December 16, 2008

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

FROM: Stephen J. Smith, Reactor Systems Engineer ***/RA/***
Safety Issues Resolution Branch
Division of Safety Systems
Office of Nuclear Reactor Regulation

SUBJECT: STAFF OBSERVATIONS OF TESTING FOR GENERIC SAFETY ISSUE 191 DURING A JULY 29 TO JULY 31, 2008 TRIP TO THE ALDEN TEST FACILITY FOR PCI STRAINER TESTS

On July 29 through 31, 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 chemical effects tests being conducted for the South Texas Project (STP) strainer modification. The participating Nuclear Regulatory Commission (NRC) staff member was Steve Smith of the Safety Issues Resolution Branch in the Division of Safety Systems. The staff interacted with personnel from the STP licensee along with vendor personnel from the Alden Research Laboratory (Alden), Areva NP Inc. (Areva), and Performance Contracting Inc. (PCI). This trip was a follow up to the staff observations made during a trip on February 12 to 13, 2008.

The enclosure summarizes the staff's visit on July 29-31, 2008.

Members of the NRC staff have previously visited the Alden Research Laboratory on March 17 to 18, 2005, on January 18 to 19, 2006, on March 8, 2006, January 16 to 18, 2008, and February 12 to13, 2008, to observe testing. Summaries of staff observations from these five visits are available in ADAMS (Accession ML052060337, ML060750340, ML061280580, ML081830645, ML080920398).

ENCLOSURE:
Trip Report

CONTACTS: Steve Smith, DSS/SSIB
301-415-3190

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DATE	12/16/08	12/16/08

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Observations of Testing at Alden Research Laboratory
July 29 to 31, 2008

Overview of Facility

This trip was a follow up to the staff observations of testing for South Texas Project (STP) that occurred from February 12 to 13, 2008. The staff considered that the follow up was necessary because of high head losses observed during the previous STP testing. The concern identified during the previous testing was that very high head losses resulted when only the particulate and fine fibrous debris had been added to the test flume. The test had to be aborted prior to the addition of the remaining fibrous debris and chemical debris.

On July 29 through 31, the staff observed a chemical effects head loss test for South Texas Project (STP) at Alden Labs. The Alden Laboratory has the capability to perform tests in two facilities. These are (1) a large tank flume for performing integral head loss testing of modular strainer arrays or strainer prototypes including near-field settling, and (2) a small-scale horizontal test loop. The staff observed a single head loss test for STP that was performed in the large test flume. The large test loop is comprised of a large tank, a pump, piping, immersion heaters, and a flume level control arrangement. There is also the ability 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 were taken to determine the pH of the water throughout the test. The large 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. Details of the test procedure and technical data were requested by the staff, but were not provided for review with the exception of a table of the debris loads used during the test. The test flume has a large capacity, but for the STP test, the plywood walls were relatively close together so the test volume was somewhat reduced from the maximum possible. 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 heating loop was isolated during the test, but the immersion heaters were used in an attempt to maintain the desired test temperature. 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."

Test Setup and Strainer Details

The test tank contained a single Performance Contracting Inc. (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 (Photo 1). The arrangement was intended to model flow to an average strainer module (with some conservatism) from the several modules that make up each STP sump strainer. STP has three redundant strainers with two required for operability. 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 40 feet upstream of the strainer and allowed to transport to the strainer. The flow velocity approaching the strainer at STP is relatively high as compared to most PWRs. In this case the flume velocity was about 0.5 ft/sec.

The 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 module was the same design as the modules installed at STP. The area of the test module was 91.44 sq. ft which represented about 2.5% of the total strainer area installed at STP considering that one train may not function following a LOCA.

The licensee had completed transport tests prior to the February 2008 testing. Based on the results of the transport test, some material was excluded from tests performed for the STP strainer.

The staff also noted that PCI/Areva/Alden were conducting a significant test program for Japanese strainers in the small test flume.

<u>Test Performance (Full Load)</u>

The full-load test is run to determine the head losses associated with the full debris load for STP. If the test ends with more than a thin bed, then a thin-bed test would be run to determine the head losses associated with reduced fibrous loading.

The staff arrived at the test facility at about 1330 on 7/29/08, after the particulate debris and fine fibrous debris had been added to the flume. Test personnel reported that the test had commenced at about 1215. The test flow rate was maintained at about 353 gpm. The test temperature was about 120 ^{o}F. Head loss was about 4.5 ft at this time. Test personnel reported that the clean strainer head loss (CSHL) measured at the beginning of the test was 0.092 ft at 120 ^{o}F.

At 1430, acrylic paint chips were added to the flume followed by small fibrous debris. Both the paint chips and small pieces of fiber appeared to be adequately prepared and both types of debris appeared to transport down the flume toward the strainer. After the addition of the paint chips and small fiber pieces, head loss increased to about 5 ft, and then slowly decreased.

At 1505 the fines considered to erode from larger pieces of debris were added to the test flume. This fibrous debris was very fine and well diluted when added to the flume. With the addition of this debris the head loss stopped decreasing and remained steady for a period of time. By 1700, the water in the flume was very clear. Small pieces of fiber were observed in the bottom of the flume (Photo 2) with a greater amount of this debris collected in the wider portions of the test flume. At this time the head loss was about 4.3 ft and slowly decreasing. The flume was allowed to run overnight and it was planned to begin adding chemical precipitates the following morning.

On 7/30/08, when test personnel arrived at the facility, a small portion of the strainer was visible through a hole in the debris floating on the surface of the flume (Photo 3 shows the opening in the surface debris). Less than 5% of the strainer was visible. The visible portion of the strainer appeared to have a thin layer of debris covering it. Some metal portions of the strainer surface were visible.

The chemical precipitates were added over a period of 2 days starting on 7/30/08. The STP chemical precipitate generation was conducted in accordance with WCAP-16530-NP. The plant-specific amount of chemical precipitate was determined with the chemical model spreadsheet contained in the WCAP. These precipitates were prepared in the Alden Lab using the methodology provided in the WCAP. The precipitate settlement for this test was measured and found to be within the WCAP specifications for testing that credits near-field settlement. There was a minimum of 2 flume turnovers between additions of chemical batches. The chemical precipitate solutions were prepared at a concentration of 11 grams/liter.

At 0800 on 7/30/08 head loss was about 3.9 ft and continuing to decrease slowly. At about 0940, the first batch of chemicals, aluminum oxyhydroxide (AlOOH), was added. Head loss increased from about 3.9 ft to 6.6 ft relatively quickly, then more slowly to about 7.3 ft. The next chemical batch added at about 1015 was calcium phosphate (CaPO). After this addition, head loss increased to about 7.5 ft. In general, the batches of AlOOH were 34 gallons while the CaPO batches were 17.5 gallons. A few more batches of CaPO were added with no marked increase in head loss although a slow upward trend was maintained. The second batch of AlOOH was added at about 1110 resulting in head loss increasing from about 7.6 to 8.0 ft. (Photo 4 shows the head loss response to these chemical debris additions.) Several additional batches of CaPO were added. Head loss slowly decreased to about 7.8 ft. At about 1220 the third batch of AlOOH was added resulting in head loss increasing to about 8.2 ft. Additional CaPO additions had no effect on head loss. The fourth AlOOH addition resulted in head loss increasing from about 8.25 to 8.35 ft. More CaPO was added and head loss slowly decreased to about 8.2 ft. A fifth batch of AlOOH was added and no effect was noted. Head loss was about 8.2 ft at this time. Testing for the day was stopped and flow through the flume was maintained over night.

When test personnel arrived at the lab on the morning of 7/31/08, it was observed that head loss had decreased to about 6.9 ft. The temperature had increased from 113 ^{o}F to 116 ^{o}F over night. The decrease in head loss resulted in a flow increase. When the flow was decreased from about 370 gpm to the target of about 353 gpm head loss further decreased to about 6.5 ft (Photo 5). The head loss appeared to respond to flow changes linearly indicating that bore holes were not present. The plan for the day was to increase the aluminum loading to determine if scaffold racks can be stored in containment. The strainer was not visible through the debris in the flume. The addition of the first batch of AlOOH at about 0800 resulted in a head loss increase to 6.6 ft. At about 0815, a second batch of AlOOH was added with another small increase in head loss to 6.7 ft. A flow adjustment increased head loss to about 6.9 ft. The third batch of AlOOH resulted in another increase in head loss to about 7.0 ft. Additional chemical additions and flow adjustments were made with similar results. After multiple additions of AlOOH, some representing the potential for aluminum loading beyond the base case, head loss reached about 9.0 ft (Photo 6). Once these chemical additions were complete, STP decided to stop the test for 15 turnovers. Head loss trended down slowly during the hold.

The staff had to leave the test facility at this time due to travel constraints. After the staff left the test facility, the flume was drained to allow observation of the debris bed on the strainer. An e-mail describing the bed on the strainer was received. The description is as follows: “After drain down, we were able to confirm visually and by observing a top disk rim sample there was less than an 1/8" fibrous bed beneath more than ½" to 1" of chemical "goo"….to be scientific. We will therefore not pursue an additional or specific thin bed test".

Test Results

The test results and physical observations are summarized as follows. Some of these results were provided to the staff via e-mail following the test:

The clean strainer head loss was measured to be about 0.092 ft for the test strainer at 120 ^{o}F.

The water temperature at the start of the test was 120 ^{o}F. The temperature decreased during the test due to the addition of colder water with the debris, especially the chemical debris.

The flume velocity flow rate was noted to be quite high for STP as compared to most other PWRs. The average flume velocity was about 0.5 ft per second.

The head loss associated with the full debris load including chemicals was reported to be 9 ft with an acceptance criterion of 10.4 ft. The 9 ft of head loss was attained with significantly more than the base aluminum loading predicted for the plant. The debris bed appeared to be a thin bed.

The pH values for the test flume were reported to be as follows:

pH Readings of Flume Testing	Time	pH	Temp ºC
7/30/2008	9:15	6.70	41.70
	10:30	6.90	41.00
	11:30	7.35	40.00
	12:43	7.55	41.00
	2:10	8.05	39.00
	3:15	7.63	41.00
	3:50	7.61	39.00
7/31/2008			
	7:45	7.43	38.00
	8:45	7.48	40.00
	9:40	7.80	42.70
	10:40	8.06	41.50
	1:20	8.20	41.00
	2:30	8.14	41.80

Differences between February and July Testing

There were significant differences between the STP tests run in February and July. This section contains a summary of the significant differences.

1) Acrylic coating fines and chips were used to represent acrylic coatings instead of walnut shell flour. The February test used about 60 pounds of walnut shell flour. The July test used about 15 pounds of acrylic fines and 52 pounds of acrylic paint chips. Tin powder was used in both tests to represent the inorganic zinc coatings. No changes were made to the amount of tin powder added to the test.

2) The amount of fibrous debris was reduced for the July testing by assuming a 7D ZOI instead of a 17D ZOI. The early testing added about 19 pounds of fine fibrous debris to the flume. The recent testing added about 4.2 pounds of fine fibrous debris to the flume. Small fibrous debris was reduced from about 27 pounds to about 9.6 pounds. The fibrous quantities referenced here include both Nukon and Thermal-Wrap. The smaller ZOI was justified by referencing a Westinghouse document that has not been accepted by the staff. It seems unusual that the fine fibrous debris was reduced to about 21% and the small fibrous debris was reduced by about 37%. In general, with a reduced ZOI, a higher percentage of fine debris would be expected to be created. The evaluation of the inputs to the test debris quantities is outside the scope of this trip report.
3) The PCI/Areva debris preparation methodology has been revised to remove any fine fibrous debris from the small debris category by subjecting "smalls" processed through a wood chipper to a shaker table with coarse screen. The old methodology left any fine debris that was created in the process of making the small debris in the mixture; whereas the new process allows loose "fines" to be removed from the "smalls". This reduces the total fine debris available for transport to the strainer to be more representative of the design basis specified by the client.
4) Instead of using Cal-Sil as a surrogate for Marinite, Marinite powder was used. No change to the amount of Marinite surrogate was made.

Because the February testing did not proceed past the initial stages and chemicals were not added, a comparison of chemical debris effects cannot be made. Other than the removal of the fine fibrous debris from the smalls and the changes in debris surrogates and amounts described above, no changes to the test protocol were noted.

Observations

The staff considered the results of the observed test to be of significant interest. The major points are as follows:

1) Testing appeared to be conducted per the staff guidance on head loss testing. The testing was conducted similarly to the February test that resulted in unacceptable head loss. The difference between the tests was that several debris amounts were reduced for the July test and some debris types were also changed. Although the test resulted in significant head loss, its magnitude was within the site's acceptance criterion. The testing was conducted in accordance with the staff review guidance on head loss and vortexing. The question that remains is whether the debris reductions credited by the licensee have adequate technical basis. Several other licensees have credited similar debris reductions for their plants. This issue is beyond the scope of this trip report.
2) A significant reduction in the fine fibrous debris loading resulted in much lower head losses than had been attained with higher fine fibrous debris loading.
3) Part of the reduction in head loss may be attributable to the use of Marinite powder in place of Cal-Sil which had been used as a surrogate for the Marinite in the previous testing.
4) Some reduction in head loss may also be attributable to the change in the coatings debris surrogate from walnut shell flour to acrylic fines. In addition, much of the paint surrogate was added as acrylic chips instead of powder as had been the case with the previous test. The fine particulate was reduced from about 60 lb to 15 lb with chips representing the remainder of the non-zinc coating debris. The treatment of coatings as other than particulate for a plant with enough fibrous debris to create a thin bed must

result from a plant specific evaluation of coatings within their containment. The evaluation of the treatment of the coatings debris is beyond the scope of this trip report.

5) Throughout the test, when debris was not being added to the test, head loss tended to trend slowly downward. A reason for this behavior was not determined. However, this has been noted at some other testing.
6) The addition of early batches of chemical debris resulted in relatively large head loss increases. Later additions of chemical debris resulted in much smaller increases.
7) The aluminum oxyhydroxide chemical surrogate caused higher head losses than the calcium phosphate surrogate. It is possible that the aluminum-based surrogate transports more readily, but this was not confirmed during this testing.
8) The filtering of chemicals from the test fluid appeared to be relatively efficient. Head loss would increase in a step following each addition, and then quickly level out.

Summary

In summary, the staff observed chemical effects testing conducted for STP by PCI and Areva at the Alden Research Laboratory. Simulated plant debris in the test observed by the staff were representative of a break location that produced a fiber bed and particulate loading expected following a LOCA with fibrous debris loading reductions justified by vendor testing. The full-load test, including chemical debris, resulted in a thin bed and significant head losses. Even with the reduced debris loading, the maximum head loss attained was 9 ft which is within the site's acceptance criterion. The testing confirmed that fine fibrous debris combined with particulate debris can produce a thin bed resulting in a high pressure drop across a sump strainer. The staff will continue to engage various licensees and vendors as sump strainer testing progresses. The staff expects these tests will provide a better understanding of plant-specific debris and chemical effects head losses.

Photo 1

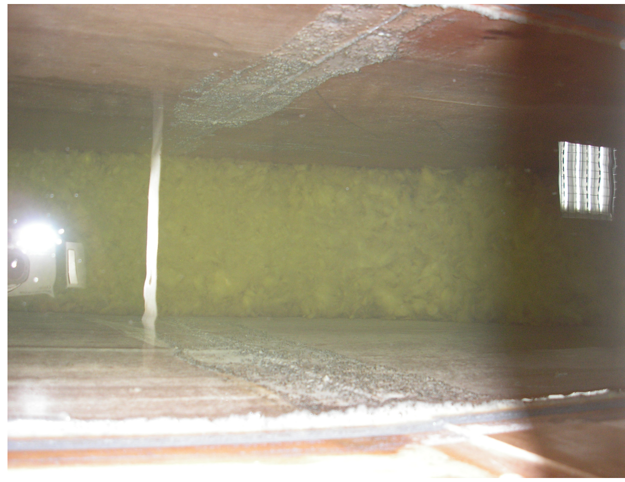

Photo 2

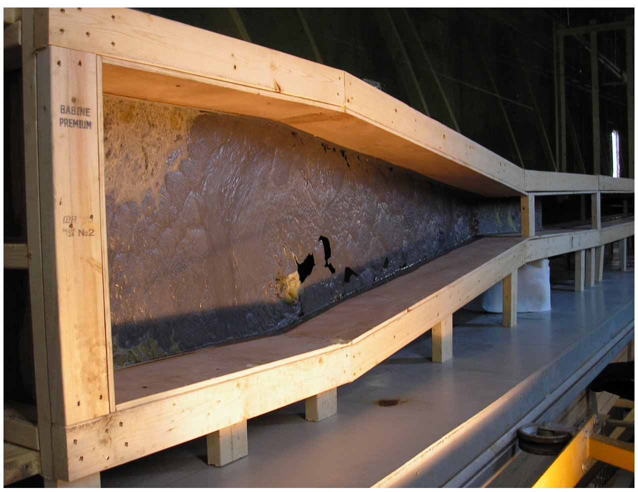

Photo 3

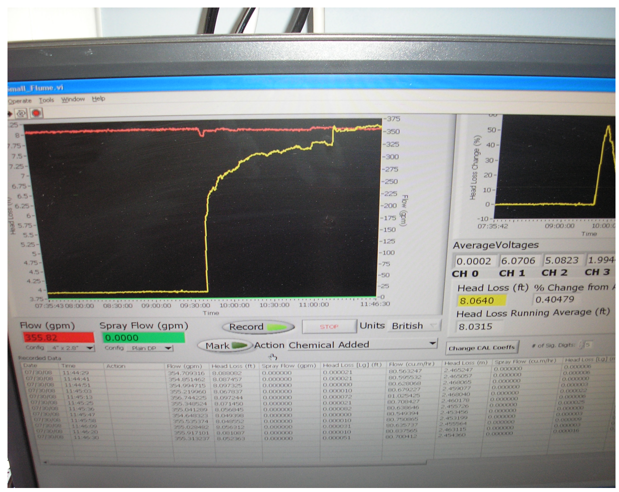

Photo 4

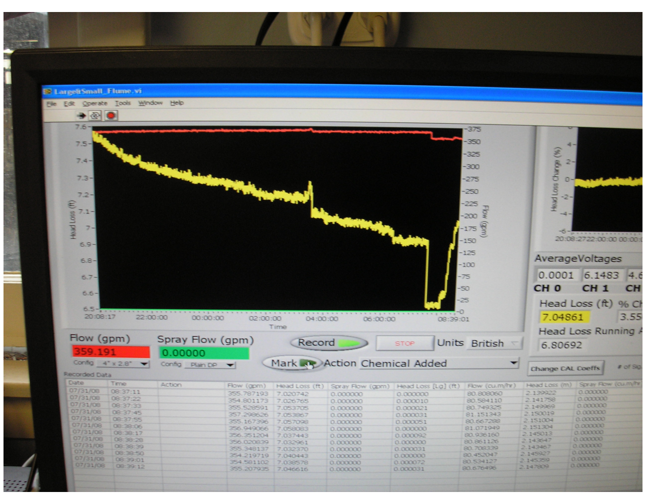

Photo 5

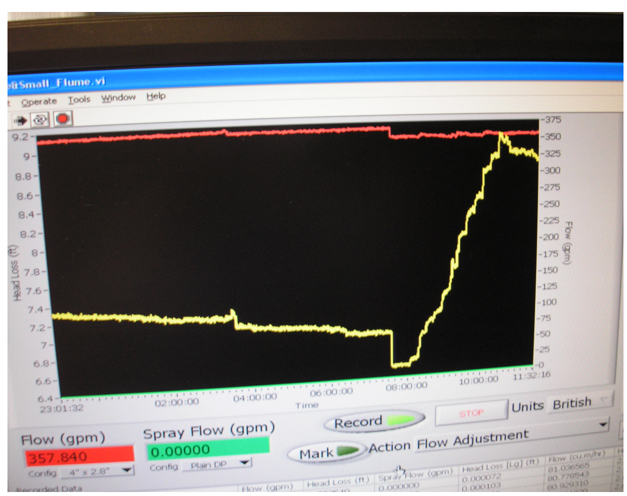

Photo 6