^{233}Uranium Downblending and Disposition Project

Technology Readiness Assessment

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Glossary

Term	**Definition**
Critical Technology Element	A technology element is "critical" if the system being acquired depends on the technology element to meet operational requirements (with acceptable development, cost, and schedule and with acceptable production and operations costs) and if the technology element or its application is either new or novel. Said another way, an element that is new or novel or being used in a new or novel way is critical if it is necessary to achieve the successful development of a system, its acquisition, or its operational utility.
Engineering Scale	A system that is greater than 1/10 of the size of the final application, but it is still less than the scale of the final application.
Full Scale	The scale for technology testing or demonstration that matches the scale of the final application.
Identical System	Configuration that matches the final application in all respects.
Laboratory Scale	A system that is a small laboratory model (less than 1/10 of the size of the full-size system).
Model	A functional form of a system generally reduced in scale, near, or at operational specification.
Operational Environment (Limited Range)	A real environment that simulates some of the operational requirements and specifications required of the final system (e.g., limited range of actual waste).
Operational Environment (Full Range)	Environment that simulates the operational requirements and specifications required of the final system (e.g., full range of actual waste).
Paper System	System that exists on paper (no hardware).
Pieces System	System that matches a piece or pieces of the final application.
Pilot Scale	The size of a system between the small laboratory model size (bench scale) and a full-size system.
Prototype	A physical or virtual model that represents the final application in almost all respects that is used to evaluate the technical or manufacturing feasibility or utility of a particular technology or process, concept, end item, or system.
Relevant Environment	A testing environment that simulates the key aspects of the operational environment (e.g., range of simulants plus limited range of actual waste).
Similar System	The configuration that matches the final application in almost all respects.
Simulated Operational Environment	Environment that uses a range of waste simulants for testing of a virtual prototype.

1 Executive Summary

A technical readiness assessment (TRA) of the ^{233}Uranium Downblending and Disposition Project (^{233}U Project) at Oak Ridge National Laboratory was conducted from July 7 through 11 2008. The ^{233}U Project's mission is to downblend the ^{233}U currently held in Building 3019 to resolve security and safety concerns and to prepare the material for transport for final disposition.

The project's plans are to downblend the ^{233}U to meet the waste acceptance criteria (WAC) at the Waste Isolation Pilot Project (WIPP) and/or the Nevada Test Site (NTS), whichever is appropriate. The Consolidated Edison Uranium Solidification Project (CEUSP) material, which makes up almost three fourths of the ^{233}U inventory, was expected to meet the WIPP WAC, even after dilution from the downblending operations. However, the team determined that based on the limited concentrations of TRU Isotopes in the CEUSP material, the uncertainties in the characterization data of that same inventory, and the potential for loss due to hold-up of TRU constituents in the processing equipment, it is uncertain whether all the downblended material would meet the WAC at WIPP. This downblended CEUSP material might meet the definition of MLLW for acceptance at NTS. However, NTS is permitted to receive only 20,000 cubic meters of MLLW and must permanently close MLLW operations by 2010 or sooner if its volume capacity is reached. Because the ^{233}U Project's blending operations will start after 2010, this will leave WIPP as the only viable path forward for the CEUSP material, unless there is policy change.

The assessment also identified four critical technology elements (CTEs) whose current level of maturity needs to be further advanced prior to the completion of final design efforts. These CTEs are in the following areas:

(1) Analytical Laboratory
(2) Concentration
(3) Product Packaging
(4) Off-Gas Treatment

In each of these areas, except for off-gas treatment, additional testing is needed to ensure the CTEs will perform their required functions as planned. For off-gas treatment, the project needs to either demonstrate that the proposed design will capture the radon daughter product particulates or modify the design to include another CTE to ensure the radon daughter product particulate is captured.

Observations relevant to the 30% Design Review, which was conducted in parallel with the TRA, are included in Appendix D.

2 Introduction

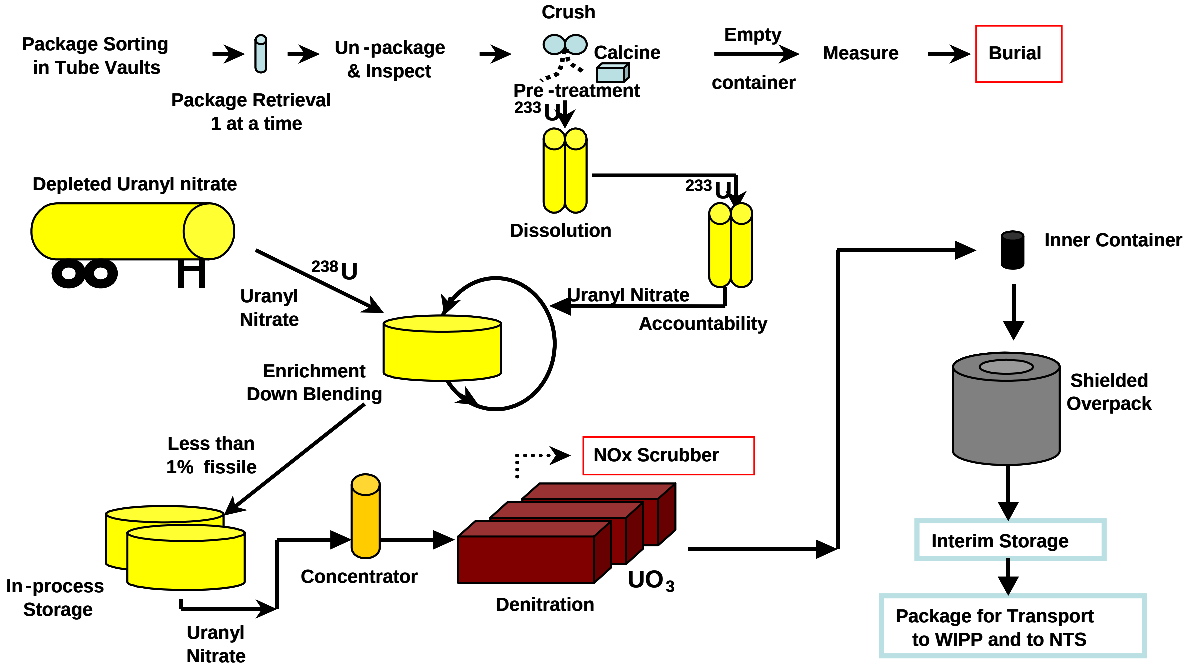
This section presents an overview of the ^{233}Uranium Downblending and Disposition Project, identifies the Technology Readiness Assessment (TRA) objectives and provides a summary of the TRA process.

2.1 ^{233}Uranium Downblending and Disposition Project

The ^{233}Uranium project was originally managed by the DOE Office of Nuclear Energy (NE) as the "Medical Isotope Production and Building 3019 Complex Shutdown Project," at the Oak Ridge National Laboratory (ORNL). The project objectives included ^{229}Th extraction from the ^{233}U for use in medical research applications. In fiscal year (FY) 2006, Congress directed the Department to terminate thorium extraction efforts and transferred responsibility for management and disposition of the ^{233}U inventory in Building 3019 to the Office of Environmental Management (EM). At the time the project was transferred to EM, the original design had reached 90% completion. NE had conducted 30%, 60%, and 90% design reviews (DRs) prior to the transfer to EM.

Under EM ownership, the project was renamed to the "^{233}U Downblending and Disposition Project" (^{233}U Project) consistent with the project objectives. The original project scope was revised to eliminate the thorium extraction step, include the processing of the ^{233}U contained in UF_6 traps obtained from the Molten Salt Reactor Experiment (MSRE), and provide for packaging and final disposal of the material. The ^{233}U Project also includes the design and construction of Building 3019A facility modifications and the installation of process equipment. The planned downblending and disposition process is illustrated below.

Figure 2-1 ^{233}U Downblending and Disposition Process Diagram



The ^{233}U Project is being implemented through a contract directly with the DOE ORO that was awarded to Isotek Systems, LLC (Isotek) which currently occupies space in and manages the operations of Building 3019A. Isotek is a partnership of Energy Solutions (ES), Nuclear Fuel Services (NFS), and Burns and Roe Enterprises, Inc. (BREI). Isotek is the prime contractor responsible for the ^{233}U Project's performance and utilizes staff and capabilities of the parent companies to accomplish project objectives. ES has been primarily responsible for management, NFS is responsible for the process definition, and BREI is responsible for equipment and facility design.

The ^{233}U Project underwent a 60% DR under EM management in December 2007. This 60% DR concluded that the design was less than 60% complete, and more likely in the early preliminary design stage because of the status of the safety analyses. The subsequent ^{233}U Project schedule identified a 30% Design Review (DR) in July 2008 on the process components downstream of enrichment downblending, the "back end" of the process.

It was at the request of the Federal Project Director (FPD) that the TRA be conducted coincident with the 30% DR for the back end of the process (GC-2 package for drying and packaging operations) to avoid scheduling separate reviews with the contractor, and to afford the project the benefits from the TRA earlier than otherwise. Although the DR only focused on the back end of the process, the scope of the TRA included the entire ^{233}U Project. The FPD intends to incorporate any technology readiness issues identified by the TRA into the ^{233}U Project's technology maturation plans and to include any design related observations identified by the TRA Team into the 30% design review, as appropriate.

2.2 TRA Objectives

The purpose of this TRA was to determine the technology readiness levels of the ^{233}U Project technology elements using the prescribed methodology contained in EM's Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide. This TRA:

- Evaluated the entire scope of the ^{233}U Project.
- Identified the critical technology elements (CTE).
- Determined the Technology Readiness Level (TRL) associated with each CTE.

This TRA also had another objective which was to identify any design observations associated with the back end of the process for use by the FPD in the 30% design review effort. These observations are included as Appendix D.

The FPD, working with Isotek, will develop the necessary technology maturation plans to ensure that the CTEs are further developed on an appropriate schedule to limit the risks that these CTEs currently pose to the project.

2.3 TRA Process Summary

EM's Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide (TRA/TMP Process Guide) was first published in March 2008. As discussed in this guide, the TRA process consists of three parts:

(1) identifying the CTEs,
(2) assessing the TRL of each CTE, and
(3) preparing the TRA report.

The TRA was performed in accordance with the process guidance contained in the TRA/TMP Process Guide.

Consistent with this guide, it is expected that for the CTEs identified by the TRA process as having achieved a readiness level below the desired level, the FPD will oversee the development of a technology maturation plan that identifies the additional development required by the contractor to attain the desired level of readiness prior to beginning final design.

2.4 TRA Team Members

The ^{233}U Project TRA was performed by the following TRA team members (the Team) whose biographies are presented in Appendix A:

Dr. Herb Sutter, Team Leader
Mr. Tim Hayes
Dr. Leroy Lewis
Dr. Steven Ross
Mr. Al Baione

The Team members have no responsibilities associated with the ^{233}U Project.

3 TRA Results

The results of the TRA are presented in this section.

The on-site portion of the TRA review was held in Oak Ridge during the period July7-11, 2008. Isotek personnel presented descriptions of the ^{233}U Project process steps, described the technology selection, research and testing plans or results, and participated in the completion of the responses to the individual questions in the TRL Calculator. The Assessment Team subsequently completed independent due-diligence reviews and evaluations of the testing and design information identified during the on-site review to validate the input obtained during the on-site working sessions.

The TRA results are presented below in two parts: the CTE determination, followed by the TRL determination for each CTE. However, before the TRA results are presented, the TRA Team identified the following significant uncertainty in the ability of the ^{233}U Project to perform its mission. This uncertainty involves whether the product resulting from processing the CEUSP material will be able to meet the waste acceptance criteria (WAC) at the Waste Isolation Pilot Project (WIPP). The downblended material might meet the definition of MLLW for acceptance at NTS. However, NTS is permitted to receive only 20,000 cubic meters of MLLW and must permanently close MLLW operations by 2010 or sooner if volume capacity is reached. Because the ^{233}U Project's blending operations will start after 2010, this will leave WIPP as the only viable path forward for the CEUSP material, unless there is policy change.

3.1 CEUSP Material may Not Be Able To Meet Product Specifications

About three quarters of the inventory of ^{233}U is in the form of CEUSP material which was produced under a prior thorium-to-uranium conversion program. The CEUSP material contains significant concentrations of cadmium (neutron poison) and based on available data, would fail the Resource Conservation and Recovery Act Toxic Characteristic Leaching Procedure, even after downblending and oxidation. It is stored in metal cylinders approximately 4 inches in diameter and about 25 inches tall. The physical form of the CEUSP material is referred to as a monolith (a right circular cylinder, resulting from the way the CEUSP monolith was formed by dripping concentrated uranyl nitrate into the hot canister so that U_3O_8 was produced). Isotek's design allows the dissolution of one CEUSP monolith per dissolution batch, and no more than six batches will subsequently be combined and downblended at a time.

Only a limited number of analytical sample results exist that describe the TRU isotopic content of the CEUSP monoliths. Two of the four available TRU isotopic concentration measurements indicate that the TRU isotope concentrations are so low that once dissolved and downblended, the resulting material would not meet WIPP's TRU WAC of 100 nanoCi/gm. Additionally, the available data is not traceable to specific containers, making it impossible to determine whether specific CEUSP monoliths chosen for a dissolution batch collectively contain sufficient TRU to meet the TRU WAC. The physical form and radiation levels associated with the CEUSP material make it difficult to obtain additional TRU isotope measurements.

Additionally, even if the TRU isotopic concentration in the CEUSP monoliths were sufficient, the process design assumes that all of the plutonium (which is the major TRU isotope in the CEUSP) dissolves in nitric acid. Although Isotek has cited prior industry experience in dissolving plutonium in nitric acid, this experience is likely based on dissolution of low-fired plutonium (plutonium resulting from processing at temperatures no greater than 600 °C to 700 °C). However, the CEUSP material was oxidized at 800°C, which is considered high-fired. Experience at LANL and PNL indicate that it is not possible to dissolve high-fired plutonium oxide in nitric acid. Consequently, because the plutonium in the CEUSP is not likely to dissolve, it will be collected as a solid in the filters downstream of the dissolution process step, further reducing the TRU content of the downblended CEUSP material.

The above was not considered a critical technology element, and consequently, it was not included as a CTE item in the discussion below.

3.2 CTE Determination

The ^{233}U Process was broken down into individual processing steps by the Team Leader. (See Figure 2.1). With the aid of Isotek staff, the assessment team evaluated each process step to determine if it was a CTE. Many of the process steps use technologies and equipment that have been successfully employed in uranium processing in private industry or elsewhere in the DOE Complex. The Technology Element Evaluation shown in Table 3-1, below contains the results of the CTE determination. See Appendix B (CTE Forms) for more details.

Technology	Scale	System Fidelity	Environment	CTE?
Canister Handling	Full	Identical	Relevant, Actual Material	No
Canister Opening	Full	Similar (Non Remote)	Relevant,Actual/Simulated (Non Remote)	No
Pretreatment (Heating/Crushing)	Full	Identical	Relevant (Uranium)	No
Dissolution	2/3 or Full	Identical	Relevant, Actual/Simulant (Uranium)	No
Accountability Fluoride Treatment	Full	Identical	Relevant, Actual/Simulant (Uranium)	No
Blenddown	Full	Identical	Relevant, Actual Material (Uranium)	No
Analytical Laboratory	**Full**	**Identical**	**Simulated, Simulant (Uranium)**	**Yes**
Depleted Uranium Operations	Full	Identical	Relevant, Actual Material	No
Concentration	**Full**	**Pieces**	**Relevant, Simulant (Uranium)**	**Yes**
Oxide Conversion	Full	Identical	Operational	No
Product Packaging	**Full**	**Pieces**	**Simulated**	**Yes**
Off-Gas Treatment	**Full**	**Pieces**	**Simulated**	**Yes**
Low Level Waste	Full	Identical	Relevant	No

Table 3-1 Technology Element Evaluation

From this table, it can be seen that at time that the ^{233}U Project was reviewed, the Team determined that there were the following four CTEs:

(1) Analytical Laboratory
(2) Concentration
(3) Product Packaging
(4) Off-Gas Treatment

3.3 TRL Determination

The Team completed a TRL assessment for each CTE using the TRL Criteria (questions) identified in the TRA/TMP Process Guide, and the results are summarized in this section. Each response to a specific TRL question was recorded, along with references to the appropriate documents. Upon completion of the due diligence review, TRL levels were adjusted as appropriate as discussed below. Appendix C provides the final TRL results for each CTE.

3.3.1 Analytical Laboratory

3.3.1.1 Function of the Analytical Laboratory

The analytical laboratory is tasked with providing analytical data for use in process control, production scheduling, material accountability, waste characterization, and nuclear criticality safety. Analyses will include: total uranium, isotopes of uranium, transuranic (TRU) isotopes, fluoride, chloride, hazardous species such as RCRA metals, and elemental impurities.

3.3.1.2 Description of the Analytical Laboratory

The laboratory will be housed in building 3019. Final plans for the laboratory layout and instrumentation have not been completed. Major instruments will include: High Resolution Inductively Coupled Plasma/Mass Spectrometer (HR-ICP-MS, for elemental, isotopic, and RCRA metal analysis), Ion Chromatograph (IC, for fluoride and chloride analysis), autotitrators (for Davies-Grey, DG, determination of total uranium), and alpha and gamma spectrometers (for radioactive species, including TRU, analysis).

Current plans are for the laboratory to obtain WIPP certification. Other certifications (e.g., RCRA) may be sought.

3.3.1.3 Relationship to Other Systems

As noted in Section 3.2.2.1 the laboratory will interact with and serve almost every part of the project. The downblending process cannot function without timely and accurate analysis. For example, a four hour maximum turn-around-time (TAT) for total uranium, isotopes of uranium and TRU is required to support production scheduling. The laboratory must also certify that wastes meet the Waste Acceptance Criteria (WAC) of the sites used for final disposition of downblended material and other wastes.

3.3.1.4 Development History and Status

Analytical approaches have not been finalized. Proposed analytical approaches listed in Table 3-2 are based on technologies and methods used in NFS laboratories, the uranium processing industry, and the DOE Complex. However, the use of HR-ICP/MS to determine Isotopic U in downblending samples is a new or novel application of an existing method/instrument. The determination of TRU by alpha spectroscopy takes 2-3 days making the method unsuitable for process control which requires a four hour TAT. The project is investigating methods (including HR-ICP/MS) that can meet TAT and TRU sensitivity requirements for process control.

Table 3-2 Proposed Analytical Approaches

Analyte	Method/ Instrumentation	History/Status
Total U	Davies-Grey titration Autotitrators	Standard method and instrumentation in use throughout the U industry and DOE Complex
Isotopic U	Mass Spectroscopy (MS) HR-ICP/MS Alpha Spectroscopy	Thermal Ionization MS (TIMS) has been the standard approach. However, meeting the 4 hour TAT requested by the project for process control would be difficult. The project is investigating the use of HR-ICP/MS which can meet the TAT. HR-ICP/MS has been used at NFS, but has not yet been demonstrated to have the sensitivity and resolution that may be required for this project. Evaluation of this instrument with two vendors is underway. U-232 is present at levels that may not be measurable by MS methods. Alpha spectroscopy is a standard analytical technique. However, it requires 2-3 days for sample preparation and counting time and is unsuitable for process control.
Isotopic TRU	Alpha Spectroscopy HR-ICP/MS Yet to be Determined	Alpha spectroscopy is a standard analytical technique for TRU determinations. The 2-3 day TAT is acceptable for meeting disposal WAC certification but not for process control. The use of HR-ICP/MS for TRU determination is being investigated with vendors. HR-ICP/MS cannot distinguish Pu-238 from U-238. Other isotopic interferences may exist. Isotek has not yet found a method for TRU analysis that can meet project requirements for TAT and sensitivity.
Elemental Impurities	ICP/MS	ICP/MS is a standard technique for elemental impurities in use at NFS and elsewhere.
Fluoride/ Chloride	Ion Chromatography (IC)	IC is a standard technique for fluoride and chloride that is in use at NFS
Fission Products	Gamma Spectroscopy	Gamma spectroscopy is a standard technique for fission products.
% Moisture in UO_3	Loss-On-Ignition (LOI)	LOI has been used by NFS in the past to determine moisture on UO_3 powders

3.3.1.5 Relevant Environment

The parameters that define the relevant environment are the concentrations of the species in the analytical samples and the accuracy and precision required for each analyte. Estimates of these parameters exist. However, detailed data quality objectives (DQOs) do not appear to exist at this time. Specifically:

1. Incoming material, especially the CEUSP material is not well characterized. TRU concentration and speciation appears to be particularly uncertain.
2. Process limits have not been translated into analytical requirements.
3. WAC requirements for the proposed disposition paths have not been translated into required accuracy and precision values.

Downblending samples will contain high concentrations of ^{238}U that may interfere with some determinations.

3.3.1.6 Comparison of the Relevant Environment and the Demonstrated Environment

The major differences between the relevant and demonstrated environment are the TATs, sensitivity and resolution that may be required for some analytes and the high uranium background in the downblending samples that may interfere with some determinations.

3.3.1.7 Technology Readiness Level Determination

The analytical laboratory was initially evaluated for TRL 5. However, the large number of negative responses generated at this level caused a second evaluation for TRL 4 where a number of negative responses were also generated. Consequently, the analytical laboratory was rated a TRL of 3. The reasons for the TRL 3 determination are contained in the TRL Evaluation Tables C-1 and C-2 in Appendix C, and include:

1. Although high level analytical needs are related to proposed analytical approaches, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements (data quality objectives, DQOs) such as detection limits, precision, and accuracy from process and waste acceptance requirements.
2. Full scale instrumentation exists, but testing is not complete.
3. Key physical and chemical properties have not been well characterized for the CEUSP material.
4. Laboratory-scale tests on a limited range of simulants, although planed, have yet to be completed for HR-ICP/MS[2].
5. There are no test plans to evaluate instrumentation other than HR-ICP/MS.

<u>Recommendations</u>:

1. The project should develop a detailed Sampling and Analysis plan.
2. The project should develop a complete set of DQOs. The DQOs should contain requirements for TATs, detection limits, precision and accuracy derived from disposal WACs, process control, and other requirements.

3. The project should develop success criteria for methods/instrument testing based on the DQOs. The HR-ICP/MS testing that is planned lacks such criteria.
4. The project should develop and test simulants for major analytical procedures. A start has been made for the HR-ICP/MS testing. Similar work should, at a minimum, be done for the TRU alpha spectroscopy procedure.
5. The project must successfully complete its search for methods for TRU analysis suitable for process control

Given the early stage of the project and the lack of defined DQOs, the analytical TRL of 3 is not surprising. Once a detailed Sampling and Analysis Plan and DQOs are established, the development and implementation of method/instrument test plans leading to a TRL of 6 should be neither difficult nor expensive to complete.

3.3.2 Concentration

3.3.2.1 Functions

The denitration pathway contains two Wiped Film Evaporators (WFEs) that operate in parallel. The WFEs increase the concentration of the uranyl nitrate hexahydrate (UNH) process stream from a nominal 400 g-U/liter input to a nominal 1,000 g-U/liter output. This increase in process stream concentration relieves a portion of the energy burden on the downstream thermal treatment units by removing a large percentage of the water. A second reason to raise the concentration is to reduce the off-gas volume which would contain uranium oxide dust. The UNH concentration (melting point 60.2 °C) becomes very high and process lines must be heated to prevent solidification in the piping.

3.3.2.2 Overall Description

The WFE input is the downblended UN from two in-process storage tanks (T_1000 and T_1001). Both storage tanks feed a single evaporator head tank (T_1005). Tank T_1005 feeds each WFEs at a nominal rate of 22 kg-U/hour (approximately 1 liter/min.). The output flow for each concentrator is about 0.37 liters/min. This output stream goes to two denitrator feed tanks (T_1006 and T_1506) and then on to the thermal treatment units.

3.3.2.3 Relationship to Other Systems

The WFEs use 125 psig steam as the heat source (approximately 180 °C) while the output process lines are heat-jacketed to maintain 80 °C to prevent in-line precipitation. The WFE ouput is monitored for density as its only process control parameter. The control limits on the WFE output is +/- 10 % of the nominal value. If the density is within this range, the WFE output goes to the denitrator feed tank. If the density exceeds this range, the concentrated output recirculates back to the evaporator head tank (T_1005) where it mixes with the low concentration feed stock as a diluent. If the output concentration is below this range, it recirculates back to the WFE for another cycle of concentration. The flow of process steam to the WFE is controlled automatically by a signal from the in-line density meter. Feedstock flow to the WFE is controlled by level monitors in the denitrator feed tank. Recirculation loops are set by manually operated valves.

3.3.2.4 Development History and Status

Wiped Film Evaporators are a mature technology used in a broad range of applications. A variant of thin film evaporators, they are used to separate volatile from non-volatile components in a process stream while minimizing product degradation and carryover. They are applied frequently in the food and pharmaceutical industries to separate heat sensitive solid products from liquid feedstocks.

WFEs are commercially available in either vertical or horizontal orientation. They work by spreading the process stream over a rotating, heated surface to achieve both rapid heat transfer and good mixing. For temperature-sensitive feedstocks, WFEs frequently are operated at partial pressure to reduce solvent boiling points. Other applications place WFEs in sequence with each stage operating at slightly different conditions to obtain the desired output concentrations. WFEs have been in use for more than 50 years and in radiologic service with at least one patent dating from 1985.

3.3.2.5 Relevant Environment

The Wiped Film Evaporator extracts water from the uranyl nitrate hexahydrate process stream. The operating environment inside the WFE is elevated temperature and reduced pressure. A feed back signal from an in-line mass flow density meter modulates the flow of nominal 125 psig steam. Assuming saturated steam, that pressure implies a temperature in the range of 175 to 180 °C. Since water has such a high latent high of vaporization, the operating temperature probably is lower. Reduced internal pressure assists vaporization by lower the boiling point of water. An ancillary vacuum pump maintains the reduced pressure at approximately 100 Torr. A low flow (2 scfh) of nitrogen cools the mechanical seals on the wiper rotor shaft. The primary feedstock enters the WFE at a temperature of 80 °C and concentration of about 400 g-U/liter which contains about 720 million Ci/liter of uranium (roughly about 5 million Ci/liter from ^{238}U and the balance from ^{233}U) assuming an intial concentration of 400 gm-downblended U/liter. It leaves with viscosity of 25 cP or greater and a two and one-half fold increase in concentration to about 1000 g-U/liter.

The external environment of the WFE is a room in Building 3019 modified to support the equipment racks of the entire process. The space is divided into confinement zones and air flow is maintained from zones of less contamination to zones of higher contamination. Air flow is sized to provide air changes sufficient to remove waste heat generated by the process equipment.

3.3.2.6 Comparison of the Relevant Environment and the Demonstrated Environment

The competing technology for the WFE is the thermosiphon (TS). TS technology has a long history of application in a radioactive environment. Although patents describing the use WFE technology in a radioactive environment were issued, the operating history does not seem to be nearly as extensive as that for TS. Selection of WFE over TS is based on the following characteristics: self-cleaning, ability to handling viscous process streams, ability to monitor performance, ability to flush prior to maintenance, and a WFE's horizontal orientation. Each factor was weighted equally. The long term performance of the bearing elastomeric seal in a radiation environment is an unknown.

3.3.2.7 Technology Readiness Level Determination

The Technical Readiness Level of the Wiped Film Evaporator was set at 4 and all negative responses were based technical aspects, all for the same reason: the need for testing with simulated wastes. In every case testing with simulants is planned and the test procedure is in development. However, since the test results are not available, affirmative responses could not be given. An unavoidable deficiency in testing is the inability to test with authentic waste. Thus, the performance of the elastomeric seal on the WFE rotor shaft will be an unknown until operational data has been collected.

Wiped Film Evaporators are a mature, reliable technology. The only thing that limits this technology to a higher TRL rating is the lack of specific test data. All other requirements at this Technical Readiness Level have been satisfied. The required testing is planned and the test procedures are in development. The expectation is that testing with simulated waste will be successful and supply the performance data desired.

3.3.3 Product Packaging

3.3.3.1 Functions

The product packaging system performs the following main functions:

- Placement of lead overpacks, preloaded with empty drums onto the conveyor system
- Overpack/Drum staging area to ensure drums are available for filling
- Overpack lid and drum secondary lid removal
- Remote drum handling to support automated loading with granular UO3 product using a bagless transfer design.
- Insuring the UO3 product is sufficiently cooled, prior to loading into the drum.
- Drum surface monitoring to demonstrate the absence of surface contamination.
- Reinstating the drum secondary lid and overpack lid

3.3.3.2 Overall Description

The product packaging portion of the process design is located on the ground floor. Using remote, automated handling techniques, it enables loading granular UO_3 product into a custom designed 55 gallon drum contained in a government-furnished, lead shielded overpack through the following process steps:

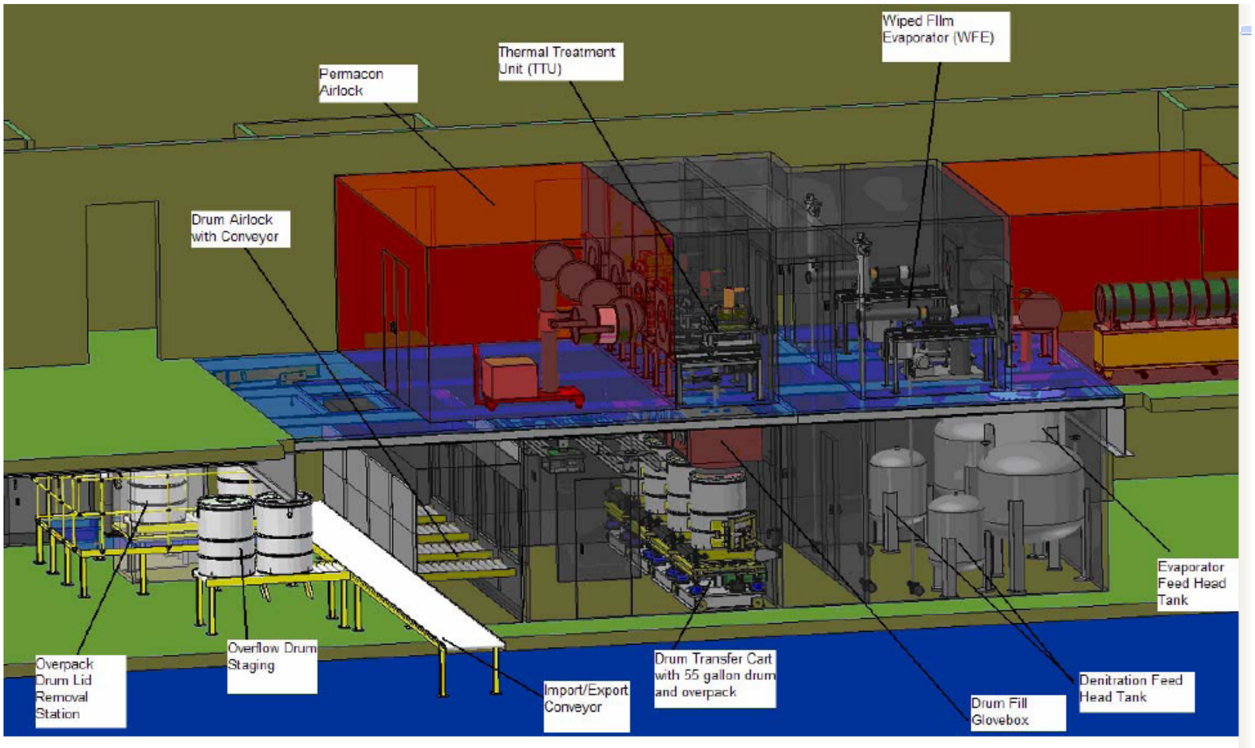
- A powered conveyer moves the drum and over-pack through an airlock and within the drum loading area.
- The drum’s outer lid is removed once inside confinement and the drum is then translated into the shielded loading station.
- The drum is raised to create a “bagless transfer” seal with the loading station.
- After the drum is raised and mated to the underside of the loading station (directly below the TTU on the main floor), the drum’s inner cover is removed.
- Once this inner cover is removed, the contaminated product transfer equipment will communicate directly with the interior of the drum, but not the external surfaces of the drum.
- Product transfer equipment is positioned to load the drum, a product transfer valve is opened and the product is transferred (by gravity) into the drum.
- Once fully loaded, the transfer equipment is retracted, drum’s inner cover is replaced, the drum is lowered and the drum is swiped and translated back to reattach the outer lid.

- The drum cover is swiped to confirm that it is not contaminated and it is moved out of the airlock.

The system design provides the ability to simultaneously load product directly from each of the four TTUs. Each loading area is isolated from the other loading areas.

The overall arrangement of the packaging equipment is shown in Figure 3-1.

Figure 3-1 Product Handling Equipment Overall Arrangement and Interfaces



3.3.3.3 Relationship to Other Systems

The product packaging system interfaces with the TTU in that it receives the uranium oxide product by gravity feed once the drum is properly positioned and the transfer valve is opened. Because the drum will communicate with the TTU when the product is being transferred, the drum will form part of the negative pressure boundary of the off-gas system.

A product cooling system is also intended to be utilized to cool the product, but because its design has not been developed, interfaces can not be identified at this time.

Additionally, the drum needs to be monitored during processing, such as during its various movements to assure proper positioning for cover removal, for product transfer sealing and alignment and during product loading in order to determine when the drum is full (e. g., measure the weight of the drum). Consequently, the packaging system's controls and associated interlocks will interface with the control room and related systems.

3.3.3.4 Development History and Status

The drum transfer system utilizes commercial conveyors configured as needed to move the drums which have external dimensions of a standard 55 gallon drum (contained within the overpack, which provides about 3" of lead shielding). Also, the drum elevation equipment design is functionally identical to a unit designed, built, tested and operated at the Idaho Advanced Mixed Waste Treatment Plant (AMWTP). At AMWTP, 100 gallon drums are raised and filled (also using a bagless transfer) to about 1,000 pounds, resulting in the two main transfer and elevation system differences between the ^{233}U Process and the AMWTP being drum size and weight.

The bagless transfer equipment custom design for the ^{233}U Process is based on other custom designed, bagless transfer equipment. Such designs are in use at AMWTP and commercially.

At the time of the TRA, the exact means of cooling the product, determining when the drum is full, how the flow of product will be interrupted during drum change-out and the process for performing the confirmatory surface contamination swipe have not been determined at the time of the TRA was conducted.

Isotek, through EnergySolutions, is currently preparing to test a full-scale bagless transfer prototype design using simulant on a project for Savannah River. This Savannah River design will automatically and remotely load drums with a low-level liquid waste slurry and Portland cement, and then mix the drum contents. Isotek plans to incorporate lessons learned from this Savannah River experience into the ^{233}U Process design.

In ISO-SDD-006, Isotek plans drum loading testing by the manufacturer, which Isotek will witness, using a surrogate material. Testing described in ISO-SDD-006 included planned integrated testing of the concentrators, TTUs and the process off-gas system, but did not include the packaging equipment and its associated bagless transfer system (which mates up with the TTU product transfer tube) as part of this integrated manufacturer testing.

ISO-SDD-006 indicated that prototypes of the custom designed 55 gallon drums are to be sent to the drum loading station vendor for use in loading station testing, although the government-furnished shielded overpack was not mentioned.

3.3.3.5 Relevant Environment

The drum packaging process needs to automatically and remotely transfer high specific activity UO_3 as a dry, thermally hot solid, which is expected to contain fine particulate, without contaminating the exposed surfaces of the drum, overpack and surrounding transfer station (e.g., the overpack handling station and conveyors below the product filling equipment containment boundary). Additionally, due to absence of a product cooling system design, the temperature that the drum transfer and closure seals need to withstand still needs to be identified.

3.3.3.6 Comparison of the Relevant Environment and the Demonstrated Environment

The relevant environment for the product packaging system includes the following conditions that were not included in the demonstrated environment identified by Isotek:

- The high specific activity of the isotopes in the product, along with some product being in the form of a fine particulate, is expected to result in migration of this particulate to non-contaminated surfaces, making its confinement hard to maintain. Isotek noted some potential for contamination of the outside surface of the inner cover after it is reattached to the drum. The Team notes that the outside surface of the cover will be exposed to contaminated surfaces when the cover is removed from the drum (the cover removal tool surfaces that are protected when it holds the cover will become exposed to the contaminated side of the transfer station when the tool is not attached to a drum cover. Subsequent attachment of this tool to the covers of subsequent drums is likely to contaminate the outer surface of these covers). Consequently, the Team expects that this cover surface will be increasingly contaminated over time as more and more drums are loaded, allowing further spread of this particulate in areas not expected by Isotek to become contaminated.

- The remote, automated positioning of the drum requires increased precision in the ^{233}U packaging because of the presence of the shielded overpack. Clearances between the drum and overpack, along with manufacturing tolerances on both pieces of equipment, will complicate drum to loading station transfer seal performance, drum cover manipulations and transfer tube positioning.

And given the incomplete nature of the design features identified in Section 3.3.3.2 above, the following considerations further illustrate the need for TTU/drum loading integrated testing:

- The total weight (drum and overpack) being lifted and held in position to maintain the drum-to-loading station transfer seal is much larger in the ^{233}U process due to the weight of the overpack. Drum content measurement (weighing) and thermal expansion (depending on the product cooling design, see below) also have the potential to affect the ability to maintain this seal.
- The temperature of the product when it reaches the drum (350°C at the TTU) may affect the performance of the drum's elastomer seals, thermal expansion may complicate maintaining a proper transfer seal and the cooler drum surface temperatures could result in condensation on internal drum surfaces.

Recommendation

Testing of the packaging system using the actual environment (^{233}U powders) is not practicable, but simulated testing with powders, multiple repetitions of simulated transfers (allowing the powder to build up on surfaces and possibly spread) and tightly specified acceptance criteria should be considered when performing integrated system testing after all design features have been defined.

3.3.3.7 Technology Readiness Level Determination

The ^{233}U Process product packaging system technology is a TRL 3, because there has not been testing of the integrated, prototypical system in the same or relevant environment. Appendix C-4 contains the answers to the TRL Criteria (questions) identified in the TRA/TMP Process Guide.

3.3.4 Off-Gas Treatment

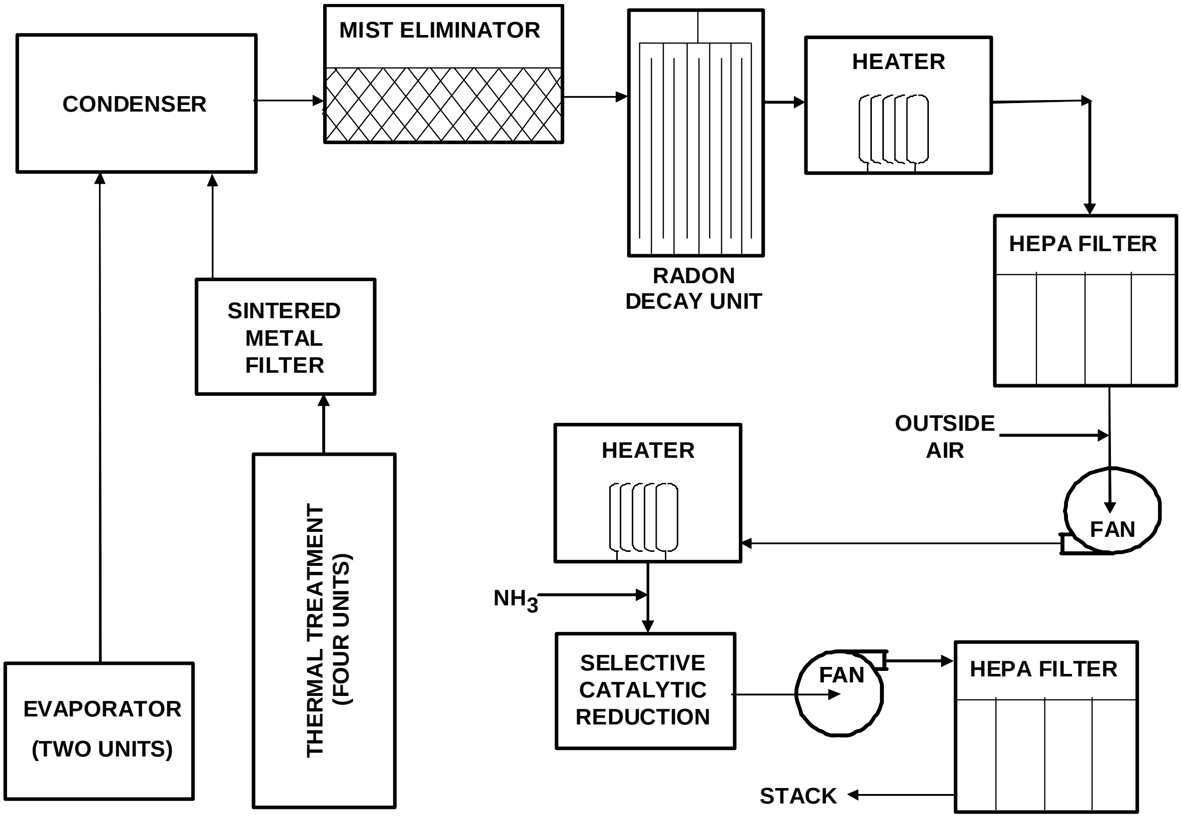
3.3.4.1 Function of the Off-Gas Treatment System

The off-gas system for the U-233 Blend-Down Project provides ventilation for the entire process of preparing the U-233 material for down-blending and denitration. The air is collected from the vessels, the cells, the laboratories and the working areas and processed through filters, condensers, and reactors to remove radioactive and chemical materials to prevent these materials being released at concentrations above the permissible levels, through a stack, to the environment. Treatment of the off-gas is required to meet the levels specified in the air permit prior to release to the environment.

3.3.4.2 Description of the Off-Gas Treatment System

A standard building ventilation system draws a vacuum from the process cells, operating corridors, and process vessels and filters it through high efficiency particulate filters (HEPA) prior to releasing it to the atmosphere through the stack. The off-gas from the dissolver, concentrator and the TTU requires more sophisticated treatment due to the presence of Radon-220, a daughter of U-232, and nitrogen oxides (NOx) released during processing. This off-gas system has two trains; the first receives the off-gas from the dissolver units and the second receives the off-gas from the evaporators and TTUs. Although this off-gas system is still being designed, the second train is expected to have the components shown in Figure 3-2 which collect the off-gas from the evaporator and TTUs.

Figure 3-2: Downblending Off-Gas system



The system consists of a sintered metal filter which is closely coupled to the TTU so that any particulate collected by the filter can be returned directly into the TTU vessel. A condenser follows the sintered metal filter and is used to remove some of the water vapor in the off-gas stream. The off-gas stream then enters a large vessel filled with a honeycomb material which is designed to delay gases for twenty-two minutes before they move to the next component in the off-gas train. This delay is sufficient to hold up the Rn-220 for more than 23 half-lives which means that the Rn-220 concentration is reduced by a factor of more than one million. Following the radon holdup tank, a heater brings the off-gas stream up to a temperature above the dew point to prevent water from absorbing on the HEPA filter media and causing a HEPA failure. Following the HEPA filter, a fan is used to increase the velocity of the air flow and to dilute it by a factor of approximately 20 with air from an outside source. This stream is then passed through a second heater to preheat the off-gas stream to facilitate the reaction with ammonia which decomposes the NOx in the solid catalytic reactor. The off gas stream then passes through a final HEPA filter and is discharged to the stack with all of the other sources of off-gas from the process and the building.

For the dissolver, its off-gas train is separate from but similar to the one shown in Figure 3-2, except that it does not include the selective catalytic reducer due to the absence of NOx in the dissolver off-gas.

3.3.4.3 Relationship to Other Systems in the Down-Blending Process

The off-gas system provides ventilation for the building, the processes in the building, and the laboratories. The off-gas system is a significant part of the safety system because it provides safe, clean air for the personnel occupied areas while removing contaminated air from the process vessels and the process cells. It also treats off-gas streams that contain hazardous particulates, chemical gasses, radioactive gasses to levels below those specified in the air permit for the site.

3.3.4.4 Development History and Status

The off-gas treatment train has been designed for the treatment of a small vessel off-gas stream which contains radon-220 and NOx. The train was designed to minimize the concentrations of Rn-220 and NOx which will be discharged from the stack. The original design used a hold-up vessel that would delay the passage of radon for eleven minutes. This time period would holdup the radon for more than eleven half-lives of the Rn-220, thus, reducing the concentration of radon to less than 0.05 % of the radon originally present when the U-233 was dissolved for the blenddown and thermally treated. The hold-up vessel design was subsequently revised to increase the holdup time to 22 minutes which provides 23 + half-lives on the Rn-220, resulting in a concentration of less than ten parts per billion of the original amount of radon fed to the dissolver and that produced by decay between the dissolver and the concentrator.

The design is currently at the 30% completion state as of the time of the review. All of the components of the design have been tested in other DOE projects and resembles the WTP melter off gas system that has been designed and tested by Energy Solutions. The only new or novel component is the radon treatment vessel and it will definitely hold up the radon until a large fraction of the radon has decayed to its decay daughters. However, the design of the treatment process did not consider the quantity of particulate daughter products of the Rn-220 that would agglomerate into particles less than the minimum particle size of 0.3 microns that the HEPA filter will trap. Since there is no simulant that would mimic this system, this has remained as an unresolved question.

Recommendations have been made to make no change in the design and take measurements on the off-gas releases from the first batch of processed material to determine whether additional measures should be taken, or to include in the design provisions for an electrostatic precipitator or a scrubber to allow the removal of these daughter products should it become necessary, and not take the chance that the off-gas will not meet the site release limits. These options are currently under consideration.

3.3.4.5 Relevant Environment

The parameters that define the relevant environment are the materials that are expected to escape operating vessels, the process cells, and the laboratories in the 3019 building and are carried by the air flow through any treatment to the stack. The contaminants in the air flow are well defined and the design has taken those into consideration in defining the parameters for the treatment systems being designed. The single unknown in this system is the behavior of the daughter products in the decay chain below radon-220. Because radon is a noble gas, it can escape into the atmosphere as soon as it is created. Thus, as the radon moves away from the parent material, subsequent daughters are produced at a remote site. These daughters are highly charged isotopes that rapidly decay to the highly energetic daughter, thallium-208. It is believed that these atoms will rapidly agglomerate through contact with solid material suspended in the air or on the surfaces in which it comes into contact. However, it is not known whether these particles would be large enough to be trapped by the HEPA filters.

3.3.4.6 Comparison of the Relevant Environment and the Demonstrated Environment

The relevant environment and the demonstrated environment are well characterized. The difference is that the capture of the radon daughters by the HEPA filters has not been demonstrated. It is postulated that the particulate will agglomerate sufficiently and that this particulate will be trapped by the HEPA filters. Because there had not been any measurements made at the levels required during the previous operations with these materials, it is not known whether sufficient agglomeration will occur to allow the HEPA filters to be effective at removing these particles. Since there is no cost effective way to simulate this phenomena, measurements may have to be made on the off-gas effluents when the processing systems are operating with the real material.

3.3.4.7 Technology Readiness Level Determination

The off-gas treatment was evaluated at a TRL 2 level because the fundamental assumption that the highly charged atomic particles are able to agglomerate enough to be trapped on a HEPA filter could not be validated. The reasons for the TRL 2 level are shown in Table 7 in Appendix C and include:

1. The predictions of HEPA filter capability were not validated by analytical studies.
2. The basic science has not been validated at the laboratory scale.
3. Laboratory experiments could not be performed because the experiments were not capable of being simulated.

Recommendations:

1. Measurements of the off-gas stream downstream of the HEPA filters during startup with the actual feed materials may show that there is no breakthrough of the daughter product particulate and that no action need be taken. However, waiting until startup to determine if the problem exists represents a substantial risk for the project, as a failure to meet emission standards could shut the project down. Laboratory testing, if it can be designed and carried out, or historical data, if it can be found, may reduce the risk.
2. Simple, commercial air cleaning equipment could be installed should it be necessary.

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5. Isotek Slide Presentation to the TRA team, 233U Project Technology, July 7, 2008
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2. *Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory,* NFS 53G-08-0006, May 2, 2008

Concentration

1. *Concentrator, Thermal Treatment Unit, Drum Packing and Process Off-Gas Structures, Systems and Components*, ISO-ENG-RPT-010, Rev. A, page 18, Energy Solutions, Oak Ridge, Tennessee, 12 May 2008;
2. Energy Solutions Drawing DOW-FO433-P, page 3 of 12;
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Product Packaging

1. DEN-530-1-M, *Drum Packaging System, Mechanical Handling Diagram*, Rev A

Off-Gas Treatment

1. *Technical Handbook of U233 Material Properties, Processing, and Handling Guidelines,* ORNL/TM-13600, April 1999

Appendix A. Technology Readiness Assessment Team Resumes and Meeting Attendees

A.1 TECHNOLOGY READINESS ASSESSMENT TEAM RESUMES

HERBERT G. SUTTER, Team Leader

Education

A.B. Chemistry, Hamilton College
Ph.D. Physical Chemistry, Brown University
Post Doctoral Theoretical Chemistry, Cambridge University, UK

Employer

Consultant

Representative Skills and Experience

Dr. Sutter has more than twenty-seven years experience in the fields of separations science, high and low level radioactive waste treatment, waste water treatment, vitrification, and analytical chemistry. For the past thirteen years he has provided technical and programmatic support to DOE's Office of Environmental Management (EM). Dr. Sutter has provided technical assistance to the DOE programs at Hanford, Savannah River, and other sites in: (1) separation technologies; (2) technology development; (3) high level waste disposal; (4); nuclear waste characterization; (5) vitrification; and (6) analytical laboratory management.

From 2005 to present, Dr. Sutter assists EM in the development of a long-term, complex-wide Project Plan for Technology Development and Demonstration that will incorporate all EM's TDD needs through completion of the EM cleanup mission. In 2002-2004, he was a senior scientist for Kenneth T. Lang Associates, Inc. and provided support to EM in several areas including the evaluation of HLW vitrification technologies at Hanford and pretreatment and separation technologies at Savannah River. He has also been a consultant to private industry on separation technologies. In 1990-2002 as a scientist for Science Applications International Corporation supported EM in the areas of nuclear waste treatment and characterization and analytical chemistry. In 1982-1990, Dr. Sutter was Vice President and Chief Scientist at Duratek Corporation and responsible for technical direction of all Duratek research and development and commercialization programs in ion exchange, filtration and separation techniques. Relevant experience includes: waste water treatment, bench and pilot testing, and waste treatment studies.

Publications

Dr. Sutter has authored or co-authored over 30 journal articles and technical reports.

Affiliations

Member of the American Chemical Society and the American Nuclear Society.

AL BAIONE

Education

BChE, Chemical Engineering, Villanova University
Graduate Studies in Chemical Engineering, Villanova University
Bettis Nuclear Reactor Engineering School (MS Equivalent), Bettis, Pennsylvania

Employer

DOE EM-21

Representative Skills and Experience

Mr. Baione possesses over 29 years experience leading teams and successfully performing technical projects for the Nuclear Regulatory Commission, the Department of Energy, Naval Reactors Headquarters and commercial customers. He is well versed in NRC licensing requirements and regulatory practices; DOE Rules, Orders and Guides; and Naval Reactors program standards, culture and practices. His experience includes nuclear facility design and construction, work planning, performance monitoring and oversight, focusing on assuring nuclear facility environment, safety and health requirement compliance. He has participated as a technical expert on DOE independent assessments and contributed to improving the safety posture of nuclear facilities at Pantex, Hanford, Rocky Flats, Savannah River, the Portsmouth Gaseous Diffusion Plant, and at the Idaho, Sandia and Los Alamos National Laboratories.

TIM HAYES

Education

B.S. Chemistry and Physics, New Mexico Institute of Mining and Technology
M.S. Chemistry, University of Nebraska

Employer

Los Alamos National Security, LLC.; Los Alamos National Laboratory – Carlsbad Operations

Representative Skills and Experience

Mr. Hayes has over 24 years experience in actinide chemistry with Los Alamos National Laboratory. In 1984 he joined the laboratory as a Graduate Student in the Uranium Chemistry and Separations Group. After completing Masters Degree in Chemistry in 1989, he returned to LANL and joined the Plutonium Recovery and Purification Group at the Plutonium Facility. In 1997, he was made Team Leader of all Recovery and Purification operations at the Plutonium Facility. In the years that followed, he held various supervisory and management positions at LANL in Waste Management, Nuclear Material Management, and Operations Management at the Division Level.

His career at LANL has given him experience performing, managing and supervising technical operations in a nuclear facility. This includes actinide recovery, technology development, nuclear materials disposition and handling, waste management, nuclear material shipping and receiving, and nuclear material control and accountability.

Currently Mr. Hayes is using his experience and background actinide science to develop plans for the disposition of difficult radioactive waste; conduct reserearch and technical analyses for the National Tranuranic Waste Program; development of position papers and upper level analyses on the dispositon of difficult waste; and the development of long-term strategies for the disposal of difficult waste.

Publications

Mr. Hayes has authored or co-authored over 20 technical reports directly related to actinide recovery operations.

LEROY C. LEWIS

Education:

B.S. Double Major in Chemistry and Mathematics, College of Idaho
Ph..D. Physical Chemistry, Oregon State University

Employer:

Battelle Energy Alliance

Representative Skills and Experience:

Dr. Lewis has more than 40 years of experience in the nuclear fuel cycle, particularly in the field of nuclear fuel reprocessing. This has included process support in separations, spent nuclear fuel storage, high and low level waste management, process development, and as the manager of the Analytical Chemistry Department performing the chemical analysis of samples generated during fuel and waste processing at the Idaho Chemical Processing Plant. During the time period from 1996 to 2003, Dr. Lewis was an Idaho National Laboratory, Science and Engineering Fellow. For the past five years, Dr. Lewis has been working in the area of Homeland Security and is providing technical assistance to DOE, Homeland Security, and DOD.

Dr. Lewis developed and patented a process that is currently still in use, for the treatment and stabilization of spent alkali metal reactor coolants. He managed a team and was actively involved in the design, construction, start-up and operation of the Remote Analytical Laboratory at the Idaho Chemical Processing Plant. He was a member of the three man team that was sent by the DOE to review the Tokaimura, Japan, criticality accident in 1999 and he was a member of an oversight committee reviewing the replacement of the in-tank precipitation process for high level waste at the Savannah River Plant. Dr. Lewis has served on DNFSB committees developing and implementing action plans for DNFSB findings, a committee reviewing the DOE Robotics Program, a committee that was developing techniques for the remote analysis of radioactive, EPA samples, Analytical Laboratory audits around the DOE Complex, and currently serves on a DOD Technical Review Panel.

Publications

Dr. Lewis has authored or co-authored over 75 journal articles, book chapters, technical reports, presentations, and has four patents.

Affiliations

Dr. Lewis is a member of the American Chemical Society, and has been a member of the American Institute of Chemical Engineers, the DOE Analytical Laboratory Managers Organization, the Institute of Nuclear Materials Management, and the ASTM.

STEVEN L. ROSS

Education

B. Sc. Chemistry, Central Michigan University
Ph. D. Biochemistry, Baylor College of Medicine
Post Doctoral Research, Biochemistry, Case Western Reserve University

Employer

U.S. Department of Energy, Office of Engineering and Technology

Representative Skills and Experience

Dr. Ross has nearly 30 years experience in the fields of high level and low level radioactive waste management, process control, equipment design and fabrication, prototyping, process chemistry and analytical chemistry. For seven years prior to coming to DOE he provided technical support to the Office of Civilian Radioactive Waste Management (RW). This work included development of the Waste Acceptance System Requirements Document, the Integrated Interface Control Document, an analysis of the Accelerator Transmutation of Waste proposal, and analyzed the impacts of a variety of U.S. Nuclear Regulatory Commission regulations on the management of radioactive waste including 10 CFR Parts 60, 61, 63, 72, 73, 74, 835, and 961.

Prior to consulting to DOE-RW Dr. Ross was the Manager of the Solidification Laboratory for Stock Equipment Company that manufacturer a cement-based system for the solidification of aqueous low-level radioactive waste (1979 – 1980). These waste streams are composed primarily of evaporator concentrates and spent ion exchange bead resin slurries, both from commercial power reactors. Dr. Ross wrote the Process Control Plan for seven different power plants. He also led the development of a solidification process using a water extendable carbohydrate polymer for waste streams that are chemically incompatible with the cement system.

Subsequent to Stock Equipment Company, Dr. Ross held several positions within ABB Automation, Inc. (1980 – 1999). These positions include Applications Engineer, Product Line Manager, and Project Manager. In these positions, he developed several process control algorithms for both small and large scale applications, using classical PID and ladder logic controllers as well as state of the art algorithms based on neural networks. Dr. Ross also was on the team that led to ABB Automation (formerly Bailey Controls Company) obtaining its first ever ISO 9000 certification.

Dr. Ross joined DOE's Office of Engineering and Technology in January 2008.

Publications and Patents

Dr. Ross has authored nine journal articles (one in press) and six patents.

A.2 MEETING ATTENDEES

The ^{233}U Project Technology Readiness Assessment Meetings were held at Pro2Serve offices in Oak Ridge on June 7-11. The participants are listed by name and organization:

Herbert Sutter, Team Lead, Pacific Northwest National Laboratory
Al Baione, Team Member, DOE HQ, EM-21
Tom Hayes, Team Member, LANL
Steven Ross, Team Member, DOE HQ, EM-21
Tim, Arcano, DOE HQ, EM-60
Gary Reiner, FPD ^{233}U Project, DOE ORO
Brian DeMonia, Project Manager, ^{233}U Project, DOE ORO
Donna Rioggs, DOE ORO
Patrick Smith, DOE ORO
Norm Brandon, Isotek
Ron Shaffer, Isotek
Clark Swenson, ORNL
Mark Smith, ORNL
John Kinlaw, ORNL
Robert Hoffman, ORNL
Kim Engle, ORNL
Vic Lomnicki, Pro2Serve
Brad Watson, Pro2Serve

Appendix B. Determination of the Critical Technology Elements

CTEs are those that are essential to successful operation of the facility, are new, or are being applied in new or novel ways or in new environments. The team determined the CTEs by assessing the each technology element against the two sets of questions identified in the EM TRA Guide. A CTE was identified if there was a positive response to at least one of the questions in each of the question sets. The specific responses to each of the questions for each technology is provided in Tables A-1 through A-13. A summary rationale for whether a technology represented a CTE is summarized below each table.

The Assessment Team identified the CTEs listed below.

- Analytical Laboratory
- Concentration
- Product Packaging
- Off-Gas Treatment

Table B-1 Technology: Canister Handling

Yes	**No**	**Set 1 - Criteria**
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Canister handling technology (involving grapples or suction cups) has been successfully employed to handle each of the waste forms involved.

Table B-2 Technology: Canister Opening

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Canister Opening technology has been successfully demonstrated for all three wasteforms.

Table B-3 Technology: Pretreatment (Heating, Crushing)

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Heating in a muffle furnace and crushing using a jaw crusher are standard technologies used in commercial uranium processing. These techniques will only be required for a limited number of samples.

Table B-4 Technology: Dissolution

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Dissolution of all three feed material forms has been demonstrated at full scale.

Table B-5 Technology: Accountability and Fluoride Treatment

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Both technologies have been demonstrated at full scale with uranium solutions.

Table B-6 Technology: Blenddown

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Uranium blenddown has been carried out at full scale by NFS.

Table B-7 Technology: Analytical Laboratory

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
X		• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

It has not been demonstrated that the standard analytical techniques (ICP-MS and Davies/Gray titration) that will be employed to measure uranium and TRU isotopes will have sufficient resolution and sensitivity in the presence of expected high concentrations of ^{238}U.

Table B-8 Technology: Depleted Uranium Operations

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Depleted uranium operations have been carried out at full scale.

Table B-9 Technology: Concentration

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
X		• Is the technology modified?
X		• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Although wiped film evaporators have been used in a wide variety of applications, the equipment represents a substantial modification of units previously used for uranium processing.

Table B-10 Technology: Oxide Conversion

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

The conversion technology and equipment has been used successfully in the uranium processing industry and the DOE Complex.

Table B-11 Technology: Product Packaging

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
X		• Is the technology modified?
X		• Has the technology been repackaged so a new relevant environment is realized?
X		• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

The bagless transfer design has not been demonstrated in the relevant environment.

Table B-12 Technology: Off Gas System

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
X		• Has the technology been repackaged so a new relevant environment is realized?
X		• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Capture of radon daughters has not been demonstrated.

Table B-13 Technology: Low Level Waste Handling

Yes	No	Set 1 - Criteria
X		• Does the technology directly impact a functional requirement of the process or facility?
	X	• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?
	X	• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?
	X	• Are there uncertainties in the definition of the end state requirements for this technology?
Yes	**No**	**Set 2 - Criteria**
	X	• Is the technology new or novel?
	X	• Is the technology modified?
	X	• Has the technology been repackaged so a new relevant environment is realized?
	X	• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?

Standard technology will be used for low level waste disposal.

Appendix C. Technology Readiness Level Calculator for the Critical Technology Elements of the ^{233}U Project

Appendix C summarizes the responses to the specific criteria identified in the Technology Readiness Level (TRL) Calculator for all critical technology elements (CTEs).

Table C-1 TRL 4: Analytical Laboratory (U and TRU Analysis)

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	The analytical needs are related to potential instrumentation in Selection of Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0003, April 30, 2008. However, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
M	Y	2. Laboratory components tested are surrogates for system components	Full scale equipment exists, but testing is not complete. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	3. Individual components tested in laboratory~~/~~ or by supplier	Full scale equipment exists, but testing is not complete. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	N	4. Subsystems composed of multiple components tested at lab scale using simulants	Full scale equipment exists, but testing is not complete. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	N/A	5. Modeling & Simulation used to simulate some components and interfaces between components	
P	Y	6. Overall system requirements for end user's application are known	The analytical needs are related to potential instrumentation in Selection of Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0003, April 30, 2008. However, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	7. Overall system requirements for end user's application are <u>documented</u>	The analytical needs are related to potential instrumentation in <u>Selection of Instrumentation for the U233 Project Analytical Laboratory</u>, NFS 53G-08-0003, April 30, 2008. However, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
P		8. System performance metrics measuring requirements have been established	Some analytical needs are related to potential instrumentation in <u>Selection of Instrumentation for the U233 Project Analytical Laboratory</u>, NFS 53G-08-0003, April 30, 2008. However, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
P	Y	9. Laboratory testing requirements derived from system requirements are established	The analytical needs are related to potential instrumentation in <u>Selection of Instrumentation for the U233 Project Analytical Laboratory</u>, NFS 53G-08-0003, April 30, 2008. However, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
M	Y	10. Available components assembled into laboratory scale system	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	11. Laboratory experiments with available components show that they work together	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	12. Analysis completed to establish component compatibility (Do components work together)	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P	N	13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	The analytical needs are related to potential instrumentation in Selection of Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0003, April 30, 2008. However, there is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
T	Y	14. Technology demonstrates basic functionality in simulated environment	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	17. Equipment scale-up relationships are understood/accounted for in technology development program	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	18. Controlled laboratory environment used in testing	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	19. Initial cost drivers identified	In project baseline costs.
M	N/A	20. Integration studies have been started	
P	Y	21. Formal risk management program initiated	Isotek program exists.
M	Y	22. Key manufacturing processes for equipment systems identified	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P	Y	23. Scaling documents and designs of technology have been completed	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	24. Key manufacturing processes assessed in laboratory	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P/T	Y	25. Functional process description developed. (Systems/subsystems identified)	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	26. Low fidelity technology "system" integration and engineering completed in a lab environment	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	N	28. Key physical and chemical properties have been characterized for a range of wastes	Ranges for CEUSP material do not exist.
T	N	29. A limited number of simulants have been developed that approximate the range of waste properties	See Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0006, May 2, 2008 for HR-ICP-MS simulants. None developed for other instrumentation.
T	N	30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	Testing in progress for HR-ICP-MS. See Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0006, May 2, 2008
T	Y	31. Process/parameter limits and safety control strategies are being explored	As part of the design process.
T	N	32. Test plan documents for prototypical lab- scale tests completed	See Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0006, May 2, 2008 for HR-ICP-MS simulants. None developed for other instrumentation.

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P	Y	33. Technology availability dates established	Instrumentation exists. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.

Table C-2 TRL 5: Analytical Laboratory (U and TRU Analysis)

Table 9. TRL 5 Questions for Critical Technical Elements			
T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T	N	1. The relationships between major system and sub-system parameters are understood on a laboratory scale.	The analytical needs are related to potential instrumentation in Selection of Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0003, April 30, 2008. However, There is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
T	Y	2. Plant size components available for testing	Full scale instrument is available for testing. See Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0006, May 2, 2008. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	3. System interface requirements known (How would system be integrated into the plant?)	See, e.g., Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0006, May 2, 2008. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	4. Preliminary design engineering begins	Full scale instrument available. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	N	5. Requirements for technology verification established	Requirements WACs for WIPP/NTS exist. However, they have not been translated directly into detailed analytical requirements. Upper level requirements for process control also exist, but detailed requirements have not been derived.
T	Y	6. Interfaces between components/subsystems in testing are realistic (bench top with realistic interfaces)	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	7. Prototypes of equipment system components have been created (know how to make equipment)	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for

Table 9. TRL 5 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
			TRU.
M	Y	8. Tooling and machines demonstrated in lab for new manufacturing processes to make component	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	9. High fidelity lab integration of system completed, ready for test in relevant environments	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	10. Manufacturing techniques have been defined to the point where largest problems defined	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	N	11. Lab-scale, similar system tested with range of simulants	Plan for HR-ICP-MS testing exists: <u>Evaluation of Mass Spectrometer Instrumentation for the U233 Project Analytical Laboratory,</u> NFS 53G-08-0006, May 2, 2008.
T	Y	12. Fidelity of system mock-up improves from laboratory to bench-scale testing	Full scale instrument available. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
M	Y	13. Availability and reliability (RAMI) target levels identified	Analytical capability required when plant is operating. Back up analytical capability provided through backup laboratory.
M	Y	14. Some special purpose components combined with available laboratory components for testing	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	15. Three dimensional drawings and P&IDs for the prototypical engineering-scale test facility have been prepared	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	16. Laboratory environment for testing modified to approximate operational environment	Plan to locate lab in existing laboratory space in 3019
T	Y	17. Component integration issues and requirements identified	Full scale instruments are available and being tested. However, no

Table 9. TRL 5 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
			method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	18. Detailed design drawings have been completed to support specification of engineering-scale testing system	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	19. Requirements definition with performance thresholds and objectives established for final plant design	Selection of Instrumentation for the Analytical Laboratory NFS 53G-08-0003, April 30, 2008. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	20. Preliminary technology feasibility engineering report completed	Selection of Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0003, April 30, 2008. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	21. Integration of modules/functions demonstrated in a laboratory/bench-scale environment	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	22. Formal control of all components to be used in final prototypical test system	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	N/A	23. Configuration management plan in place	
T	N	24. The range of all relevant physical and chemical properties has been determined (to the extent possible)	The analytical needs are related to potential instrumentation in Selection of Instrumentation for the U233 Project Analytical Laboratory, NFS 53G-08-0003, April 30, 2008. However, There is no document, such as a detailed Sampling and Analysis Plan that derives analytical requirements such as detection limits, precision and accuracy from process and waste acceptance requirements.
T	N	25. Simulants have been developed that cover the full range of waste properties	Partially true for HR-ICP/MS, but not final for alpha spectroscopy. It is not clear that full range of properties has been considered.

Table 9. TRL 5 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	26. Testing has verified that the properties/performance of the simulants match the properties/performance of the actual wastes	Verified by chemical knowledge.
T	N	27. Laboratory-scale tests on the full range of simulants using a prototypical system have been completed	Some full scale tests are planned but not completed.
T	N	28. Laboratory-scale tests on a limited range of real wastes using a prototypical system have been completed	There are no plans to do actual material testing before facility operation.
T	N	29. Test results for simulants and real waste are consistent	There are no plans to do actual material testing before facility operation.
T	Y	30. Laboratory to engineering scale scale-up issues are understood and resolved	Full scale instruments are available and being tested. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
T	Y	31. Limits for all process variables/parameters and safety controls are being refined	30% design documents contain some limits..
P	N	32. Test plan for prototypical lab-scale tests executed – results validate design	Full scale tests are planned for HR-ICP/MS, but not final for alpha spec. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	33. Test plan documents for prototypical engineering-scale tests completed	Full scale tests are planned for HR-ICP/MS, but not final for alpha spec. However, no method/instrumentation has been identified to meet process control requirements (TAT sensitivity) for TRU.
P	Y	34. Risk management plan documented	There is a risk management plan.

Table C 3 TRL 4: Concentration

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T	Y	1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	Design criteria document ISO-ENG-DCD-001
M	Y	2. Laboratory components tested are surrogates for system components	Full scale unit being tested
T	Y	3. Individual components tested in laboratory~~/~~or by supplier	Proprietary agreements; has been tested.
T	N	4. Subsystems composed of multiple components tested at lab scale using simulants	Planning on testing with simulants. Test plan exists. Detailed test procedures are being developed.
T	Y	5. Modeling & Simulation used to simulate some components and interfaces between components	Elastomer tolerance to radiation field.
P	Y	6. Overall system requirements for end user's application are known	Design document
T	Y	7. Overall system requirements for end user's application are documented	Design document
P	Y	8. System performance metrics measuring requirements have been established	Design document
P	Y	9. Laboratory testing requirements derived from system requirements are established	Full Scale Test; Test Plan; Detailed test procedures are being developed.
M	Y	10. Available components assembled into laboratory scale system	Actual Full Scale Unit
T	Y	11. Laboratory experiments with available components show that they work together	Working with a full scale system
T	Y	12. Analysis completed to establish component compatibility (Do components work together)	Working with a full scale system
P	Y	13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	Criteria in test plan; Detailed test procedures are being developed.
T	N	14. Technology demonstrates basic functionality in simulated environment	Will be completed; in the test plan; Detailed test procedures are being developed.
M	Y	15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	Testing full scale
P	Y	16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	30% design package

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
M	Y	17. Equipment scale-up relationships are understood/accounted for in technology development program	Testing at full scale
T	Y	18. Controlled laboratory environment used in testing	Test Plan; Detailed test procedures are being developed.
P	Y	19. Initial cost drivers identified	30% design package
M	Y	20. Integration studies have been started	Test plan; Detailed test procedures are being developed.
P	Y	21. Formal risk management program initiated	Project management plan; risk register
M	Y	22. Key manufacturing processes for equipment systems identified	Made a full scale unit
P	Y	23. Scaling documents and designs of technology have been completed	Made a full scale unit
M	Y	24. Key manufacturing processes assessed in laboratory	Made a full scale unit
P/T	Y	25. Functional process description developed. (Systems/subsystems identified)	30% Design package
T	Y	26. Low fidelity technology “system” integration and engineering completed in a lab environment	Made a full scale unit
M	Y	27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	Made a full scale unit
T	Y	28. Key physical and chemical properties have been characterized for a range of wastes	DCD
T	Y	29. A limited number of simulants have been developed that approximate the range of waste properties	Test plan; Detailed test procedures are being developed.
T	N	30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	Testing is planned; test plan; Detailed test procedures are being developed.
T	Y	31. Process/parameter limits and safety control strategies are being explored	Test plan; Detailed test procedures are being developed.
T	Y	32. Test plan documents for prototypical lab- scale tests completed	Test plan; Detailed test procedures are being developed.
P	Y	33. Technology availability dates established	Have a full scale unit

Table C 4 TRL 4: Packaging

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	**Y/N**	**Criteria**	**Basis and Supporting Documentation**
T	Yes	1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	“^{233}U Design Criteria;” ISO-ENG-DCD-001, Revision 0, March 2008
M	Yes	2. Laboratory components tested are surrogates for system components	Some components exist within the Complex. Slide presentation from Energy Solutions Hanford.
T	Yes	3. Individual components tested in laboratory~~/~~or by supplier	Some components exist within the Complex. Slide presentation from Energy Solutions Hanford.
T	No	4. Subsystems composed of multiple components tested at lab scale using simulants	Has not been tested using a simulants for the bagless transfer system.
T	Yes	5. Modeling & Simulation used to simulate some components and interfaces between components	Slide presentation from Energy Solutions Hanford
P	Yes	6. Overall system requirements for end user's application are <u>known</u>	“^{233}U Design Criteria;” ISO-ENG-DCD-001, Revision 0, March 2008
T	Yes	7. Overall system requirements for end user's application are <u>documented</u>	“^{233}U Design Criteria;” ISO-ENG-DCD-001, Revision 0, March 2008
P	No	8. System performance metrics measuring requirements have been established	Some in “^{233}U Design Criteria;” ISO-ENG-DCD-001, Revision 0, March 2008; not clear on others.
P	No	9. Laboratory testing requirements derived from system requirements are established	Test plans are yet to be developed
M	Yes	10. Available components assembled into laboratory scale system	Full scale exists at Hanford
T	Yes	11. Laboratory experiments with available components show that they work together	Full scale exists at Hanford
T	Yes	12. Analysis completed to establish component compatibility (Do components work together)	Full scale exists at Hanford
P	No	13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	Test plans are yet to be developed
T	No	14. Technology demonstrates basic functionality in simulated environment	Test plans are yet to be developed
M	Yes	15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	Full scale exists at Hanford

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P	Yes	16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	"233U Project, Title I Design Report, Concentrator, Thermal Treatment Unit, Drum Packaging and Off-Gas Structure, Systems and Components," ISO-ENG-RPT-010, Rev. A
M	Yes	17. Equipment scale-up relationships are understood/accounted for in technology development program	Full scale exists at Hanford
T	No	18. Controlled laboratory environment used in testing	Test plans are yet to be developed
P	Yes	19. Initial cost drivers identified	"233U Project, Title I Design Report, Concentrator, Thermal Treatment Unit, Drum Packaging and Off-Gas Structure, Systems and Components," ISO-ENG-RPT-010, Rev. A
M	Yes	20. Integration studies have been started	Full scale exists at Hanford
P	Yes	21. Formal risk management program initiated	PMP; Risk register from Isotek
M	Yes	22. Key manufacturing processes for equipment systems identified	Full scale exists at Hanford
P	Yes	23. Scaling documents and designs of technology have been completed	Full scale exists at Hanford
M	Yes	24. Key manufacturing processes assessed in laboratory	Full scale exists at Hanford
P/T	Yes	25. Functional process description developed. (Systems/subsystems identified)	"233U Project, Title I Design Report, Concentrator, Thermal Treatment Unit, Drum Packaging and Off-Gas Structure, Systems and Components," ISO-ENG-RPT-010, Rev. A
T	Yes	26. Low fidelity technology "system" integration and engineering completed in a lab environment	Full scale exists at Hanford
M	Yes	27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	Full scale exists at Hanford
T	Yes	28. Key physical and chemical properties have been characterized for a range of wastes	"^{233}U Design Criteria;" ISO-ENG-DCD-001, Revision 0, March 2008

Table 8. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	No	29. A limited number of simulants have been developed that approximate the range of waste properties	Test plans are yet to be developed
T	No	30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	Test plans are yet to be developed
T	Yes	31. Process/parameter limits and safety control strategies are being explored	"233U Project, Title I Design Report, Concentrator, Thermal Treatment Unit, Drum Packaging and Off-Gas Structure, Systems and Components," ISO-ENG-RPT-010, Rev. A
T	No	32. Test plan documents for prototypical lab- scale tests completed	Test plans are yet to be developed
P	Yes	33. Technology availability dates established	Project Baseline from IsoTek

Table C-5 TRL 3: Off-gas Treatment (Radon Decay Tank)

Table 7. TRL 3 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T	Y	1. Academic (basic science) environment	Based on the concentration of U232
P	Y	2. Some key process and safety requirements are identified	Design Criteria Document (DCD)
T	N	3. Predictions of elements of technology capability validated by analytical studies	There are no analytical studies of the particle agglomeration behavior of the decay products of Rn-220 in an air stream
P	N	4. The basic science has been validated at the laboratory scale	There are no analytical studies of the particle agglomeration behavior of the decay products of Rn-220 in an air stream
T	N	5. Science known to extent that mathematical and/or computer models and simulations are possible	Agglomeration behavior is not known
P	Y	6. Preliminary system performance characteristics and measures have been identified and estimated	Design Criteria Document
T	N	7. Predictions of elements of technology capability validated by Modeling and Simulation (M&S)	Information to create a model is not available
M	N	8. No system components, just basic laboratory research equipment to verify physical principles	Information to create a model is not available
T	N	9. Laboratory experiments verify feasibility of application	Simulants are not available for lab tests
T	N	10. Predictions of elements of technology capability validated by laboratory experiments	Simulants are not available for lab tests
P	N/A	11. Customer representative identified to work with development team	
P	N/A	12. Customer participates in requirements generation	
P	N/A	13. Requirements tracking system defined to manage requirements creep	
T	Y	14. Key process parameters/variables and associated hazards have begun to be identified.	Design Criteria Document
M	Y	15. Design techniques have been identified/developed	Standard Engineering Procedure
T	Y	16. Paper studies indicate that system components ought to work together	Commercial products
P	Y	17. Customer identifies technology need date.	30% design meeting
T	Y	18. Performance metrics for the system are established (What must it do)	30% design meeting

Table 7. TRL 3 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P		19. Scaling studies have been started	30% design meeting
M	Y	20. Current manufacturability concepts assessed	Commercially available components
M	N/A	21. Sources of key components for laboratory testing identified	
T	N/A	22. Scientific feasibility fully demonstrated	
T	Y	23. Analysis of present state of the art shows that technology fills a need	Standard Engineering Practice
P	Y	24. Risk areas identified in general terms	To be completed by test plan
P	Y	25. Risk mitigation strategies identified	To be completed as part of design
P	N	26. Rudimentary best value analysis performed for operations	Off-gas Measurements must be done
T	N/A	27. Key physical and chemical properties have been characterized for a number of waste samples	
T	N/A	28. A simulant has been developed that approximates key waste properties	
T	N/A	29. Laboratory scale tests on a simulant have been completed	
T	N/A	30. Specific waste(s) and waste site(s) has (have) been defined	
T	N/A	31. The individual system components have been tested at the laboratory scale	

Appendix D. TRA Review Team Observations Relevant to the ^{233}U Project

The following items were observed by the TRA Team during its review and are offered for consideration by the Federal Project Director.

1. Product Packaging System

<u>Drum Position Under Telescoping Fill Pipe</u>
System relies on centering pins for precise drum location. If these pins are located on the ceiling, then the drum must move slightly to allow mating with the fill pipe. However, drum will be in a shield cask and the total weight is greater than 6,000 lbs. If the drum enters slightly off-center, the positioning pins are not likely to be able to slide at that weight. What can be expected to happen is the drum and shield cask may tip slightly off centerline and reduce clearance available for mating with the down comer. The drum needs Y positioning motion as well as X-Z motion to avoid misalignment with the fill pipe.

<u>Drum weight Measurement</u>
The current plan is to use load cells to detect when the drum has been lifted to the correct height for mating with the fill pipe. As the elevator lifts the drum and shield cask and the upper surface contacts the bottom of the penthouse, an increase in load cell reading should be observed. The manufacturer needs to demonstrate that the load cell is able to detect the slight increase in force on the load cell. In essence, the circuitry will have to be able to discriminate dynes in background of newtons. Elevator may continue to drive drum upward and cause slight buckling of enclosure roof. This could result in misalignment of fill pipe with drum bung. A misalignment of drum could cause premature engagement with guide pin putting additional force on load cell and giving false positive that drum is in position. There is no feedback signal that the drum is in its proper position.

<u>Drum Closure Cap</u>
Process control circuitry on the status of the drum closure cap is nonexistent. There is no feedback signal that the cap is engaged with the removal collet. There is no feedback signal indicating that an empty drum has a cap in place. There is no feedback signal indicating cap extractor is in either position (extended or retracted). There is no feedback signal indicating drum cap has been removed. Thus, there is no real knowledge of the status of the drum closure cap within the filling enclosure. All knowledge of the closure cap is based on the assumption that the cap manipulator never fails.

<u>Additional Observations on the Product Packaging system</u>

- The drum may act as a cold trap that condenses moisture from the TTU
- Drum secondary cover threads are vulnerable when mating with loading station
- Drum loading for shipment may be limited by drum handling sling load limits. The only certified drum shipment vendor requires the use of these slings in loading the drums into the RH72B shipping container.
- Drum loading area should allow more complete swipe survey of drum/overpack before removal from containment

- Drum cover lifting device release mechanism failure can prevent reattaching the cover on a loaded drum
- The drum cover's filter allows the unintended release of Radon
- Radon daughter particulates in the drum decay tube need to be trapped by the drum filter

2. Waste Disposal

It has been proposed that the characterization of the waste be accomplished by sampling at the accountability tanks or down blend tanks. This is a sound strategy for the down blended material but it may not apply as well to the characterization of process waste streams.

For example, the design calls for direct discard of failed or plugged equipment. WIPP waste acceptance criteria requires specific knowledge of the exact amount of nuclear material and TRU isotopes plus their total measurement uncertainty before disposal. If an evaporator fails it will be removed from the line and discarded. There is no mention of how the amount of nuclear material and TRU isotopes will be determined or how the measurement uncertainty will be determined. Other waste acceptance criteria also apply such as the amount of free liquid, Fissile Equivalent Mass (FEM) requirements, and RCRA waste codes to name a few.

Other process waste streams such as gloves, discarded cans and containers, Pyrex columns, and piping also may not fit into the current certification strategy of sampling at the tanks and using Acceptable Knowledge sufficiency to discard at WIPP.

3. TTU Feed

The TTU feed line is a small diameter line containing concentrated uranium nitrate solution which must be kept warm to prevent the precipitation of the uranium nitrate. It has been Isotek's experience that if uranium nitrate precipitates in small diameter pipes then it is very difficult to dissolve. The current design calls for the removal of the pipe if uranium nitrate should precipitate in the line. Should the heating fail or a nucleation center be introduced into the line the line could freeze causing a single point failure in the system.

4. Expected Throughput

It has been proposed by the design team that the down blending process be placed in a hot shut down over weekends during process operation. This would amount to running fifteen shifts during five days of the week and, and for the facility's operations to be down for six shifts over the weekend (instead of operating twenty-one shifts over the seven days of the week).

Experience with operating a continuous process is that there are operating risks, as well as safety considerations, every time a process is shut down and then restarted. Starting up a process is a risky operation because there has been a break in the routine. These breaks result in the loss of continuity which can result in the new start up crew coming in on Monday without fresh knowledge of what was going on during the shut down shift on Friday night; the risk of equipment failing during the shutdown and not being noticed; flow failures due to crystallization or precipitation; and process anomalies such as siphoning from one tank to another, leaking valves, leaks from failed piping, gasket failures in flanges, or failed valves; equipment failure such as pumps, sensors, or other equipment utilizing motors or electrical lines; or other such problems which can take place during an idle period. These problems can vary from minor incidents to criticalities. In a process such as this one that is operating in a facility as old as building 3019 which depends on contact maintenance, even a trivial problem in a normal process can result in major problems and significant personnel exposure when it has to be resolved with a cell entry to repair or remove a failed component.

It has been observed that when the routine of a continuous process is interrupted by a shutdown, it will take several shifts before the smooth operation is re-established. An incident that occurs during a shutdown can result in a much larger problem due to the lack of attention being paid to the entire process. This could result in incidents that could require a significant amount of time and personnel exposure to resolve, reducing throughput below design levels

Appendix E: Disposition of Comments from the Factual Accuracy Review

The following numbered comments were provided by Isotek as part of the factual accuracy check of the draft version of this report. The resolution of each Isotek comment, or the basis for not resolving the comment, is shown in italics following the comment.

1. General comment: The project has adopted the short notation of U233 Project (not ^{233}U Project).

   The notation used is correct, and the project can continue to use its current notation.

2. Section 1, second paragraph, last sentence: The certainty of "it is likely that the downblended material would not meet the WAC at WIPP" is questionable. Suggest changing to "it is uncertain whether some of the downblended material would meet the WAC at WIPP".

   Incorporated changing the concern to "uncertain" from "likely."

3. Section 1, third paragraph: Isotek is developing final design details. Suggest changing "…prior to start of final design efforts…" to "…prior to the completion of final design efforts…"

   Incorporated.

4. Section 2.4 the bio for Mr. Hayes is missing.

   Incorporated.

5. Section 3, second paragraph: The U233 Project mission is to disposition the downblended material. This includes but is not limited to disposition at WIPP. The mission can still be accomplished as long as the WAC is met for a selected disposition site.

   Incorporated.

6. Section 3.1 title change CUESP to CEUSP.

   Incorporated.

7. Section 3.1: The normal CEUSP canister is about 25-inches tall, not 3-feet tall. The two canisters that are taller than the current shielded carrier contain MSRE fuel salts not CEUSP material. The CEUSP monolith was formed by dripping concentrated uranyl nitrate into the hot canister so that U_3O_8 was produced; it was not "poured into the cylinder". The WIPP WAC is 100 nanoCi/gm, not microCi/gm.

   Incorporated.

8. Section 3.1: The report contains no definition of “high fired”. The statements regarding dissolving plutonium in nitric acid appear to be related materials that are essentially all plutonium. When plutonium is a contaminant in a uranium matrix, the properties of plutonium may be different. There are various technical documents that indicate the plutonium should dissolve in nitric acid.

   High fired is defined as it is in the report. Documents were provided by the team subsequent to the site visit (see the report’s references) that show that high fired plutonium oxide will not substantively dissolve in nitric acid.

9. Section 3.2: Figure 1.1 is missing.

   Incorporated.

10. Section 3.2: Since the laboratory CTE relates primarily to the ICP-MS and not to the entire laboratory, suggest adding “equipment” after Analytical Laboratory.

    The lab CTE is concerned with instrumentation (technologies) and procedures (relevant environment). The section heading should remain as Analytical Laboratory.

11. Table 3.2 ICP/MS: High resolution (HR) ICP-MS is what is being evaluated as opposed to the normal ICP-MS. HR-ICP-MS techniques have sensitivities and resolution approaching or equaling TIMS for the types of samples to be analyzed by the U233 Project.

    Incorporated.

12. Table 3.2 Alpha Spectrometry: NFS has been using alpha spectrometry to certify downblended uranium (about 5% assay) for several years. The method lower limit of detection is <1 bq/g U for Pu and Np.

    Incorporated.

13. Table 3.2 Fluoride/chloride: change fluorife to fluoride.

    Incorporated.

14. Section 3.3.1.4: TRU will be determined by alpha spectroscopy not ICP-MS. Isotek intends to adopt the NFS procedure for TRU analysis. This procedure measures downblended uranium (about 5% assay) and has a lower limit of detection is <1 bq/g U for Pu and Np.

    The alpha spectroscopy is an excellent technique. It will be used for final WIPP certification. However, the turn around time of 2-3 days makes it unsuitable for process control. Doug Davis has confirmed that at this time Isotek does not have a method suitable for process control.

15. Section 3.3.1.5: Last sentence insert ^{238}U.

    Incorporated.

16. Section 3.3.1.7: Recommendation 1: A high level sampling plan does exist for the project. It is agreed that the plan needs to include more detail as per Recommendation 2.

    Comment incorporated by using the terminology "detailed Sampling and Analysis Plan."

17. Section 3.3.1.7 Item 5: There are no test plans since the same instrumentation is routinely used in the NFS laboratories. Isotek intends to adopt the NFS procedures to the Isotek instrumentation.

    Comment rejected. Statement in report is correct.

18. Section 3.3.1.7 Recommendation 4: Isotek intends to adopt the NFS procedure for TRU analysis. This procedure measures downblended uranium (about 5% assay) and has a lower limit of detection is <1 bq/g U for Pu and Np.

    The alpha spectroscopy is an excellent technique. It will be used for final WIPP certification. However, the turn around time of 2-3 days makes it unsuitable for process control. Doug Davis has confirmed that at this time Isotek does not have a method suitable for process control.

19. Section 3.3.2.1 In addition to energy burden, another reason for going to ~ 1000 gU/L is to reduce the volume of offgas (most of which is water), because the offgas has U oxide dust entrained in it. The lower the volume of offgas, the less high dose U oxide particulate that needs removal.

    The following text has been added to Section 3.3.2.1: "A second reason to raise the concentration is to reduce the off-gas volume which would contain uranium oxide dust."

20. Section 3.3.2.5: Change "vaporatization" to "vaporization", correct the units on "2 schf".

    Incorporated.

21. Section 3.3.2.6: The last sentence needs grammatical revision.

    The sentence has been revised to read: "The long term performance of the bearing elastomeric seal in a radiation environment is an unknown."

22. Section 3.3.3.1, For clarity, suggest changing the bullets as follows:

    - Placement of lead overpacks, preloaded with empty drums onto the conveyor system
    - Overpack / Drum staging area to ensure drums are available for filling
    - Overpack lid and drum secondary lid removal
    - Remote drum handling to support automated loading with granular UO_3 product using a bagless transfer design.
    - Insuring the UO_3 product is sufficiently cooled, prior to loading into the drum.
    - Drum surface monitoring to demonstrate the absence of surface contamination.
    - Reinstating the drum secondary lid and overpack lid

Incorporated.

23. Section 3.3.3.2, seventh and eighth bullet: swiping is done prior to moving to the station to attach the overpack lid.

    Incorporated.

24. Section 3.3.3.3: It is assumed that "shown below" refers to Figure 3-1. There are no plans to discharge the cooling medium to a sanitary sewer.

    Incorporated.

25. Section 3.3.3.4, first sentence: The custom designed inner container does have dimensions similar to a standard 55-gallon drum. However the inner container is inside a shielded overpack that includes 3-inches of lead shielding.

    Incorporated.

26. Section 3.3.3.5: For clarity, the "surrounding transfer station" in this context refers to the overpack handling station and conveyors. It is recognized that the interior of the box housing the product filling equipment will be contaminated.

    Incorporated.

27. Figure 3.2: The dissolvers will discharge through a condenser and demister prior to going to radon decay. The dissolution system is separate from the drying and packaging system and does not include catalytic reduction.

    A mist eliminator has been added and the dissolution system has been deleted from Figure 3.2, and additional discussion has been added to the report to reflect that the dissolution vessels are served by an off-gas system that is similar to the one shown in the figure, except that it does not include the selective catalytic reducer due to the absence of NOX in the dissolver off-gas.

28. Section 3.3.4.2, second paragraph: Delete "the dissolver" since it is not part of the system being discussed. The off-gas will also include nitric acid vapor.

    This TRA is a technical review of the process---not a part of the design review of the portion of the process that was taking place concurrently with the TRA review. The TRA charter was to review the technical merit of the entire process. Thus, the dissolution is a part of the TRA review and must stay in the paragraph and be considered as part of the TRA. The second part of the comment was accepted and its resolution is shown in italics in the paragraph above.

29. Section 3.3.4.2, third paragraph: the primary reason for the heater is to pre-heat the gas going into the catalytic reduction to facilitate the catalytic reaction in decomposing the NOx.

    There are two heaters in the system. The first one heats the off gas above the dew point to protect the HEPA and the second preheats the off gas to facilitate the reaction with the solid catalytic reactor.

30. Section 3.3.4.4, first paragraph: The sentence beginning "This time period…" needs grammatical revision. In the last sentence change "dissolver" to "concentrator" since the dissolver is not part of the system.

    Incorporated, and also see the response to comment number 28.

31. Section 3.3.4.6 Change "hoped" to "postulated". The sentence "If there are problems with release, scrubbers or electrostatic filters could be used to resolve the problem" is conjecture and should be deleted.

    Incorporated.

32. Appendix A.2: Correct spelling of Shaffer.

    Incorporated.

33. Table B-7: Davies-Gray titration measures total uranium. The amount of depleted uranium (i.e. ^{238}U) will not matter.

    Incorporated.

34. Appendix D, Observation 1: For clarity, the inner container will be a custom design drum with a welded top. The center fill hole and vent hole will be part of the fabrication specification. These containers will be subjected to appropriate QA/QC oversight during fabrication.

    Observation deleted.

35. Appendix D, Observation 1, third bullet: The inner container design will include provisions for handling so that the drum handling sling (i.e. plastic bag) will not be needed.

    The drum handling sling is the approved method of loading 55 gallon drums into the RH72B. If plans have changed to include the design a new drum handling device this could become another CTE.

36. Appendix D, Observation 3, Second bullet: There is no intent to leave uranyl nitrate in the TTU feed line during hot standby. Part of the preparation for achieving hot standby will be to flush the feed line using water.

    This information was not part of what was conveyed to the team and as a result, the observation has been removed.

37. Appendix D, Observation 4: The dissolution and downblending processes are batch operated, not continuous. Isotek personnel have operating experience in both 21 shift per week operation (7 days) and 15 shift per week operation (5 days) including thermal processes. It has been observed that more serious adverse consequences occur during a 21 shift operation than during a 15 shift operation. The only continuous processes involve the concentration and thermal treatment processes. These will not be shutdown per se but instead will be in a hot standby mode.

    The Team recognizes that this comment reflects Isotek's position.