December 27, 2009

Ms. Shirley Olinger, Manager
U.S. Department of Energy
Office of River Protection
P.O. Box 450 MSIN: H6-60
2440 Stevens Center Place
Richland, WA 99354

RE: CRESP Review Team Letter Report 6

Dear Ms. Olinger:

This letter report is to provide rapid feedback in response to the CRESP review team[1] meeting on December 16-17, 2009 focused on the status of progress by ORP and its contractors to achieve resolution and closure to the External Flowsheet Review Team (EFRT) issue of M-3 Undemonstrated Mixing as part of the Pretreatment Facility (PT) at the Waste Treatment Plant (WTP). This meeting was in follow up to the review meeting that focused in part on M-3 on September 10-11, 2009, and CRESP Letter Report 5 (October 2, 2009). The DOE managers who attended our review specifically requested that we provide you and the Department with this preliminary letter report to allow you and your management an early opportunity to consider possible responses to these initial findings while we simultaneously develop a more complete and mature review report.

The CRESP team continues to be frustrated by the last minute and incomplete nature of materials provided to form the review basis. This highlights the team's concern that it is not possible for ORP to have a credible and defensible design basis without sufficient logic linking important programmatic criteria and supporting information, engineering analysis and data clearly and thoroughly presented in carefully prepared and referenced reports.

The specific objective of the review was to "assess the technical adequacy of the Waste Treatment and Immobilization Plant (WTP) Program for conducting an Engineering Analysis for

[1] Richard V. Calabrese served as an advisor to the CRESP team.

determination of the capability of selected Pulse Jet Mixed Vessels to comply with their mixing requirements."[2]

The December 16-17, 2009 review focused on the following vessels: FRP-2A/B/C/D, HLP-22, UFP-1A/B, FEP-17A/B, PWD-33, PWD-43 and PWD-44. These vessels are categorized as each containing up to 3.8 to 16 wt% solids (the maximum is dependent on the specific vessel) with the resultant slurries behaving as Newtonian fluids. Below is the list of the objectives identified by ORP for the scope of the review[3], together with the review team's direct responses to each of these objectives. Next, the review team what it considers to be major issues and initial recommendations for immediate action :

<u>Review Scope Objectives and Review Team Responses</u>

1. Understanding the PJM mixing phenomena

   <u>Review team comments</u> – The WTP Contractor and its supporting contractors (e.g., Dave Dickey, Art Etchells, PNNL and others) appear to have personnel and teams that understand the relevant mixing phenomena. However, it is not clear that past research and operating experience with PJMs on behalf of ORP or others has been carefully considered and assimilated into the current understanding of mixing in the vessels, the design basis under development or planned experimentation. To date, we have not received a report reviewing the previous work, establishing the experimental data currently available, the design basis for the currently fabricated vessels, and identifying the knowledge gaps and limitations of the prior work. For example past testing has reviewed possible PJM operating modes and power levels, and has identified apparent boundaries.[4] The Contractor did not address this past work and its strengths and weaknesses. Rather the impression is that the effort is starting over. An example includes providing a basis for the current selection of simulants being used for testing in the context of (i) the range of actual waste properties anticipated for each vessel under evaluation, and (ii) prior testing that occurred with a range of simulants and the conclusions reached. Similarly, clear documentation of the recent and current work that describes the test beds, simulant used, experimental conditions, experimental results, conclusions and limitations has not been provided.

2. Understanding the PJM vessel mixing requirements

   <u>Review team comments</u> – There appears to be a limited set of essential functional requirements for the vessels: (i) provide sufficient mixing under normal operating conditions to facilitate necessary reactions (e.g., leaching) and avoid accumulation of rapidly settling particles within the vessels, (ii) provide sufficient mixing under upset conditions (design basis event) to insure adequate clearing of hydrogen that would

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[2] R. Gilbert, G. Brunson and L. Holton, 2009. Consortium for Risk Evaluation with Stakeholder Participation (CRESP) Review of the Waste Treatment and Immobilization Plant (WTP) Pulse Jet Mixer Program. Presentation to CRESP review team, Dec. 16, 2009.

[3] Ibid.

[4] J. R. Bontha, G. R. Gokar, and N. Hannigan, Aug. 2000. Demonstration and Optimization of BNFL's Pulsed Jet Mixing and RFD Sampling Systems Using NCAW Simulant. PNWD-3054, BNFL-RPT-048, Rev. 0.

accumulate within settled solids as a result of radiolysis, (iii) provide sufficient mixing during operating and upset conditions to ensure that particle segregation does not occur and to obtain a representative sample for analysis in support of process control. There appears to be a clear understanding of these functional requirements but it is only now that the definition of the specific criteria that need to be met to fulfill these requirements is evolving.

3. Evaluating the technical strategy and relationship between: (a) vessel functional requirements, (b) methods used to assess mixing vessel design adequacy and, (c) testing requirements to validate the identified computational methods and/or mixing vessel design.

   Review team comments – The Contractor technical strategy is difficult to understand or characterize from the presentations and limited draft reports supplied to the CRESP team. There is no logical structuring from overall requirements to specific requirements for each vessel. In addition the tests that have been performed or are planned have not been clearly related to specific requirements and the overall technical strategy. The technical strategy does not draw a relationship between current design requirements for already fabricated equipment and the ongoing test effort. For example, will the current and planned testing address current specifications for already fabricated equipment and how has the testing been scaled to address the specific configuration of each vessel.

4. Evaluating the computational methods proposed for assessing PJM vessel mixing design adequacy, including; (a) methods to scale test information from model scale experiments to the full scale plant vessel, (b) methods to validate the scaling methods, and (c) utility and precision associated with the use of the scaling method(s) including assessing the impact of uncertainties in testing information on full scale vessel projections and address the relationship of simulant test information to actual waste performance.

   Review team comments – In 2000 BNFL recommended use of CFD modeling of PJM phenomena and design. The proper use of validated CFD methods can have two valuable outcomes. First, they allow testing results carried out under different conditions to be integrated and evaluated in a flexible CFD model and then the model can be used for evaluating the range of operating conditions established for the plant, and alternative mixing control strategies. This requires that planned testing provide the bracketing information necessary to demonstrate the CFD model spans the range of anticipated operations. Second, CFD models can be integrated into a suite of simulation software for operator training. The work to date has been useful but will not result in CFD models and results that establish that the design of the already fabricated equipment is adequate. In so far as the review team can determine, ongoing CFD development, has not been verified and validated (V&V'd) and it is unclear whether a sufficient basis in relevant experimental data has been developed to support necessary CFD model verification and validation.

Additional Major Issues

The following are additional major issues identified as part of this review and the review team comment below augment our earlier review (October 2, 2009):

1. The CRESP Letter Report 5 (October 2, 2009) recommended:

   "There should be a clear and succinct description of the logic that indicates the flow from the PJM mixing requirements as the WTP vessel design basis down to specific testing approaches (e.g., testing in scaled down vessels, full-scale single pulse-jet testing in a flume, use of simplified simulants such as glass beads vs. simulants representative of waste feeds). This description should provide a clear mapping of how each type of test provides required information to establish the mixing scale-up relationships along with the methodology, verification of the scale up methodology with independent calibration and verification data, and criteria to verify adequate mixing design in WTP PJM mixed vessels. Verification should be through testing with waste simulants that includes representative concentration, particle size and rheological properties. Consideration should be given using chemical simulants as part of the testing program."

   This has not been accomplished and remains a critical need. Some progress appears to have been made in developing criteria and testing for one of the designated vessels but inadequate documentation was available to provide the necessary review.

2. There is a lack of careful, integrated criteria development, engineering analysis, experimental design and execution, and follow through to full-scale system design. There is inadequate organization, structure and documentation in problem resolution. Examples include the basis for mixing performance criteria, simulant selection, scaling bases, and experimental design (including uncertainty quantification).

3. Different aspects of the mixing problem and experimental design have different scaling bases, based on the fundamental phenomena involved. For example, mass transfer and mass transfer-controlled reaction rates are scaled based on power per unit mass (often represented as power per unit volume for constant density systems) and is considered conservative for other mixing phenomena such as blending. Currently, the scaling ratio being employed is approximately 200:1 (not 6:1 as implied by the ratio of vessel radii). The scaling basis for other factors (e.g., PJM duty cycles (power and frequency), nozzle velocities, placement, bed depths, suction drain location, etc.) needs to be defined and the basis for integrated testing (including limitations) needs to be clearly articulated and documented. Scaling of critical phenomena should be verified by experimental testing at multiple scales.

4. The amount of power provided to the system, when properly applied, should be able to exceed the minimum necessary to clear the vessels as the vessels are drained. However, the basis for mixing process control has not been established (e.g., PJM firing strategy). We are concerned that a PJM duty cycle and control strategy that provides simultaneous operation of all PJMs and allows intermittent settling of solids will likely result in periodic behavior with spatially and temporally variable particle gradients within the vessels. The planned PJM control strategy also may result in a stratification of particle sizes and densities. A lack of uniform particle distribution within a vessel creates an

extremely challenging situation for defining a sampling strategy which is an essential component for process control. A lack of uniform particle distribution also could be especially troublesome during an upset.

5. An adequate basis for analyzing gas clearing during normal operations and design basis events (upset scenarios) has not been documented (nor clearly articulated). Although the mechanism for generating hydrogen is well-understood, the growth of hydrogen bubbles and their coalescence is not discussed. Similarly, a clear understanding of the mechanism for hydrogen clearing from the suspension and the interaction of the time scales for this and that of the reformation of the yield stress of the sludge is not articulated.
6. The availability of a V&V'd CFD model and a prototypical test bed will be essential tools for development of process control and operational strategies. The actual V&V process, including development of an adequate experimental basis, will likely take longer than one year.

Recommendations for Immediate Action

Considering the current status, rate of progress, and urgency in resolving of the EFRT M-3 issue, the review team makes the following recommendations for immediate action:

1. The design basis for each vessel should be established on clearly defined mixing requirements with the scaling basis for each such requirement founded on physical mechanisms. For tanks with multiple requirements, the controlling criterion, or the means to its determination, should be identified.
2. For consistency, all documentation and future communications should use either standard or well-defined nomenclature and terminology.
3. A report should be developed that provides the basis for selection of simulants currently being used and to be used in the future as part of testing in support of the design of the vessels under consideration. The report should document the selection of simulants in the context of (i) the range of actual waste properties anticipated for each vessel under evaluation, and (ii) prior testing that occurred with a range of simulants. Consideration should be given to particle segregation, during normal operation and system upsets, that may result due to different particle densities and sizes.
4. A report should be developed that reviews prior information on mixing requirements and available data, and establishes the needed experimental data and design basis prior to the testing carried out under the current program. Further, the report should identify the knowledge gaps and limitations of the prior work, and should include a clear definition of the materials or simulants processed, the test bed or operating system configuration, and key test results obtained.
5. A report should be developed that provides a detailed description of the test beds and testing completed to date as part of this program. The report should include the objectives, relationship to development of scaling or design basis, experimental design, results, conclusions and limitations (including uncertainty) associated with each experimental campaign.

6. A report should be developed that provides the basis for assessment of the first vessel for which DOE concurrence is being sought that includes the engineering design basis or criteria initially used for designing the vessel, the current criteria, scaling approach, experimental objectives, experimental results, conclusions and limitations (including uncertainty) for that specific vessel. This report should establish a template for future approval of the remaining vessels.
7. The review team strongly recommends that the CFD V&V plan be independently reviewed under the auspices of DOE and include review of the adequacy of the experimental data base for V&V.

The intended purpose of the above recommended reports is to provide a clear foundation for future design decisions and to provide a basis for independent review of the developed designs. Each of the reports should be concise, and well-documented with key information and readily available citations. We anticipate that each report will be relatively brief, and that the documentation, such as previous reports, would be either readily available or provided as attachments.

In addition to follow up on the issues and recommendations indicated above, we recommend that future CRESP review team efforts include evaluation of the sampling strategies, information required from samples, and their relationship to mixing and other processing requirements.

We hope you find these comments helpful in your evaluation and we are available to discuss any questions you may have regarding this review.

Sincerely,

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