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Department of Energy
Washington, DC 20585

May 17, 2010

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DNF SAFETY BOARD

The Honorable Peter S. Winokur
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue N.W.
Suite 700
Washington, DC 20004-2901

Dear Mr. Chairman:

This is in response to the Defense Nuclear Facilities Safety Board's (Board) January 6, 2010, letter concerning the design and testing of pulse jet mixing (PJM) technology being deployed in the Pretreatment Facility at the Waste Treatment and Immobilization Plant (WTP) at the Hanford site. In that letter the Board expressed concerns that the functional requirements for the mixing and transport systems do not adequately bound the properties of waste to be processed. Further the Board postulated that this could result in three significant safety issues; a criticality event, a flammable gas explosion, or a component material failure due to PJM overblows.

The staff report enclosed with the Board's letter addressed this issue and was based upon staff interactions with the Department of Energy (DOE), Office of River Protection (ORP) and WTP contractor Bechtel National, Inc., (BNI) staff in June, September, and October 2009, and the Board's staff analysis during that timeframe. That report reflects the ORP and BNI findings that the current PJM design for some WTP vessels lacks sufficient power. Vessels with insufficient power have the potential to inadequately mix and transport the most challenging fraction of the solids expected to be present in the Hanford waste inventory.

Since the time period addressed by the Board's letter, ORP and WTP have identified the additional testing and analysis needed to improve the capability of the PJM design. A series of seven key documents were developed and shared with the Board's technical staff that describes the approach to: (1) establish functional requirements and technical criteria for safe operation of the integrated WTP pulse jet mixing, transport, and sampling systems; (2) establish bounding PJM design basis requirements for particle size and density based on feed qualification data; (3) develop design methods that demonstrate that system performance can meet functional requirements with bounding design basis inputs; and (4) establish a criticality safety strategy that reflects the capabilities of the mixing, transport and sampling systems. A summary of these seven documents is provided as Enclosure 1. One of these documents, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy* (24590-WTP-RPT-ENG-10-001) provides the top level description of the approach to these four elements.

DOE and BNI provided a detailed briefing to the Board on these documents, as well as the timeline for resolution of the PJM issue in March 2010. These briefings also addressed the technical studies and design changes that will be made to add vessel access ports and heel pump-out capability for certain vessels in which testing has determined such systems are necessary. Technical discussions for each of the topics contained in the Board's letter are provided in Enclosures 2 through 5.

DOE is committed to resolving the issues identified in the Board's letter. Testing of the five Newtonian vessels containing high solids concentrations are completed and significant insights have been gained from that testing and analysis. DOE has committed to several modifications to address vessel mixing issues and provide increased confidence in successful operation of the WTP. These include:

- Adding additional PJMs to vessels HLP-VSL-00022 and UFP-VSL-00001 A/B;
- Adding vessel inspection and heel removal capability with enhanced transfer capacity for ten high-solids vessels;
- Performing a double decant of Low Activity Waste (LAW) feed in the Tank Farms and dedicating a transfer line for LAW feeds to minimize the potential for High Level Waste solids to enter the LAW receipt vessels;
- Adjusting vessel operating limits to assure adequate mixing; and
- Performing integrated tests of the mixing, transfer, sampling and PJM control systems at a larger scale.

In addition, preparations are being made to test the most challenging non-Newtonian vessel configurations that contain high solids concentrations, should testing be determined to be required. The DOE will also make contract changes to WTP waste feed specifications to provide additional defense in-depth while not adversely impacting overall mission life.

A standing briefing schedule between the Board technical staff, ORP and WTP has been established to keep the Board apprised of progress in executing this strategy and completing the testing and design process related to PJM technology.

If you have any questions, please contact me or Dr. Steven L. Krahn, Deputy Assistant Secretary for Safety and Security Program at (202) 586-5151.

Sincerely,

Inés Triay

Inés R. Triay
Assistant Secretary for
Environment Management

Enclosures

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ENCLOSURE 1

Technical Discussion: Defense Nuclear Facilities Safety Board (Board) Issue Report

1.0 Defense Nuclear Facilities Safety Board (Board) Issue and Related Comments

In its letter to the Department of Energy (DOE) Office of River Protection (ORP) dated January 6, 2010, the Board expressed concerns over three principal safety issues related to the capability to mix slurries in the Waste Treatment and Immobilization Plant (WTP) and requested a response that addressed four elements.

> *"This response should describe an approach to (1) establish functional requirements and technical criteria for safe operation of the integrated WTP pulse jet mixing, transport, and sampling systems; (2) establish bounding design basis requirements for particle size and density based on feed qualification capabilities; (3) develop design methods that demonstrate that system performance can meet functional requirements with bounding design basis inputs; and (4) establish a criticality safety strategy that reflects the capabilities of the mixing, transport and sampling systems."*

2.0 Background

ORP and the WTP contractor, Bechtel National, Inc. (BNI) have reassessed the additional testing and analysis needed to improve the capability and demonstrate the safety of the Pulse Jet Mixing (PJM) design. A series of seven key documents have been developed and shared with the Board's technical staff that describes the approach to address the Board's concerns. This report provides a short overview of the key documents and their relationship to those response elements.

3.0 Technical Approach to Resolve Issues

Comprised of two key issues: 1) Key documents; and 2) Relationship of key documents

3.1 Key Documents

ORP and BNI reassessed the additional testing and analysis needed to improve the capability and demonstrate the safety of the PJM design. A summary of each the seven key documents that guide the resolution and closure of technical issues associated with pulse jet mixing follows.

- 24590-WTP-RPT-ENG-10-001, Rev 0, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy, February 20, 2010*

  This document is the top level strategy document describing the phased approach to addressing PJM related issues, including mixing, transport, sampling and control. It also provides a summary of the engineering methods that will be used to assess vessel mixing performance, the deliverables that will be used to underpin mixing issue (M3) closure, the management of residual risks. This strategy document is supported by the other key documents discussed below.

- 24590-WTP-RPT-ENS-10-002, Rev 0, *M3 Criticality Safety Test Requirements, March 3, 2010*

  This document discusses the PJM mixing issues and test objectives that directly support the criticality safety strategy and identifies test requirements to support criticality safety analysis. It provides an overview of the current criticality safety strategy, including controls and open issues. It summarizes issues related to PJM mixing associated with the current approach taken in the Criticality Safety Evaluation Report (CSER) and identifies a strategy and approach for resolving the issues. It is one of the source documents for the plan of testing.

- 24590-WTP-RPT-PET-10-007, Rev 0, *Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels, February 17, 2010*

  This document is organized in two parts to address two aspects of mixing to release gas. Part 1 describes the phenomenon of gas retention and the mechanism by which mixing releases the gas. Part 2 assumes a settled solids layer forms and retains gas when mixing does not occur for a post-Design Basis Event (DBE) period lasting up to 1000 hours, then quantifies the amount of sediment mobilization needed during periodic mixing to release the gas and prevent the Lower Flammability Limit (LBL) in the headspace from being reached.

- 24590-WTP-RPT-PET-10-008, Rev 0, *Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies, March 4, 2010*

  This document describes the waste simulants to be used for testing to close the first phase of the *Integrated Pulse Jet Mixed Vessel Design and Control Strategy.* It describes the simulant selection strategy and ties it back to the waste feed stream characteristics basis provided in Correspondence Control Number (CCN): 211892, *M3 Mixing Requirements.*

- 24590-PTF-PL-PET-10-00001, Rev 0, *Plan For M3 Test Platform Testing, March 3, 2010*

  This document describes the plan of testing required to close the first phase of the *Integrated Pulse Jet Mixed Vessel Design and Control Strategy.* It provides the testing basis, testing objectives, testing success criteria, and the test data to be provided. It also summarizes quality requirements and reporting requirements.

- CCN: 211892, *M3 Mixing Requirements, February 27, 2010*

  This document summarizes the waste feed stream characteristics to be used to support the assessment and design of PJM mixed vessels, tracing them back to source documents. It also provides interim mixing requirements agreed upon by ORP and BNI to be used for the testing and assessment of selected PJM mixed vessels, pending their incorporation into the WTP mixing requirements document.

- CCN: 210455, *Scaling of PJM Vessels Containing Settling Solids in Newtonian Slurries, March 4, 2010*

  This document describes the scaling bases to be used for scaling phenomena associated with PJM mixed vessels containing settling solids in Newtonian slurries. Topics discussed include scale up for the following: 1) solids mobilization; 2) solids suspension; 3) zone of influence; 4) passive devices; 5) pump suction lines; and 6) sampling. It is used with other analysis methods by WTP Engineering to support specification of testing parameters and assessment of PJM mixed vessel performance.

3.2 Relationship of Key Documents to Elements of Board Requested Response

This section provides a summary of the relationship of the key documents to the four elements as discussed previously and requested to be included in the Board's letter.

<u>Establish Functional Requirements and Technical Criteria for Safe Operation of the Integrated WTP Pulse Jet Mixing, Transport, and Sampling Systems</u>

The functional requirements and technical criteria for safe operation of the integrated WTP pulse jet mixing, transport, and sampling systems are described in CCN: 211892, *M3 Mixing Requirements*, as supported by 24590-WTP-RPT-ENS-10-002, Rev 0, *M3 Criticality Safety Test Requirements,* and 24590-WTP-RPT-PET-10-007, Rev 0, *Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels.*

Establish Bounding Design Basis Requirements for Particle Size and Density Based on Feed Qualification Capabilities

The basis of the waste feed characteristics used for vessel design, assessment, and testing is described in attachment 8 of CCN: 211892, *M3 Mixing Requirements.* It is carried forward into PJM mixed vessel testing as described in 24590-WTP-RPT-PET-10-008, Rev 0, *Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies.*

Develop Design Methods that Demonstrate that System Performance Can Meet Functional Requirements with Bounding Design Basis Inputs

Design methods to be used by WTP Engineering, along with the methods to be used to assess various aspects of PJM mixed vessel performance are described in 24590-WTP-RPT-ENG-10-001, Rev 0, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy.* This document is further supported by 24590-PTF-PL-PET-10-00001, Rev 0, *Plan For M3 Test Platform Testing;* 24590-WTP-RPT-PET-10-008, Rev 0, *Revised Simulant Design and Basis for FEP-17, FRP-02,HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies;* and CCN: 210455, *Scaling of PJM Vessels Containing Settling Solids in Newtonian Slurries,* March 4, 2010.

Establish a Criticality Safety Strategy that Reflects the Capabilities of the Mixing, Transport and Sampling Systems

The approach to establish an updated criticality safety strategy is discussed in 24590-WTP-RPT-ENS-10-002, Rev 0, *M3 Criticality Safety Test Requirements* and implemented in 24590-PTF-PL-PET-10-00001, Rev 0, *Plan For M3 Test Platform Testing* (Appendix D).

4.0 References

1. *Pulse Jet Mixing Issues,* Presentation to the Defense Nuclear Facilities Safety Board, Greg Ashley, WTP Project Technical Director, March 17, 2010
2. 24590-WTP-RPT-ENG-10-001, Rev 0, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy*
3. 24590-WTP-RPT-ENS-10-002, Rev 0, *M3 Criticality Safety Test Requirements*
4. 24590-WTP-RPT-PET-10-007, Rev 0, *Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels*
5. 24590-WTP-RPT-PET-10-008, Rev 0, *Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies*
6. 24590-PTF-PL-PET-10-00001, Rev 0, *Plan For M3 Test Platform Testing*
7. CCN: 211892, *M3 Mixing Requirements,* February 27, 2010
8. CCN: 210455, *Scaling of PJM Vessels Containing Settling Solids in Newtonian Slurries, March 4, 2010*

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ENCLOSURE 2

Technical Discussion: Potential for Inadvertent Criticality

1.0 Defense Nuclear Facilities Safety Board (Board) Issue and Related Comments

From the Defense Nuclear Facilities Safety Board (Board) January 6, 2010, letter, first bullet:

> *Dense particles rich in plutonium and uranium are expected to settle preferentially on the bottom of tanks. These settled particles may form a sediment layer with sufficient fissile mass in a geometry such that a criticality accident is credible. Furthermore, if the vessels are not well mixed, samples drawn from the vessels to ensure that such an event does not occur will not be representative.*

Related comments from the Enclosure to the Board letter:

> ***Potential for Inadvertent Criticality.*** *Particles with high concentrations of fissile materials (e.g., uranium or plutonium) are expected to be dense, rapidly settling particles. Test results show that rapidly settling particles can settle preferentially and accumulate as sediment in tanks with underpowered pulse jet mixers. The result is the potential for inadvertent criticality in the WTP Pretreatment Facility. BNI deems criticality incredible in WTP based on assumptions regarding the ratio of plutonium to absorber metals and the ratio of fissile uranium to total uranium. These assumptions will be confirmed through sampling of the process slurry in the feed receipt vessel to a criticality safety requirement that incorporates "5 percent margin allowed for the sample non-representativeness." The criticality safety evaluation report identifies two open technical items in this strategy that are negatively affected by underpowered pulse jet mixers. These items are discussed below.*
>
> *Gravity Segregation -- The majority of plutonium in the Hanford tank farm inventory is believed to have been co-precipitated to the solid phase with other metals that will absorb neutrons. The ratio of the plutonium to co-precipitated metals is believed to always satisfy the criticality safety limits. However, plutonium-rich particles with low levels of neutron absorbers have been observed in micrographs of waste samples from tank SY-102. This tank is considered an anomaly as it contains plutonium-rich waste from Plutonium Finishing Plant (PFP) operations. However, a second tank, TX-118, has been identified as containing similar waste from PFP. The current WTP criticality safety evaluation report states, "Some HTF [Hanford tank farm] waste, such as that in the SY-102 tank, may not be disposed via WTP processing and is therefore outside of the CSER [criticality safety evaluation report] scope." However, DOE ORP indicated*

that both SY-102 and TX-118 wastes will be processed in WTP. Sodium diuranate ($Na_2U_2O_7$) and related uranium minerals have been observed in significant quantities throughout the Hanford tank farm. These plutonium- and uranium-bearing solids could accumulate in the bottom of tanks with underpowered pulse jet mixed vessels and exceed the current criticality safety limits.

Nonrepresentative Sampling -- If plutonium-bearing solids reside at or near the bottom of tanks with underpowered pulse jet mixers, sampling the vessel contents to an accuracy within the "5 percent margin allowed for the sample non-representativeness" is not feasible. In the scientific literature, MacTaggart and colleagues experimentally tested sampling techniques for a slurry with two primary particle sizes in a mechanically agitated vessel. Significant difficulty was noted in obtaining a representative sample. These difficulties were due to a number of factors, e.g., the variability of sample solids concentration with operating conditions, sample tube geometry, sample tube orientation with respect to the fluid flow, sample velocity, and particle size and concentration. Overall, they found, "It is practically impossible to obtain reliable measurements of local solids concentration by sample withdrawal from a mixed tank."

The difficulty of sampling from slurry tanks was identified by the third-party review as another potential design issue. BNI responded with a testing program for the sampling systems. However, the focus of this testing was on the Low-Activity Waste and High-Level Waste facilities, where conventional mechanical agitation is employed. No testing of the sampling system for pulse jet mixed vessels is planned. DOE-ORP indicated that the only testing of sampling accuracy performed with pulse jet mixed vessels is discussed in a report developed for the previous WTP design authority, British Nuclear Fuels Limited (BNFL). That report presents the results of reverse flow diverter sampler tests from vessels with pulse jet mixer agitation. The test results indicate that the BNFL system was not capable of achieving sampling accuracies within the "5 percent margin allowed for the sample non-representativeness" discussed in the current WTP criticality safety evaluation report, however, the WTP sampler design has changed and currently does not employ reverse flow diverters. The feed to the current sampling system is withdrawn directly from the transport pipeline. Consequently, the project would benefit from an integrated program to test the adequacy of the pulse jet mixers and pipeline transport system with sampling systems.

2.0 Background

The current Criticality Safety Evaluation Report (CSER) (*Preliminary Criticality Safety Report for the WTP* (24590-WTP-CSER-ENS-08-0001) provides a preliminary evaluation of the criticality safety of WTP processing of the fissionable material contained in Hanford Tank Farms (HTF) waste feed planned for transfer to WTP (HNF-SD-WM-SP-012, *Tank Farm Contractor Operation and Utilization Plan*).

The requirements for criticality safety are specified in the *Safety Requirements Document Volume II* (SRD), 24590-WTP-SRD-ESH-01-001-02, Section 3.3, *Criticality*, Safety Criteria 3.3-1 and 3.3-2. Specific SRD standards for criticality safety are American National Standards Institute (ANSI)/ American Nuclear Society (ANS)-8.1, *Nuclear Criticality Safety in Operations with Fissionable Material outside Reactors*, and ANSI/ANS-8.19, *Administrative Practices for Nuclear Criticality Safety.* These are driven by compliance DOE O 420.1B, *Facility Safety.* The CSER was prepared in accordance with DOE-STD-3007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities.*

For WTP, the preliminary CSER concludes that the operations will be safely maintained and subcritical under both normal and credible contingent conditions. Criticality Safety Limits (CSL) are derived to ensure that criticality will remain incredible. Because criticality is considered incredible, application of the Double Contingency Principle of ANS/ANSI-8.1 is not required.

Fissile plutonium, ^{239}Pu, is the primary criticality concern in the WTP operations. The CSER credits certain metal neutron absorbers (Fe, Ni, Mn and Cd) to ensure Pu is maintained subcritical in both solids and liquid phases. In addition, Pu concentration is credited in the liquid phase to maintain subcriticality. For fissile uranium (^{235}U and ^{233}U), ^{238}U is credited as an absorber to limit the fissile U reactivity. The CSER provides CSLs as a means to ensure the assumptions used in the analysis remain valid and that conditions in the WTP process remain subcritical.

Some of the assumptions and bases for criticality safety have not yet been verified or demonstrated. These are identified as action items in Appendix A of the CSER and include items such as sample non-representativeness uncertainty (A.1.2), feed vectors that may exceed a CSL (A.1.3), and the effects of gravity segregation (A.1.6).

2.1 Current Criticality Safety Approach

The WTP Criticality Safety Program (CSP) ensures the WTP operations involving fissile material will remain safely subcritical under all normal and credible abnormal conditions as required by ANSI/ANS 8.1, Section 4.1.2 "Process Analysis". The primary criticality safety concerns arise within the Pretreatment (PT) and High-Level Waste (HLW) facilities that are Hazard Category 2. Controls have been developed in the CSER, which selects the parameters that provide the most effective operational controls and derives safe limits for these parameters based on validated computational methods. The information in this section summarizes the criticality safety approach for WTP and is taken from a current draft of 24590-WTP-PSAR-ESH-01-002-01, *Preliminary Documented Safety Analysis to Support Construction Authorization; General Information*, Chapter 6.

2.1.1 Criticality Concerns

The criticality concerns during WTP processing arise because the feed streams have fissile nuclides, including ^{239}Pu, ^{235}U, and ^{233}U, although the concentrations of these nuclides are low. ^{239}Pu is the primary concern and is present because of transmuting ^{238}U during past operation of the Hanford reactors. Since the objective of reactor operations was to produce Pu, the separations processing recovered most of the Pu and only a small portion reached the waste that will be fed to WTP. The CSER provides an estimated 770 kg of Pu inventory in all the WTP feed batches. This Pu mass may be conservatively considered entirely to be the ^{239}Pu fissile nuclide and nearly all of it is held within the solid phase of the waste feed. Nonetheless, because the Pu inventory to be processed at WTP is held within about 8.5 million liters of waste solids that are to be delivered with about 350 million liters of waste liquid, the Pu concentrations within the waste feed are very low compared to concentrations where criticality concerns arise. The CSER addresses processes that could increase Pu concentrations especially those processes with potential for increasing Pu concentration relative to neutron absorptive materials concentrations.

The ^{235}U is in the WTP waste feed because it was the fuel for the Hanford reactors and produced the neutrons to transmute the ^{238}U. The ^{233}U in the waste is from two isolated reactor production campaigns that produced ^{233}U by transmuting thorium. The estimated total mass of the ^{235}U and ^{233}U fissile nuclides is less than four Metric Tons (MT) in the feed batches to be processed through WTP. The criticality concerns with these fissile masses are mitigated by large ^{238}U masses that provide neutron absorption and lower the effective fissile U enrichment to well below 1 % in the waste feed. Because of this low U enrichment in the waste feed, the ^{235}U and ^{233}U fissile nuclides are considered as lower criticality concerns than the ^{239}Pu, although the safety of the fissile U is still addressed in the CSER. In addition to the fissile ^{239}Pu, ^{235}U, and ^{233}U, the waste feed to WTP contains other fissile and fissionable nuclides that are of much lower criticality concern, as discussed in the CSER.

2.1.2 Criticality Controls

Criticality evaluations generally consider that nine basic parameters are available to provide criticality safety control: absorbers, enrichment (or isotopics), concentration (or density), volume, geometry, interaction, fissile mass, moderation, and reflection. Because large waste volumes are processed at WTP, the first three of these parameters, absorbers, enrichment, and concentration, are selected for the WTP criticality control scheme. These controls are derived from computer code calculations validated by comparison with critical experiments in order to provide sufficient subcritical margins consistent with ANSI/ANS-8 standards.

Specifically, of the four criticality safety controls in the current CSER:

- Two apply to Pu-to-absorber metal mass ratios;
- One applies to U enrichment; and
- One applies to Pu concentration.

Contingency analyses presented in the CSER are used to verify that the WTP criticality control scheme ensures safety for credible conditions of plant operation. The analyses include use of Hazard and Operability Analysis (HAZOP) to ensure that the credible contingent or upset conditions are identified. Controls are developed based on normal conditions and on unlikely, but credible (contingent) conditions.

Several metal absorbers, including iron (Fe), nickel (Ni), manganese (Mn), and cadmium (Cd), are credited for controlling the fissile Pu reactivity. Selection of these metal absorbers for crediting Pu subcriticality is based on various factors, including:

- Absorber abundance in the waste streams;
- Absorber effectiveness in reducing reactivity;
- Limited potentials for solid/liquid phase changes that might separate the Pu and metals, such as due to wash/leach, acid dissolution, evaporation, precipitation, PJM; and
- Chemical similarity and solubility such that the metals will remain with the Pu during credible upsets.

The Fe and Ni metals are conservatively credited as the absorbers for ensuring Pu subcriticality in the solids, while all four metals are credited in the liquids phase. The difference is because of wash/leach processing under caustic conditions that has the potential for Mn and Cd dissolution into the liquid phase. Criticality safety controls for Pu in WTP are implemented as safe Pu/metal loading limits for both the solid and liquid phases of the waste.

Criticality evaluation and hazards analysis address credible potentials within the WTP processing for separating the Pu from the credited metal absorbers. For example, wash/leach processing removes relatively more Fe and Ni than Pu to increase the Pu/metal loading in the high-level waste solids, but this effect is conservatively accounted for in implementation of the criticality safety control on Pu/metals loading.

Evaluation, performed as part of the CSER, concludes that sufficient absorber metals will remain with the Pu in both the solids and liquids phases to ensure subcriticality under all normal and credible upset conditions.

The non-fissile ^{238}U is credited for controlling reactivity and establishing the safety of the fissile ^{235}U and ^{233}U. The ^{238}U absorber is a natural choice for crediting control of ^{235}U and ^{233}U reactivity because these U nuclides have the same chemical forms in the waste and could only be segregated by isotopic separation processes not present in the WTP. Evaluation concludes that the criticality safety control, which is effectively a limit on the U enrichment parameter allowed for acceptance into the WTP, provides a robust control and ensures subcriticality for all normal and credible upset conditions.

Results of testing with Hanford tank waste and indicates that the solids phase of the waste holds more ^{239}Pu, ^{235}U, and ^{233}U fissile inventory than the liquid phase. Evaluation indicates no credible events would exceed subcritical limits for fissile concentrations and Pu/metal loadings in the liquid phase.

2.1.3 Double Contingency Principle

The Double Contingency Principle (DCP) requires that:

> Process designs incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible [ANSI/ANS-8.1-R2007].

From DOE O 420.1B, a fundamental requirement for the WTP Criticality Safety Program (CSP) is that fissile material operations will be evaluated and documented to demonstrate they will be subcritical under both normal and credible abnormal conditions. No single credible event or failure is to result in the potential for a criticality accident.

DOE-STD-3007-2007 states that if a criticality accident is not credible, then the risk of a criticality accident is lower than that provided by the application of the DCP. In cases where a mitigated (credited controls prevent the accident) criticality is not credible, then demonstrating fulfillment of the DCP in a CSER is not required.

Because the CSER concludes that a criticality accident is considered not credible, application of the DCP is not required for WTP.

3.0 Technical Approach to Resolve Issue

24590-WTP-RPT-ENS-10-002, *M3 Criticality Safety Test Requirements*, discuss the mixing issues (M3) and test objectives that directly support the criticality safety strategy and to identify M3 test requirements necessary to support criticality safety analysis.

These test objectives directly support resolution of the two criticality safety issues identified in the Board letter. The first issue, gravity segregation, is related to tank mixing and retrieval. The second is nonrepresentative sampling. These two issues will be addressed by the M3 resolution program as follows:

3.1 Tank Mixing and Retrieval (Gravity Segregation)

3.1.1 Issue

There are two criticality concerns related to PJM tank mixing that must be addressed to ensure assumptions in the CSER remain valid. The first is a postulated phenomenon that the differential settling rates between PJM pulses will allow dense PuO_2 particles that have no coprecipitated metal absorbers to concentrate in the solids layer on the bottom of the tank. The second concern is that inadequate mixing could allow an unretrievable layer of solids to form on the bottom of the tank, or a buildup of material in the tank heel could develop over time, with a potentially unacceptable concentration of fissile material.

3.1.2 Strategy for Resolution

M3 testing must demonstrate that there is no unacceptable accumulation or concentration of fissile material in the mixing vessel over the life of the project; there is no unacceptable change in the particle size distribution as the material is removed from the vessel. A batch is a single transfer of waste into the WTP feed receipt vessel from the tank farm that complies with all WTP contract requirements. Criteria for this testing is specified in the *Plan for M3 Platform Testing,* 24590-PTF-PL-PET-10-00001, Rev 0. Vessel test results will be incorporated into the analytical computer models used for criticality safety analysis, with the CSER to be updated accordingly. For example, should vessel mixing test results show that accumulations or concentration of fissile particulate in vessels occurs, then this will be modeled in the Monte Carlo N-Particle (MCNP) software to ensure that the concentrations are safe. For a single batch, analysis will be performed to demonstrate that formation of a critical configuration is not credible.

3.2 Sampling

3.2.1 Issue

24590-WTP-3YD-ASX-00001, *System Description for the Autosampling System (ASX)*, describes the autosampling (ASX) system. The ASX automates the sampling of the receipt vessel and other vessels to minimize sampling times, potential for human failures, and personnel doses. Samples are withdrawn from the re-circulating sample line in each vessel by an ISOLOK sampler. Once the samples are drawn, the ASX system transports them along pneumatic tubes to the sample receipt locations in the hot cells or rad labs of the Laboratory Building. The system typically uses sample volumes of ~15 mL for the HLW and PT facility samples.

Section 3.7 of 24590-WTP-RPT-ENG-10-001, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy*, discusses that for PJM mixed vessels sending a sample to the ASX system, solids suspension may not be uniform at the pump suction. For PT, the ASX autosamplers are located in shielded units on the 56 ft. elevation. The pumps are located in the main hot cell at the 0 ft. elevation. The distance between the pump and autosampler is estimated to be more than 100 ft. The pump lines have all been designed considering the critical velocity of the particles in the fluid, to ensure no settling of the observed bounding particle in the lines. Prior to sampling, the pump is run in recirculation through the sample loop line to clear the line of flush material.

The ISOLOCK sampler injects 5 mL samples through separate strokes of a plunger into sample bottles. Typical samples are taken in three separate strokes for a volume of 15 mL. Based upon the current routine samples which require solid analysis from PJM mixed vessels, a sample volume of approximately 100 mL is collected by filling eight sample bottles. The sampler sequence is not timed to the PJM cycle, so the sample will be randomly collected between the PJM drive and refill cycles. For weight percent solids and viscosity in the sample, the PJM cycles may cause the results to vary from the average for a given vessel. Additionally, with PJM mixed vessels, the concentration of faster settling solids may not be uniform in the vessel. This weight percent solid uncertainty would mainly affect HLP-22. To characterize this sampling issue in current planned M3 testing for HLP-22 with the multi-particle simulant, samples will be taken from the M3 test platform sampling loop. Sample results and data from the test loop Coriolis meter will be used to better characterize the time dependent behavior of solids in the sampling loop. This includes data on the peak and average solids concentration during the PJM cycles.

The CSER identifies four CSLs, each requiring sampling to verify waste parameters are adequate to ensure criticality remains incredible. The current CSLs require sampling of waste in either the feed receipt vessels or, in some cases, in subsequent vessels in the PT process. The stated uncertainty value of 5% for how representative the sample is of tank contents may not be achievable with the current sampling and vessel mixing design. The PJM tank mixing system does not provide a continuous homogeneous waste mix with respect to solids that settle rapidly between pulses (for criticality concerns, most notably large PuO_2 particles), making it difficult to obtain representative samples for solids with the current ASX. The ability of the ASX itself to provide representative samples may also exceed the 5% uncertainty assumption.

3.2.2 Strategy for Resolution

There are two potential options for resolving the issues associated with the current PJM mixed feed receipt vessel sampling system capability. A new sampling system could be designed and implemented for the PJM mixed feed receipt vessels (HLP-22 and FRP-02 A/B/C/D) to provide for acceptable sample representativeness. Alternatively, sampling to ensure criticality assumptions remain valid could be included as part of WTP feed prequalification as described in 24590-WTP-PL-OP-07-0001, *Plan for WTP Feed Prequalification.*

Redesigning the Sampling System for PJM Mixed Vessels

To use a sample from the feed receipt vessels as a basis for ensuring waste feed meets the requirements for criticality safety, a new or revised design that is able to provide a statistically valid, representative sample of the solids fraction will have to be developed and implemented. For example, a system that draws a continuous sample during PJM vessel mixing that would ensure rapidly settling slurry components are included as part of the sample volume could be devised and would provide an adequate sampling basis to meet criticality safety requirements. Such a system would be a departure from the current ASX design and would likely also require modification or expansion of the laboratory sample analysis capabilities of the current WTP design. If, as discussed below in 3.2.2, vessel test criteria for heavy particle accumulation and particle size distribution changes in the PJM mixed vessels is met, the vessel recirculation line will provide a continuous stream that could be fitted with a new sampling system to meet criticality safety requirements.

Sample for Criticality as Part of WTP Feed Pre-qualification

Sampling at the tank farms is currently required in the WTP contract, RPP-WTP Interface Control Document (24590-WTP-ICD-MG-01-019, *ICD 19 - Interface Control Document for Waste Feed*), and the Integrated Sampling and Analysis Requirements Document (ISARD) (24590-WTP-PL-PR-04-0001). Because sampling in the WTP feed receipt vessels is problematic, the sample location for CSLs to ensure waste acceptability prior to transfer to WTP could be shifted to the tank farm staging tanks (for example, sample point Tank Farm 1b as identified in the Integrated Sampling and Analysis Requirements Document (ISARD)). Sampling at the tank farms would have the following advantages:

- Larger samples are possible (200 ml vs. 15 ml samples);
- Potentially better mixing (mechanical mixing that could potentially provide a more representative sample of the solids compared to the current sampling system design for the WTP receipt vessels); and
- Tank farm sampling would provide more lead time to address sample results that are not within the CSL with minimal impact on WTP operations.

However, as discussed in the Safety Evaluation Report (SER) (CCN 204621) for the current CSER, sample homogeneity and representativeness of tank farm staging tanks will have to be demonstrated. This will require establishing criteria that:

- Ensures the tank farms sample is representative and is effective in identifying large particles of concern such as PuO_2;
- Specifies tank farms staging tank mixing requirements;

- Determines sampling and analysis requirements, including any analytical or laboratory scale simulation requirements necessary to account for the WTP process; and
- Provides a process to ensure that if waste does not meet CSL requirements, it will not be transferred from tank farms to WTP receipt vessels without first being modified to meet requirements (blending, absorber addition, etc.).

The CSER would also have to be revised to account for sampling at tank farm waste staging tanks instead of WTP receipt tanks if this sampling strategy were adopted. This would require updates to sampling uncertainties and evaluation of contingencies to show that the process cannot alter Pu/metal ratio beyond analyzed limits. Other samples specified in the CSER, such as those for liquid prior to transfer from permeate tanks would have to be revised accordingly.

Requirements for the tank farms are defined in Section C, Statement of Work, of the *Tank Operations Contract, Contract No. DE-AC27-08RV14800, Modification No. 042.* HTF sampling requirements are being defined as part of interface development for tank waste feed staging requirements for WTP to show compliance with the existing waste acceptance criteria and authorization basis requirements. This output from this development is documented in *ICD 19 - Interface Control Document for Waste Feed,* 24590-WTP-ICD-MG-01-019, Rev 4. Ensuring this sampling also meets CSER requirements will be included in those efforts.

The feed vector from the tank farms will continue to evolve over time. The tank farms in its modeling for WTP feed can check for and identify any batches that might pose a criticality concern within the WTP. Any future changes to the WTP feed vector will be evaluated to assure that batches sent to WTP are within the current CSLs for the WTP.

3.3 Test Requirements to Support Criticality Safety

Vessel testing must demonstrate the following to support criticality safety and provide input to future updates to the CSER.

- Solids accumulation is prevented such that solids will not accumulate from batch to batch, which will demonstrate that a sediment layer or buildup of PuO_2 particles in the tank heel cannot occur over time;
- The bounding PuO_2 particle is defined and represented in the stimulant;
- The design basis PuO_2 particle is mobilized and removed from the vessel; and
- M3 testing will also provide data from the test sample loop to evaluate the representativeness of the recirculation line contents with respect to vessel contents.

M3 testing uses simulant to represent PuO_2 particles. Simulant specifications to represent the observed bounding particles are defined in 24590-WTP-RPT-PET-10-008, *Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22 and UFP-01 Vessels for EFRT M3 Mixing Studies.* The observed bounding particle is defined in CCN-211814, *Evaluation of Plutonium Settling in Pretreatment Vessels.*

Although outside the scope of M3 testing, it must also be demonstrated that the observed bounding particles are transported through the WTP systems and do not accumulate in transfer piping or other WTP components. This was achieved by the M-1 test program (CCN: 186331). Transport of particles through WTP will be further demonstrated in integrated tests planned to demonstrate mixing, transfer, sampling, and PJM control functions. This testing will be part of the Phase 2 testing described in the *Integrated Pulse Jet Mizxed Vessel Design and Control Strategy.* Additionally, WTP will install heel removal capability with enhanced transfer capability. These have been shown conceptually at higher velocities and positive displacement pumps.

4.0 Summary

The Board letter of January 6, 2010, stated a concern with respect to dense particles rich in plutonium and uranium. Specifically, such particles will settle preferentially in WTP tanks and could form a sediment layer with sufficient fissile material to make a criticality accident credible. The letter also stated concern that current mixing and sampling capability may not be sufficient to support any CSL that depends upon sampling of a WTP tank to ensure criticality is not credible.

The current CSER provides a preliminary evaluation of the criticality safety of WTP processing of the fissionable material contained in Hanford Tank Farms (HTF) waste feed planned for transfer to WTP. Fissile plutonium, ^{239}Pu, is the primary criticality concern in the WTP operations. The CSER provides CSLs as a means to ensure the assumptions used in the analysis remain valid and that conditions in the WTP process remain subcritical.

24590-WTP-RPT-ENS-10-002, *M3 Criticality Safety Test Requirements*, discuss the M3 mixing issues and test objectives that directly support the criticality safety strategy and to identify M3 test requirements necessary to support criticality safety analysis. These test objectives directly support resolution of the two criticality safety issued identified in the Board letter. The first issue, gravity segregation, is related to tank mixing and retrieval. The second is nonrepresentative sampling. M3 testing must demonstrate that there is no unacceptable accumulation or concentration of fissile material in the mixing vessel over the life of the project. Issues associated with sampling may be resolved through design changes to the current sampling process, or ensuring criticality assumptions remain valid as part of WTP pre-qualification.

4.0 References

1. 24590-WTP-ICD-MG-01-019, *ICD 19 - Interface Control Document for Waste Feed.*
2. 24590-WTP-CSER-ENS-08-0001, *Preliminary Criticality Safety Evaluation Report for the WTP.*
3. 24590-WTP-RPT-ENG-10-001, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy*
4. 24590-WTP-PL-OP-07-0001, *Plan for WTP Feed Pre-qualification.*
5. 24590-WTP-PL-PR-04-0001, *Integrated Sampling and Analysis Requirements Document (ISARD).*
6. 24590-WTP-PSAR-ESH-01-002-01, *Preliminary Documented Safety Analysis to Support Construction Authorization; General Information.*
7. 24590-WTP-RPT-PET-10-008, *Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22 and UFP-01 Vessels for EFRT M3 Mixing Studies (DRAFT).*
8. ANSI/ANS-8.1, *Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors.*
9. ANSI/ANS-8.19, *Administrative Practices for Nuclear Criticality Safety.*
10. CCN 204621 (09-NSD-034), Letter, S. J. Olinger to T. C. Feigenbaum, *Conditional Approval of Bechtel National, Inc. (BNI) - 24590-WTP-RPT-NS-01-001, Rev. 6, "Preliminary Criticality Safety Evaluation Report (CSER) for the Waste Treatment and Mobilization Plant."*
11. CCN 211814, *Evaluation of Plutonium Settling in Pretreatment Vessels* DOE O 420.1B, *Facility Safety.*
12. DOE-STD-3007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities.*
13. HNF-SD-WM-SP-012, *Tank Farm Contractor Operation and Utilization Plan.*
14. Contract No. DE-AC27-08RV14800, *Tank Operations Contract, Modification No. 042*
15. CCN: 186331, Technology Steering Group - Issue Closure Record - EFRT Issue M1 - Plugging in Process Piping

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Technical Discussion: Prevention of Flammable Gas Condition in Vessel Headspace

1.0 Review of Items Discussed in the January 6, 2010 Letter

The flammable gas item related to mixing effectiveness that was highlighted in the January 6, 2010, letter provided by the Board was stated as follows:

> *"The development of a sediment layer on the bottom of the tanks may reduce the effectiveness of the pulse jet mixing systems below that assumed in the design. As a result, an initially thin sediment layer could grow sufficiently to retain significant quantities of flammable gas. The existence of a deep sediment layer would not be recognized by plant operators because there is no instrumentation that indicates the quantity of sediment. Gas release events from this sediment layer could exceed the lower flammability limit in the vessel headspace and result in an explosion."*

The Enclosure to the letter, dated November 11, 2009, goes on to reiterate with respect to flammable gas control that if mixing has a reduction in effectiveness there is a potential for solids to settle and accumulate over time during normal operations. The Enclosure goes on to indicate the following:

2.0 Background on Gas Generation and Release Evaluations

2.1 Hydrogen Generation Rate Determination

In 2004 the Hanford Tank Waste Treatment and Immobilization Plant (WTP) Project developed the WTP hydrogen generation rate correlation (24590-WTP-RPT-RT-04-0002, Rev 0), which adapted the Hanford tank farm's correlation described in the reference, Hu 2002, to establish hydrogen generation rates for WTP process wastes. The WTP correlation has since been applied to the determination of vessel specific hydrogen generation rates and times to reach the lower flammability limit in the calculations 24590-WTP-M4C-V11T-00004, Rev C and more recently 24590-WT-M4C-V11T-00011, Rev B. In general, these calculations evaluate vessel contents, where solids were assumed to be suspended and distributed throughout the waste volume. The calculations provided hydrogen generation rates used to establish design air purge flow rates applicable to normal and off-normal conditions in the vessels.

2.2 Assessment of Gas Generation, Retention, and Release When Mixers are not Operating

To support the effort to finalize the vessel mixing requirements, evaluations were initiated in 2007 to assess mixing design and approach applicable to normal operations and to review the conditions where mixers are not operational following a design basis event (24590-PTF-TSP-RT-06-007, Rev 0). A portion of the evaluation focused on understanding the slurry settling, mobilization, and retention behavior for wastes in pulse-jet mixed vessels [24590-QL-HC9-WA49-00001-03-00025, Rev 00A (Gauglitz 2009)]. The report, *Investigation of Gas Retention in WTP PJM Mixed Newtonian Vessels* (24590-WTP-RPT-M-09-003, Rev. 0) issued in April 2009 provided review of the gas generation, retention, and release potential in settled solids layers that could form without mixing in Newtonian pulse-jet mixer vessels.

In September 2009 an assessment of gas retention and release in a settled solids layers was completed that considered the time it would take for sufficient gas to be generated to exceed the lower flammability limit in the vessel headspace assuming all of that gas was retained in the settled solids layer and then released either spontaneously or through mixing (24590-WTP-RPT-PET-09-005, Rev 0). A draft of this report was reviewed with the Board staff in early September 2009. The assessment report provided input to mixing controls described in the Preliminary Documented Safety Analysis Addendum (24590-WTP-PSARA-ENS-09-0001, Rev 1) which was approved by DOE-ORP in October 2009. The gas retention and release behavior for conditions following a design basis event have been and continue to be evaluated to confirm design and operating capability. The project is in the process of updating the assessment of the settled solids layer retention and release (24590-WTP-RPT-PET-09-005*under development*) and the hydrogen generation rate calculation (24590-WTP-M4C-V11T-00011*under development*) to address DOE-ORP comments. These will be complete in mid 2010.

2.3 Evaluation to Determine How Much Mixing is Needed Following a Design Basis Event

In December 2009 efforts were initiated to identify how much gas needs to be released through mixing following a design basis event to ensure that the lower flammability limit in the vessel headspace is not exceeded. The results of the evaluation are included in the report, *M3 – Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels* (24590-WTP-RPT-PET-10-007, Rev 0). The report includes an overview of the phenomenology of how mixing releases retained gases for both normal and off-normal conditions and how much mixing will be needed for vessels with times to the lower flammability limit that are less than 1000 hours.

3.0 Technical Approach

3.1 Solids Accumulation during Normal Operations

In the evaluation of gas generation and retention, it is assumed there is no accumulation of solids during normal operations (24590-WTP-RPT-PET-10-007, Rev 0), as one of the principle requirements of closure of the M3 PJM mixing issue, is to assure ability to clear solids. The vessel mixing requirements include the requirement to prevent the accumulation of solids in vessels that contain settling solids. Testing will confirm that this requirement is achieved. This is part of the test plan 24590-PTF-PL-PET-10-0001, Rev 0. In vessels where there are settling solids, there may be some stratification of heavier particles in the vessels. However, these solids are mobilized as the mixers operate so that gases generated in the process waste are released to the headspace, and swept away by the headspace purge throughout normal operations.

The January 6, 2010, Board letter indicates, "*The existence of a deep sediment layer would not be recognized by the plant operators.*" However, density detection is available to show potential increases or decreases in density over time in the vessel, thus providing indication to the operator of formation of a sediment layer. Pump amperage variation during transfers is also available to the operator to indicate changes in slurry properties (*how hard the pump is working*) associated with the formation of a settled solids layer.

3.2 Mixing to Release Gas Following a Design Basis Event

The gas retention and release behavior that could lead to exceeding the lower flammability limit is associated with quiescent, undisturbed sediments fully covered by undisturbed liquid. In these conditions, gases generated have been assumed to be retained until the sediment is disturbed or the quantity of gas is sufficient to lift up portions of the sediment causing gas to rise up out of the sediment layer. This is not a condition that applies to normal operating periods when the pulse-jet mixers are operated. The evaluation of the quiescent conditions where no mixing was occurring was described in the document, *Assessment of Time to LFL and Buoyancy Ratio for Select Newtonian Vessels*, (24590-WTP-RPT-PET-09-005, Rev 0) and how much mixing was needed is described in the report, *M3 – Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels* (24590-WTP-RPT-PET-10-007, Rev 0).

For vessels where a settled solids layer could accumulate gas if mixing were lost during a design basis event, an Important to Safety (ITS) mixing system is included in the design (powered by emergency diesel generators) to ensure that mixing is retained following the event. Important-to-Safety bubblers are also present in several vessels that will facilitate gas release. Testing is being performed as part of the M3 test plan to demonstrate that the amount of solids mobilization needed to release gases that could have been generated and retained in an undisturbed layer of settled solids is achieved through periodic mixing after a design basis event (24590-WTP-RPT-PET-10-007, Rev 0).

The November 11, 2009, Enclosure to the Board letter states, "*During off-normal events, DOE-ORP is planning to cease pulse jet mixing in Newtonian vessels.*" However, pulse-jet mixing does not cease during off-normal events. For vessels where the time to the lower flammability limit is less than 1000 hours, periodic PJM mixing is continued at frequencies and durations to release gas. Additionally, the ability to mix is maintained for selected vessels with a time to the lower flammability limit that is greater than 1000 hours, as warranted by the consequences of an explosion. These controls are described in 24590-WTP-PSARA-ENS-09-0001, Rev 1 which was approved by DOE-ORP in October 2009.

The letter also states, "*DOE-ORP has not considered the formation of sediment layers in vessels with pulse jet mixers as an important aspect of the management of flammable gases in vessel headspaces.*" However, as described in Section 2 (above), there has been an on-going evaluation on the formation of a settled solids layer and potential for gas generation, retention, and release for Newtonian vessels. The evaluations have included operating conditions such as those at maximum solids loading and maximum overflow volumes for the vessels, Assessment of Time to LFL and Buoyancy Ratio for Select Newtonian Vessels, (24590-WTP-RPT-PET-09-005, Rev 0; September 14, 2009).

3.3 Work in Progress Related to Flammable Gas

The following work is underway to evaluate and demonstrate mixing capability to prevent retention of flammable gas in the vessels:

- Updating the hydrogen generation rate calculation (24590-M4C-V11T-00011, Rev C under development), which accounts for heat load and thermal profiles in the settled solids layer that is assumed to form without mixing. The updated calculation is in project review.
- Providing the amount of sediment that needs to be moved to release sufficient gas (if it were all retained) to prevent the vessel headspace from exceeding the lower flammability limit following a design basis event. The report, *M3 – Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels* (24590-WTP-RPT-PET-10-007, Rev 0), will be updated when the revised hydrogen generation calculation is available to ensure the most recent gas generation results are applied.
- Testing planned to demonstrate solids mobilization that will release gas (24590-PTF-PL-PET-10-0001, Rev 0) was completed successfully.

- Quantifying gas generation and potential retention as the solids settle after the mixers stop due to a design basis event. WTP and the Pacific Northwest National Laboratory (PNNL) personnel are working to provide an analysis of hindered settling on potential hydrogen retention (24590-WTP-RPT-10-012, Rev 0 under development).

4.0 Summary

Pulse-jet mixers normally operate continuously. During periods where the mixers are operating, the vessel contents will be disturbed. The solids will be shifting and moving during the operation of the mixers, preventing the retention of flammable gas in quantities large enough to exceed 25% of the lower flammability limit in the vessel headspace. Complete suspension of solids is not necessary to mitigate the retention of flammable gases.

The assumed development of a sediment layer during normal operations is prevented by achieving the vessel mixing requirements associated with limiting accumulation of solids. These include assuring no stagnant areas on the vessel bottom during the PJM drive, assuring large dense particles are lifted to the pump suction, and assuring that the solids concentration and particle size distribution (PSD) in the heel (at end of pump down) are less than or equal to starting the concentration and PSD. The M3 program will confirm that these requirements are achieved.

DOE-ORP has given significant consideration to the potential for flammable gas to be retained and released from a settled solids layer that could form following a design basis event where routine operation of the mixers may not be available. These evaluations establish a basis for mixing controls needed for conditions following a design basis event as outlined in the preliminary document safety analysis addendum (24590-WTP-PSARA-ENS-09-0001, Rev 1). The gas retention and release behavior for conditions following a design basis event have been and continue to be evaluated to confirm design and operating capability. The WTP hydrogen generation rate calculation (24590-WTP-M4C-V11T-00011, Rev C *under development*) is being updated to include the settled solids layer analysis of gas generation and retention in the formal calculation.

A review and explanation of how mixing allows retained gases to be released and a determination of how much sediment needs to be mobilized to release gas if solids settle when the mixers are not operating is included in the report, *M3 – Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels* (24590-WTP-RPT-PET-10-007, Rev 0). This report will be revised once the hydrogen generation rate calculation that includes the analysis of the settled solids layer is complete, expected in June 2010. The test approach for the demonstration of the sediment mobilization needed to release gas and keep the vessel headspace from reaching the lower flammability limit is in progress.

5.0 References

1. 24590-WTP-RPT-PET-10-007, Rev 0, *M3 – Gas Release in Newtonian Pulse-Jet Mixer (PJM) Mixed Vessels.*
2. 24590-WTP-RPT-PET-09-005, Rev 0, *Assessment of Time to LFL and Buoyancy Ratio for Select Newtonian Vessels.*
3. 24590-WTP-M4C-V11T-00004, Rev C, *Calculation of Hydrogen Generation Rates and Times to Lower Flammability Limit for WTP.*
4. 24590-WTP-M4C-V11T-00011, Rev B, *Calculation of Hydrogen Generations Rates and Times to Lower Flammability Limit to Support Seismic and Severity Level Assessments.*
5. 24590-WTP-PSARA-ENS-09-0001, Rev 1, *Preliminary Documented Safety Analysis - Control Strategy Changes for the PT Facility*
6. 24590-WTP-RPT-RT-04-0002, Rev 0, *Modifying the Hu Correlation to Predict Hydrogen Formation in the Hanford Waste Treatment and Immobilization Plant.*
7. 24590-WTP-RPT-M-09-003, Rev 0, *Investigation of Gas Retention in WTP PJM Mixed Newtonian Vessels.*
8. 24590-QL-HC9-WA49-00001-03-00025, Rev 00A, *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels* (WTP-RPT-177, Rev 0 – Gauglitz, et al., 2009).
9. Hu, T.A., 2002. *Empirical Rate Equation Model and Rate Calculation of Hydrogen Generation Rates for Hanford Waste Tanks*, RPP-3851, Rev 0B. CH2M Hill Hanford Group, Inc. Richland, WA USA.

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ENCLOSURE 4

Technical Discussion: Material Component Failures (Bubbler & PJM Control)

1.0 Defense Nuclear Facilities Safety Board (Board) Issue and Related Comments

In its recent letter to the Department of Energy (DOE) Office of River Protection (ORP) dated January 6, 2010, the Board expressed concern about the potential for PJM control systems to be affected by development of a deep sludge layer causing overblow induced material failures. The full text of this issue follows:

The presence of a deep sediment layer may also have a detrimental effect on the performance of the bubbler systems used to measure tank level and average density in the vessels. The tank level and average density are inputs to the calculation of the drive time of the pulse jet mixers, which is relied upon to prevent overblows. The cumulative effect of many overblows could result in the material failure of components internal to process vessels located in black cells.

Additional background about this concern is contained in the text of the staff report enclosed to the Board letter.

2.0 Background

The Board's concern is the result of several postulated conditions applied in series to hypothesize an adverse safety outcome. These postulates are:

- A sediment layer will exist in WTP vessels;
- The sediment layer will adversely effect measurement of vessel slurry level and average density;
- The instrumentation effects will increase the frequency of PJM overblow events beyond those allowed for in the design;
- The increased overblows will lead to failure of structural components in black cell vessels; and
- The reliability of the PJM control system has not, and will not be demonstrated through testing.

The discussion of the technical approach to resolution of this safety concern is organized around these postulates.

3.0 Technical Approach to Resolve Issues

3.1 A Deep Sediment Layer will be Present in a Vessel

The mixing requirements include a requirement to limit the accumulation in the vessel such that the wt% solids in the vessel at the end of batch (heel level) is less than or equal to the starting concentration. This will ensure that a deep sediment layer is not allowed to build up during normal operations. During normal operations, it is possible that a thin layer of sediment could be present due to rapid settling of the particles during the PJM refill cycle. The depth of this potential layer will be evaluated and included in the design of the bubbler heights. Post Design Basis event, a deeper sediment layer could develop. The depth of this layer will be dependent on the time between mixing of the vessels and is primarily focused on the HLP-22, UFP-1 A/B and FEP-17 vessels that are currently planned to be mixed intermittently with ITS air supplied in a post-design basis event. The timing for the operation of the PJMs post-design basis event in these vessels will be evaluated to determine a maximum sediment depth, which will then be incorporated in the evaluation of the control of the PJMs post design basis event.

3.2 Sediment Layer Will Affect Performance of Bubbler System

The effect of a settling sediment layer is being evaluated in the design of the PJM control system and bubbler system. Testing to date with non-Newtonian simulants has shown that the PJMs can re-suspend the solids; however, those tests did not include fast settling solids and simulants that more closely represent those that may be experienced in WTP. Full scale testing of PJMs, PJM controls, prototypic bubblers and fast settling solids are needed to assure the details of the design will support mixing. As reported in CCN 208253 (Response to the Board Pretreatment Engineering Platform questions) there are other issues that will be included in the planned full scale test, such as, acceptable fluid velocities from pump suction piping and increased power of PJM's effect on bubbler performance. CCN 208253, *An Analysis of Bubbler Level and Density Performance at the Pretreatment Engineering Platform (PEP),* analyzed the performance of level and density bubblers in the PEP. The bubbler level and density measurements were repeatable, consistent and provided acceptable control signals for control of the vessels, spargers and PJMs with the exception of when the slurry pump was functioning on vessel T02A.

In a meeting on September 3, 2009, with the Board staff, the issue of PJM controls and startup of mixing to re-suspending solids was discussed. The following is the written response to the Board question supplied during the meeting with the re-suspension subject highlighted:

i) *Discuss, in detail, modification of the control algorithm to reduce the potential for an overblow event. Specifically include a detailed discussion of the incorporation of the Stroke Timing Experiment (System Description for Pulse Jet Mixer and Sparging Mixer Subsystems, 24590-WPT-3YD-50-00003 Rev B, Appendix F).*

The controls for the PJM operation has been designed to minimize the possibility of an overblow.

During all operations of the PJMs there are diagnostics performed on the controls to assure all components are functioning properly. The opening and closing of the drive and suction valves are checked by the transmitters below these valves. At the same time the regulator pressures are verified. Should a transmitter drift or be inoperable it is checked against the regulator set pressure. If a diagnostic check fails the PJM is turned off and reported to the operators. This assures that each component is operating within appropriate control bands.

In all PJM operations the drive stroke will only be initiated if a charge vessel full (CVF) signal is received for a specific PJM. To minimize overblows it is important to know that the charge vessel is full since the drive stroke time assumes a full charge vessel.

PJM operation begins with a startup mode, flutter, to re-suspend solids which will allow the level and density instruments to read correctly. The flutter mode will be done in a manner which will not challenge an overblow event. Flutter mode will be done, starting with charge vessel full (CVF) signal in each PJM with a reduced stroke time, approximately 50%. Therefore, the charge vessel will be approximately half full when the drive phase is terminated during flutter mode.

Next, based on level and density information, and the Bernoulli-equation model to determine a suction and drive time the PJMs will be operated in Scout Mode. Scout mode is the operation of each PJM individually to test the acceptability of the drive time to not cause an overblow. The goal of the scout mode is to determine that the drive time is appropriate and if an overblow occurs that only a single overblow results. Since an overblow should not occur based on the algorithm and control strategy, the PJMs are stopped if an

> *overblow is detected. The cause of the overblow will be investigated before PJM operation is resumed. After each PJM is operated successfully in scout mode normal synchronous PJM operation commences.*
>
> *Synchronous PJM operation is the normal mixing mode. Stroke times are based on the level and density compensation. Mixing will continue until mixing is no longer deemed necessary in accordance with mixing guidelines in the PJM system description or when level and density have changed significantly enough to warrant scout mode operation to assure correct drive times are being used.*
>
> *To assure the measured level and density are as reliable as possible the three sets of level and density instruments from the vessel are compared electronically in the normal control system. The signals will be compared to determine the best information for the control algorithm. This part of the control strategy minimized the potential of bad instrument performance from challenging an overblow. If the level density channels differ by a certain amount an alarm will alert the operators to the condition.*

The approach above indicates that normal mixing will be synchronous PJM operation. WTP is evaluating sequential firing of PJMs in current testing, as an alternate operating mode. This control strategy would further reduce the potential for multiple overblows. The approach will be expanded to include the results of the additional testing to deal with the issue of fast settling solids and the sediment layer. In addition, the location of the bubblers have been raised in some vessels to decrease the likelihood of being covered by the sediment layer.

The experience to date in testing PJMs with the prototypical control system in building 336 indicates the control system will be highly reliable. In the latest PNNL testing, WTP-RPT-179, the PJMs were cycled over 9000 times, and the PJM and control system operation were predictable and repeatable. There were no inadvertent overblows.

As mentioned earlier, to assure the measured level and density are as reliable as possible the three sets of level and density instruments from the vessel are compared electronically in the normal control system. This feature provides added assurance that a process effect on one of the level- density bubbler tubes will be detected and alert the operator to the condition. The additional planned testing will be used to locate bubblers in as advantageous a position as possible to minimize process effects. Startup testing will further validate that the performance is acceptable. These aspects of the control system design and plans should minimize bubbler uncertainties leading to inadvertent overblows.

All the vessels where PJM operation is classified as safety-class or safety-significant have three sets of level and density indication and the above strategy will be incorporated. The vessels where PJM operation is classified as non-safety have one set of level and density indication and the above strategy cannot be employed, however, the scout mode will be used to minimize the overblows that could be caused by level and density uncertainty.

The Diagnostics of the control system are designed to prevent inadvertent PJM operation causing an overblow. The table below illustrates the control component failures that would be detected by the diagnostics. There are only two failures that would result in an overblow. These are the failure of the drive valve to stick open or the drive solenoid valve to stick open. The drive valve reliability is in the millions of cycles. Reliability of the drive valves was previously reported to the Board in response to WTP-09-099-26. Solenoid valves have a Mean Time to Failure (MTTF) rate of 81 years according to ISA Technical Report TR 84.00.01-2002, table 5.1. This MTTF is for safety system applications where the demand is less frequent than that for PJM operation. However, it is an indication of a highly reliable component. In the PNNL testing at building 336, WTP-RPT-179, there were eight solenoid valves operating the four PJMs without failure in over 9000 cycles. The solenoid vendor has not been selected for WTP. When the vendor is selected, reliability data is to be supplied as part of the vendors submittals. The present information available to WTP is that both the drive valve and solenoid valves are highly reliable and should not contributed significantly to PJM overblows.

PJM Control Component Failures Causing Overblows

Tag Number	Component Description	Fail high / open can cause overblow	Fail low / closed can cause overblow	Failure Analysis
PCV 1234A	Suction pressure regulator	No	No	Diagnostics stop PJM shortly after suction valve opens
PCV 1234B	Drive pressure regulator	No	No	Diagnostics stop PJM shortly after drive valve opens
YV 1234A	Suction valve	No	No	Diagnostics stop PJM on failure and suction phase can not result in overblow.
YV 1234C	Drive valve	**Yes**	No	Failure of drive valve remaining open can cause overblow. Failure of drive valve to open will stop PJM.
YY 1234D	Flush valve	No	No	Valve remaining closed does not result in overblow. Valve remaining open would result in continued flushing but no overblow.
YY 1234A	Suction solenoid valve select PPJ/PCJ	No	No	Valve is normally energized by PPJ open to provide PCJ control. Failure to remain open removes control from PCJ and diagnostics will stop PJM .
YY 1234C	Drive solenoid valve select PPJ/PCJ	No	No	Valve is normally energized by PPJ open to provide PCJ control. Failure to remain open removes control from PCJ and diagnostics will stop PJM .
YY 1234E	Suction Solenoid valve	No	No	Diagnostics stop PJM on failure and suction phase can not result in overblow.
YY 1234G	Drive Solenoid valve	**Yes**	No	Open failure causes drive valve to remaining open resulting in overblow. Failure of valve to open will be stopped by diagnostics.
YY1234D	Flush solenoid valve	No	No	Valve remaining closed does not result in overblow. Valve remaining open would result in continued flushing but no overblow.
PT 1234A	Suction pressure transmitter	No	No	Diagnostics stop PJM on either failure.
PT 1234B	Drive pressure transmitter	No	No	Diagnostics stop PJM on either failure.
PT 1234E	Flush line pressure transmitter	No	No	Diagnostics stop PJM on either failure.

3.3 Effect of Performance of Bubbler System will be Detrimental to Calculation of PJM Drive Time

The level and density bubbler systems are used in the PJM controls to predict the suction time and determine the drive time during mixing after the startup phase to re-suspend the sediment layer. Testing reported in WTP-RPT-146, section 12.0 by PNNL indicate that the density and level effect on PJM suction and drive time change these times by 21% to 27%. In operating the PJM the majority of the suction and drive time are determined by the time to move the vessel liquid through the PJM nozzle. The density and level adjustments to these times are a smaller factor. Therefore, high accuracy is not necessary to determine the amount to adjust these times. As the PJM control design is completed the specific change in the suction and drive time for each vessel as a result of level and density will need to be determined to evaluate accuracy needed in these measurements to minimize overblows.

This issue was also discussed during the September 3, 2009, meeting with the Board. The following is the written response to the Board question supplied during the meeting about this subject:

> *i) Discuss the progress made in analysis of the time to overblow. Specifically, which precursor parameters are most effective at predicting the occurrence of an overblow and how are the corresponding sensor errors characterized?*
>
> *Time to overblow and suction fill time measurements were taken in building 336 and are reported in WTP-RPT-146, section 12. Tables summarize the data on page 12.3. The longest time to overblow was 29.5 seconds for the tank filled with clay at the highest level. The shortest time to overblow was 24.3 seconds for the tank filled with water at the lowest level. These measurement confirm that the longest time will occur when there is the greatest back pressure on the PJM nozzle and the fluid is dense. These measurements also confirm that the shortest time will occur when there is the lowest back pressure on the nozzle and the fluid is less dense. The change in drive time is 5.2 seconds between these two extremes which is 21% of the shortest drive time.*
>
> *The longest time to suction fill the PJM was 45.7 seconds with clay at the lowest level. The shortest time to suction fill the PJM was 35.8 seconds with water at the highest level. These measurements indicate that the time is affected by the back pressure, which assists in filling the PJM, and the density, which affects the rate fluid pass through the orifice of the PJM. The change in drive time is 9.9 seconds between these extremes which is 27% of the shortest suction time.*

This indicates that the level and density measurements are not the predominate factor in the drive and suction time of the PJM. The predominate factor is the differential pressure across the orifice of the PJM nozzle created by the JPP which controls the time to move the fluid through this nozzle. Level and density measurement need to be considered in determining the drive and suction time, however, the errors in level and density measurements calculated to be about 2% should not significantly contribute to the probability of an overblow.

During commissioning it may be observed that there is process noise introduced into these measurements. This can be compensated by filtering the signal, taking measurements at certain quieter times, such as vent and suction times, or in the worse case periodically stopping PJM operation for a brief time to allow for the process effects to diminish and allow for accurate measurement.

3.4 Miscalculated PJM Drive Time will Cause PJM Overblows

The control philosophy developed for PJM operation is to minimize the probability of overblow. This approach was discussed in section 3.2 above.

However, if an overblow occurs during normal or safety operation of a PJM then the PJM is shutdown. This philosophy has been adopted because the intent of the design is to minimize overblows and if one occurs it is an indication of a failure in the system that needs to be correct prior to continued PJM operation. In PNNL report, WTP-RPT-179, the probability of detecting an overblow is greater than 99%. Therefore, the likelihood of detection and dealing with the issue is very high.

3.5 Cumulative Effect of Overblow Results in Material Failure of Components Internal to Black Cell Process Vessel

The cumulative effect of increased overblow events/cycles is material dependent in applying the relevant design fatigue curve and values from American Society of Mechanical Engineers (ASME) VIII Division 2. The design curves along with the number of cycles and the calculated stress results from the analysis ($P_L + P_b + Q + F$)* are used to evaluate the associated fatigue limits. In general, the internal components within the vessel would be challenged by increased PJM overblow cycles but not the vessel shell. In accordance with ASME VIII Division 2, the fatigue analysis looks at the cumulative usage factor for fatigue which must be less than 1.0 to comply with ASME VIII . Exceeding the cumulative usage factor could lead to cracks and possible fatigue failure of the internal structures. The PJM overblow loads primarily impact the larger

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* From ASME VIII: P_L = Local Primary Membrane Stress, P_b = Primary Bending Stress, Q = Secondary Stresses (Membrane or bending), and F = Stress concentration Peak Stress

components such as PJMs and Charge vessels internal to the vessel. The recent work performed by BNI on PJM overblow and the PJM overblow criteria established in Calc 24590-WTP-MVC-50-00011 "Pulse Jet Overblow Vessel Loads" indicates that for small structures the effect of the PJM overblow is very minor in magnitude (0.10 psig). The stresses and fatigue in these areas of the vessels in general are less than the endurance limit. This would indicate that the small internal piping structures can also withstand a higher number of PJM overblow cycles and normal PJM operational cycles. However, for larger structures such as the PJMs and Charge vessels this is not always the case. Currently, the criterion for PJM overblow is 1000 events (hard overblow) in which 40 cycles are produced on the internal components per an overblow event (i.e., 40,000 cycles, in total). Preliminary scoping studies indicate that for a 4-in nozzle the number of hard overblow events can increase to 10 times the current number of cycles and still stay below a cumulative usage factor of 1.0. The preliminary scoping study looked at UFP-VSL-00001A/B. This vessel also has large thermal stress cycling effect in addition to the PJM dynamic effects of normal operation and PJM overblow. All vessel load cases but seismic are addressed in the fatigue analysis for determining that the cumulative usage factor is below 1.0 and the analysis meets ASME VIII Division 2. Because UFP-VSL-00001A/B is also challenged by high thermal stress cycling, the overall number of cycle for PJM overblow is less of an increase than those vessels which do not have high thermal stress cycling. Therefore, the number of PJM overblow cycles for other vessels with low thermal cycling could have greater increase in the number of cycles/events than the UFP-VSL-00001A/B example for a 4-in PJM nozzle. Determining the maximum number of PJM overblow cycles per vessel could be addressed in the fatigue analysis of each vessel by evaluating the stress conditions of the vessels under fatigue loading and maximizing the number of cycles of PJM overblow load case. Then, BNI would evaluate the maximum allowable increase in PJM overblow cycles such that the cumulative usage factor remains less than 1.0 and then establish a not to exceed PJM total overblow cycles. This analysis will be updated to evaluate 4.25 in nozzles that are being considered for selected vessels.

4.0 Summary

The effect of a potential settling sediment layer has been anticipated in the design of the PJM control and bubbler system to resuspend solids. Testing to date has shown that the bubbler level and density measurements were repeatable, consistent and provided acceptable system control. In the most recent testing there were no overblows in over 9000 PJM cycles the PJMs operated predictably without an inadvertent overblow providing confidence in the reliability of the controls and predictability of the PJM operation. The control strategy is designed to minimize overblows and to shut down if an inadvertent overblow occurs. Test analysis indicates that the probability of detecting an overblow is greater than 99% providing assurance that control system adjustments will be made should an overblow take place during facility operation.

The effects of overblows are accounted for in the fatigue analysis of each vessel design. A recent scoping analysis of the most challenging vessel design indicates that the number of overblows allowed could be increased tenfold and still not challenge the ASME requirements. For other vessels the potential allowance could be increased further. WTP does not currently plan to use this margin, but may consider increasing the allowable PJM overblow cycles on a case by case basis. Rather vessel fatigue analyses will be monitored and trended for any indication that additional action is required and the need for full scale integrated tests to further mitigate risk will be evaluated.

5.0 References

1. 24590-WTP-MVC-50-00011, Revision B, Pulse Jet Mixer Overblow Vessel Loads.
2. PNNL-17231 Rev 1/WTP-RPT-150 Rev 1, Pulse Jet Mixer Overblow Testing For Assessment of Loadings During Multiple Overblows.
3. American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section VIII, Division 2, 2004 Edition.
4. CCN 208253, An Analysis of Bubbler Level and Density Performance at the Pretreatment Engineering Platform (PEP).
5. 24590-QL-HC9-WA49-00001-03-00017, Pacific Northwest National Laboratory, WTP-RPT-179, PJM Controller Testing with Prototypic PJM Nozzle Configuration.
6. CCN 210358, WTP-09-099-26,_Provide Valve Reliability Assessment of the Valves Used in the PJM Controls.
7. ISA Technical Report TR 84.00.01-2002, table 5.1, Reliability Data for Solenoid Valves.
8. 24590-101-TSA-W000-0004-180-00001, Pacific Northwest National Laboratory, WTP-RPT-146, Pulse Jet Mixer Controller and Instrumentation Testing.

SEPARATION

PAGE

ENCLOSURE 5

Technical Discussion: Waste Treatment Plant Design Basis Requirements for Particle Size and Density

1.0 Defense Nuclear Facilities Safety Board (Board) Issue and Related Comments

In a recent letter to the Department of Energy (DOE) Office of River Protection (ORP) dated January 6, 2010, the Defense Nuclear Facilities Safety Board (Board) expressed a concern over several safety issues related to the capability to mix slurries in the River Protection Project (RPP) Waste Treatment and Immobilization Plant (WTP). One of the concerns is stated as follows:

> *"The Department of Energy's Office of River Protection has suggested that these safety issues could be addressed by preventing rapidly settling particles from entering WTP using controls that would limit the particle size and density of the waste stream from the tank farm. This approach would necessitate deployment of new mixing, sampling, and separation systems. The result would be new design basis requirements for particle size and density for WTP that must be consistent with the performance of the newly deployed systems."*

2.0 Background

Two definitions of the term "solids" are relevant to the WTP. One definition is termed as "entrained solids" in the BNI contract (DE-AC27-01RV14136) and the WTP basis of design (24590-WTP-DB-ENG-01-001). Entrained solids are associated with Low Activity Waste (LAW) transfers from the Hanford Tank Farms to the WTP. The entrained solids are generally defined as those solids which are readily suspended (or entrained) in the liquid phase transfers resulting from decant operations performed by tank farm operations to provide LAW liquids to the WTP FRP vessels. The other definition of solids is that associated with the high level waste (HLW) transfers to WTP and are partly defined in the BNI contract as "Envelope D". The Envelope D solids are generally the bulk of solids present in the waste transfers from the Hanford Tank Farms to the WTP.

3.0 Technical Approach to Resolve the Board Issue

3.1 LAW Strategy FRP-VSL-00002 A/B/C/D

A study to define the acceptance limits for entrained solids properties was recently performed and issued (24590-PTF-ES-ENG-09-001, "*Pretreatment FRP-VSL-00002A/B/C/D Vessel Mixing Assessment*". This document evaluated the predicted mixing capability of the WTP LAW receipt vessels (FRP-VSL-00002A/B/C/D). The FRP vessels were predicted by the referenced study to be capable of mixing a particle that had a settling rate of 0.03 ft/minute[1]. This settling velocity was incorporated into the recent WTP PJM mixing tests as a specified design basis for FRP-VSL-00002 A/B/C/D. CCN 211892 *(M3 Mixing Requirements)*, 24590-PTF-PL-PET-10-00001 *(Plan for M3 Test Platform Testing)*, 24590-WTP-RPT-PET-10-008 *(Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies)* provide an overall summary of the PJM mixing design basis for the LAW.

In order to protect the specified settling rate of 0.03 ft/min, a double settle/decant process and a dedicated LAW line transfer line have been evaluated and agreed by DOE Hanford Tank Farm Operating Contractor and the WTP. This approach was discussed during the Board briefing on March 17, 2010, and is discussed in the draft documents 24590-WTP-RPT-PET-10-005 *(Feed Receipt Vessel Mixing Design Best Value Study – Tank Farms Transfers)* and 24590-WTP-RPT-PET-10-004 *(Feed Receipt Vessel Mixing Design Best Value Study – Internal WTP Transfers)*. In addition, the WTP is evaluating the potential for placement of filter in the LAW feed/transfer line to limit the particle size to less than five microns as a back-up plan if the double settle decant and dedicated transfer line cannot protect the specified settling rate.

3.1 High Level Waste Strategy

For High Level Waste (HLW feed, CCN 211892 *(M3 Mixing Requirements)* provides the design basis relative to the PJM mixed vessels that receive feed direct from the tank farms. As discussed in this CCN, the particle size distribution, maximum particle density, maximum Pu particle size, and bulk density are consistent with the design basis from the External Flowsheet Review Team (EFRT) M1 closure report (Closure Package CCN 186331) and the recent evaluation of existing tank waste characterization information *Estimate of Hanford Waste Insoluble Particle Size and Density Distribution* (24590-101-TSA-W000-0004-114-00021 (WTP-RPT-153)).

24590-WTP-RPT-PET-10-008 *(Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies)* implements this design basis into the test program and relates the simulant that has been developed for the PJM mixed vessel testing to the design basis. As noted in the report, the simulant bounds the particle and slurry properties specified in CCN 211892. The HLW simulant is a combination of inert (in water, at ambient temperature) particles that achieves the following objectives:

- Conservatively approximates the RPP-9805 95%UL waste particle size distribution; especially at the largest particle sizes;
- Has an average solid density of at least 2.9 g/ml; and
- Provides a simulation of a 10 micron PuO_2 particle.

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[1] Example: solid particle of 11 microns diameter with a density of 2.9 kg/liter in water (1cP, 1.0 kg/liter). A 22 micron particle with a density of 2.9 kg/liter in a 2.94 cP, 1.2 kg/liter carrier fluid also has a settling velocity of 0.03 ft/min.

The 700 micron, 2.9 Specific Gravity component envelopes more than 99.9% of Hanford wastes. The 10 micron Tungsten Carbide particles used as a surrogate for PuO_2 exceed the volume of the largest observed PuO_2 crystal by ~300%. This assures that the simulant is reasonably conservative.

It should be noted that the particle size distribution that is specified in CCN 211892 has not been limited by the critical velocity of 4 ft/sec that is specified in the WTP approved interface control document titled, 24590-WTP-ICD-MG-01-019, "*ICD 19 - Interface Control Document for Waste Feed.*" As a defense in depth, WTP is including the design of a heel removal system in 10 key vessels (HLP-22, UFP-1 A/B, FEP-17 A/B, UFP-2 A/B, HLP-27 A/B, and HLP-28). This will provide a means to dilute and flush the heel from the identified vessels forward in the process. Finally, a study that is documented in the draft document 24590-WTP-RPT-PET-10-006 *(HLW Feed Receipt Vessel Mixing Design Best Value Study)* has been initiated to determine the recommended transfer process and route in the event that the evaluation of the HLW sample provided by the Hanford Tank Farm Operating Contractor does not satisfy the design basis properties for the WTP.

4.0 Conclusion

The Board issue is stated as:

> *"The Department of Energy's Office of River Protection has suggested that these safety issues could be addressed by preventing rapidly settling particles from entering WTP using controls that would limit the particle size and density of the waste stream from the tank farm. This approach would necessitate deployment of new mixing, sampling, and separation systems. The result would be new design basis requirements for particle size and density for WTP that must be consistent with the performance of the newly deployed systems."*

CCN 211892 provides the definition of the design basis for M3 pulse jet mixed vessels as it relates to the LAW and HLW feed from the tank farms and is based on the current/existing data. As discussed above, no new mixing, sampling or separation systems are planned to control the feed to the WTP. The following summarizes the primary controls:

- Double settle/decant for LAW feed to WTP utilizing a dedicated transfer line;
- PJM mixed vessel testing with simulant that bounds the design basis; and
- Addition of the heel removal system for defense in depth.

Finally, LAW and HLW alternative studies have been performed and the following additional options are being studied:

- Implement a five micron filter in the WTP prior to receipt of the LAW feed stream; and
- Implement a by-pass route to handle potential feed streams that are outside the design basis specified for the WTP.

5.0 References

1. DE-AC27-01RV14136; *BNI contract*
2. 24590-WTP-DB-ENG-01-001; *WTP Basis of Design*
3. 24590-PTF-ES-ENG-09-001;*Pretreatment FRP-VSL-00002A/B/C/D Vessel Mixing Assessment*
4. CCN 211892; *M3 Mixing Requirements*
5. 24590-PTF-PL-PET-10-00001; *Plan for M3 Test Platform Testing*
6. 24590-WTP-RPT-PET-10-008; Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-1 Vessels for EFRT M3 Mixing Studies
7. 24590-WTP-RPT-PET-10-005; *Feed Receipt Vessel Mixing Design Best Value Study – Tank Farms Transfers*
8. 24590-WTP-RPT-PET-10-004; *Feed Receipt Vessel Mixing Design Best Value Study – Internal WTP Transfers*
9. CCN 186331; *Technology Steering Group - Issue Closure Record EFRT Issue M1 - Plugging in Process Piping*
10. 24590-101-TSA-W000-0004-114-00021 (WTP-RPT-153); *Estimate of Hanford Waste Insoluble Particle Size and Density Distribution*
11. 24590-WTP-ICD-MG-01-019; *ICD 19 - Interface Control Document for Waste Feed.*
12. 24590-WTP-RPT-PET-10-006 *(HLW Feed Receipt Vessel Mixing Design Best Value Study*