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DEFENSE NUCLEAR FACILITIES SAFETY BOARD

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November 4, 2002

The Honorable Jessie Hill Roberson
Assistant Secretary for Environmental Management
Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0113

Dear Ms. Roberson:

The staff of the Defense Nuclear Facilities Safety Board (Board) conducted two reviews of the process used for safety basis development to support the design and construction of the Waste Treatment Plant (WTP) at the Hanford Site. The staff focused on the Preliminary Safety Analysis Reports (PSARs) and design basis events (DBEs) for the pretreatment and high-level waste (HLW) facilities.

The WTP project has implemented a unique Integrated Safety Management (ISM) review process intended to evaluate the design's adequacy, and to ensure that all safety issues have been addressed and that safety functions have been captured and incorporated into the design. The staff's reviews revealed that there may be systemic weaknesses in this ISM review process. It appears that some of these ISM reviews are not sufficiently rigorous. The staff identified a number of conditions that were not adequately addressed in the PSARs and were not captured during the ISM reviews. These conditions may require additional controls or design modifications before sufficient levels of safety are achieved.

Furthermore, the staff found that the design calculations contain numerous unverified assumptions and incomplete design inputs that were not being properly tracked. It is critical that all assumptions be verified and all required design inputs be available to support the aggressive construction schedule and to ensure adequate time for a comprehensive design review.

The staff's review also revealed the safety requirements delineated in Department of Energy (DOE) Order 420.1, *Facility Safety*, and DOE standard DOE-STD-3009-94, Change Notice 2, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, are not being fully met. Specifically, DOE's design contractor appears to have implemented a process that treats DOE's evaluation guidelines as fixed criteria for determining the acceptability of the design. Appendix A to DOE-STD-3009-94 clearly specifies that the evaluation guideline is to be used for the classification of controls and identification of safety-class systems, not as a firm acceptance criterion. This misapplication of the DOE evaluation guideline could lead to the development of a less-than-adequate design.

Pursuant to 42 U.S.C. § 2286b(d), the Board requests a report within 60 days of receipt of this letter that documents how DOE will resolve the deficiencies identified in the enclosed staff reports.

Sincerely,

John T. Conway
Chairman

c: Mr. Roy J. Schepens
Mr. Mark B. Whitaker, Jr.

Enclosures

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

October 3, 2002

MEMORANDUM FOR: J. K. Fortenberry, Technical Director

COPIES: Board Members

FROM: F. Bamdad
S. Stokes

SUBJECT: Safety and Design Basis Activities, Hanford Waste Treatment Plant

This report documents the results of a review performed by the staff of the Defense Nuclear Facilities Safety Board (Board) of safety and design bases for the Hanford Waste Treatment Plant (WTP). Staff members F. Bamdad, J. Contardi, M. Feldman, J. Plaue, R. Quirk, S. Stokes, and A. Wong, together with the Board's site representative, M. Sautman, participated in this review. To perform this review, the staff examined relevant documents; toured the construction site; and held on-site discussions April 30–May 2, 2002, and follow-up discussions July 29–August 2, 2002.

Background. The Department of Energy (DOE) has contracted with Bechtel National, Inc. (BNI) to design, construct, and commission the WTP at Hanford. This facility will treat and vitrify waste from the Hanford high-level waste tank farms. The construction of this facility has begun, and design calculations are being performed to support the construction schedule.

Discussion. The staff's review addressed two aspects of safety basis development for the WTP: (1) the safety standards and processes generated by the contractor to meet the requirements of DOE's Office of River Protection (ORP), and their application to design and construction activities for the WTP; and (2) the design basis event (DBE) analyses supporting the Preliminary Safety Analysis Reports (PSARs) for the high-level waste and pretreatment facilities, a representative set of which was reviewed in detail. The following discussion summarizes issues identified by the Board's staff related to safety standards and processes that could have an adverse impact on the safety of the WTP facility; the technical issues related to the DBE analyses are addressed in a companion report.

Safety Requirements—BNI developed a Safety Requirements Document (SRD) establishing a set of radiological and chemical safety standards to meet the expectations of DOE-ORP. These safety standards are to be used in the design, construction, and operation of the WTP facility.

The structures, systems, and components (SSCs) that serve to provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public and workers are classified as important to safety. This classification includes SSCs designated as safety design class (SDC) and safety design significant (SDS), as well as some

SSCs that provide defense-in-depth called risk reduction components. The SDCs are those SSCs identified to protect the public and workers from receiving radiological or chemical exposures that exceed standards defined in the SRD. Table 2-1 of the SRD establishes radiological dose standards that must be met to ensure adequate protection of the public and workers. For example, the criteria for protection of the public and workers from unlikely events (probability of 1.0E-2 to 1.0E-4 per year) are 5 and 25 rem committed effective dose equivalent (CEDE), respectively, and the criterion for extremely unlikely events (probability of 1.0E-4 to 1.0E-6 per year) is 25 rem CEDE for both populations.

Appendix B to the SRD establishes a defense-in-depth approach by defining the minimum number of SSCs and associated engineering requirements for the control of hazards of a particular severity. This approach is intended to be used in conjunction with the safety requirements discussed above. Table 1 of Appendix B lists the number and attributes of the physical barriers, as well as the application of the single-failure criterion to SSCs as required to implement defense in depth adequately. The adequacy of defense in depth for a given event is evaluated using numerical values given as target frequencies. For example, for the hazards of the highest severity level (SL-1), two independent physical barriers are required, the single-failure criterion shall be applied, and the probability of the event shall be less than 1.0E-6 per year after taking credit for the controls.

The safety criteria and methodology presented in the SRD, as applied by BNI, do not reflect several key requirements for preparation of a PSAR as set forth in DOE Order 420.1, *Facility Safety*, and DOE standard DOE-STD-3009-94, Change Notice 2, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*. The following examples illustrate the issues identified by the staff:

- The numerical value of 25 rem given as the radiological exposure standard in Table 2-1 of the SRD for protection of the public is consistent with the evaluation guideline established in DOE-STD-3009-94 for identification of safety-class SSCs. The DOE evaluation guideline was intended to be used in conjunction with the unmitigated accident consequences for identification of safety-class SSCs. However, the staff's review identified several instances in which SSCs were credited in comparing the consequences with the criteria given in Table 2-1 of the SRD. For example, Section 3.4.1.1.5 of the PSAR for the HLW facility credits the high-efficiency particulate air (HEPA) filters in calculating the consequences for comparison with the SRD. This is in contrast to the recommended approach in DOE-STD-3009-94—that the unmitigated consequences should be compared with the evaluation guidelines for classification of the SSCs. As a result, the safety significance of the HEPA filters may have been masked due to the lack of knowledge of the unmitigated consequences.

  Follow-up discussions with the contractor revealed that the guidance on using the mitigated accident consequences as the basis for comparison with the radiological exposure standards in Table 2-1 of the SRD was provided by DOE-ORP. Any changes to this approach would require negotiations between the contractor and DOE, which are pending at this time.

- Appendix A to DOE-STD-3009-94 states that the evaluation guidelines are not to be used as firm criteria when determining the acceptability of control strategies/systems. Discussions with contractor representatives revealed that these radiological exposure standards are generally regarded as cut-offs for determining the effectiveness of a control system.

- BNI is using target probabilities given in Appendix B of the SRD as acceptance criteria without considering the uncertainties involved in the analysis. For example, an SL-1 event with a calculated frequency of 0.65E-6 per year was given no further consideration because the target frequency of 1.0E-6 per year was not exceeded. This approach does not reflect the substantial uncertainties in this frequency estimate and could yield a design that does not fully develop the defense-in-depth concept articulated in the SRD. Specific examples of the uncertainties discovered in several of BNI's frequency estimates are cited below:

  - The probabilities used in frequency estimates were sometimes inappropriately based on a best estimate rather than a conservative estimate.

  - When data on the failure probability of some systems were unavailable, assumptions used by BNI regarding the applicability of similar data did not appear to be technically justified. Moreover, the extrapolation of these data for use within the DBE analysis did not appear to have been done in a conservative fashion.

  Follow-up discussions with DOE and its contractor confirmed the staff's findings and resulted in a potential change to the defense-in-depth methodology applied to the WTP design. While the contractor has proposed replacing the quantitative frequency requirements with qualitative determination of the adequacy of the control set, there does not appear to be a clear methodology for identifying the required SSCs, their classification, and a concise definition of their boundaries. This activity appears to be work in progress and may impact the design of the SSCs important to safety if not completed in a timely manner.

Beyond Design Basis Accidents—The safe harbor to Title 10 of the Code of Federal Regulations, Part 830 (10 CFR 830), *Nuclear Safety Management,* for the WTP is DOE standard DOE-STD-3009-94. Section 3.4.3 of DOE-STD-3009-94 states that an evaluation be performed that simply provides insight into the magnitude of consequences of beyond design basis accidents (DBAs). This insight from beyond DBA analysis has the potential for identifying additional facility features that could prevent or reduce severe beyond DBA consequences. BNI, however, does not evaluate the consequences of chemical hazards if the unmitigated probability of an event is estimated to be less than 1.0E-6 per year. This practice may discount chemical hazards with significant consequences (but low probability) that may warrant additional controls to protect the public and workers.

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

October 4, 2002

MEMORANDUM FOR: J. K. Fortenberry, Technical Director

COPIES: Board Members

FROM: J. Plaue and M. Feldman

SUBJECT: Safety Basis for Waste Treatment Plant

This report documents two reviews by the staff of the Defense Nuclear Facilities Safety Board (Board) of the Waste Treatment Plant (WTP) at the Hanford Site. This report focuses on technical concerns associated with Preliminary Safety Analysis Reports (PSARs) and design basis events (DBEs) for the pretreatment and high-level waste (HLW) facilities. A companion report addresses the staff's findings associated with the process used for safety basis development for this project.

BACKGROUND

The Department of Energy (DOE) has contracted with Bechtel National, Inc. (BNI) to design, construct, and commission the WTP at Hanford. The purpose of these facilities is to pretreat and vitrify high-level and low-activity waste as a means of remediating the existing inventory of the Hanford tank farms.

DESIGN BASIS EVENTS

Preparation of the safety and authorization bases and the supporting design work are under way in support of ongoing construction. The staff's reviews addressed the development of the DBEs to support the PSAR for the pretreatment and HLW portions of the plant. The following discussion summarizes significant issues related to the development of DBEs and other technical matters.

Hydrogen Generation Rates. Hydrogen is a significant hazard within the WTP. The current control strategy is to maintain hydrogen concentrations below 25 percent of the lower flammability limit (LFL). BNI's design approach involves providing sufficient dilution ventilation during all plant conditions (e.g., normal operating and upset conditions) and therefore requires an accurate understanding of hydrogen generation rates within each WTP vessel. Dilution air is provided by the process vessel purge (PVP) system.

BNI has chosen to model hydrogen generation rates using a model developed for the tank farms. This model was developed in the early 1990s to better understand flammable gas generation in Tank SY-101. The model is based on thermodynamic data taken from a single grab sample of Tank SY-103 and excludes other data produced since that time. BNI believes that these data conservatively predict hydrogen generation rates. In developing the estimates for tank-by-tank hydrogen generation rates, however, BNI is relying on the use of conservative inputs for only some of the first-order parameters (temperature, total organic carbon, aluminum, and radionuclide concentrations). This approach may not produce sufficiently conservative generation rate values since it does not address other important variables involved in hydrogen generation.

For example, under certain temperature and waste conditions, thermolysis rather than radiolysis will be the dominant contributor to the hydrogen generation rate. An understanding of thermolysis conditions in each tank is therefore necessary. In particular, when thermolysis is the driving mechanism, the hydrogen generation rate is exponentially dependent upon input values for temperature and activation energy. It is unknown whether a PVP system sized for generation rates at maximum operating temperature using the current estimation of activation energy (91 kJ/mole) would adequately bound generation rates expected under the higher temperatures of accident scenarios. Furthermore, evidence exists to suggest that 91 kJ/mole is not a conservative estimate of the activation energy within this system.

In at least one instance, the model underpredicted by approximately 25 percent the hydrogen generation within Tank AW-101 compared to that tank's measured generation rates. This discrepancy is significant as Tank AW-101 will provide feed during the initial WTP operating period (Phase 1). Moreover, this discrepancy demonstrates that the current model may not yield conservative or bounding hydrogen generation rates. A proper understanding of the driving mechanisms behind hydrogen generation and the sensitivity of various inputs is required, rather than an increase in the conservative estimates for some individual inputs. Additionally, as the PVP system is currently in design and nearing procurement, a sufficiently conservative predictive model for hydrogen generation rates needs to be developed in a timely manner.

Erosion and Corrosion of Pipes and Vessels. The staff performed a preliminary review of the project's design activities aimed at determining procurement requirements for the piping systems. The project has increased the pipe wall thickness by 0.125 inch to allow for the predicted erosion of pipes due to the movement of waste containing solid particles. This allowance is based on the corrosion and erosion of similar materials in straight pipes within the chemical industry. However, it does not account for higher erosion in nonlinear segments, particularly in bends and elbows.

Cesium Ion Exchange. The cesium ion exchange process (CXP) poses significant safety challenges due to the high radiation field resulting from the accumulation of cesium-137 and the pressurized operation needed to prevent fluidization of resin particles. BNI is redesigning the CXP columns to address issues related to hydrogen accumulation. The previous design called for a gas separation vessel connected to the top of the CXP column via piping. Concerns regarding the ability of the column to adequately vent hydrogen during abnormal conditions prompted a redesign. The new design eliminates the gas separation vessel, instead carrying out the pressurized purge ventilation functions in an enlarged column headspace.

During a loss-of-power event, two hazardous conditions could impact the CXP system: (1) buildup of hydrogen gas, resulting in a deflagration; and (2) overheating of the resin material, leading to an explosion. As with all vessels, the BNI strategy for preventing a hydrogen deflagration is to provide an important-to-safety purge to the CXP columns to maintain headspace concentrations below 25 percent of the LFL. Overheating of the resin can be prevented by the addition of dilute caustic or water to the CXP columns. The current design includes an emergency elution capability; however, use of this capability has not been identified as a control strategy. While the current control strategy should adequately manage the overheating hazard, use of the emergency elution capability would eliminate the hazards associated with organic ion exchange resin under high radiation fields. It is not clear to the staff why this capability has been included in the design yet not credited as a preventive control strategy, and whether its utility for safety purposes has been fully evaluated.

INTEGRATED SAFETY MANAGEMENT

The staff observed several indications that there may be a systemic failure to properly execute Integrated Safety Management (ISM) within the project. The following discussion illustrates the potential problems noted by the staff.

Feedback and Improvement: Tracking of Design Assumptions Critical to Safety. During the staff's initial visit, design assumptions used during safety analyses were not being tracked. BNI has taken the initiative to partially remedy this situation by developing a method for tracking the closure of unverified safety basis assumptions. The database had not been fully developed and placed into use at the time of the staff's second visit, but it was clear that significant effort had been expended to address this issue. During a follow-on discussion with representatives of Research and Technology (R&T) and Environment, Safety, and Health (ES&H), it did not appear that research tasks necessary for closure of some unverified assumptions were being properly communicated. Specifically, discussions concerning nitric acid/resin reactions revealed that ES&H personnel believed the data concerning aged and air-exposed resins were still pending, while R&T personnel indicated that the relevant experiments were complete, and no additional studies were necessary. The staff believes that, to ensure that all unverified safety basis assumptions are properly closed, BNI's tracking system should indicate the significance of an assumption to the design, specify necessary research needs, and prioritize verification activities. This is in addition to the data tracking and issue resolution capability already in development.

Implementation of Safety Controls: Design Features Critical to Safety. In discussions with BNI and DOE personnel, the Board's staff expressed concern that the ISM process may not be successfully capturing critical design features being relied upon for safety. For example, BNI determined that it was impossible for CXP resin to come in contact with sodium permanganate. During analysis, minimal vessel heel volume was identified as a design feature that would dilute potential improper additions of sodium permanganate. The staff questioned whether this design feature would be preserved for implementation in future safety requirements, for example, to prevent emptying of the vessel and thereby creating a significantly increased risk of CXP resin contacting sodium permanganate. Though BNI has developed a system for tracking safety-related requirements, this minimal heel design feature was not added to the database properly. As a result of the staff's inquiry, BNI is now tracking this specific design feature correctly. A closer review of how the ISM process records other design features and assumptions and their importance to safety would be beneficial. At the time of the staff's review, senior BNI ES&H personnel indicated that a management assessment would be conducted to accomplish this review.

Analyze Hazards: Unanalyzed Conditions. The following scenarios identified by the staff did not appear to be identified and evaluated during the ISM process:

Loss of Cooling Impacts—Currently, the cooling of vessels in the pretreatment facility is not classified as an important-to-safety function; therefore, emergency/backup power is not supplied to this system. Following a loss of cooling capability, however, increased tank temperatures would result from ongoing radioactive decay and chemical reactions. This increased tank temperature would in turn result in hazards not considered during the Hazard and Operability Analysis or the subsequent ISM review:

- *Increased hydrogen generation rates*—The rate of hydrogen generation due to thermolysis is exponentially dependent on the waste temperature (Arrenhius dependence). The capacity of the PVP is currently based on expected maximum operating temperatures. A loss-of-cooling accident could result in significantly higher temperatures, and thus exponentially higher hydrogen generation rates. As a result of the staff's inquiry, BNI is now evaluating the impact of this scenario on the PVP design.

- *Ventilation system loading*—Significant increases in tank temperatures would result in an increased vapor and aerosol loading to the Process Vessel Ventilation System (PVVS). Preliminary calculations performed by BNI in response to the staff's inquiry indicate that the increased load resulting from just one tank boiling for the duration of a loss-of-offsite-power event (8 hours) could challenge the high-efficiency particulate air filtration capacity of the PVVS.

Flashing Through Spray Leaks—Several pipes, jumpers, and vessels located within the Feed Evaporation Process system operate under temperature and pressure conditions such that a spray leak event could cause the waste to flash to vapor. The possibility of a flashing event for spray leaks was not evaluated by BNI. As discussed above, the increased vapor load resulting from a flashing event could significantly increase the release of radioactive material, and potentially result in a higher dose to the public and workers than is currently evaluated in the severity-level calculations.

Engineering Calculations. The staff's initial review of DBE and severity-level calculations revealed that these calculations lacked technical quality. The weaknesses varied from small mathematical errors to possibly inappropriate empirical correlations and unjustified assumptions. As a result of the staff's observations regarding poor-quality calculations, BNI undertook a detailed management assessment of this issue. BNI's review showed that all calculations contained some errors, with an average of 40 errors per calculation. Ultimately, BNI implemented a more rigorous peer review process, augmented by external reviewers, to address this issue. The staff considers BNI's approach regarding poor-quality calculations to be timely, aggressive, and sufficient to resolve the problems identified. However, the ability of BNI to produce high-quality technical products will continue to be challenged given the schedule necessary to support construction, and consistent management vigilance will be required.