ENCLOSURE

TANK 48 FLUIDIZED BED STEAM REFORMING PROJECT SUMMARY

Process Overview. The Tank 48 Fluidized Bed Steam Reforming (FBSR) project is designed to process the contents remaining in Tank 48 from the cancelled In-Tank-Precipitation (ITP) process. Tank 48 contains 238,000 gallons of high-level waste (HLW) including precipitated cesium tetraphenylborate (TPB), fission products, and actinides from the ITP testing. The FBSR is designed to:

- Convert all organics to carbon dioxide and water vapor
- Convert nitrates and nitrites directly to nitrogen gas
- Convert inorganic constituents into a solid product
- Convert the solid product into a slurry for final processing

Process Components—FBSR will share space in Building 241-96H with the Monosodium Titanate Addition Tank and support equipment for the Actinide Removal Process. The main processing units for the Tank 48 FBSR process are listed below.

- The Waste Feed System consists of a recirculating 4,000 gallon tank that receives batch-wise waste transfers from Tank 48 through an above-ground, jacketed, shielded transfer line and feeds waste to the Denitration Mineralization Reformer (DMR) at a nominal 0.25 gallons per minute.

- The DMR consists of an 18-inch diameter fluidized bed reactor operating at 680°C at atmospheric pressure. Waste is fed to the DMR through an atomizing nozzle. Solid carbonate product is collected in the product receipt tanks while the resultant gases and remaining fine granular material pass to the High Temperature Filter (HTF).

- The HTF collects fine granular metal carbonates that may escape the DMR and feeds them to the product receipt tanks. Gases and extremely fine particulates pass through the HTF to the Carbon Reduction Reformer (CRR).

- The CRR consists of a fluidized bed operating at 850–1000°C and slight vacuum. The CRR acts both as a reducing (lower part of bed) and oxidizing (upper part of bed) system. The gas exiting the CRR consists of carbon dioxide, nitrogen, oxygen, and water.

- The product receipt and mix system consists of tanks receiving product from the DMR, HTF, and CRR where the product is reslurried and pumped batch-wise back to Tank 51 for future processing in the Defense Waste Processing Facility (DWPF).

- The off-gas system consists of an off-gas cooler using nitrogen-atomized water to cool the gases to 150–200°C by evaporation.

Facility Structure—The FBSR process is to be installed in a former ITP facility, Building 241-96H. This building has been assessed previously in the Documented Safety Analysis for the Concentration, Storage, and Transfer facilities. Building 241-96H is comprised of two main structural systems: reinforced concrete portions including the filter cells and hold tank room, and a steel frame enclosure building. While Building 241-96H has been functionally classified as Process Support, it has been analyzed to a higher level of seismic design because the waste transfer line entering the hold tank room is functionally classified as safety class. Building 241-96H has been analyzed to Performance Category (PC)-3 seismic design requirements. The higher level of seismic evaluation includes assessing the building for ground motion shaking and dynamic soil settlement that result from the design basis earthquake.

Building 241-96H was not built to modern seismic design standards. As expected, the seismic analysis found that portions of the building do not meet current seismic design requirements, and as a result do not have the necessary seismic margins expected of a PC-3 building. The reinforced concrete portions of the building are more seismically robust than the steel frame enclosure building. In particular, dynamic soil settlement will result in structural deformation, although the building is not expected to collapse. While Building 241-96H does not meet current seismic design requirements for a PC-3 facility, the Board's staff believes it is sufficiently robust to support the FBSR process, which is expected to have a relatively short operational lifetime (less than 2 years).

Process Testing. The Thermal Organic Reduction (THOR®) steam reforming process is the candidate technology for destroying the nitrates, nitrites, and TPB in Tank 48 prior to transfer to DWPF. The contractor commissioned several different tests to determine the capability of the steam reforming process.

Early Testing—A test conducted at the Science and Technology Application Research (STAR) Center in Idaho Falls, Idaho, demonstrated the ability of the process to treat a Tank 48 simulant. The test at STAR did not combine all the major unit operations and equipment that would be necessary for actual processing, and the small size of the fluidized beds used did not represent the operation of production-scale units. However, it was proven that steam reforming was a viable option for pretreatment of the Tank 48 waste. In 2002, bench-scale tests at the Savannah River National Laboratory provided proof that actual Tank 48 waste could be treated by steam reforming.

Hazen Tests—A larger pilot-scale unit was built and operated at the Hazen Research, Inc. facility in Golden, Colorado. This unit is a nine-tenths-scale Tank 48 FBSR process and includes all unit operations present in the full-scale unit, excluding the product packaging equipment. The Hazen unit was designed, constructed, and functionally tested, logging more than 500 hours of "full-up" operations during scoping and production runs using various waste simulants.

During September and October 2006, operators at Hazen completed a series of optimization and production tests. The tests included variable operating conditions of feed composition, feed rate, DMR temperature, and reductant form in the DMR and CRR. During these tests, 3,310 gal (32,900 lb) of Tank 48 simulant were processed into 6,912 lb of granular solid product during 310 hours of "feed-on" operation. In summary, the Hazen tests met all the test objectives and demonstrated that the Tank 48 FBSR is a viable and effective process to treat Tank 48 waste. The tests demonstrated that the process can:

- Destroy the nitrates, nitrites, and organics in the Tank 48 solution
- Produce a relatively benign off-gas mixture of water, nitrogen, and carbon dioxide
- Produce a dry, carbonate solid as intended

Safety Requirements. Among other safety requirements, project managers have committed to implementing DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets*, and the intent of DOE Standard 1189, *Integration of Safety into the Design Process* (STD-1189). Project managers also intend to follow the Implementation Plan for the Board's Recommendation 2004-2, *Active Confinement Systems*.

DOE Order 413.3A—DOE Order 413.3A was approved July 28, 2006 with the objective to provide DOE with direction for project management for acquisition of capital assets. Its goal is to deliver projects on schedule and within budget while fully meeting mission performance, safeguards and security, and environmental, safety, and health standards. The Critical Decision-1 (CD-1) package approved for the Tank 48 FBSR process did not entirely conform to the requirements of DOE Order 413.3A. DOE has committed to use DOE Order 413.3A, but since the Tank 48 FBSR project is a "subproject" and has been delegated to the DOE Savannah River Operations Office (DOE-SR), not all DOE Order 413.3A requirements are being followed verbatim.

DOE Standard 1189—DOE approved STD-1189 in March 2008. Its purpose is to facilitate the integration of safety into the design of new nuclear facilities. Since STD-1189 had not yet been issued when the CD-1 package was approved, project personnel developed an interim guidance document: *Tank 48 Process Conceptual Design DOE-EM Interim Guidance Implementation* (Interim Guidance). The Interim Guidance includes several recommended parameters to be used in the accident analysis to arrive at reasonably conservative results. These inputs are described in the authorization basis section below. The Board's staff understands that DOE intends to comply with the intent of STD-1189 as outlined in the letter from the Deputy Secretary of Energy to the Board dated July 12, 2007.

Authorization Basis Documents. DOE included several authorization basis documents in the CD-1 package: a Preliminary Consolidated Hazard Analysis (PCHA), a Conceptual Safety Design Report (CSDR), and a Preliminary Safety Validation Report (PSVR). DOE Order 413.3A also requires a Technical Independent Project Review (TIPR).

Preliminary Consolidated Hazard Analysis—Contractor analysts completed a PCHA that documents the bounding accidents, including fire, explosion/deflagration, loss of confinement,

direct radiological exposure, external and natural phenomena events, and the potential for significant consequences to the public. The bounding radiological event was a full facility fire consuming the entire waste inventory in the facility. The unmitigated consequences of the bounding event were less than all evaluation guidelines. All mitigated events were negligible for the public, collocated workers, and facility workers. Project analysts concluded that no safety-class (SC) or safety-significant (SS) controls were needed because the postulated events do not exceed evaluation guidelines.

The PCHA did identify 14 open items. The Board's staff agrees that the open issues can all be addressed by design maturation in the next phase of the project. The Board's staff intends to follow all open items to completion. Of particular interest is the open item to complete the Recommendation 2004-2 evaluation of the 241-96H ventilation system.

Conceptual Safety Design Report—Following completion of the PCHA, the contractor completed a CSDR for the FBSR project. The contractor made a determination of the preliminary hazard categorization of the FBSR using DOE Standard 1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23 Nuclear Safety Analysis Reports*. Based on a maximum inventory of 8,000 gallons of Tank 48 waste at any one time in the FBSR process and the nominal curie content of Tank 48, the FBSR would exceed the Hazard Category (HC)-3 threshold and would approach but not exceed the HC-2 threshold. However, project managers and analysts decided to designate the FBSR as a HC-2 activity for the following reasons:

- HC-2 precludes the need to provide segmentation from other processes
- HC-2 provides more flexibility in the design of the reslurrying process
- HC-2 does not materially increase risk, cost, or controls
- HC-2 eliminates the need for a safety-related control for maximum inventory

The analyses in the CSDR reconfirmed that no SS or SC controls are needed because the potential accident consequences do not exceed the onsite or offsite evaluation guidelines. The Board's staff agrees with the conservative approach of declaring the FBSR a HC-2 activity. Although the CSDR identifies no SS or SC controls for the FBSR, the Board's staff notes that the Recommendation 2004-2 process will impose the rigor of SS requirements on the confinement ventilation system during the ventilation system evaluation.

Preliminary Safety Validation Report—DOE Order 413.3A requires that DOE review and approve the CSDR via a PSVR. Since no guidance for a PSVR existed at the time of submission of the CD-1 package, DOE used the format for a Safety Evaluation Report (SER), since SERs perform the same function. DOE completed the PSVR in January 2008, and concluded that designating the FBSR as a HC-2 activity was appropriate, that the methodology for calculating a fire event consuming the entire inventory and an unmitigated explosion event in the FBSR was adequate, and that a criticality event was not credible.

The Board's staff notes that the PSVR adequately considers the open issues from the PCHA and that these issues can be addressed in the next design phase of the project. DOE provided no conditions of approval in the PSVR.

Technical Independent Project Review—The Board's staff found that DOE did not perform a TIPR prior to the CD-1 milestone, as required by DOE Order 413.3A. Although the project was subjected to several independent reviews, such as the Independent Technical Review in 2006 and a Technology Readiness Assessment in 2007, these reviews focused predominantly on technical issues, not safety issues. DOE Order 413.3A explicitly requires the conduct of a TIPR, "the focus of which is to determine that the safety documentation is sufficiently conservative and bounding to be relied upon for the next phase of the project." The Board's staff believes an independent safety review would have been beneficial. Given the relatively low risk of the FBSR project, and its planned short duration, the Board's staff does not believe DOE must retroactively perform a TIPR. However, the Board's staff strongly suggests that as the project proceeds, DOE more fully comply with the requirements of DOE Order 413.3A and STD-1189.

Interim Guidance—Since STD-1189 had not yet been issued as of the CD-1 submittal, project personnel produced the Interim Guidance document to meet the intent of STD-1189. The Interim Guidance includes several input parameters to be used in the safety basis for the FBSR. These parameters consist of reasonably conservative values for curie content of the waste, tank volumes, vapor space volumes, waste feed rates, etc.

Using 95 percent meteorology and a surface roughness factor of 3 cm in the dispersion calculations (as required by DOE Headquarters), analysts calculated the following accident consequences:

- Vessel spill: 4.3 rem collocated worker, 0.0009 rem offsite
- Facility spill (4 times vessel spill): 17 rem collocated worker, 0.004 rem offsite
- Facility fire: 46 rem collocated worker, 0.03 rem offsite
- Explosion/spill: 38 rem collocated worker, 0.02 rem offsite
- Seismic event: <85 rem collocated worker, <0.05 rem offsite

The contractor concluded that since the FBSR does not challenge the evaluation guidelines (25 rem offsite and 100 rem onsite), the FBSR does not warrant SC or SS controls, and does not warrant PC-3 design criteria.

The Board's staff agrees with the reasonably conservative inputs provided by the Interim Guidance. However, the Board's staff does not necessarily agree with the conclusion that safety systems are not required until the design advances beyond the conceptual design phase and the ventilation system evaluation is complete.

Project Management Documents. Project management documents include the Project Execution Plan (PEP), Risk Analysis Report (RAR), and a Quality Assurance (QA) Program.

Project Execution Plan—DOE issued the PEP, *Project Execution Plan for Project G002 Tank 48 Treatment Process (TTP) Project*, in February 2008. In this document, DOE Headquarters has assigned approval authority for the CD-1 package to DOE-SR. The PEP states subsequent Critical Decisions will be approved by DOE-SR since operation of the Tank 48 Treatment Process is expected to be less than 2 years in duration and independent reviews of design, cost estimates, and the performance baseline are planned. Early Critical Decisions are to be requested to authorize long lead procurements and early vendor fabrication. DOE approval must be requested and received prior to commencing any early material procurement or construction before Preliminary Documented Safety Analysis approval. The PEP has identified a Federal Project Director and defined the organization (with roles and responsibilities) for the Integrated Project Team.

Risk Management Plan—The RAR (which serves as the Risk Management Plan and the Risk and Opportunities Assessment) encompasses standard risks expected on major design and construction projects. For example, the assumptions made in developing the safety basis have been captured as specific risks. The contractor originally documented more than 60 risks for the project. After further analysis, and implementation of risk-mitigating strategies, the remaining risks included 4 high risks, 16 moderate risks, and 25 low risks. The 4 high risks are:

- Scope reductions or CD-1 package assumptions do not materialize
- High silicon in feed creates problems with the 2H Evaporator
- Technical issues make deployment of the Tank 48 recovery process impractical
- Heel removal of Tank 48 residue does not meet expectations

Except for delaying the return of Tank 48 to service, the Board's staff does not believe these risks are safety related. The risks identified in the RAR appear to be inclusive, and the controls to mitigate these risks are acceptably conservative.

Quality Assurance—The PEP includes guidance for a QA Program for the Tank 48 FBSR project. The Tank 48 FBSR project will follow the site QA Manual which is responsive to the requirements of DOE Order 414.1A, *Quality Assurance*. It is expected that the QA Program will be fully employed without any deviations.

Alternatives and Technology Evaluations. Since 1996, leading up to the CD-1 milestone, DOE and the contractor conducted many evaluations of alternative technologies to process the Tank 48 contents. They also commissioned an independent review by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP). The key technical challenge is the difficulty of processing TPB in a radioactive environment. The evaluations included:

- Several chemistry studies, 1996–1998
- Five systems engineering evaluations, 2002–2007
- An Independent Technical Review (J. DeVine, et al.), 2006
- The CRESP review (D. Kosson, R. B. Matthews, et al.), 2007

- A Technology Readiness Assessment (H. Harmon, J. DeVine, H. Sutter, et al.), 2007
- A Corporate Program Review (M. Hughes, J. DeVine, et al.), 2008

In the early studies, the contractor considered several dozen technologies. These were narrowed down to a few technologies including acid hydrolysis, FBSR, aggregation, Fenton's reagent, and wet air oxidation (WAO). By 2006, and in all subsequent reviews, each team recommended FBSR as the preferred alternative with WAO as a backup. Significant findings from these reviews included the need to consider final heel removal from Tank 48, and a need to conduct better assessments of worker safety during potential upset conditions and during maintenance activities. Additionally, the later reviews identified a need to perform a risk assessment for the WAO technology.

The Technology Readiness Assessment team concluded that both FBSR and WAO had achieved technology readiness levels of 3; however, the team concluded that FBSR was somewhat more mature. Based on the findings of this assessment, the contractor began to develop Technology Maturation Plans for both technologies.

Although every review team since 2006 has recommended FBSR, and FBSR was selected as the preferred alternative in March 2008 when DOE-SR approved CD-1, DOE is now unsure of the decision. DOE-SR is reevaluating the FBSR and WAO options due to cost and technical maturity concerns. DOE-SR plans to make a "business decision" in June 2009 to select the real preferred alternative. The Board's staff intends to closely follow this process to ensure the appropriate application of DOE Order 413.3A and STD-1189.

Conclusion. Based on a review of the information available to date, the Board's staff believes that the FBSR project can be safely designed and operated to achieve the project objectives.