November 10, 2010

MEMORANDUM TO: Stewart N. Bailey, Chief
Safety Issues Resolution Branch
Division of Safety Systems
Office of Nuclear Reactor Regulation

FROM: Blake A. Purnell, Project Manager ***/RA/***
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SUBJECT: SUMMARY OF OCTOBER 4 AND 19, 2010, PHONE CALLS WITH PERFORMANCE CONTRACTING, INC. AND LICENSEES TO DISCUSS ITS LARGE FLUME TEST PROTOCOL

On October 4 and 19, 2010, U.S. Nuclear Regulatory Commission (NRC) staff held teleconferences with representatives of Performance Contracting, Incorporated (PCI) and its partners (the vendor) to discuss technical issues concerning PCI's large flume test protocol for testing pressurized-water reactor containment sump strainer performance. Client licensees of PCI also participated in the calls. These teleconferences were closed to the public due to the proprietary nature of the discussions. These teleconferences were a continuation of a teleconference held on August 4, 2010. A publicly available summary of the August 4, 2010, teleconference is available in the NRC Agencywide Documents Access and Management System (ADAMS) under Accession Number ML102180217.

The following proprietary PCI documents were discussed during these calls:

- PDT-2010.07.26-1 Rev 1, "Approach Velocity Analysis," prepared by Alden Research Laboratory, Inc., dated September 2010
- PCI Document No. PDT-2010.07.20-1 Rev 1, "Large Flume Test Protocol: Debris Addition Distance," prepared by Alden Research Laboratory, Inc., dated September 2010
- PCI Document No. PDT-2010.09.07 Rev 0, "Experiments on the Breakup of Liquid Jets and Sheets," prepared by Alden Research Laboratory, Inc., dated August 2010
- PDT-2010.07.26-2 Rev 0, "Narrow Flume Influence Evaluation Procedures," prepared by Alden Research Laboratory, Inc., dated July 2010
- "Narrow Flume Problem Statement & Response R01," dated October 2010

DISCUSSION OF "APPROACH VELOCITY ANALYSIS"

The NRC staff agreed that computing 2000 pathlines in the computation fluid dynamics (CFD) model would be adequate. The vendor stated that it could justify using fewer pathlines by showing convergence of the calculations, but agreed to use 2000 pathlines.

The NRC staff agreed that using a shortened flume would be an acceptable approach in cases where more than 50 percent of pathlines do not extend the full flume length. The length of the shortened flume should be based on full inclusion of at least 50 percent of the pathlines. If a licensee plans to use an alternative approach of flow splitting to address the condition where less than 50 percent of the pathlines travel the full flume length, the staff recommends that the licensee discuss the approach with staff prior to implementation.

The staff noted that the vendor had revised its treatment of turbulence and bimodal flow distributions based on feedback from the NRC staff during a previous call. The staff considered the vendor's revisions to be consistent with the intent of previous discussions and did not have further feedback or comments in these areas.

DISCUSSION OF "DEBRIS ADDITION DISTANCE"

The NRC staff stated that the outer surface of the strainer should be used, rather than its geometric center, when defining the debris addition distance. The staff considers the physical dimensions of plant strainers as too large to neglect in this determination. The vendor stated it can probably agree to this position but needs some more time to consider this change beforehand.

The NRC staff stated that, to represent debris sources entering the containment pool within one flume length of the strainer, debris should be added to the test flume at a representative distance associated with that specific location, rather than a procedurally specified distance that is fixed for all tests. For example, if a hatch or refueling canal drain is located within one flume length of the strainer, the staff stated that debris associated with drainage from this source should be added at the location of the source rather than a procedurally fixed distance that is more distant from the strainer. The vendor stated it needed to look at this and work through an example.

DISCUSSION OF "BREAKUP OF LIQUID JETS AND SHEETS"

Although noting that useful insights may be provided, the NRC staff remained skeptical of the vendor's approach for modeling the momentum transfer rate of plunging jets and sheets. The staff's skepticism is largely due to uncertainties as to how the small-scale experiments can be scaled to the larger-scale plant conditions. For example, it was not clear to the staff whether the dimensionless scaling parameters proposed by the vendor would provide prototypical or conservative results when scaled to dimensions significantly beyond those tested. One source of uncertainty is that various important phenomena are described by different dimensionless numbers that scale differently.

The staff questioned whether the vendor had determined which of the dimensionless parameters are most important to preserve and how discrepancies in other parameters would be resolved. The staff particularly questioned the applicability of Froude number scaling for sheet flow based on the vendor's analysis. The vendor stated that the breakup length will be scaled by pipe diameter. Although the staff believes scaling by pipe diameter is appropriate, per the preceding remarks, it is not clear that this is sufficient by itself. The staff recommended that the vendor validate its scaling methodology against data from large-scale experiments to demonstrate the reliability of its predictions.

The staff stated that a lack of clarity as to the range of plant parameters for which the vendor intends to apply the test results for plunging jets and sheets prevents the determination of whether the proposed test conditions could be considered to envelop the plant conditions. The vendor agreed that scaling of data to any particular plant condition would have to be justified and based on the collected information. The vendor stated that the specific plant conditions may be tested to expand the applicability of the prior test results if not already bounded. The staff considered it appropriate that plant-specific conditions would be bounded by test results, but recommended that agreement be reached on the prototypicality of the planned tests relative expected plant conditions prior to initiation of testing.

The staff stated that most or all plant post-accident conditions will involve partially filled pipes rather than completely filled pipes. The staff stated that the vendor had not shown that full-pipe results will bound partially filled pipe scenarios. The vendor stated that it believes this demonstration will be made during the testing.

The staff stated that it needs more information to understand the experimental setup with the water pool on the load cell to determine whether the test conditions would be prototypical of expected plant conditions and would permit sufficiently noise-free and reliable measurements of the momentum transfer rate. The staff recommended that the vendor benchmark the load cell setup against theoretical predictions for cases with minimal breakup and losses to demonstrate its accuracy.

The staff stated that it does not believe that a precise breakup length can be determined for plant-scale plunging jets or sheets. Although outer layers of the plunging jet may break up and exhibit some degree of spreading, large-scale experiments show that the inner core remains intact well beyond the distance at which surface breakup begins. As such, the staff would not expect a full-scale plunging jet to have uniform properties. Therefore, the staff stated that the concept of breakup length may not be useful for modeling this phenomenon. The vendor indicated that it is primarily interested in the momentum profile as a function of elevation rather than measurement of the jet diameter or a breakup length. The staff understood that the vendor's primary objective in conducting the experiments will be to measure the rate of momentum transfer to the water column. Although the staff agreed that the momentum transfer rate can be considered one of the driving parameters associated with modeling the impacts of drainage on containment pool flows, without a clear description of the vendor's approach for implementing these test results into its protocol, the staff could not conclude whether accurate measurement of other parameters would also be necessary.

The staff stated that using a weir to generate sheet flows may generate flows that are more similar to plant flows than the use of a slotted orifice.

Based on the discussion above, the staff stated that it is not convinced that the experimental method for the breakup of liquid jets and sheets will provide a basis for licensees to reduce the momentum addition rate of water drainage into the containment pool. Currently, the accepted approach for considering momentum transfer from drainage to the containment pool is based on the conversion of the full gravitational potential of the fluid into kinetic energy, along with the kinetic energy of the fluid at the location where freefall begins. The vendor stated that the planned inputs to the CFD model for drainage into the containment pool are intended to bound the experimental results conservatively. The vendor stated that they would undertake a limited scope test program to validate that the scaling is predictable before beginning the full test program.

DISCUSSION OF "NARROW FLUME INFLUENCE EVALUATION PROCEDURE"

This discussion began with the October 4 call and was continued in the October 19 call. Prior to the October 19 call, PCI provided its assessment (Enclosure 2) of the outstanding issues and proposed method to reach a resolution to help facilitate the discussion.

The staff reiterated that its concerns are not just limited to the vendor's treatment of small fibrous debris, but applies to all debris sizes and types, including fine debris and chemical precipitate.

Although the staff has already expressed agreement with the processes the vendor would use to fragment fibrous insulation into fines and small pieces (ADAMS Accession Number ML102080213), the staff noted that the nomenclature used by the vendor in the Narrow Flume Problem Statement & Response document (Enclosure 2) was not consistent with the definition of "small fines" established in the NEI 04-07 guidance report. The NEI 04-07 guidance defines "small fines" as a superset of all small pieces and fines. However, the vendor's definition of this term referred to prepared debris that was intended to represent only small pieces. The staff believes the behavior of small pieces of fiber in the narrow flume will be different than what would be encountered in a plant. The narrow flume may tend to cause debris to be blocked such that the only transport path is over the top of the blockage; whereas, in the plant, the flow may go around the blockage and continue to transport debris along less impeded paths due to the increased width of the plant flow channels.

The vendor stated that the flume flow velocities are sometimes too low to transport small debris. The staff stated that small debris is a range of sizes—not just one size—some of which may be only slightly larger than fines and would be transportable at lower flow velocities. The vendor stated that batch testing could show acceptability. The staff noted that a flume that does not prototypically scale the quantity of floor-transporting debris per unit flow channel width would lead to an underestimate of debris transport to the strainer, regardless of the debris addition rate. The vendor's problem statement discussed potential issues with subsequent debris addition batches due to piling up of debris. The staff noted that, if batch sizes were too large, piling could potentially affect even the first batch.

The vendor questioned why an over concentration of debris on the floor would underestimate debris transport to the strainer. The staff replied that this is because it is more difficult to transport debris in a vertical direction against gravity than to transport it horizontally in a plane perpendicular to gravity. Also when debris pieces come into contact, the pieces tend to adhere and act as a single larger piece that is more difficult to move. Similar behavior occurs when debris contacts flume walls. These governing principles have been observed in a number of tests of tumbling of individual debris pieces, debris interceptors, and flume transport sensitivity tests. The vendor stated that while debris piles in a flow block transport to some extent, they also block flow and thereby generate a higher than prototypical velocity going over the debris pile. The vendor stated that ongoing testing indicates there is a tradeoff between reduced transport due to pile presence and increased transport of the pile due to increased velocity over the pile. The staff understood that the potential for offsetting effects exists, but considered it unlikely, based on existing data, that the net effect of the presence of a debris pile is conservative relative to overall debris transport, particularly in a very long and narrow flume. The staff stated that the vendor's testing did not appear sufficient to resolve these questions per the discussion below.

The staff noted that the specific matrix of tests proposed did not appear to envelop expected plant conditions or proposed test conditions. For example, it appeared to the staff that the density of debris per unit floor area and per unit flow channel width proposed for the narrow flume are not directly representative of plant conditions or proposed test conditions. The vendor acknowledged this was true. The vendor questioned why the over concentration of debris causes any non-conservatism, since, in its experience, this represents a conservative condition. The staff disagrees with the vendor for the reasons stated above. The staff further noted that testing with only small pieces of fibrous debris would not address questions with other types of debris. For example, fine fibers could agglomerate or become more difficult to resuspend, depending on the batch size and batch addition rate. Fine particulate and chemical precipitates will interact more with debris piles the deeper they are, and are expected to be more difficult to resuspend after they interact with deep piles of fibrous debris. The proposed test matrix would not address these expected effects. As a result, the staff did not have confidence that the proposed testing would demonstrate the validity of testing in a narrow flume.

The staff also expressed concern that the effects of the narrow flume may affect debris transport independently of debris interactions in addition to the potential for such interactions. For example the staff was concerned about debris interactions with the edges of the flume and the turbulence level within the flume compared to the plant. During this call, the staff further noted a question of whether large piles of settled debris could impact the proposed means to add turbulence to the test flume. The vendor agreed to consider protecting the operation of the turbulence generator for the flume from settled debris. There was not discussion of how this would be accomplished.

During these calls and in previous calls, the NRC staff discussed with the vendor a number of significant challenges and scaling compromises inherently associated with performing a single test that attempts to simultaneously scale parameters associated with both debris transport and debris head loss. Based on the concerns discussed above, the staff questioned whether consideration of alternate approaches, such as separating the transport and head loss aspects of the current testing approach, could be beneficial. However, no details of such alternate approaches were discussed during the call.

The vendor indicated that it plans to complete the narrow flume testing and will provide its results to staff by November 9. The vendor stated after the staff has reviewed the results it would like to discuss how to proceed.

Enclosure 1: List of Attendees
Enclosure 2: PCI Narrow Flume Problem Statement and Response (Proprietary)

cc: James Bleigh/PCI

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cc: James Bleigh/PCI

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List of Participants for October 4 and 10, 2010, Meetings With PCI and Licensees

Name	Affiliation
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Wes Schulz*	STP Nuclear Operating Co.
Bill Beckius	Entergy Nuclear Operations, Inc. (Palisades)
Keith Smith*	Palasades
Tom Kendall*	FPL Energy Point Beach, LLC (Point Beach)
Jim Bleigh	PCI
Chris Kudla	PCI
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Steve Smith	NRC
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* Only participated in October 4, 2010, call
** Only participated in October 10, 2010, call

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