June 9, 2010

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

FROM: Joseph A. Golla, Project Manager ***/RA/***
Generic Communications and Power Uprate Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF APRIL 28, 2010, CLOSED MEETING WITH PERFORMANCE CONTRACTING, INCORPORATED AND LICENSEES TO DISCUSS THE PERFORMANCE CONTRACTING INCORPORATED LARGE FLUME TEST PROTOCOL

On April 28, 2010, Nuclear Regulatory Commission (NRC) staff met with representatives of Performance Contracting, Incorporated (PCI), and client licensees of PCI to discuss technical issues concerning PCI's large flume test protocol for testing pressurized-water reactor containment sump strainer performance. The meeting was closed due to the proprietary nature of the discussions. Prior to the meeting the vendor properly submitted a letter and affidavit, according to Title 10 of the *Code of Federal Regulations, Section* 2.390, "Public inspections, exemptions, requests for withholding," requesting that the meeting be closed.

Enclosure 1 provides a list of those in attendance. Enclosure 2 is the meeting agenda. Two vendor documents were used to facilitate discussion. These documents are proprietary and therefore not available for the public to view. They are retained non-public. One document is titled "SFS UG Large Flume Testing Protocol Elements," dated April 21, 2010. This document is organized in a tabular format, and contains the vendors' (PCI, AREVA NP, Inc./Alden Research Laboratory) large flume test protocol elements. The other document is a slide show presentation titled, "Large Flume Test Protocol," dated April 28, 2010.

The agenda for this meeting (Enclosure 2) reflects ten items. The staff and vendors were not able to complete this agenda on April 28, 2010. Therefore, another meeting was scheduled to continue it. It was also decided that, if need be, a third meeting would be held to complete all agenda items.

The staff and vendors discussed topics per the order they are presented in the tabular "elements" document listed above. The topics in this document address the meeting agenda items albeit in a different order than the agenda. This meeting summary will present items in the order of the elements document.

To start the meeting, opening remarks were made by Mr. James Bleigh, Engineered Systems Group Manager, PCI, and Mr. Michael Scott, Branch Chief of the NRC Safety Issues Resolution Branch of the Office of Nuclear Reactor Regulation concerning the status of the vendors' large flume test protocol and the staff's review of it.

Following is a synopsis of the items covered in the Large Flume Testing Protocol Elements document, Section A therein, including items requiring followup action or "Action Items." The indented information summarizes the discussion at the meeting:

**A. Computational Fluid Dynamics (CFD) Modeling of the Licensee Plant-Specific Containment (Elements Document)**

1. Use Fluent to understand and evaluate the Licensee's plant specific post-loss of coolant accident (LOCA) containment flow stream velocities and kinetic energy for the final 20-30 ft of flow path approaching the strainer(s).

> The use of CFD is appropriate. However some issues, such as specification of boundary conditions and modeling of break and spray drainage, have been identified in implementation of models by some licensees.

2. Apply the Alden Weighted Average Methodology to define the approach flow velocities to the test strainer module which yields a flow velocity higher than the mean; but less than the maximum flow velocity.

> Current approach may be prototypical in some cases but has also been considered non-conservative in some others the staff has reviewed.

3. The test flume turbulence level, as calculated by CFD, is equal to or higher than that calculated for the near field of interest to the strainers in the plant CFD calculations.

> Concept as stated would be appropriate.

4. The test flume turbulence level, as calculated by CFD post test, is slightly lower than that observed for the near field of interest to the strainers in the containment debris transport CFD calculations.

> Staff has perceived significant differences in turbulence after allowing for a justifiable temperature correction. Staff attributes this turbulence difference largely to differences in the geometry of the test flume as compared to typical containment pools.

5. Assuming the test flow stream velocity and test flow stream turbulence are "acceptable", debris is allowed to settle prior to reaching the screen.

> Review guidance allows credit for debris settlement, but tests crediting settlement have been complex and difficult to implement in practice. Similarity of velocity and turbulence are necessary to support this testing. Other key aspects, such as debris preparation and addition, will be discussed further in a future meeting.

The following comments and Action Items address the vendor's presentation slides that pertain to Element A above, CFD Modeling:

**Vendor Presentation Slide 14 &15 Flow Sources:**

Vendor proposed (conceptually) more realistic modeling of break and sheet flow entering the pool. The staff considered the modeling of drainage sources to be significant and had questions about the approach.  Additional review of technical references is necessary to support future discussion.

**Action:** Staff will review the references provided and give feedback on this proposal (by May 19, 2010).

**Action:** Based on staff feedback noted above, if appropriate, vendor will develop experiments for water sheets (by May 26, 2010).

**Vendor Presentation Slide 7 Flume Flow Modeling - Velocity:**
Staff feedback- Vendor current approach of determining approach velocity and location of averaging planes is subjective. Taking a simple or even a weighted average may be non-conservative in some cases.  Staff would like to see a more rigorous approach used.  The path forward is to work on enhancing the calculated average flow methodology.

**Action:** Vendor to come up with a methodology (by May 26, 2010).  [Note this is same action as that listed below under Slide 16.]

**Vendor Presentation Slide 8 Flume Flow Modeling - Turbulence:**
These *possible* paths forward were suggested by the vendor and discussed as options:
1. Consider a more prototypical model of break flow to avoid an overly conservative turbulence level in the test flume.
2. Ensure the test flume is as turbulent as the containment is predicted to be based on existing conservative models of break and drainage flow.
3. Introduce turbulence by unsteady injection of fluid at a defined frequency by solenoid valve injection from nozzles along the flume sidewalls.
4. Monte Carlo simulation to determine the increased percentage of debris reaching the screen due to higher levels of turbulence not explicitly modeled during previous flume testing.

**Vendor Presentation Slide 16 Flume Flow Velocity:**
Vendor proposes new method to average flow stream using 1000-3000 pathlines.  Staff agrees method is more rigorous than existing averaging plane approach.  There is a remaining question on the treatment of variability and whether weighted averaging is needed to avoid non-conservatism.

**Action:** Vendor will propose a detailed methodology to address staff's concern and a couple of examples of its application to plant cases including large and small variability in the velocity along different flow paths to the strainers (by May 26, 2010).

**Vendor Presentation Slide 9 Clarification of Initial Position:**
No comment.

**Vendor Presentation Slide 18 Flume Turbulence:**
Vendor- proposes to reduce conservatism used for calculated containment turbulence levels.
Staff- Application depends on outcome of review of break and sheeting flow drainage model. This approach is potentially reasonable though it may not be fully sufficient to address turbulence issue depending on plant conditions.

**Vendor Presentation Slide 19 Flume Turbulence:**
Vendor- proposes new turbulence introduction method using unsteady injection from solenoid nozzles.
Staff- Whatever method is chosen, the vendor should be able to demonstrate the test flume is prototypical of containment conditions. Specifically, the turbulence in the flume water column as a function of distance from the strainer should be prototypical or conservative with respect to the plant, not just the total amount of turbulence added to the flume.

**Action:** Vendor to provide some details on how to implement and how to adjust energy levels. Also, vendor to provide a system description of the nozzle array and location, etc.
(by May 26, 2010).

**Action:** Upon receipt of that information, staff will provide feedback. Staff noted it is challenging to review this approach in absence of acceptance criteria for determining the amount of turbulence added, the position(s) where it is added, and how the turbulence propagates through the flume fluid volume. Vendor may choose to propose acceptance criteria. Staff stated an acceptable approach that would provide turbulence as a function of position would be to perform a CFD simulation of the test flume and compare to the plant containment CFD results.

**Vendor Presentation Slide 20 Flume Turbulence:**
Vendor- Proposes Monte Carlo simulation to determine the increased percentage of debris reaching the screen due to turbulence.
Staff- If this approach is pursued, the cases to consider should include initial addition of debris and recirculation of debris. Not preferred as the general approach but use of the underlying principle could help to demonstrate margin for some cases that have a small turbulence discrepancy, with or without a Monte Carlo simulation.

Following is a synopsis of the items covered in the Large Flume Testing Protocol Elements document, Section B therein, including items requiring followup action or "Action Items." The indented information summarizes the discussion at the meeting:

**B. Licensee Plant-Specific Large Test Flume Configuration (Elements Document)**
1. Test with a full-scale Sure Flow Strainer (SFS) module that represents the same approach velocity at the strainer surface of the plant SFS modules.

> This is a standard scaling item. The staff agrees that the approach is adequate.

2. If sacrificial surface areas are planned by the Licensee; increase the pump flow through the SFS test module proportionately.

> Staff agrees with intent. Debris bed thickness would also be affected by this amount of assumed sacrificial area. Vendor stated existing testing reflects effect on bed thickness.

3. Submerge the test strainer less than or equal to the plant condition; meaning the distance from the plant pool surface to the top of screen shall not be exceeded.

> Standard scaling application. Staff considers acceptable.

4. Water introduced during debris introduction shall be removed by way of an overflow pipe to maintain the water level throughout testing.

> Related to previous item. Artifact to the way the test is done. Staff considers acceptable.

5. Debris spilling into the overflow pipe with the water is collected in a filter and periodically returned to recirculation.

> Similar comment to 4. Approach is adequate assuming debris is reintroduced without agglomeration.

6. The test flow stream bounds the simple calculated average for each flow stream to each strainer in the plant configuration.

> Previously addressed in Section A issues discussion.

7. Design the width of the flume based on plant-specific CFD calculations to create the targeted “bounding” test flow stream velocity. The flume width is calculated based on a fixed test pump flow rate and design basis water level. This width of flume is by necessity a flume width of only 4” or so for some designs to maintain the bounding test flow velocity.

> See discussion below concerning Flume Width slides. Staff considers similarity between the width of plant flow channels and the test flume to be significant and has continuing issues with this item.

8. Rather than adjust the flume width for each one-foot increment upstream of the test strainer, the flume is only adjusted in widths a few times over several feet to reduce the number of flume width changes to construct. This adds conservatism to the flow stream as it is never wider than allowed for each one foot increment.

> Method acceptable. Staff acknowledges conservatism but expects the impact is minor.

9. Introduce all debris at a location upstream of the test strainer that is within the modeled plant flow stream. No debris is introduced upstream of the bounding test flow stream.

The debris introduction zone is located by the Licensee plant-specific CFD model. The distance of the debris introduction zone from the test strainer is limited by either the Licensee's plant configuration or by the Large Test Flume facility's length. The debris introduction zone location is closer than debris will travel "on average" for the Licensee's specific plant configuration and post-LOCA design basis conditions. For example, if the debris introduction zone is 30 feet from the test strainer, then the average distance debris must transport to the Licensee's strainer is more than 30 feet.

> Staff does not consider it acceptable to compute an average distance and add all debris at that point. This point is discussed further below regarding Slides 12, 13, and 24.

10. Orient the upstream face of the test strainer parallel or perpendicular to the test flow stream with an objective to maintain the test flow velocity targeted for the end of the flow stream.

When the upstream face is parallel to the flow stream, this requires debris to turn 90 degrees to collect on the test strainer. This is representative of some, but not all plant configurations. For those where this is not representative, this test configuration is considered more conservative than slowing the bounding flow stream with an increasing flume width to allow debris to reach the full width of the strainer face.

When the upstream face is perpendicular to the test flow stream, the flow stream is adjusted to transition to the fully exposed face of the test strainer in a short distance to minimize debris settling prior to collection on the test strainer.

> Staff considers this to be an artifact of this test approach. It does not appear to have had a major effect in previous testing in either the conservative or non-conservative direction. The staff considers this practice acceptable provided that debris beds continue to be uniform, i.e., provided the strainer orientation does not cause non-uniformity of the bed formation.

11. Confine the sides of the test strainer adjacent to other strainers equal to half the clearance between other strainers in the configuration. The downstream face of the test strainer shall be limited to not more than the closest obstruction in the plant.

> The staff noted that the confined arrangement may not be specifically representative of all strainer installations, but considered this approach to be acceptable as long as no debris larger than the gap modeled would reach the test strainer.

12. Test in hot water; ~120 ˚F versus post-LOCA design basis temperatures of > 212 ˚F

> Staff considered test temperature to be acceptable, and expected that the temperature impact is relatively minor given that debris is typically pre-soaked prior to addition.

The following comments and Action Items address the vendor's presentation slides that pertain to Element B above, Licensee Plant-Specific Large Test Flume Configuration:

**Vendor Presentation Slide 11 Flume Width:**
Staff Feedback- Narrowness of flume leads to turbulence dampening and higher concentrations of debris, which leads to more interaction of debris than in plant and excessive agglomeration. Staff considered the use of a flume width typically much narrower than plant flow channels to be one of the most significant concerns associated with the test protocol. PCI thinks increased velocity makes up for this.

Staff and vendor discussed flume width issue. Staff agreed to provide a reference regarding the significance of wall effects. Vendor could consider possible experiments to show that wall effects are minor. Vendor will consider path forward and discuss with staff.

**Action:** Vendor stated they have evidence there is no build up along walls. Staff stated there is evidence of buildup of debris along walls of flumes during previous transport tests. Evidence is in an NRC technical report (NUREG). Action is to look up the NUREG number and cite to vendor (by May 26, 2010). Subsequent to the meeting the staff identified the technical report as NUREG/CR-3616, "Transport and Screen Blockage Characteristics of Reflective Metallic Insulation Materials. This action is closed.

**Action:** Vendor will consider coming up with a test to address this, i.e., to show wall effects are minor. Vendor to provide proposed path forward (by May 26, 2010).

**Vendor Presentation Slide 12 & 23 Debris Addition Distance:**
Staff and vendor discussed concern about averaging the distance debris travels. Staff did not agree with current approach of adding all debris one flume length away from strainer.

The vendor proposed several paths forward:
1. Comparing transport at different introduction distances versus depth.
2. Attempting to credit that debris beyond a given distance would not transport to strainer.

Staff feedback: Regarding the first item, staff is skeptical as to whether this approach will resolve the issue. Second item focused on eliminating debris originating from beyond a certain distance from the strainer test. Staff not sure of intent and how non-transportability would be demonstrated beyond a given distance. Vendor said they would need to provide a more detailed plan concerning this if it were to be pursued. These concepts are "tabled" for now based upon staff feedback that they appear difficult to justify. Vendor will consider whether to discuss further.

**Vendor Presentation Slide 24 Debris Addition Distance:**
Vendor proposed multiple debris addition distances for future testing based on assuming that debris is spatially distributed among a set of proximity zones in containment at the beginning of recirculation.

Staff agreed that the approach, in general, is acceptable with the following comments:
1. If a discrete point where significant debris is added to the containment pool exists within the range of distances modeled in the test flume, that addition point should be modeled explicitly in the testing.
2. The specification of the size and shape of each proximity zone for defining debris addition distances is subjective and could have a significant impact on the resulting transport behavior and head loss for a strainer test. Proximity zone boundaries should be defined in a manner that minimizes the impact of subjectivity on the test results.

**Action:** Staff suggested vendor provide an example to help illustrate proximity zone definition and a description of the methodology that would be used to generate proximity zones (by May 26, 2010).

**Vendor Presentation Slide 10 Flow Modeling – Temperature:**
Vendor and staff discussed their views on the effect of temperature on terminal settling velocity. The staff considered this a major issue with respect to the determination of whether the flow conditions in the test flume are representative of plant containment pools.

**Action:** Staff and vendor to review each other's supporting technical references and discuss at the next meeting.

Enclosure 1: List of Attendees
Enclosure 2: Meeting agenda

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2. The specification of the size and shape of each proximity zone for defining debris addition distances is subjective and could have a significant impact on the resulting transport behavior and head loss for a strainer test. Proximity zone boundaries should be defined in a manner that minimizes the impact of subjectivity on the test results.

**Action:** Staff suggested vendor provide an example to help illustrate proximity zone definition and a description of the methodology that would be used to generate proximity zones (by May 26, 2010).

**Vendor Presentation Slide 10 Flow Modeling – Temperature:**
Vendor and staff discussed their views on the effect of temperature on terminal settling velocity. The staff considered this a major issue with respect to the determination of whether the flow conditions in the test flume are representative of plant containment pools.

**Action:** Staff and vendor to review each other's supporting technical references and discuss at the next meeting.

Enclosure 1: List of Attendees
Enclosure 2: Meeting agenda

DISTRIBUTION: See next page

**ADAMS ACCESSION NUMBER:** ML101600123

| OFFICE | LA:DPR:PGCB | PM:DPR:PGCB | BC:DSS:SSIB |
|---|---|---|---|
| NAME | CHawes CMH | JGolla | MScott |
| DATE | 6 /9/2010 | 6/9//2010 | 6/9/2010 |

**List of Attendees for April 28, 2010,**
**Meeting With PCI and Licensees**

| | |
|---|---|
| Chris Kudla | PCI |
| Jimmy Seawright | Luminant Power |
| Ron Holloway | WCNOC |
| George Goralski | Entergy |
| Fariba Gartland | Areva |
| Charles Feist | Luminant Power |
| Tom Bilger | Areva |
| Ludwig Haber | Alden |
| Tom Kendall | FPL/Nextera |
| Jim Bleigh | PCI |
| Stu Cain | Alden |
| John Butler | NEI |
| John Lehning | NRC |
| Steve Smith | NRC |
| Mike Scott | NRC |
| Clint Ashley | NRC |
| Joe Golla | NRC |
| Wes Schultz* | South Texas |
| Bill Beckius* | Palisades |
| Lori Christensen* | Kewaunee |
| Scott Putman* | Kewaunee |
| Matt Plante* | Areva |
| Erik Eller* | Areva |

* Indicates participated via telecom

MEETING AGENDA
U.S. NUCLEAR REGULATORY COMMISSION (NRC)
MEETING WITH PERFORMANCE CONTRACTING, INC.(PCI) AND PRESSURIZED-WATER REACTOR LICENSEES
**(MEETING CLOSED TO THE PUBLIC)**

April 28, 2010

| Agenda Item No. | Time | Agenda Topic for Discussion | Discussion Leader |
|---|---|---|---|
| Item 1 | 9:00-9:10 | Introductions and meeting purpose | NRC |
| Item 2 | 9:10-10:30 | PCI review of test protocol elements | PCI/NRC |
| | **10:30-10:45** | **Break** | |
| Item 3 | 10:45-11:30 | PCI review of test protocol elements contd. | PCI/NRC |
| | **11:30-12:30** | **Lunch** | |
| Item 4 | 12:30-1:00 | Test debris size distribution (e.g., mechanical removal of fines from small pieces and erosion) | NRC/PCI |
| Item 5 | 1:00-1:30 | Consistency of debris preparation and addition practices | NRC/PCI |
| Item 6 | 1:30-2:00 | Addition of debris with pump stopped | NRC/PCI |
| Item 7 | 2:00-2:30 | Modeling almost all debris as transporting to the strainers from one flume length away | NRC/PCI |
| | **2:30-2:45** | **Break** | |
| Item 8 | 2:45-3:15 | Flow modeling | NRC/PCI |
| Item 9 | 3:15-3:45 | Flume width | NRC/PCI |
| Item 10 | 3:45-5:00 | Next Steps: path forward, time frame, extent of NRC involvement (additional discussion on review of protocol, testing observation, etc.) | NRC/PCI |

Enclosure 2

Memorandum to Michael Scott from Joe Golla

SUBJECT: SUMMARY OF CLOSED MEETING ON APRIL 28, 2010, WITH PCI AND LICENSEES TO DISCUSS PCI's LARGE FLUME TEST PROTOCOL

**E-Mail**:
RidsNrrOd
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Steve Smith
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