DEFENSE NUCLEAR FACILITIES SAFETY BOARD
Washington, DC 20004-2901

December 17, 2010

The Honorable Steven Chu
Secretary of Energy
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Chu:

On December 17, 2010, the Defense Nuclear Facilities Safety Board (Board), in accordance with 42 U.S.C. § 2286a(a)(5), unanimously approved Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*, which is enclosed for your consideration.

After you have received this Recommendation and as required by 42 U.S.C. § 2286d(a), the Board will promptly make it available to the public. The Board believes that this Recommendation contains no information that is classified or otherwise restricted. To the extent that this Recommendation does not include information restricted by the Department of Energy (DOE) under the Atomic Energy Act of 1954, 42 U.S.C. §§ 2161-2168, as amended, please arrange to have it placed promptly on file in your regional public reading rooms. The Board will also publish this Recommendation in the *Federal Register*.

The Board will evaluate DOE's response to this Recommendation in accordance with the Board's Policy Statement 1, *Criteria for Judging the Adequacy of DOE Responses and Implementation Plans for DNFSB Recommendations*.

Sincerely,

Peter S. Winokur, Ph.D.
Chairman

Enclosure

c: Mrs. Mari-Jo Campagnone

RECOMMENDATION 2010-2 TO THE SECRETARY OF ENERGY
Pulse Jet Mixing at the Waste Treatment and Immobilization Plant
Pursuant to 42 U.S.C. § 2286(a)(5)
Atomic Energy Act of 1954, As Amended

Dated: December 17, 2010

Introduction

Legacy wastes from decades of nuclear weapons production by the Department of Energy (DOE) and its predecessor agencies include high-level radioactive waste stored in 177 underground tanks at the Hanford Site. The risk posed by the continued storage of wastes in these tanks is considerable. Many of the tanks have a history of leakage, several are more than 60 years old, and most will be far beyond their intended service life by the time the wastes are retrieved and processed into stable forms. DOE must ensure that the Hanford Waste Treatment and Immobilization Plant (WTP) in conjunction with the Hanford tank farm waste feed delivery system will operate safely and effectively for many decades to eliminate the safety hazards posed by the wastes. This imperative requires that the pulse jet mixing and transfer systems relied upon in the WTP design perform reliably and effectively for decades of WTP operations, and that technical issues with the performance of these components be resolved in time to enable DOE to meet its existing commitment to begin WTP operation in 2019.

Background

In a letter to DOE's Assistant Secretary for Environmental Management dated January 6, 2010, the Defense Nuclear Facilities Safety Board (Board) summarized its concerns related to WTP's mixing and transfer systems; specifically, that the pulse jet mixers (PJM) lacked sufficient power to mix adequately and to transfer the most rapidly settling particles expected to be present in the Hanford waste inventory. In its letter, the Board identified three significant safety issues related to pulse jet mixing: (1) retention of fissile materials in vessel heels would present a criticality safety concern, (2) retention of flammable gas due to the presence of solids in vessel heels, and (3) the presence of a large solids inventory could have a detrimental effect on the vessel level instrumentation, which is required to control the PJMs.

In its May 17, 2010, response to the Board's letter, DOE committed to take actions to increase confidence in successful operation of WTP. These actions included integrated testing of vessel mixing and transfer systems at a larger scale. However, DOE did not provide details such as the scope and schedule for this effort.

On July 1, 2010, the Consortium for Risk Evaluation and Stakeholder Participation (CRESP), an independent technical review team under contract to DOE, issued a report that identified concerns similar to the Board's. Specifically, CRESP found that there was uncertainty in PJM performance and that the absence of full-scale or near full-scale testing represented a

large risk for the WTP program. The CRESP report presented DOE with thirteen recommendations that addressed topics of Board concern, e.g., large-scale testing, reliance upon computational fluid dynamics modeling, functional performance specifications for inspecting and accessing vessel bottoms, heel removal needs and operating strategies, and criticality safety.

On October 7–8, 2010, the Board held a public hearing on WTP issues, of which one session focused on evaluating the state of the PJM design. In advance of the public hearing, the Board asked DOE to respond to written questions related to PJMs. These questions focused on the scope of integrated testing at larger scale and DOE's actions to address the concerns raised by CRESP. DOE provided written responses to the Board's questions on September 8, 2010, but did not provide insight into the scope or schedule of the large-scale testing. DOE's responses stated that the objectives and schedule for the large-scale testing were projected to be established by the end of calendar year 2010; this has since been revised to January 2011. DOE's response also stated that DOE and its contractors would address the recommendations from the CRESP report, but that schedules for addressing most of the recommendations had not yet been established.

The Board's written questions also asked DOE to describe each open safety issue related to PJM performance. DOE responded that the primary safety-related issue that remained open was associated with performance of the integrated mixing and transfer system, which includes the PJM mixing system and associated controls, the suction line, and the vessel sampling system. DOE did not identify any concerns related to accumulation of solids in WTP vessels.

In response to the questions posed by the Board, DOE included a response from Pacific Northwest National Laboratory (PNNL) providing its expert opinion on the adequacy of the PJM design. PNNL has performed considerable testing and analysis in support of the WTP mixing system design. PNNL noted in part:

- Phase 1 testing performed by PNNL predicted inadequate mixing in some vessels. The WTP project team subsequently changed the mixing criterion from complete off-bottom suspension to a bottom-clearing metric. This change represents a significant reduction of the mixing criterion.

- The WTP project team commissioned additional testing to this new criterion using waste simulants. PNNL has several concerns related to the simulants used in the WTP project team's tests, as the simulants were not necessarily physically representative or bounding of actual waste. PNNL expressed the concern that mixing performance observed in the WTP project team's tests may be better than actual plant performance.

- The current design lacks an adequate scaling basis to relate small-scale test results to full-scale plant performance. The scaling of the mixing, transfer system, and pump-down process is complex. The absence of an experimentally validated scaling basis for pump-down represents a significant weakness of the current design basis.

During the Board's public hearing, DOE and its contractors acknowledged the need for large-scale testing and committed to complete relevant portions of such testing before installing process vessels in the WTP Pretreatment Facility, which is currently under construction at the Hanford Site. DOE informed the Board that development of suitable waste simulants would likely be the most time-consuming aspect of the preparations for large-scale testing. DOE's commitment to complete applicable portions of a large-scale testing program prior to installation of the Pretreatment Facility vessels is a positive development.

Unresolved Concerns

The Board believes that the testing and analysis completed to date have been insufficient to establish, with confidence, that the pulse jet mixing and transfer systems will perform adequately at full scale. The Board's unresolved technical concerns are summarized below:

Limitations of the small-scale testing program—The small-scale testing program did not investigate the performance limits of the PJM design. Rather, it demonstrated that the mixing system met a reduced mixing criterion using simple simulant materials that were not fully representative of the characteristics of Hanford's high-level wastes. The testing program did not evaluate the entire range of WTP operating conditions, used non-prototypic equipment for much of the testing, and did not include multi-batch test runs to establish whether the mixing and transfer systems could operate for long periods under a variety of operating conditions. The program did not address the behavior of non-Newtonian wastes, such as the effects of variations of viscosity within a vessel, or the unique arrangement of PJMs in vessels containing these wastes. Pump-out testing did not include prototypic simulant or transfer system components, and lacked a well-established scaling basis. Large-scale testing would remedy this issue.

Modeling of mixing performance—Computer simulations of mixing performance, such as the Low Order Accumulation Model, have not been verified and validated, yet have been used to advance the WTP mixing design. DOE plans to use computer simulations in validating the final WTP mixing design and is working to verify and validate a computational fluid dynamics code (FLUENT) for this purpose. Any use of computer simulations must be technically defensible, and the limits of each computational fluid dynamics simulation need to be well understood to prevent potential safety issues from arising during operations.

Waste characterization and feed certification—The WTP safety strategy depends upon obtaining representative samples from the high-level waste feed tanks to support WTP's waste feed certification requirements, and from WTP process vessels to ensure safety-related criteria are met. This capability has not been demonstrated in the Hanford Tank Farms or WTP process vessels. Obtaining samples that are sufficiently representative to support bounding estimates of the composition and properties of both the solid and liquid fractions of the high-level waste is required in order to demonstrate that the WTP can be operated safely (e.g., prevent inadvertent criticality and plugging of transfer lines).

The WTP project team has altered its mixing performance criterion and made changes to the waste acceptance criteria, such as reducing the allowable solids concentration for WTP feed to address unfavorable mixing test results. DOE and its contractors have not yet been able to explain the full impact of these changes on DOE's ability to qualify WTP feed and process the entirety of Hanford's high-level waste using WTP. Additionally, DOE and its contractors have not been able to explain how representative samples from PJM-mixed tanks will be obtained.

Planned WTP process vessel modifications—DOE is planning to add capabilities for heel dilution, vessel pump-out, and visual inspection to address potential risks and uncertainties remaining from small-scale testing; however, the specifications for and capabilities of these systems have not been established.

Limitations of PJM controller and instrumentation testing—DOE has not performed PJM controller and instrumentation tests with a combination of (1) a prototypic simulant; (2) a full-scale PJM system driven by jet pump pairs; and (3) prototypic level/density instrumentation and controllers. Pretreatment Engineering Platform testing revealed that the level/density probes provided spurious data because of plugging and interference resulting from hydrodynamic pressures from the PJMs and transfer pumps. In addition, PNNL stated that the PJM controller testing performed in 2009 had several limitations and that "any extrapolation of the data above and beyond the scope of the present work should be done with extreme caution."

Recommendation

Therefore, the Board recommends that DOE:

1. Develop a large-scale test plan, including a schedule and milestones that addresses the issues raised by the Board in this recommendation, by CRESP in its letter reports addressing pulse jet mixing, and by PNNL. The objective of the test plan should be to define the limits of the WTP pulse jet mixing and transfer systems given the complete range of physical properties for the high-level waste stored in the Hanford Tank Farms. The elements of the test plan should include: (1) design of simulants; (2) design of the prototypic mixing systems, including PJM control and tank level control systems, and the transfer system for the large-scale test; and (3) criteria for review and interpretation of the large-scale test results. The test plan schedule should be constructed such that results from the testing can be used to inform WTP process vessel design decisions. The large-scale test platform must integrate the scaling of the mixing and transfer systems such that the scaling of the test platform is technically defensible.

2. Develop waste simulants for the mixing and transfer system testing that envelope the complete range of physical properties for the high-level waste stored in the Hanford Tank Farms. The simulant selection should include simulants representative of the waste's Newtonian and non-Newtonian properties and particle shape, e.g., irregularly shaped simulant particles. The physical properties selected for each simulant must reflect uncertainties in the existing characterization of the high-level wastes.

3. Complete verification and validation of any computational models used by the WTP project team (e.g., Low Order Accumulation Model and FLUENT) based on the results from the large-scale testing.

4. Demonstrate the ability to obtain representative samples of the solids and liquids in all of WTP's vessels, including demonstrating that representative samples can be obtained even if the assumed WTP design particle size or density is exceeded. This will ensure that the sampling system does not exclude large, dense particles and artificially bias the measured particle size and density distribution. The representativeness of these samples must be statistically defensible and meet appropriate confidence limits given the significance of the safety-related issues in WTP.

5. Define the impact on the waste retrieval, feed delivery, and feed certification processes due to any limitations of the WTP mixing and transfer systems, and demonstrate the ability to obtain adequately representative samples from the waste feed tanks to ensure the WTP waste acceptance criteria can be reliably enforced.

6. Establish functional design criteria for the heel dilution, heel pump-out, and visual inspection functions, and demonstrate the capabilities and limits of these systems through the large-scale testing.

7. Identify the technical and safety-related risks that remain unresolved upon completion of the large-scale testing and establish suitable risk management strategies to ensure that each remaining risk will have little, if any, potential impact on DOE's ability to begin WTP operations safely and consistent with existing commitments.

In order to preclude unnecessary delay in the WTP project, the Board urges the Secretary to avail himself of the authority under the Atomic Energy Act (U.S.C. § 2286d(e)) to "implement any such recommendation (or part of any such recommendation) before, on, or after the date on which the Secretary transmits the implementation plan to the Board under this subsection."

Peter S. Winokur, Ph.D., Chairman