April 20, 2006

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

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

SUBJECT: TRIP REPORT REGARDING STAFF OBSERVATIONS OF SCALED FLUME TESTING OF THE POINT BEACH NUCLEAR PLANT PROPOSED REPLACEMENT SUCTION STRAINER DESIGN

On January 18-19, 2006, the NRC staff traveled to Holden, MA, to observe scaled flume testing of the proposed replacement suction strainer for the Point Beach Nuclear Plant (PBNP) at the Alden Research Laboratory test facility. During the trip, the staff engaged licensee and vendor personnel in a variety of technical discussions pertaining to scaled flume test procedures and associated analyses. Participating vendors included Framatome/Areva, Alden Research Laboratory, and Performance Contracting, Inc. Participating staff included John Lehning of NRR/DSS/SSIB, along with contractors Clint Shaffer of ARES Corporation and Marcos Ortiz, an independent consultant.

The staff's primary objective was to observe large flume testing that the licensee plans to rely upon in determining near-field debris transport, strainer debris accumulation, and strainer head loss for the PBNP design basis. The test strainer was a scaled prototype of a single module of one of the two modular arrays proposed to replace the existing PBNP sump suction strainers. The test observed by the staff included debris from insulation, coatings, latent dirt and dust, miscellaneous sources (e.g., tape, labels), and chemical debris. The recently issued Westinghouse Owners Group (WOG) report on chemical effects testing was used to justify the test procedures associated with the chemical surrogate debris. Although chemical effects specialists were not available to observe the test, a set of written questions from NRR/DCI staff was transmitted to the licensee during the trip, and a teleconference was arranged to facilitate follow up discussion.

In addition to observing the scaled flume test, the staff discussed with licensee and vendor personnel a variety of technical issues associated with scaled flume testing, including (1) the prototypicality of debris settling near the strainer (i.e., the near-field effect), (2) the basis for considering the surrogate test debris as similar to actual plant debris, and (3) the scaling of the flume flow rate to create a prototypical velocity through circumscribed debris beds.

Specific staff observations are documented in the enclosure to this memorandum.

Enclosure: Trip Report Regarding Point Beach Flume Testing Observation

CONTACT: John Lehning, NRR/DSS/SSIB
301-415-1015

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NAME	JLehning		MLScott	
DATE	04/03/06		04/20/06	

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Trip Report Regarding Point Beach Flume Testing Observation

The NRC staff visited Alden Research Laboratory (ARL) in Holden, MA, on January 18, 2006, with the primary purpose of observing linear flume testing for the Point Beach Nuclear Plant replacement strainers. Participating staff included John Lehning of NRR/DSS/SSIB and contractors Clint Shaffer of ARES Corporation and Marcos Ortiz, an independent consultant. Representatives from Point Beach Nuclear Plant and vendors were in attendance at the head loss test observed. ARL personnel operated the test apparatus according to test procedures supplied by Framatome/Areva. Performance Contracting Inc. (PCI) supplied the test debris and will supply the plant replacement strainers. The staff observed one flume head loss test and held discussions with the licensee and vendors concerning various topics associated with ARL flume testing and Generic Safety Issue 191. The staff stated to the licensee that, while a report would be issued to document the observations made during the trip, at the present time, a decision on whether the staff will perform an audit of Point Beach's response to Generic Letter 2004-02 has not been made.

Licensee Strainer Design

The licensee plans to install two 1493.3 ft^2 strainers. Each replacement strainer consists of modules of rectangular-shaped stacked disks connected together to form a long string of these disks. Each disk has a height of 33 inches (whether or not the width is the same as the height is unknown to the staff) with a 3-inch clearance underneath the strainer. The licensee has indicated that there will be at least 2 inches of water over the top of the strainer during the recirculation phase of an accident. (This information was obtained from the test procedure and a draft drawing of the replacement strainers provided to the staff.) The strainer module tested at ARL consisted of 6 disks and had a total area of 20.05 ft^2 (approximately 1/75th scale). As the strainer module was mounted horizontally, the disks were oriented vertically. The width of the test strainer disks was about 18 inches, much smaller than the width of the replacement strainer disks. (A schematic of the test strainer was provided in the test procedure document but the dimensions were not legible.) The ARL head loss testing was based on the operation of one recirculation pump train connected to one of the two replacement strainers. Given this testing arrangement, the head loss aspects would appear to have been correctly simulated since both strainers should behave essentially the same, but clearly the sump pool transport velocities will be different when comparing the operation of one versus both trains. The total flow for the plant for this scenario was 2200 GPM; therefore, the scaled down flow for the flume test was 29.5 GPM (i.e., 2200 GPM * 20.05 ft^2 / 1493.3 ft^2). Given these rates of flow and screen areas, the screen approach velocity was 0.0033 ft/s.

Licensee Computational Fluid Dynamics Analyses

The staff was shown several plots illustrating computational fluid dynamics (CFD) results for the Point Beach sump pool. These CFD calculations were performed by ARL using the FLUENT code and were based on the existing sump screens and the operation of one ECCS train.

However, the CFD calculations did not explicitly model the drainage of the containment sprays into the sump pool, and the staff noted that the refueling pool drainage would occur near enough to one of the replacement strainers to potentially affect debris transport and accumulation on that strainer. The staff also noted that certain breaks may occur near one of the strainers, which, for these cases, may have a similar effect on debris transport and accumulation. Licensee personnel stated during the trip that they plan to recalculate the CFD results based on the finalized replacement strainer design (in subsequent follow-up discussions, however, the licensee indicated that CFD recalculations do not appear warranted based upon additional insights from the ongoing review of existing test results and analysis). It was apparent during this brief review that the CFD-predicted containment sump pool velocities were significantly faster than the flume test velocities (similar to the Watts Bar CFD to flume velocity comparison). The CFD results also appeared to generally show flow velocities near the recirculation strainers that were slower than the velocity required to move Nukon™ shreds along the pool floor. If the velocities for the replacement strainers are this slow, then the licensee may be able to make a case that only the suspended debris would actually accumulate on the strainers and can perhaps use CFD analyses to validate the near field debris settling seen in the head loss testing. However, such conclusions should also consider the debris transport associated with the operation of both trains, to ensure this case remains bounded. The licensee-sponsored CFD analyses did not appear to include the sump pool velocities associated with operating both ECCS trains simultaneously, or with evaluating the flows specifically for the replacement strainers (in subsequent follow-up discussions, the licensee noted that current Point Beach procedures preclude the simultaneous operation of both ECCS trains). The staff's concerns are: (1) the flume linear flow velocity is not prototypical of the plant sump pool velocities, and (2) the increased velocities and pool turbulence associated with the spray drainage into the pool were not evaluated. The staff communicated these concerns verbally to licensee and vendor personnel.

Test Matrix

The staff did not obtain a test matrix for the overall head loss test program, but it is apparent that two tests were to be conducted. These include a maximum fiber test and a thin-bed test. The staff observed the thin-bed test, which the vendor deemed to be the most limiting test condition. A previously conducted maximum fiber debris test was briefly described. The observed thin-bed test is described first, followed by the limited description of the maximum fiber tests, followed by a discussion of the testing prototypicality.

Thin-Bed Test

For the thin-bed test, the staff observed the prepared debris prior to its introduction into the flume, the filling of the flume, establishing the water level in the flume, debris introduction, the head loss test and data accumulation, and the flume drainage, including the condition of the post-test strainer test module. The staff held discussions with licensee and vendor representatives before, during, and after the test.

The debris types considered for testing for the Point Beach head loss tests include:

- Stainless steel RMI
- Fibrous
  - Nukon™
  - Temp Mat
  - Mineral Wool
  - Asbestos
  - Latent fiber
  - Unspecified fiberglass
- Particulate
  - IOZ and epoxy coating particulate
  - Asbestos binder
  - Latent dirt
  - Calcium silicate
  - Chemical byproducts
- Tags and Labels

Surrogate substitutions were made for most of these debris types, as shown in Table 1. RMI debris was manufactured from prototypical foils. In the observed thin-bed test, Nukon™ was used to simulate all of the fibrous debris, which was justified by the licensee because Nukon™ represented the largest quantity of fiber, and the purpose of the fiber in this test was only to accumulate sufficient fiber to establish a thin-bed where the head loss would be primarily due to the particulate. A silica sand mix was used for the latent dirt based on recommendations from NUREG/CR-6877 that include a recommended particle size distribution. Powdered tin was substituted for inorganic zinc (IOZ) coatings particulate because ARL would have considerable difficulty disposing of the IOZ and water contaminated with IOZ in the state of Massachusetts. Walnut shell flour was used to simulate the epoxy coatings particulate. Note that all coatings debris was considered to be particulate rather than chips. PCI supplied their manufactured calcium silicate to simulate the Point Beach calcium silicate and also the binder contained in the plant asbestos insulation.

The licensee included sodium-aluminum silicate ($NaAlSi_3O_8$) in a powder form as a chemical particulate in the test to simulate potential chemical byproducts. The draft guidance from the Westinghouse Owners Group (WOG) was used to specify the quantity and type of potential chemical byproducts for the Point Beach testing. (Note that, at the time of the trip, the WOG guidance report had not been made available for NRC staff review.) The licensee apparently based the chemical species of sodium aluminum silicate on Test No. 4 from the Integrated Chemical Effects Test (ICET) project. The staff provided a set of written questions to the licensee concerning chemical effects to support a future discussion via teleconference.

Table 1. Test Debris Surrogates

Plant Debris Source	Surrogate Debris
SS RMI	Manufactured debris from 2 mil SS foil
Nukon™	Nukon™ Shreds
Temp Mat	JPS Glass® Temp Mat Fiberglass Fibers*
Mineral Wool	Shredded Owens Corning® Mineral Wool*
Asbestos (90% of total mass)	Inswool® Ceramic Fibers*
Unspecified Fiberglass	Shredded Owens Corning® Fiberglass Wool*
Latent Fiber	Finer Hand-Shredded Nukon™
Latent Particulate	Blended Silica Sand (NUREG/CR-6877) ·37% Mass < 75 microns ·35% Mass 75 to 500 microns ·28% Mass > 2000 microns
IOZ Coatings	Powdered Tin Metal ·50% of 1-5 micron particles ·50% of ~10-44 micron particles (Similar IOZ and Tin Specific Densities)
Epoxy Coatings ·Density ~100 lbs//ft^3	Powdered Walnut Shells ·75% Particles Smaller Than 44 microns ·Specific Gravity 1.2 to 1.4 ·Density of 87 lbs/ft^3
Calcium Silicate Asbestos Binder (10% of total mass)	Powdered Calcium Silicate (PCI Supplied)
Chemical Byproducts	Sodium Aluminum Silicate ($NaAlSi_3O_8$) ·WOG Guidance (Draft) ·Applying ICET Test 4
Tags and Labels	Pieces Cut from Sheet Materials ·50% Tape ·50% Labels
* An Equal Mass of Nukon™ Substituted for Observed Thin-Bed Test	

As a conservative measure, the licensee determined the quantities of debris in this test, except for the fibrous debris, based on the largest quantities of each type of debris across the range of accident scenarios considered in the debris generation evaluations (i.e., these maximum quantities of debris would not be expected to occur simultaneously for any given pipe break scenario).

The pump flow rate for the head loss test was scaled down from the plant flow rate by the ratio of the screen area for the test module to the screen area of the replacement strainer area (i.e., 20.05 ft^2 / 1493.3 ft^2). The test flow rate was 29.5 GPM, as compared to 2,200 GPM for the proposed design flow value. In addition, the debris introduced into the test flume was also scaled by this ratio. The water used in the test was untreated tap water with the temperature ranging between 40 and 50 ^{o}F. One observed pH measurement showed a pH of 9.

During the observed test, a continuous water flow was provided to the vertical downcomer sparger pipes near the flume end furthest from the test strainer to simulate the effect of water sources such as containment sprays falling into the actual containment pool. Currently the licensee does not credit sprays, but hopes to in conjunction with the submission of a future alternate source term (AST) amendment. The licensee mentioned a potential break that could occur relatively near one of the replacement strainers. In addition, a refueling cavity drain also terminates near one replacement strainer. This sparger pipe flow introduced turbulence into the flume that tended to enhance debris suspension, although it was not clear what effect this extra turbulence had on debris transport or that the sparger pipe flow introduced a quantity of turbulent energy that would scale to the quantity that a break and cavity drains would in the actual plant. The CFD analyses did not appear to address these flows explicitly.

The test started with a water level in the flume of 26 inches (i.e., a 3-inch submergence of the test strainer). The test water level went up to 38 inches to simulate the effect of containment sprays continuing to drain down the RWST after the ECCS switches over to recirculation. The plant would eventually reach a 60-inch depth in the pool, but this level could not be simulated due to physical limitations of the ARL flume.

The dry debris were measured and saved in individual buckets prior to the staff arrival at the test laboratory. The Nukon™ insulation was already shredded and that portion representing latent fibers was additionally hand shredded more finely. All of this debris was then mixed with water prior to introducing the debris into the flume, including the sodium-aluminum silicate simulating chemical byproducts. The target concentration for the sodium-aluminum silicate was 589 mg/L.

The thin-bed test observed by the staff was conducted with significantly less fiber than the design-basis loading (7 lbm of fibrous debris as opposed to a maximum load of 113 lbm), since the goal was to accumulate only enough fiber to effectively filter the particulate so that a layer of particulate would cause the head loss. The vendor understood that a thin-bed accumulation can cause higher head losses than a maximum fiber load accumulation.

After partially filling the flume with water, the prepared debris was poured into the flume with the intent to distribute the debris 3 to 15 ft upstream of the strainer. Then the targeted water level was achieved and the recirculation pump started. The average approach velocity to the strainer screen surfaces (29.5 GPM through 20.05 ft^2) was 0.0033 ft/s. The linear flume flow velocity at water levels of 26 and 38 inches was 0.014 and 0.0094 ft/s, respectively. All but the suspended debris in the flume settled to the flume floor where it resided for the duration of the test. The flume water was so opaque due to the suspended particulate that the test module could not be seen at all for the duration of the test (roughly 3 hours).

During the testing, the staff observed a layer of fiber along with some light-colored particulate floating over approximately half of the flume's water surface. The staff has not previously observed a layer of floating Nukon fibrous debris in head loss testing, and the explanation for this phenomenon was not conclusively discerned. This fiber layer was on the order of 1/4" to 3/8" thick. One observation made by the staff was that for this test, two of the overhead sparger pipes were used to return water to the flume. The splashing of this water down into the flume appeared to aerate the water, and the effect of rising air bubbles could have had a role in lifting the fibers to the surface. The staff observed that air bubbles were present amid the fibers; however, it was not clear whether these air bubbles had helped to lift the fibrous debris, or had been coincidentally trapped by the fibrous layer on their way to the surface. Without this effect more fiber would have accumulated on strainer. It is not clear whether this effect would be prototypical of the plant sump pool.

The head loss was measured as debris accumulated on the strainer, and downstream samples were taken in accordance to procedure. The test was terminated when the pool volume was calculated to have recirculated 5 times at the test flow rate. At this time the increases in head loss were less than the 1% in 5 minute termination criteria set in the test plan. The strainer head loss at test termination was 1.17 ft. However, the staff noted that at termination, the head loss was steadily increasing at slow rate that appeared to be nearly linear. The staff discussed concerns that this slow increase could well be important if it continued for a relatively long time (until the operators throttled back on the pumps).

After the test was terminated, the flume was slowly drained until the test module was completely exposed for viewing. During the draining process, the debris bed tended to slide off of the vertically oriented screen surfaces. The debris accumulation on the thin horizontal disk edge at the top of the strainer remained largely in place, and this debris appeared to confirm that a thin bed had formed on the strainer. With relatively little fiber visible, this bed consisted primarily of particulate with a mucky gray appearance. Likely the tin contributed the gray color, but the particulate would have been a mixture of the various particulate added to the flume. The thickness of the fiber layer could not be observed, especially in terms of the uncompressed bulk density of Nukon™. Whether or not the fiber thickness corresponded to the minimum 1/8 inch criterion of the GR is not known, but from the casual observation, the fiber thickness did not seem very substantial. Rather, it was the continuity of the particulate 'mud', as well as the relative increase in head loss (still relatively small given an approach velocity of 0.0033 ft/s), that confirmed the formation of a thin-bed accumulation.

Although the thin-bed test appeared to be valid, the staff has concerns regarding whether or not this test represents a worst case or even the most realistic case for a thin-bed head loss. These concerns include:

- The staff is concerned that only one thin-bed test will be conducted to determine the worst case head losses in qualifying the replacement strainer. In the NRC-sponsored calcium silicate head loss tests (NUREG/CR-6874), for example, it was found that a modest increase in the fiber and calcium silicate on the test screen (from 12 to 15 g of fiber corresponding to an increase in the uncompressed bed thickness from 0.19 to 0.23 inches while maintaining a particulate to fiber mass ratio of 0.5) increased the head loss at a flow approach velocity of 0.4 ft/s from about 2 ft to 13 ft. Thin-bed formation can be sensitive to the fiber quantity that filters the particulate, and the fiber quantity used in the Point Beach thin-bed test was quite subjective. Due to uncertainties associated with test transport and procedure issues, the actual quantity of accumulated fiber could easily vary substantially from the quantity found to accumulate on the test strainer during a single test. Perhaps more fiber might have caused higher filtration efficiency and a higher head loss. Only variations in the testing can determine whether or not the worst case thin-bed head loss has been achieved; therefore, additional benefit may be possible from an expanded test matrix, especially if the plant does not have excessive NPSH margin.

- The staff is concerned that the steady increase in head loss rate measured at test termination could result in a significant head loss increase over time. The staff suggested to the vendor that the criterion for termination be tightened. At a minimum, the staff suggested that the termination rate of head loss increase be linearly extrapolated to the plant operating procedure time for reducing pump flow rate to determine how serious this concern could become.

- The plant insulation types include substantial quantities of high density fibrous insulations (HDFG) (e.g., Temp mat and mineral wool), but the thin-bed test was conducted using only the low density fiberglass, Nukon™. The HDFG and mineral wool debris has a substantially lower porosity than Nukon™, which makes these materials more efficient at filtering particulate. The staff is concerned that had the HDFG materials been represented in the observed test, the HDFG could have filtered more of the finer suspended particulate than did Nukon™, which most likely would have increased the head loss across the test strainer. The staff also notes, however, that HDFG fragments are generally less transportable than fragments of low-density Nukon™; thus, the overall conservatism of this debris substitution is not clear.

- The head loss associated with a thin-bed depends strongly on the fineness of the particulate filtered from the flow. The staff did not examine in detail the characterization of the surrogate particulates used in the test as compared to plant particulate. It was not clear whether this activity had been completed and formally documented.

Completion and documentation of this activity would remove a source of uncertainty in the prototypicality of the thin-bed head loss test.

Maximum Fiber Debris Test

The vendor briefly described an earlier design-basis fiber loading test conducted for Point Beach where the maximum quantities of debris were introduced into the flume, including the maximum volume of fibrous debris. The vendor described a large mass of debris blocking up the approach to the strainer and creating a sort of debris dam that visibly lowered the water level on downstream side of the flume. This description sounded similar to the debris accumulation during testing observed March 17-18 at ARL by the staff where the debris formed a kind of a discontinuous bulk accumulation around and approaching the strainer and exposing the top of the strainer. Prior to the strainer being exposed, a circumscribed accumulation was mentioned where the gaps between the disks had filled with fibrous debris. Once the strainer subsequently became partially uncovered due to the formation of the debris dam, the debris bed partially slumped off the test strainer, resulting in a clearing of some of the interstitial areas. Following this full fiber loading test, the licensee altered the design of one of the two replacement strainers, effectively moving that strainer approximately 1 to 1.5 ft away from a nearby wall. This change will reduce hydrodynamic loads and allow more effective debris accumulation on the back side of the strainer (e.g., avoiding this potential damming effect).

During the trip, the staff did not collect sufficient information to evaluate this test fully. However, crude scaling of basic dimensions from the schematic drawings provided by the licensee indicates that the circumscribed approach velocity for a replacement strainer would be about 0.025 ft/s compared to approximately 0.008 ft/s for the test module. The pump recirculation flow rate for this test was apparently also 29.5 GPM. Therefore, it appears that the test module circumscribed approach velocity was about a factor of 3 less than the corresponding flow for a replacement strainer. Therefore, the corresponding head loss measured across the circumscribed bed in the maximum load test was likely also a factor of 3 below prototypicality. In addition, it is not clear that the observed flume blockage caused by the relatively large quantities of fiber introduced into the test flume would also occur in the plant sump. If this plant is audited, then this test and these numbers should be evaluated more closely.

Test Prototypicality

Head loss testing of a strainer prototype requires both transport and head loss aspects of the test to be prototypical (or conservative) with respect to the plant sump and replacement strainer. The demonstration of prototypicality should include showing that the debris used in the testing has prototypical characteristics relative to the postulated plant debris. For the ARL testing, the transport within the test flume should be prototypical to the plant sump with respect to flow velocities and pool turbulence. The strainer approach velocities should be prototypical for the type of debris accumulation being tested. For a thin-bed accumulation where debris accumulates relatively uniformly across the entire screen surface, then the flow scaling approach should be based on the entire screen surface area. But, if the debris accumulation is circumscribed (i.e., distributed around the perimeter area of the strainer), then the circumscribed velocity should be prototypical. Recognizing that all of these prototypical aspects may not be simultaneously possible, the key aspects to the test objectives must be the focus of the test.

A prototypicality evaluation of test debris should demonstrate that the characteristics (e.g., densities, fiber diameters, porosities, specific surface area, filtration efficiency, compressibility) respectively governing transport, head loss, and downstream effects are either comparable or conservative in performance. The vendor did not specifically address each of the aspects of prototypicality as part of the staff's observation. Only limited data was provided for the selected particulates regarding specific gravities and particle size distributions. For example, the walnut shell flour substitution for epoxy coatings particulate was not completely justified in the test procedure. The walnut flour specifications state that 75% of the particulate mass is smaller than 44 microns, whereas the Nuclear Energy Institute Guidance Report (GR) recommends assuming the particles break down into 10 micron particles. Noting that smaller particles have a greater impact on head loss than larger particles, the breakdown of particle sizes less than 44 microns becomes important, particularly for particles less than about 10 microns. Latent particulate is known to have a significant amount of particles smaller than 10 microns, although NUREG/CR-6877 did not quantify the amount. In addition, the question of whether or not walnut floor will absorb enough water to alter its size distribution was not specifically addressed. Calcium silicate insulation is known to vary with manufacturer; however, it was not clear that a comparison of the plant calcium silicate to that used in the testing to validate the use of the PCI calcium silicate had been performed. The staff did not examine the characteristics of the sodium aluminum silicate, specifically the particle structure and size distribution relative, perhaps to the corresponding ICET sample. Potential chemistry of surrogate materials relative to plant materials was not discussed during the trip, e.g., tin versus IOZ.

In regards to fibrous debris, its ability to filter fine particulate depends upon its porosity. Nukon™ is considerably more porous than HDFG insulations. The porosity, as well as fiber diameter, of surrogate fibrous debris should be justified as prototypical. In addition to starting with prototypical fibrous materials, these materials should be properly prepared to create prototypical debris sizes. At these low transport velocities, it is essentially the suspended debris that will accumulate on the strainers. Therefore, it is this size category that must be conservatively represented. Latent fibers, for example, should essentially be individual fibers since it basically consists of miscellaneous fibers from all the various surfaces and there is no apparent justification to assume that the latent fibers will have a chance to accumulate into larger agglomerations.

The vendor anecdotally reported test results for an unnamed plant that compared test procedures of (1) manually tearing up fibers and introducing debris all along the flume versus (2) using a food processor and introducing the fiber adjacent to the test strainer. The staff did not review any documentation concerning either the procedures or results for these tests. The apparent intended purpose of the exercise was to determine if the finer shredding of the fiber was necessary in the ARL flume testing. The vendor stated that the final results showed similar head losses except for the timing, i.e., the test where the debris was introduced near the strainer took significantly less time to build. The staff questioned whether or not this result was generally applicable to all test conditions. One possible explanation for the observed test results is that sufficient fiber existed to create a thin bed in either case. The staff's key concern would be plant situations where the licensee is trying to justify that there is not sufficient fiber to form a fibrous layer capable of filtering particulate. In such a case, the fineness of the fibrous debris intended to simulate latent fiber should be fine enough for complete transport to the strainer since there is no technical basis to support a less conservative position. For Point Beach, latent fibers represent a minor portion of the total fibrous debris; therefore the fineness of the latent fibers was relatively much less important. That said, finely blending surrogate latent fibers to enhance transport would seem prudent as a standard test practice.

The test observed for Point Beach demonstrated that, like the other tests observed at ARL, the majority of the debris settled to the flume floor, such that the debris accumulation on the test module was essentially suspended fiber and particulate. Similar results have been observed at other vendor laboratories. This transport behavior has been referred to as the near field effect, and vendors are in general taking credit for this settling (i.e., assuming the same settling would occur in the plant sump). Although the plant sump flow velocities are generally slower than the velocity required to transport Nukon™, according to the CFD plots shown to the staff during the course of the test, the flume linear flow velocity at a minimum water level of 0.014 ft/s seems much slower than the CFD plots.

The staff discussed aspects of the near field debris settling with licensee and vendor personnel with the focus of the discussion on the Watts Bar testing previously observed. Watts Bar was used as a point of discussion because the staff has had the opportunity to study the plant CFD results and the prototype testing extensively enough to support the discussions; whereas the Point Beach information was more limited and had not been fully analyzed. For Watts Bar, the linear flume velocity was 0.036 ft/s, but the CFD results showed a sump pool where a majority of the pool was flowing faster than 0.28 ft/s, with some flows approaching the strainer exceeding 0.5 ft/s. The staff pointed out the discrepancy and stated that the vendor should address the discrepancy. The vendor noted that the CFD had been performed for the existing strainer and assumed that the velocities would decrease if the CFD were to be repeated using the proposed replacement strainers. The staff acknowledged that velocities near the strainer would be altered by using the actual replacement strainer but noted the flows were too complex to predetermine the results without doing the calculation and that flows well away from the strainer would likely not change that much. It would be a good standard practice for licensees to finalize CFD results by modeling the final replacement strainer design if near field settling is credited.

An additional staff concern regarding the Point Beach CFD analyses is that the CFD results were based on the operation of a single train, presumably so that the CFD analyses correlated with the head loss testing. However, when two trains are operating, not to mention adding in the containment sprays, the sump pool would become a significantly, if not substantially, faster flowing pool than the current analyses indicate. In general, licensees should evaluate sump pool debris transport for operating both trains simultaneously, as well as separately, before conclusions are drawn that floor debris will not reach the strainer. In addition, for plants with independent strainers, a demonstrably conservative basis should exist to show that the evaluated cases are bounding (e.g., that single strainer operation is more conservative than dual strainer operation, or vice versa). In subsequent follow-up discussions, the Point Beach licensee noted that procedures preclude the simultaneous operation of both trains of ECCS.

The staff discussed the prototypicality of testing debris beds that build circumferentially around the strainer module. There are a couple of ways that this type of accumulation could happen. Even at low velocities, fibers can accumulate inside the gaps between the strainer disks until these gaps are full; then subsequent accumulations are around the perimeter area of the strainer, which is realistic for high fiber plants. The strainer could also become fully engulfed with larger debris that would not fit into the gaps between the strainer disks. This type of accumulation is not realistic unless transport and strainer approach velocities are relatively fast and the strainer sits low to the floor (perhaps recessed below the floor) so the debris can fall onto the strainer. When the staff observed the Watts Bar testing, the vendor informally tried to simulate this type of accumulation by artificially piling RMI and paint chips on and around the test module. The point that the staff raised to the vendor personnel was that the correct prototypical velocity for determining the head loss for circumscribed accumulation was the circumscribed strainer velocity (i.e., pump recirculation flow rate divided by strainer perimeter area). The velocity of flow as it passes through the debris, as well as the bed thickness and composition, determine the resultant head loss. For the Watts Bar circumscribed test, the staff estimated the circumscribed approach velocity was 0.022 ft/s, whereas the plant circumscribed approach velocity was estimated at 0.14 ft/s; a factor of 6.4 higher. This implies that the vendor test head loss for this test was too low by a factor of at least 6.4 (perhaps as large as about 6.4 squared = 40). The staff also noted that, because the strainer prototype tested was a single scaled module (downsized from 33-in to about 18-in) of the array that is planned to be installed in the plant, it may not be possible to simultaneously scale both the strainer surface velocity and the strainer circumferential velocity. The staff pointed out that, during a test which results in circumferential debris accumulation, the flume flow may have to be scaled to the strainer circumscribed velocity to ensure prototypicality with the plant replacement strainer.

The staff also commented on the relevance of test procedures relative to near field settling. The vendor appeared to be operating the tests using one basic test procedure. The point was made that any prototypical test procedure would not actually represent the plant accident scenario due to the wide variety of plant accident scenarios, the unknown nature of processes such as coatings failure time, uncertainties in the various processes, etc., not to mention the differences between the test apparatus and the plant sump. The staff suggested that the testing procedure should be considered a test variable. If two different procedures, equally valid, resulted in two different head loss results, then the most severe head loss would be the conservative result for strainer qualification. One possible variation would be to introduce the debris slowly after the recirculation pump was started rather than rapidly before starting the pump, which could reduce potential debris agglomeration and settling.

During staff discussions, it was suggested that the test report, or a separate report, should specifically address prototypicality issues. Also, the staff mentioned during the course of these discussions that the issue of the near field debris settling was under staff review and that staff is working on additional near-field effects guidance.

Refueling Cavity Modification

The Point Beach licensee discussed the refueling cavity drain strainer noted in the response to Generic Letter 2004-02. The strainer was described as being constructed from two pieces of 10" pipe into a cruciform shape. Two hundred holes, each 1" in diameter were drilled through the strainer to provide a net open area of approximately 157 in^2 (1.09 ft^2). The refueling cavity drain strainer is expected to be capable of preventing large pieces of debris from blocking the refueling cavity drain, thereby reducing the likelihood of unanalyzed water hold up in the refueling cavity.