Department of Energy
Washington, DC 20585

JUN 0 3 2011

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

Dear Mr. Chairman:

This is in response to your April 5, 2011, letter expressing concerns on the methodology for assessing dose consequences from pressurized spray leaks at the Department of Energy's (DOE) Waste Treatment Plant (WTP). In your letter, you requested a report that describes our approach for performing a reasonably conservative, well-formulated spray leak analysis that accounts for the uncertainties and non-conservatisms in the WTP accident analyses and an outline of any research and development activities DOE will perform to reduce uncertainties in the analysis approach. Enclosed is the report you requested.

WTP recognizes the need to improve the defensibility of the spray release methodology in preparation for final Documented Safety Analysis (DSA) documents. While the spray leak model developed by the WTP represents a substantial improvement over prior methodology, it does not provide a sufficient basis for the DSA. To narrow the uncertainties for the DSA, the WTP project is developing a scope of work for the DOE Pacific Northwest Site Office, with testing and analysis to be performed at the Pacific Northwest National Laboratory. Upon completion of the testing, WTP will evaluate the new information and appropriately incorporate the results into the WTP design, DSA, and Technical Safety Requirements. We will discuss the actual test plan with the Board staff during development, and the final Plan will be provided to the Board when approved by DOE.

As you point out in your letter, DOE's Office of Health, Safety and Security (HSS) is addressing the complex-wide concerns related to using DOE Handbook 3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities,* for pressurized spray release consequence calculations. HSS expects to complete their analysis by September 2011.

The enclosure also responds to the specific issues associated with orifice configuration, droplet size distribution, and agglomerate structure, as described in your letter. DOE looks forward to working with your staff in this area as additional experiments and analysis are performed to reduce the uncertainties of the current model.

If you have any questions, please contact me or Mr. Kenneth G. Picha Jr., Acting Deputy Assistant Secretary for Safety and Security Program, at (202) 586-5151.

Sincerely,

Inés R. Triay
Assistant Secretary for
Environmental Management

Enclosure

U.S. Department of Energy, Waste Treatment and Immobilization Plant Project Response to the Defense Nuclear Facilities Safety Board: Spray Leak Methodology

In response to the Defense Nuclear Facilities Safety Board (Board) April 5, 2011, letter regarding the Waste Treatment and Immobilization Plant (WTP) methodology for assessing dose consequences from pressurized spray leaks involving radioactive liquids, the Department of Energy (DOE) WTP affirms its commitment to ensure an effective safety control for spray leak events and overall operations of the plant. This commitment is considerate of the broad range of uncertainty implied by the sensitivity analyses within the WTP project spray leak report, now supplemented by the Board's letter. Our response also affirms that DOE is not solely relying upon the analysis and methodology previously reviewed by the Board, but upon the addition of experimental testing to narrow these uncertainties as the basis for the final WTP safety strategy and design.

WTP follows existing DOE standards and control methodologies in developing the overall safety strategy for the WTP project; these requirements apply to the approach for performing a reasonably conservative, well-formulated spray leak analysis that accounts for the uncertainties and non-conservatisms in the WTP accident analysis. Last year, the WTP project developed the project specific approach for analyzing spray leaks after the DOE standard methodology (DOE Handbook 3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities)* was determined to be potentially non-conservative in estimating radioactive doses to the public and onsite receptors caused by spray leaks. This is the methodology reviewed by the Board in the referenced letter.

WTP believes this spray leak model (as described in document 24590-WTP-RPT-ENS-10-001, Rev. 1, *WTP Methodology for Spray Leak Scenarios*) represents a substantial improvement over the prior model, and that it provides valuable insight in identifying pertinent uncertainties and their relative importance as a guide for planning experiments, but no longer considers it a sufficient basis for the future facility Documented Safety Analysis (DSA). As a result, WTP, in compliance with applicable DOE requirements for safety analysis at the DSA stage, will ensure spray leaks are appropriately modeled and require an effective Safety Class control strategy for mitigating spray leak events, assuming consequences from a spray leak might exceed evaluation guidelines given the uncertainties, to include those identified by the Board, supplementing the new experimental data with a more formal/rigorous uncertainty process (e.g., expert elicitation) only if necessary.

WTP has chosen filtered ventilation as the required Safety Class control based on a conclusion that significant spray leak events cannot be precluded, particularly for jumpers or valve packing that may leak in the hot cell. Therefore, mitigation provides the most robust barrier to significant exposures outside the unoccupied hot cells and black cells, overriding the preference for a preventive control. Nevertheless, piping systems containing high-level waste are to be chosen as major contributors to defense-in-depth, preventive Safety Significant controls, ensuring appropriate design attention to the minimization of the potential for a spray leak event. Structures, Systems, and Components (SSCs) appropriate for leak detection and pump shutdown will have, at minimum, a defense-in-depth safety function. Pump shutdown eliminates the assumed driving pressure and effectively stops a spray leak event.

Further, WTP recognizes that the functional performance of the C5V High Efficiency Particulate Air (HEPA) filtration system may not be demonstrable over the applicable range of spray leak uncertainties. Any leak detection and pump shutdown SSCs required to ensure the Safety Class filtered ventilation function will be functionally classified as appropriate for that preventive function. While no specific Safety SSC has been identified for this purpose yet, a rate of change of differential pressure across the HEPA filters has been identified as feasible fallback using equipment already being installed as Safety Class. This detection strategy becomes increasingly effective as the spray leak challenge increases. The design also affords the capability for manual pump shutdown, judged appropriate to ensure termination of an actual event without introducing new failure modes of concern.

Additionally, the potential for a spray leak resulting from a seismic event is separately addressed by Safety Class detection of significant seismic activity to be followed by manual isolation valve closures at the Seismic Category I boundaries for each significant hazard piping system in the hot cell and pump power removal as well. These isolation functions are accomplished with Safety SSCs to be designed to appropriate requirements. This layering of protection is also reflected in the Conditions of Approval in the most recent Safety Evaluation Report (SER) for the Pretreatment Facility Preliminary Documented Safety Analysis (PDSA) Addendum, whereby DOE ensures that appropriate defense in depth and leak detection design decisions are considered to the extent that they are not part of the current design and are being addressed.

As for concerns with uncertainties and the potential for non-conservative analysis results, WTP recognizes the need to improve the defensibility of the spray release methodology in preparation for final DSA documents. Ongoing WTP design activities and separate DOE Environmental Management External Technical Review (ETR) recommendations have resulted in a revised approach to spray leak evaluation and design in which the project is ensuring contingent capability to address a broad range of outstanding uncertainties. Specifically, the ETR concluded that the, *"spray leak methodology development and associated documentation is insufficiently formal and systematic"* to meet final DSA requirements. While the WTP expects that the current model will ultimately be shown to be "reasonably conservative," such a result is not yet assured and was not assumed by the DOE as noted in the SER for the Pretreatment Facility PDSA Addendum, Revision 3, approved March 15, 2011.

To narrow the uncertainties for the DSA, the WTP project is developing a scope of work that describes the specific testing information and data analysis that the project will sponsor. The testing has been established through the DOE Pacific Northwest Site Office to be performed at the Pacific Northwest National Laboratory.

This work will be available to support the development of the final DSA. We will discuss the actual test plan with the Board staff during development, and the final Plan will be provided to the Board when approved by DOE. Upon completion of the testing, WTP will evaluate the new information and appropriately incorporate the results into the WTP design, DSA, and Technical Safety Requirements (TSR's). The current safety control strategy for mitigating spray leak events described above is judged to be sufficiently conservative to support historical and ongoing design and construction until testing results are incorporated.

With regard to the currently described WTP project approach for accommodation of uncertainty in the spray leak methodology, responses to the Board's specific concerns are outlined below.

Board issue: *Orifice configuration--The WTP methodology uses a single rectangular slit to represent all potential leak site geometries. Leak site geometry is a major contributor to the total quantity of radioactive material released and the distribution of droplet sizes. Both of these parameters have a direct effect on the postulated unmitigated dose consequences to the public receptor. An analysis by the Board's staff shows that using different possible leak site geometries (i.e., several small orifices encompassing no more total crack area than assumed in the WTP analysis) results in higher unmitigated dose consequences to the public receptor. The small orifices may be more representative of an actual crack that causes a spray leak.*

Response: The WTP project accepts the Board's judgment as being within the diversity of interpretation regarding the credible range of breach configurations that must be accommodated by the WTP design. In particular, the extent of damage that might be caused by erosion/corrosion prior to detection is recognized to be uncertain. WTP reviewed the Hanford Tank Farm model that used a breach length based on historically observed breach configurations (i.e., breach length equal to the pipe diameter for piping up to 3 inches) from RPP-13750, *Waste Transfer Leaks Technical Basis Document.* Hanford Tank Farms concluded that most failure openings were too large to result in a spray release. Nonetheless, WTP determined there was not a sufficient phenomenological basis to establish the bounding configuration of concern for WTP based on Hanford Tank Farms experience. WTP instead adopted the US Nuclear Regulatory Commission medium break model using a rectangular breach slot based on the pipe diameter and width based on half the pipe wall thickness. This breach configuration was believed to be an appropriate model for pipe jumper misalignments where large opening size and assumed efficient jet breakup resulting in high discharge flows is judged to be conservative for the radiological material dispersed in the respirable size range. WTP considered this breach configuration sufficiently conservative for the PDSA, but recognizes that an experimental test program is needed to provide insight on phenomenological behavior of slurries through these leak paths to establish the bounding configuration required for the DSA. Two important pieces of evidence that the WTP project expects its experimental program to provide are directly applicable to this uncertainty: first, we expect to acquire data on jet breakup for prototypic slurry solutions over a range of breach configurations; and second, we expect to acquire data on prototypic slurries plugging small orifices.

Board issue: *Droplet size distribution--The WTP methodology assumes that the distribution of droplet sizes in a spray release is accurately described by a Rosin-Rammler probability distribution (with assumed values for the mean and variance of the distribution). The type of droplet size distribution and its variance have a significant impact on the postulated unmitigated dose consequences to the public receptor. The Rosin-Rammler distribution, a cumulative Weibull distribution, was originally proposed as a natural distribution of particle diameters from crushing and grinding coal, although it has been used in industry for spray droplet size distributions. An analysis by the Board's staff shows that other equally viable distributions of droplet sizes, such as the lognormal distribution, will result in higher unmitigated dose consequences to the public receptor because they have more small droplets .*

Response: The WTP project also acknowledges the Board's judgment regarding the credible range of droplet size distributions that must be accommodated by the WTP design as being within the diversity of interpretation. The Rosin-Rammler distribution was adopted by the Project drawing upon the Hanford Tank Farm precedent. Recent information by CH2M HILL Plateau Remediation Company, PRC-STP-CN-N-00401, Rev. 1, *Sludge Treatment Project – Engineered Container Retrieval and Transfer System Draft Preliminary Design Accident Analysis* (March 2011), indicates that, for the same median and variance in the range of predicted Sauter Mean Diameters, the Rosin-Rammler probability density function has a significantly greater number of particles predicted at the smaller sizes and is conservative relative to the lognormal probability density function in predicting the fraction of respirable droplets in the spray. WTP, however, recognizes the distribution to be uncertain for slurries, which can be expected to behave with significant differences even assuming the distribution is valid for all liquid data. Nonetheless, the Rosin-Rammler distribution was found to provide a good fit for the WTP solid particle size data evaluated to determine deposition velocity during atmospheric transport of respirable particles. We recognize, however, that jet breakup liquid droplet size and the corresponding distribution of solid material may well be different. WTP expects the additional experimental work to provide droplet size distribution data in conjunction with jet breakup measurements for prototypic slurry solutions. Further, we will seek information on the distribution of solid material within those liquid droplets. If these measurements prove impractical, an alternative composite measurement of the airborne respirable fraction carried into the exhaust ductwork would be considered.

Board issue: *Agglomerate structure--WTP process slurry contains a significant population of submicron-sized particles that could form loosely packed agglomerates; however the WTP methodology assumes that the dried agglomerates transform from multiple discrete particles into a solid monolith with no void space. Analyses considering a more probable sub-micron behavior of formation of agglomerates instead of a solid monolithic particle upon drying yield higher unmitigated dose consequences to the public receptor.*

Response: The Board notes that the WTP process slurry contains a significant population of submicron-sized particles that could form loosely packed agglomerates. The Board does not accept the judgment they find in the WTP methodology that *"dried agglomerates transform from multiple discrete particles into a solid monolith with no void space."* The Board states, *"Analyses considering a more probable sub-micron behavior of formation of agglomerates instead of a solid monolithic particle upon drying yield higher unmitigated dose consequences to the public receptor."*

To clarify, the WTP model assumes the specified (average) solid fraction in each spray droplet. The solid particle sizes are not identified, but implicitly involve combinations of the original solid particle size distribution that yield the assumed fraction of solids in the droplet. Typically, there would be multiple smaller particles that may or may not be in direct contact within the droplet. As evaporation occurs, the solid particles would approach each other within the droplet held together by surface tension of the exterior liquid surface. As such, there are two cases of interest:

- For the solutions with significant Na, the evaporation process stops when a 19 M NaOH solution remains. The thick, residual sodium hydroxide solution is assumed to hold the remaining particles together in a coherent droplet. No void space is postulated in calculating the droplet size, since drying is not approached in these cases. For WTP, the significant Na cases are not the bounding cases.

- For solutions without significant Na, it is assumed that essentially all of the liquid can evaporate provided the initial droplet size is 100 μm or less. Evaporation occurs as the droplet is falling toward the cell floor. The remaining solid particles are assumed to stay together absent any evident mechanism to separate them.

Mr. Jofu Mishima, one of the principal authors of DOE-HDBK-3010-94 and one of the independent reviewers of the WTP spray methodology, recently provided additional basis for this judgment, stating that simply de-agglomerating particles packed during storage requires the application of a significant force in the small space between the particles where they are attached and considerable force is needed to separate particles held together by van der Waal's forces and the presence of liquid and salt that collects in the space between the particles adds additional strength to the adhesion. This is illustrated in DOE-HDBK-3010, Figure A.41, which shows that it requires a significant force (prolonged sonic dispersion) to de-agglomerate packed, ball-milled uranium dioxide powder; 5 minutes of hand shaking was not enough. This captures the WTP projects understanding of particle agglomeration for the low-Na waste streams. Again, no void space is postulated in calculating the final droplet size; this assumption was compared to a postulated 64 percent packing density and was found to maximize the initial particle size that became respirable and thus to maximize the radiological release for the limiting case involving waste from HLP-VSL-00028. This sensitivity conclusion appears to depend on case specific parameters.

In conclusion, WTP believes this spray leak model represents a substantial improvement over the prior model and that it provides valuable insight in identifying pertinent uncertainties and their relative importance as a guide for planning experiments, but no longer considers it a sufficient basis for the future facility DSA. All of the above noted actions and activities, supporting the final DSA and related safety controls (e.g. TSR's, SAC's, etc.) will provide "*...a well-formulated analysis that accounts for the uncertainties and reduces the potential for non-conservative results associated with the analysis of spray leaks.*" Utilizing the Safety Class confinement provided by the facility structure and exhaust ventilation in these areas meets the intent of appropriate "engineered" controls being utilized ahead of other administrative controls, though it is fully expected that additional surveillances and specific administrative controls will be developed during the final DSA preparation with regard to plant operations and leak detection, thus protecting the public, workers, and the environment.