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

May 13, 2009

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

SUBJECT: PALISADES PLANT – REPORT ON RESULTS OF STAFF AUDIT OF CHEMICAL EFFECTS RELATED 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, which operates Palisades Nuclear Plant, has conducted an evaluation of recirculation sump performance for Palisades.

Consistent with the discussion in the "Reasons for Information Request" Section of GL 2004-02, the Nuclear Regulatory Commission (NRC) staff performed sample audits of nine licensees to help verify that licensees have resolved the concerns in the generic letter. Since licensee chemical effects evaluations were not complete during the earlier nine audits, the NRC staff concluded that it would be appropriate to perform some additional audits focusing on chemical effects. The NRC issued the first chemical effects audit report for North Anna Power Station Units 1 and 2 on February 10, 2009 (Agencywide Documents Access and Management System (ADAMS) Package No. ML090410626).

The NRC staff and NRC contractor visited Palisades Nuclear Plant (PNP) from March 3 to 6, 2009, to perform the chemical effects audit. The enclosed audit report provides feedback to Entergy on its GL 2004-02 corrective actions and supporting analyses in the chemical effects area. Also, when made publicly available, this audit report will inform other pressurized water reactor licensees of the NRC staff's technical positions.

Entergy was very supportive during all phases of the audit as it provided appropriate office space, office equipment, and had the appropriate technical staff present to promptly address NRC staff questions. The licensee's support during the preparation and conduct of the audit was helpful to the fullest extent possible.

There are two open items resulting from this chemical effects audit. The enclosed audit report describes the open items in detail but does not reach a conclusion regarding overall adequacy of Entergy's GL 2004-02 corrective actions. Entergy's GL 2004-02 supplemental response is expected to provide a comprehensive description of the corrective actions and supporting analyses and evaluations for Palisades.

NRC staff consideration of the GL 2004-02 supplemental response will result in a letter to Entergy assessing the overall adequacy of the Palisades GL 2004-02 corrective actions. In case of any further questions or concerns please feel free to contact me at 301-415-8371 or Mahesh.chawla@nrc.gov.

Sincerely,

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: Palisades Audit Report

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Palisades Audit Report
Corrective Actions for Generic Letter 2004-02 Chemical Effects

1.0 INTRODUCTION

The Nuclear Regulatory Commission (NRC) staff has performed sample audits of corrective actions for Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004, for nine licensees. The purpose of these audits was to help verify that licensee's have resolved the concerns in the GL. Audit candidates were selected based on a sampling basis related to reactor type, containment type, strainer vendor, NRC regional office, and sump replacement analytical contractor. Since licensee chemical effects evaluations were in progress during the nine earlier audits, the NRC staff was not able to reach a conclusion about the adequacy of chemical effects evaluations for the 69 U.S. operating pressurized water reactors (PWRs). Therefore, the NRC staff determined that it would be appropriate to perform some additional limited scope audits focusing on chemical effects.

In general, these chemical effects audits will consider the chemical effects evaluation guidance document process flow sheet (see Figure 1, Agencywide Documents Access and Management System (ADAMS) Accession No. ML080380214) as a useful guide for the audit scope. The NRC staff is interested in the licensee's overall strategy for evaluation and accommodation of chemical effects, including why the licensee thinks chemical effects have been addressed in a representative or conservative manner. Specific topics that are of interest to the NRC staff include:

- Plant-specific debris mix (non-chemical)
- Plant–specific debris bed (non-chemical)
- Plant-specific environment (pH, buffer chemicals, temperature profile)
- Method used to calculate the plant-specific chemical precipitate load
- Supplemental testing (e.g., bench top tests) used as part of the chemical effects evaluation.
- Any assumptions used to reduce the predicted plant-specific precipitate load
- Integrated (with chemical effects) head loss test protocol and any open generic issues related to the vendor's test protocol
- Precipitate generation method for integrated head loss testing
- Settlement of chemical debris during head loss testing
- Integrated head loss test plot(s)
- Test termination and head loss extrapolation, if applicable
- Data analysis

Palisades was selected as one of the plants for a chemical effects audit since it is a representative plant for the chemical effects evaluation approach performed by the team of AREVA, Alden, and Performance Contracting, Inc (PCI). The NRC staff and an NRC contractor visited Palisades from March 3-6, 2009, to perform the chemical effects audit. Prior to the on-site portion of the audit, the NRC staff had the benefit of reviewing relevant documents related to chemical effects analysis and integrated head loss test results for Palisades.

2.0 OVERALL CHEMICAL EFFECTS APPROACH

The Palisades plant has a variety of different types of insulating materials, including: CalSil®, Mineral Wool, Nukon®, and Reflective Metal Insulation (RMI)®. The calculation of the mass of debris loading from the insulation and other sources was performed using the guidance provided in NEI 04-07. The zone of influence (ZOI) provided in that guidance was used to estimate the mass of each type of debris and assess the limiting case for debris.

The plant also has an extraordinarily large mass and surface area of aluminum that can be potentially exposed to containment spray or be submerged during a loss of coolant accident (LOCA). Historical plant documents were first used to calculate the mass and surface area of aluminum in containment. It was soon realized that many changes had been made to the plant over the operating history that could be credited to reduce the amount of aluminum.

Originally the plant used trisodium phosphate (TSP) as their sump pool buffering chemical. However this chemical was changed to sodium tetraborate (STB) during the Palisades 2007 refueling outage because of the significant challenges that the combination of varied calcium containing insulating materials and TSP presented in terms of chemical precipitates following a LOCA. This change provided a significant first step in the reduction of post-LOCA chemical effects precipitate from the interaction of the TSP in particular with calcium silicate (CalSil®). The beneficial effects of this change were shown in chemical effects testing done by Westinghouse in WCAP-16596 (Reference 6). As a result of the switch to STB, the only significant chemical precipitates that are predicted to be present in the post-LOCA solution are aluminum oxy-hydroxide (AlOOH) and sodium aluminum silicate (NAS). For head loss testing aluminum oxy-hydroxide is used as a surrogate for all chemical precipitates.

Additional changes made during the 2007 refueling outage were to:

- Install strainers based on what were believed to be bounding tests from other plants' chemical effects testing
- Modify the containment spray valves so that additional net positive suction head (NPSH) could be provided for the containment recirculation pumps.
- Modify the high pressure safety injection (HPSI) pump seals to eliminate use of cooling water from the sump so that mechanical wear on the seals following a LOCA would not be an issue.

During the months that followed the 2007 outage additional refinements were made to the analysis used for chemical effects testing. These mainly dealt with debris generation and transport calculations.

3.0 ASSESSMENT OF TOTAL ALUMINUM MASS DISSOLVED

Palisades' initial attempts to quantify aluminum used original design documents to estimate the total surface area of aluminum in containment. This is identified in Table 1 (Identity Table) of Reference 1.

During the more than 30 years of commercial operation, the original metallic insulation that contained aluminum was removed when possible, or had been covered over with stainless steel. These changes were initially made to limit the amount of oxidizable metal to reduce the build up of hydrogen gas following a LOCA. Some of these changes to protect aluminum were made under work orders to plant equipment that allowed replacement of aluminum jacketing with stainless steel as a "craft skill." Thus much of this reduction went undocumented.

Another addition to the mass of aluminum that would be part of the final mass of AlOOH formed was from aluminum paint. The estimate for this surface area was based on a Sargent and Lundy Report1 in response to Generic Letter 98-04, "Potential for Degradation of the Emergency Core Cooling System After a Loss of Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment."

Palisades realized that using only the original design documents would provide an extremely high estimate of the aluminum surface area. Therefore they performed visual inspections inside containment to identify those areas where credit could be taken for aluminum that had been replaced, aluminum that would not be exposed to spray, and aluminum that would not be submerged.

The categories that were used to reduce the total aluminum that either no longer existed or were no longer contributors to the aluminum corrosion were:

1. Visual inspections of materials in the containment that were no longer aluminum
2. Aluminum metal that could not be contacted by the containment spray because they were "protected" by other containment structures like concrete ceilings or floors
3. RMI that has been covered by stainless steel

Containment walk downs were performed to confirm or refute the presence of aluminum on certain surfaces where undocumented material changes may have occurred. Additionally, the surface areas of aluminum that could not be exposed to spray were qualitatively assessed according to WCAP-16530 guidance and assigned a contribution of zero mass of aluminum in the post-LOCA effects. The licensee stated that they had started with the original WCAP spreadsheets for the aluminum calculation but modified them using their own calculations based on mass and surface areas exposed in the containment building at Palisades. This was necessary because the thin foil RMI that was used to a significant extent in containment would be completely dissolved in a short period of time, but using the WCAP calculation the surface area ascribed to this aluminum would keep contributing to the dissolved mass. Thus their change to the aluminum calculation was to reduce the exposed square footage of aluminum following the complete dissolution of this foil. It should be noted however that the full mass of the dissolved thin foil RMI was included in the mass calculation.

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1 Sargent and Lundy, DIT-CPC-038-00. This report was not provided during the audit.

Of the above measures used to reduce the exposed surface area of aluminum, by far the largest impact is seen for the protected aluminum. The surface area of aluminum that is not considered to be contacted by containment spray is approximately 64,000 square feet (ft), corresponding to approximately 47 percent of the total aluminum surface area in containment. The contribution to the potential aluminum loading in the sump from these areas identified as "protected" was said to be zero. The audit team questioned whether condensation on the protected surfaces could result in aluminum corrosion and thus contribute more dissolved aluminum to the pool. Palisades provided additional analysis showing that even if all of the protected aluminum was subjected to condensation the amount of aluminum that would be contributed to the sump was insignificant and bounded by conservatisms in other aspects of the calculation. In addition, it was noted that a large percentage of the protected aluminum is actually inside of cladding and adjacent to insulation materials. This portion of the aluminum surface area would not be able to release aluminum to the pool even if it were fully wetted by condensation.

4.0 CREDIT TAKEN FOR SILICA INHIBITION

The amount of aluminum-based precipitates in the sump is dependent upon the surface area of aluminum available, sump fluid temperature, and the pH. Another factor that can affect the mass of aluminum dissolved is aluminum corrosion inhibition by silica. Most plants have chosen not to use this factor to reduce the aluminum mass that dissolves since it can be difficult to demonstrate that all plausible break locations produce a sufficient dissolved silica pool concentration that results in silica inhibition of aluminum.

Entergy credited some suppression of aluminum corrosion by the presence of silica leached from the CalSil®, Mineral Wool, and Nukon® insulation materials that are part of the debris resulting from the LOCA. During the audit the NRC staff questioned whether the initial high aluminum concentration in the sump water would form a precipitate on the fiberglass surface thereby restricting the leaching of silica, as was observed in the Integrated Chemical Effects Test No. 1. If this were to occur, there would be much less silica in solution from fiberglass debris to inhibit aluminum corrosion. The licensee provided documentation showing the sources and relative quantities of materials from which silica may be leached. Palisades has several sources of silica including CalSil® insulation, fiberglass, and inorganic zinc silicate coatings. The predicted silica concentration from these sources well exceeds the 75 parts per million that the licensee credits. The staff expects that the dissolved aluminum from corrosion of aluminum RMI may inhibit leaching of silica from fiberglass at Palisades. Leaching of silica from fiberglass is expected to take longer than the introduction of silica from CalSil® dissolution. However, given the quantity of CalSil® and other silicate containing material in the Palisades containment that will readily leach silica and the predicted margin of excess silica in solution, relative to that shown to passivate aluminum, the staff agrees that Palisades will have sufficient silica levels such that some inhibition of aluminum corrosion by silica will occur.

This reduction in corrosion rate due to silica inhibition is not applied to the aluminum foil RMI since the aluminum RMI is projected to completely dissolve before any credit for aluminum passivation is applied. The licensee performed a sensitivity analysis that confirmed the overall benefit of silica inhibition of aluminum corrosion is far less than may be expected from the significant reduction in aluminum corrosion rates since most of the aluminum is dissolved before aluminum passivation is credited.

The above methodology was used to calculate the final mass of aluminum that would be present in the sump at the end of 30 days. Using the above assumptions and WCAP-16530 the amount of NAS and AlOOH formed were calculated. As described previously AlOOH was used as a surrogate for all precipitates in head loss testing. The NAS mass was converted to AlOOH on a molar basis of aluminum. This mass was then used for the head loss test run #4 (Reference 2).

5.0 INTEGRATED HEAD LOSS

5.1 PCI/AREVA Test Facility

PCI/AREVA performed the Palisades strainer testing at Alden Labs in Holden, Massachusetts. These tests were performed in a large flume designed for performing integral head loss testing of modular strainer arrays or strainer prototypes. The test methodology includes near-field settling (i.e., allows credit for settlement of debris in the flume upstream of the test strainer module). The staff has observed several head loss tests in the large test flume at Alden Labs, but did not witness the Palisades testing. The test loop is comprised of a large tank, a pump, piping, immersion heaters, and a flume level control arrangement. The facility also has the necessary equipment to heat the tank water with an external loop. The test loop contains valves necessary to isolate or throttle flow and drain the flume. The pump is driven by a variable-speed motor to assist in controlling flow rate. Also installed are instrumentation for reading flow, pressure differential, and temperature. Some of the instrumentation is connected to a desktop computer for trending and data collection. Grab samples can be taken to determine the pH of the water throughout the test. The test loop also has sample probes for taking samples to determine the amount of debris that bypasses the strainer.

The flume is about 45 ft long and 10 ft wide. Within the walls of the flume, plywood walls are built to vary the flow velocity of the water to simulate the flow velocity of water in the plant as it approaches the strainer. The velocity is changed by narrowing or widening the channel formed by the plywood walls. The entire flume is flooded, but only the water within the plywood channel is circulated. The water outside of the plywood walls is solely to prevent the walls from collapsing due to the force of the water inside the walls. The test flume has a large capacity, but for the Palisades test the plywood walls were relatively close together so the test volume was somewhat reduced. Alden Labs also has the chemicals and equipment needed for generating precipitates using the methodology outlined in WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191."

For the Palisades test, the test tank contained a single PCI strainer module connected to an outlet plenum. The outlet plenum was connected to the suction header for the test loop pump. The strainer array was contained within the plywood walls that provide the channel representing the flow stream to the strainer. The arrangement was intended to model flow to an average strainer module (with some conservatism) from the several modules that make up each Palisades strainer section. Palisades has a single sump with four strainer sections filtering the recirculating water before it is piped to the sump. The strainers are located on the floor level in the bottom of containment.

The testing at Alden Labs is designed to take credit for near-field settlement of debris. The channel provides a flow stream evaluated as prototypical (with some conservatism). The evaluation of the flow stream was based on comparisons of computational fluid dynamics

(CFD) analyses for the plant sump pool and the test flume. The majority of the debris is placed in the flow stream about 30 feet upstream of the strainer and allowed to transport to the strainer. Due to plant-specific features, the average flow velocity approaching the strainer at Palisades is relatively low as compared to most PWRs. In this case the flume velocity was about 0.1 ft/sec.

The test strainer module was relatively typical of the PCI design, which includes flow control to distribute flow more evenly among modules and within each module. The test module was the same design as the modules installed at Palisades. The area of the test module was 152.8 square feet which represented about 4.5 percent of the total strainer area installed at Palisades (3514.7 square feet) minus 100 square ft of area sacrificed to miscellaneous material such as tags and labels that could collect on the strainer.

5.1.1 Test Program Design

Early Palisades testing was not able to demonstrate that the debris laden head loss across the strainer would remain low enough to provide assurance of adequate NPSH margin for the Containment Spray (CS) pumps. During recirculation, the Emergency Core Cooling System (ECCS) pumps take suction from the discharge of the CS pumps and therefore there is adequate NPSH available for the ECCS. Because the early testing did not produce acceptable results, Palisades designed a test program to identify a plant configuration that would ensure adequate NPSH margins during recirculation. This type of test design is known as a "test for success" program. The licensee tests various configurations until one or more successful tests are completed. Based on the test results, the licensee determines plant modifications to be made so that the plant conservatively reflects the test conditions.

5.2 Systems Drawing Suction from the Containment Sump

During the recirculation phase of an accident, the CS pumps take suction from the emergency sump. The CS pumps provide suction flow to the HPSI pumps. Therefore, the only pumps designed to take suction from the emergency sump are the CS pumps. The HPSI and Low Pressure Safety Injection (LPSI) pumps can also take suction from the sump. However, the LPSI pumps trip when the recirculation phase starts, so the test configuration only considers the CS pumps. A single failure could result in the failure of a LPSI pump to trip which would result in higher flow through the strainer for a short period of time. The evaluation of the LPSI pump failure to trip is outside the scope of this audit. The flow from two CS pumps is reported to be 3591 gallons per minute.

5.3 Strainer Testing Summary

The Palisades strainer evaluation initially relied on a comparison between the Palisades conditions and another plant's strainer testing. Palisades later performed plant specific testing at Alden Labs in May, 2008. The testing resulted in higher than anticipated head loss across the strainer.

Based on the results of the initial plant specific testing, Palisades determined that additional testing should be conducted to identify a plant configuration that would assure adequate NPSH margin for the pumps taking suction from the emergency sump. Based on this decision, a series of tests was designed that would test various plant configurations until a head loss that would assure proper strainer performance was achieved. Once the plant configuration was identified, Palisades began planning to implement modifications to make the plant match the acceptable test conditions.

Palisades' test program, conducted in November, 2008, included eight tests. Only six of these tests were run because a successful test precluded the need to perform additional testing. All of the tests were run with different inputs than the original site specific test (May 2008). Changes were made to the testing parameters in the following areas:

1) Debris generation was changed based on revised zones of influence (ZOIs)
    a. Fibrous debris was reduced from 50 lb to 32 lb (test amount)
    b. Fine fiber remained about the same at 24 lb
    c. Cal-Sil debris was increased from 11 lb to 22 lb
    d. WCAP AlOOH precipitate was increased from 36 lb to 40 lb
2) The CFD was revised as the result of moving STB baskets away from the strainer thus reducing the calculated average velocities in the area of the strainer
3) The strainer hole size was increased from 0.045 in to 0.095 in (for the successful test)

Test 1 – The first test conducted was a clean strainer head loss test for the strainer with 0.045 inch holes. This was a baseline test to determine the clean strainer portion of head loss during the testing.

Test 2 – The second test was a full debris load test. In essence it was a re-performance of the May, 2008 test with changes based on the updated debris load and CFD analysis. Similar to the May 2008 test, the strainer hole size was 0.045 inches. Results similar to those attained during the May testing were obtained.

Test 3 – The third test was a clean strainer head loss test for the strainer with 0.095 inch holes.

Test 4 – The fourth test was performed similarly to the second test except that the test strainer module had 0.095 inch perforations instead of 0.045 inch holes. There was one additional potentially significant difference between the second and fourth test. In test 2, the fibrous debris was added separately. In test 4, the fine Nukon® debris was mixed with the fine mineral wool debris prior to addition. The fourth test resulted in an acceptable head loss value.

Two tests that were designed to determine the effect of adding strainer modules in containment were not conducted once it was determined that the strainer with the 0.095 inch hole size yielded acceptable results. Two additional tests were performed to determine strainer bypass fractions. Those tests are not relevant to this audit. Tests 2 and 4 are the tests most relevant to this audit. Therefore, other tests conducted during the November test dates will not be discussed in detail in this report.

5.4 Potential Strainer Test Issues

During the audit, details of the testing were discussed with the licensee. Only the issues which are likely to have a significant affect on head loss testing results are presented in this audit report along with supporting details for each issue. Other issues that received significant attention during the audit are also documented in this section.

5.4.1 Effect of Strainer Hole Size on Head Loss

The licensee's conclusion that the difference in head loss test results obtained by changing the hole size from 0.045 to 0.095 inches is solely due to the change in hole size are inconsistent with other data that the staff is aware of and contradicts similar strainer testing, even testing conducted with PCI strainers. In general, available data indicates that head loss, even with openings up to 1/8 inch, is more strongly dependent on the debris bed deposited on the strainer than the strainer hole size. Debris bed degradation may occur at lower head losses with larger openings, but has not been observed to occur at head losses as low as those observed in Test 4. The staff understands that debris bed degradation is a complex phenomenon driven by the bed morphology and the head loss across the strainer. The following are areas that the NRC staff believes could have an impact on the evaluation:

1) The licensee stated that the strainer vendor had information from tests conducted for Japanese plants that indicated that strainers with small hole sizes were likely to attain higher head losses than strainers with larger holes tested under similar conditions. Specifically, PCI has data from Japanese testing that indicates strainers with 0.033 and 0.045 inch holes result in higher head losses than those with 0.062 and 0.066 inch holes. The information provided to the staff regarding the Japanese testing was verbal and no details were available. No test data or test conditions were provided for staff review. No analysis comparing the results of the Japanese tests considering the relevant variables was provided.

2) The head loss in Test 4 did not appear to be high enough to result in bed degradation. If the degradation had been due to hole size, head loss would have built similarly in both tests, but limited due to degradation once it reached a value that would promote that phenomenon. Instead the non-chemical head loss in Test 4 continued to increase and did not reach a plateau even after several hours.

3) It was noted that the Nukon® fines were added separately from the mineral wool fines in Test 2, but the fibrous debris was mixed during Test 4. It was also noted that when the mineral wool was added to Test 2 that no increase in head loss occurred. Therefore it appears that the mineral wool may not transport similarly to the Nukon®. It is possible that the Nukon®/mineral wool mixture did not transport as readily as the separate Nukon® would. Because the debris concentration in the test flume is much higher than it would be in the plant, it is unlikely that the Nukon® and mineral wool would have a large probability of mixing in a manner similar to that which the test introduction methods created.

4) From post-test photographs it appeared that there were differences in the debris beds between the Test 2 and Test 4. Test 4 appeared to be a mostly chemical debris bed with little non-chemical debris under it. Test 2 appeared to have a debris bed with a

thicker underlying non-chemical bed. It does not seem plausible that the debris bed appearance would change significantly solely due to a change in strainer hole size. However, the staff is aware that the appearance of the debris bed may change during the drain down of the flume.

5.4.2 General Observations on the Testing Methodology

The NRC staff reviewed the general testing methodology used for the testing of the Palisades strainers. The testing was based on a general PCI/AREVA procedure used for strainer testing at Alden Laboratories in Holden, Massachusetts. The NRC staff had several discussions with PCI/AREVA and the licensees planning to test their strainers at Alden Labs prior to the implementation of the test program. The NRC staff had considerable interest in the test program because it credits near-field settling which removes a significant conservatism that has been employed in most other test methodologies. Testing that credits near field settling allows some of the debris to settle out in the test flume based on the premise that similar settling will occur in the plant. The test flume should have realistic velocity and turbulence as compared to the plant in order to assure representative transport of debris to the strainer. Because of uncertainties involved in the reproduction of these variables the NRC staff relies on the test procedures to introduce some conservatism into the methodology. Testing that does not credit near-field settling provides agitation to ensure that a majority of the debris reaches the strainer. The following areas regarding testing methodology are of interest to the NRC staff. The significant concerns in this area are related to debris generation and introduction.

1) 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. Alternately, the debris may have been prepared to the proper size distribution, but 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.

2) The debris introduction sequence for the testing did not appear to be performed in accordance with the procedure previously discussed between PCI/AREVA and the 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 staff could not determine that an adequate evaluation of these variables and their uncertainties was attained prior to the determination of debris introduction sequencing.

3) In some photos, especially the fiber only test photos, some fine fibrous debris appeared to be clumped into balls. The staff has observed other tests where shredded fiber can clump 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.

4) The head loss testing did not appear to include fiber to represent the erosion of this debris that was analytically assumed to have transported to the strainer yet settled in the test flume. Therefore the licensee's consideration of debris erosion may be non-conservative. Neither the analysis nor the head loss testing accounted for the erosion of debris that settled during the head loss testing, but was assumed to reach the strainer as a result of the transport evaluation.

5) Some debris may enter the containment pool closer than 30-40 feet 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.

6) 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.

5.4.3 Test Flume Flow Modeling

The NRC staff could not determine whether the overall modeling of flow in the test flume would result in transport typical of that which would occur in the plant. The two variables the NRC staff believe are key to this concern are velocity and turbulence. Although concerns remain in this area, they will not be included as open items in the audit report. Issues in this area will be reviewed during the NRC staff review of Palisades' GL 2004-02 responses. Because the issues were discussed during the audit they are documented here.

1) During the audit, the NRC staff reviewed the methodology used to determine the test flume flow velocity profile. Although the methodology resulted in a conservative flow rate based on the average flow to all strainer modules in the plant, the NRC staff could not determine with certainty that the test flume velocities resulted in an overall conservative transport in the flume. This is due to the magnitude of uncertainties associated with how debris may transport in the plant when some flow streams are

relatively fast and some are relatively slow. However, based on the conservatism added the NRC staff concluded that the velocity profile used in the test was reasonable.

2) The NRC staff questioned whether the 90 degree angle at the end of the test flume just prior to the strainer had any affect on transport or debris bed formation. Based on the review of post-test photographs of the debris bed on the strainer and the flume in the area of the strainer the NRC staff determined that the flume configuration near the strainer likely had little affect on the outcome of the test.

3) The NRC staff requested a comparison of turbulence in the strainer near field in the plant and in the test flume. The licensee responded that additional turbulence was not added to the test flume for the following reasons:

   a. Energy associated with spray drainage was not predicted to have a significant affect on turbulence.
   b. Attempts to introduce energy into the flume could inhibit the transport of debris by sequestering it upstream of the turbulence zone.
   c. Energy introduced near the strainer could affect the debris bed formation.

4) The NRC staff remains concerned that the flow regime in the test flume may be non-conservative with respect to the plant (turbulent vs. laminar).

5.5 Chemical Effects Head Loss Results

Test 4 is the test being used by the licensee for strainer qualification. Once the non-chemical debris beds for Test 4 had reached a suitably stable head loss value, test personnel proceeded to introduce chemical debris in batches into the flume. The total duration of the test was about 80 hours. The results of the test for the Palisades strainer were reported as follows:

Test 2 (0.045 inch strainer holes)
Debris bed without chemicals – 9.858 ft
Debris bed with chemicals – Not tested

Test 4 (0.095 inch strainer holes)
Debris bed without chemicals – about 0.42 ft
Debris bed with chemicals (design load) – 0.7402 ft

Based on these test results, the licensee determined that the currently installed strainer (0.045 inch holes) should be replaced with a strainer that has 0.095 inch holes.

5.6 Head Loss Summary

Based on the information gathered during the audit, the NRC staff determined that Palisades should provide additional information to justify that the testing conducted to ensure that the plant strainer will function adequately under LOCA conditions resulted in realistic or conservative results. Additional information is required to justify that the differences in test results between Test 2 and Test 4 were a result of the change in strainer hole size, and not some other test variable. Information is also required to provide justification that the debris preparation and introduction methods used during the testing resulted in realistic or conservative head losses. These issues are listed as open items in Section 6.0.

6.0 OPEN ITEMS

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 to 0.095 inches would result in a change in head loss of greater than an order of magnitude. The issues discussed in Section 5.4.1 of this report should be considered in the development of the response to this open item.

Open Item 6.2
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. Items 1, 2, and 3 discussed in Section 5.4.2 should be considered when developing the response to this open item.

7.0 CONCLUSIONS

Based on the references provided and the discussions with plant staff the NRC audit team concludes that regarding the chemical effects calculations and assumptions used to calculate the mass of chemicals precipitating, Palisades has performed an acceptable analysis. The switch to STB from TSP as the sump buffering chemical has had a positive effect on the total mass of dissolved solids that can be formed. The NRC staff finds that the licensee's analysis for total dissolved aluminum, including credit taken for corrosion inhibition by silica, accurately represents the Palisades specific environment.

The NRC staff identified 2 open items related to the head loss testing methodology. Those items are discussed in detail in the body of this report and summarized in the Section 6.0 of this report. Resolution of these open items will occur as part of the NRC staff's review of the final Palisades supplement to GL 2004-02.

8.0 REFERENCED DOCUMENTS

1. "Aluminum Location, Corrosion and Precipitation Post LOCA in the ECCS Sump for GSI-191", EA-EC7539-01 (February 2009).

2. "Palisades Final Test Report for ECCS Strainer Performance November 2008 Testing", 66-9097941-000 (AREVA, February 2009).

3. "Palisades Test Plan", 63-9095797-001 (AREVA, November 2008).

4. WCAP -16785, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model" May 2007 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML072010381).

5. NEI 04-07 Sump Performance Task Force, "Pressurized Water Reactor Sump Performance Evaluation Methodology", Revision 0, Volume 1, December 2004. (ADAMS Accession No. ML050550138).

6. WCAP-16596, "Evaluation of Alternative Emergency Core Cooling System Buffering Agents", July 2006.

7. NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008, (ADAMS Accession No. ML080230038).

ATTACHMENT 1 MEETING ATTENDANCE SHEET
PALISADES NUCLEAR PLANT
27780 Blue Star Memorial Hwy
Covert, MI 49043

Meeting Description: Exit meeting for NRC Chemical Effects Audit

Date: 3/6/09 Time: 09:30 Location: Site VP Conference Room

Inspection No: Inspection Period: 3/3/09-3/6/09

Attendee Name	Company/Title
1. Matt Yoder *	NRC audit lead
2. Steve Smith *	NRC
3. Bob Litman *	NRC Consultant
4. Chris Schwarz	Site VP
5. Charles Arnone	Nuclear Safety Assurance Director
6. Alan Blind	Acting Eng Director
7. Brian Kemp *	Acting Design Eng Manager
8. George Goralski *	Design Engineer
9. Laurie Lahti *	Licensing Manager
10. Jim Kuemin *	Licensing Engineer
11. Neil Lane	Project Management Manager
12. Bill Ford	Maintenance Manager
13. Chuck Sherman	RP Manager
14. Marty Richey	Planning and Scheduling Manager
15. Tom Kirwin	Plant General Manager
16. Sam Rothenbach *	Design Engineer
17. John Ellegood *	NRC Sr. Resident Inspector
18. Keith Smith *	Project Manager
* indicates persons at the entrance meeting on 3/3/09	

Enclosure

NRC staff consideration of the GL 2004-02 supplemental response will result in a letter to Entergy assessing the overall adequacy of the Palisades GL 2004-02 corrective actions. 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: Palisades Audit Report

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NAME	MChawla	BTully	MYoder	LJames (PST for)
DATE	05/06/09	05/06/09	05/07/09	05/13/09

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