Office of Enterprise Assessments Review of the Hanford Site Waste Treatment and Immobilization Plant Low-Activity Waste Facility Hazards Analysis Reports for the Melter and Melter Offgas Systems

September 2015

Office of Nuclear Safety and Environmental Assessments
Office of Environment, Safety and Health Assessments
Office of Enterprise Assessments
U.S. Department of Energy

Table of Contents

Acronyms

BNI	Bechtel National, Inc.
BOF	Balance of Facilities
C5	Confinement Zone 5
C5V	C5 Ventilation System
CFR	Code of Federal Regulations
CRAD	Criteria, Review, and Approach Document
DBA	Design Basis Accident
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EA	Office of Enterprise Assessments
HAR	Hazards Analysis Report
HAZOP	Hazard and Operability Analysis
HEPA	High Efficiency Particulate Air (Filter)
HLW	High-Level Waste
HID	Hazard Identification
LAB	Analytical Laboratory
LAW	Low-Activity Waste
LBL	Low-Activity Waste Facility, Balance of Facilities, and Analytical Laboratory
LMP	Low-Activity Waste Facility Melter System
LOP	Low-Activity Waste Facility Primary Offgas System
LVP	Low-Activity Waste Facility Secondary Offgas/Vessel Vent System
MAR	Material-at-Risk
OFI	Opportunity for Improvement
ORP	Office of River Protection
SBRT	Safety Basis Review Team
WTP	Waste Treatment and Immobilization Plant

Office of Enterprise Assessments Review of the Waste Treatment and Immobilization Plant Low-Activity Waste Facility Hazards Analysis Reports for the Melter and Melter Offgas Systems

EXECUTIVE SUMMARY

The U.S. Department of Energy Office of Enterprise Assessments (EA) performs targeted oversight activities for selected high-hazard nuclear facility design/construction projects. One of the targeted oversight activities is the DOE Office of River Protection Waste Treatment and Immobilization Plant, managed by Bechtel National, Inc. Currently, EA is evaluating the development of the documented safety analysis for the Low-Activity Waste facility. EA examined the development of the hazards analyses for the melter and melter offgas systems, because their operations pose significant hazards to co-located workers and adjacent nuclear facilities. EA observed the Bechtel National, Inc. hazards analysis teams' activities associated with these systems and reviewed the *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 4, Melter System*, which was approved in March 2015, and the *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 5, Melter Offgas System*, which was approved in January 2015.

The hazards analysis teams implemented a thorough hazard identification process, making effective use of hazard identification checklists to ensure that the hazards analysis was complete. Overall, the hazards analysis teams analyzed event types applicable to the systems and developed a comprehensive set of events. The teams were suitably focused on analyzing events that are unmitigated by controls, and the teams included conservative estimates of the material-at-risk and the unmitigated consequences. Generally, the hazards analysis teams identified an appropriate mix of preventive and mitigative candidate controls, and the hazard analysis reports provide a nearly complete set of candidate controls to support control selection. Notably, the teams identified a number of candidate controls that are not in the facility's current design.

Nonetheless, the EA review identified a significant weakness that neither hazard analysis report fully justifies the selection of some candidate design basis accidents as representative of the underlying bounded hazard events. Candidate design basis accidents were copied from specific analyzed events, instead of being constructed to represent a group of events. As a result, the controls in the candidate design basis accidents are not aligned with the bounded events, and the candidate design basis accidents omit a number of preventive controls. Consequently, some candidate design basis accidents do not provide a fully representative set of accidents in preparation for control selection and accident analysis.

The review also identified some weaknesses in the areas of hazards analysis and candidate hazard control documentation. The hazards analysis teams did not fully identify or include candidate controls for the inputs, initial conditions, and assumptions used in the analyses. The teams also did not always describe the hazard event sequence sufficiently to support identifying causes and potential controls. Additionally, in some cases, the teams did not define the operating configurations of the facility/systems sufficiently to support the analysis and identification of facility operating modes. Further, the team that analyzed melter hazards did not evaluate some melter thermal stress events. Finally, in choosing candidate controls, the melter team's control strategies involving the C5V ventilation system serving the process cells and melters (including the melter annulus and melter plenum pressure control) were inconsistently applied, unclear, or incomplete.

EA will continue to follow the progress of the hazard and accident analysis for the melter and melter offgas systems, including the site's completion of the hazards analysis, control selection, and accident analysis, in accordance with the EA plan for reviewing the development of the Low-Activity Waste facility's documented safety analysis.

Office of Enterprise Assessments Review of the Waste Treatment and Immobilization Plant Low-Activity Waste Facility Hazards Analysis Reports for the Melter and Melter Offgas Systems

1.0 PURPOSE

As part of the U.S. Department of Energy's (DOE's) self-regulatory framework for safety and security, DOE Order 227.1, *Independent Oversight Program*, assigns the Office of Enterprise Assessments (EA) the responsibility for implementing an independent oversight program and requires EA to conduct independent evaluations of safety and security. To fulfill these responsibilities, EA performs targeted oversight activities for select high-hazard nuclear facility projects during the design and construction phase. The DOE Office of River Protection (ORP) Waste Treatment and Immobilization Plant (WTP), managed by Bechtel National Inc. (BNI), is one of the projects identified for targeted oversight activities.

A focus area of EA oversight activities for the WTP is to provide independent oversight of the development of the documented safety analysis (DSA) for the Low-Activity Waste (LAW) facility. Oversight activities are focused on the extent to which nuclear safety is integrated into the design of the LAW facility in accordance with DOE Order 420.1B, *Facility Safety*, and DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*.

This report documents EA's review of the *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 4, Melter System*, and *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 5, Melter Offgas System*. For the LAW facility, the hazards analysis report (HAR) volumes document the system-specific hazards analyses and identify candidate hazard controls to support development of the DSA. Since autumn 2012, EA has conducted periodic independent oversight reviews at the WTP and observed the conduct of BNI hazards analysis team meetings, reviewed hazard event tables, and interviewed key members of the hazards analysis teams. EA observed hazards analysis team activities for the systems covered by HAR Volumes 4 and 5 during several onsite reviews. BNI approved HAR Volume 5 on January 14, 2015, and Volume 4 on March 30, 2015, and subsequently made them available for ORP and EA review.

2.0 SCOPE

In accordance with EA's *Plan for the Independent Oversight Review of the Hanford Site Waste Treatment Plant Low-Activity Waste Facility Documented Safety Analysis Development*, April 2013, EA reviews focus on hazards analyses of selected structures, systems, and components involving the most hazardous and complex operations. The LAW facility melter (LMP) and melter offgas systems are being reviewed because of the potentially high consequences from accidents involving these systems. This review focused on hazard analysis activities for LAW DSA development to verify that the hazards associated with the facility's scope of work have been accurately identified and analyzed, suitable candidate hazard controls have been proposed, and a complete set of candidate design basis accidents (DBAs) has been identified for further analysis.

3.0 BACKGROUND

The LAW facility is part of the WTP, which is being designed and constructed by BNI at the DOE Hanford Site, with DOE field management and oversight by ORP. The mission of the WTP is to process and immobilize the Hanford high-level tank waste into a stable glass form suitable for permanent

disposal. The LAW facility is designed to incorporate liquid low-activity waste into glass that is poured into immobilized low-activity waste containers for subsequent disposal at the Hanford Site Integrated Disposal Facility. Currently, LAW facility construction is more than 70% complete.
The LAW facility, the Balance of Facilities (BOF), and the Analytical Laboratory (LAB) facility of the WTP are collectively known as the LBL facilities. The present safety basis for these three facilities is a collection of preliminary documented safety analyses, which were not prepared using a “safe-harbor” methodology, such as that described in DOE-STD-3009-94, to comply with the Nuclear Safety Management rule (10 CFR 830, subpart B). In December 2011, ORP provided direction to BNI to resolve contractual inconsistencies concerning implementation of 10 CFR 830 and DOE-STD-3009-94 in DSA development (reference: ORP letter 11-WTP-470). Thereafter, BNI implemented DOE-STD-3009-94 methodologies in procedures and guidance documents and trained its technical staff in DOE-STD-3009-94 requirements. Thus, the WTP project is developing a set of rule-compliant DSAs for submittal to ORP for review and approval. The LAW DSA submittal is currently scheduled for January 2017.

To support DSA development and ultimately the commissioning and operation of the LAW facility, BNI initiated a series of system-by-system hazards analyses. These system hazards analyses, which are being consolidated into a multi-volume HAR, constitute an intermediate step toward preparing the LAW DSA Chapter 3, Hazard and Accident Analyses. Although DOE approval of the HAR volumes is not required, the HARs form an integral part of DSA development by identifying and evaluating hazards and potential hazard controls. HAR results also feed into the accident analysis process and provide input to control evaluation and selection; therefore, an understanding of the LAW HAR is critical to reviewing the adequacy of LAW DSA Chapters 3 and 4. The system HAR volumes and subsequent draft chapters of the LAW DSA are being made available to the Safety Basis Review Team (SBRT) for review and comment.

As part of the DOE-STD-3009-94 implementation, BNI started new hazards analyses for LAW and LAB facility systems in the fall of 2012 (reference: 24590-WTP-PL-ENS-11-0001, Rev. 0). On November 6, 2012, BNI paused its initial processes for the hazards analysis based on ORP, EA, and Defense Nuclear Facilities Safety Board staff observations and feedback that identified weaknesses in the hazards analysis process; such as, failure to perform unmitigated analysis of events (reference: CCN 249553). In early March 2013, BNI revised its process and resumed hazards analysis activities using a new set of process procedures and handbooks that implemented hazard and operability analysis (HAZOP) techniques for the complicated, high hazard process nodes and emphasized the use of unmitigated scenario analysis.

4.0 METHODOLOGY

EA’s reviews focus on BNI’s development of select HAR volumes associated with the highest-hazard systems, such as the LMP system and the melter offgas system, which includes the primary offgas (LOP) system, the secondary offgas/vessel vent (LVP) system, and associated supporting/interfacing systems. Review activities include sampling information from the safety basis and supporting documents in the following broad areas:

- Hazard identification.
- Hazard evaluation using the HAZOP and “What-if” methodologies.
- Identification of hazard controls, including safety structures, systems, and components and administrative controls.
- Identification of candidate DBAs for further treatment in the accident analysis.

During the onsite review periods, EA observed the hazards analysis and hazard control identification activities. EA observed hazard analysis team activities for the LMP system in March and October 2013 and the melter offgas system in May-June and October 2013 and February and April 2014. During each of the onsite visits, EA reviewed the current hazard event documentation generated from the hazards analysis activities, submitted technical review comments to BNI, and met with BNI personnel to clarify the comment responses. EA documented these activities in a series of operational awareness records (references: HIAR-WTP-2013-03-18, HIAR-WTP-2013-05-13, HIAR-WTP-2013-10-21, HIAR-WTP-2014-01-27, and IAR-WTP-2014-03-31).

To maximize the effectiveness of these oversight activities and minimize the impact on WTP project organizations, EA conducted its reviews concurrently with the ORP SBRT reviews and oversight activities. However, EA provided its comments and observations to BNI separately, and received BNI's responses independent of the SBRT review process.

Following issuance of BNI-approved HAR volumes for the LMP and melter offgas systems, EA reviewed the HARs and related supporting documentation using the review criteria and guidance in Criteria, Review, and Approach Document (CRAD) 45-58, *Review of Documented Safety Analysis Development for the Hanford Site Waste Treatment and Immobilization Plant (LBL Facilities)*. The results of these EA reviews are discussed in Section 5, which is divided into four subsections: hazard identification, hazards analysis, candidate hazard controls, and accident selection. The specific criteria from 10 CFR 830, Subpart B, (Nuclear Safety Management) Safety Basis Requirements are included in italicized text at the beginning of each subsection.

Section 6 of this report summarizes EA's conclusions, and Sections 7 and 8 list EA's findings and opportunities for improvement (OFIs), respectively. Items for EA follow-up are identified in Section 9. Supplemental information about the team responsible for this review is provided in Appendix A, and the list of documents, interviews, and observations is provided in Appendix B. References are listed in Appendix C.

5.0 RESULTS

As part of its multi-phased review of the development of the LAW HARs, EA reviewed the approved *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 4, Melter System*, and *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 5, Melter Offgas System*. EA provided comments on the HARs to BNI for written response. After reviewing BNI's written responses, EA met with BNI personnel to clarify the comment responses. BNI subsequently revised its responses and provided them to EA through electronic messages (reference: e-mails from Kraig Wendt to James Low, April 29, 2015 and May 7, 2015). In its final responses, BNI identified a number of follow-on actions to resolve EA's comments.

5.1 Hazard Identification

The documented safety analysis for a hazard category 1, 2, or 3 DOE nuclear facility must, as appropriate for the complexities and hazards associated with the facility, provide a systematic identification of both natural and man-made hazards associated with the facility. (10 CFR 830.204.b.2)

To determine whether the hazards analysis teams developed a comprehensive list of hazards, EA observed a number of sessions in which the hazards analysis teams identified and reviewed the hazardous materials and energy sources, particularly for the LOP and LVP systems, and reviewed the approved HARs. EA did not identify any hazardous materials or energy sources that the hazards analysis teams had not already addressed.

The BNI hazards analysis teams conducted the hazard identification process using extensive hazard identification (HID) checklists that included not only the hazardous materials present in the system, but also the energy sources that could contribute to the release of hazardous material. After completing the initial HID checklist, the teams revised the checklists as additional information was identified during the analysis of the systems. The hazardous materials and energy sources identified by the teams are documented in Appendix C of the HARs (Completed HID Checklists) for the LMP and melter offgas systems.

To identify the location of the hazardous material or energy source, the melter hazards analysis team used a single checklist covering each of the phases of melter operation, and the melter offgas team used two hazard identification checklists (one for the first three nodes and a second for the nodes four through seven). Standard industrial hazards were screened from further consideration based on an appropriate set of screening criteria. After completing the hazards analyses, the team reviewed the HID tables to ensure that all the hazardous materials and energy sources had been addressed; the tables include notes that cross-reference the hazard to the analyzed events.

5.2 Hazards Analysis

The documented safety analysis for a hazard category 1, 2, or 3 DOE nuclear facility must, as appropriate for the complexities and hazards associated with the facility, evaluate normal, abnormal, and accident conditions, including consideration of natural and man-made external events, identification of energy sources or processes that might contribute to the generation or uncontrolled release of radioactive and other hazardous materials, and consideration of the need for analysis of accidents which may be beyond the design basis of the facility. (10 CFR 830.204.b.3)

The purpose of the hazards analysis is to present a comprehensive evaluation of potential process-related, natural, and man-made external hazards that can affect the public, workers, and the environment. In accordance with DOE-STD-3009-94, consideration must be given to all modes of operation, including startup, shutdown, and abnormal testing or maintenance configurations. EA observed selected hazards analysis team meetings for the melter offgas system and several meetings for the LMP, and reviewed the draft hazard evaluation documents and issued HARs.

The hazards analyses identify and evaluate potential radiological, chemical, and physical hazards of the LMP and melter offgas systems. The scopes include system-specific hazards, area-based hazards that consider system interactions, and external hazards to the facility (e.g., seismic). The scope of the LMP HAR (Volume 4) includes melter glass production operations, melter idle, and consumable replacement (i.e., three analysis nodes based on the operating configuration of a melter). Glass production operations include steady-state glass production, the conditions when the melter cold cap is partially or fully formed, the transition from steady-state to idle operations, and the transition from idle to steady-state operations. Idle operations occur when there is no intent to discharge (pour) molten glass and the cold cap is not present. Consumables replacement occurs during idle operation.

The melter offgas system includes the LOP and LVP systems. Each melter has a dedicated LOP that consists of a film cooler, submerged bed scrubber, and wet electrostatic precipitator. Secondary offgas serves both melters and the vessel vent system and provides abatement of the offgas from the LOP and a flowpath to the offgas exhaust stack. The scope of the melter offgas HAR (Volume 5) includes seven nodes from the outlet of the melter at the film cooler to the exhaust stack:

- Node 1 – LOP system.

- Node 2 – Vessel ventilation.
- Node 3 – High efficiency particulate air (HEPA) filtration (radiological abatement).
- Node 4 – Mercury abatement (commonly called the carbon bed absorber).
- Node 5 – Volatile organic carbon and NOx (nitrogen oxides) abatement.
- Node 6 – SOx (sulfur oxides) abatement (commonly called the caustic scrubber).
- Node 7 – Exhausters and stack monitoring.

External events and facility-wide events, such as aircraft crashes and natural phenomena events, are included in the scope of the LAW Facility-Wide HAR (Volume 10).

Using the hazard identification table as a reference, the hazards analysis teams completed the hazard analyses using both HAZOP and What-If methodologies. For the more complicated elements of the LMP and melter offgas subsystems, the HAZOP technique was selected for its systematic, analytical approach. For example, the LMP hazards analysis team conducted the hazard analysis for glass production operations primarily using the HAZOP technique, while analysis of the simpler consumable replacement activities was completed using a What-If approach. Similarly, the melter offgas hazards analysis team used the HAZOP technique for most of the analysis and used the What-if analysis for simple systems, such as those in the vessel vent system and HEPA filtration. The HAZOP analysis used a systematic parameter/guideword pair matrix, and the What-if analysis used brainstorming from a table of what-if questions. Each analyzed event is documented in a hazard evaluation table (in HAR Appendix D).

The hazards analysis team used a computer-based tool, INSIGHT (reference: 24590-WTP-GPG-RANS-NS-0005) to guide the evaluation and document the team's conclusions for each analyzed event. The team documented each analyzed event in a specific hazard event table (identified by system, node, event type, and number; e.g., LMP01-1-001 for the first fire event in node 1 of the melter). The teams developed event descriptions, including the event sequence, release mechanisms, the location(s) of the upset condition, and an estimate of MAR and causes, which are included in the hazard evaluation tables. The teams also included the likelihood of the events and conservatively estimated consequences (chemical, radiological, and physical) for the facility worker, co-located worker, the public, and the environment in the hazard evaluation tables. The LMP and melter offgas hazards analysis teams concluded that many of the unmitigated events would lead to releases of molten glass and/or offgas from either or both of the melters, as well as releases of ammonia from the thermal catalytic oxidizer/ selective catalytic reducer skid and releases of mercury and sulfur dioxide from the carbon beds.

The LMP hazards analysis team analyzed a total of 170 events, including fires, explosions, loss of confinement, and natural phenomena hazards; most of the events involved loss of confinement. Fire events included fires in the melter galleries starting from in-situ and transient combustibles and flammable liquids. Explosive events included both molten sulfate interactions with water and flammable gas formations. The analysis of loss-of-confinement events (123) included a variety of operational upsets. Analyses of natural phenomena events addressed earthquakes.

The melter offgas hazards analysis team analyzed a total of 313 events, including fires, explosions, and loss of confinement. The team examined a comprehensive set of fire events that addressed fires in each of the facility fire areas traversed by the offgas system, including, for example, a large fire that involves both process cells and the effluent cell and fires in the melter gallery, exhauster rooms, and filter room. Generally, fires were postulated to start from in-situ and transient combustibles and flammable liquids. Analyzed explosive events included ignition of offgas compositions above the lower flammability limit and ammonium nitrate compounds. The analysis of loss-of-confinement events (245) included a variety of operational upsets in the primary and secondary offgas systems. Overall, the LMP and melter offgas hazards analysis teams analyzed event types that are appropriate to the system and constitute a comprehensive set.

Neither the LMP HAR nor the melter offgas HAR identifies any unmitigated events that challenge the radiological evaluation guideline to the maximally exposed offsite individual. During a large fire involving both process cells and the charge floor, the unmitigated analysis of the melter offgas events identified high consequences to the facility and co-located workers and moderate consequences to the public from radiological exposures. The hazards analysis identified high consequences to the public for a number of chemical releases during melter offgas events (ammonia pipe breaks), but did not identify high or moderate chemical consequences to the public during the postulated melter events or other melter offgas system events. The estimated consequences for chemical releases from many unmitigated LMP and melter offgas events are high to both the co-located and facility worker.

The hazards analysis teams conducted extensive discussions of the postulated hazard events, identifying causes and corresponding preventive and mitigative controls. Although the hazards analysis was nearly complete and included an extensive number of analyzed events, EA identified some deficiencies, as discussed below.

Section 4.1 of both the LMP and melter offgas HARs covers the inputs, initial conditions, and assumptions used in the hazards analysis. The LMP HAR discusses assumptions associated with piping failures, ammonia releases, and criticality, as well as inputs for the MAR in the analysis. The melter offgas HAR provides an extensive discussion of the hazards analysis inputs that defined the events, such as the analysis of the fires by zone, the classification of some controls when two melters are operating, the level of failures assumed in the computer control system, and the logic for assigning MAR based on the location and initiator of an event. Nonetheless, the HARs do not fully identify the inputs, initial conditions, and assumptions or include candidate controls to ensure that these assumptions are protected. For example:

- Neither HAR discusses the inputs, initial conditions, and assumptions for the explosion events, which are based in part on temperature, air flow into the melter, offgas flow rates, and compositions of feed streams (see calculation 24590-LAW-M4C-LOP-00002). Although some candidate controls (for example, sugar and total organic compounds in the feed) have been identified, the candidate controls do not address all the relevant operating parameters (such as melter temperature and melter air in-flow).
- The melter offgas HAR does not include the inputs, initial conditions, and assumptions used for estimating the MAR, even though the MAR used to estimate the offgas system event consequences is based in part on initial conditions for offgas flow rates and compositions (e.g., calculation 24590-LAW-Z0C-LOP-00001, Rev E).
- The melter offgas HAR does not discuss the assumptions for parameters associated with estimating the consequences from the release of mercury, sulfur dioxide, and iodine-129 during a postulated carbon bed fire (see calculation LAW-Z0C-20-00002, Rev D).
- The LMP HAR discusses the assumptions related to the criticality hazard that “would require control” in event LMP01-0-002 and determines that on the basis of these assumptions, a criticality event cannot occur. The HAR includes an open action item to complete the criticality analysis, but it does not include a candidate control (e.g., waste characterization) to protect the assumption.
- The LMP HAR indicates that the MAR will be “fully defined and established” in the LAW Facility-Wide HAR, but does not include an open action item to track the incorporation of MAR controls in the Facility-Wide HAR, whose recent draft (dated January 12, 2015) did not address MAR controls.
- A number of events associated with drops onto the melter (e.g., candidate DBA LMP01-3-074) contain a note indicating that the analysis of drops onto the north structure/platform applies only to

drops of 3 feet or less. Drops from greater heights are currently unanalyzed, but the HAR does not include an open action item to track completion of the load drop analysis and revise the hazard analysis if necessary.

Failure to fully identify, control, and track the inputs, initial conditions, and assumptions in the HAR could result in selection of an incomplete set of candidate controls (see **OFI-LAW-OMP-1**).

The operating configurations of the facility have not always been defined sufficiently to support analysis of the potential hazardous events that is consistent with the accepted methodology of DOE-STD-3009 (i.e., American Institute of Chemical Engineers *Guidelines for Hazard Evaluation Procedures*). Generally, the LMP and melter offgas HARs assume that both melters are operating and do not discuss the operational permutations of the facility, such as one melter in idle or consumable replacement with the other melter in operation, or isolation of the LOP system with the other melter operating. For example:

- Sections 2.3.2 and 2.3.3 of the LMP HAR briefly describe the operational configuration that was used to evaluate the idle and consumable replacement modes for the melter, but the descriptions do not include the status of both melters, address the operation of the offgas system (e.g., low flow expected during idle and consumable replacement), or describe the ventilation system lineup that supports the consumable replacement. For example, the C5 (confinement zone 5) area (i.e. C5 encompasses the process cell, melter and melter enclosure areas with the potential for high contamination) ventilation system (C5V) is designed to provide additional flow through the annulus during these evolutions.
- The melter offgas HAR assumes that both melters are operating for nearly all the analyzed events, using idle as the initial condition in two events and "idle too long" as the potential cause of three events.
- The LMP HAR also does not fully evaluate upsets from potential melter operating configurations in which some of the melter components are not in service, such as operation with one or more bubblers or feed nozzles out of service.

Failure to fully identify the initial operational configuration can lead to unclear sequences of events and missing events, which can adversely impact the identification of an appropriate set of candidate DBAs and hazard controls (see **OFI-LAW-OMP-2**).

The event descriptions, release mechanisms, and causes are identified in the hazard evaluation tables, and the event descriptions generally include the mechanisms by which material is released. The "unmitigated" portion of the event analysis assumes that all available controls fail. As a result, event descriptions do not always describe the full sequence of the event that leads to the release. For example:

- In the LMP HAR, loss of cooling water (from loss of BOF plant cooling water) is listed as a cause for candidate DBA LMP01-3-043, which leads to loss of the second operating melter due to imbalance in the offgas system. Loss of BOF plant cooling water is a common-cause loss of cooling to both melters, which would lead to a different sequence of events and possibly a different set of candidate controls than those described in the hazard evaluation.
- In the LMP HAR, candidate DBA LMP01-3-064, which postulates a release from the melter annulus into the melter gallery, does not have a clear sequence of events and corresponding candidate preventive engineered controls. The melter shield wall, annulus drain, and melter enclosure are all designed to capture the leakage as described in the sequence of events and to retain the hazardous material within the confinements, but the event description does not include the failure of the melter enclosure.
- In the melter offgas HAR, events involving film cooler or downstream pipe plugging (e.g., events LOP01A-3-005, -006, and -007) lead to releases of molten glass and offgas from both melters, but the

event descriptions do not explain the sequence that leads to failure of the second melter.

Failure to fully identify and analyze the sequence of events may result in the omission of appropriate candidate controls (see **OFI-LAW-OMP-3**).

Some event descriptions and analyses in the melter HAR do not support the conclusion that these sequences represent "no event" or "process upsets." These include:

- Event LMP01-8-006 considered foaming in the melter as an operational upset and not an event. A note in the event table indicates that the melter design (tall plenum), operational controls, and sampling are used to prevent foaming events, but no initial conditions or controls are proposed in the HAR to protect these assumptions.
- The event description for event LMP01-8-011 states that "isolation of the melter annulus ventilation flowpath results in an upset of the melter plenum pressure control," but it does not address whether the isolation of the C5V ventilation would adversely affect the air in-leakage into the melter and create the potential for an explosive event in the melter or melter offgas system.
- The event description for event LMP01-8-014 indicates that the loss of mixing (agitation) is strictly a process event that reduces melter efficiency. The event does not indicate whether operating with partial agitation could affect the potential for developing a bridged cold cap, sulfur layer, or large temperature differential between melter zones that could lead to loss of confinement (see 24590-LAW-RPT-ML-04-0001).

Incomplete analysis of an event can adversely impact the identification of potential events and candidate controls (see **OFI-LAW-LMP-4**).

Finally, although the set of analyzed melter and melter offgas events is comprehensive, the team did not evaluate melter hazards caused by significant temperature differences and some potential thermal stress initiators in the melter. The melter HAZOP guideword pair – event matrix does not include guideword pairs for temperature differentials and rate of temperature change. High temperature differentials and thermal stress could develop when operating the melter with some components out of service (e.g., without feed to a melter zone), and thermal stresses can develop if the melter heats up or cools down too rapidly to allow system components to remain within an allowable design margin (e.g., exceeding the 50º C/hour rate constraint for temperature changes in melter HAR Section 2.2.5). Large thermal stresses could result in component failures and subsequent loss of confinement. Failure to fully identify and analyze hazards associated with melter temperature differentials could lead to an incomplete set of hazard events and candidate controls (see **OFI-LAW-LMP-5**).

5.3 Candidate Hazard Controls

The documented safety analysis for a hazard category 1, 2, or 3 DOE nuclear facility must, as appropriate for the complexities and hazards associated with the facility, derive the hazard controls necessary to ensure adequate protection of workers, the public, and the environment, demonstrate the adequacy of these controls to eliminate, limit, or mitigate identified hazards, and define the process for maintaining the hazard controls current at all times and controlling their use. (10 CFR 830.204.b.4)

The hazard evaluation tables include candidate preventive and mitigative controls, both engineered and administrative, for further evaluation during control selection, which is the next step following the hazards analysis. EA focused on whether the candidate controls included in the candidate DBAs are developed to the extent that the control selection process can arrive at an adequate set of hazard controls. EA also examined whether the candidate controls reflect DOE's preferred hierarchy of controls as input to the control selection process. DOE's hierarchy of controls, described in DOE-STD-3009, emphasizes engineered controls over administrative controls, preventive controls over mitigative controls, and passive controls over active controls.

The HAR volumes include lists of candidate preventive and mitigative engineered and administrative controls in the tables of candidate bounding events (Table 4-11 in the LMP HAR and Table 4-2 in the melter offgas HAR). These lists are built from the individual event entries for the candidate DBAs in the hazard evaluation tables, and do not include all the controls associated with the bounded events. Bounded events that do not share all their controls with the candidate DBA are identified in the tables with an asterisk. Notes for the asterisked items in Table 4-11 and Table 4-2 state that "the bounding relationship is very dependent on the control strategy implemented in control selection and should be re-evaluated during control selection." Appendix E in each HAR volume provides a table of all the candidate controls (both for the candidate DBAs and the bounded events) that includes the control title, attribute, function, and type, along with a list of the related hazard events.

Section 4.3.4 of the LMP HAR describes the hazards analysis team's general strategy for choosing candidate controls, based on three conditions of increasing magnitude of the melter pressure transient:

- Melter pressure upsets.
- Uncontrolled fast pressurization of melter with inadvertent pour.
- Uncontrolled fast pressurization of melter with inadvertent pour plus structural failure of the melter.

Table 4-12 lists the candidate controls associated with slow melter pressure upsets and includes the preventive features provided by the melter differential pressure interlocks, offgas system, and standby offgas line. Tables 4-13 and 4-14 provide additional candidate controls for more rapid and severe pressure transients, as well as additional controls that build on the controls identified for the lesser pressure transients. Section 4.3.5 includes a summary discussion of the candidate DBAs and the associated preventive candidate controls.

Section 4.3.4 of the melter offgas HAR includes brief discussions of the candidate control strategies for room fires, explosions from explosive offgas mixtures and ammonium nitrate, and loss of confinement. The discussion of control strategies for loss-of-confinement candidate DBAs is not directed toward specific candidate DBAs, but rather offers a general approach to the treatment of candidate engineered and administrative controls, both preventive and mitigative.

The hazards analysis teams added candidate controls that were not in the current design to augment existing controls in support of control selection. Using this approach, the hazards analysis teams identified a number of candidate controls that are not currently in the facility design. The melter offgas hazards analysis identified a number of risks representing deficiencies (or vulnerabilities) in design, along with opportunities to improve the design (e.g., offgas HAR Volume 5 Table 4-3). The LMP hazards analysis team also identified a number of "not-in-current-design" controls, including an active feature to provide an alternate release path for melter pressure relief that would route the relief discharge to an engineered safe location.

Although the identified candidate controls and the specified safety functions and attributes result in a nearly complete set of candidate controls to support control selection, EA identified some deficiencies in this area.

First, in a number of instances, candidate DBAs have incomplete candidate control sets. For example, in the LMP HAR:

- Candidate DBAs LMP01-2-001, -2-002, -3-003, -3-024, -3-043 and -3-074 all postulate event progressions in which structural damage to the first melter leads to loss of pressure control in the second melter, but they do not identify preventive (or mitigative) engineered controls to interrupt the postulated progression of events (e.g., preventing catastrophic failure of the first melter or preventing the loss of the second melter).
- Candidate DBA LMP01-3-043, which postulates continued melter joule heating following loss of electrical isolation between the heating electrodes and melter shell, and event LMP01-3-059, which postulates electrode failure due to high power, omit electrical protection devices as candidate controls.
- Candidate DBA LMP01-3-074 for dropped load events does not include preventive engineered controls for equipment or computer failures. The causes include these types of failures, which are not directly addressed by the proposed administrative hoisting and rigging program control.

And in the melter offgas HAR:

- Candidate DBA LO/VP-3-002 describes a loss of offgas flow due to high temperature effects on control systems in various rooms containing offgas components (listing loss of cooling as one of the causes), but does not identify the ventilation and air conditioning system components serving the event locations as candidate controls.

In addition, some events in the LMP HAR have inappropriate or misclassified candidate hazard controls. For example:

- Candidate DBA LMP01-1-001 includes a special relief device as a mitigative control for damage and breach of the melter due to fire, but the control would have no clear mitigative effect.
- Hazard event LMP01-3-063 provides a melter high level feed-stop interlock as a mitigative control relating to a high level event in the melter where the control would actually be a preventive control by preventing an inadvertent pour.

Missing, inappropriate, or incomplete candidate control sets could adversely impact the ability to select controls that prevent the candidate DBA (see **OFI-LAW-OMP-6**).

In the LMP HAR, the control strategies involving the C5V system, whose overall purpose is to maintain negative pressure on areas with potential for high contamination, were inconsistently applied, unclear, or incomplete. The C5V system works in conjunction with a number of melter annulus design features and components to act as a secondary confinement system for the melter. Together with the facility structure, the C5V system also provides confinement of releases into C5 areas, such as the process cell. In conjunction with the melter shell and enclosure; the confinement zone 3 ventilation system (C3V), which services potentially low-level contamination areas; and the offgas system, the C5V system also helps provide air flows via in-leakage to the melter plenum due to the designed cascading differential pressures. In a number of events in which the C5V system functions as a preventive or mitigative control, the required configuration of the C5V system and the associated design features is not adequately discussed. Also, controls relating to ventilation and confinement are alternately characterized as preventive or mitigative for events with similar consequences. In addition, the controls related to melter annulus ventilation and confinement are incorrectly identified as mitigative in a number of events that involve a breach of the gas barrier by either melter gases or molten glass, where annulus ventilation and confinement systems would serve to prevent a release. For example:

- Although candidate DBA LMP01-2-002 lists “engineered melter air in-bleed” as a control, the description of this control does not include the active and passive design features (e.g., melter enclosure, C5V, and offgas) that provide the air in-bleed.

- The candidate control strategy for slow pressurization events (melter Table 4-12) identifies the melter shield wall as a passive mitigative feature, but does not include the combined function of the C5V system and melter enclosure to maintain the differential pressure between the melter annulus and the lower melter gallery. These are an integral part of the overall confinement function, which in this event type prevents a hazardous material release to the facility.
- Candidate DBA LMP01-3-003 identifies the melter confinement as a mitigative control. In combination, the melter shield wall (C5 confinement), melter annulus, and C5V ventilation of the melter annulus are preventive controls that prevent a release into the facility for many of the anticipated process upsets, protecting both facility and co-located workers from exposure to hazardous material release.
- The preventive engineered controls for candidate DBA LMP01-3-086 include the melter shell (for offgas confinement) but do not include the C5V system (for maintaining ventilation through the annulus and a confinement path to the stack). The C5V controls are included in the candidate DBA as mitigative controls, but they function to prevent the release of hazardous materials into the facility.

Failure to fully establish and implement a control strategy can lead to the selection of an inadequate or ineffective set of controls (see **OFI-LAW-LMP-7**).

5.4 Accident Selection

The documented safety analysis for a hazard category 1, 2, or 3 DOE nuclear facility must, as appropriate for the complexities and hazards associated with the facility, evaluate normal, abnormal, and accident conditions, including consideration of natural and man-made external events, identification of energy sources or processes that might contribute to the generation or uncontrolled release of radioactive and other hazardous materials, and consideration of the need for analysis of accidents which may be beyond the design basis of the facility. (10 CFR 830.204.b.3)

The process of selecting candidate DBAs is based on identifying unique and representative accidents that provide a limited subset of events for potential inclusion in the accident analysis. As discussed in DOE-STD-3009, unique accidents are those hazard events with sufficiently high-risk estimates to justify individual examination to support control functional classification and evaluation. Representative accidents bound a number of similar accidents of lesser risk and are expected to have similar control sets; they are also further examined to verify that they do not contain unique accidents. At least one representative DBA from each of the major types determined from the hazards analysis (e.g., fire or explosion) should be selected unless the DBA consequences are “low.”

EA evaluated whether the HAR volumes contain unique and representative candidate DBAs for the melter and melter offgas systems. Section 4.3 of each HAR volume includes a set of candidate DBAs for fires, explosions, and operational upsets. Individual subsections describe the underlying event scenarios, describe the candidate DBAs, and list the candidate controls. Candidate DBAs often share similar causes with the underlying events (e.g., equipment failure, operator error, and system impacts or load drops).

In the LMP HAR, the selection of candidate DBAs was based on grouping similar events, identifying the event or events with the highest consequences and frequency of occurrence in each group, and identifying the event or events with the set of candidate controls that most represents the control strategy for the group. The result is a set of candidate DBAs that includes a single fire event, two explosion events, ten loss-of-confinement events, one direct exposure event, and one natural phenomena hazards event. The candidate DBAs for loss of confinement include introduction of excess feed, water or air into the melter, damage to the melter lid, cooling panel problems, leaks into the melter enclosure, impacts or drops, and upsets during consumable replacement activities.

In the melter offgas HAR, the selection of candidate DBAs was based on grouping events with similar causes, release mechanisms, and candidate control strategies and choosing an event that is representative and bounds the consequences of the grouping. The result was a set of candidate DBAs that includes 2 fire events, 3 explosion events, 11 loss-of-confinement events, 1 direct exposure event, and 1 external event. The candidate DBAs for loss of confinement include, for example, offgas system failure due to elevated room temperatures, system overpressurization due to plugging, overpressurization of the ammonia skid, overpressurization resulting from load drops or impacts that pinch the offgas piping, breach of system piping or equipment, and failure of the offgas exhauster fans.

In both HARs, the candidate DBAs are chosen as specific analyzed events. As discussed above in Section 5.3, the candidate controls listed in the LMP HAR (Table 4-11) and melter offgas HAR (Table 4-2) identify controls only for the candidate DBAs, and many of the underlying bounded events are marked with an asterisk, indicating the need to re-evaluate the bounding relationship in control selection. As a result, the correlation of preventive controls between the candidate DBAs and the bounded events and justification of the candidate DBA as representative is incomplete. For example:

- Candidate DBA LMP01-3-003, which has a cause of integrated computer network failure (control or status error) is described as an event in which excessive waste feed, water flush, or the introduction of air increases melter plenum pressure, resulting in a release of radioactive and chemically hazardous material. Bounded events LMP01-3-006 through LMP01-3-011 involve pressurization of the melter due to film cooler blockage, either from long-term buildup of material or short-term material buildup due to excess agitation. These events have causes related to failure to adequately flush the film coolers or control splatter that are not addressed by the preventive controls in the candidate DBA.
- Events LMP01-3-026 and -027 are listed as underlying bounded events for candidate DBA LMP01-3-024. The candidate DBA progresses from melter lid compartment damage due to thermal stress or corrosion to a lid leak that increases plenum pressure, with subsequent loss of containment and offgas release to the melter gallery or process cell. The underlying bounded events describe a lid leak from a load drop or an impact, respectively. These two underlying bounded events are more closely related to candidate DBA LMP01-3-074, which involves a load drop onto the melter.
- Events LMP01-3-055, -056, and -057 are also identified as underlying bounded events for candidate DBA LMP01-3-024. These events involve melter high temperature causing film cooler/offgas spool structural damage that results in an offgas release to the melter annulus, followed by a release to the melter gallery and/or process cell. Although the events share some common preventive controls, the candidate DBA is associated with water cooling system problems and does not include several preventive engineered controls (such as film cooler cooling air and the emergency air in-bleed interlock) that are specific to these underlying events.

Similarly, the melter offgas HAR has a number of events in which the relationship between the candidate DBAs and the underlying bounded events is not discussed sufficiently to justify the selection of candidate DBAs as representative. For example, although the bounded events share a number of mitigative engineered controls with the candidate DBA (LVP06A-3-002), a number of preventive engineered controls are not included in the candidate DBA. Within the LVP, approximately ten safety-related interlocks and a number of design features in the underlying bounding events are not included in the candidate DBA. For example:

- Events LVP03B-3-001, -002, -003 and -004 (low or no flow through the HEPA filters) have only one common preventive engineered control (piping design) with the candidate DBA, which does not include the safety-related design features and interlocks (such as the safety-related preheater, high differential pressure interlock, and filter valve position interlocks) from the bounded events that are intended to maintain flow.

- LVP04-3-007 (internal blockage in the mercury mitigation skid) shares two preventive engineered controls (melter differential pressure interlock and piping design) with the candidate DBA, which does not include the skid high differential pressure interlock as a candidate control.
- LVP02-3-004 and -005 are listed as underlying bounded events. Although these events share a common set of mitigative controls with the candidate DBA, the events do not share any candidate preventive engineered controls (other than piping design).

Within the LOP, several safety-related interlocks and design features in the bounded events are not included in the candidate DBA:

- Events LOP1B-3-004, -005, and -006 (high levels in the submerged bed scrubber) have only one common preventive engineered control (piping design) with the candidate DBA and the submerged bed scrubber high level interlock is not included.
- LOP01C-3-007 (high level in the wet electrostatic precipitator) shares only one preventive engineered control (piping design) with the candidate DBA, and the wet electrostatic precipitator high level interlock and drain size (design feature) controls are not included.

Finally, the HAR volumes do not explain the parameters that will subsequently be used to evaluate whether the candidate DBAs are representative or to fully justify the selection of candidate DBAs as representative (see Finding **F-LAW-OMP-1** and **OFI-LAW-OMP-8**).

6.0 CONCLUSIONS

The BNI hazards analysis teams implemented a thorough hazard identification process to identify the hazards requiring further analysis, making effective use of hazard identification checklists to ensure that the hazards analysis was complete. The teams conducted the hazards analysis using a mix of HAZOP and What-if analysis techniques that was appropriate to the complexity of the node. Overall, the hazards analysis teams analyzed event types applicable to the systems and developed a comprehensive set of events, including fires, explosions, and loss-of-confinement. A computer-based tool helped guide the performance of the analysis and documentation of the hazard events, including descriptions of the event sequence, causes, and consequences. The analyses were suitably focused on completing unmitigated event analyses and, for the most part, included conservative estimates of MAR and unmitigated consequences. Generally, the hazards analysis teams selected an appropriate mix of candidate controls based on prevention and mitigation. The HARs provide a mostly complete set of candidate controls to support control selection. Notably, the teams identified a number of candidate controls that are not in the facility's current design. Finally, the hazard analysis teams usually selected candidate DBAs by grouping similar events and selecting an event that represents the causes, release mechanisms, and candidate controls of that group.

The EA review identified one significant weakness: that in some cases the HAR volumes do not adequately describe the relationship between the candidate DBAs and the underlying bounded hazard events to justify the selection of candidate DBAs as representative. Instead of being constructed to represent a group of events (i.e., revising the initial candidate DBA to include a broad set of causes that encompass more bounded events), the candidate DBAs were designated from specific analyzed events. As a result, the controls in the candidate DBAs do not align with the bounded events; some controls for some of the underlying bounded events (particularly the preventive controls) are not included in the candidate DBA control set. Consequently, some candidate DBAs design basis accidents do not provide a fully representative set of accidents in preparation for control selection and accident analysis.

EA identified a number of weaknesses in the hazards analysis and candidate hazard control selection. The hazards analysis teams did not fully identify or include candidate controls for the inputs, initial conditions, and assumptions used in the analyses. Also, the teams did not always describe the hazard event sequence sufficiently to support identification of causes and potential controls, and sometimes the teams did not define the operating configurations of the facility/systems sufficiently to support the analysis and identification of facility operating modes. In addition, the LMP hazards analysis team did not analyze the potential for melter events arising from high temperature differences in the melter and did not sufficiently support some conclusions that certain potential event sequences did not lead to events with consequences. Further, in selecting candidate controls, the control strategies involving the C5V system/melter plenum pressure control were inconsistently applied, unclear, or incomplete. Finally, some candidate controls were missing or were not correctly characterized.

7.0 FINDINGS

As defined in DOE Order 227.1, *Independent Oversight Program*, findings are significant deficiencies or safety issues that warrant a high level of management attention. If left uncorrected, findings could adversely affect the DOE mission, the environment, the safety or health of workers and the public, or national security. Findings may identify aspects of a program that do not meet the intent of DOE policy or Federal regulation. DOE line management or contractor organizations must develop and implement corrective action plans for EA review findings. Cognizant DOE managers must use site- and program-specific issues management processes and systems in accordance with DOE Order 227.1 to manage these corrective action plans and track them to completion. (Note: Findings are numbered as F-LAW-OMP-x; where OMP signifies a finding that applies to both HAR volumes.)

Bechtel National, Inc.

F-LAW-OMP-1: Some candidate DBAs in both HAR volumes are not representative of the underlying bounded hazard events. (DOE-STD-3009-94, Section 3.0)

8.0 OPPORTUNITIES FOR IMPROVEMENT

This EA review identified eight OFIs. These potential enhancements are not intended to be prescriptive or mandatory. Rather, they are suggestions that may assist site management in implementing best practices or provide potential solutions to minor issues identified during the EA review. In some cases, OFIs address areas where program or process improvements can be achieved through minimal effort. It is expected that the responsible line management organizations will evaluate these OFIs and accept, reject, or modify them as appropriate in accordance with site-specific program objectives and priorities. (Note: OFIs are numbered as OFI-LAW-LMP-x, OFI-LAW-LOP-x, or OFI-LAW-OMP-x, where LMP signifies an OFI for the melter HAR only, LOP an OFI for the melter offgas HAR only, and OMP an OFI for both HAR volumes.)

Bechtel National, Inc.

While evaluating actions to address the weaknesses identified in this report, consider the following actions.

OFI-LAW-OMP-1: Identifying and controlling all applicable inputs, initial conditions, and assumptions in the hazards analysis.

OFI-LAW-OMP-2: Revising the hazards analysis to include a detailed description of the operating configuration for the melter idle and consumable replacement modes, as well as the status of both melters for offgas release events, consistent with the accepted methodology in the American Institute of Chemical Engineers *Guidelines for Hazard Evaluation Procedures*.

OFI-LAW-OMP-3: Reviewing and revising the candidate DBA event descriptions as necessary to ensure that the sequence of events is sufficiently described to support identification of the causes and potential controls for the event.

OFI-LAW-LMP-4: Re-evaluating and documenting the justification for designating some events as process upsets or non-events.

OFI-LAW-LMP-5: Adding guideword pairs to support HAZOP evaluation of large temperature differences and excessive heatup and cooldown rates to the guideword pair matrix and re-evaluating the hazard events analyzed for the LMP system.

OFI-LAW-OMP-6: Adding or revising some candidate controls and correcting the classification of some mischaracterized controls.

OFI-LAW-LMP-7: Re-evaluating and documenting the candidate control strategies involving the C5V system and melter plenum pressure control.

OFI-LAW-OMP-8: Revising the candidate DBA event descriptions as necessary to ensure that they are sufficiently representative of the underlying events.

9.0 FOLLOW-UP ITEMS

EA will continue to follow the progress of the hazard and accident analyses for melter and melter offgas system events, including revision of safety basis development processes, completion of the hazards analysis, control selection, and accident analysis. EA will then review the LAW DSA when it is submitted for approval.

This review updated previously identified OFIs associated with LAW hazards analysis activities. During a review of LMP system hazards analysis activities in 2012, EA (then HS-45) identified several OFIs, documented in *Independent Oversight Review of the Hanford Site Waste Treatment and Immobilization Plant Low-Activity Waste Melter Process System Hazards Analysis Activity*, December 2012. EA considers all 11 OFIs, including all sub-items, to be closed, with the exception of two items:

- OFI-2012-1-A-15 remains open pending resolution of the consequences of glass-concrete reactions.
- OFI-2012-1-B-1 remains open pending evaluation of the controls for the melter wheels seismic locks.

Appendix A

Supplemental Information

Dates of Review

Onsite Review: March 2013
May-June 2013
October 2013
February 2014
April 2014

Document Review: January to May 2015

Office of Enterprise Assessments

Glenn S. Podonsky, Director, Office of Enterprise Assessments
William A. Eckroade, Deputy Director, Office of Enterprise Assessments
Thomas R. Staker, Director, Office of Environment, Safety and Health Assessments
William E. Miller, Director, Office of Nuclear Safety and Environmental Assessments
Patricia Williams, Director, Office of Worker Safety and Health Assessments

Quality Review Board

William A. Eckroade
Thomas R. Staker
William E. Miller
Karen L. Boardman
Michael A. Kilpatrick
John S. Boulden III

EA Site Lead for Office of River Protection

Robert Farrell

EA Reviewers

James O. Low – Lead
Kevin E. Bartling
Roy R. Hedtke
Mary Miller
David J. Odland
Daniel M. Schwendenman

Appendix B

Key Documents Reviewed, Interviews/Discussions, and Observations

Documents Reviewed

- 24590-101-TSA-W000-0009-166-00001, *Regulatory Off-Gas Emissions Testing on the DM1200 Melter System using HLW and LAW Simulants, VSL- 05R5830-1*, Rev 00B
- 24590-BOF-Z0C-AMR-00001, *Design Basis Accident: Anhydrous Ammonia Release*, Rev 1
- 24590-BOF-Z0C-AMR-00001, *Design Basis Event: WTP Ammonia Release*, Rev 0
- 24590-ENS-DI-RANS-NS-0003, Hazards Analysis Report Format and Contents Desk Instruction, Rev. 0, June 13, 2013
- 24590-LAW-FHA-RAFP-FP-0001, *Fire Hazards Analysis (FHA) for the Low- Activity Waste(LAW) Facility*, Rev 0
- 24590-LAW-HAR-NS-13-0001-04, Rev 0, *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 4, Melter System*, March 2015
- 24590-LAW-HAR-NS-13-0001-05, Rev 0, *Hazards Analysis Report for the Low-Activity Waste Facility, Volume 5, Melter Offgas System*, January 2015
- 24590-LAW-M4C-LOP-00001, *LAW Melter Offgas System Design Basis Flowsheets*, Rev 3
- 24590-LAW-M4C-LOP-00002, *LAW Off-Gas Flammability Assessment*, Rev 0
- 24590-LAW-M6C-LOP-00008, *Code Case 2211-1 Overpressure Protection Evaluation of the LAW Primary Off-gas (LOP) system*, Rev 1
- 24590-LAW-M6C-LVP-00004, *Offgas Pipe and Exhauster Sizing for LOP and LVP System*, Rev 1
- 24590-LAW-M6C-LVP-00006, *Code Case UG-140 Overpressure Protection Evaluation of the LAW Secondary Off-gas (LVP) System*, Rev 1
- 24590-LAW-RPT-ML-04-0001, *Surges in LAW Melter*, Rev. 1, 7/2004
- 24590-LAW-RPT-M-09-001, *LAW Melter Off-Gas Data Summary for Flammable Species*, Rev 0
- 24590-LAW-Z0C-20-00002, *Design Basis Event: LAW Fire Analysis*, Rev D
- 24590-LAW-Z0C-20-00002, *Design Basis Event: LAW Fire Analysis*, Rev E
- 24590-LAW-Z0C-LOP-00001, *Design Basis Event: LAW Melter Offgas Release*, Rev. E
- 24590-LAW-Z0C-W14T-00008, *Severity Level Assessment for the LAW Facility*, Rev. B
- 24590-QL-POA-MWK0-00001-09-00031, *Data Sheet - Carbon Fire and Design Temperature Analysis, LAW*, Rev 00I
- 24590-QL-POA-MWK0-00001-13-00006, *Test - Ammonium Nitrate Formation Studies Test Results, LAW*, Rev 0C
- 24590-RANS-F00012, WTP Hazard Identification Checklist / Standard Industrial Hazards and Chemical Screening, Rev. 0
- 24590-RANS-F00012-I, Instructions for Completing the WTP HID Checklist, Rev. 0, 12/17/12
- 24590-WTP-BEAP-SA-13-002, *LAW Carbon Bed Replacement - Working With Contaminated Carbon Adsorbent Media and Access Cover That Were Exposed to the Off Gas Stream*, Rev 0
- 24590-WTP-CSER-ENS-08-0001, *Preliminary Criticality Safety Evaluation Report (CSER)*, Rev B
- 24590-WTP-DB-PET-09-001, *Process Inputs Basis of Design (PIBOD)*, Rev 001
- 24590-WTP-GPG-RANS-NS-0002, *Hazard Analysis Handbook*, Rev. 0, 7/24/12
- 24590-WTP-GPG-RANS-NS-0002, *Hazard Analysis Handbook*, Rev. 3C, 10/31/14
- 24590-WTP-GPG-RANS-NS-0004, *Control Selection Process Handbook*, Rev. 1A, June 2, 2014
- 24590-WTP-GPG-RANS-NS-0005, *WTP Insight User’s Guide for Supporting Hazards Analysis*, Rev 1B, July 10, 2014
- 24590-WTP-GPP-RANS-NS-0005, *Hazard Analysis Procedure*, Rev. 1, June 13, 2013

- 24590-WTP-RPT-ENS-13-009, *DRAFT Ammonium Nitrate Accumulation in WTP LAW Offgas System*, Rev 0
- 24590-WTP-Z0C-W13T-00017, *Inhalation Dose Rate from LAW Melter Offgas (LMP06)*, Rev 0
- 24590-WTP-Z0C-W14T-00020, *Updated Unit Dose Factors and Flow Stream Parameters for Use in Safety Analysis Calculations*, Rev 3
- 24590-WTP-Z0C-W14T-00026, *Toxicological Hazards of WTP Liquid Process Waste*, Rev A
- CCN 223395, *Response to the Office of Health, Safety and Security (HSS) Observations on the LAW Melter Process System Hazards Analysis Activity*, August 5, 2013
- E-mail: Kraig Wendt to James Low, Subject: *LAW Melter HAR EA-31 Comment Resolution Revised*, May 7, 2015 8:22 AM (PST) - with attachment
- E-mail: Kraig Wendt to James Low, Subject: *Revised EA-31 Comment Resolutions*, April 29, 2015 1:44 PM (PST) - with attachment

Interviews/Discussions

- LAW Nuclear Safety Manager
- Hazards Analysis Team Leads
- Hazards Analysis Team Members
- Subject Matter Experts

Observations

- LAW Melter Offgas Systems Hazards Analysis Team Daily Meetings

Appendix C

References

- 24590-WTP-PL-ENS-11-0001, Rev. 0, *Safety Basis Development Project Execution Plan for the Analytical Laboratory, Low-Activity Waste and Balance of Facilities*, January 2, 2012
- CCN 249553, *Documentation of Meeting with Safety Design Integration Teams and Hazard Analysis Leads and Scribes Regarding Hazard Analysis Operational Pause*, November 13, 2012
- CRAD 45-58, *Review of Documented Safety Analysis Development for the Hanford Site Waste Treatment and Immobilization Plant (LBL Facilities)*, April 2013
- DOE-STD-3009-1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Document Safety Analyses*, Change Notice 3, March 2006
- *Guidelines for Hazard Evaluation Procedures – Second Edition with Worked Examples*, Center for Chemical Process Safety (American Institute of Chemical Engineers), September 1992
- HIAR-WTP-2013-03-18, Office of Enforcement and Oversight's Office of Safety and Emergency Management Evaluations Activity Report for Follow-up of Waste Treatment and Immobilization Plant Low-Activity Waste Melter Process System Hazards Analysis Activity Review, March 2013
- HIAR-WTP-2013-05-13, Office of Enforcement and Oversight's Office of Safety and Emergency Management Evaluations Activity Report for Follow-up of Waste Treatment and Immobilization Plant Low-Activity Waste Melter Off-gas Process System Hazards Analysis Activity Observation, June 2013
- HIAR-WTP-2013-10-21, Office of Enforcement and Oversight's Office of Safety and Emergency Management Evaluations Activity Report for Observation of Waste Treatment and Immobilization Plant Low-Activity Waste Melter and Melter Off-gas Process System Hazards Analysis Activities, October 2013
- HIAR-WTP-2014-01-27, Office of Enforcement and Oversight's Office of Safety and Emergency Management Evaluations Activity Report for the Observation of Waste Treatment and Immobilization Plant Low-Activity Waste Facility Off-gas Systems Hazards Analysis Activities, February, 2014
- IAR-WTP-2014-03-31, Office of Environment, Safety and Health Assessments Activity Report for the Observation of the Waste Treatment and Immobilization Plant Low-Activity Waste Facility Hazards Analysis Activities, April 2014
- Independent Oversight Review of the Hanford Site Waste Treatment and Immobilization Plant Low-Activity Waste Melter Process System Hazards Analysis Activity, December 2012
- ORP Letter 11-WTP-470, R. Dawson to F. Russo, Subject: Proposed Changes to the WTP Regulatory Construct to Support Project Transition to Commissioning and Operations, December 22, 2011