June 30, 2006

MEMORANDUM TO: Jared S. Wermiel, Deputy Director
Division of Safety Systems

FROM: Michael L. Scott, Chief ***//RA by S. Lu for//***
Safety Issues Resolution Branch
Division of Safety Systems

SUBJECT: STAFF OBSERVATIONS REGARDING FLUME TESTING OF A PROTOTYPE PORTION OF THE PROPOSED REPLACEMENT SUCTION SCREEN DESIGN FOR THE COMANCHE PEAK STEAM ELECTRIC STATION (DOCKET NOS. 50-445 AND 50-446)

PURPOSE:

This memorandum reports the U.S. Nuclear Regulatory Commission (NRC) staff observations at the Alden Research Laboratory, Inc., (ARL) on flume testing of a proposed replacement sump screen at Comanche Peak Steam Electric Station (CPSES or the licensee) on March 8, 2006.

BACKGROUND:

An NRC staff member traveled to the ARL located in Holden, MA, to observe flume testing of a prototype portion of the proposed replacement sump screen at CPSES. Hanry Wagage, from NRC's Division of Safety Systems in the Office of Nuclear Reactor Regulation (NRR), observed the testing. At the ARL test facility, Framatome ANP, Inc., (FANP) tested the sump screens for CPSES. CPSES plans to use screens designed and constructed by Performance Contracting, Inc. In addition, a CPSES representative and the vendors FANP, ARL, and Performance Contracting, Inc., were present during the testing. Enclosure 1 lists the participants.

DISCUSSION:

The primary objective was to observe large-scale flume testing that the licensee plans to rely on in addressing near-field debris transport, screen debris accumulation, and screen head loss for the CPSES design basis. The test screen was a prototype that represented 1/197 of the screen area of the modular array proposed for replacing the existing CPSES screens in each of the two sumps. For the tests, FANP used debris representing insulation, coatings, latent dirt and dust, miscellaneous sources (e.g., tapes and labels), and chemical products. FANP stated

CONTACT: Hanry Wagage, NRR/DSS/SCVB
301-415-1840

that it followed the guidelines prescribed in WCAP-16530-NP, Rev. 0, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," dated February 2006 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML060890509). In addition to observing this testing, Dr. Wagage had consulted the staff from NRR's Division of Containment Integrity on chemical effects testing before the trip and conveyed the division's comments to the CPSES representative.

Although FANP used these tests to measure head loss, FANP also collected, at given intervals, samples of debris passing the test screen. FANP will send these samples to another laboratory for analysis.

Enclosure 2 describes specific observations as noted during the testing. Enclosure 3 shows pictures of the tests taken by CPSES and provided to the NRC staff. Enclosure 4 gives CPSES comments on a draft of this trip report.

SUMMARY:

During the FANP-conducted tests, CPSES addressed several issues the staff had raised during its previous visits to observe testing at ARL on March 17 and 18, 2005; November 29 and 30, 2005; and January 18 and 19, 2006. (The trip reports on the March 2005 and January 2006 visits, dated August 11, 2005, and April 20, 2006, are available at ADAMS Accession Nos. ML052060337 and ML060750340. The November 2005 visit was a part of Watts Bar audit on its response to Generic Letter 2004-02. This audit is in progress and a trip report has not been issued at the time of publication of this report.) FANP collected screen bypass samples, and CPSES plans to analyze the samples and address downstream effects. For the tests, FANP used the chemical products recommended in WCAP-16530-NP, and CPSES plans to fully address the chemical effects.

Enclosures:
1. Attendees for Flume Testing of a Prototype Portion of the Proposed Replacement Suction Screen for the Comanche Peak Steam Electric Station on March 8, 2006
2. Staff Observation of Flume Testing of a Prototype Portion of the Proposed Replacement Suction Screen for the Comanche Peak Steam Electric Station
3. Pictures of the Tests Taken by CPSES and Provided to the Staff
4. Enclosure 4: CPSES Comments on and Input to NRC Draft Trip Report

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ADAMS Accession # ML061710147 Package
Trip report: ML061280580 memo and Enclosures 1 and 2
Enclosure 3: ML061310520
Enclosure 4: ML061730164 NRR-105

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NAME	HAWagage	MLScott
DATE	6/ 22 /06	6/ 30 /06

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Attendees for Flume Testing of a Prototype Portion of the Proposed Replacement Suction Screen for the Comanche Peak Steam Electric Station on March 8, 2006

No.	Name	Organization
1	Brian McMahan	Alden Research Laboratory, Inc.
2	Charles Feist	Comanche Peak Steam Electric Station
3	Dean White	Alden Research Laboratory, Inc.
4	Frank Sabatini	Framatome ANP, Inc.
5	Gorden Hart	Performance Contracting, Inc.
6	Hanry Wagage	U.S. Nuclear Regulatory Commission
7	Harold Beck	Framatome ANP, Inc.
8	Ken Greenwood	Framatome ANP, Inc.
9	Ray Phan	Framatome ANP, Inc.
10	Stuart Cain	Alden Research Laboratory, Inc.
11	Tim Sassaman	Alden Research Laboratory, Inc.

Staff Observation of Flume Testing of a Prototype Portion of the Proposed Replacement Suction Screen for the Comanche Peak Steam Electric Station

An NRC staff member traveled to Alden Research Laboratory, Inc., (ARL) located in Holden, MA, to observe flume testing of a prototype portion of the proposed replacement sump screen at Comanche Peak Steam Electric Station (CPSES). Hanry Wagage, from NRC's Division of Safety Systems in the Office of Nuclear Reactor Regulation, observed the testing. At the ARL test facility, Framatome ANP, Inc., (FANP) tested the sump screens for CPSES. CPSES plans to use screens designed and constructed by Performance Contracting, Inc. In addition, a CPSES representative and the vendors FANP, ARL, and Performance Contracting, Inc., were present during the testing. Enclosure 1 lists the participants.

FANP conducted the testing between March 6–8, 2006; on March 8, the staff observed two tests, Tests 1 and 5, conducted for debris head loss across and bypass through the screen. Test 1 modeled debris generated from a postulated CPSES design-basis loss-of-coolant accident (LOCA) as discussed in CPSES's response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (PWRs)." Test 1 used surrogate materials to represent chemical products that may form in the containment following a LOCA. The staff raised concerns that the chemical surrogate material and the test environment may not represent the actual plant conditions. Commenting on a draft of this trip report, CPSES later stated in an email, dated June 13, 2006, (Enclosure 4) that it considered these as generic issues and that it was working with Nuclear Energy Institute, PWR Owners Group, and vendors to address them. Test 5 modeled a significant amount of fiber insulation in addition to the debris load of Test 1. Test 5 provided a sensitivity case with high-fiber loading for CPSES and a piggyback test for Wolf Creek Nuclear Operating Corporation's NUKON™ insulation (i.e., the additional fiber debris).

The CPSES prototype sump screen was a Performance Contracting, Inc., design and had a surface area of 20.23 ft^2, which was 1/197 scale of the surface area of proposed sump screens of 3993 ft^2 each. Scaling the design emergency core cooling system and containment spray flow rate of 12,420 gpm per train using the same factor gave a test flume flow rate of 62.9 gpm. However, to account for the approach velocity increase resulting from sump screen blockage from tags and labels, the tests used an increased flume flow rate of 66.3 gpm, which was 1/187 scale of the CPSES sump flow rate. The perforated plate of the screen had a hole diameter of 0.095 inches.

Table 1 lists the debris used for Test 1, which were 1/197 scale of that calculated for the CPSES design basis. In addition to the debris used for Test 1, Test 5 used 20.67 lbm of shredded NUKON™ insulation representing 1,700 ft^3 (4,080 lbm).

ARL technicians placed the prepared debris into buckets and partially filled and mixed them with water to remove air in the debris. Then the technicians poured the debris-water mixture into a partially filled flume upstream and within 3 feet of the test screen in the following order: reflective metallic insulation, particulate, fiber, latent fiber, and chemical debris. The flume was filled to the initial water level for recirculation. The technicians stirred debris in the flume to make it suspend in the water.

The technicians started the test with a partially submerged screen with a flume flow rate of 26.7 gpm, representing an emergency core-cooling system flow rate of 4,900 gpm. The calculated approach velocity at the test screen corresponding to this flow rate was 0.0040 ft/s. After ramping up the flume water level for 25 minutes, the technicians increased the flume flow rate to 66.3 gpm. This flow rate gave a calculated approach velocity at the submerged test screen of 0.0073 ft/s. The technicians collected screen bypass samples at 10-minute intervals during the first hour and at 20-minute interval during the second hour of testing. FANP will send these debris bypass samples to another laboratory for analysis.

In its December 6, 2004, safety evaluation on the Nuclear Energy Institute's Pressurized Water Reactor Sump Evaluation Methodology, the staff stated that when evaluating downstream effects licensees may not take credit for the filtering effects of the debris bed formed on the sump screen. Commenting on a draft of this trip report, CPSES later stated in its June 13, 2006 email that it used this information during test planning and the following:

> The primary purpose of these tests was head loss and the debris was selected to make that conservative. Downstream sampling was added to gather "data" during that testing. We decided not to run a special bypass test in this series. In addition to Test 1 and 5, downstream samples were taken for Test 2 with higher fiber than Test 1 and for Test 3 with paint chips for unqualified epoxy. Test 2 had just enough fiber for a thin bed. However, Test 3 had no fiber. Test 3 tested for unqualified coatings failure in the absence of fiber in accordance with the December 6, 2004, safety evaluation on Nuclear Energy Institute's Pressurized Water Reactor Sump Evaluation Methodology. The data from Test 3 is consistent with the staff's view on this.

The staff did not observe Test 3 or review its data.

After five turnovers of the volume of water in the flume (81 minutes), the measured screen head loss was 0.356 ft, and it was increasing at a rate of less than 1% for a 5-minute interval. The temperature of water in the flume was 47 EF. Note that in commenting on a draft of this trip report, CPSES later stated in its June 13, 2006 email that after correcting for clean strainer head loss, suction pipe head loss, and pipe velocity head loss, the preliminary debris load head loss for this case was 0.285 ft. Given that a significantly higher sump pool water temperature is expected following a LOCA that lowers viscosity and thus the head loss, the staff noted that the head loss measured in the test was conservatively higher than that expected in the plant. The technicians then increased the flume flow rate to 101.8 gpm, which was 160% of the design value (62.9 gpm for the flume). This was to represent the condition of a higher approach velocity to the test screen when debris covered the space between disks, reducing its effective area and making the circumferential area the effective area of the screen. The corresponding screen head loss measured was 0.630 ft.

After completing Test 1, the technicians brushed the accumulated debris on the test screen into the flume and started Test 5 by pouring the NUKON™-water mixture into the flume. The test screen head loss measured was about 0.1 ft, which is lower than that measured in Test 1. The staff noted that Test 1 used finely hand-shredded NUKON™ representing latent fiber but Test 5 used coarsely machine-shredded NUKON™, which may have contained some fiber fines that was formed during shredding. The finely-shredded NUKON™ used in Test 1 would have supported forming a thin debris bed giving a higher head loss than in Test 5. However, the presence of a large amount of coarsely-shredded NUKON™ and the low approach velocity to the screen would have prevented forming a thin bed and thus would have resulted in a lower head loss in Test 5 than in Test 1. It is possible that the debris which was brushed from the screen at the end of Test 1 may have been in clumps and thus settled on the floor of the flume and not transported on to the screen during Test 5. The large amount of coarsely-shredded NUKON™ formed a more porous and thicker debris bed in which the low approach velocity caused lesser compression giving less head loss.

During the test, the staff noted a layer of fibrous debris floating on the surface of the flume. The staff had previously observed this behavior in the ARL flume during testing performed for Point Beach Nuclear Plant Units 1 and 2 (ADAMS Accession No. ML060750340). The overhead sprays water was aerated and penetrated below the water surface of the flume. The aerated water released bubbles which adhered to fibers making them float. This behavior reduced the quantity of fibrous debris reaching the test strainer. However, it is not clear to what extent this effect is representative of the actual plant containment pool, which may also undergo a similar behavior.

During its previous visits to observe testing at ARL on March 17 and 18, 2005 and January 18 and 19, 2006, the staff had raised concerns about how FANP and ARL conducted flume testing. (The corresponding trip reports, dated August 11, 2005 and April 20, 2006 are available at ADAMS Accession Nos. ML052060337 and ML060750340.) As a result, FANP and ARL changed the test procedures for CPSES. Table 2 lists these changed test procedures and the staff's conclusions regarding the changes.

Table 1. Debris Used for Test 1

No.	Debris Type (Unit)	LOCA Design Condition	Test (lbm)	Debris Form/Surrogate
1.	Reflective Metallic Insulation	25,387 ft^2	10.46	Cut 2-mil thick stainless steel pieces
2.	Coatings			
	Qualified High Build Epoxy Epoxy Inorganic Zinc Silicone	 12.9 lbm 4360.5 lbm 342.3 lbm 70.2 lbm	 0.07 22.09 1.73 0.36	Tin powder surrogate for inorganic zinc and ground walnut shell surrogate for epoxy, enamel, and alkyds
	Unqualified Inorganic Zinc Epoxy Enamel	 25,634 lbm 12,920 lbm 992 lbm	 129.88 65.46 5.03	
3.	Fiber			
	Latent Fiber	9.9 ft^3	0.12	Finely hand-shredded NUKON™
	Low Density Fiberglass	20.9 ft^3	0.582	Shredded Owen Corning fiberglass
	Lead Blanket Covers	7.7 ft^3	2.988	Shredded actual blanket material
	Lead Wool	13.5 ft^3	8.208	Stainless steel wool
	Min-K	0.5 ft^3	0.152	Shredded Min-K fabric
4.	Particulate			
	Latent Particulate (Dirt and Dust)	144.5 lbm	0.73	PCI-PWR mix
	Min-K	30.7 lbm	0.16	Shredded Min-K particulate
5.	Tags and Labels	1,400 ft^2	0.779	Provided by CPSES
6.	Chemical Debris			
	Aluminum Hydroxide (AlOOH)	80 lbm	0.4	Powder
	Sodium Aluminum Silicate ($NaAlSi_3O_8$)	200 lbm	1.0	Powder

Table 2. Previously Raised Staff Concerns (*Not All Inclusive*) on FANP/ARL Flume Testing and Resulting Procedure Changes for CPSES Flume Testing

No.	Staff Concern	New Test Procedure	Staff Comment
1.	Coarsely machine-shredded NUKON™ insulation pieces representing latent fiber debris may be larger than prototypic debris resulting in a nonconservative head loss.	Test 1 used finely hand-shredded NUKON™ representing latent fiber debris.	This change addresses the staff concern.
2.	Debris settling in the flume before reaching the test screen (near-field debris transport) may not represent the plant conditions.	Before starting the pump, pour the debris into the flume within 3 feet of the test screen, and stir debris in the flume to make it suspend in the water.	Without further reviewing the test report and applicable test procedures, the staff cannot determine whether this concern is addressed. The staff will evaluate licensee submittals to address Generic Letter 2004-02 to determine whether this concern has been satisfactorily addressed.
3.	When pouring debris in the flume, denser debris may trap lighter debris, which floats and thus be more transportable, causing it to sink giving non conservative results.	Pour debris into the flume in the order heavier to lighter debris and thus avoid the possibility of heavier debris trapping and sinking lighter debris.	This change addresses the staff concern.

Table 2. Previously Raised Staff Concerns (*Not All Inclusive*) on FANP/ARL Flume Testing and Resulting Procedure Changes for CPSES Flume Testing *(continued)*

No.	Staff Concern	New Test Procedure	Staff Comment
4.	During a flume test, debris keeps accumulating on the test screen and increasing the head loss although the rate of increase drops with time. If the test were to continue for a longer time, the head loss may have increased to more than the net positive suction head (NPSH) margin.	Extrapolate the measured head loss for the number of sump water turnovers during the plant mission time: conservatively assume that the rate of head-loss increase at the desired time for stopping the test will stay constant. (The test-flume and plant-sump water turnover times were 16 and 32 minutes.) Ensure that the extrapolated head loss is below the NPSH margin.	This change addresses the staff concern. With an NPSH margin of 5.6 ft and a measured head loss of 0.356 ft at the end of Test 1 (design condition), CPSES showed that the extrapolated head loss was below the NPSH margin. Given that a significantly higher sump pool water temperature is expected following a LOCA that lowers viscosity and thus the head loss, the staff noted that the head loss measured in the test was conservatively higher than that expected at the plant. However, a similar extrapolation of measured head loss may not work for other plants with a lower NPSH margin and/or higher head loss.
5.	The approach velocity to the test screen will increase if debris covers the space between disks, reducing its effective area and making the circumferential area the effective area of the screen.	Run a sensitivity case for the condition that the circumferential area becomes the effective area of the screen. For CPSES this represented a flume flow rate of 160% of the nominal value to account for the increase in approach velocity.	This change addresses the staff concern. This concern, which applies to Performance Contracting Inc. sump screen design, may or may not apply to other sump screen designs.