reasons:

a. *The licensee assumed debris all washed down prior to switchover, minimizing transport to the VC sump. The RAI response stated if washdown were delayed to 4 hours, the transport of fines to the VC sump would be about 4 percent. The NRC staff finds this response inadequate in that, when a realistic delay is assumed, in conjunction with the other items noted below, it could lead to greater than 5 percent transport to the VC sump.*

b. *The NRC staff noted that the fiberglass erosion curve presented by the licensee was based on data from Alion that anomalously showed significantly less cumulative erosion for long-term tests than for short-term tests. The staff also noted that the curve fit is not consistent with data seen from tests better suited to assessing time-dependence, and does not seem consistent with the most recent test data that Alion is collecting concerning erosion and its time dependence.*

c. *The licensee indicated that the strainers have bypass eliminator mesh installed, which would significantly reduce the quantity of fibers and some other types of debris that may pass through the strainers. The staff questions, however, whether the 100 percent capture assumption for fine particulate (e.g., 10-micron diameter) is realistic, as simulations have shown that 10-15 pool turnovers are needed to filter out fine particulate for a debris bed of representative porosity. The staff does not agree with the licensee that after 24 hours for a single-train case less than 5 percent of the fine particulate debris would remain in suspension based on the times associated with forming a debris bed with high filtration efficiency and subsequently to achieve 10-15 pool turnovers.*

d. *The licensee stated little debris bed movement was observed during Indian Point plant-specific testing, that check valves would prevent significant reverse flow into the internal recirculation strainers, and the debris bed would not be easily broken down due to agglomeration of constituent debris pieces. The licensee stated that released debris would not easily transport due to being in a pit that is physically separated from the VC sump. The NRC staff did not fully agree with these statements. The staff has observed that accumulated air could result in significant debris release; has seen considerable debris bed movement following pump stoppage; and if only the top row of top hats releases debris, and only a tenth of this debris is released and transported, about 1 percent of the total internal recirculation sump debris load could be on the VC sump strainer.*

e. *The licensee stated that debris would not be directed toward the VC sump during blowdown. The NRC staff generally agrees that significant transport would not occur during blowdown based on the barriers the licensee installed that were described as preventing blowdown transport. However, for pool-fill, although a significant part of the fines may still be in upper containment, blowdown transport is chaotic and difficult to predict. Therefore, the staff expects that pool-fill would result in the transport of a fraction of the fine debris to the VC sump. Although difficult to predict accurately, it is not clear to the staff that a non-recirculation transport (i.e., primarily through pool-fill) fraction less than a percent or two can be justified for fines (as an order of magnitude), which would pass through the perforated barriers.*

The NRC staff questions the 5 percent assumption given the items identified above. Please justify the assumption in light of the items above, or else please provide a description and results of an evaluation of how the plant's system response would be affected by potentially greater debris transport to the VC strainer based on these considerations.

Entergy Response

Delayed Washdown (RAI 7, Item a)

The original Debris Transport Calculations assumed that all debris was washed down to the sump pool prior to the start of recirculation. While it is a reasonable assumption based on test data discussed in NUREG/CR-6369, this assumption was identified as a potential non-conservatism in RAI 7.

The previous RAI response presented an example where washdown was delayed for four hours. This was a hypothetical scenario postulated to demonstrate that the transport to the VC sump would be below 5%; however, the data in NUREG/CR-6369 indicates that a 4 hour delay is excessive. A more accurate estimation of the total transport fraction can be developed by using a more realistic delay of washdown based on a conservative interpretation of the washdown time data in NUREG/CR-6369. The tests were run for 30 minutes and yielded washdown fractions of less than 50% for 1.5 inch fiberglass pieces. It was also noted in the observations that the majority of washdown occurred in the first 15 minutes. Therefore, a time-dependent washdown curve can be estimated using a data point of 50% washdown at 30 minutes, which predicts a conservatively late washdown. As shown in Figure 1, the majority of washdown occurs in the first 1.5 hours, which is a realistic delay for washdown. Instead of using the previous assumption that all debris is in the pool at the beginning of recirculation (~40 min), it is assumed that all debris enters the pool at 1.5 hours after an accident, or approximately 50 minutes after the start of recirculation (based on IP3 parameters). This reduces the amount of debris collected by the IR sump because of the reduced number of pool turnovers in the first 24 hours. The effect of any small amount of debris that enters the pool after 1.5 hours is offset by assuming that no debris collects on the IR sump prior to 1.5 hours. Additionally, no washdown would occur after 4-6.5 hours into the LOCA scenario because sprays are highly likely to be terminated during this time period in accordance with the Emergency Operating Procedures.

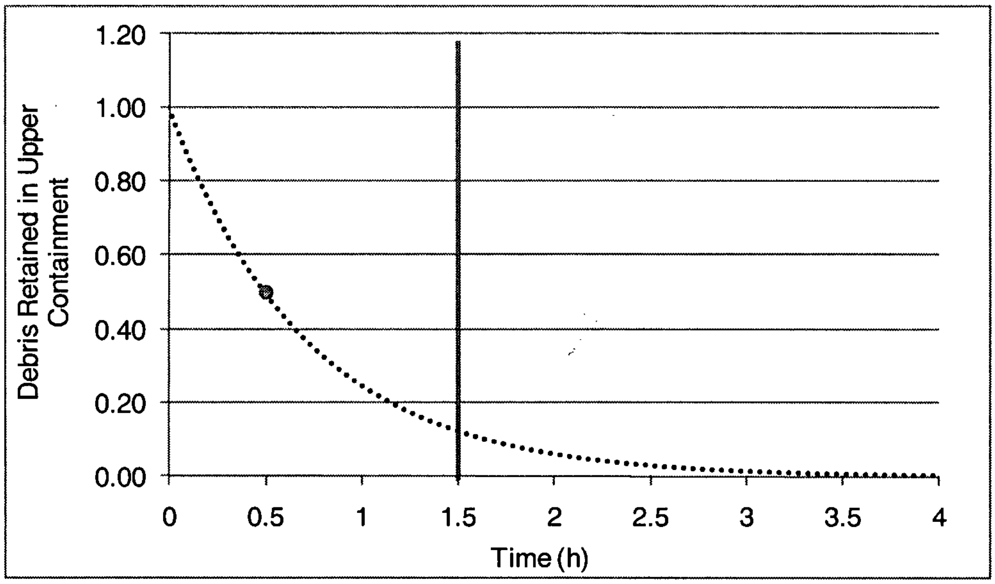

Figure 1: Washdown as a Function of Time Based on NUREG/CR-6369

Assuming that the debris in the pool is uniformly distributed and the water entering the pool is clean, an exponential decay model (see Equation 1) based on pool turnovers can be used to estimate the quantity of debris in the pool at 24 hours. This methodology was used in the Debris Transport Calculations to determine the time-dependent debris transport fractions. Using an initial fraction of one and the same conservatively low flow rates (for IP3) and maximum sump pool volumes as the Debris Transport Calculations, Equations 2 – 4 show that debris depletion from 1.5 hours to 24 hours will leave 0.9% of the total debris in the sump pool. This transport fraction will be used in calculating the total debris transport. Note that three equations are needed due to different flow rates for the various time periods after an accident. This assumption and methodology is conservative because it includes all debris (i.e. smalls and fines), not just the debris that is washed down from upper containment.

$$x(t) = x_i e^{-t\left(Q/V_{pool}\right)} \qquad \text{Equation 1}$$

Fraction of debris remaining in the pool after 4 hours:

$$x(t_{1.5-4hr}) = 1.0 \cdot \exp\left[-\frac{2.5\text{hr} \cdot 60\frac{\text{min}}{\text{hr}} \cdot 3{,}517\text{gpm} \cdot 0.1337\frac{\text{ft}^3}{\text{gal}}}{49{,}998\,\text{ft}^3}\right] = 0.24 \qquad \text{Equation 2}$$

Fraction of debris remaining in the pool after 5.5 hours:

$$x(t_{4-5.5hr}) = 0.24 \cdot \exp\left[-\frac{1.5\text{hr} \cdot 60\frac{\text{min}}{\text{hr}} \cdot 1{,}402\text{gpm} \cdot 0.1337\frac{\text{ft}^3}{\text{gal}}}{49{,}998\,\text{ft}^3}\right] = 0.17 \qquad \text{Equation 3}$$

Fraction of debris remaining in the pool after 24 hours:

$$x(t_{5.5-24hr}) = 0.17 \cdot \exp\left[-\frac{18.5\text{hr} \cdot 60\frac{\text{min}}{\text{hr}} \cdot 1{,}000\text{gpm} \cdot 0.1337\frac{\text{ft}^3}{\text{gal}}}{49{,}998\,\text{ft}^3}\right] = 0.009 \qquad \text{Equation 4}$$

Fiberglass Erosion (RAI 7, Item b)

The Debris Transport Calculation methodology included 10% erosion of the small and large pieces of fiberglass in the sump pool at the beginning of recirculation. Ninety-five percent (95%) of the transportable debris is collected on the IR sump prior to VC sump recirculation. Thus, 5% of the total 10% erosion occurs after 24 hours, which is 0.5% (0.1*0.05) of the full amount of small and large fiberglass debris generated. The value was rounded up to 1% for conservatism in the Debris Transport Calculations. It should be noted that erosion does not apply to fine debris because it is assumed to be 100% transportable (or 5% to VC sump after time-dependent reduction).

The most recent erosion testing by Alion provides a time-dependent profile of the erosion process for small fiberglass pieces. It shows that the flow erosion fraction for small pieces is 3.59% for 30 days, while the flow erosion fraction before 24 hours is 0.7%. Using a simple ratio, 81% of the total erosion occurs after 24 hours. However, the average velocity in the testing was much greater than the average velocity around non-transporting debris at Indian Point.
The containment recirculation CFD model was used to analyze the fluid velocities over the areas in the containment buildings where small piece debris does not transport. Using the IR sump maximum flow rates, the average fluid velocities were determined inside the crane wall at the 46' elevation, in the annulus, and in the in-core instrumentation tunnel/under vessel area. The in-core instrumentation tunnel/under vessel area for IP3 has the highest average fluid

velocity, 0.0897 ft/s. The CFD models show that approximately 85% of area inside the crane wall has sufficient velocity to transport small fiberglass pieces to the tunnel, while approximately 25% of the area inside the crane wall has sufficient velocity to transport large fiberglass pieces to the tunnel. However, the velocity in the tunnel is insufficient for either size debris to transport out of the tunnel. Therefore, a large portion of small and large pieces is predicted to remain within the under vessel area or in the tunnel. For the purposes of this evaluation, a velocity of 0.0897 ft/s will be used for conservatism. For the VC sump LBLOCA 24 hr case being analyzed here, the flow rate is only 1,350 gpm, and the flow barriers are assumed to be blocked such that the full flow is directed through the in-core instrumentation tunnel. The fluid velocity is likely to be less than analyzed here because the flow barriers will be partially blocked. Fluid velocities for VC sump recirculation can be approximated using a ratio of the flow rates. A conservative safety factor of 2 is included to obtain a scaled velocity of 0.045 ft/s ([0.0897*1350/5400]*2).

The industry erosion testing was conducted at a fluid velocities ranging from 0.119 ft/s to 0.229 ft/s, and a correlation was developed to relate erosion fraction to velocity, $1.0674*v^{1.8884}$. Because the velocity around eroding debris at IP (0.045 ft/s) is lower than the average velocity in the erosion testing (0.162 ft/s), the correlation can be used to determine a more accurate and bounding erosion fraction for Indian Point. Using a velocity of 0.045 ft/s, the erosion fraction can be estimated as 0.31% ($1.0674*0.045^{1.8884}$). However, this value is based on an erosion data that produced an erosion fraction of 3.59%, which is lower than the assumed (and NRC accepted) value of 10%. For this reason, the value is scaled up using a ratio of 10/3.59 for the total erosion, then multiplied by the 0.81 fraction (81%) that was previously determined to erode after 24 hours. Using this methodology, the erosion fraction of small debris after 24 hours for Indian Point is 0.70%, which is less than the 1% value used in the Debris Transport Calculations. Therefore, the existing time-dependent analysis for erosion is bounding.

<u>Strainer Bypass (RAI 7, Item c)</u>

The time-dependent methodology used total particulate transport fractions that are significantly higher than the 5% of fine particulate debris quoted in RAI 7. All un-qualified coatings (outside the ZOI) and all fines due to erosion of Cal-Sil/Asbestos are not included in the debris that collects on the IR sump in the time-dependent debris transport analysis. Instead, 100% of these quantities are conservatively assumed to transport to the VC sump. Additionally, it is important to compare these values to the transport fractions for the IR sump to put the values in the proper perspective. The transport fraction for Cal-Sil to the IR sump is not 100% because a portion of the Cal-Sil is destroyed as small or large pieces and doesn't transport to either sump (see Table 1). The transport fraction for coatings debris to the IR sump is not 100% because a portion of the unqualified epoxy paint fails as chips and doesn't transport to either sump (see Table 2). These values skew the transport fractions when comparing the values for the IR sump and VC sump. As shown in Tables 1 and 2, the difference in IR sump transport fraction and the VC sump time-dependent transport fraction is not as large as it initially appears.

Table 1: Comparison of Transport Fractions for Cal-Sil*

	Time-Dependent Transport of Cal-Sil to VC Sump	Transport of Cal-Sil to IR Sump
IP2	9%	65%
IP3	9%	59%

*Percentages are based on the total amount of Cal-Sil generated

Table 2: Comparison of Transport Fractions for Coatings

	Time-Dependent Transport of Coatings to VC Sump	Transport of Coatings to IR Sump
IP2	33%	83%
IP3	7%	59%

*Percentages are based on the total amount of coatings generated

The capture of particulate debris is dependent on full coverage of the strainers by fibrous debris. If the strainers are fully covered, the fiber acts as an effective filter, and if the strainers have clean screen area, the particulate simply recirculates or settles. Both scenarios will be discussed in detail below.

In order to credit a fully covered strainer for filtering particulate, there needs to be reasonable assurance that sufficient fiber will collect on the strainer. Several scenarios exist that have the potential to deposit a small amount of debris on the IR strainer. First, a small amount of debris could be generated; this scenario is evaluated in the clean screen section below. Secondly, debris transport to the IR sump could be significantly less during the first 24 hours. For this scenario, it is reasonable to expect the transport to the VC sump to be less than the 5% used in the analysis, especially since the flow rates will be less than 1/3 of those for the IR sump (7,100 gpm or 5,400 gpm for the IR sump versus 1,350 gpm for the VC sump at 24 hours). Finally, the transport of debris to the IR sump could be delayed. The Delayed Washdown Section demonstrates that 1.5 hours is a reasonable delay for debris washdown, and a delay of this magnitude would result in 99% transport of fibrous debris to the IR strainers. Therefore, all plausible scenarios are being covered by this evaluation.

Strainers with Clean Screen Area

The prototypical array testing for the IP2 and IP3 VC sump time-dependent (after 24 hours) debris transport cases demonstrates that significant clean screen is present due to the low debris loads. The total fiber load for the IP2 time-dependent case is 5.54 lbs (Table 3, Test G: 4.47+1.07), and the total fiber load for IP3 time dependent case is 8.02 lbs (Table 3, Test D: 3.66+4.23+0.13). The thin-bed tests required fiber amounts of 8.55 lbs (Table 3, Test F) to 15.13 lbs (Table 3, Test A1) to fully cover the screens. Without fully covered strainers, the particulate would simply recirculate (or settle), rather than collect on the screens and contribute substantially to head loss. Additionally, the prototypical testing in 2009 included tests with a wide range of particulate amounts, and the head loss results do not indicate that they are strongly dependent on particulate amounts (see Table 3). For example, Tests D and G were conducted to address the IP2 and IP3 time-dependent debris transport cases. The head loss results were essentially equal (5.81 ft versus 5.42 ft) for the two tests which included 22.34 lbs and 77.26 lbs of particulate. In summary, test results and theory indicate that any increase in particulate load is unlikely to increase the debris head loss.

The clean screen scenario also applies to the IR sump. At first glance, it would seem that this would lead to a case where the particulate does not collect on the IR sump but then collects on the VC sump. The IR strainer surface area for IP2 and IP3 is approximately 3 times that of the VC strainer, and the debris transported to the VC sump is less than 1/3 that of the IR strainer (fine debris: 100% transport to IR vs. 5% transport to VC). Therefore, for a case where insufficient fiber is generated to cover the IR sump strainer, there would less fiber per strainer area for the VC sump which would also be insufficient to cover the screen.

Table 3: Summary of Prototypical Array Test Debris Loads and Results

		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 Stages	A (Thin Bed)	13.54	0.00	0.00	9.66	80.49	15.57		1.83		
	A1-6 (Thin Bed)	15.13	0.00	0.00	9.66	80.49	15.57	6.54	0.96	8.54	9.98
	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
	D-1	3.66	4.23	0.13	4.85	16.26	1.23	9.33	0.13	3.49	5.42
	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
	G-1	4.47	1.07	0.00	3.01	73.30	0.95	6.84	0.10	3.45	5.81

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

Fully Covered Strainers

The prototypical array testing in 2009 also demonstrates that the full debris load on the IR sump is a very effective filter for particulate debris as evidenced by sharp decreases in turbidity after each debris addition. To evaluate this information, the number of pool turnovers required to filter the majority of particulate is determined. Pool turnovers is the appropriate metric to compare the test with the plant because it accounts for the differences in scale. Since very little particulate is required to increase turbidity, it is assumed that turbidity values less than 100 NTUs indicate that very little (<5%) particulate remains in the recirculating fluid. This is reasonable considering that the 25% of particulate added in the first debris addition for Test C increased the turbidity to over 600 NTUs (see Figure 2). For the 4 debris additions in Test C, the time to reduce the turbidity to 100 NTUs ranged from 36 minutes to 14 minutes (see Figure 2). This corresponds to an average of 3.7 pool turnovers, while the minimum number of pool turnovers in the first 24 hours for the Plant is 5.3 and 5.0 for IP2 and IP3, respectively. These pool turnover values are based on the minimum flow rates used in Equations 2 – 4 in the delayed washdown section, and the actual pool turnovers in the Plant could be two or more times greater. Therefore, a fully covered strainer in the Plant is expected to be an effective filter for particulate in the first 24 hours.

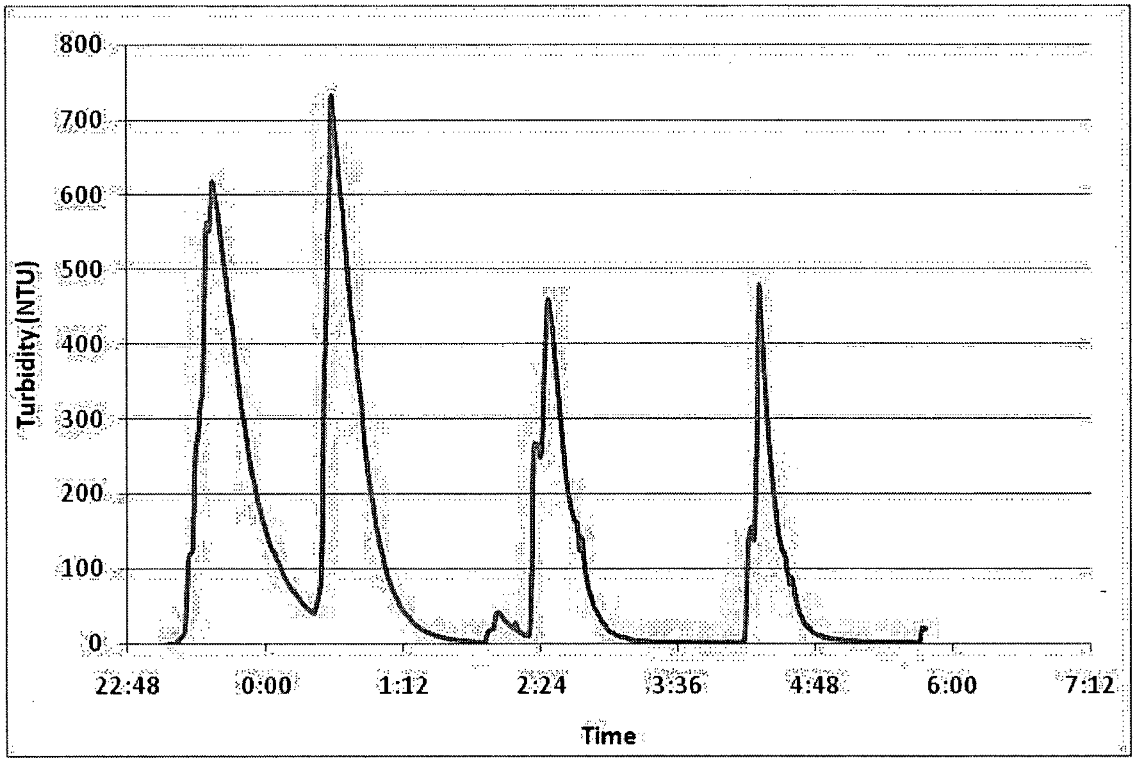

Figure 2: Turbidity Data for Test C

Debris Movement after Securing Pump (RAI 7, Item d)

The updated Generic Letter 2004-02 Response provided to the NRC included a practical explanation as to why debris would not be resuspended when the IR pumps are secured. The reasons included:

- very little (if any) debris bed movement when pumps were secured during testing,
- the presence of check valves in close proximity to the recirculation pumps,
- agglomeration of debris observed for all prototypical tests,
- the strainers are situated in a pit,
- the strainer pit is located in a room that is not in the flow path,
- the flow paths would not promote transport from the IR sump to the VC sump.

However, for the purposes of this evaluation, a conservative non-zero value will be considered for material released from the IR sump debris bed. The Indian Point IR strainer design consists of an array where each column has 9 Top Hats. Consequently, approximately 11% (1/9*100%) of the strainer surface area is located in the top row. It is assumed that only the strainer surface area in the top row would be susceptible to debris movement and that approximately 20% of the fine fiberglass collected on these screens could be released and transported when the IR pumps are secured. This release is equivalent to 2.2% of the total fine fiberglass debris, which will be used to evaluate total transport in Table 4. The small volume of particulate released from the top row of the IR sump after the IR pumps are secured will not appreciably contribute to head loss (see Strainer Bypass Section) and will not be further considered by this evaluation.

Pool-fill Transport to VC Sump (RAI 7, Item e)

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, through the crane wall, along the annulus, 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 232 ft^3 (5'6"x5'6"x7'8") for IP2 and 496 ft^3 (8'×8'×7'9") for IP3. Although some fine debris could be transported to the VC sump during the pool fill-up period, the pit volume is small compared to the minimum water volume. At the beginning of recirculation, the total pool volume for an LBLOCA is at least 35,080.32 ft^3 and 29,527.72 ft^3 for IP2 and IP3, respectively. Consequently, the ratio of VC sump pit to minimum water level is 0.7% and 1.7% for IP2 and IP3, respectively. A transport value of 1.7% is used for conservatism in calculating the total debris transport. An additional conservatism not included in this transport value is the fact that the VC sump and IR sump cavities would be filled simultaneously early in the event. 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 would actually be less than 1.7%.

Total Time-Dependent Transport Fraction

The sections above evaluate each of the five potential non-conservatisms identified by the NRC in RAI 7 and estimate a conservative transport fraction for each individual item. For fine debris, the cumulative effect of the applicable items is estimated to be the sum of the four individual items. As shown in Table 4, the total time-dependent debris transport fraction for fine debris, using the conservative methodology presented above, is 4.8%. Therefore, the 5% transport determined for fine debris in the Debris Transport Calculations is considered bounding. In addition to the 5% transport of fine debris, the small and large fiberglass pieces are subject to erosion. Erosion is evaluated above and determined to be less than the 1% utilized in the Debris Transport Calculations.

Table 4: Total Time-Dependent Debris Transport Fraction for Fine Debris

Item	Transport Fraction (%)
Delayed Washdown	0.9
Strainer Bypass	0
Debris Movement after Securing Pump	2.2
Pool-fill Transport to VC Sump	1.7
Total	**4.8**

Conclusions

The transport fraction determined in this evaluation contains considerable conservatism considering that the number of pool turnovers is calculated using very conservative inputs of minimum flow rates and a maximum pool volume. Because the pool volume will be lower and the flow rate will be higher, the fraction of fine debris remaining in the pool will be lower than 4.8%. Additionally, the recirculation transport for the VC sump is based on maximum flow rates for the beginning of recirculation, 3,700 gpm for the VC pumps. The alignment is switched to the HHSI pumps by 6.5 hours, and the flow rate is reduced to approximately one-third (1,350 gpm or less) for the remainder of the 30 day mission time.

After applying a conservative methodology for each of the 5 RAI items, the transport fraction for fine fibrous debris is less than the values used in the Debris Transport Calculations. Indian Point's prototypical array testing demonstrates that the majority of particulate will collect on the IR sump prior to 24 hours. However, if the particulate amount is greater than that determined in the analysis, test data indicates that the head loss would not be significantly affected due to the presence of clean screen area. Finally, because of the low velocities around non-transporting debris at Indian Point, test data indicates that the erosion fraction will be less than the 1% used for post-24 hours in the Debris Transport Calculations. Therefore, the existing analysis, which includes NPSH margins of 2.51 ft for IP2 and 4.41 ft for IP3, is justified as bounding.