UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 8, 2010

Vice President, Operations
Entergy Nuclear Operations, Inc.
Palisades Nuclear Plant
27780 Blue Star Memorial Highway
Covert, MI 49043-9530

SUBJECT: PALISADES NUCEAR PLANT – REQUEST FOR ADDITIONAL INFORMATION REGARDING ACTIONS TO ADDRESS GENERIC LETTER 2004-02 (TAC NO. MC4701)

Dear Sir or Madam:

Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," requested that all pressurized-water reactor licensees (1) evaluate the adequacy of the emergency sump recirculation function with respect to potentially adverse effects associated with post-accident debris and (2) implement any plant modifications determined to be necessary. Entergy Nuclear Operations, Inc. (the licensee), which operates Palisades Nuclear Plant, has conducted an evaluation of recirculation sump performance for Palisades.

On May 13, 2009, Nuclear Regulatory Commission (NRC) staff provided a report on results of NRC staff audit of chemical effects related actions to address GL 2004-02 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML091070664). In a letter dated June 30, 2009 (ADAMS Accession No. ML091890430), Entergy provided proprietary information to support follow-up supplemental response to GL 2004-02.

On December 24, 2009, the NRC staff requested additional information from the licensee in e-mails (ADAMS Accession Nos. ML100050602, ML100050587, and ML100050623). There was a teleconference held between the NRC staff and your representatives on January 20, 2010, to discuss this information. The licensee requested clarifications on some of the NRC staff questions. As a result of this discussion, there was a follow-up teleconference held on January 28, and the revised request for information was sent to the licensee in an e-mail on February 16 (ADAMS Accession No. ML100492055). On February 22, 2010, there was another teleconference held with NRC staff to discuss vendor testing and the path forward to complete this effort. The enclosure provides the finalized version of the request for additional information (RAIs).

During the discussions, a general consensus was reached to schedule an agenda call to discuss some of the RAIs and the remainder of the information to be resolved during a public meeting. This was determined to be the most effective way of resolving the issues related to GL 2004-02. The licensee has also agreed to provide the resolution to the requested information a week in advance of the agenda phone call to provide the NRC staff enough time to evaluate the information to be provided by the licensee.

Please provide the dates for the agenda teleconference and the public meeting and the response to the enclosed RAIs in a timely fashion as discussed above. In case of any further questions or concerns please feel free to contact me at 301-415-8371 or Mahesh.chawla@nrc.gov.

Sincerely,

Chawla ML

Mahesh L. Chawla, Project Manager
Plant Licensing Branch III-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-255

Enclosure:
As stated

cc w/encl: Distribution via ListServ

Palisades
Request for Additional information for resolution of issues relating to Generic Letter (GL) 2004-02

A. Break selection

1. Entergy Nuclear Operations, Inc. (the licensee) stated in its submittal dated June 30, 2009, that the break selection process was re-performed after fibrous debris zones of influence (ZOI) were reduced. However, the licensee further stated that after a significantly large fiberglass component was identified, deference was given to evaluating breaks for other debris sources. The Nuclear Regulatory Commission (NRC) staff cannot determine from this information whether the break selection was conservative. Please verify and justify that the break selection process identified the break that results in the maximum potential fibrous debris load and that this debris load was considered in the remaining portions of the head loss evaluation.

B. Debris generation/zone of influence (ZOI)

Note: Questions 2 through 9 below are being addressed in whole or in part by the Pressurized Water Reactor Owners Group. The NRC staff expects the degree to which the Owners Group is able to generically resolve these issues to be clear by the time the licensee's responses to these requests for additional information (RAIs) are due. As appropriate, the licensee may respond to these RAIs with reference to NRC staff official correspondence on resolution of the staff's questions of the Owners Group. In any event, some of the questions will need a plant-specific response.

2. The supplemental response dated June 30, 2009, credited a reduced ZOI for low-density fiberglass. Please describe the jacketing/insulation systems used in the plant for which the testing was conducted and compare those systems to the jacketing/insulation systems tested. 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. How did 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. Was the insulation and jacketing system used in the testing of the same general manufacture and manufacturing process as the insulation used in the plant? If not, 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.

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 Westinghouse Commercial Atomic Power (WCAP) reports the licensee used to justify reduced ZOIs. 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.

4. 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.

a. Was the analysis based on initial conditions (temperature) that matched the initial test temperature? If not, please provide an evaluation of the effects of any differences in the assumptions.

b. Was the water subcooling used in the analysis 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. How was the associated debris generation test mass flow rate determined? If the experimental volumetric flow was used, then 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, then 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, how was the transient behavior considered in the application of the ANSI/ANS-58-2-1988 standard? Specifically, did 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, 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.

5. 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. What were the assumed plant-specific reactor coolant system (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. What was the calculational method used to estimate the plant-specific and break-specific mass flow rate for the postulated plant loss-of-coolant accident (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, what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections? Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

6. 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. How was the fact that the fluid near the nozzle was colder than the bulk fluid accounted for in the evaluations?

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

c. What was the specified rupture differential pressure of the rupture disks?

7. If the application of the reduced ZOI is applied to components other than piping, please respond to this question. 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 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. One WCAP reviewed asserts that a jet cannot directly impact the steam generator, but will flow parallel to it. It seems that some damage to the SG insulation could occur near the break, with the parallel flow then jetting under the surviving insulation, perhaps to a much greater extent than predicted by the testing. Similar damage could occur to other component insulation. 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.

8. 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.

9 At least one WCAP noted damage to the cloth blankets that cover the fiberglass insulation in some cases resulting in the release of fiberglass. The tears in the cloth covering were attributed to the steel jacket or the test fixture and not the steam jet. It seems that any damage that occurs to the target during the test would be likely to occur in the plant. Was the potential for damage to plant insulation from similar conditions considered? For example, the test fixture could represent a piping component or support, or other nearby structural member. The insulation jacketing is obviously representative of itself. What provides the basis that damage similar to that which occurred to the end pieces is not expected to occur in the plant? It is likely that a break in the plant will result in a much more chaotic condition than that which occurred in testing. Therefore, it would be more likely for the insulation to be damaged by either the jacketing or other objects nearby.

C. Debris Characteristics

10. In RAI 2 from the NRC's letter dated December 24, 2008 (ADAMS Accession No. ML083450689), the NRC staff requested information concerning debris characteristics for several debris sources listed in the February 27, 2008, supplemental

response to GL 2004-02. The licensee responded in the June 30, 2009, supplemental response. However, the NRC staff has the following questions remaining on this response.

a. Please provide the basis for concluding that exposure of unjacketed fibrous material to containment spray will not result in the generation of debris.

b. Please provide the basis for concluding that pieces of Marinite debris will not transport to the strainers or erode in the post-LOCA containment pool. Although Section 4.2.2.2.5 of NEI 04-07 states that Marinite can be assumed to be broken into large chunks, the NRC staff could not determine that NEI 04-07 or the accompanying safety evaluation provides a basis for concluding that this Marinite is not susceptible to transport or erosion. The NRC staff has seen results from testing demonstrating that Marinite does erode when submerged and exposed to flow.

11. In RAI 3 from the NRC's letter dated December 24, 2008, the NRC staff requested that the licensee discuss any changes that have been made to the licensee's analysis that are associated with debris characterization at a level of detail consistent with the NRC supplemental response content guide. The licensee responded in the June 30, 2009, supplemental response by providing tables of debris quantities for each break. Although knowing the debris quantities is helpful, it is unwieldy to compute the percentages of debris in each size category for each ZOI subregion for each break. Since the percentages are the most important aspect of determining the adequacy of treatment of debris characterization, please provide the percentages of debris assumed in each category within the ZOI or ZOI subregion, as applicable.

12. In RAI 4 from the NRC's letter dated December 24, 2008, the NRC staff requested that the licensee provide debris characteristics information for Alpha Maritex insulation. The licensee responded that characterization information for this debris was obtained from WCAP-16727. The licensee summarized WCAP-16727 as stating that from 10-25 percent of the material would be characterized as small pieces and fines, and further stated that the debris would readily settle and would not transport in the containment pool based in part on a comparison to paint chip transport test data and an experiment in the head loss test flume at Alden Research Laboratory. The NRC staff did not consider this response to be adequate for the following reasons: (1) it was not clear that the debris generation testing discussed in WCAP-16727 was adequately scaled to collect debris characterization information, (2) it was not clear that comparison of Alpha Maritex (a fibrous material) to paint chips is valid with respect to debris transport properties, (3) it was not clear that the transportability of Alpha Maritex fines was addressed by the licensee, and (4) as discussed in a subsequent RAI, it is not clear that the "averaged" flow conditions simulated in the head loss testing for Palisades were prototypical or conservative with respect to the plant condition. Please address the above issues regarding the Alpha Maritex insulation.

13. The assumed debris size distribution of 60 percent small fines and 40 percent large pieces for jacketed Nukon and Thermal Wrap within a 5D ZOI is inconsistent with Figure II-2 of the NRC staff's SE dated December 6, 2004 (Agencywide Documents

Access and Management System (ADAMS) Accession No. ML043280007), 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 in the vicinity of 18-19 pounds per square inch (psi). At 5D (5 times the pipe diameter), the jet pressure is close to 30 psi, which significantly exceeds this threshold. Furthermore, the licensee's assumption that the size distribution for debris in a range of 5D to 7D is 100 percent intact blankets also appears to be inconsistent with existing destruction testing data. These assumptions for the jacketed Nukon and Thermal Wrap debris size distributions appear to be based on the recent Westinghouse/Wyle ZOI testing discussed in WCAP-16710-P. However, that testing was not designed to provide size distribution information, and much of the target material was exposed to jet pressures much lower than would be expected for a prototypically sized break. Furthermore, given the assumption that insulation between 5D and 7D is 100 percent intact pieces that do not transport or erode, the licensee has effectively assumed a 5D ZOI rather than a 7D ZOI for jacketed Nukon and Thermal Wrap. In light of this information 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 5D ZOI to be conservative or prototypical, as well as the distribution of 100 percent intact pieces in a 5D to 7D ZOI subregion.

14. The June 30, 2009, supplemental response appeared to indicate that only 50 percent of the calcium silicate within a 5.45D ZOI was assumed to be destroyed into small fines. The other 50 percent of the calcium silicate within this ZOI was assumed to remain intact following the impact of the LOCA jet. The assumed size distribution appeared to be based on OPG testing for which less than 50 percent of the target calcium silicate was damaged by jet impingement. Please address the following items concerning the assumed calcium silicate debris distribution:

    a. Significant portions of the target insulation in the OPG tests were not exposed to jet forces representative of the calculated ZOI. In other words, the insulation targets used for testing were so long (48 inches) that, due to the small size of the jet nozzle (2.86 inches), a significant portion of the insulation targets was not subjected to destruction pressures prototypical of a complete rupture of RCS piping. In addition, some OPG tests demonstrated the occurrence of insulation damage at distances in excess of that corresponding to a spherical 5.45D. Although a 5.45D ZOI was accepted for calcium silicate based on the OPG testing, the NRC staff's safety evaluation on NEI 04-07 conservatively recommended that 100 percent of the calcium silicate within a spherical 5.45D ZOI be assumed to be destroyed into small fines, which compensated for these test setup issues. Thus, please justify assuming a 5.45D ZOI with 50 percent intact pieces in light of the information presented herein.

    b. Please identify the jacketing and banding, latching, etc., of the calcium silicate insulation at Palisades and compare this insulation material to the material that was tested by OPG to support the assumed debris characterization of 50 percent intact pieces based on the application of the OPG test results. Please also compare the manufacturing process for the calcium silicate at Palisades with that

used for the OPG testing (i.e., hydraulically pressed or molded – see Section 3.3.3 of Indian Point Audit Report).

c. The 50 percent of the calcium silicate considered to be undamaged was not considered for potential erosion and transport to the strainer. However, for a number of the OPG tests, the insulation jacketing was removed, even when the base insulation material was not completely removed from the pipe. In light of the removal of the jacketing in a number of tests, please justify that erosion of the calcium silicate remaining on pipes need not be considered.

D. Debris Transport

15. The licensee's June 30, 2009, supplemental response stated that large pieces of debris were assumed to be retained on the 608′6″ elevation (EL) rather than transporting to the 590′ EL. The licensee's response added that it was ultimately inconsequential whether the large pieces were retained on the 608′6″ EL or washed down to the 590′ EL, since direct transport to the strainer would not occur in either case, and an equivalent degree of erosion would occur regardless of the elevation on which the debris was assumed to settle. It was not clear to the NRC staff that it was inconsequential whether large pieces remained on the 608′6″ EL or transported to and settled on the 590′ EL. In particular, the NRC staff expected that the flow conditions (e.g., velocity and turbulence) on these two elevations could be significantly different, thereby leading to different percentages of eroded debris. In particular, the NRC staff expected that erosion would be more severe on the 608′6″ EL because: (1) shallow pools exist, (2) there is significant potential for break and/or spray drainage to create high-velocity and high-turbulence flow conditions, and (3) the potential exists for direct exposure to break and/or spray drainage flows. It is not clear to the NRC staff that flow conditions of this sort are bounded by industry erosion testing conducted with significant submergence, no direct exposure to drainage flow, and relatively low velocity and turbulence values, and how this potential discrepancy has been addressed in the licensee's strainer performance evaluation. Therefore, please identify the range of water velocity and turbulence levels expected on the 608′6″ EL, the expected water depth, as well as the basis for concluding that an equivalent degree of erosion would occur for debris retained on the 608′6″ EL as would occur on the 590′ EL considering the industry erosion test conditions and results. As applicable, please also provide similar discussion for any other locations where significant debris holdup was credited for which erosion may occur under similar conditions to that applicable to the 608′6″ EL (e.g., the stairwells leading from the 608′6″ EL to the 590′ EL).

16. Although the licensee's June 30, 2009, supplemental response quoted a statement in NUREG/CR-2982 indicating that mineral wool can remain afloat for extended periods of time, it did not appear that the licensee had accounted for the potential for floatation adequately in the following two respects:

a. No basis was presented to justify the assumption that no large pieces of mineral wool would be capable of transporting over the 6-inch curb, in part due to floatation by virtue of trapped air.

b. No basis was presented to justify that no large and small pieces of mineral wool would be capable of transporting to the strainers, in part due to floatation by virtue of trapped air. Although strainer testing was performed with mineral wool debris, based on the PCI test procedure, this material was thoroughly soaked with water, and thus the potential for transport by floatation was not examined.

Please provide additional information to justify the assumption regarding flotation of mineral wool, considering the above.

17. The June 30, 2009, supplemental response provided cumulative erosion percentages for frangible debris in Table 3e4. Several values in this table in the copy of the document available to the NRC staff in ADAMS Accession No. ML091820275 were illegible. Please provide another copy of Table 3e4 that can be clearly read. Please also provide a description of any testing performed to support the assumed erosion percentages for debris pieces in the containment pool or other areas of containment where erosion was assumed to occur (e.g., 608'6" EL, stairwells, etc.). Please specifically include the following information:

a. Please describe the test facility used for any erosion testing and demonstrate the similarity of the flow conditions (velocity and turbulence), chemical conditions, and fibrous material present in the erosion tests to the analogous conditions applicable to the plant locations where erosion could occur.

b. Please identify the duration of the erosion tests and how the results were extrapolated to the sump mission time.

c. Please provide a basis for adding debris attributed to erosion processes after the addition of small debris pieces. The addition of fines after small pieces is not consistent with previous debris sequencing discussions for the Performance Contracting, Inc. (PCI) test protocol or the NRC staff's March 2008 head loss review guidance. In addition, some industry test results have suggested that erosion occurs to a significant extent relatively soon after debris pieces are exposed to flow.

Although the June 30, 2009, supplemental response provided discussion intending to demonstrate that sufficient margins existed in the licensee's strainer performance analysis to bound the quantity of fibrous fines that would be associated with explicitly analyzing the erosion of small pieces of fibrous debris settling in the test flume, the NRC staff did not consider the margins discussed to be sufficient based on the following reasons:

Although the analytical transport calculation did not credit the settlement and holdup of fine debris, the NRC staff considers that the head loss testing permitted substantial credit for fine settlement.

Based on the flume velocities used for the licensee's head loss testing, the NRC staff expected that a significant majority of the small pieces of fiber added to the test would not have reached the strainers.

Based on the test scaling leading to denser debris piles in the test flume than expected for prototypical plant conditions and the fact that the small pieces of debris added to the test had been mechanically shaken to release loosely attached fibers, the NRC staff expected that the actual erosion in the test flume would be very small and would not be representative of erosion under plant conditions.

It was not clear to the NRC staff that significant credit could be taken for the capture of fines in inactive volumes based on the accepted guidance positions that a significant fraction of the fines would tend to be distributed to upper containment during blowdown, and that inactive volumes would be filled early in the event, prior to the completion of the bulk of debris washdown.
It was not clear to the NRC staff that significant retention credit could be taken for small pieces in upper containment, since small pieces of debris are considered to be of a size small enough to pass through gratings. Based on NRC-sponsored washdown tests, it was recommended that retention credit on gratings not be taken on debris smaller than the size of the grating opening. It is not clear to the NRC staff that sufficient retention credit is appropriate for other locations in upper containment.

18. The June 30, 2009, supplemental response states that flow pathlines and velocity isocontours were used to identify isolated eddies that had velocities higher than the incipient tumbling velocity but did not contribute to debris transport from the zone. A plot that appears to show minimal trapping in eddies enclosed by or connected to transporting isocontours for a sample case was included in the supplemental response, but it was not clear whether this behavior is also characteristic of the limiting design case. Therefore, for the limiting design basis conditions, please either demonstrate that minimal credit for hold-up in such eddies was taken, or else identify the types and quantities of debris assumed to be trapped in eddies of this sort, and provide the basis for not considering debris assumed to be present in these areas at the switchover to recirculation as transporting to the strainers considering the following points:

    a. Even in steady-state flow problems, chaotic perturbations result in variance in the solution that will alter the flow pattern in isolated eddies and allow fluid and debris elements in these eddies to escape as time progresses (or the number of computational iterations increases).

    b. Sophisticated turbulence models are expected to be necessary to accurately predict the behavior of eddies if they are credited with the retention of debris. Please discuss the fidelity of the turbulence model used in the computational fluid dynamics (CFD) code and discuss whether the converged solution was run further and checked at various intervals after convergence was reached to demonstrate evidence of the stability of any eddies credit debris hold up.

    c. Suspended phases and floor-transporting debris do not precisely follow streamlines of fluid flow. Phase slip can be particularly significant when the streamlines exhibit significant curvature, such as in an eddy.

    d. There are significant uncertainties associated with modeling blowdown, washdown, and pool fill transport mechanisms. The initial debris distribution at switchover can vary significantly.

19. Please provide cumulative transport percentages for each type of debris that are integrated over all regions of the containment pool for the limiting design basis case. Please specify for which break the results are applicable.

20. The June 30, 2009, and February 27, 2008, supplemental responses indicate that a blowout panel has been installed to impede air flow into the air room while simultaneously preventing water hold up. The NRC staff noted that the transport analyses for Palisades appeared to have been performed with the air room door closed (NRC staff could not determine whether this referred to the blowout panel or another door). Please clarify whether this assumption refers to the blowout panel or another door, and additionally confirm that the assumption of the air room door being closed either results in conservative debris transport results or is a valid assumption.

21. The NRC staff understood that the head loss testing conducted by PCI modeled flow conditions during the recirculation phase of a LOCA and modeled all debris (other than a fraction of the latent debris added with the recirculation pump stopped) as entering the containment pool one flume-length (nominally 30 feet) away from the containment sump strainers. Flow conditions during the pool-fill phase of the LOCA were not modeled in the testing, nor was the potential for debris to enter the containment pool closer than one flume-length from the strainer due to the effects of blowdown, washdown, and pool fill transport. The lack of modeling of these two transport aspects of the head loss testing appeared to result in a non-prototypical reduction in the quantity of debris reaching the test strainer and, ultimately, non-conservative measured head loss values. This is a significant issue because of the large settlement credit allowed during the head loss test. Please provide the technical basis for not explicitly modeling transport modes other than recirculation transport, considering the following points:

    a. As shown in Appendix III of he NRC staff's SE on NEI 04-07, containment pool velocity and turbulence values during fill up may exceed those during recirculation, due to the shallowness of the pool. Some debris that would not transport during recirculation may transport during the pool-fill phase. In addition, latent debris on the containment pool floor could be stirred into suspension by these high-velocity, turbulent flows, unlike the latent debris added to the quiescent PCI flume.

    b. The pool fill phase will tend to move debris away from the locations where it washes down to the 590' EL, and a fraction of this debris would be moved nearer to the recirculation sump strainers.

    c. Representatively modeling the washdown of some fraction of the debris nearer the strainer than one flume-length away would be expected to increase the quantity of debris transported to the strainer and the measured head loss, since a shorter flume would offer less opportunity for debris to settle. This statement applies both to debris that tends to settle in the head loss test flume, as well as debris considered to settle analytically.

22. Please discuss any sources of drainage that enter the containment pool near the containment sump strainers (i.e., within the range of distances modeled in the head loss

test flume) and identify their locations and flow rates. Please identify whether the drainage would occur in a dispersed form (e.g., droplets) or a concentrated form (e.g., streams of water running off of surfaces). Based on the June 30, 2009, supplemental response, it appears that sources of drainage were not modeled in the head loss test flume. The NRC staff expects that the lack of modeling of these drainage sources led to non-prototypically low transport results in the test flume. Therefore, please provide contour plots of the calculated turbulence (which include a numerical scale with units) for the CFD calculation for the test flume and compare it to that for the full-containment plant CFD calculation. The NRC staff does not consider the licensee's theoretical arguments supporting a higher level of turbulence in the linear flume as compared to the plant to be convincing in light of CFD comparisons for other plant conditions to flume flows at corresponding velocities that have typically shown the plant condition to experience significantly higher turbulence.

23. The June 30, 2009, supplemental response described the licensee's methodology of averaging velocities along different approaches to the strainer modules in order to determine the flow conditions for the head loss test flume for the Palisades strainer testing. During the chemical effects audit for Palisades, the NRC staff also considered this methodology based on the more detailed descriptions and results from the CFD modeling report. Based on this information, the NRC staff considered the licensee's methodology for determining the head loss test flume flow conditions as lacking adequate justification and appearing non-conservative. In particular, the average velocities calculated for a number of the cases and configurations included approaches to the strainer that experienced relatively little flow of water and debris. The velocities associated with these relatively stagnant approaches that appeared to have little impact on debris transport to the strainer were arbitrarily weighted equally with higher velocity pathways by which the majority of the water flow and generated debris appeared to reach the strainers. This practice appeared to result in non-prototypically low flume velocities for strainer testing, leading to increased debris settling and lower head losses than expected for the plant condition. Therefore, please provide the following information to justify the velocities chosen for the head loss test flume:

    a. Velocity contour plots for the containment pool, including close-up plots in the vicinity of the strainers, as well as a table of the velocities used in the head loss test flume for comparison.

    b. Justification for weighting stagnant approaches to the strainers, along which little debris transport occurs, equally with high-velocity approaches by which the majority of debris transports to the strainers.

24. In RAI 13 from the NRC's letter dated December 24, 2008, the NRC staff requested information regarding the postulated single failure of a low-pressure safety injection (LPSI) pump to automatically trip following receipt of a recirculation actuation signal. After reviewing the licensee's response in the June 30, 2009, supplemental response, the NRC staff did not consider the issue fully addressed with respect to debris transport for the following reasons: (1) modeling the failure of a LPSI pump to trip automatically would likely lead to additional debris transport in the head loss test flume, as well as in the analysis, (2) the NRC staff expects that the transport of additional fines and/or small

pieces would have increased the head loss for the Palisades design basis test, and (3) it is not likely that the LPSI pump flow would be terminated in time such that the transport effects from this flow can be completely neglected. The supplemental response argues that 15 minutes is an appropriate time for crediting remote operator actions to ensure that the LPSI pump flow is terminated. However, because the failure mechanism and necessary recovery action (e.g., tripping the pump breaker or remotely tripping the pump) would not be known ahead of time, based on the information provided by the licensee, it was not clear to the NRC staff that the remote operator actions could reasonably be accomplished in 15 minutes. It is not clear, for example, that the first remote operator action would be successful for all potential failure modes, or that applicable procedures include sufficiently detailed guidance for the operators. Please provide additional information to address the NRC staff's concerns and state how much time is required for one turnover of the containment pool volume in the case of a LPSI pump failure to trip.

E. Head Loss and Vortexing

25. In RAI 13 from the NRC's letter dated December 24, 2008, the staff asked for information regarding the single failure of a LPSI pump to trip at the time of switchover to recirculation, or to be restarted during the event. This issue was not fully addressed in the supplemental response with respect to the affect on head loss and vortexing. The licensee stated that the emergency operating procedures have been revised to remove the steps that directed restarting the LPSI pump, and the licensee evaluated the overall head loss associated with a running LPSI pump. The evaluation was acceptable except that it did not address the potential for additional transport to the strainer (as discussed above) if head loss testing had been conducted with the higher flow rate.

    Please provide the assumptions of the analytical evaluation and its results, with adequate bases for the assumptions, and verify that the results do not affect the head loss evaluated both for the short-term LPSI pump run duration and for the mission time of the strainer. In addition, please verify that the higher LPSI flow rates would not result in air entrainment (vortexing or deaeration) either at the strainer or the ECCS pump suction pipe in the sump due to the potentially higher head losses if the level behind the strainer were drawn down into the sump. Also, please verify that the strainer testing conservatively represented the flow velocities near the strainer under the LPSI failure-to-trip scenario or provide information that shows that testing contained adequate representation of the flows under this condition.

26. Some subparts of the licensee's response to RAI 14 from the NRC's letter dated December 24, 2008, were not responded to satisfactorily, as follows.

    a. 14.e: Debris preparation and introduction methods.

        The licensee provided the debris preparation and introduction methods. The NRC staff observed issues with the debris preparation and introduction during the review of test video. The Palisades supplemental response stated that some of the fines were removed from the small fibrous debris prior to addition to the test flume. The PCI method of removing these fines from the smalls is to shake the smalls on a shaker table. The NRC staff does not believe that this is

conservative or prototypical of plant debris as some fines are likely contained in small fibrous pieces. The removal of the fines from small pieces for testing may be non-conservative when compared to the plant condition. The licensee should provide justification that the removal of the fines from the small fibrous debris prior to the introduction of smalls into the flume is prototypical or conservative with respect to debris that would be generated in the plant. Additionally, the licensee should provide information that justifies that debris used in the testing was prototypically sized. Please provide information that justifies that the debris introduction sequence did not non-conservatively affect transport during testing.

b. 14.g: The February 27, 2008, supplemental response states that containment accident pressure was not credited in evaluating flashing across the strainer. However, the submergence of the strainer is small when compared to the strainer head loss. In the supplemental response the licensee's discussion of air ingestion into the strainer is not well supported. The licensee stated on Page 41 that the NUREG/CR-6224 correlation indicates 0.0 percent void fraction downstream of the screen. This statement does not appear correct, particularly in light of the statement on Page 46 of the supplemental response that no containment accident pressure was credited in the flashing calculation. The bases for the conclusion that flashing will not occur should be provided.

The licensee provided updated information on the potential for flashing across the debris bed. Upon further review of the strainer design, the NRC staff believes that, since the strainer is vented to the atmosphere, flashing will not occur across the debris bed. The exception to this is if the water height in containment exceeds the elevation of the strainer vents. This could occur because the vents are relatively low in elevation. The vents are about 2.2 ft above the top of the strainer. Therefore if debris head loss is maintained less than 2.2 ft, flashing should not occur. The strainer design limits debris head loss to 1.57 ft. If this design parameter is not changed flashing will not occur. Please provide the maximum LOCA flood level and verify that the vent is not covered or evaluate the potential effects on deaeration and flashing.

New Head Loss & Vortexing Issues based on the Palisades Chemical Effects Audit

27. (Audit Open Item 6.1) The licensee should provide a justification that Test 4 resulted in a realistic or conservative head loss for the strainer. Specifically, the licensee should provide additional information that justifies that a change in strainer hole size from 0.045 inches (Test 2, high head loss) to 0.095 inches (Test 4, low head loss) would result in a change in head loss of greater than an order of magnitude. The issues identified briefly below and discussed in detail in the NRC staff Chemical Audit Report of Palisades (ADAMS Accession No. ML091070664) should be considered in the development of the response to this open item. The audit report should be referenced and the issues discussed in the report should be fully addressed. The licensee provided some information regarding this issue and its sub-parts. However, additional information is required as described below.

a. Please describe the testing methodology for the referenced PCI testing for foreign plants that shows that strainer hole size results in significant changes in head loss across the strainer. Provide information that validates that the testing was conducted similarly to the Palisades testing or that the results of the testing can be applied to the Palisades strainer.

b. Please provide an evaluation of the information provided by PCI to the NRC staff in ADAMS Accession No. ML090050043 (proprietary) that states that hole size has not been observed to directly impact head loss performance and provide information as to why the Palisades strainer would not behave similarly to the description in that document.

c. Please provide an evaluation of why the addition of eroded fines resulted in a significant head loss increase indicating that additional fibrous debris transport affected the ability of the bed to create head loss. This evaluation should concentrate on justification that fibrous debris transport issues during the test did not result in the large difference in head loss between the two tests.

d. Please provide an evaluation of the information supplied by PCI that speculates that the effect of hole size diminishes above 0.045 inches and how this relates to the smaller Palisades hole size of 0.045 inches.

e. Please provide an evaluation of the physical phenomenon caused by the difference in strainer hole size that resulted in a debris bed morphology difference significant enough to result in the large difference in head loss values between the two tests.

f. Please provide an evaluation of how the debris addition sequence differences between the two tests affected the results. Specifically, address why the separate addition of Nukon and mineral wool in Test 2 provided similar transport of the fiber when compared to transport when the fiber addition consisted of a mixture of Nukon and mineral wool. Provide justification that excessive interaction of the fiber types did not occur and that transport was not affected non-conservatively. Consider that the concentration of the fibrous debris in the test flume is likely much higher than would be expected in the plant. Provide information from the testing that validates the evaluation. Alternately provide information that shows that the two fibrous debris types would both be generated by all break scenarios and arrive at the strainer near field simultaneously, and that the concentration in the test flume had no significant effect.

28. (Audit Open Item 6.2, related to 14.e above) The licensee should provide information that the test methodology resulted in realistic or conservative strainer head loss testing results. In particular, debris preparation and introduction methods used during testing should be justified as prototypical or conservative. The issues identified briefly below and discussed in detail in the NRC staff Chemical Audit Report of Palisades (ADAMS Accession No. ML091070664) should be considered in the development of the response to this open item. Items 1, 2, and 3 discussed in Section 5.4.2 of the audit report should be considered when developing the response to this open item. The licensee provided

responses to the issues listed below, but additional information is required as described below:

a. Observation of test video documenting the addition of fibrous debris indicated that the debris may not have been prepared as finely as NRC staff guidance would suggest or may have agglomerated during the debris introduction process. There are several examples on the video that indicate that fiber preparation and/or introduction may not have been controlled to the degree prescribed in NRC staff guidance. The licensee stated that the debris distribution used during the testing was representative of the post-LOCA debris distribution expected for the plant. The licensee further stated that the protocol implemented was consistent with other tests run by PCI that the NRC staff had observed. In addition, it was noted that some variation in debris form is expected depending on the debris preparation and introduction methods. The NRC staff's position is that these processes should be controlled such that consistent debris characteristics are maintained. The NRC staff's observations of previous testing for various plants resulted in trip reports that documented that fibrous debris preparation and introduction needed to be more closely controlled to ensure that fine fibers were properly prepared and introduced into the test flume. The NRC staff has noted inconsistency with these processes during PCI test observations as documented in trip reports. The agglomeration noted on the video of the Palisades test was excessive for fine fibers. The licensee further noted that any clumped fibrous debris would break up as it entered the flume and that the video alone is not a valid basis for judging the final form of the fiber once it enters the flow stream. The NRC staff agrees that some break down of clumps will likely occur when the fiber enters the flow stream. However, the degree of this effect is unknown. In addition, the NRC staff could not determine that the debris added to the flume was actually fine debris and may have been larger pieces. In the past, when the NRC staff noted excessive agglomeration, PCI has adjusted its practices to ensure that the debris was separated adequately that it could be seen that the debris was fine and not agglomerated. The licensee's response does not adequately address this issue. Please provide information that justifies that debris introduction and preparation provided prototypical or conservative test results.

b. The debris introduction sequence for the testing did not appear to be performed consistent with the procedure previously discussed between PCI/AREVA and the NRC staff. Some more easily transportable debris was added after less transportable debris. For example, debris added as eroded fibrous material was added after larger fibrous pieces. This is a potential non-conservative practice because in the test a large debris pile may form in the test flume. This pile may act as an impediment to the transport of debris that may otherwise transport if the pile was not present. In the plant such a debris pile is less likely to form because the concentration of debris is much lower than in the test. The debris captured in the flume overflow filters was also added at the original drop zone which is behind the debris pile. A portion of the latent fiber was added to the test flume prior to starting the recirculation pump. This may be non-conservative from a transport perspective because washdown and pool fill up transport is not modeled. It has

been noted that the velocity of the flume is increased if a debris pile is present. While the debris pile will increase flume velocity to some extent, a porous debris pile on the flume bottom could capture debris such that the affect of higher flume velocity is negated. There are many variables that affect debris transport. The NRC staff could not determine that an adequate evaluation of these variables and their uncertainties was attained prior to the determination of debris introduction sequencing. The licensee stated that the addition of the eroded debris near the end of the non-chemical debris introduction is representative of the expected plant response. With the exception of the debris pile in the flume that would not be present in the plant, this is true. However, there are competing effects such that the debris pile in the flume may adversely affect the transport of the eroded fines. The NRC staff expects that the transport of fibrous debris in the flume over the debris pile may be dependent on the flume flow velocity with transport being more likely in higher flow streams. Because fine fibrous debris is known to be problematic for head loss, the licensee should employ test practices that ensure that the fibrous debris has an opportunity to transport similarly to expected plant transport. Alternately, the licensee could provide information that shows that the fine debris transports. During observations of a different test that added eroded fibers to the flume after other debris, the NRC staff was able to verify that the debris transported (based on changes in the head loss trend). A review of the head loss trend supplied in the licensee's supplemental response did not provide definitive information for this issue. Please provide justification that the debris introduction sequence did not affect head loss test results non-conservatively.

c. In some photos (especially the fiber only test photos), some fine fibrous debris appeared to be clumped into balls. The NRC staff has observed other tests during which shredded fiber has clumped into balls if not properly blended. The observed fibrous debris did not appear to exhibit properties that would be expected to result from jet impingement. The licensee stated that the debris was prepared prototypically. However, this question was specifically related to the pea-sized balls of fiber observed in the fiber-only test. The licensee should provide additional information that justifies that the fine fiber in the plant would exist, at least partially, in the form of small tight spheres, or provide an alternate explanation of the appearance of the finely prepared fiber.

d. Some debris may enter the containment pool closer than 30-40 ft from strainers during the blowdown, washdown, and pool fill-up phases of the LOCA. This debris would be more likely to transport to the strainer and less likely to contribute to the debris pile in the test flume. The test procedure did not attempt to model this aspect of the postulated event. This potential issue would likely have more influence as flume flow velocities decrease because settling would tend to occur over a shorter distance in a low velocity flow stream. Palisades' velocities are relatively low. The licensee provided information regarding the probable distribution of debris in the containment at the start of recirculation. The information appears to be reasonable. However, the test input parameters were based on debris amounts predicted by the transport evaluation to be at the strainer, not 30 ft away. It is apparent that not all of the debris reached the strainer during the test. The NRC staff believes that some debris would be closer

than 30 ft and some further at the onset of recirculation. Due to variables in post accident debris distribution and transport phenomenon, the NRC staff cannot conclude whether the practice of placing most of the debris 30 ft from the strainer is conservative or prototypical. The level of confidence with this practice resulting in a realistic or conservative head loss is dependent upon individual plant parameters and test implementation. Because of the level of uncertainty in some aspects of the head loss evaluation, the licensee should ensure that sufficient conservatism is included in the testing to assure an overall conservative or prototypical result. In this area conservatism has not been demonstrated. Please discuss the acceptability of testing procedures given the above.

e. The relatively low flume volume has an effect on the concentration of particulate and fine debris suspended in the flume. The volume of the flume affects the scaling between the strainer surface and the pool volume. Having a flume with a larger volume could avoid some of the concerns with over-concentration of debris in the flume and may reduce agglomeration. Flume debris concentration is significantly higher than the plant condition. The licensee did not provide a separate response to this issue, but referenced the response to the issues discussed above. Please provide justification that the concentration of debris in the test flume did not affect transport during head loss testing.

F. Net Positive Suction Head (NPSH)

29. The June 30, 2009, supplemental response indicates that throttling the containment spray flow is credited to ensure adequate NPSH margin. Please provide the basis for determining the reduced spray flow required during recirculation mode.

30. The June 30, 2009, supplemental response described components for which friction losses were considered. As requested in the content guide for GL 2004-02 responses, please also describe the methodology and/or references used to derive the formulas for calculating flow losses for these components in the NPSH margin calculation.

31. A number of objects were cited as displacing water in the post-LOCA containment sump pool, including the reactor vessel insulation, pressurizer heater transformers (both of which objects appeared to be potentially non-leak-tight and to have some hollow internal volume) and the containment buffer, which would presumably dissolve in the containment pool water. Please clarify whether other dissolvable or hollow and non-leak-tight objects are credited with displacing volume in the post-LOCA containment pool, estimate the total displaced volume credited, and provide justification for crediting such objects with displacing water.

32. Please clarify the assumption concerning the pump curves applied in the design analysis including a 7 percent allowance for flow degradation in the containment spray pumps, and an 8 percent allowance for flow degradation in the high-pressure safety injection pumps as it relates determination of conservative pump flow rates for the NPSH analysis. While not fully understanding the licensee's methodology, the NRC staff generally believes that assuming pump degradation when determining minimum NPSH margins for pumps could be non-conservative, since the required NPSH would seemingly be lower

for a degraded pump with reduced flow. Please clarify whether the pumps are assumed to operate above or below their certified head-flow performance curves in determining NPSH margin and provide a basis for considering the calculated NPSH margins to be limiting in light of this flow assumption.

G. Debris Source Term

33. In RAI 18 from the NRC's letter dated December 24, 2008, the NRC staff asked about the typical amounts of algae and/or slime that are removed from the sump and why this amount of biological material does not need to be considered as an additional debris source after a postulated LOCA. The licensee provided the requested information which identified an amount of oil sludge, estimated at 27.5 gallons, which is contained in a cavity which connects, by means of a pipe, to the sump area downstream of the strainer. The licensee stated that due to the large amount (250,000 gallons) of what it considered "hot soapy sump water," the 27.5 gallons of either oily emulsion or algae created biological material would be dissolved. In addition, the licensee stated that the extreme agitation as it transits through the sump area will ensure good mixing takes place and will enhance the process of dissolution of solubles or suspension of small particles. The NRC staff believes that it is unlikely that the oil-based slime identified by the licensee will dilute in the sump pool as stated in the response, and that there is a potential for this material to be transported to the reactor core and spray nozzles. The bases for the NRC staff's concern is that the sludge has been proven difficult to remove, as indicated in page 168 of the June 30, 2009 RAI response, which states, "...the high viscosity of the material made a bubble form in the small screen squares and it resisted removal by a stiff wire brush that rode over the high points on the screens. Adding soapy cleaning solution did nothing to help this phenomenon." The physical and chemical properties of the oil sludge may not allow it to be easily diluted. Please provide further information on your plans to address the oil sludge during future plant operation. If it were to transport downstream of the strainer, has the amount of sludge been evaluated as part of the downstream effects analysis? Were any other approaches (e.g. hard piping the sump where the sludge is located from the strainer) considered?

Please provide the dates for the agenda teleconference and the public meeting and the response to the enclosed RAIs in a timely fashion as discussed above. In case of any further questions or concerns please feel free to contact me at 301-415-8371 or Mahesh.chawla@nrc.gov.

Sincerely,

/RA/

Mahesh L. Chawla, Project Manager
Plant Licensing Branch III-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-255

Enclosure:
As stated

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