June 24, 2008

MEMORANDUM TO: Michael L. Scott, Chief
Safety Issues Resolution Branch
Division of Safety Systems
Office of Nuclear Reactor Regulation

FROM: Allen L. Hiser, Jr., Chief ***/RA/ Matthew Yoder for***
Steam Generator Tube Integrity and
Chemical Engineering Branch
Division of Component Integrity
Office of Nuclear Reactor Regulation

SUBJECT: STAFF OBSERVATIONS FROM JANUARY 2008 TRIP TO THE PCI/ALDEN TEST FACILITY TO OBSERVE HEAD LOSS TESTING FOR WOLF CREEK AND CALLAWAY PLANTS

On January 16 to January 18, 2008, NRC staff traveled to the Alden Research Laboratory in Holden, Massachusetts to observe testing associated with the resolution of Generic Safety Issue 191 (GSI-191). The objective of the trip was to observe integrated sump strainer head loss testing being performed for the Wolf Creek and Callaway Nuclear Plants. The participating Nuclear Regulatory Commission (NRC) staff members were Paul Klein from the Division of Component Integrity and Mr. Ralph Architzel from the Division of Safety Systems. NRC staff were accompanied by Clint Schaffer from ARES Corporation. The staff interacted with personnel from the two licensees, along with vendor personnel from the Alden Research Laboratory (Alden), Areva NP Inc. (Areva), and Performance Contracting Inc. (PCI).
The enclosure summarizes the staff's discussions and observations from the January 16 to January 18, 2008 visit.

Members of the NRC staff have previously visited the Alden Research Laboratory on March 17 to 18, 2005, on January 18 to 19, 2006, and on March 8, 2006, to observe testing. Summaries of staff observations from these visits are available in ADAMS (Accession ML052060337, ML060750340, ML061280580). A new head loss test protocol was developed prior to the staff's January 2008 visit. In addition to the earlier trip reports, a trip report from a subsequent staff visit in February, 2008 is also available in ADAMS, ML080920398.

Enclosure:
Trip Report

CONTACTS: Paul Klein , DCI/CSGB
(301) 415-4030

June 24, 2008

MEMORANDUM TO: Michael L. Scott, Chief
Safety Issues Resolution Branch
Division of Safety Systems
Office of Nuclear Reactor Regulation

FROM: Allen L. Hiser, Jr., Chief ***/RA/ Matthew Yoder for***
Steam Generator Tube Integrity and
Chemical Engineering Branch
Division of Component Integrity
Office of Nuclear Reactor Regulation

SUBJECT: STAFF OBSERVATIONS FROM JANUARY 2008 TRIP TO THE PCI/ALDEN TEST FACILITY TO OBSERVE HEAD LOSS TESTING FOR WOLF CREEK AND CALLAWAY PLANTS

On January 16 to January 18, 2008, NRC staff traveled to the Alden Research Laboratory in Holden, Massachusetts to observe testing associated with the resolution of Generic Safety Issue 191 (GSI-191). The objective of the trip was to observe integrated sump strainer head loss testing being performed for the Wolf Creek and Callaway Nuclear Plants. The participating Nuclear Regulatory Commission (NRC) staff members were Paul Klein from the Division of Component Integrity and Mr. Ralph Architzel from the Division of Safety Systems. NRC staff were accompanied by Clint Schaffer from ARES Corporation. The staff interacted with personnel from the two licensees, along with vendor personnel from the Alden Research Laboratory (Alden), Areva NP Inc. (Areva), and Performance Contracting Inc. (PCI).
The enclosure summarizes the staff's discussions and observations from the January 16 to January 18, 2008 visit.

Members of the NRC staff have previously visited the Alden Research Laboratory on March 17 to 18, 2005, on January 18 to 19, 2006, and on March 8, 2006, to observe testing. Summaries of staff observations from these visits are available in ADAMS (Accession ML052060337, ML060750340, ML061280580). A new head loss test protocol was developed prior to the staff's January 2008 visit. In addition to the earlier trip reports, a trip report from a subsequent staff visit in February, 2008 is also available in ADAMS, ML080920398.

Enclosure:
Trip Report

CONTACTS: Paul Klein , DCI/CSGB
(301) 415-4030

DCI:RF	SSI:RF	RArchitzel	MScott	JLehning	SSmith	RTorres
PKlein	LWhitney	JGolla	MYoder	AHiser	EGreiger	EWong

ADAMS Accession No.: ML081830645

OFFICE	NRR/DCI/CSGB	NRR/DSS/SSIB	NRR/DCI/CSGB
NAME	PKlein	RArchitzel	AHiser
DATE	6/23/2008	6/17/2008	6/24/2008

OFFICIAL RECORD COPY

OBSERVATIONS OF TESTING AT ALDEN RESEARCH LABORATORY
JANUARY 16 TO JANUARY 18, 2008

1.0 Overview

The staff visited the Alden Research Laboratory (ARL) in Holden, MA during January 16-18, 2008 to observed head loss testing being conducted for the Wolf Creek and Callaway nuclear power plants. The head loss testing was being performed using the revised AREVA/Performance Contracting Inc. (PCI) scaling methodology and testing protocol and the newly completed test flume designed to prototypically simulate the flow conditions approaching the plant strainers. Through the use of prototypical flow conditions approaching the strainer, the licensees intended to credit settlement of debris in the test flume upstream of the strainer.

During the visit, the staff observed a series of tests in the recently constructed large flume facility at the Alden Laboratory. The flume consists of a large tank, a pump, piping, immersion heaters, and a flume level control arrangement. The flume geometry can be adjusted to simulate the presence of a sump pit, the configuration that is representative of the Callaway and Wolf Creek plants. The tank water is able to be heated with an external loop. For the test observed on this trip, the external heating loop was used to bring the temperature up to the desired temperature of about 120^{o}F prior to the test start. 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. The system also contains instrumentation for recording and reading flow, pressure differential, temperature, and measuring turbidity. Some of the instrumentation is connected to a desktop computer for trending and data collection. The large test loop also has sample ports for taking water samples and to determine the amount of debris that bypasses the strainer.

The flume cross section approaching the test strainer is varied by the placement of plywood walls to change the flow velocity of the water thereby simulating water flow in the plant as it approaches the strainer. 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.

Alden Labs also has the chemicals and equipment needed for generating and storing precipitates using the methodology outlined in WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191." WCAP-16530-NP chemical precipitates are added to the test flume after plant debris has been added and the pressure drop across the test strainer has stabilized.

2.0 Head Loss Testing

2.1 Thin Bed Head Loss Testing

The determination of whether or not there would be sufficient fibrous debris accumulation to form a fibrous debris bed capable of effectively filtering particulate was based on a single fiber- only test that was performed prior to the staff's arrival. The Wolf Creek design basis load of fibrous debris was introduced in batches with at least 2 pool turnovers between batches until the introduction was complete. No particulates or chemical effects precipitates were added in this test. Two pool turnovers should allow about 80% of the suspended fiber to filter from the pool before the next batch in introduced. Using this introduction procedure, it was unlikely that any significant agglomeration of the fine suspended fibers occurred. An underwater camera was located between two strainer disks roughly midway up in the stack so that the accumulation of fibrous debris could be viewed. After all the fibrous debris was introduced, followed by a minimum of 5 pool turnovers, it was determined from the camera visualization that there was not sufficient fiber on the strainer for effective particle filtration to occur and the test was terminated. Had the thin bed determination been otherwise, the particulate and chemicals would have been introduced. The licensee stated that substantial screen area was observed to be effectively free of fibers.

The staff noted several concerns with the procedure used for this test, including:

- The camera viewed only one location.
- The determination of the fiber bed thickness is subjective and different people could make different determinations.
- The visual criteria for the determination on whether a thin bed is possible was based on a $1/8^{th}$ of an inch, although thin beds have occurred with thinner layers of fibrous debris.
- The most effective method of determining whether or not a layer of fibrous debris will filter particulates and particularly the chemical effects precipitates is by introducing these materials and experimentally determining the filtration effectiveness.
- The accumulation of the fibrous debris may be more uniform when the particulates are present than without the particulates.
- The peak head losses associated with a thin bed have typically occurred with debris beds thicker than $1/8^{th}$ of an inch, e.g., ¼ of an inch.

The Wolf Creek total design basis load of fibrous debris is 107.3 ft^3 assuming a 7D ZOI for fiber, and it would take about 34.5 ft^3 to cover the plant strainer with a layer of fiber $1/8^{th}$ of an inch thick. That means that about 32% of the fiber load would have to essentially transport as individual fibers to develop the $1/8^{th}$ inch thick bed. The licensee should address the concerns expressed herein regarding their estimate of the fine fibrous debris and ensure that the quantity of true fines in the testing was prototypically represented.

2.2 Wolf Creek-Callaway Full Debris Load Test

The licensees conducted a test on January 16^{th} where the full design basis load of debris was introduced. The design basis load combined the maximum quantities of each type of debris from both Wolf Creek and Callaway, i.e., maximum fiber from Wolf Creek and maximum particulate from Callaway. The objective of this bounding combined debris test was to satisfy the testing requirements for both plants, if the head loss results were determined to be acceptable. However, the resultant test head loss of about 7 ft was higher than the acceptance criteria.

Whereas the debris in the thin-bed test was slowly introduced by hand pouring the fiber containers into the test flume, the debris in this combined full load test was introduced using pre-load hoppers with a funneled shaped bottom and a valve at the exit. The concept was to slowly open the valve allowing a regulated flow of pre-mixed wetted debris to enter the test flume. In practice, however, the valve did not work as expected and the debris from the hoppers were drained into the flume rapidly. The licensee speculated that the rapid introduction of debris may have caused enhanced transport of the fibrous debris to the strainer that was not prototypical of the plant transport processes.

The post-test evaluation of the debris accumulation suggested that the relatively high head loss was probably caused by a thin-bed consisting of walnut shell flour and chemical precipitates held in place by a thin layer of fibers. An alternate theory was proposed where fibrous debris effectively bridged the entrance into the pits causing the head loss due to the higher flow velocities at that location. Actually, both phenomena may have contributed to the measured head loss.

Because the debris bed was disrupted upon pump termination, the post test examination of the debris bed accumulation does not conclusively show what processes caused the relatively high head losses. In head loss testing, the flow at pump trip can disrupt the debris bed due to short duration fluctuations as the flow goes from the test flow rate to zero. One method of minimizing disruption of the debris bed at the end of the test is to slowly throttle the flow down using control valves until the flow is slowed as much as possible, then trip the pump.

Figure 1 shows evidence that a thin bed accumulation formed. In this photo, small sections of accumulation at the edges of the disks look like a classic thin bed formation. At others location, such as on the bottom disk in the photo, globs of scooped up thin bed debris can be seen. It is unrealistic to assume a thin bed can form at selected locations, such as at disk edges, and have no debris accumulate on other screen surfaces. The reasonable conclusion was that a thin bed formed on all strainer surfaces but was subsequently highly disrupted at test termination which effectively cleared substantial screen surface of debris. A head loss calculation using the NUREG/CR-6224 correlation demonstrates that a thin bed consisting of the walnut flour and the chemical precipitates could cause the observed head losses. In this calculation, the full load of walnut flour and the chemical precipitates was assumed to accumulate in the debris bed and that the specific surface area of the chemical precipitates was on par with that of calcium silicate. The correlation indicated that the walnut flour alone could not cause such a high head loss.

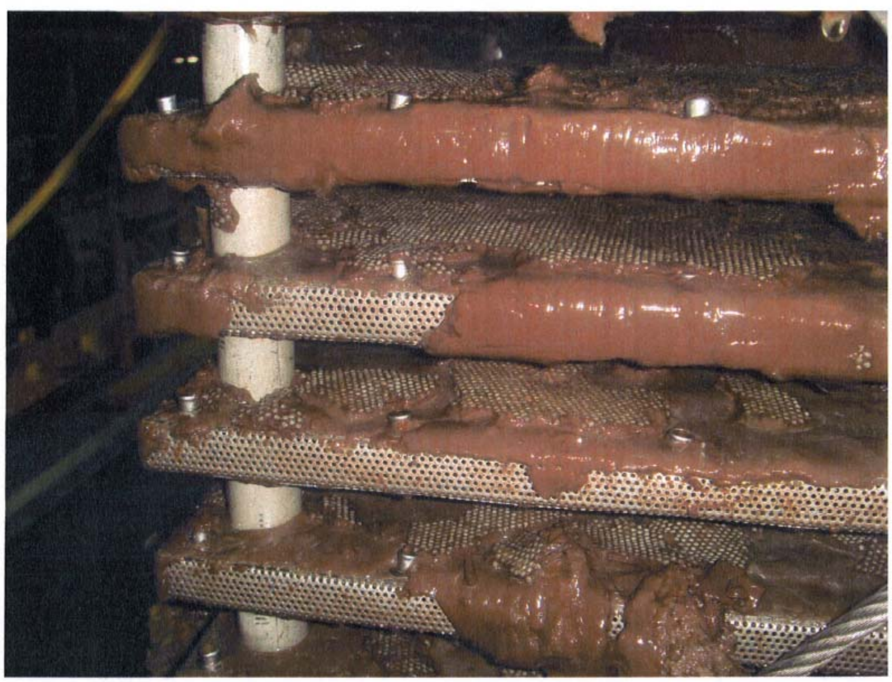

Figure 1. Evidence of Thin-Bed Debris Accumulation

Regarding the debris bridging theory for causing the relatively high head losses, the application of the NUREG/CR-6224 correlation indicates that a completely bridging debris bed of about 3 inches of fibers over a flow area of about 5 ft^2 along with an accumulation of particulates/precipitates could cause the observed head losses. The photo in Figure 2 shows the top portion of the front strainer module extending above the flume floor after the water was drained. The bridging debris bed would have had to bridge the front portion of the lead strainer above the flume floor as well as the upper surfaces to form a complete bridge. The bridging along the front of the strainer above the floor is not seen in this photo, therefore if that bridging did occur; it must have been completely disrupted at test termination. The photo shows debris on the top surfaces but this debris could simply be the buoyant debris that accumulation on the water surface during the test, as shown in the photo in Figure 3. Most likely, the head loss was caused primarily by a thin bed debris accumulation.

The amount of buoyant debris appears to be substantially more than the staff has typically seen in either NRC sponsored or vendor head loss testing. This buoyancy suggests air entrainment in the debris, which could well be associated with use of the new hopper introduction approach. The vendor should evaluate the potential of non-prototypical air entrainment in their testing protocol.

Figure 2. Post Test Debris Accumulation on Top of Strainer Module

Figure 3. Buoyant Fibrous Debris Located Above Strainer Modules

While this full load test may be an invalid test due to the unusual rapid introduction of debris that could have enhanced the debris transport, the test results do show the potential of thin bed head losses and the necessity of ensuring that the thin bed test procedures are valid. The licensee stated that they planned to discontinue use of the hopper for debris introduction and return to the practice of slowly pouring debris into the flume.

2.3 Particulate Only Testing

The licensee conducted a test on January 17th where the maximum load of particulates was introduced. No fibrous debris or chemical effects precipitates were introduced. The purpose of this test was to conduct particulate bypass sampling under maximum bypass conditions.

2.4 Wolf Creek Full Debris Load Test

On January 18th, the last day of the staff visit, another full load test was started based on the full debris load for the Wolf Creek plant. For this test, the debris was measured out into containers prior to the arrival of the staff but the staff was able to observe the wetting of the debris and the debris introduction, which was by slowly pouring the debris into the flume, all of which went as expected. As the staff prepared to depart the site, the head losses on the laboratory monitor were up to 3.9 ft of head loss.

The interesting aspect of this observed head loss is that the finding from the previous thin bed testing indicated that there was that there was not sufficient fiber to form an effective fibrous layer for the filtering the particulate/precipitates, but the filtration was obviously occurring in this last observed test. Note that the thin bed determination was based on the maximum fiber load for Wolf Creek which had a greater potential for generating fibrous debris relative to Callaway. This test illustrates that: 1) there was more fibrous debris accumulation on the screen in the thin bed test than was apparent through the camera visualization, or 2) the quantity of fibrous debris needed to filter particulate/precipitates was substantially less than the 1/8-in criterion, or 3) somehow the quantity or preparation of the fibrous debris, or its transport to the strainer was different between this test and the thin bed test. It also should be considered that the accumulation of fibers on the strainer may be different when the filtration of particulate/precipitates occurs than when these effects are not present. If a spotty accumulation of fibers were to occur, then the subsequent filtration of particulate at those spots would tend to alter/shift debris accumulation to other screen areas, i.e., smoothing the accumulation process over the entire strainer. The camera may have been focused on a location of weak fiber accumulation. When the particulate were present the strainer location would begin to receive the shifted fiber accumulation. It is also possible, as has been observed at other test facilities, that chemical precipitates may require less fiber for effective filtration compared to the standard particulates for which the general 1/8-inch criterion was based. Yet another consideration is that the approach velocity may be faster nearer the core tube than at the edges of the strainer.

3.0 NRC Staff Observations/Comments

3.1 Debris Preparation

The preparation of the debris and its surrogate characteristics should prototypically or conservatively match up with the licensee's debris generation/transport evaluations. The staff did not identify any issues with the vendor selections of surrogate debris. The issue identified by the staff is whether or not the preparation of the fibrous debris provides sufficient quantities of fibrous fines with the key characteristic of remaining suspended under conditions prototypical of the plant.

The PCI preparation protocol of shredding fines, small piece, and large piece debris may actually have sufficient fines in the mix since the shredding process created individual fibers, as well as, the larger pieces of debris. The problem raised by the staff is that the actual portion of the overall debris that is truly fines has not been experimentally assessed. The vendor judgment is that sufficient fines were produced, but this issue is sufficiently important that a specific test be performed to validate the preparation. For example, the vendor could conduct characterization tests where a debris sample was introduced upstream in the flume and transported fibers collected on a simple screen at an appropriate downstream location, dried and weighed to ascertain a reasonable transport fraction which would basically translate into the fraction of the debris that was generated loosely enough to transport as suspended fines. The transport issue is also important because even if sufficient fine debris is created by the shredding process, if fine debris is added with larger debris it may agglomerate, settle, and fail to transport to the strainer. The PCI test protocol was designed to add the most transportable debris first to prevent this issue, so the assertion that the larger debris contained enough fine debris may not be valid for a test that credits near field settling.

Although the PCI preparation of the fines is likely on par with the fines prepared by other vendors, the other vendors are not attempting to simulate the near field debris settling for most tests. The other vendors are in generally introducing the debris close enough to the strainer or agitating the tank to reduce settling in the tank to an acceptable low level. A rough observation of the other vendor fine debris, is that the majority accumulates. With PCI transport flume, it appears that at least half, but more likely about 2/3 of the fine debris settles. Therefore, only a minority, rather than a majority, of the fine debris actually accumulates.

3.2 Debris Introduction

The introduction of the test debris was performed in a reasonable manner with the exception of the potential slug of debris introduced from the hopper at one time, The use of the hopper should either be perfected or its use discontinued. It was noted that some of the fibrous debris was agglomerated when it was poured into the pool by hand. It is possible that this resulted in reduced transportability of the fibrous debris. The vendor could consider introducing the fines nearer the strainer to reduce the settling of debris intended to remain suspended. The vendor could also consider greater dilution of the debris to ensure it is not agglomerated when added to the flume.

The procedure of introducing batches of fibrous debris with an interval of at least 2 pool turnovers between batches until the introduction was complete is valid. Two pool turnovers should allow about 80% of the suspended fiber to filter from the pool before the next batch in introduced. Using this introduction procedure, it was unlikely that any significant agglomeration of the fine suspended fibers occurred.

3.3 Thin Bed Head Loss Test Procedure

Besides the issue with the preparation and introduction of the fibrous fines, the other issue identified was the thin bed test protocol. The staff has several concerns with the PCI approach and the application of the thin bed test protocol which likely led to the determination that there was insufficient fiber to form a thin bed. In contrast, the final observed test, that did not suffer from the hopper delivery problem and had particulate added to the flume prior to the fiber, was developing substantial head loss at the time when the staff ended their visit to ARL. The staff concerns include:

- With only one camera mounted between two strainer disks, only one location on the debris bed was viewed to make a thin bed determination. This practice has the inherent assumption that the bed will accumulate uniformly so that one view is all that is needed. It is likely, that when particulate filtration is ongoing, that the flow will deposit fibers more uniformly due to localized pressure differentials across the bed. Without the particulates nor chemical precipitates in the test, the localized pressure differentials may not be significant enough to achieve uniform fiber accumulation. It is possible that the camera in the thin bed test was looking at one spot in a spotty accumulation that would transition to uniformity if particulates and/or precipitates had been involved.

- The visual determination of the fiber bed thickness based on the camera was subjective. A quantitative method of thin bed determination should be used. Multiple people viewing the debris could estimate many different thicknesses when viewing the same debris bed.

- The peak head losses associated with a thin bed have typically occurred with debris beds thicker than 1/8th of an inch, e.g., ¼ of an inch. Further, thin beds with chemical precipitates have occurred at bed thickness less than 1/8 inch and a bed thickness criterion has not been established for the chemical precipitates. Therefore, visual determination of a thin bed during fiber testing is problematic if based on a bed thickness criterion alone.

- The most effective method of determining whether or not a layer of fibrous debris will filter particulates and particularly the chemical effects precipitates is by introducing these materials and experimentally determining the filtration effectiveness.

3.4 Full Debris Load Head Loss Test Procedure

There are no additional major issues associated with the full debris load protocol. The issue with the preparation of the fine fibrous debris that was raised for thin bed testing also applies to the full load testing.

3.5 Test Termination Procedure

The test termination criteria includes: 1) less than 1% increase in head loss in 30 minutes unless otherwise directed by the test engineer, and 2) a minimum of 15 pool turnovers after all debris has been introduced. The 15 pool turnovers was a staff recommendation to the vendor and therefore acceptable. However, the staff has consistently been concerned with the 1% in 30 minutes criterion because head losses have been seen to still be significantly increasing under this criterion. The protocol includes an approach for extrapolating the test data to the 30 day mission time; however the documentation did not provide a full-enough description to properly evaluate this extrapolation method. The vendor's extrapolation approach includes an equation to scale down the 30 day mission time to 2.28 days based on the ratio of the number of plant pool turnovers to the test pool turnovers, i.e., the number of times the flume water would effectively pass through the test strainer in 2.28 days would equal the number of times that the plant sump water would pass through the plant strainer in 30 days. This approach is new to the staff and the staff is concerned that important time-dependent head loss processes may not be properly represented in 2.28 days.

At test termination, throttling the pump flow down as far as reasonably possible with the flow control valves before tripping the pump could substantially alleviate the debris bed disruption caused by flow oscillations associated with tripping the pump. Alleviating, if not preventing, the pump oscillation disruption of the debris bed would enhance the post test evaluation of the debris bed.

3.6 Chemical Effects

The plant-specific chemical precipitate load is calculated using the chemical precipitate spreadsheet associated with WCAP-16530-NP. Chemical precipitate is prepared outside the test flume using the guidance provided in WCAP-16530-NP. To account for the volume of chemical precipitate solution added to the test, the flume is designed with an overflow area that drains through a fine bag filter. Material caught in the filter is returned to the test flume. For the Wolf Creek plant-specific test, approximately 150 gallons of precipitate solution were added which resulted in approximately 4% of the total flume volume spilling over the side to the drain. Licensee's tests with significantly greater volumes of chemical precipitate solution added to the test should either ensure that the fluid passing through the filter bag does not contain significant quantities of fine particulate and precipitate or account for the loss of this material.

The staff reviewed the one-hour WCAP-16530-NP chemical precipitate settlement measurements. The NRC staff's WCAP-1650-NP safety evaluation contains a condition and limitation for precipitate settlement for head loss testing in which the objective is to settle chemical precipitate and other debris as follows:

> Aluminum containing surrogate precipitate that settles equal to or less than the 2.2 g/l concentration line shown in Figure 7.6-1 of WCAP-16530-NP (i.e., 1 or 2 hour settlement data on or above the line) is acceptable. The settling rate should be measured within 24 hours of the time the surrogate precipitate will be used.

The precipitate settling rates for the Wolf Creek full debris load test were reviewed and determined to be acceptable.

Given that the initial test flume temperature was 120^{o}F, the NRC staff questioned whether this temperature would increase the solubility of the aluminum oxyhydroxide and sodium aluminum silicate precipitate added to the test flume. AREVA personnel indicated that a thermodynamics equilibrium program was used to model the temperature and that no differences were predicted at 120^{o}F compared to room temperature. The staff indicated that relying on a thermodynamic equilibrium program to analyze short term test conditions was probably not reliable. The potential impact on solubility is dependent upon the test flume pH, with a relatively insignificant effect near neutral pH and increasing solubility with increasing pH. For example, Argonne National Laboratory scoping calculations estimated the solubility at 120^{o}F and pH values of 7, and 8 as 1 mg/l, and 11 mg/l, respectively. After all debris was added to the Wolf Creek test, the flume pH was near neutral so solubility effects would be minimal. Licensees with different plant-specific debris should measure the test flume pH and account for solubility, if needed.

<u>Summary</u>

The approach taken by the PCI/AREVA/ARL team of designing and constructing a test flume that would set up prototypical flow conditions for the near field debris transport appears to be generally a valid approach. Ensuring that the preparation of the surrogate debris is either prototypical or conservative is very important. The primary generic concerns or plant specific concerns based on the staff observations and the new PCI test protocol are:

1. The preparation of the fibrous debris may not generate a sufficient quantity of fine fibers, basically characterized as individual fibers, that do not tend to settle at prototypical sump pool flow conditions. The fibrous debris is generated as fines, small pieces, and large pieces, each of which contains a certain fraction of basically individual fibers but without an experimental determination of these fractions, it cannot be validated that a licensee's generation/transport estimate for fine fibers is adequately represented in the tests. Some licensee's generation/transport evaluations show that all fibrous debris approaching the strainers is suspended fiber. For these plants the vendor may have to introduce a greater quantity of their prepared fine debris into the test flume to ensure the correct quantity reaches the strainer. During the introduction of the debris, particularly the fine fibrous debris, adequate dilution should be ensured to prevent agglomeration of the debris.

2. The new PCI test protocol for thin bed testing could lead to incorrect conclusions. All of the full load tests resulted in substantial head losses, whereas the thin bed test resulted in the conclusion that there was not sufficient fiber to form a thin bed. These two results are conflicting. Either the fiber only test resulted in a sufficiently non-uniform accumulation that the one camera view led to an incorrect conclusion or the filtration of the particulate and/or chemical precipitates does not require a uniform layer of fiber for effective filtration or both. It is likely that the fiber accumulation is more uniform with particulates than without particulates and there may be an approach velocity variance between the outer portions of a disk and at the inner portions.

3. The peak head losses associated with a thin bed have typically occurred with debris beds thicker than 1/8th of an inch, e.g., ¼ of an inch. Further, thin beds have occurred at bed thicknesses less than 1/8 in and a bed thickness criterion has not been established for the chemical effects precipitates. Therefore, relying on testing personnel to visually estimate whether or not a bed is at least 1/8 in thick is difficult and may not be the appropriate thickness criterion. For a thin bed sensitivity test using fiber only, the NRC staff has stated that the formation of a bed over the entire strainer surface would be a more appropriate criterion for determining if a thin bed could occur.

4. The licensee test termination criteria and data extrapolation protocol were questioned. The concept of compressing the 30 day mission time down to 2.28 days based on pool turnovers is a new concept that the staff has not reviewed. The concern is that important time-dependent head loss processes may not be properly represented in the compressed time. The NRC staff head loss guidance provides an expectation that final test head loss be based on a time-based extrapolation of data, not a turnover based extrapolation of data.

5. The Wolf Creek/Callaway licensees needs to ensure that the quantity of truly fine fibrous debris characterized as suspended fines has been conservatively estimated. The current estimate of 6% seems to be much too low to account for all of the LOCA-generated fines, the fines from erosion, and the latent fibers.

6. While the staff found the Wolf Creek approach for chemical precipitate production and testing to be acceptable, the staff considers the following are key areas that licensees should pay attention to during future testing: (1) precipitate settlement criteria are met, (2) relatively large volumes of liquid lost during chemical precipitate solution addition do not result in significant losses of fine particulate and precipitate through the filter bags, and (3) the 120^{o}F temperature and test flume pH do not cause the re-dissolution of a significant amount of chemical precipitate.