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CALVERT CLIFFS
NUCLEAR POWER PLANT

July 23, 2010

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Request for Additional Information Regarding Generic Letter 2004-02

REFERENCE: (a) Letter from Mr. D. V. Pickett (NRC) to Mr. G. H. Gellrich (CCNPP), dated April 2, 2010, Request for Additional Information Re: Generic Letter 2004-02 Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 – (TAC Nos. MC4672 and MC4673)

In Reference (a), the Nuclear Regulatory Commission (NRC) staff requested additional information to complete their review of our response to Generic Letter 2004-02. On May 24, 2010 a public phone call was held with the NRC staff to discuss our draft responses to the Staff's request for additional information. During this phone call and subsequent interactions, the draft responses were found acceptable by the Staff.

The final responses are based upon testing conducted prior to receipt of the Request for Additional Information. Additional testing was recently undertaken using the parameters noted in the responses. The test results, and final plant modification commitments and schedule will be provided to the NRC before the end of 2010.

A116
NRR

Should you have questions regarding this matter, please contact Mr. Douglas E. Lauver at (410) 495-5219.

Very truly yours,

George Gellrich

STATE OF MARYLAND :
: **TO WIT:**
COUNTY OF CALVERT :

I, George H. Gellrich, being duly sworn, state that I am Vice President - Calvert Cliffs Nuclear Power Plant, LLC (CCNPP), and that I am duly authorized to execute and file this response on behalf of CCNPP. To the best of my knowledge and belief, the statements contained in this document are true and correct. To the extent that these statements are not based on my personal knowledge, they are based upon information provided by other CCNPP employees and/or consultants. Such information has been reviewed in accordance with company practice and I believe it to be reliable.

Geo Gellrich

Subscribed and sworn before me, a Notary Public in and for the State of Maryland and County of St. Mary's, this 23rd day of July, 2010.

WITNESS my Hand and Notarial Seal:

Janet L. Scully
Notary Public

My Commission Expires:

March 1, 2011
Date

GHG/PSF/bjd

Attachment: (1) Request for Additional Information Regarding Generic Letter 2004-02

cc: D. V. Pickett, NRC
M. L. Dapas, NRC
Resident Inspector, NRC
S. Gray, DNR

ATTACHMENT (1)

REQUEST FOR ADDITIONAL INFORMATION REGARDING

GENERIC LETTER 2004-02

Calvert Cliffs Nuclear Power Plant, LLC
July 23, 2010

Debris Generation/Zone of Influence (ZOI)

In item 1 of its request for additional information (RAI) dated December 8, 2008, the NRC [Nuclear Regulatory Commission] staff requested that the licensee state whether the testing identified in the Westinghouse WCAP-16710-P and WCAP-16720-P test reports was specific to the CCNPP [Calvert Cliffs Nuclear Power Plant] insulation systems (Nukon™, Transco Thermal-wrap®, calcium silicate, generic fiberglass and Temp-Mat). The licensee stated in its response that the insulation systems installed in CCNPP are representative of the systems tested in the WCAP-16710 and 16720 tests. The licensee noted that the Transco reflective metallic insulation (RMI), generic fiberglass and Temp-Mat insulation systems were assigned ZOIs consistent with the Nuclear Energy Institute (NEI 04-07) guidance. Subsequent to the licensee's response, the staff has learned of issues with the Westinghouse testing. The staff has provided more detailed questions to the pressurized water reactor owners group (PWROG) and affected licensees regarding this testing. These questions (RAIs 1-9) follow, as applicable to CCNPP, and they replace the previous RAI 1. In addressing these questions, the licensee should confirm that debris generation analyses from steam space break was conducted using appropriate ZOIs, and not ZOIs based on saturated or sub-cooled water tests except as previously approved by the staff. The licensee should provide the requested information for Nukon jacket with standard bands, Transco Thermal Wrap, Calcium Silicate, and Marinite® board. Comparisons with tested components should include evaluations of both metal jacketing and cloth covers as applicable.

NRC RAI 1:

1. *Although the ANSI/ANS standard referenced in WCAP-16710-P and WCAP-16720-P predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would necessarily correspond to a generally conservative debris generation result. Please justify the initial debris generation test temperature and pressure with respect to the plant-specific reactor coolant system (RCS) conditions, specifically the plant hot and cold leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Please explain whether any tests were conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications. If so, please provide that assessment.*

CCNPP RAI 1 Response:

On February 12, 2010 CCNPP received a 10 CFR 21.21(a)(2) notification from Westinghouse informing us of certain technical issues identified with the jet impingement testing that had provided the basis for the reduced ZOI data contained in WCAP-16710 and WCAP-16720. As a result Calvert Cliffs is no longer using the revised ZOI data contained in WCAP-16710 and WCAP-16720. Therefore, we believe it is no longer necessary to respond to RAIs 1-8 as they deal exclusively with the Westinghouse jet impingement testing.

In response to this issue, Calvert Cliffs is revising the ZOI data previously reported in our response to questions 3b1 and 3b2 of Reference 1. The revised ZOI data is provided in Table 1-1:

Table 1-1, Revised ZOI Data

Material	Old ZOI	New ZOI
Transco reflective metal insulation	2 & 7	2 & 17
Transco mineral wool	7	17
Nukon jacketed with standard bands	7	17
Nukon jacketed with Sure Hold bands	---	2.4[1]
Transco Thermal Wrap	7	17

Table 1-1, Revised ZOI Data		
Material	**Old ZOI**	**New ZOI**
Calcium-silicate insulation	3	5.45[2]
Generic fiberglass insulation	17	17
Temp-Mat insulation	11.7	17[3]
Inorganic Zinc coatings without topcoat	5	10[4]
Epoxy coatings	4	4[4]
Marinite board	9.8	17[5]
Lead Blankets	1.25	2.50[6]

Notes:

1 Applies only to piping components 12" nominal pipe size and smaller.

2 Stainless steel jacketing and bands are used on calcium-silicate insulation at Calvert Cliffs. Band spacing is 3 inches. Piping having calcium-silicate insulation is 2" nominal pipe size and smaller.

3 See also response to RAI 9.

4 Though not identified in these RAIs, Calvert Cliffs understands there were also issues with the WCAP-16568 coatings jet impingement work. We believe the new ZOIs listed above for coatings have previously been agreed upon with the NRC.

5 See also response to RAI 11.

6 Applicable to free hanging blankets.

The primary impacts of the revised ZOIs are that a significantly larger portion of our thermal wrap insulated steam generators are now inside the ZOI for thermal wrap insulation, and significant portions of our Nukon insulated pressurizer are now in the ZOI for Nukon insulation. The additional fibrous load resulting from the revised ZOIs will likely require field modifications to make reductions in fibrous insulation load. The magnitude of these potential reductions was determined during head loss testing in June/July 2010.

NRC RAI 2:

2. *Please describe the jacketing/insulation systems used in CCNPP and compare those systems to the jacketing/insulation systems tested. Please demonstrate that the tested jacketing/insulation system adequately represented the plant jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including steam generators, pressurizers, reactor coolant pumps, etc. At a minimum, the following areas should be addressed:*

   a. *Please explain how the characteristic failure dimensions of the tested jacketing/insulation compare with the effective diameter of the jet at the axial placement of the target. The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system, e.g., for a stainless steel jacket held in place by three latches where all three latches must fail for the jacket to fail, then all three latches must be effectively impacted by the pressure for which the ZOI is calculated. Applying test results to a ZOI based on a centerline pressure for relatively low L/D nozzle to target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.*

   b. *Please explain whether the insulation and jacketing system used in the testing was of the same general manufacture and manufacturing process as the insulation used in the plant. If not, please explain what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the plant insulation. For example, it is known that there were generally two very different processes used to manufacture calcium silicate whereby one* *type readily dissolved in water but the other type dissolves much more slowly. Such manufacturing differences could also become apparent in debris generation testing, as well.*

c. *The information provided should also include an evaluation of scaling the strength of the jacketing or encapsulation systems to the tests. For example, a latching system on a 30 inch pipe within a ZOI could be stressed much more than a latching system on a 10 inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches in the testing could be significantly under-stressed. If a prototypically sized target were impacted by an undersized jet it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation (OPG) report on calcium silicate debris generation testing.*

<u>CCNPP RAI 2 Response</u>:

See response to RAI 1.

<u>NRC RAI 3</u>:

3. *There are relatively large uncertainties associated with calculating jet stagnation pressures and ZOIs for both the test and the plant conditions based on the models used in the WCAP reports. Please explain what steps were taken to ensure that the calculations resulted in conservative estimates of these values. Please provide the inputs for these calculations and the sources of the inputs.*

<u>CCNPP RAI 3 Response</u>:

See response to RAI 1.

<u>NRC RAI 4</u>:

4. *Please describe the procedure and assumptions for using the ANSI/ANS-58-2-1988 standard to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle. In your description, please address the following points.*

   a. *Please evaluate any difference in the analysis initial temperature condition and the initial test temperature.*

   b. *Please explain whether the water subcooling used in the analysis was that of the initial tank temperature or was it the temperature of the water in the pipe next to the rupture disk. Test data indicated that the water in the piping had cooled below that of the test tank.*

   c. *The break mass flow rate is a key input to the ANSI/ANS-58-2-1988 standard. Please explain how the associated debris generation test mass flow rate was determined. If the experimental volumetric flow was used, please explain how the mass flow was calculated from the volumetric flow given the considerations of potential two-phase flow and temperature dependent water and vapor densities. If the mass flow was analytically determined, please describe the analytical method used to calculate the mass flow rate.*

   d. *Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, please explain how the transient behavior was considered in the application of the ANSI/ANS-58-2-1988 standard? Specifically, please explain whether the inputs to the standard represent the initial conditions or the conditions after the first extremely rapid transient, e.g., say at one tenth of a second.*

e. *Given the extreme initial transient behavior of the jet, please justify the use of the steady state ANSI/ANS-58-2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.*

CCNPP RAI 4 Response:

See response to RAI 1.

NRC RAI 5:

5. *Please describe the procedure used to calculate the isobar volumes used in determining the equivalent spherical ZOI radii using the ANSI/ANS-58-2-1988 standard.*

   a. *Please describe the assumed plant-specific RCS temperatures and pressures and break sizes used in the calculation. Note that the isobar volumes would be different for a hot leg break than for a cold leg break since the degrees of subcooling is a direct input to the ANSI/ANS-58-2-1988 standard and which affects the diameter of the jet. Note that an under calculated isobar volume would result in an under calculated ZOI radius.*

   b. *Please discuss the calculational method used to estimate the plant-specific and break-specific mass flow rate for the postulated plant LOCA, which was used as input to the standard for calculating isobar volumes.*

   c. *Given that the degree of subcooling is an input parameter to the ANSI/ANS-58-2-1988 standard and that this parameter affects the pressure isobar volumes, please explain what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated loss-of-coolant accident (LOCA) degree of subcooling for the plant debris generation break selections? Please explain whether multiple break conditions were calculated to ensure a conservative specification of the ZOI radii.*

CCNPP RAI 5 Response:

See response to RAI 1.

NRC RAI 6:

6. *Please provide a detailed description of the test apparatus, specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system.*

   a. *Based on the temperature traces in the test reports it is apparent that the fluid near the nozzle was colder than the bulk test temperature. Please explain how the fact that the fluid near the nozzle was colder than the bulk fluid was accounted for in the evaluations.*

   b. *Please explain how the hydraulic resistance of the test piping which affected the test flow characteristics was evaluated with respect to a postulated plant-specific LOCA break flow where such piping flow resistance would not be present.*

   c. *Please provide the specified rupture differential pressure of the rupture disks.*

CCNPP RAI 6 Response:

See response to RAI 1.

NRC RAI 7:

7. *Please discuss the potential for a shock wave resulting from the instantaneous rupture of piping, considering in particular the following points.*

   a. *Please explain whether any analysis or parametric testing was conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions. Please explain whether temperatures and pressures prototypical of PWR hot legs were considered in this analysis or testing.*

   b. *Please explain whether the initial lower temperature of the fluid near the test nozzle was taken into consideration in the evaluation. Specifically, please explain whether the damage potential was assessed as a function of the degree of subcooling in the test initial conditions.*

   c. *Please explain the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping.*

   d. *Please explain how the effect of a shock wave was scaled with distance for both the test nozzle and plant condition.*

CCNPP RAI 7 Response:

See response to RAI 1.

NRC RAI 8:

8. *Please provide the basis for concluding that a jet impact on piping insulation with a 45° seam orientation is a limiting condition for the destruction of insulation installed on steam generators, pressurizers, reactor coolant pumps, and other non-piping components in the containment for which the testing is credited. For instance, considering a break near the steam generator nozzle, once insulation panels on the steam generator directly adjacent to the break are destroyed, the LOCA jet could impact additional insulation panels on the generator from an exposed end, potentially causing damage at significantly larger distances than for the insulation configuration on piping that was tested. Furthermore, it is not clear that the banding and latching mechanisms of the insulation panels on a steam generator or other RCS components provide the same measure of protection against a LOCA jet as those of the piping insulation that was tested. Please provide a technical basis to demonstrate that the test results for piping insulation are prototypical or conservative of the degree of damage that would occur to insulation on steam generators and other non-piping components in the containment if the testing is credited for these components.*

   Some piping oriented axially with respect to the break location (including the ruptured pipe itself) could have insulation stripped off near the break. Once this insulation is stripped away, succeeding segments of insulation will have one open end exposed directly to the LOCA jet, which appears to be a more vulnerable configuration than the configuration tested by Westinghouse. As a result, damage would seemingly be capable of propagating along an axially oriented pipe significantly beyond the distances calculated by Westinghouse. Please provide a technical basis to demonstrate that the reduced ZOIs calculated for the piping configuration tested are prototypical or conservative of the degree of damage that would occur to insulation on piping lines oriented axially with respect to the break location.

CCNPP RAI 8 Response:

See response to RAI 1.

NRC RAI 9:

9. *The licensee's response stated that it revised the ZOI for Temp-Mat from 17D (pipe diameters) to 11.7D. The 17D ZOI had originally been assigned because the Temp-Mat installed at CCNPP did not have the wire retainer installed and the 11.7D ZOI was determined from testing conducted on Temp-Mat with the wire retainer installed. The staff had considered the 17D ZOI to be appropriate. The licensee should provide justification that the Temp-Mat installed at CCNPP can be considered to have the same ZOI as the Temp-Mat with the wire retainer that was evaluated during ZOI testing.*

CCNPP RAI 9 Response:

The debris generation analyses at Calvert Cliffs use a ZOI of 17D for Temp-Mat insulation. The Temp-Mat pads at Calvert Cliffs use 16 gauge stainless steel wire to secure the pad to the pipe or valve being insulated. Temp-Mat insulation pads at Calvert Cliffs are a field fabricated product, therefore it is difficult to ensure that the pads are always installed in the same configuration as that used during the ZOI testing. Therefore, to be conservative for the debris generation analyses, Calvert Cliffs has previously used a 17D ZOI for Temp-Mat instead of the 11.7D reported in Reference 1.

Debris Characteristics

NRC RAI 10:

10. *The assumed debris size distribution of 60 percent small fines and 40 percent large pieces for Nukon and Thermal Wrap low-density fiberglass within a 7D ZOI is inconsistent with Figure 11-2 of the NRC staff's safety evaluation (ADAMS Accession No. ML043280641), on NEI 04-07, which considers past air jet testing and indicates that the fraction of small fines should be assumed to reach 100 percent at jet pressures greater than or equal to about 18-19 pounds per square inch (psi). Based on the predictions of the ANSI model, jet pressures equal to or exceeding that necessary to generate essentially 100% small fines would exist within a 7D ZOI. In light of the discussion above concerning previous testing experience, please provide a basis for considering the assumed debris size distribution of 60 percent small fines and 40 percent large pieces within a 7D ZOI to be conservative or prototypical for Nukon and Thermal Wrap.*

CCNPP RAI 10 Response:

As described in the response to RAI 1, Calvert Cliffs is no longer using the reduced ZOI of 7D for thermal wrap or Nukon insulation systems. Therefore the question of appropriate size distribution at this reduced ZOI is no longer applicable.

For the new 17D ZOIs for thermal wrap and Nukon insulation systems, Calvert Cliffs will either use 100% small fines size distribution for Nukon insulation with sure hold bands, or the following for thermal wrap insulation and Nukon insulation on large components:

Table 10-1, Debris Size Distribution

ZOI Range	% Fines	% Small Pieces	% Large Pieces	% Intact Blankets
0.0-7.0D	20%	80%	0%	0%
7.0-11.9D	13%	54%	16%	17%
11.9-17.0D	8%	7%	41%	44%

This size distribution is documented in Reference 2.

NRC RAI 11:

11. *Table 3.c.1-1 in the licensee's October 23, 2009, supplemental response indicates that only a relatively small quantity of Marinite fragments is assumed to become debris when subjected to LOCA blowdown. Based on the licensee's response to item 3.b.3 in the same document, it appeared that this size distribution was based on destruction testing performed at Wyle Laboratories. The staff understands that the minimum distance from the Wyle test nozzle at which the Marinite board was positioned was equivalent to a 3.4D ZOI. As such, it appeared to the staff that application of the debris characterization results from this testing to Marinite located within 3.4D of postulated pipe ruptures would be non-conservative. Please clarify the distance of the installed Marinite from potential break locations that could result in the need for sump recirculation and provide justification regarding application (if any) of the Wyle test results to Marinite within 3.4D of potential break locations.*

CCNPP RAI 11 Response:

Calvert Cliffs does not have any Marinite board located within 3.4D of any potential break location. Marinite board is separated from a potential break location by at least 5D. Calvert Cliffs used a ZOI of 9.8D for Marinite board. As a consequence of the error in nozzle size noted in the Wyle Labs testing, Calvert Cliffs will use a ZOI of 17D for Marinite board in future testing and analyses. This change in the ZOI changes the bounding Marinite board debris quantity from 0.104 ft^3 to 0.188 ft^3. We will continue to use the size distribution of debris generated from the Wyle Labs testing (see Table 11-1).

References 3 and 4 document testing performed in order to determine realistic jet impingement destruction data for Marinite board. Reference 3 documents that of a total of 13 destruction tests performed with Marinite with ZOIs ranging from 13.3D to 3.4D, only three of the tests generated visible debris. The visible debris was generated at ZOIs of 5.5D, 4.5D, and 3.4D. Calvert Cliffs had conservatively assumed a ZOI for Marinite board of 9.8D. This will now be increased to 17D to conservatively address concerns about the nozzle size used in the jet impingement testing.

Reference 4, pages 4-2 and 4-3, describe how, for testing done with the jet perpendicular to the Marinite board, the boards remained intact, no large pieces of debris were generated, and a maximum percentage of material lost as small fines was 0.87%. Two tests were also performed with the Marinite board at a 45° angle to the jet so that the jet impinged on the edge of the board, and one test was performed such that the jet impinged normal to the thickness of the board. A higher percentage of small fines (1.3%) were generated from the non-perpendicular orientation. For conservatism it is assumed that 1.3% small fines are generated at the selected ZOI of 9.8D regardless of cable tray orientation relative to the LOCA break jet.

The visible debris from the jet impingement tests was documented to have the following size distribution (see Reference 5):

Table 11-1, Marinite Board Debris Size Distribution

Size	Distribution
Fines (particulate)	1.3%
Small Pieces[1]	0.5%
Large Pieces[2]	2.7%
Remains on Target	95.5%

Notes:

[1] Greater than ½" and less than 2"

[2] Greater than 2"

The Wyle Lab test work used ½ inch Marinite I. Calvert Cliffs has ½ inch Marinite XL installed. It was confirmed with the vendor that Marinite I is the replacement to Marinite XL, and the two are equivalent materials. Calvert Cliffs uses stainless steel bands to attach the Marinite board to the cable trays consistent with the test article shown in Figure 4-1 of Reference 4.

Latent Debris

NRC RAI 12:

12. *The licensee's October 23, 2009, response included the following statement regarding the samples taken as part of the latent debris survey: "The latent debris was described as dust with no fiber in any sample". Given the quantity and multiple types of debris insulation present in CCNPP containment, it seems highly unlikely that latent debris found in containment would be composed of all particulate and no fiber. In addition, an all-particulate assumption for latent debris is inconsistent with the 2004 NRC SE on NEI 04-07 and with data from other PWRs. The SE recommends using an 85% particulate / 15% fiber latent debris composition. The composition was determined by sampling performed, via sweeping with a Masolin cloth and vacuuming using HEPA filters, in a number of volunteer plants. Please justify no consideration of fibers for latent debris as applied to strainer performance testing.*

CCNPP RAI 12 Response:

Calvert Cliffs fiber load from insulation is 3000-4000 lbs, so another 25 lbs from latent debris is essentially non-detectable in terms of impact on strainer head loss testing. Assuming all latent debris was particulate is conservative because particulate appears to have a larger effect on head loss. Calvert Cliffs has conducted additional strainer head loss testing in June/July 2010. To avoid any potential inconsistencies with published guidance, we assumed that 15% of the latent debris is fiber.

Debris Transport

NRC RAI 13:

13. *The staff considers the single failure of a low-pressure safety injection (LPSI) pump to trip at the time of switchover to recirculation to not be fully addressed in the licensee's October 23, 2009, supplemental response. Therefore, please address the following items related to the potential operation (including failure to trip) of a LPSI pump during recirculation:*

    a. *Please identify how much time operators would need to terminate the additional flow associated with a LPSI pump that failed to automatically trip and the means by which the flow would be terminated. Please provide a basis for the assumed time period of operation that considers whether the operator actions to address this potential failure are proceduralized and can be accomplished from the control room.*

    b. *Please state whether conditions exist for which emergency operating procedures would either direct or allow plant operators to operate a LPSI pump in recirculation mode under design basis conditions (e.g., during hot leg recirculation). If such conditions exist, please identify their impact on the strainer performance analysis.*

    c. *Increased sump flow from an operating LPSI pump could lead to increased debris transport (e.g., transport of coating chips or large pieces of debris) that was not considered in the debris transport calculation or flume testing. Please provide a basis for concluding that the increased flows associated with LPSI pump operation would not lead to additional transport beyond that considered in the existing analysis.*

d. *Please explain how the failure of the LPSI pump to trip was considered in the head loss testing.*

e. *Please provide the details of the evaluation of net positive suction head (NPSH) margin associated with the failure of the LPSI pump to trip. Provide the effects on the high-pressure safety injection (HPSI) pumps and the containment spray pumps to the extent they are required to operate during the recirculation phase of the event.*

CCNPP RAI 13 Response:

Current Condition

a. Verification that the LPSI pumps tripped automatically on a Recirculation Actuation Signal (RAS) is the first step in the RAS verification checklist contained in our emergency operating procedures. This checklist is reviewed immediately after a RAS is received. If a LPSI pump did not automatically trip, the Operators would attempt to manually trip the pump from the Control Room. This would be accomplished at essentially the same time as the verification step.

   If the pump could not be manually tripped from the Control Room, then the Operators would throttle the LPSI flow by closing 3 of the 4 LPSI header motor-operated valves, and throttling the fourth to 600 gpm (indicated). Currently, this proceduralized action is expected to be completed within four hours of receipt of a RAS.

   The above actions can be accomplished from the Control Room.

   Future Condition

   Procedure changes are being pursued to manually stop the LPSI pumps prior to receipt of a RAS, and if one LPSI pump cannot be turned off then the procedure would require that pump be throttled to 600 gpm (indicated flow) prior to receipt of a RAS. Additionally, if a LPSI pump could not be secured prior to receipt of a RAS, procedure changes are being pursued to secure one HPSI pump. This ensures that the total strainer flow in this condition is less than or equal to the nominal strainer flow.

   Also, as discussed in the response to RAI 19e chemical precipitants are assumed to form when the sump pool temperature drops to 140°F. Therefore, another procedure change is being pursued to have a throttled LPSI pump secured prior to the sump pool temperature dropping to 140°F. Our plans for securing the LPSI pumps prior to a sump pool temperature of 140°F are described in the response to RAI 13d.

b. Calvert Cliffs preferred method for providing core flush flow is to use the HPSI pumps aligned for pressurizer injection. If equipment availability does not allow this, or the required pump flow is not being met, then an alternate action is to use a LPSI pump for hot leg injection. One HPSI pump would be secured in the lineup. Because this flow loop uses 2" piping with a 2" motor-operated valve, the head loss in this alignment is such that the low-head LPSI pumps would provide between 150-250 gpm which is considerably less flow than a HPSI pump (nominal 500 gpm). Therefore, the total strainer flow rate in a configuration where a LPSI pump will be providing hot leg injection is bounded by the flow rates considered in head loss testing.

   To expedite the plant cool down, plant procedures allow the option of using LPSI pumps aligned to provide shutdown cooling flow while taking suction from the containment sump. The flow required is 3000 gpm (indicated). Of the many pre-requisites required for this action, one is that both containment spray pumps be secured (total flow approximately 3425 gpm). Since the combined flow of the two containment spray pumps is greater than the LPSI pump flow, the configuration is bounded by the previously conducted head loss testing.

c. We believe, based on the discussion below that the failure of a LPSI pump to stop upon receipt of a RAS would not result in additional transport of debris beyond that assumed in existing analyses. However, as noted in RAI 13a, Calvert Cliffs is pursuing procedure changes which would secure or throttle the LPSI pumps prior to receipt of a RAS. These procedure changes would also direct that if a LPSI pump could not be secured prior to receipt of a RAS then a HPSI pump will be secured to ensure that the total strainer flow in this condition would be less than or equal to the nominal strainer flow. This eliminates the effect of additional LPSI flow on debris transport. Also, see the response to RAI 14a.

Coating Chips:

Calvert Cliffs performed coating chip testing to understand the propensity for those unqualified coatings which are predicted to fail as chips (i.e., epoxy coatings) to be transported to the containment sump strainer. Four test flow velocities were considered, each a multiple of our nominal strainer volumetric flow of 5000 gpm. These flows include:

Nominal Flow	= 0.11 in/sec	≈ 0.009 ft/sec
2 x Nominal Flow	= 0.22 in/sec	≈ 0.018 ft/sec
4 x Nominal Flow	= 0.44 in/sec	≈ 0.036 ft/sec
8 x Nominal Flow	= 0.88 in/sec	≈ 0.072 ft/sec

This test flume flow rate was scaled so that the test flume approach velocity is representative of the approach velocity into the sump strainer pockets in the actual containment pool. Because of variations in containment pool geometry the actual flow velocity away from the strainer may be different. Therefore, higher flow rates up to 8 x nominal were considered in the coating chip transport testing to account for this uncertainty. A LPSI pump operating at full flow (with all other pumps running) would increase the total strainer flow to approximately 2 x nominal flow. At this flow rate, 5% of the coating chips went backwards and 94% came to rest in the forward direction within 10 inches of the release point. The remaining 1% came to rest within 1 meter of the release point (see Table 14-1).

Similar results were obtained at the 4 x nominal flow rate where 10% of the coating chips went backwards and 88% came to rest in the forward direction within 10 inches of the release point. The remaining 2% came to rest within 1.25 meters of the release point (see Table 14-1).

Regardless of the flow considered, the coating chips came to rest once they reached the floor of the test tank. Note that the strainer filtration surface is approximately 2 ½ inches above the sump pool floor. Based on this, we conclude that the failure of a LPSI pump to stop on upon receipt of a RAS does not invalidate assumptions that coating chips will not transport to the sump strainer.

The coating transport work done by Calvert Cliffs is corroborated by Reference 6 which identifies the velocity needed to move various coating types and sizes. The concluding statement conveys that coating systems possessing characteristics similar to the coatings we tested will likely not transport significant distances at uniform stream velocities of 0.2 ft/sec or less.

Large Insulation Pieces:

Similar to coating chips, large insulation pieces were not assumed to transport because of the low sump strainer velocity even with a LPSI pump operating. During strainer head loss testing, insulation debris was added at flows equal to 2.7 x nominal flow of the strainer, which encompasses the flow rate assumed if a LPSI pump failed to stop upon receipt of a RAS. Even at this flow rate, steady agitation was required to move even small insulation fines to the sump screen. A single 1"x1" cube of Temp-Mat insulation was added to the test tank for one test, and this insulation piece would not transport given the same amount of agitation. Therefore, it is reasonable to conclude large insulation pieces would not transport to the sump strainer with a LPSI pump operating.

d. During the addition of fiber and particulate, the strainer head loss test flow was 2.7 x the nominal flow of the strainer. The nominal volumetric flow of the strainer is 5000 gpm, so the test flow during the addition of fiber and particulate was equivalent to a strainer flow of 13,500 gpm. The LPSI pumps at Calvert Cliffs have a run out flow of 4500 gpm (per the vendor pump curve). Therefore, the flow from a LPSI pump is more than bounded by the flow considered in the head loss testing during the fiber and particulate addition.

   Prior to adding chemical precipitates to the test loop, the test flow was reduced to the nominal strainer flow which does not bound the flow which might exist if a LPSI pump did not stop upon receipt of a RAS. Changes to the emergency operating procedures are being pursued to require the LPSI pump be secured prior to 140°F. This temperature is the point where chemical precipitates are assumed to occur (see RAI 19e). Additionally, Calvert Cliffs is evaluating a plant modification to install redundant sump temperature indication to support securing LPSI flow prior to reaching a 140°F sump temperature. Therefore, this additional LPSI flow was not considered once chemical precipitates were added in the head loss testing.

   Note that future head loss testing will be performed with flow rates that reflect plant conditions, including appropriate procedure changes related to LPSI operation.

e. No formal evaluation of the NPSH margin under the condition where a LPSI pump failed to stop upon receipt of a RAS was performed.

   As discussed in the response to RAI 13a, changes to the emergency operating procedures are being pursued to secure the LPSI pumps prior to receipt of a RAS. These procedure changes will also direct that if a LPSI pump cannot be secured, then that pump will be throttled to 600 gpm indicated flow and a HPSI pump will be secured prior to receipt of a RAS. With these procedure changes, the total strainer flow post-RAS with a LPSI pump throttled will be less than the nominal strainer flow rate. Therefore, a separate NPSH evaluation for the case of a LPSI pump failing to trip was not performed.

NRC RAI 14:

14. *The licensee's October 23, 2009, supplemental response reached the conclusion that transport of coating chips would not be expected during post-LOCA recirculation. A conclusion also appears to have been made that large debris pieces will not transport to the strainers. To fully support these conclusions, please provide the following additional information:*

   a. *Please identify the average flume velocity for the testing described in response to item 3.h.3, during which coating chips were observed to sink directly to the bottom of the flume, even when dropped in front of the strainer. Please further identify whether the testing performed* *considered whether the coating chips were able to transport by tumbling or sliding along the flume floor and onto the strainer surface after falling out of suspension settling onto the floor.*

b. *Please provide a conservative estimate of the velocities in the containment pool along flowpaths by which sump fluid would reach the strainer. The staff understands that a computational fluid dynamics analysis was not performed for the post-LOCA containment pool and does not consider it necessary given other conservatisms in the transport analysis. However, the clean strainer flow calculation in response to item 3.e.1 is not sufficient to analyze debris transport to the strainer because it does not consider external flow features upstream of the strainer that could have a significant influence on pool flow. Please include an estimate of the limiting pool velocities for the case of a LPSI pump single failure to trip as well as the limiting flow case without consideration of a LPSI pump failure to trip.*

CCNPP RAI 14 Response:

a. The average flume velocity for the testing described in response to item 3.h.3 where coating chips were observed to sink directly to the bottom of the flume even when dropped in front of the strainer was 0.11 in/sec (test tank flow rate = 4.1 m^3/hr) which corresponds to our nominal plant strainer flow of 5000 gpm. (Note: This test flume flow rate is scaled so that the test flume approach velocity is representative of the approach velocity into the sump strainer pockets in the containment pool.)

   The original coating system for Calvert Cliffs, and the one constituting the majority of coatings in Containment is the Zinc-Epoxy (ZE) coating system. As a replacement coating system a two-layered epoxy system (E2) may also be used. Regardless of the coating system, only the epoxy portion of the unqualified coating is assumed to fail as chips larger than 1/32 inch. If the unqualified coating has an inorganic zinc primer, this primer is assumed to fail as particulate. Calvert Cliffs assumes that unqualified epoxy coatings outside the ZOI fail as chips (refer to Reference 7).

   The chip thickness considered in Reference 6 for ZE and E2 coating systems were 7.1 and 8.6 mils, respectively. This is consistent with the standard 3-4 mil primer/4-6 mil topcoat specified during plant construction.

   With the care now being used in the application of replacement coatings it is not likely that the E2 coatings would be unqualified due to improper application techniques. Some portion of the coating may be damaged due to physical abrasion, but this is not a significant portion of unqualified coatings.

   In the event that degraded coatings were to fail as chips during a LOCA, Reference 6 investigated the propensity for these chips to transport in the sump pool. The general conclusion is that coating chips possessing physical characteristics similar to the coatings considered in Reference 6 will not transport significant distances at uniform stream velocities of 0.2 ft/s or less.

   Unqualified coatings are assumed fail in a random manner with much of it coming to rest on the Containment floor. From Table 4-3 of Reference 6, 1/64-1/32 inch ZE coating chips have an incipient tumbling velocity of 0.42 ft/s and a bulk (80%) tumbling velocity of 1.36 ft/s. For E2 coating chips of this size the velocities are 0.66 and 1.34 ft/s, respectively. At the nominal strainer flow of 5000 gpm, the approach velocity in the strainer pockets is 0.013 ft/s. The average velocity into the strainer is 15 times less than the 0.2 ft/s velocity required to transport coating chips, and 32 times less than the 0.42 ft/s velocity required to move some coating chips that have come to rest on the sump pool floor, and 104 times less than the tumbling velocity required to move 80% of the coating chips that have come to rest on the sump pool floor.

The conservatism described above serves to account for any local flow velocity variations which result from flow constrictions in the sump pool. Additionally, note that we have an open sump pool configuration which does not have flow constrictions in the general sump pool area. Figure E is a plan view of the Containment lower level. Potential hot leg break spillage locations are highlighted in red, and a typical cold leg break spillage location is highlighted in pink. As can been seen in this figure, there are no compartments or flow constrictions that could have a significant effect on local flow velocities. There is approximately 20 feet of separation from a potential hot leg break (limiting break condition) and the nearest portion of the strainer filtration surface, and over 10 feet of separation between a potential cold leg break location, and the nearest portion of the strainer filtration surface. Furthermore, because of the widely distributed arrangement of the filtration surface of the Calvert Cliffs strainer much of the total strainer would have significantly more separation distance than this. These distances mitigate the effects that higher velocities due to splashing might have on debris transport to the strainer filtration surface.

As seen in Figure E, the potential break spill locations and the sump strainer are on the same semi-circle region of Containment; therefore, at least half of Containment will not have amplified local velocities resulting from the break spillage flow and its accompanying turbulence. Furthermore, as can be visualized from Figure E, the planar region from potential break spillage to the strainer is approximately 1/3 of the semi-circular region containing the sump strainer. Therefore, assuming equal distribution of unqualified coatings around Containment would mean that approximately 1/6 of the unqualified coatings are in the potential high flow velocity region which might be strong enough to result in coating chip transport to the strainer. Therefore, it would be appropriate to consider transport of a quantity of coating chips equal to 1/6 (17%) of the unqualified epoxy coatings. However, to account for the subjectively in the above discussion, Calvert Cliffs will perform strainer head loss testing with a quantity of coating chips representing 25% of the unqualified epoxy coatings.

The above paragraph explains why the amount of coating chips to be included in head loss testing is reasonably conservative. Further support for this position can be garnered from previous testing conducted by Calvert Cliffs. As mentioned in the response to RAI 13c, Calvert Cliffs has conducted coating chip transport testing. Coating chips were observed to either go backwards (against direction of flow), go forwards by less than 10", or go forward some maximum length. The results of this testing are summarized in Table 14-1:

Table 14-1, Coating Chip Transport Test Results

Flow Rate	Velocity	% Bkwd	% Fwd < 10"	Longest Transport
0	= 0.00 in/sec	50%	50%	Almost perfect bell curve
Nominal Flow	= 0.11 in/sec	30%	~70%	17" by less than 1%
2 x Nominal Flow	= 0.22 in/sec	5%	94%	40" by 1%
4 x Nominal Flow	= 0.44 in/sec	10%	88%	50" by 2%
8 x Nominal Flow	= 0.88 in/sec	0%	70%	20" by 28% & 79" by 2%

All coating chip transport occurred while the chips were settling in the tank water. Once the chips reached the tank floor, forward motion stopped. Thus, even at flow velocities 8 times higher than the nominal strainer approach velocity significant coating transport was not observed.

b. As seen in Figure E, the lower level of Calvert Cliffs Containment is not compartmentalized; therefore flow can reach the sump strainer from all around the strainer. There is no constriction point through which all or even a majority of the flow must pass. This greatly minimizes any local flow effects. Additionally, in the region of the sump strainer there are no objects which could cause a significant flow constriction. The most significant flow constriction between a potential break and the sump strainer is the 9 foot span between the reactor cavity pedestal and the steam generator pedestal.

For the case where all LPSI pumps turn off upon receipt of a RAS, the flow out of the RCS break will be limited to approximately 800 gpm. Assuming that this flow and 1/3 of the 3425 gpm containment spray flow go through the reactor cavity pedestal – steam generator pedestal gap, the resultant velocity would be 0.14 ft/sec. This is less than the 0.2 ft/sec velocity that Reference 6 (See response to RAI 13c) concluded was necessary for coating chip transport.

As described in RAI 13a Calvert Cliffs is pursuing procedures changes which would secure or throttle LPSI pumps prior to receipt of a RAS, so that the nominal strainer flow is not exceeded. Therefore, consideration of a LPSI pump failure to turn off upon receipt of a RAS is not required.

Head Loss and Vortexing

NRC RAI 15:

15. *Please evaluate the potential for deaeration across the debris bed. If deaeration is predicted to occur, please determine and describe the effect on NPSH required for the required pumps according to the guidance in Reg. Guide 1.83, Rev. 3, Appendix A.*

CCNPP RAI 15 Response:

The head loss measured during strainer testing was found to exceed the existing submergence of the sump strainer; therefore, there is the possibility of dissolution of gas from the water as it passes through the strainer. Under the assumption that the gas travels with the water at the water velocity, the maximum gas volume fraction would be less than 0.013.

However, the assumption that the gas and water would travel at equal velocities is not supportable. At the computed Froude numbers for our system, the inertial forces will not be sufficient to overcome the buoyancy forces and as a result, air accumulation in the strainer is predicted to occur. Ultimately air accumulation in the strainer will reach levels that result in air being drawn into the recirculation header, and from there stratified flow would develop in the horizontal portion of the recirculation header. This could result in a loss of approximately 14 feet of NPSH. Furthermore, air transport to the pump suction could be in a cyclic manner where intermittent large volumes of air would enter the pump possibly causing loss of performance.

Therefore, the strainer testing performed in June/July 2010 focused on methods to reduce the strainer head losses to values below that of the strainer submergence. As noted in RAI 18, modifications are also planned to increase strainer submergence.

NRC RAI 16:

16. *The licensee provided information on the calculation of clean strainer head loss (CSHL) in section 3f9 of the final supplemental response. The information provided was found to be acceptable since the calculation used industry standard practices to determine the CSHL. However, the response did not state whether the CSHL calculation assumed equal flow through all strainer modules as could occur for a debris laden strainer, or if the calculation assumed higher flow for the modules nearer the pump suction. The staff expects CSHL calculations to assume flow distributed evenly among all strainer perforated surfaces in order to determine a realistic CSHL portion for a debris laden strainer. Please provide the assumptions that were made for flow through the strainer during the evaluation of CSHL.*

CCNPP RAI 16 Response:

The CSHL for the Calvert Cliffs strainer consists of the head loss across the filtration surface, combined with the head loss of the downstream strainer internals which direct the flow to the Emergency Core Cooling System (ECCS) recirculation header inlet.

The CSHL of the filtration surface was determined during strainer head loss testing to have an average value of 0.2 mBar, at the nominal strainer design flow of 5000 gpm.

The CSHL of the strainer internals consists of head loss in three regions:

i. Head loss of the cartridges.
ii. Head loss in the axial flow channel between cartridges.
iii. Head loss in the radial duct.

The flow velocity in the strainer internals is well within the turbulent range, and therefore, the head loss in the strainer internals is proportional to the square of the flow velocity. Head losses were determined based on a loss factor (ζ) multiplied by the velocity head of the flow. This is shown by the equation:

$$HL = \zeta (\rho_w \times v^2) / 2$$

The loss factors (ζ) were determined using classical formula from Reference 8. Once all the loss factors were determined, and combined in series or parallel, as appropriate, an excel spread sheet was used to iterate until a solution resulting in hydraulic equilibrium was reached.

The results of this calculation show that for a debris-laden screen (i.e., equal flow through all the strainer filtration cartridges) the head loss of the strainer internals was a maximum of 0.288 feet. For comparison, for a debris-free screen (i.e., higher flows through cartridges nearest to pump suction) the head loss for the strainer internals was 0.280 feet.

NRC RAI 17:

17. *In RAI 14 of the staff's December 8, 2008 letter, the staff requested a vortexing evaluation. Based on the licensee's response, the staff believes that it is likely that the evaluation bounded the design conditions. However, the response was not clear on all aspects of the evaluation. Please provide the additional information regarding the vortex evaluation:*

    a. *The licensee's response to section 3f4 indicated that testing was conducted at about 4 inches submergence and that flow rates during clean strainer testing ranged from 80% to 500% of the nominal design flow rate. Section 3f3 and the response to RAI 14 stated that testing was conducted at 1 inch and about 6 inches. Please explain whether observation for vortex formation was conducted at the minimum submergence of 1 inch. If so, please state what flow rates were used during this testing.*

    b. *Please provide the maximum flow rate attained at each submergence level during testing.*

    c. *Please state the maximum postulated flow rate through the strainer nearest the pump suction, and explain whether the maximum flow rate during testing bounds this value.*

    d. *If testing was not conducted at the minimum submergence and maximum flow rate, please provide additional details on how it was concluded that vortex formation would not occur.*

CCNPP RAI 17 Response:

a. As part of the protocol for strainer head loss testing, the strainer flow rate was varied between 80% and more than 500% of the nominal strainer flow. The approximate submergence during some of these tests was 4 inches as indicated in our response to question 3f4. A range of submergence values between 4-14 inches were used in the strainer head loss testing. During each of these tests no visual evidence of vortexing activity was observed, even when the flow was 500% of the nominal strainer design flow. For clarification, there were no Calvert Cliffs head loss tests performed at a submergence of 1 inch.

   The formal evaluation of vortexing potential with the Calvert Cliffs strainer utilized the Control Components, Incorporated (CCI) generic vortexing test report (Reference 11). Reference 11 used testing at a range of flow rates and submergences to determine at what combination of parameters vortexing activity would be significant. The results are shown in a graph with Froude number on the abscissa, and Submergence on the ordinate. (Note: In this work Froude number is defined as velocity squared divided by the quantity of gravity multiplied by the strainer submergence.) A limit line is plotted on the graph to separate the range of conditions for which unacceptable vortices are predicted from the range of conditions having acceptable conditions – referred to in Reference 11 as the "Safe Domain."

   Figure A is a replica of the CCI graph obtained from Reference 11. The star plotted on this figure represents the condition of the Calvert Cliffs strainer for the case where the submergence is approximately 1 inch (0.0298 m) and the approach velocity is 0.027 m/s. This velocity represents the velocity of the fluid entering the module closest to the pump suction (i.e., peak velocity), and is obtained using the system of hydraulic resistance coefficients of the strainer internals described in the response to RAI 16. This velocity is obtained using the strainer flow rate of 5000 gpm multiplied by approximately 6.6 (see response to RAI 19e). As seen on Figure A the data point representing the minimum submergence condition at the nominal strainer flow rate of 5000 gpm is far to the left of the limit of unacceptable conditions, and is well inside the "Safe Domain." Figure A thus demonstrates that no significant vortexing activity would occur under these conditions.

b. Calvert Cliffs did not conduct any testing specifically for the purposes of observing vortex formation; however, observations for vortex formation were included in head loss testing. Our head loss testing did encompass the peak strainer module flow rate of 6.6 times the nominal flow rate, but it did not include minimum submergences. Submergences ranged between approximately 4 inches to approximately 14 inches.

c. The maximum postulated flow rate through the strainer module nearest the pump suction is approximately 6.6 times greater than the nominal strainer flow rate. This equates to a velocity of 0.027 m/s. The maximum flow rate during testing of 27.0 m^3/hr does bound this value. This peak flow rate was evaluated using Reference 11 (see response to RAI 17a), and was used in the head loss testing during the initial fiber and particulate debris additions.

d. Head loss testing was not conducted by Calvert Cliffs using the minimum submergence. Vortex formation was evaluated using Reference 11 as described in RAI 17a. The maximum postulated flow rate through the strainer nearest the pump suction for the case where a LPSI pump did not turn off upon receipt of a RAS was not considered in the analyses or testing. However, with a LPSI pump operating, the total strainer flow rate will be approximately double the nominal strainer flow rate of 5000 gpm. Doubling the peak velocity of 0.027 m/s computed by CCI would result in a Froude number of 0.01. Again, plotting on the graph CCI developed for assessing vortex formation this condition still results in being in the "Safe Domain" for vortex formation (see Figure B). Therefore, it was concluded that vortex formation would not occur even for the peak velocity at minimum submergence if a LPSI pump failed to turn off upon receipt of a RAS.

NRC RAI 18:

18. *RAI 15 of the staff's December 8, 2008 letter requested the licensee to discuss whether any significant sources of water drainage could enter the containment pool directly above or in the immediate vicinity of the strainer, and whether this drainage could result in significant splashing and/or disturbances at the containment pool surface and therefore lead to unacceptable air entrainment through the strainer surface. In addition, it asked the licensee to clarify whether the top surface of the strainer modules (i.e., the upper face of the cartridges) is perforated or solid plate. The licensee provided additional information on the installation of the strainer and how water drainage might fall into the containment pool near the strainer. The response stated that the top of the strainer is solid (not perforated). The licensee also stated that a majority of the strainer is covered so that break or spray flow could not impact the pool near those sections. However, the response indicated that portions of the strainer are not covered, and drainage from collected spray flow could fall directly onto these parts of the strainer. Because of the low submergence, please provide additional technical basis for the assertion that the drain flow could not result in unacceptable air entrainment into the strainer.*

CCNPP RAI 18 Response:

Calvert Cliffs has planned plant modifications to increase the strainer submergence. The new submergence is expected to be at least 24 inches for a large-break LOCA case, and at least 18 inches for small-break cases when safety injection tanks do not empty to the RCS. This increased submergence is sufficient to prevent air entrainment from containment spray drainage flow.

NRC RAI 19:

19. *In RAI 16, the staff requested the licensee to provide the results and methodology for the final strainer qualification testing for head loss and vortexing with a level of detail consistent with the information requested in the NRC staff's content guide for supplemental responses. The licensee provided additional information regarding the test methodology and results for the final strainer qualification testing. In general, the information provided indicates that the testing was conducted in accordance with staff guidance. However, figure 3f4-2 of the supplemental response appeared to show that the testing was conducted with a two-sided strainer. This figure does not correspond to figure 17-1 provided in the RAI response, which shows a single-sided strainer. In addition, the flow rate was reduced during the testing. It appeared that flow was reduced following the addition of non-chemical debris and before the addition of chemical debris. There were several changes in head loss as observed on the head loss plots provided with the RAI response (Figure 16-1) and the final supplemental response (Figures 3o2.26-1, 2, and 3). No explanations for the changes in head loss were provided. In addition, the staff could not determine what condition each of the three tests presented in section 3o represented. Please provide the following information regarding the testing:*

    a. *Please explain whether the test was conducted with a 2-sided strainer (i.e. with pockets facing away from each other discharging into a central plenum with the pump taking suction from that plenum). If the testing was conducted with a single-sided strainer questions 19.b through 19.d below do not require a response.*

    b. *Please explain how the debris amount that transports to each side of the strainer was determined.*

c. *Please provide the debris split between the two sides of the strainer and explain how debris was added to the test for each side.*

d. *Please provide photographs of the debris deposition on the rear strainer pockets and front strainer pockets and evaluate and differences in the amounts of debris deposited in the front and rear pockets.*

e. *Please provide the flow rates used during the testing and the basis for any changes in flow rates during testing. (e.g. why was flow rate reduced after non-chemical debris addition and before chemical precipitate addition?)*

f. *Please provide the maximum head loss attained with each debris load at each flow rate. Head losses during the final flow sweeps need not be provided.*

g. *Please provide the purpose for each of the tests presented, including differences in how the tests were performed to meet the expected plant conditions that the tests represented.*

h. *Please provide an explanation for significant head loss changes that occurred during the tests where it is not evident from the test plot that a debris addition was initiated, flow change was made, etc.*

i. *Please provide an evaluation of the sharp increase followed by a relatively rapid decrease in head loss following the initiation of sodium aluminum silicate addition.*

CCNPP RAI 19 Response:

a. The strainer head loss tests that provided the basis for Reference 1 were all single-sided tests.

   The NRC staff has correctly identified that Figure 3f4-2 shows a picture of a double-sided strainer, and therefore, this figure is not a completely accurate representation of the test loop configuration used for our design basis strainer head loss testing. Some earlier Calvert Cliffs head loss testing had been conducted using double-sided tests. The picture used in Figure 3f4-2 comes from this earlier testing.

   Figure 17-1 from Reference 10 clearly shows the single sided test configuration.

b. No response required.

c. No response required.

d. No response required.

e. The following flow rates were used during each of the strainer head loss tests. Each test flow rate is also distinguished by comparison to the test flow rate equivalent to the strainer nominal flow rate of 5000 gpm.

Table 19-1, Testing Flow Rates

Flow Rate (m^3/hr)	**Comparison to Nominal Flow**
27.0	6.6 x nominal
18.5	4.5 x nominal
15.3	3.7 x nominal
10.9	2.7 x nominal
4.1	1.0 x nominal

To ensure that the flow rates used during debris additions were conservative, Calvert Cliffs used the flow rates associated with the strainer module having the peak flow (i.e., the strainer module closest to the pump suction). As discussed in the response to RAI 17 above, in the clean strainer condition the module closest to the pump suction will have a peak flow rate which is 6.6 times greater than the nominal flow rate. Therefore, fiber and particulate debris was initially added at this flow rate.

As a debris bed builds on the strainer, the flow at the strainer module closest to the pump suction will decrease because the increased head loss associated with this debris bed will increase the overall friction resistance factor of this module so that it is equal to that of a larger portion of the other strainer modules. The flow rate through the strainer module closest to the pump suction will thus decrease. Therefore, once the head loss measured during testing reached a prescribed value, the flow rate in the test was then reduced (first reduction was to a flow rate equal to 4.5 x nominal value).

Fiber and particulate continued to be added in increments specified by the test plan (see RAI 20 below) until the head loss rose to the next prescribed value at which time the flow was reduced again (second reduction was to 3.7 times the nominal strainer flow rate). This was followed once again by adding fiber and particulate in the specified increments until the head loss reached a prescribed value at which time the flow was reduced to 2.7 times the nominal value. No further reductions in flow rate were implemented during the fiber and particulate addition.

The CCI calculation on CSHL (see response to RAI 16 above) is the basis for the head losses at which flow reductions were made, and the flows used in the test.

In reality, the flow rate at the module closest to the pump suction would not be reduced in a stepped manner as was done in the test, but would change continually as head loss increased. The flow rates and head losses were selected to approximate this curve similar to the use of Simpson's Rule in integral calculus.

As mentioned above the flow rate was at least 2.7 x nominal strainer flow throughout the addition of fiber and particulate which bounds the total strainer flow if a LPSI pump is operating at full flow.

As discussed earlier with the NRC staff, Calvert Cliffs assumes chemical precipitate formation will not occur until the sump temperature has been reduced to 140°F. Using design basis inputs, a sump temperature of 140°F will not be reached until more than five days after the start of the accident. Assuming a maximum cool down rate, this temperature would not be reached within five hours. In the time it takes to reach 140°F, the sump flow rate will be reduced to or below the nominal strainer design flow (see response to RAI 13d). Therefore, immediately prior to the addition of chemical precipitates the test flow was reduced to the equivalent of the nominal design flow rate to reflect this.

Figures C and D are Figures 3o2.26-2 and -3 (Reference 1) which have been annotated to show the flow changes described above. As described in RAI 19g, Figure 3o2.26-1 is no longer applicable due to a plant modification completed in March 2010. Note that some of the intermediate flows used in the test were not in effect for much more than 15 minutes. Compared to the time scale used in the head loss plots of Figures 3o2.26-2, -3 (Reference 1) this is a short period of time, and therefore, the Figures may not appear to reflect all flow changes.

f. Table 19-2 provides the maximum measured head losses for the debris cases of fiber/particulate only, and fiber/particulate with precipitate added. The nominal strainer flow is 5,000 gpm and this flow bounds the operation of both trains of HPSI and containment spray. A nominal strainer flow rate 13,500 gpm bounds the flow from the case where a LPSI pump failed to turn off upon receipt of a

RAS. Since the LPSI pumps would be secured prior to reaching a temperature of 140°F (see RAI 13d), the table does not include the case of a LPSI pump operating with chemical precipitates in the debris mix.

Table 19-2, Measured Head Loss

Debris Type	Test Flow	Equivalent Strainer Flow	Head Loss	Test No.
Fiber / Particulate	10.9 m^3/hr	13,500 gpm	22.9 mBar	7
Fiber / Particulate	4.1 m^3/hr	5,000 gpm	8.2 mBar	7
Add Precipitate	4.1 m^3/hr	5,000 gpm	694.1 mBar	6

g. The head loss testing which formed the basis of Reference 1 was performed from approximately the middle of October 2008 to the middle of December 2008. A total of seven tests were conducted.

Tests 1 and 2 were conducted per test protocol, however, it was determined that a test fixture allowed a non-prototypical debris bed "break-through" to occur when chemical precipitates were added. This resulted in non-conservative head loss results. Therefore, these tests were not presented in Reference 1.

Test 3 was conducted with the non-prototypical "break-through" eliminated by fixture redesign; however, the debris load did not represent the maximum debris load case. Therefore, this test was not presented in Reference 1.

Test 4 was performed for a trisodium phosphate dodecahydrate buffered plant, and was included in Reference 1. This test utilized a much higher amount of Temp-Mat insulation to reflect the condition of our Unit 1 plant at that time. During the 2010 Refueling Outage the Unit 1 buffer was changed to sodium tetraborate decahydrate (STB), and the major source of Temp-Mat insulation was replaced with Nukon insulation. Both Units at Calvert Cliffs now have STB as the sump pool buffer material, therefore, Test 4 is no longer applicable.

Test 5 was not conducted per test protocol as the strainer flow rate was not adjusted as specified. Therefore, this test was not presented in Reference 1.

Tests 6 was performed per test protocol using a debris load which bounded plant conditions (prior to issue identified in RAI 1) and considered a STB buffer. This test was presented in Reference 1.

Test 7 used somewhat higher debris loads than Test 6 to provide margin for future plant contingencies. This test was also presented in Reference 1.

Tests 2-7 were conducted in basically the same manner. Fiber and particulate debris were added in five increments each containing 20% of the total fiber and particulate debris load. The flow rate scheme described in RAI 19e was also used for each test. Once all fiber and particulate had been added, the flow was reduced to the nominal strainer flow prior to adding the chemical precipitate.

RAI 20a goes into detail on the debris addition sequence used for the thin-bed testing done as part of Test 1.

h. Significant variations of the head loss occurred for each test once the chemical precipitants were added to the test loop.

   In Tests 6 and 7 (STB buffer) the head loss spikes up to a maximum value about 2.5 hours after the start of chemical precipitate addition. Once the strength of the debris bed was reached a "break-through" in the debris bed occurred and the head loss fell at a precipitous rate. The head loss would increase again as the debris bed "healed," and this increase would be rapid; however, in both Tests 6 and 7 the secondary peaks never approached the head loss value obtained during the initial peak. Once all the precipitate had been added to the test tank the head loss would reach a steady-state value, and remain there until the loop had been agitated. Agitating the test loop resulted in re-suspension of the precipitate which in turn would cause a quick increase in head loss. These head loss increases show up as spikes as a "break-through" would occur shortly afterwards causing the head loss to decrease again.

i. As described in RAI 19h, the sharp increase is from the addition of the chemical precipitates, and the sharp decrease results from a "break-through" in the debris bed which occurred because the pressure differential exceeded the strength of the debris bed.

<u>NRC RAI 20</u>:

20. RAI 22 asked the licensee to identify the debris loading conditions for which the final strainer maximum head loss occurs and confirm that testing has been performed to verify that the strainer, when laden with a thin bed or maximum debris loading, would not result in unacceptable head losses. The licensee's response stated that the loading included theoretical fibrous debris loads from 0.10 inches to 1 inch. 50% of the particulate debris was added at the theoretical thickness of 0.10 inches and the remaining 50% of the particulate was added at the theoretical thickness of 0.15 inches. This is reasonable. However, the licensee did not provide all of the requested information for this issue, sufficient to confirm that head loss had been determined prototypically or conservatively. Please provide the following:

a. The results of thin bed test showing the head loss at the various debris loads from 0.10 to 1.0 inch theoretical bed thicknesses.

b. The masses for each type of debris added during the thin bed test, broken down into the amount included in each separate debris addition.

c. The mass of each debris type added to the maximum load tests.

d. The mass of chemical debris added during each chemical precipitate addition and the time at which the debris was added, or the window in which the precipitates were added if it was a continuous addition.

e. The scaling factor(s) used during the testing.

f. The test strainer area.

The staff considers that much of this information would be most easily presented on an annotated plot of head loss and flow during the testing in conjunction with a debris addition schedule for each test.

<u>CCNPP RAI 20 Response</u>:

a. The thin-bed testing was conducted as part of Test 1 (see RAI 19g). As described in RAI 19g, Test 1 was not presented in Reference 1 because of non-prototypical "break-throughs" during the maximum load/chemical precipitate portion of this test. However, the thin-bed portion of this test was conducted without incident, and the results and observations from this portion of the test were not compromised.

Table 20-1 provides the head loss at various debris loads ranging from 0.12 inches to 1.20 inches theoretical bed thickness. It should be remembered that the fiber-bed did not form uniformly on the test screen strainer so the bed thickness given below is theoretical. Also, the fiber started to protrude from the strainer pocket before all the fiber debris was added. Such behavior is not addressed by the theoretical bed thickness computations. Finally, for some steps, two flows are shown. This represents the flow reduction scheme discussed in RAI 19e.

Table 20-1, Head Loss vs Debris Load

Step	% Part.	% Fiber	Mass Fiber	Bed Thickness	Flow	ΔH_L
1	50%	10%	0.271 kg	0.12"	6.6 X 4.5 X	0.5 mBar 0.4 mBar
2	100%	15%	0.406 kg	0.18"	4.5 X 3.7 X	1.0 mBar 1.5 mBar
3	100%	20%	0.541 kg	0.24"	3.7 X 2.7 X	2.4 mBar 1.6 mBar
4	100%	30%	0.812 kg	0.36"	2.7 X	2.9 mBar
5	100%	40%	1.083 kg	0.48"	2.7 X	4.7 mBar
6	100%	60%	1.625 kg	0.72"	2.7 X	8.5 mBar
7	100%	80%	2.167 kg	0.96"	2.7 X	12.7 mBar
8	100%	100%	2.709 kg	1.20"	2.7 X 1.0 X	16.0 mBar 5.3 mBar

b. The masses of fiber and particulate used in the thin bed test (Test 1) are as follows:

1st Addition:
- 0.133 kg Epoxy Dust
- 0.995 kg Stone Flour (IOZ Coatings)
- 0.087 kg Nukon
- 0.106 kg Thermal Wrap
- 0.025 kg Temp-Mat
- 0.042 kg Generic fiber glass
- 0.011 kg Mineral Wool

2nd Addition:
- 0.133 kg Epoxy Dust
- 0.995 kg Stone Flour (IOZ coatings)
- 0.043 kg Nukon
- 0.053 kg Thermal Wrap
- 0.012 kg Temp-Mat
- 0.021 kg Generic fiber glass
- 0.006 kg Mineral Wool

3rd Addition:
- 0.043 kg Nukon
- 0.053 kg Thermal Wrap

0.012 kg Temp-Mat
0.021 kg Generic fiber glass
0.006 kg Mineral Wool

4th & 5th Addition:
0.087 kg Nukon
0.106 kg Thermal Wrap
0.025 kg Temp-Mat
0.042 kg Generic fiber glass
0.011 kg Mineral Wool

6th - 8th Addition:
0.174 kg Nukon
0.213 kg Thermal Wrap
0.049 kg Temp-Mat
0.083 kg Generic fiber glass
0.022 kg Mineral Wool

c. There were two full-load tests reported in Reference 1. The mass of each debris type for each test is as follows:

Test 6:
2.042 kg stone flour (IOZ coatings)
0.382 kg epoxy dust
0.889 kg Nukon
1.065 kg Thermal Wrap
0.455 kg Temp-Mat
0.530 kg Generic fiber glass
0.771 kg Mineral Wool

Test 7:
2.042 kg stone flour (IOZ coatings)
0.382 kg epoxy dust
0.926 kg Nukon
1.111 kg Thermal Wrap
0.341 kg Temp-Mat
1.149 kg Generic fiber glass
1.928 kg Mineral Wool

d. Chemical precipitate was added slowly and more or less uniformly over a several hour period and not in discrete increments. The masses added are as follows:

Test 6:
0.339 kg Sodium Aluminum Silicate added over approximately 5 hours.

Test 7:
0.418 kg Sodium Aluminum Silicate added over approximately 5 hours.

e. The scaling factor during the test was 282.25:1 based on the ratio of plant strainer area to test strainer area.

f. Two CCI cassettes having at total of 36 pockets were utilized in the strainer testing. The total test area was 1.87 m^2.

Net Positive Suction Head (NPSH)

NRC RAI 21:

21. *Please provide an evaluation of how the following phenomenon could affect the containment sump water level or state how they are accounted for in the current sump level calculation:*
    a. *water droplets in transit from the spray nozzles to the containment pool*
    b. *holdups on vertical surfaces due to condensation and filming*
    c. *holdups on horizontal surfaces*
    d. *shrinkage of water volume due to cooling of RCS inventory*

CCNPP RAI 21 Response:

a. The effects of water in transit from the Containment Spray nozzles to the sump pool, and the hold up of water due to condensation and filming are not explicitly accounted for in our water-level calculation. A layer of water of 1/16 in depth was assumed to hold-up over a surface area equal to the entire Containment cross-section.

   When performing the sump water level calculation, Calvert Cliffs did not include the RCS inventory in the sump pool water level calculation. This assumption is conservative based on the limiting pipe break locations. The only break that would result in the majority of the RCS inventory remaining in the RCS is a break at the top of the pressurizer. This is not a limiting break in terms of debris generation. This conservative assumption outweighs the effect of the items identified here. Also note that RAI 18 describes our efforts to increase the sump water level significantly.

b. See response to RAI 21a.

c. See response to RAI 21a.

d. The sump level calculation did not credit the expansion of water volume due to the heating of the refueling water tank inventory once it mixed into the sump pool. Therefore, this question only becomes applicable once the water temperature drops below the maximum refueling water tank initial temperature of 100°F. At these temperatures the Containment Spray flow would be secured, and the strainer flow would be 20% or less of the nominal strainer flow. Also, at these cooler temperatures additional sub-cooled margin becomes available. Therefore, the NPSH margin at sump pool temperatures below 100°F is not the limiting condition. Furthermore, with the containment spray pumps secured there is no longer the concern of air entering the strainer because of spray flow drainage near the strainer. Therefore, explicit accounting of sump pool shrinkage is not required.

NRC RAI 22:

22. *Please provide a summary of ECCS and containment spray pump NPSH margins at additional sump fluid temperatures. In particular, an evaluation of NPSH margins at elevated sump temperatures should be included. Please provide an explanation for the reason that the NPSH margins provided in the final supplemental response included margins for the LPSI pumps when the LPSI pump suction source is not generally considered to be the containment sump. Additional information*

regarding the margin for the containment spray pumps should be provided since these pumps are generally considered to take suction from the ECCS sump. The staff also noted an apparent typographical or calculation error in the table on page 28 of the updated supplemental response. That is, the margin for the LPSI pump at 120°F was listed as 8.9 ft while the difference between the $NPSH_A$ and $NPSH_R$ columns was 9.9 ft. Please include in the information provided an evaluation for all pumps taking suction from the ECCS sump. The information should include the full range of sump conditions and the limiting flow rates evaluated (including LPSI flow if applicable). If a time- or temperature-dependent head loss evaluation (e.g. delayed onset of chemical effects) was used for CCNPP, this effect should be evident in the information provided. (See RAI 23 below.)

CCNPP RAI 22 Response:

The maximum sump fluid temperature at which the NPSH margin analysis is performed is 212°F. At this temperature there is no sub-cooled margin, and NPSH available comes only from the static head of water. The NPSH margin is also analyzed at 140°F because this is the temperature at which chemical precipitates are assumed to form. A sub-cooled margin of 25.36 feet is included at this temperature. Increased head loss due to the effect of chemical precipitates is included in the 140°F cases as well. Table 22-1 does not consider the failure of a LPSI pump to stop upon receipt of a RAS as discussed in RAI 13. A LPSI pump could be used for hot leg injection at approximately 8 hours into the accident (See RAI 13b). Net positive suction head is evaluated at both the 212°F case (with no sub-cooled margin) and the 140°F case to ensure all possible scenarios are bounded.

Table 22-1, NPSH vs Sump Temperature

	Sump Temp.	Flow Rate	$NPSH_R$	Static Head	ΔH_L	Margin
HPSI Pump	212°F	620 gpm	19.5'	25.75'	4.2 ft	25.75-4.2-19.5=2.05'
HPSI Pump	140°F	620 gpm	19.5'	25.75'	27.36'	25.75+25.36-27.36-19.5=4.25'
LPSI Pump	212°F	250 gpm	10.0'	25.00'	<5'	25-5-10=10'
LPSI Pump	140°F	250 gpm	10.0'	25.00'	<29'	25+25.36-29-10=11.36'
CS Pump	212°F	1726 gpm	22.7'	25.92'	1.68'	25.92-1.68-22.7=1.54'
CS Pump	140°F	1726 gpm	22.7'	25.92'	24.84'	25.92+25.36-24.84-22.7 = 3.74'

Chemical Effects

NRC RAI 23:

23. *The licensee's October 23, 2009, submittal (Attachment 1, page 48) states that CCNPP conservatively assumes that aluminum will precipitate out as sodium aluminum silicate and will begin to affect head loss at sump pool temperatures between 140°F and 110°F. Please confirm whether all chemical precipitate was assumed to form at 140°F. If all precipitate was not assumed to form at 140°F, please provide a detailed discussion and justification regarding the amount of precipitate assumed to form as a function of temperature.*

CCNPP RAI 23 Response:

All chemical precipitate is assumed to form at 140°F (see response to RAI 19e).

For the strainer testing conducted in June/July 2010, Calvert Cliffs used Reference 9 to predict the worst-case material dissolution and precipitation profile for the duration of a LOCA. The results will be used for gradual application of chemical precipitate head loss over the accident duration. This approach will yield a more accurate representation of post-accident strainer operation and is expected to reduce early-accident strainer head loss.

The timing of the gradual corrosion and dissolution of Reference 9 materials will be considered. This method will address Limitation and Condition #3 in the Reference 9 Safety Evaluation regarding the release rate of metallic aluminum in the WCAP model compared to the release rate observed in ICET #1. The metallic aluminum release rate correlation included in the Reference 9 model metallic aluminum release will be modified to conservatively bound the ICET #1 aluminum release profile.

To conservatively predict the metallic aluminum release rate at Calvert Cliffs, the Reference 9 metallic aluminum release rate equation will be doubled. This doubled release rate correlation, which bounds the ICET #1 aluminum release profile, will be used in the Reference 9 model for Calvert Cliffs until one of the following conditions is met:

1. Fifteen days have elapsed. If this condition is met first, the unmodified aluminum release rate will be used for the remainder of the accident duration within the model or until the total aluminum release from metallic aluminum sources equals the maximum amount predicted by the unmodified Reference 9 release rate correlation whichever occurs first.
2. The total aluminum released from the metallic aluminum sources in the Calvert Cliffs Containment has reached the maximum amount predicted by the unmodified Reference 9 release rate correlation. If this condition is met first, no additional aluminum will be predicted to be released from metallic aluminum sources.

Using this methodology, the ICET #1 aluminum release results from metallic coupons will be conservatively bounded and the total amount of aluminum released and the total quantities of precipitates generated over 30 days will not change.

This enhanced Reference 9 model will be used to conservatively predict the material dissolution and precipitation profiles at Calvert Cliffs as a more representative chemical effects approach. This model is not intended to take credit for delayed formation of precipitates but rather to more closely model bed formation. The predicted plant strainer chemical effects head loss profile will be based on the results of this enhanced model, and will provide a strainer chemical effect head loss curve for the accident duration.

REFERENCES:

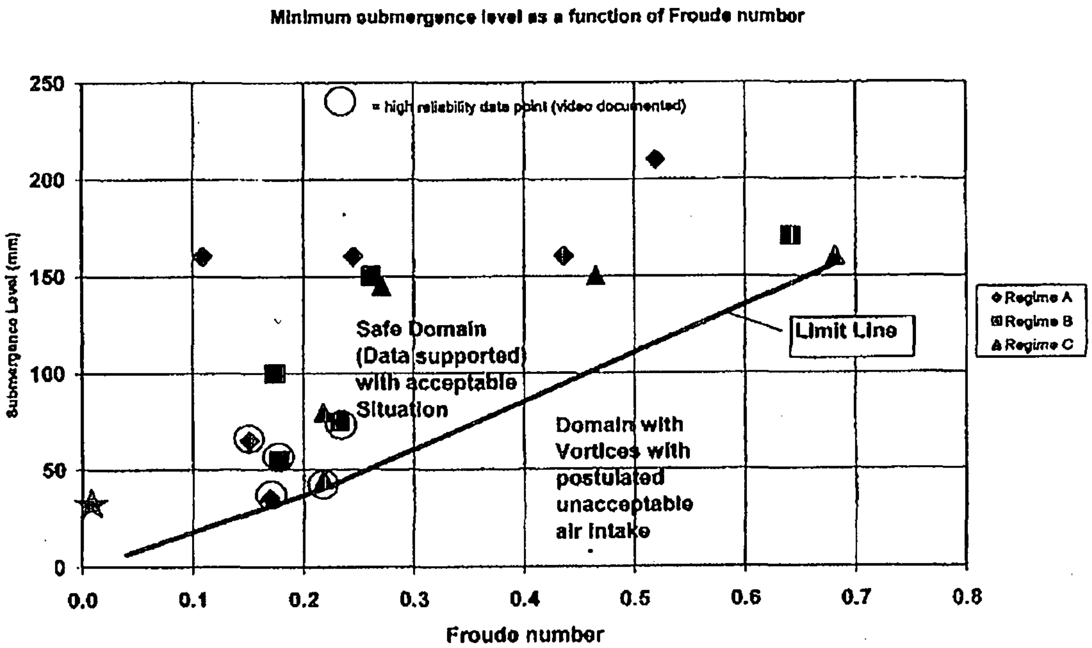
1. Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated October 23, 2009, Supplemental Response to Generic Letter 2004-02
2. ALION-REP-ALION-2806-01, Revision 4, Insulation Debris Size Distribution for Use in GSI-191 Resolution
3. Wyle Laboratories Report No. 54497R07, Revision B, dated August 31, 2007, Jet Impingement Test of Electromark Labels and Thermal and Fire Barrier Insulation
4. Sargent & Lundy Report Number SL-009195, Project No. 12105-506, Revision 0, dated November 9, 2007, Wyle Jet Impingement Testing Data Evaluation
5. ALION-CAL-AEP-3085-12
6. NUREG/CR-6916, dated December 2006, Hydraulic Transport of Coating Debris
7. Keeler & Long PPG Report No. 06-0413
8. Idlechik and Fried, Flow Resistance, a Design Guide for Engineers

9. WCAP-16530-NP-A, dated March 2008, Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Supports GSI-191

10. Letter from Mr. J. A. Spina (CCNPP) to Document Control Desk (NRC), dated March 4, 2009, Supplemental Response to Generic Letter 2004-02

11. CCI Report 680/41434, Revision 0, February 12, 2008, Vortexing Report for Clean Strainers

Figure A
CCI Generic Vortexing Analysis



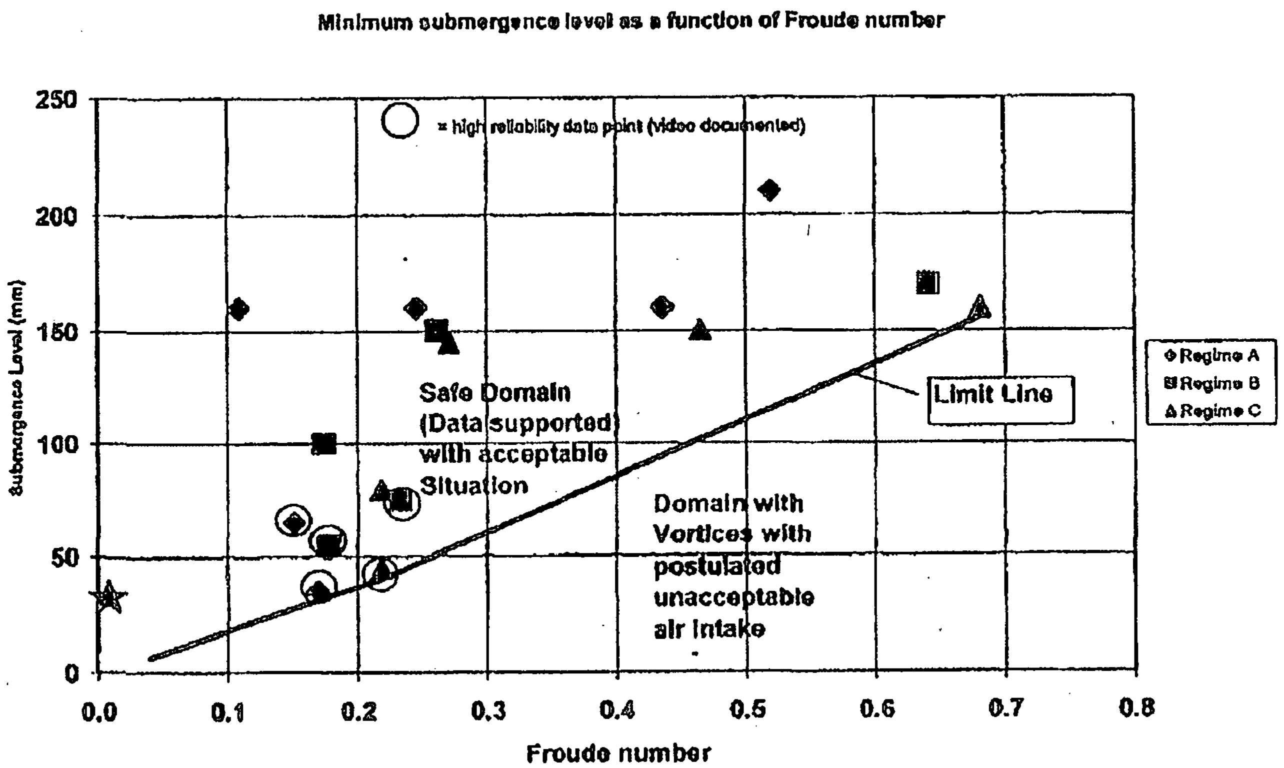
The Froude number definition is $Fr = v^2 / g / h$

Froude = $0.027^2 / 9.81 / 0.0298 =$ **0.0025**

Result is for strainer module having peak velocity during clean strainer condition. Result is for strainer flow having both trains of HPSI and Containment Spray Pumps.

Result identified by a ★.

Figure B
CCI Generic Vortexing Analysis



<u>Froude =</u> $(2x.027)^2 / 9.81 / 0.0298 =$ **<u>0.0100</u>**

Result is for strainer module having peak velocity during clean strainer condition. Result is for strainer flow having both trains of HPSI and Containment Spray, and one LPSI pump.

Result identified by a ★.

Figure C

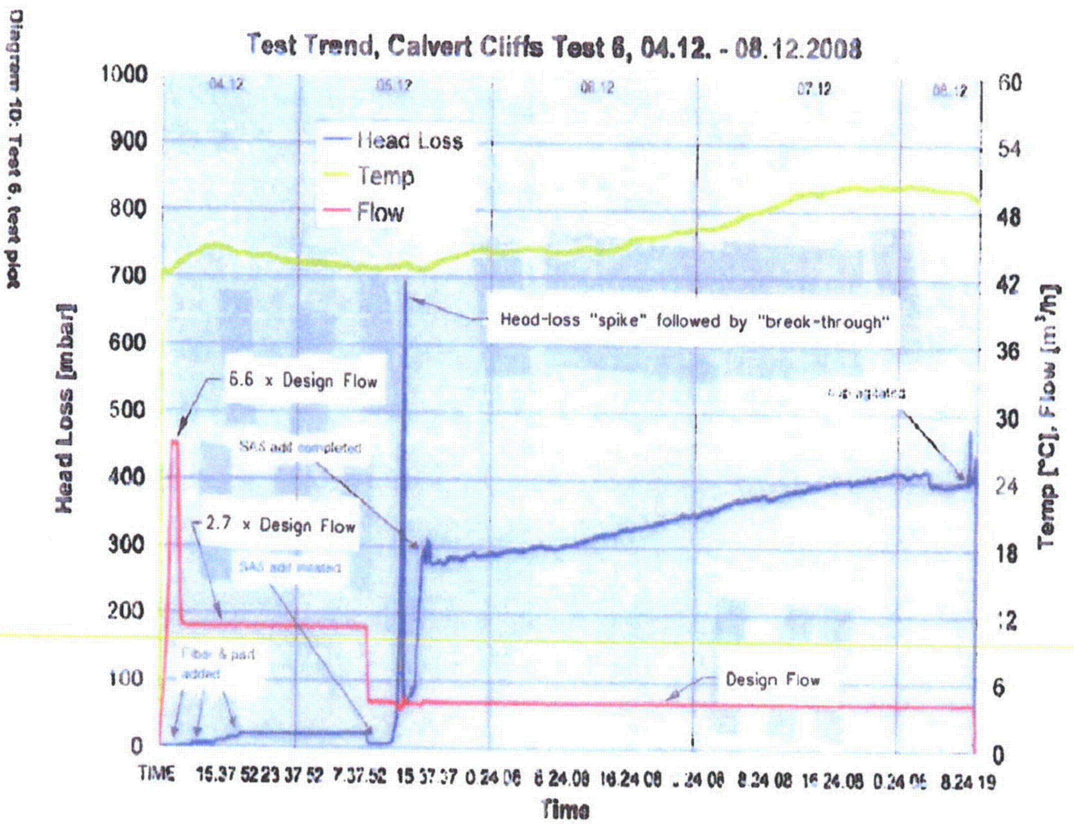


Diagram 10: Test 6, test plot
Test Trend, Calvert Cliffs Test 6, 04.12. - 08.12.2008
Head Loss
Temp
Flow
Head-loss "spike" followed by "break-through"
6.6 x Design Flow
2.7 x Design Flow
Design Flow
Head Loss [mbar]
Temp [°C], Flow [m³/h]
Time

Figure D

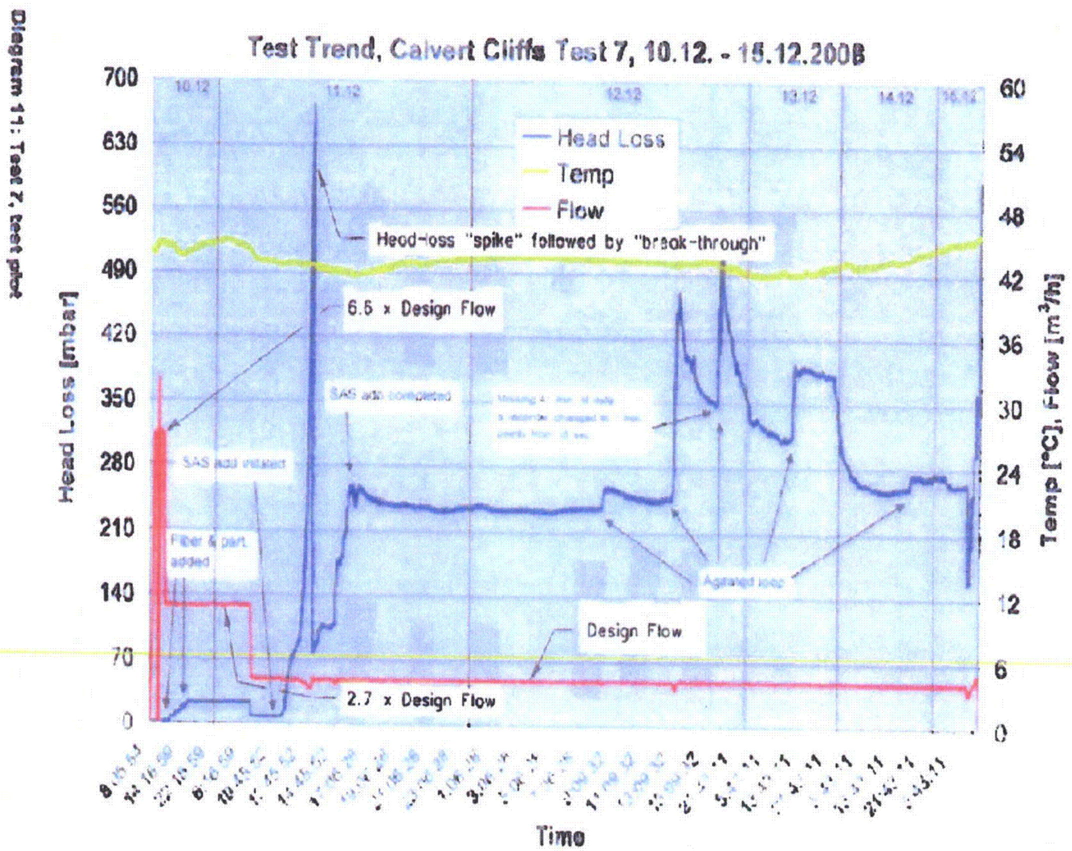
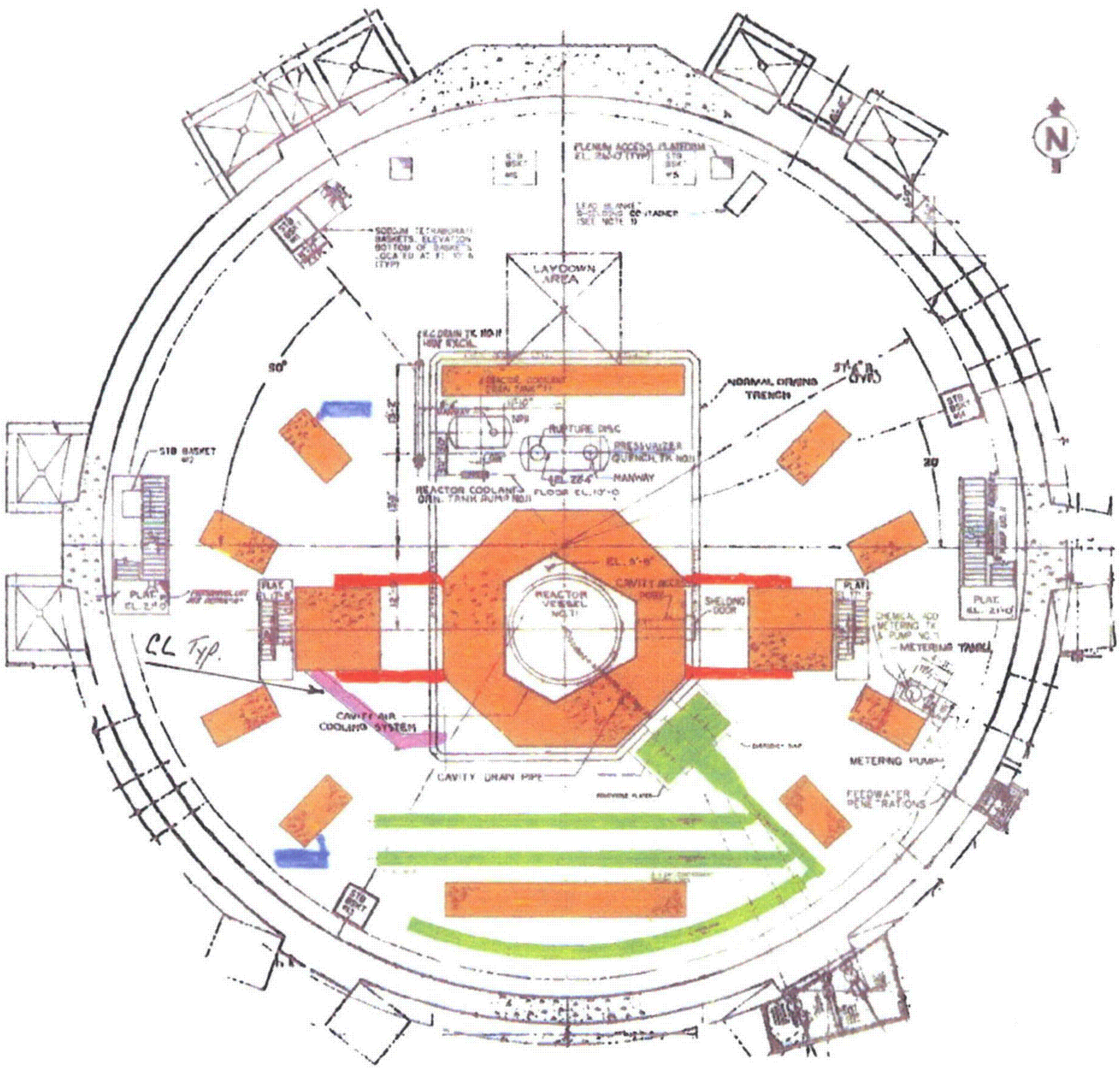


Diagram 11: Test 7, test plot
Test Trend, Calvert Cliffs Test 7, 10.12. - 15.12.2008
Head Loss
Temp
Flow
Head-loss "spike" followed by "break-through"
6.5 x Design Flow
2.7 x Design Flow
Design Flow
SAS add completed
SAS add initiated
Fiber & part. added
Agitated loop
Head Loss [mbar]
Temp [°C], Flow [m³/h]
Time
700
630
560
490
420
350
280
210
140
70
0
60
54
48
42
36
30
24
18
12
6
0

Figure E
Containment Floor Elevation



Note: Shaded areas indicate floor level obstructions.