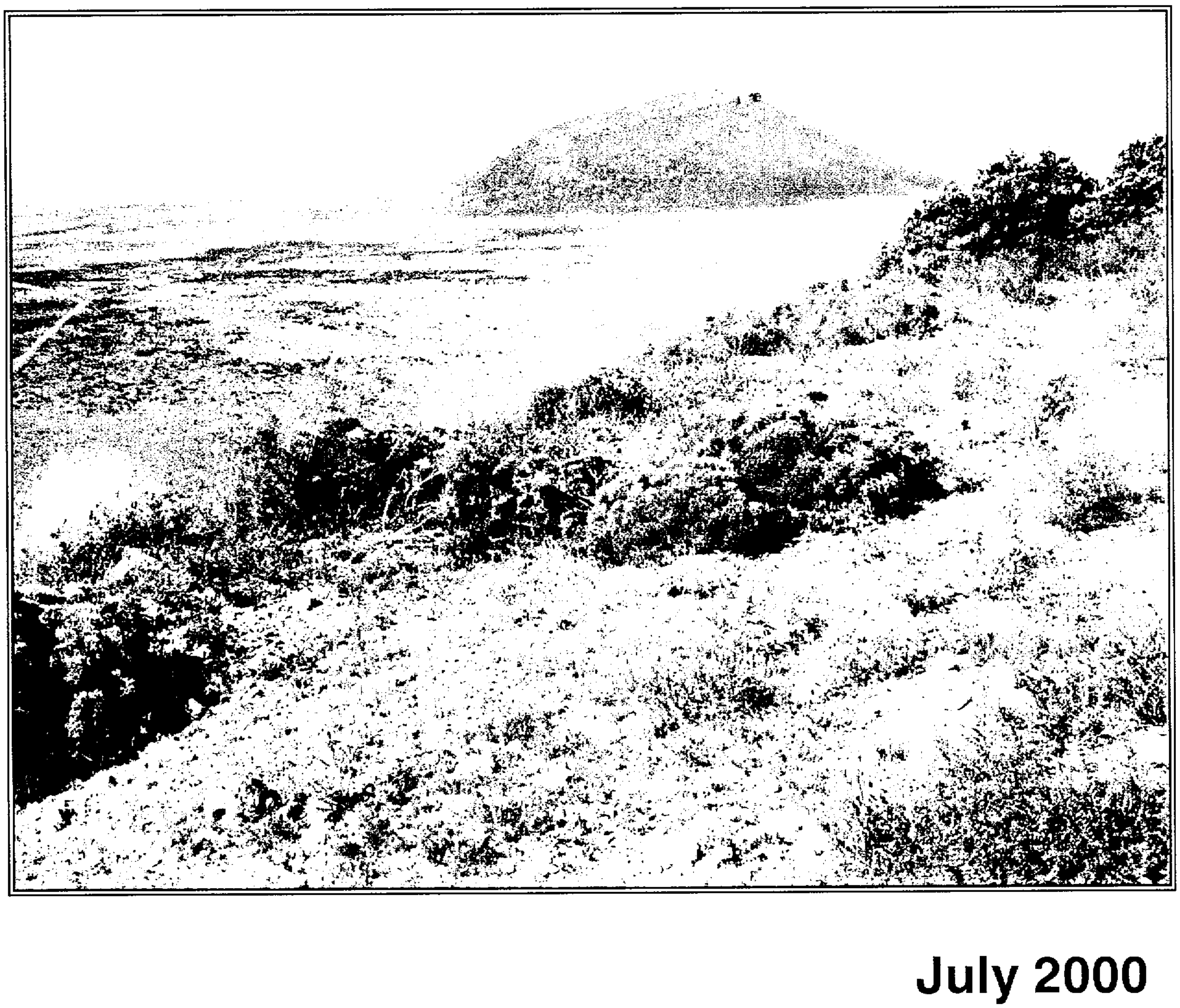
PNNL-13268

TANKS FOCUS AREA

Assessment of Selected Technologies for the Treatment of Idaho Tank Waste and Calcine



July 2000

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
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Pacific Northwest National Laboratory
Richland, Washington, 99352

Executive Summary

More than one-million gallons of liquid radioactive waste (designated sodium-bearing waste [SBW]) are stored in eleven 300,000-gallon underground tanks at the Department of Energy's (DOE's) Idaho National Engineering and Environmental Laboratory (INEEL) in southern Idaho. Another 4,386 m^3 of a dry, granular waste form, legally designated high-level waste (HLW) and referred to as "calcine," are stored in vented silos, called "bin sets." A 1995 agreement among the DOE Idaho Operations Office (DOE-ID), the state of Idaho, and the Department of the Navy defined a schedule for treatment and disposal of the SBW and calcine. This agreement calls for the removal of the liquid waste and ceasing use of the eleven underground storage tanks by 2012 and making the waste, including the calcine, "road ready" for transportation to an offsite disposal site by 2035.

In December 1999, DOE-ID issued for public comment a draft environmental impact statement (EIS) evaluating various alternatives to support ceasing use of the tanks and making the treated waste (SBW and calcine) "road ready" by the compliance dates. DOE-ID requested the Tanks Focus Area, a national technology program for developing solutions to DOE's radioactive tank waste remediation challenges, to provide additional information for the decision making process. The Tanks Focus Area convened a review team of national experts (Review Team) to independently assess technical alternatives bounded by the Draft EIS. A DOE Decision Management Team, convened to advise DOE-Headquarters and DOE-ID on the Final EIS and Record of Decision, is evaluating a preliminary list of options and is also considering a narrowed list. The Decision Management Team will consider the results of the Review Team assessment as they proceed in their evaluation process.

From June 19-23, 2000, the Review Team met in Idaho Falls, Idaho, for briefings by DOE-ID and INEEL contractor staff on the selected list of treatment options and associated technology development activities. Results of the Review Team's analysis are contained in this report. Key conclusions and recommendations are provided below.

1. DOE-ID, INEEL, and contractor staff have implemented a technology selection process and path forward planning approach that is likely to succeed in meeting technical and regulatory requirements for both SBW and calcine.
2. The process used to select treatment options was sound and did not overlook highly promising options.
3. The Review Team concurs with dropping further consideration of SBW treatment options using the calciner facility.
4. The Review Team concurs with proceeding rapidly with SBW treatment but deferring selection of a calcine treatment option.
5. The Direct Vitrification option should be adopted as the baseline for SBW treatment with the Cesium Ion Exchange option as the backup; the Solvent Extraction option should be eliminated.
6. The Review Team believes that either the Direct Vitrification or the Cesium Ion Exchange option can be developed and deployed to meet the 2012 compliance date for ceasing use of the tanks.
7. To ensure success, regardless of the SBW and calcine technologies ultimately selected, detailed technology roadmapping must be performed and adequate resources made available to support evaluation and development of technology alternatives.
8. The Hot Isostatic Pressing option for treating calcine should be eliminated, but the Direct Vitrification and two separation options should be developed to a logical decision point within a few years.
9. The necessary waste characterization should be carried out, consistent with the schedules for developing and selecting SBW and calcine technology options.

10. A ruling on whether SBW is high-level waste or waste incidental to reprocessing should be pursued aggressively.
11. While integration of processes for treating NGLW, SBW, tank heels, and calcine may have attractive features, this possibility should not be allowed to detract from the work needed to meet the 2012 compliance date.

In summary, the Review Team strongly endorses the timeliness and approaches being taken to address treatment and disposal of SBW and calcine. The Review Team believes the necessary components are in place for successfully managing and implementing the disposition of these wastes.

Acknowledgements

The Review Team is deeply indebted to many individuals for their valued assistance throughout our review. We especially acknowledge the following:

Mr. Thomas Brouns (TFA). In his capacity as TFA Technical Team Manager, Mr. Brouns was directly responsible for assembling and organizing the Review Team. We thank him for his efforts on our behalf.

Ms. Betty Carteret (TFA). The Review Team greatly appreciated her knowledge and leadership in coordinating and facilitating the review meeting at Idaho and seeing the report through to completion.

Ms. Lynne Roeder-Smith (TFA). As Communications Specialist for the TFA Technical Team, her skills and patience in preparing and editing many drafts of our report were outstanding.

Ms. Bonnie Williams (TFA). Her careful attention to necessary administrative items for the review is much appreciated.

Mr. Phil McGinnis and Dr. William Holtzscheiter (TFA). As TFA Technology Integration Managers for Pretreatment and Immobilization, their complex-wide insights were much appreciated by the Review Team.

Mr. Joel Case, Mr. Keith Lockie, and Mr. Richard Kimmel (DOE-ID). The Review Team benefited greatly from their excellent presentations and keen insights on the Idaho high-level waste program.

Mr. Arlin Olsen, Mr. James Murphy, Mr. James Valentine, and other BBWI participants. Their highly informative presentations and deep insights into the technical aspects of the Idaho high-level waste program were invaluable to the Review Team.

Ms. Ann Dold (State of Idaho Oversight for INEEL). The Review Team gained new perspectives from hearing the State of Idaho's views on technical alternatives and regulatory boundary conditions.

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Acronyms and Abbreviations

AMP-PAN	ammonium molybdophosphate-polyacrylonitrile
BBWI	Bechtel BWXT Idaho, LLC
BDAT	Best Demonstrated Available Technology
BNFL, Inc	the United States subsidiary to British Nuclear Fuels plc, of the United Kingdom
CsIX	cesium ion exchange
CH-LLW	contact-handled low-level waste
CH-TRU	contact handled transuranic waste
CST	crystalline silicotitanate
DOE	Department of Energy
DOE-ID	Department of Energy, Idaho Operations Office
DQO	Data Quality Objective
DWPF	Defense Waste Processing Facility
EIS	environmental impact statement
HIP	Hot Isostatic Pressing
HLW	high-level waste
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LLW	low-level waste
MACT	Maximum Achievable Control Technology
NAS	National Academy of Sciences
NGLW	Newly Generated Liquid Waste
NOX	nitrogen oxides
RCRA	Resource Conservation and Recovery Act
RH-LLW	remote-handled low-level waste
RH-TRU	remote-handled transuranic waste
SBW	sodium-bearing waste
SNF	spent nuclear fuel
SRS	Savannah River Site
TCLP	toxic characteristic leaching procedure
TFA	Tanks Focus Area
TRU	transuranic elements
TRUEX	Transuranic Extraction
UNEX	Universal Solvent Extraction
WIPP	Waste Isolation Pilot Plant
WIR	waste incidental to reprocessing
WVDP	West Valley Demonstration Project

1.0 Background

1.1 *Idaho High-Level Waste Program*

From 1952 to 1992, spent nuclear fuel (SNF) and irradiated targets were processed at the Idaho Chemical Processing Plant (since renamed the Idaho Nuclear Technology and Engineering Center, or INTEC) in southern Idaho. The INTEC is a major facility at DOE's Idaho National Engineering and Environmental Laboratory (INEEL). This reprocessing work resulted in millions of gallons of radioactive liquid high-level waste (HLW). Additional liquid wastes resulting from a variety of processes (e.g., laboratory operations and decontamination processes) are not specifically defined as HLW. Approximately 1,000,000 gal of these wastes, called sodium-bearing waste (SBW), are stored temporarily in 300,000 gal underground storage tanks. Each tank is constructed of a single shell of stainless steel containing cooling coils, which is surrounded by a concrete vault. The SBW stored in the tanks may qualify as "waste incidental to reprocessing" (WIR), but a final determination on this designation has not been made. If designated as WIR, the SBW would not be subject to the requirements for treating and disposing HLW defined in the Nuclear Waste Policy Act.

From 1963 to 1998, liquid HLW and SBW was converted to a dry, stable, granular form of HLW called "calcine" using the site's waste calcining facilities. The resulting 4,386 m^3 of calcine is stored in six vented silos, called "bin sets." A seventh bin set has never been used. When reprocessing was discontinued in 1992, the site mission shifted to management and disposition of the accumulated HLW and SBW from past SNF processing operations, ongoing operations, and the waste generated by decontamination and decommissioning and final closure operations. INEEL's waste treatment program is executed by the prime site contractor, currently Bechtel BWXT Idaho, LLC (BBWI).

A 1995 compliance agreement between the DOE Idaho Operations Office (DOE-ID), the state of Idaho, and the Department of the Navy defined a schedule for treatment and disposal of the SBW and calcine. To determine the most appropriate strategy for removing the SBW, ceasing use of the tanks by 2012 and making the calcine "road ready" by 2035 as specified in the agreement, DOE-ID issued for public comment a draft environmental impact statement (EIS) evaluating various alternatives and their associated impacts. DOE plans to issue a final EIS in January 2001 and a Record of Decision on SBW and calcine disposition in March 2001. A Decision Management Team consisting of senior DOE managers with strong nuclear waste technical and regulatory backgrounds will advise DOE Headquarters and DOE-ID on preferred alternatives to include in the final EIS and Record of Decision.

1.2 *Review Team Charter*

DOE-ID requested the Tanks Focus Area (TFA), a national technology program for developing solutions to DOE's radioactive tank waste remediation challenges, to provide additional information for their decision making process. The TFA convened a review team of national experts (Review Team) to independently assess the technical alternatives bounded by the Draft EIS and to focus on a narrowed list of options under consideration by the Decision Management Team. The DOE request for assistance from the TFA and the Review Team's Statement of Work are provided in Appendix A. From June 19-23, 2000, the Review Team met in Idaho Falls, Idaho, for briefings by DOE-ID and INEEL contractor staff on SBW and calcine treatment strategies and associated technology development activities

1.3 *Review Team Members*

The Review Team consisted of nine members:

- P. Gary Eller, Los Alamos National Laboratory, Team Chairman
- Joseph A. Gentilucci, Consultant, JAG Technical Services, Inc., Savannah River Site retiree
- Christine A. Langton, Westinghouse Savannah River Company
- Wallace W. Schulz, Consultant, W2S Company, Inc., Hanford Retiree, Team Deputy Chairman
- John L. Swanson, Consultant, Hanford Site retiree
- Lawrence L. Tavlarides, Syracuse University
- Russell L. Treat, Consultant, Dade Moeller and Associates, Inc.
- E. Thomas Weber, Consultant, Hanford Site retiree
- Raymond Wymer, Consultant, Oak Ridge National Laboratory retiree

Resumes of the Review Team members are provided in Appendix B.

1.4 *Draft EIS Waste Processing Alternatives*

The following Idaho waste processing alternatives were analyzed in the Draft EIS (DOE/EIS-02870):

1. No Action
2. Continued Current Operation
3. Separations (with three treatment options)
4. Non-Separations (with three treatment options)
5. Minimum INEEL Processing

An overview of the modular waste management elements that make up the Draft EIS alternatives and options is provided in Figure 1.1. Appendix C summarizes key uncertainties and assumptions that underlie the Draft EIS options. Appendix D shows the treatment roadmap for the SBW treatment options involving separations technologies. Hybrid options with respect to mixed HLW treatment technologies, mixed transuranic waste/SBW pretreatment requirements, and post-treatment storage and disposal options can be constructed from these elements. Hybrid options considered by the Decision Management Team and the Review Team are identified in the following section.

Figure 1.1 Modular Waste Management Elements Included in Draft EIS

Alternatives and Options	Waste Management Elements														
	Pre-treatment Storage		Pre-treatment Process Permitted Calciner[2]	Treatment Process							Post-treatment storage on the INEEL	Post-treatment Disposal Destinations			
	As liquid in tanks[1]	As calcine in bin sets		Vitrification borosilicate glass	Separations			Grout/cement ceramic				REP HLW	WIPP TRU	Near surface landfill options for LLW	
					Cs	Sr	TRU	HLW	LLW	TRU				On INEEL	Off INEEL
NO ACTION ALTERNATIVE	♦	♦													
CONTINUED CURRENT OPERATIONS ALTERNATIVE		♦	♦												
SEPARATIONS ALTERNATIVE															
• FULL SEPARATIONS OPTION	♦	♦		♦	♦	♦	♦	♦[3]	♦		♦	♦		♦	♦
• PLANNING BASIS OPTION		♦	♦	♦	♦	♦	♦	♦[3]	♦		♦	♦			♦
• TRANSURANIC SEPARATIONS OPTION	♦	♦					♦		♦	♦	♦		♦	♦	♦
NON-SEPARATIONS ALTERNATIVE															
• HOT ISOSTATIC PRESSED OPTION		♦	♦					♦			♦	♦			
• DIRECT CEMENT WASTE OPTION		♦	♦					♦			♦	♦			
• EARLY VITRIFICATION OPTION	♦	♦		♦				♦[3]		♦[3,4]	♦	♦	♦		
MINIMUM INEEL PROCESSING ALTERNATIVE	♦	♦		♦[5]	♦		?[6]	?[6]		♦[4]	♦	♦	♦	?[6]	?[6]

Cs=cesium Sr=strontium HLW=high level waste TRU=transuranic waste LLW=low level waste REP=HLW Repositories WIPP=Waste Isolation Pilot Plant

1. DOE must cease-use of five pillar and panel vault tanks by 2003 (these are single-shell tanks with an external secondary contaminant structure that is not expected to meet seismic design criteria). Except for the No Action Alternative, DOE would cease use of the monolithic vault tanks by 2012 to 2016 (these are single-shell tanks with an external secondary contaminant structure that is more likely to meet seismic design criteria than the pillar and panel tanks).
2. Calcination is considered to be pretreatment under RCRA.
3. These waste management elements are currently not included in the alternatives or treatment options but could be considered for development of hybrid alternatives.
4. Liquid mixed transuranic waste/SBW in underground tanks at INTEC is to be treated and sent to WIPP. In the Minimum INEEL Processing Alternative, cesium will be separated and sent to Hanford to be treated with INTEC HLW.
5. Vitrification of calcine will be performed at Hanford, as part of Phase II design decisions.
6. Hanford's Phase II design decisions will determine if these separation technologies will be used and, therefore, what waste fractions will be generated.

1.5 *Candidate Waste Processing Alternatives*

Many experimental and engineering studies have been performed during the past 15 years at the INEEL to analyze various alternatives for processing and disposing SBW and calcine. An extensive compilation of references to these studies is provided in Appendix A of the 1999 National Research Council/National Academy of Sciences report, "Alternative High-Level Waste Treatment at the Idaho National Engineering and Environmental Laboratory" (NAS 1999).

More recently, in connection with the preparation and issuance of the Draft EIS, DOE-ID and INEEL sponsored intensive evaluations and analyses of the various options for processing the SBW and calcine (DOE 1999a, Murphy et al. 2000). The goal of these efforts was to evaluate promising available alternatives for SBW and calcine that could be further considered in the EIS decision-making process for selecting a preferred alternative and issuing the Final EIS and Record of Decision.

Table 1.1 lists seven hybrid options recently evaluated by DOE-ID and the Decision Management Team for processing SBW as presented to the Review Team at the Idaho review meeting. Appendix E contains the listing of these options, the criteria used in their evaluation, and the results. Table 1.2 lists five calcine processing options evaluated in the Draft EIS. Table 1.3 presents a narrowed list of options that is being evaluated by the Decision Management Team. These options were presented to the Review Team during the June 2000 meeting. The Decision Management Team is considering an option of processing SBW without delay and deferring selection of an option(s) for processing calcine. The scope of the Review Team's assessment includes an evaluation of the Draft EIS and Decision Management Team's options for processing both SBW and calcine and the path forward for disposition of these wastes.

Table 1.1 Candidate Options Evaluated for Processing SBW

Calcine Maximum Achievable Control Technology (MACT)
Cs Ion Exchange (CsIX)
Solvent Extraction (UNEX)
(Two-stage) Evaporation
Direct Vitrification
Silica Gel
Steam Reforming

Table 1.2 Draft EIS Candidate Options Evaluated for Processing Calcine

Hot Isostatic Pressing
Direct Cementing
Direct Vitrification
Separations – Vitrification
Minimum INEEL Processing

Table 1.3 Decision Management Team's Narrowed List of Options Under Consideration for Processing SBW and Calcine

SBW		Calcine
Direct Vitrification		Direct Vitrification
Cs Ion Exchange (CSIX)		Full Separations - Vitrification
Solvent Extraction (UNEX)		UNEX Separations – Vitrification
		Hot Isostatic Pressing

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2.0 Assessment Methodology

The Review Team was provided information about the INEEL waste and processing options prior to the formal meeting in Idaho Falls on June 19-23, 2000. A list of this information is included in Appendix F. DOE-ID and BBWI personnel made informative presentations at the June meeting, which greatly clarified and supplemented the review documentation. Mr. Phil McGinnis and Dr. William Holtzscheiter, TFA's Pretreatment and Immobilization Technology Integration Managers, respectively, were present for most of the formal review meeting and furnished additional insights in their respective areas of expertise.

Prior to the Review Team's evaluation, DOE-ID and BBWI personnel used detailed multi-attribute approaches to evaluate candidate options for processing SBW and calcine. The Review Team leaders spent considerable time establishing an appropriate methodology to assess the validity and significance of the DOE-ID/BBWI evaluations in the time available to complete the review. The following considerations played a key role in arriving at an effective assessment methodology:

- The limited review time available precluded the application of involved ranking and scoring methods.
- The Review Team concluded that the comprehensive multi-attribute decision techniques used in the DOE-ID and BBWI assessments were sound and the assessment approaches could not be improved in the time available to the Review Team to conduct this review and provide conclusions and recommendations.
- The Review Team's scope of work did not require selection of a top-ranked candidate for processing SBW and calcine. Instead, the Review Team was asked to judge if the Draft EIS and DOE-ID/BBWI had reasonably identified processing options for SBW and whether it agreed with the option to defer the decision to select a processing option for calcine.

In light of these considerations, the Review Team relied on two assessment approaches that it could reasonably apply:

- expert opinions of the Review Team members, and
- standard DOE stage and gate technique for evaluating technology maturity (DOE 1997).

Specifically, each Review Team member provided expert judgment concerning:

- the option to defer selection of a processing alternative for calcine,
- the options for near-term processing of SBW, and
- the options for deferred processing of calcine.

Individual unit operations for each option were discussed by the Review Team. These discussions led to consensus opinions on the options. In addition to providing expert opinion on the selection of waste processing options, Review Team members recommended various paths forward. Consensus recommendations given in this report resulted from those deliberations.

Table 2.1 provides a brief description of the stages of technology development used by DOE's Environmental Management Office of Science and Technology to evaluate the maturity of technologies (DOE 1997). Additional details on the evaluating technical maturity and gate status of a technology using this assessment method are given in Appendix G.

Table 2.1 DOE Environmental Management Stages of Technology Development

Stage	Title	Activities
1	Basic Research	Basic laboratory experimentation, development of theory and analytical models, and proof of principal
2	Applied Research	Proof of principle and lab-scale experimentation
3	Exploratory Research	Laboratory-scale prototyping, analysis of user needs, estimates of life-cycle costs, and identification of functional performance requirements and operational concepts
4	Advanced Development	Full-scale laboratory testing, preliminary field tests, technical specification development, and infrastructure development plans
5	Engineering Development	Documentation such as drawings and computer codes, construction and demonstration units, prototypes and pilot-scale systems, system evaluations, reliability testing, infrastructure plans, and procurement specifications
6	Demonstration	"Real world" demonstrations using actual waste streams and under anticipated operating conditions
7	Deployment	In service

The Review Team members separately judged the current development stage for selected SBW processing options. Individual rankings were compiled into a composite ranking that represented the collective judgment of the Review Team. The composite results are shown in Table 2.2. As Table 2.2 shows, the Review Team rated the relative technical maturity of SBW options as follows: Direct Vitrification > Cs Ion Exchange > UNEX Solvent Extraction. Results of a prior TFA stage and gate evaluation (TFA 2000) also are presented in Table 2.2 for comparison. The TFA evaluation ranked the order of technical maturity as Direct Vitrification = Cs Ion Exchange > Solvent Extraction. The Review Team was informed that a recent multi-attribute evaluation conducted by INEEL personnel resulted in a higher relative ranking for the Solvent Extraction option.

Table 2.2 Review Team Stage Maturity Evaluation for SBW Processing

Technology	Review Team Ranking	TFA Ranking*
Direct Vitrification	5	4
Cs Ion Exchange		
• CST	4	4
• AMP-PAN	3	4
UNEX Solvent Extraction	3	3
Calciner MACT	5	-
Steam Reforming	3	-
2-stage Evaporation	3	-
Silica Gel	2	-

*Ranking based on a prior gate evaluation (TFA 2000)

3.0 Sodium-Bearing Waste Processing Options

Seven options for processing SBW were evaluated recently by DOE-ID (Appendix E). These options were listed previously in Table 1.1. The Decision Management Team is considering a narrowed list of three options (shown in Table 1.3). Section 3 discusses the narrowed list of options, and the characterization and retrieval technologies common to each option. The Review Team's rationale for concurring with elimination of the other four processing options is also provided in this section.

3.1 *SBW Characterization*

Characterization of the tank waste provides data that is essential for developing, designing, and operating the treatment process and, in some cases, for validating the acceptability of the waste products for storage and disposal. Increasing degrees of characterization are needed at advancing stages of process development. Thus, there is an element of judgement involved in deciding how much characterization is needed for decision making at each stage of process development. Less information is needed to select a treatment alternative than to implement it successfully.

NAS 1999 summarizes existing characterization data on SBW. The Review Team concluded that these data are adequate for ongoing development work and, depending on the desired confidence level, may be adequate for technology down-selection. However, the Review Team believes that the current data are not adequate for detailed process design. Near-term characterization efforts should center on providing the data needed to assure a high confidence level for selecting a final, viable treatment alternative. Additional analyses should be performed later to obtain the data necessary for detailed process design and operations planning.

The SBW waste in the tanks is primarily a liquid, but solids of potential importance are also present. Prior heel samples taken with the Light Duty Utility Arm showed the existence of a layer of solids in the bottom of several tanks (Patterson 1999). The Review Team was told that retrieval of solids along with the liquid is not necessary to meet the agreement with the State of Idaho to cease-use of the tanks by 2012. However, the Review Team believes that characterization of both liquid and solid fractions should be pursued because solids are likely to be entrained during liquid retrieval. Characterization of the residual solids will also be necessary to complete tank closure.

The Review Team believes that sampling of the SBW liquid for characterization should be relatively straightforward because the liquids can be pumped to an existing station where sampling can be performed. However, the Review Team believes that sampling of the tank solids for proper characterization will be much more difficult, especially with regard to obtaining samples that are representative of the total solids present. The Review Team recommends that methods used elsewhere for sampling tank solids be reviewed for applicability at INEEL.

The Review Team further recommends use of a technically driven Data Quality Objective (DQO) methodology to identify the sampling and analytical needs for the SBW liquids and the associated solids. These needs should be considered for each alternative waste treatment path selected for continued evaluation, as different alternatives will have different characterization needs.

Recommended analyses on the liquid SBW samples likely would include:

- major cations and anions;

- minor cations and anions, and other properties important to establishing the feasibility of the candidate unit operations that make up an alternative;
- components important to RCRA "listing" and leachability of waste products; and
- radionuclides of importance to immobilized waste dose rates and other nuclear safety issues, waste classification and acceptance criteria, and process effluent and emissions limits.

The Review Team believes that it may be possible to minimize the analytical effort required for adequate characterization of the liquid by prudent routing of the evaporator bottoms during the SBW consolidation efforts planned for the near future. If the different batches of evaporator bottoms are divided essentially equally among the waste storage tanks planned to contain the consolidated wastes, then the concentrations of components in those tanks should be essentially equal. In this case, the detailed characteristics of waste components would need to be determined in only one of the tanks. The advantages of waste blending are further discussed in Section 3.2. The effort to develop a viable treatment process would also be simplified greatly for a single blended waste composition.

Characterization of solid samples obtained from the tank heels should include measurement of particle size and settling rate, in addition to the chemical and radiochemical analyses outlined above for tank liquids. Sampling of the heel solids should be considered from two aspects: (1) the solids that will be removed along with the liquid during liquid retrieval operations, and (2) the solids that will likely not be retrieved from the tanks during retrieval. The Review Team believes that efforts to sample solids that are unlikely to be retrieved with the liquid should be pursued. Such efforts should not be allowed to detract from obtaining the data needed to meet the 2012 cease-usecompliance date, however.

3.2 *SBW Retrieval*

According to the information presented to the Review Team, concentrated SBW will be consolidated in four tanks to await retrieval and treatment. Three of the tanks will be filled with concentrated SBW over the next few years; the fourth tank (WM-180) already contains concentrated SBW deemed ready for processing. The Review Team was told that the current plan involves sequential filling of the three tanks with concentrated SBW, and that the resulting concentrated wastes could vary in composition by approximately two-fold.

Such variability could have important impacts on treatment process flowsheets, especially for a vitrification process. Up to four different waste glass formulations and process flowsheets (one for each tank) would be required to accommodate a two-fold range in waste composition. Such variability in waste composition may increase the risk of phase separation in the waste glass. The Review Team was informed that the average sulfate and fluoride compositions are near the points at which a separated sulfate salt phase and a distributed fluoride crystalline phase may form.

The Review Team recommends that an alternative approach for consolidating the concentrated SBW liquids in the four receiver tanks be considered to minimize compositional variability and simplify process development. For example, it may be possible first to empty three tanks at INTEC and then add one-quarter portions of the contents of WM-180 to each. Subsequent batches of concentrated evaporator bottoms could then be distributed equally among the three tanks and WM-180, to give a uniform composition throughout these tanks.

The Review Team was told that retrieval of SBW from the tanks using existing steam jetting equipment is planned. According to INEEL staff, steam jetting should be effective in retrieving all but about a 10-inch heel of the waste, which will contain several inches of settled solids, on average. The steam jetting action is expected to entrain a small fraction of the settled solids. The Review Team was told that INEEL plans to disposition the 10-inch heel of liquid and solid wastes as a part of tank closure, and that methods of mobilizing the solids for removal are under consideration.

The initial batch of liquid waste retrieved from a tank is likely to include entrained solids of a composition that could cause operating and product quality problems if not accounted for in downstream treatments. Only two samples of the settled solids have been collected; one has been analyzed. The impact of retrieving solids along with the liquid SBW may be more problematic for the ion exchange alternative than the vitrification alternative as it is likely the solids can be incorporated into the glass waste form. For ion exchange operations, the retrieved waste could be filtered and the solids returned to the tank if it becomes necessary to reduce the impacts of incompatible solids. Depending on the outcome of the WIR determination regarding SBW, the retrievable fraction of the settled solids may be designated HLW and thus be subject to applicable HLW treatment requirements. The Review Team recommends that methods of removing and treating the retrievable solids be developed on a schedule that supports treatment of the solids simultaneously with or following treatment of the liquid fraction. The design of the liquid waste treatment system should include provisions for immobilizing the retrievable solids in accordance with the WIR determination.

The Review Team debated whether substantial efforts should be made to remove the bulk of the tank solids along with the SBW liquid. It was agreed that attempts to remove these solids would likely be required at some point. The consensus of the Review Team was that development and use of methods to retrieve these solids along with the SBW liquid should be pursued only if it does not jeopardize meeting the 2012 cease-usecompliance date. If a method to maximize solids removal during liquid retrieval can be applied without impacting the primary goal of liquid removal and treatment, the Review Team sees significant advantage in dealing with this waste during a single operation rather than requiring a separate future retrieval and treatment campaign. Use of a direct vitrification treatment process should allow the flexibility to incorporate the solids directly into the waste form.

3.3 *SBW Processing Options*

This section addresses the three SBW processing options under consideration by the Decision Management Team: (1) Direct Vitrification, (2) Cs Ion Exchange, and (3) UNEX Solvent Extraction.

3.3.1 Direct Vitrification

The Review Team recommends Direct Vitrification as the baseline processing option, even though there has been a relatively small investment to date by INEEL in the development of this approach. The Review Team's compelling reasons for recommending vitrification as the baseline process to treat SBW are:

- flexibility of disposal locations for the immobilized waste, regardless of the outcome of the WIR determination;
- production of a fully qualified, RCRA-compliant, "road ready" waste form that is safe for long-term interim storage, which is an especially important consideration if opening the geological repository is delayed;
- maturity of the technology, with successful deployment at similar or larger scales in the U.S. and abroad; and

- confidence in the ability to meet the 2012 tank cease-use date, assuming adoption of aggressive project engineering and management practices and immediate enhancement of technology development efforts

These advantages are regarded by the Review Team as an acceptable trade-off for the potentially higher costs of vitrification compared to the other alternatives.

The Review Team understands that the INEEL experience base is limited with regard to vitrification processing. Moreover, most of the evaluation and testing efforts to date have focused on calcine rather than on SBW. However, a viable range of glass compositions which accommodate SBW are being defined through a Composition Variability Study. The INEEL Principal Investigator presented to the Review Team preliminary results of work being collaboratively conducted by INEEL and Savannah River Technology Center. Attractive waste loadings (30-38%), which are higher than those produced in most current waste vitrification plants, have been obtained in laboratory and pilot melter testing. Only one pilot melter test using simulated SBW has been performed to date, but the glass melting performance with a nominal SBW formulation apparently was successful.

Concern was expressed in the Draft EIS regarding the ability of thermal treatment processes to comply with requirements for atmospheric emissions. The Review Team believes that for vitrification, there are strong precedents in existing plants to expect that Maximum Achievable Control Technology (MACT) compliance can be successfully engineered into a melter off-gas system for abatement of nitrogen oxides (NOX), for example. Characterization data on volatile species, such as mercury, cesium, technetium, and iodine, if present in sufficient quantities, will be needed to engineer an appropriate system.

The Review Team also recognizes that processing acidic SBW poses different design challenges than processing alkaline wastes, which is occurring at the West Valley Demonstration Project (WVDP) and the Savannah River Site (SRS), and planned at the Hanford Site (Hanford). The Review Team regards this as a manageable implementation issue, even though additional technology development specific to this acidic waste is needed. Successful, large-scale vitrification of acidic melter feeds has been implemented in England, France, Belgium, and Russia. This experience should be thoroughly reviewed and accessed, as appropriate.

The Review Team believes that improved SBW characterization data, as discussed in Section 3.1, are critical to the development of acceptable glass formulations and evaluation of the acceptability of waste form products. Characterization of the SBW must be considered in conjunction with the retrieval strategy to be implemented. If a retrieval method that maximizes solids removal to minimize future retrieval requirements is considered, a waste sampling and analysis plan that provides for evaluating the expected combined solid and liquid composition will need to be developed. Good characterization data will be important if INEEL uses a strategy similar to that employed at SRS to qualify the DWPF waste product through process qualification and process controls. Understanding the variability in composition of the waste feed stream is critical to successfully implementing this approach.

The Review Team recommends that DOE-ID and INEEL staff engage the services of an established vitrification contractor to provide expertise for the pre-conceptual and conceptual design stages of a vitrification plant, in the very near-term. Further, there may be benefit in evaluating the technical and engineering methods used recently by BNFL, Inc. to expedite process development and design schedules for the Hanford vitrification plant.

Continued collaboration with subject matter experts through the TFA technology development program provides an additional avenue that should be pursued to draw on experience and process knowledge across the DOE complex. Leveragin prior DOE investments and contractor experience in vitrification is expected to be important to meeting the 2012 compliance date for ceasing use of the SBW tanks.

The Review Team recommends that vitrification development efforts in the near-term focus primarily on SBW. However, a scoping assessment that compares fundamental facility size and process specifications, and treatment requirements for processing SBW and calcine, may provide an opportunity to determine whether a single plant could be constructed and used to treat both streams sequentially. If this analysis could be performed readily without diverting attention from the primary goal of treating the SBW, it could offer an opportunity for significant cost savings in meeting the 2035 compliance date for having the calcine waste "road ready". The Review Team also recommends that the roadmap for developing the vitrification technology for SBW include the following elements:

- Conduct a near-term assessment of process technology options for capture of mercury (Hg), either from feed or off-gas, and isolation of Hg into a form suitable for disposition.

- Assess the compositional range of other potential off-gas constituents of concern to establish technical options for abatement, capture, and recycle. Constituents of concern to include iodine-129 (^{129}I), technetium-99 (^{99}Tc), and NOX. Off-gas characterization should be emphasized in future laboratory and melter testing. Assessments should consider both dry off-gas systems, similar to those used in Europe, and wet scrubber systems typical of those used at WVDP and DWPF.

- Adopt a phased approach to refining glass composition as improved knowledge of the range of waste compositions is gained (see Section 3.2, which recommends blending of SBW to minimize compositional variability to lessen the need for process development).

- Identify gaps in meeting design, regulatory, safety, and operating requirements, and then pursue appropriate pilot-plant testing to adequately support process definition, plant design basis, melter selection, waste qualification, and process operation.

3.3.2 Separations and Grouting

The potential for minimizing costs for transporting and disposing the immobilized waste streams is the primary reason any separations option would be considered for implementation. The relative costs of disposal were presented to the Review Team in the following order: HLW > remote-handled (RH)-transuranic waste (TRU) >> contact-handled (CH)-TRU >> RH- low-level waste (LLW) > CH-LLW. If the WIR determination for SBW is not successful (i.e., the SBW is determined to be HLW), the reduced radioactivity stream(s) resulting from separations processing must then be considered "incidental waste" in accordance with the Implementation Guide for use with DOE M 435.1-1 (DOE 1999b) for some of the separations options being considered to be viable. Waste streams resulting from processing HLW at WVDP, SRS, and Hanford have been successfully classified incidental wastes. This classification has resulted in significant cost avoidance. The capability of WIPP to accept much more CH-TRU than RH-TRU and the potential limitations on the capacity of the repository for disposal of HLW are other potential benefits of separations.

This section discusses the two separations technologies for SBW that are under consideration by the Decision Management Team, following a brief discussion of the potential importance of solid-liquid separation to these technologies.

3.3.2.1 Solid-Liquid Separations

The success of the two radionuclide separations technologies requires removal of the solids that are retrieved along with the SBW liquid. Solids can hamper the operation of equipment in which ion exchange and solvent extraction processes are employed, as well as reduce the potential for achieving the desired radionuclide removal levels. In addition, degradation of the ion exchange sorbent media may necessitate removal of resulting small sorbent particles from the ion exchange column effluent to achieve the desired radionuclide removal level.

Development efforts at INEEL appear to have centered on the use of cross-flow filtration to achieve solid-liquid separation. In accord with NAS 1999, the Review Team believes that other mature filtration technologies may have advantages for some applications, and that such technologies should be considered when specific applications become better defined. Among the factors to be considered, are:

- solids removal efficiency
- ease of handling and processing or disposing of the removed solids
- amount and impact of secondary waste (e.g., spent filter-aid material, failed or used equipment)
- reliability, availability, and maintainability

The Review Team strongly believes that development work in the solid-liquid separation area should emphasize simple filtration testing on actual waste samples, and that such testing be done early in the testing process.

Testing with simulated wastes should be minimized. The Review Team believes that conservative equipment design (overdesign) may be a better approach than extensive characterization and simulant testing to try to optimize the design of solid-liquid separation equipment.

3.3.2.2 Ion Exchange Removal of Cesium (CsIX)

In this option, as presented to the Review Team, the SBW would be passed through a bed of ion-exchange sorbent designed to remove cesium-137 (^{137}Cs). The effluent solution would be neutralized and grouted, the grouted effluent would be disposed at WIPP as CH-TRU, and the Cs-loaded sorbent would be disposed as RH-LLW at Hanford. The objective of such processing is to engineer the dose rate at the surface of the immobilized waste containers to less than 200 mrem/h so that the immobilized waste can be disposed as CH-TRU rather than as RH-TRU.

The Review Team was told that two different Cs sorbents are currently being considered for this application: crystalline silicotitanate (CST), and ammonium molybdophosphate (AMP)- polyacrylonitrile (PAN), or AMP-PAN. The Review Team was not presented a comparison of the relative merits of these sorbents, but was told that selection of a sorbent is scheduled for June 2001. The Review Team judged the CST technology to be more mature than the AMP-PAN technology because of the extensive development efforts that have been made to use CST to process alkaline solutions.

The Review Team believes that SBW may contain radionuclides other than ^{137}Cs (e.g., europium-154) in concentrations sufficiently high that the treated waste will still be RH-TRU after the ^{137}Cs has been removed. Other uncertainties that should be addressed in selecting the sorbent and developing the process include:

- Will the sorbent become sufficiently contaminated with TRU elements that it will require disposal as TRU waste rather than as LLW?
- Is the sorbent sufficiently resistant to disintegration in acidic solutions, such as SBW?
- Does the sorbent have sufficient mechanical stability that it can be loaded into and removed from the process without excessive attrition?
- Is the performance of the sorbent in terms of its decontamination factor and Cs loading capacity sufficiently robust to satisfactorily accommodate likely variations in feed composition?
- Can the safety and performance implications of sorbent stability be managed in long-term operation?
- Can direct grouting, drying, and packaging, or some other approach meet the requirements for safe handling, transport, and disposal of the loaded sorbent?

The Review Team believes that much of this testing can be performed satisfactorily using properly-formulated simulated wastes, but also believes that tests with actual waste are essential to confirm that the sorbent does not become contaminated with TRU elements and acceptable Cs decontamination factors and loadings are achievable.

3.3.2.3 Solvent Extraction (UNEX) Removal of Cesium, Strontium, and Transuranics

Another potential processing option for SBW being considered by the Decision Management Team is the UNEX Solvent Extraction option. This technology employs a four-component solvent system to remove in one step not only ^{137}Cs from the bulk waste (as in the ion exchange option discussed above), but also strontium-90 (^{90}Sr) and TRU elements. The Review Team was told the bulk waste would be sufficiently decontaminated to be disposed as CH-LLW following neutralization and grouting. The separated high-activity would be sent to the WIPP as RH-TRU following evaporation, crystallization, and packaging.

The Review Team recommends the UNEX approach be removed from consideration for processing SBW, so that limited available resources can be channeled to the development of the Direct Vitrification and CsIX options. While the UNEX Solvent Extraction approach may offer some advantages relative to the other two options, it was judged by the Review Team to be less mature.

3.3.2.4 Grouting and Storage of Pretreated Bulk Waste Streams

According to the information presented to the Review Team, the acidic bulk waste stream would be neutralized and grouted after removal of the targeted radionuclide components to provide a solid waste form suitable for disposal. Two potential approaches were presented to the Review Team. One involves a one-step, in-drum, combined neutralization and immobilization process, and the other involves neutralization, mixing the neutralized waste and grout formers, and pouring the resulting mixture into drums where it would harden. It appears that feasibility testing on a similar INEEL waste stream (newly generated liquid waste [NGLW]) forms a basis for the development of a grout treatment process for the SBW stream.

A significant Review Team concern with grouting is the potential for drum corrosion and waste form degradation during storage prior to disposal, especially if such storage is of long duration. Experience in the DOE complex has repeatedly confirmed that this is a serious problem. Such problems are related to the amount of free and unbound water that is present in the grout.

Experience in the DOE complex also has repeatedly confirmed that minor waste components can significantly affect the setting, strength, leachability, and other properties of the grout. This experience emphasizes the importance of testing with actual wastes.

The proposed disposal of grouted INEEL waste at the LLW disposal facility at Hanford raised other Review Team concerns regarding this option. Even though such disposal may be technically feasible, it may well be problematic because of Hanford's decision to proceed with vitrification of its low-activity incidental waste rather than grouting due to stakeholder concerns. Therefore, the potential for not being able to ship the waste to Hanford adds risk to this option.

3.4 *Rationale for Eliminating SBW Processing Options*

The Review Team concurs with the Decision Management Team's narrowed list and consideration of eliminating the following SBW processing options from further evaluation : (1) Calcine MACT, (2) Two-stage Evaporation, (3) Silica Gel, and (4) Steam Reforming. The Review Team's rationale for eliminating these four options is presented below.

- Calcine MACT. In this option, described in the Draft EIS as the Continue Current Operations Alternative, the New Waste Calcining Facility (NWCF) would be upgraded to the MACT requirements under RCRA to enable calcination of the bulk of the SBW. The SBW heel liquids would be treated using ion exchange and immobilization processes, with disposal of the immobilized TRU stream at WIPP and disposal of the grouted LLW stream at INEEL. Advantages of this alternative include the established capability at INEEL for safely operating the NWCF and potentially lower initial capital costs than other options. Disadvantages include:

    - high future costs for subsequently processing the calcine to a form suitable for disposal;
    - uncertainties in selecting, permitting, and operating off-gas treatment technologies to satisfy MACT requirements;
    - uncertainties in the operability of the NWCF after the extended shutdown period;
    - availability of the existing trained staff after the 6-year period needed to complete the MACT upgrades;
    - unfavorable cost-benefit for installing and operating the ion exchange and immobilization system for processing the low volume of heel waste (estimated to be less than 200,000 gallons); and
    - high-risk of not being able to obtain the required operating permits from the State of Idaho, even with the MACT upgrades.

- Two-stage Evaporation. Two-stage evaporators and variations of the technology have been successfully operated with commercial and DOE wastes for many years. The Two-stage Evaporation option was suggested for consideration in NAS 1999. Applications at other sites have typically involved evaporation of low-dose wastes. This allows a substantial level of contact maintenance to deal with frequent equipment fouling problems. In addition to the high frequency of equipment fouling, disadvantages include the potential for inadequate dewatering of salts in the second-stage evaporation process (which could require a third-stage drying process), high potential for generation of radioactive dusts, and high likelihood of failing to meet RCRA delisting and toxic characteristic leaching procedure (TCLP) requirements.

- Silica Gel. Absorption of the waste on silica gel with subsequent drying is another method for fixing radioactive liquids. This technology was developed in Russian where it has been applied to various liquid nuclear wastes. The primary advantage of this technology is its capability to convert liquid radioactive and hazardous materials to a dry powder form at low processing temperatures (<200°C). The waste product is highly dispersable, however, and therefore requires further encapsulation or high-temperature treatment to stabilize it. Processes for stabilizing the silica gel waste product have not been demonstrated on a large scale (Herbst, A.K., and R.J. Kirkham 2000). The Review Team sees no incentive to use silica gel absorption and drying if high-temperature treatment is required to stabilize the silica gel waste product since the liquid waste could otherwise be vitrified directly.

- Steam Reforming. Steam reforming has been developed for treating a broad range of commercial waste streams, some of which are similar in composition to SBW. A proposed treatment process was informally proposed to INEEL as part of the EIS comment process, which resulted in this option being added to the list under consideration (Studsvik Inc. 2000). Advantages include production of a granular metal oxide waste product that may result in a lower volume than waste glass, and destruction of the bulk of the nitrates present in the waste. Disadvantages relative to vitrification include:

  - the need to neutralize the waste before processing;
  - the potential for alkali slagging in the pyrolysis reformer with attendant need for remote methods to remove the slag;
  - a more complex product handling system consisting of solids hoppers, a residue separator, stabilization processor, salt separator, and salt dryer;
  - a much higher potential for generation of highly radioactive fines with associated containment challenges;
  - generation of flammable synthesis gases that must be oxidized at high temperatures (up to 1200°C); and
  - increased potential for failing to meet RCRA delisting and/or TCLP requirements to enable disposal.

The Review Team concluded that each of the four options has merit for treating liquid SBW. However, the Review Team believes that use of any of these options would likely result in waste forms that require further treatment to enable disposal. The Review Team prefers options that result in solidified waste forms that are highly likely to satisfy requirements for disposal.

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4.0 Calcine Waste Processing Alternatives

As previously shown in Table 1.2, five options for processing HLW calcine were identified in the Draft EIS: (1) Hot Isostatic Pressing (HIP), (2) Direct Cementing, (3) Direct Vitrification, (4) Separations-Vitrification, and (5) Minimum INEEL Processing. The Decision Management Team is considering narrowing the list of options to HIP, Direct Vitrification, and two Separations/Vitrification options. The Review Team concurs with eliminating the Direct Cementing and Minimum INEEL Processing options from further consideration, and recommends elimination of the HIP option as well. This section describes issues and the Review Team's recommendations regarding the three retained options. Each of these options includes characterization and retrieval steps and possibly grouting of secondary wastes. The rationale for recommending elimination of the Direct Cementing, Minimum INEEL Processing, and HIP options is also provided in this section.

4.1 *Calcine Characterization*

Calcine is stored in bins, with significant variability in the composition of the calcine from bin-to-bin and layer-to-layer. NAS 1999 conveniently summarizes available calcine characterization data. Beck 2000[1] provides estimated chemical and radiochemical inventories for the calcine in each bin set. Current compositional data were largely derived from "process knowledge" based on the quantities and compositions of liquids that were fed to the calciner. The data are incomplete with respect to analytes of regulatory concern and of concern for selecting a viable calcine treatment process. No data are provided for volatile organic compounds, carbonates, and elemental carbon, for example. NAS 1999 notes a significant number of errors in the reported data. The Review Team recommends that ongoing efforts to correct and validate the data be completed as a high priority.

The Review Team believes that the principal uncertainties in planning the characterization of calcine are primarily in defining which bins to sample, the locations to sample in the selected bins, and the number of samples and volume of calcine per sample. The required chemical and radiochemical analyses for calcine are essentially the same as those for SBW. Physical properties important to retrieval (e.g., degree of powder agglomeration and powder flowability) will also be needed. The Review Team recommends a DQO methodology be used for defining calcine sampling and analysis needs.

The validity of calcine compositional data based on process knowledge is a major uncertainty. The Review Team believes that while these data may have been adequate for the initial selection of the alternatives, direct sampling and more comprehensive analyses of calcine samples are needed to support selection of the final calcine treatment alternative with confidence, and to provide data adequate for detailed process design and process operations.

The Review Team also believes development (if required) and implementation of a suitable method to obtain layer-by-layer samples of calcine should be vigorously pursued. The first such sampling would most beneficially be made where process knowledge indicates the presence of calcine layers in a single bin with compositional variations that largely bound the full range of calcine compositions in all bins. Subsequent sample analysis and comparison of the measured chemical and radiochemical compositions with those estimated from process knowledge and storage history would then provide the basis for determining any additional sampling requirements.

[1] Memo from M.D. Staiger and C.B. Millet to J.T. Beck, "*Inventory Estimates for the Tank Farm and CSSF's*", dated Feburary 18, 2000, revised March 29, 2000 (J.T. Beck, MDS-01-00 / Mil-01-00)

4.2 *Calcine Retrieval*

The Review Team was told that calcine will be retrieved from the storage bins using a vacuum system that has been under intermittent development at INEEL since 1963. Prototype testing of this system using simulated calcine apparently was successful. The system includes a vacuum nozzle and a closed-circuit television camera mounted on an articulated arm. These features enable the vacuum nozzle to be positioned anywhere inside a bin. The articulated arm assembly will be installed sequentially through different ports on bins with annular construction to accommodate the restricted range of motion of the arm in bins of this design.

Samples of alumina and zirconia calcines that had been stored for about 10 years at 200°C were collected in 1978 and judged by INEEL staff to be retrievable using the vacuum method then in use. The zirconia calcine was found to be free-flowing, but the alumina calcine required prodding to remove it from the sample tube (NAS 1999). NAS 1999 also reported there had been problems from plugging transfer lines and the cyclone when the alumina calcine was made. At the June 2000 meeting, INEEL staff reported that methods for inducing the flow of sticky calcines are under consideration. These methods include vibration and air injection.

The Review Team believes that calcines that have been stored for extended periods - alumina calcines in particular – pose elevated risks of plugging retrieval equipment. The lower temperatures observed near the wall of the bins may exacerbate handling problems due to the potential for greater moisture absorption at this temperature. This would increase the transfer of water vapor from the air to the calcine, which may increase stickiness and cause more severe plugging problems than encountered with freshly made calcines.

Despite these reservations, the Review Team believes the vacuum retrieval system planned by INEEL is likely to be successful in removing the bulk of the calcine from the bins. NAS 1999 also concluded the system could be made to work. Significant amounts of sticky calcine may not be retrievable using the current system, however. The Review Team recommends that INEEL consider designing a sampling device to obtain a sample of potentially sticky calcine from a point close to the wall of a bin likely to contain a problematic, compacted calcine. INEEL has been storing a sample of alumina calcine for many years. The Review Team recommends testing subsamples of this calcine under the worst-case conditions anticipated during retrieval and subsequent handling operations. Worst-case conditions for calcine stickiness include the lowest anticipated storage/processing temperature, the highest anticipated humidity, and the highest compaction pressure. The purpose of sampling sticky calcines and performing worst-case testing is to support the evaluation of potential calcine handling problems and the effectiveness of candidate recovery methods. If INEEL's vibratory and/or air injection methods are found to be ineffective, other methods such as purging the calcine with hot, dry air should be considered.

4.3 *Calcine Separations Options*

The Draft EIS states that the estimated volumes of treated HLW from the Direct Vitrification option are 8,500 m^3 and 470 m^3 from a separations option. A potential disposal cost avoidance of nearly $6 billion was calculated for the separations options based on the currently estimated cost of $540,000 per canister disposed in a HLW repository and an assumed canister capacity of 0.7 m^3 of waste glass. The Review Team agrees that performing separations of selected radionuclides to decrease the volume of treated HLW may minimize the overall life-cycle costs. The Review Team therefore recommends pursuit of technology development activities in this area so that the magnitude of potential disposal cost avoidance and the cost of performing separations to reduce disposal costs can be better defined. The Review Team believes that such activities are necessary to the development of total life-cycle costs, which should be a primary basis for comparing the different options.

The Review Team discussed whether development work should continue on dissolved calcine or be deferred for several years. The majority believed that deferral would be desirable only if proceeding with development at this time would detract from efforts to meet the 2012 cease-use deadline for the tanks.

The calcine must be dissolved before the separations processes under consideration can be implemented. The limited information presented to the Review Team indicated that approximately 90 to 98% of the calcine can be dissolved in nitric acid (NAS 1999). The residual solids have not been well characterized, but the Review Team believes that they will likely require disposal as vitrified HLW. Determination of the quantity and variation in composition of these solids will be important to assessing their impacts on potential vitrification options.

Separation of undissolved solids from the dissolved calcine liquid will be important to the success of calcine separations processes. The discussion of solid-liquid separations in Section 3.3.2.1 for SBW processing alternatives is pertinent to dissolved calcine as well.

The separations approaches considered in the Draft EIS for dissolved calcine are aimed at separation of ^{137}Cs, ^{90}Sr, and TRU elements from the bulk waste constituents. One of these approaches, termed "Full Separations", involves the following three separate, sequential unit operations to remove these radionuclides: (1) ion exchange to remove ^{137}Cs; (2) the SREX solvent extraction process to remove ^{90}Sr; and (3) the TRUEX solvent extraction process to remove TRU elements. The second separations approach, termed UNEX, removes all of these radionuclides in one solvent extraction process. This is the same process considered for SBW treatment in Section 3.3.2.3.

While the Review Team recommends that solvent extraction not be developed for SBW, it supports development of this technology for potential application to dissolved calcine. The primary reasons for this difference in perspective are: (1) the longer time available for developing separations processes for calcine than for SBW, and (2) the much larger potential economic benefit to performing separations on calcine than on SBW due to the substantially greater volume of HLW glass required to immobilize the calcine.

4.4 *Vitrification in Calcine Processing Alternatives*

The Review Team understands that a vitrification system likely will be needed for either the Direct Vitrification option or for the separations options to vitrify undissolved calcine solids and radionuclides separated from the dissolved calcine solutions. The required capacity of the vitrification system will depend on the treatment option selected.

The chemical and physical characteristics of the calcines, undissolved solids, and separated radiochemical streams are expected to vary widely. The Review Team recommends that INEEL plan to retrieve and blend large batches of calcine to reduce compositional variability prior to processing. This will reduce the range of vitrification and separations flowsheets that must be evaluated to a more manageable set. The current compositions of the calcines largely are based on process knowledge as discussed in Section 4.1. Further analyses of the calcines are recommended over the next several years to validate compositions based on process knowledge and to fill data gaps important for assessing process feasibility. Further analyses of undissolved solids remaining after dissolving calcines of different process origins are also recommended to evaluate the flexibility of vitrification to accommodate chemical variability in this waste stream.

The Review Team recommends development of detailed flowsheets for each proposed calcine process and batch blend to assess of the feasibility and flexibility of each unit operation that will be employed, including those in the off-gas treatment systems. The development of detailed vitrification flowsheets should be based on comprehensive reviews of applicable waste vitrification systems and their supporting off-gas treatment systems in the U.S. and Europe. Significant testing of vitrification and off-gas treatment systems should not be initiated until testing needs are identified through analysis of emissions limits, immobilized waste acceptance criteria for storage and disposal, and the variabilities embodied in the bounding flowsheets.

The Review Team believes it is highly likely that vitrification of the calcine, undissolved solids, and separated streams will be proven feasible. The Review Team recommends periodic re-evaluation of the vitrification alternative against the evolving requirements and costs for disposal of treated HLW.

4.5 *Grouting in Calcine Processing Alternatives*

Both separations and vitrification options for calcines will produce aqueous waste streams that likely are amenable to grouting. For the separations processes, the bulk solution from which radionuclides are removed must be immobilized for disposal as LLW. The Review Team believes grouting should be the baseline for such immobilization. Separations and vitrification processes may produce other aqueous wastes that may also be grouted. The Review Team recommends the separations and vitrification process flowsheets be developed to a level of detail that defines bounding feed compositions for grouting. These bounding compositions should be used for grout treatability testing. The discussion of SBW grouting in Section 3.3.2.4 is also pertinent to aqueous waste streams produced by separations and vitrification processes for aqueous calcine waste streams.

4.6 *Rationale for Eliminating Calcine Processing Options*

The Review Team concurs with the Decision Management Team's consideration for eliminating the Direct Cementing and Minimum INEEL processing options from further evaluation, and recommends elimination of the HIP option as well. The Review Team's rationale for eliminating these three options is presented below.

- Direct Cementing. In this option the New Waste Calcining Facility would be upgraded to meet MACT requirements and the SBW would be calcined as in the Calcine MACT option for SBW (see Section 3.4). The existing calcine and new SBW calcine would be mixed with grout-forming materials and water, and the resulting grout mixture would be poured into canisters. The canisters would then be treated under elevated temperatures and pressures to accelerate curing of the grout product. Disadvantages of this option include those described for the Calcine MACT option, which the Review Team recommended be eliminated. The volume of the grouted product also would be greater than the volume of vitrified product in any option. The acceptability of the grouted product for disposal in a HLW repository is highly uncertain. The elevated temperatures and pressures required for processing introduce corrosion concerns and complicate remote maintenance of the autoclaves in which the elevated temperature and pressure processing would be conducted. Another concern is the potential for pressurizing the sealed canisters as a consequence of decomposing residual water or organic materials in the grouted product.

- Minimum INEEL Processing. In this option all of the calcine would be packaged and shipped to Hanford where it would be separated into HLW and low-activity waste fractions and vitrified. The SBW would be processed as in the CsIX option for SBW described in Section 3.3.2.2. Disadvantages of the Minimum INEEL Processing option include: (1) safety issues associated with transporting thousands of containers of highly dispersible calcine product to Hanford; (2) the potential for the calcine to be chemically and physically incompatible with the Hanford separations and vitrification systems, resulting in the need to perform significant refitting of equipment; and (3) the likely unwillingness of the State of Washington to accept HLW produced elsewhere, especially until all existing Hanford tank waste is properly dispositioned.

- Hot Isostatic Pressing (HIP). In this option, the calcine would be mixed with chemicals and converted to a glass-ceramic waste product. The HIP option appears to have the potential of producing a waste form that meets the leach-resistance and waste loading requirements for disposal in an HLW repository. The irregular shape and doubtful integrity of the HIP canister (caused by the collapse of the canister as the waste product densifies under high pressures and temperatures) requires use of an overpack container. The net waste loading in the overpack container probably is similar to that achievable in a glass waste form, which requires a single container.

  In the Review Team's view, the HIP option has numerous disadvantages when compared to the Direct Vitrification option. HIP requires extremely high pressures (~ 20,000 psi) combined with high temperatures (~1,000°C). The waste contains chemicals, including chlorides, fluorides, and phosphates, that can be highly corrosive under these conditions. The need to inspect the pressure vessels for evidence of corrosion would be complicated by the high radiation environment and the dispersable nature of the calcine. HIP requires dry mixing and possibly coincident grinding of the waste as a prerequisite for producing a relatively homogeneous product. The presence of chemical fluxes such as sodium, potassium, and boron in the calcine requires careful analysis and blending with the proper additives to avoid entrapment of gas bubbles by the vitreous phase which could reduce the waste loading and quality of the waste form.

  The throughput rate of the HIP process is slow relative to joule-heated vitrification. Multiple processing lines may be required depending on the throughput requirements. Each processing line would require a significant number of mechanical handling steps that must be performed under remote operating conditions. Remote mechanical steps unique to HIP include dry blending, filling thin-walled canisters with the blend, compacting the blend (possibly with vibration), sealing off the blend addition port, moving the thin-walled canister to the heated pressure vessel, attaching the vacuum line to extract gases as they are released from the heated canister, sealing the pressure vessel to ensure attainment of 20,000 psi of pressure, removing the collapsed product canister after HIP, cutting the gas extraction tubing, and inserting the collapsed product canister into an overpack container. The Review Team believes the safety and operational complexities of the HIP process significantly outweigh the limited advantages.

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5.0 Potential For Process Integration

The preceding two sections discussed the processing of SBW and calcine as independent and separate entities. Reasons for separately processing these wastes are provided below.

- There are significant differences in the physical forms, compositions and sources of these wastes.
- The calcine is currently stored in a much more stable and safer form than the SBW.
- The compliance dates for disposition of the two wastes are markedly different, with a great deal more urgency attached to the 2012 date for removal of SBW and ceasing use of the tanks, compared to the urgency to have the calcine "road ready" for shipment from Idaho by 2035.

The Review Team recognized that significant cost savings may be realized by integrating the processing of SBW and calcine, and possibly tank heels and NGLW. It is also recognized that excessive emphasis on planning for integrated use of processing facilities has the potential to delay the schedule to meet the 2012 compliance date. In the Review Team's collective opinion, a high degree of focus needs to be maintained on the primary path to retrieve and process SBW, with minimal distractions from exploring alternatives for processing the other waste types.

However, in consideration of the Review Team's recommendation that Direct Vitrification be adopted as the baseline for processing SBW and the potential role of vitrification for processing calcine, the prospect of using the SBW vitrification plant to process calcine and possibly tank heels should be assessed. At issue is the degree to which a vitrification plant optimized for SBW could be modified or refitted to accommodate either direct vitrification of calcine, or vitrification of pertinent streams from calcine separations processes. Significant differences in melter feed preparation and possibly melter capabilities are expected for the two waste types. Also, it appears that the vitrification throughput rate required to process the SBW inventory by 2012 could dictate a large plant. A dilemma arises in justifying the investment in a large plant for a relatively short processing campaign, when other options such as stretching out the SBW processing time or using the plant's capability for follow-on processing of calcine are more reasonable. The Review Team recognized that options for dealing with this dilemma while achieving cost-effective compliance could involve:

- including substantial surge tank capacity within the SBW treatment plant to allow more time for SBW processing;
- renegotiating a later tank cease-use date to accommodate a reasonable throughput rate without the need for substantial surge tank capacity; and
- designing for refitting the facility to process calcine or streams from calcine separations processes.

Section 3.3.1 includes discussion on the Review Team's recommendation on performing an assessment of sequentially vitrifying SBW and the other waste streams in which these issues could be addressed. Also recognized were similar issues if the CsIX option were to be changed from backup to baseline status. These issues include how to plan the CsIX option for SBW in relation to the separations options under consideration for calcine, and how to evaluate the benefits that might accrue from use of additional tankage to meet the 2012 compliance date while operating smaller facilities over a longer period of time.

The Review Team also recognized that combined (rather than sequential) processing of SBW and calcine (and possibly heels), if all are to be disposed of in an HLW geological repository, might reduce the total number of waste canisters produced. While this option could be addressed in the recommended assessment of sequential vitrification, it likely would add excessive complexity and increase the risk of not substantially meeting the 2012 compliance date.

The Review Team considers the solids in SBW tank heels to pose difficulties for processing and for ultimate closure of the tanks, as discussed in Section 3.2.1. Retrieval of the tank heels, which are high in solids, along with the bulk of the SBW has potential to enhance the overall tank cleanup process. The Review Team believes that vitrifying these solids as a minor component of the SBW stream should be feasible. The Review Team recommends that development of technology to retrieve high-solids heels with the bulk SBW should be pursued only if it does not jeopardize meeting the 2012 compliance date.

Information provided to the Review Team on grouting NGLW and separated SBW streams indicated that development and design activities are progressing with good results and momentum. The Review Team regards grouting as an appropriate treatment for these streams, despite the issues identified in Section 3.3.2.4. The effort to develop grouting capability should be rescoped to address NGLW as the primary focus, with only limited consideration given to using the same system to grout the separated, low-activity stream from the CsIX backup option.

6.0 Conclusions and Recommendations

Key conclusions and recommendations from the earlier sections of this report are summarized and integrated in this section.

6.1 *General Conclusions and Recommendations*

1. INEEL, DOE, and contractor staff have implemented a technology selection process and path-forward planning approach that is likely to be successful in meeting technical and regulatory requirements for SBW and calcine.

2. The multi-attribute approaches used by DOE-ID and its contractor personnel to narrow options for the EIS and Record of Decision was comprehensive, did not overlook highly promising technologies, and produced reasonable alternatives for SBW and calcine disposition. Specifically, the Review Team concurred with eliminating the Two-stage Evaporation, Steam Reforming, Calcine MACT, and Silica Gel options from the list of SBW processing technologies, and the Direct Cementing and Minimum INEEL Processing options from the list of calcine technologies recommended for further consideration.

3. The Review Team concurs with the NAS recommendation (NAS 1999) and Decision Management Team preference to proceed rapidly with SBW treatment but defer a decision on a calcine treatment alternative. The key rationale for this conclusion is that liquid SBW stored in aging tanks that cannot be permitted under RCRA poses a more immediate environmental threat (and is subject to a much nearer compliance date) than stabilized calcine which is stored in a dry state in robust bin sets. In addition, it should be possible to defer selecting a final calcine treatment alternative for several years without compromising the ability to meet the 2035 "road ready" compliance date.

4. The Team concurs with immediately dropping all options involving calcination. While calcination is thoroughly demonstrated for INEEL liquid wastes and has attractive features for solidifying existing SBW and NGLW, permitting and stakeholder uncertainties significantly increase the risk of never restarting the calciner.

5. While integration of processes for treating NGLW, SBW, tank heels and calcine may have attractive features, this possibility should not be allowed to detract from the work needed to meet the 2012 compliance date for ceasing use of the tanks. Because these four waste streams vary greatly in quantity, composition, physical form, and legal definitions, the Review Team believes attempts to force an unnatural engineering fit could serve as a major distraction and resource drain in meeting the tank cease-use deadline. However, a scoping assessment that compares fundamental facility size and specifications for processing SBW and calcine may provide an opportunity to determine whether a single plant could be constructed and used to treat both streams sequentially. If this analysis could be performed readily without diverting attention from the primary goal of treating the SBW, it could provide an opportunity for significant cost savings and increase the likelihood of having the calcine waste "road ready" by 2035.

6. The requisite roadmapping to support technology selection and development should proceed expeditiously. The SBW roadmaps for the Direct Vitrification and CsIX Separation options (the Review Team's two preferred options for SBW) can and must be fleshed out quickly to define in detail the waste characterization and treatment technology development program required to select a

final technology alternative within two years. There is less urgency for developing the calcine characterization and treatment technology roadmap, but this roadmap also should be developed more fully in the near term without diminishing the urgency for the detailed SBW roadmap.

7. To ensure success for any SBW or calcine processing option, adequate development resources must be made available to more fully characterize the waste, develop flowsheets, and fill performance data gaps through appropriate testing. Significant technical uncertainties exist for all options, and these can only be resolved sufficiently through a highly focused, aggressive, and adequately robust technology development program. This program is critical to the final alternative selection and subsequent engineering design.

8. The necessary sampling and analysis to support technology selection and development should be done expeditiously. For every SBW and calcine treatment option, significant questions remain to be addressed because of the limited characterization carried out to date. Adequate characterization of the actual wastes would benefit the technology selection process and fill data gaps. Likewise, sufficient quantities of actual waste will be needed to conduct processing tests at a reasonable scale to confirm the validity of larger-scale tests that involve simulated wastes.

9. Pilot-scale testing will likely be required to validate design assumptions for critical unit operations. In the baseline process, pilot testing will also provide a vehicle for acquainting and training engineers and operators in the processing technology. The Review Team recommended the Direct Vitrification option as the baseline for treating SBW. It is reasonable to begin planning for a SBW vitrification pilot plant that includes a melter and critical unit operations for treating off-gases. It is premature to plan for a calcine treatment plant because a baseline for treating calcine has not yet been defined.

   Certain unit operations in the vitrification system – including HEPA filtration, glass formers blending, and probably liquid-solid separation – do not require pilot-testing because their performance parameters are well known, or lab-scale testing (as with liquid-solids separation) should provide an adequate design basis. Significant groundwork must be performed to establish which unit operations should be included in the pilot plant and which design and operating parameters should be measured during pilot-testing. The groundwork includes making fundamental decisions and conducting supporting analysis to define the type of melter (joule-heated or cold crucible) and the type of off-gas treatment system (wet or dry scrubbing) to be used. These decisions and studies should form the framework for the preconceptual design, which in turn should serve as the primary basis for defining the elements of the pilot plant and its testing objectives.

   Other key bases for the pilot plant are: (1) bounding flowsheets (the Review Team recommended blending to produce a single SBW composition which would greatly simplify characterization and process development); (2) plant emissions limits and waste form transportation and acceptance criteria, and associated compliance strategies; (3) applicable literature, designs, operating constraints, and latitudes; and (4) data gaps derived from a DQO-based evaluation of requirements and available design bases.

6.2 *Conclusions and Recommendations for SBW*

1. The Direct Vitrification option should be adopted as the SBW baseline. Some of the key factors underlying this and other Review Team recommendations for SBW are summarized in Table 6.1; further rationale for recommending Direct Vitrification is as follows:

- The Review Team judged the Direct Vitrification option as the most mature choice for processing SBW. Even though only limited vitrification of simulated SBW has been performed, large quantities of related wastes have been vitrified successfully at WVDP, SRS, and in Europe. Issues involving the control of off-gas from the melter are a major concern for SBW, but were judged by the Review Team to be manageable.

- The Direct Vitrification option produces only one waste form (glass). Glass is the only product from a SBW candidate treatment process that already qualifies for disposal in an HLW repository. If SBW is determined to be TRU waste under the WIR determination process, the same vitrified waste product would be acceptable at WIPP. In contrast, separations processes generate at least two primary waste products that likely would be disposed at different sites and are sensitive to incidental waste determinations.

- A strong possibility exists that the treated SBW will be held in interim storage for an extended period. Vitrified waste will not subject its container to corrosion, as would grout and other waste forms that contain unbound water and corrosive chemicals.

- Available cost estimates of the various SBW processing options were judged by the Review Team to be highly uncertain. The Review Team concluded that the differences in cost at this stage may not be significant. In any case, the financial penalty if higher waste volume costs actually are incurred for the Direct Vitrification option would be relatively moderate considering the limited volume of vitrified SBW product. The Review Team believes the risk of this potential cost penalty is offset by the high likelihood for success of Direct Vitrification.

- Regulatory and off-site waste acceptance issues related to delisting, transportation, and waste form qualification are substantially less significant for vitrified waste compared to other waste forms.

2. The CsIX option should be pursued as the backup to the Direct Vitrification option. The Review Team concluded that only this option should be developed as a backup because of its potential to minimize life-cycle costs and its perceived higher technical maturity relative to other separations options. Evaluation of the CsIX option over a two-year period should ensure adequate time to resolve critical technical uncertainties and clarify issues related to waste product transportation, disposal costs, and other factors.

3. The Solvent Extraction option for processing SBW should be eliminated from further consideration and associated resources refocused on the application of this technology to calcine.

4. The Review Team believes that with aggressive roadmapping, technology development, and involvement of expertise from successful vitrification programs, the 2012 compliance date can be met. Specifically, the Review Team believes that preconceptual design could begin almost immediately to help identify waste characterization and process testing needs.

5. Retrieval methods that maximize the removal of heel solids should be considered seriously, but not to the detriment of meeting the 2012 compliance date.

6. A WIR determination for SBW should be pursued aggressively, regardless of the options selected for development and implementation. This determination is critical for justifying any SBW options other than the Direct Vitrification option. A successful WIR determination also would allow disposition of vitrified SBW in the existing WIPP repository.

Table 6.1 SBW Options: Technical Bases for Recommendations

Option	Cost*	Relative Technical Uncertainty	WIR Determination Vulnerability	Waste Form Interim Storage Acceptability	Waste Product Parameters*		
					Type	Volume (m^3)	Disposal Site
Direct Vitrification	760	L	L	H	RH-TRU	440	WIPP or Yucca Mountain
CsIX	370	M	H	L	CH-TRU	500	WIPP
					RH-TRU	54	WIPP
					RH-LLW	40	Hanford
UNEX	610	H	H	L	CH-LLW	6,400 **	Hanford
					RH-TRU	400	WIPP
					Organic TRU	Unknown but low	Unknown

* Cost estimates and waste products shown are as presented to the Review Team. Cost uncertainties are high and estimates may not be inclusive.
** 6,400 m3 ≅ 32,000 drums

6.3 *Conclusions and Recommendations for Calcine*

1. The Direct Vitrification option and the two Solvent Separations options should be carried forward to a decision date consistent with appropriate plans to meet the 2035 "road ready" compliance date.

2. The HIP option should be eliminated from further consideration. The Review Team judged the safety and operational complexity issues associated with this option to be prohibitive. Moreover, the likelihood of qualifying non-vitrified waste forms for disposal at an HLW repository is highly uncertain at the present time, and likely will be for the foreseeable future.

In summary, the Review Team strongly endorses the timeliness and approaches being taken to address treatment and disposal of SBW and calcine. The Review Team believes the necessary components are in place for successfully managing and implementing the disposition of these wastes.

7.0 References

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Murphy, J., B. Palmer, and K. Perry. 2000. *Sodium Bearing Waste Processing Alternatives Analysis*, INEEL/EXT-2000-00361, Pre-Decisional Draft – May 1, 2000, Idaho National Engineering and Environmental Laboratory.

National Academy Press (NAS). 1999. *Alternative High-Level Waste Treatments at the Idaho National Engineering and Environmental Laboratory*, Washington, D.C.

Patterson, M. 1999. *Light Duty Utility Arm Deployment in Tank WM-188*, INEEL/EXT-99-01302, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

Studsvik, Inc. 2000. *Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement DOE-EIS-0287D*, Columbia, South Carolina.

Tanks Focus Area (TFA). 2000. *TFA Midyear Review Report FY2000*, PNNL-13205, Richland, Washington.

U.S. Department of Energy (DOE). 1997. Interim Guidance, *US DOE Standard Operating Procedures – OST Technology Decision Process*, Office of Environmental Management. As shown at http://www.oakridge.doe.gov/em/td/sop-r7.pdf on June 29, 2000.

U.S. Department of Energy (DOE). 1999a. Process for Identifying Potential Alternatives for the Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement, Revision 1. DOE-ID 10627, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1999b. *Radioactive Waste Management Manual*, DOE M 435.1-1, Washington, D.C.

APPENDIX A

DOE Request to TFA for Technology Assessment, Statement of Work, and Simplified INEEL Flowsheet/Disposition Map

Appendix A: DOE Request to TFA for Technology Assessment, Statement of Work, and Simplified INEEL Flowsheet/Disposition Map

United States Government **Department of Energy**

memorandum

Idaho Operations Office

RECEIVED
T.M. BROUNS
MAY 8 2000

Date: May 4, 2000

Subject: Request for Tank Focus Area (TFA) Support -- Idaho High Level Waste and Facility Disposition Environmental Impact Statement (EIS) Technology Assessment (EM-HLW-EIS-00-029)

To: Paul Kruger, Assistant Manager for Science and Technology
Richland Operations Office

The purpose of this memorandum is to request Tank Focus Area (TFA) support in conducting an independent technical review of technologies under evaluation at the Idaho National Engineering and Environmental Laboratory for treatment of INEEL High Level Waste. I have discussed this request with both Mr. Ted Pietrok of your staff and Mr. Thomas Brouns of the Pacific Northwest National Laboratory (PNNL) and outlined the scope and schedule for this effort at an April 17 meeting with them. The scope of this effort would be to assemble a team of subject matter experts from the TFA to provide a review of the technology(s) under consideration for the treatment of liquid sodium bearing waste and calcine HLW at the INEEL. This effort would also include a review of characterization and retrieval requirements associated with the stored calcine HLW.

The INEEL HLW Program is currently evaluating treatment alternatives for processing the remaining liquids and solid calcine HLW. We currently have approximately 1.4 million gallons of liquid waste stored in 11 stainless steel tanks and approximately 4,000 cubic meters of solid HLW calcine stored in 6 bin sets. A draft Environmental Impact Statement concerning treatment of these wastes was issued on January 21 of this year. The EIS evaluates various treatment alternatives for these wastes, including no action. The EIS did not identify a preferred alternative. The public comment period for the EIS closed on April 19. We are currently evaluating comments and developing the preferred alternative. A decision management team, composed of representatives from DOE Idaho, Richland, Savannah River and HQ, will provide a recommendation to EM-1 on the preferred alternative. This recommendation will be provided on August 30, 2000.

A key decision criterion in identification of the preferred alternative(s) is technical maturity. The alternatives under evaluation represent a broad spectrum of technical knowledge. As part of the preferred alternative decision making process, I am looking for an independent technical review of the technologies being considered for waste treatment. This assessment would include an evaluation of the R&D work performed to date, technical gaps/uncertainties, scale-up (implementation), and recommended technical path forward. This review would focus on the alternatives evaluated through the EIS process and on the suite of alternatives being considered for the final preferred alternative recommendation.

The period of performance would be from June 1, 2000 through July 31, 2000. One meeting of the team is assumed for the week of June 19 through June 23 in Idaho Falls. A final report of the assessment would be provided to DOE-ID by July 5. Assuming that the TFA can support this request, the next step would be for the TFA provide to me a brief proposal outlining TFA

Paul Kruger 2

implementation of the scope, identification of recommended team members (including the team lead), and funding requirements. As I discussed with Ted and Tom, we are willing to fund this review, preferably through a cost share arrangement.

I look forward to working with the TFA on this important task. Please call me at 208-526-6795 if you have any questions.

Joel T. Case, Director
INTEC Waste Program

cc: Kurt Gerdes-DOE-HQ
Ted Pietrok DOE-RL
✓Tom Brouns -PNNL
Sally Robison-DOE-HQ
Lisa Green, DOE-ID
Richard Kimmel, DOE-ID
Tom Williams, DOE-ID
Gerald Boyd -DOE-HQ
Mike Worley DOE-HQ

Idaho HLW EIS Technology Assessment Review Team Statement of Work (DRAFT)

Background

The Tanks Focus Area (TFA) was established to deliver and work with users to implement technical solutions to safely and efficiently accomplish tank waste remediation across the Department of Energy (DOE) complex, specifically at those DOE sites which have high level radioactive waste (HLW) tanks. On May 4, 2000, DOE Idaho Operations Office (DOE-ID) requested that the TFA conduct an independent technical review of technologies under evaluation at the Idaho National Engineering and Environmental Laboratory (INEEL) for treatment of INEEL HLW.

The INEEL HLW Program is currently evaluating treatment alternatives for processing the remaining liquids and solid calcine HLW. INEEL currently has approximately 1.4M gallons of liquid waste stored in 11 stainless steel tanks and ~4,000 cubic meters of solid HLW calcine stored in 6 bin sets. A draft environmental impact statement (EIS) concerning treatment of these wastes was issued on January 21 of this year. The EIS evaluates various treatment alternatives for these wastes, including no action. The EIS did not identify a preferred alternative. The public comment period for the EIS closed on April 19. INEEL/DOE-ID is currently evaluating comments and developing the preferred alternative. A Decision Management Team, composed of representatives from DOE-ID, Richland, Savannah River and Carlsbad, will provide a preferred alternative recommendation to EM-1 on August 30, 2000.

The requested review will focus on the alternatives evaluated through the EIS process and on the suite of alternatives being considered for the final preferred alternative recommendation. Results of the review will contribute to the preferred alternative decision making process.

To address this request, the TFA will convene a panel of national experts in the appropriate technical areas to perform the assessment. The assessment will include an evaluation of the suite of alternatives considered and preferred alternatives currently proposed, research and development work on the preferred alternatives performed to date and technical gaps and uncertainties, and a recommended technical path forward. A draft final report of the assessment will be provided to DOE-ID by July 7, 2000.

Dr. P. Gary Eller of Los Alamos National Laboratory has been selected to lead this panel of national experts in the role as review team leader.

Scope of the Review

A key objective of the review is to assess whether the preferred alternative(s) proposed are appropriate and represent a reasonable technical risk. Key decision criteria for identification of the preferred alternative(s) include technical uncertainty and technology maturity. The alternatives under evaluation represent a broad spectrum of technical knowledge related to waste treatment.

The scope of the review will include an assessment of the technologies under consideration for the treatment of liquid sodium bearing waste and calcine HLW at the INEEL. This effort would also include a review of characterization and retrieval requirements associated with the stored calcine HLW.

The assessment will include:

- Review of the alternatives considered through the EIS process and the proposed preferred alternatives. A key question is:

- Do the preferred alternatives represent the right set of alternatives to pursue with acceptable levels of technical risk?
- Evaluation of the R&D work performed to date on the preferred alternatives, technical issues and uncertainties that must be addressed, and work activities required to address those issues. Key questions include:
- Have all of the critical technical risks and uncertainties been identified?
- Are the work activities and schedules proposed to address the technical issues and scale-up the technology alternatives adequate?
- Can the technologies be ready to support the INEEL HLW treatment schedule?

Approach

Under the lead of Dr. Eller, the review team will review technologies under evaluation at the INEEL for treatment of HLW by completing the following activities:

- The team will review the EIS options considered and previous alternatives considered by the National Academy of Sciences/National Research Council (NAS/NRC). The team will be provided information and reports to familiarize themselves with the INEEL wastes and technology options. In early June, 2000, team members will receive advance information including:
- Idaho High-Level Waste & Facilities Disposition: Draft *Environmental Impact Statement - Summary*.
- National Research Council report *Alternative High-Level Waste Treatments at the Idaho National Engineering and Environmental Laboratory*

- Review Proposed Preferred Alternatives. The team will receive technical information describing the proposed preferred alternatives and downselection information. During the week of June 12, 2000, technical reports will be provided to the review team for consideration. Information to be provided will include:
- Technical basis for screening of technology options
- Simplified flowsheets and technology information on the preferred alternatives considered
- Technology maturity status for alternatives considered
- Status of efforts to address recommendations from the National Academy of Sciences/National Research Council report
- Proposed technology roadmaps for the preferred alternatives

- The review team will meet in Idaho Falls, ID on June 19-23 for detailed briefings on the proposed preferred alternatives, maturity of the technologies within the preferred alternatives and corresponding technical issues and uncertainties, proposed work activities and schedule to address the identified issues. The meetings will include time for questions and discussion between the review team, INEEL staff, and TFA staff. These discussions will provide opportunity for the team to:
- Review the alternatives considered through the EIS process and the proposed preferred alternatives
- Evaluate the R&D work performed to date on the preferred alternatives, technical issues and uncertainties that must be addressed, and work activities required to address those issues

The review team leader and TFA will work with DOE-ID and INEEL staff to prepare a detailed agenda for the meeting. Presentations from DOE-ID and INEEL staff with adequate time for discussion will be the primary focus of the meeting. It is expected that meeting presentations may include information on related TFA investments. Two TFA Technology Integration Managers will participate to provide the review team information on past and ongoing investments relevant to this assessment.

- Executive sessions of the review team will be held on June 22-23 to identify recommendations and conclusions. The team may request additional information from INEEL staff to support deliberations. A draft review report will be initiated. The review panel will provide a meeting closeout briefing to TFA and INEEL management on Friday, June 23 with initial reactions from the review.

- The Review Team leader, with TFA support, will consolidate input and comments from team members and prepare a draft final report (letter report). Review team members will review, comment, and provide additional input to the team leader between June 26-30, 2000. A summary of the Review Team recommendations will be provided by June 30 to DOE-ID. The draft final report will be issued to DOE-ID by July 7, 2000.

- The Review Team Leader will brief DOE-ID and the Decision Management Team the week of July 10, 2000 on the team's recommendations.

Schedule and Deliverables

The review period will be June 1 – July 7, 2000. One meeting of the team is assumed for the week of June 19-23 in Idaho Falls. A draft final report of the assessment would be provided to DOE-ID by July 7. A briefing to the Decision Management Team will be provided by the Review Team Leader the week of July 10, 2000.

Non-Disclosure Agreement

It is possible that some of the information being reviewed will require review team members to sign and abide by a non-disclosure agreement. This will be determined prior to the start of the review team meeting.

Review Team Membership

The following personnel have been selected for the TFA review team

Team Members

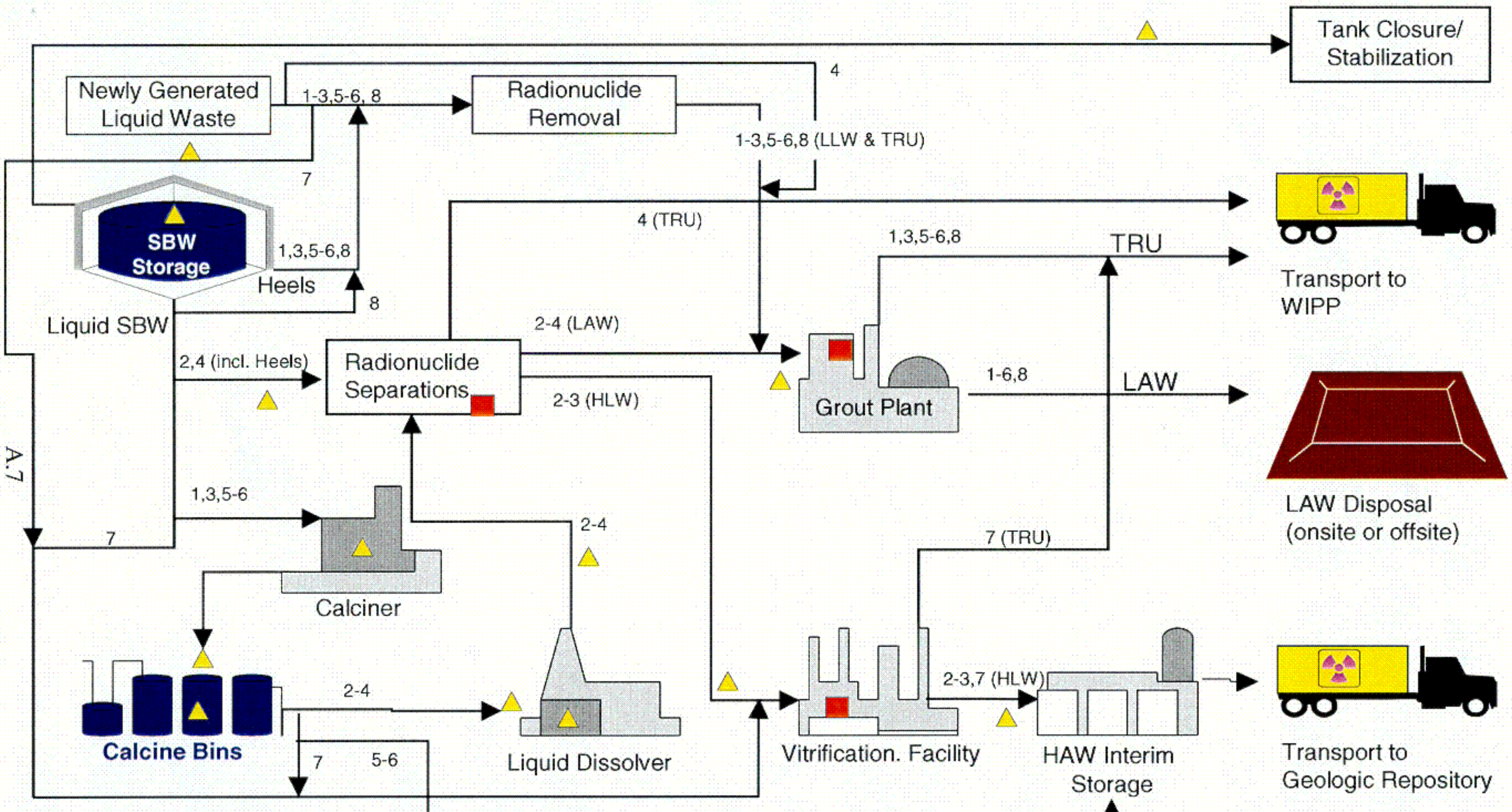
P. Gary Eller, Team Leader	Los Alamos National Laboratory
Wallace W. (Wally) Schulz	Consultant, W2S Company, Inc.
Raymond (Ray) Wymer	Consultant
Joseph A. (Joe) Gentilucci	Consultant, JAG Technical Services, Inc.
John L. Swanson	Consultant
E. Thomas (Tom) Weber	Consultant
Lawrence L. (Larry) Tavlarides	Syracuse University
Christine A. (Chris) Langton	Westinghouse Savannah River Company
Russell L. (Russ) Treat	Consultant, Moeller and Associates

TFA Staff Support

The following TFA Technical Team staff will be supporting the review team in conduct of the review.

Betty A. Carteret, Review Coordinator
Lynne Roeder-Smith, Communications
C. Phil McGinnis, Pretreatment Technology Integration Manager
E. W. (Bill) Holtzscheiter, Immobilization Technology Integration Manager

INEEL Process Options - HLW Disposition



EIS Processing Alternatives
1. Continued Current Operations
2. Full Separations
3. Planning Basis
4. Transuranic Separations
5. Hot Isostatic Pressed Waste
6. Direct Cement Waste
7. Early Vitrification
8. Minimum INEEL Processing

C01

APPENDIX B

Assessment Team Member Resumes

P. GARY ELLER, Ph.D.

Current Address

Nuclear Materials Technology Division
Los Alamos National Laboratory
Phone: (505) 667-7111; FAX (505) 665-4394
email: p_gary_eller@lanl.gov

Education

1971	Ph.D. – Inorganic Chemistry, Ohio State University
1967	B.S. – Chemistry, West Virginia University

Professional Experience

June 1999 – present	Staff member/Technical advisor to LANL EM/MD, nuclear materials program manager, 94-1 R/D program and Nuclear Materials Focus Area (Los Alamos National Laboratory)
April 1998 – June 1999	Project Leader, DNFSB 94-1 R/D Program
Aug 1996 – April 1998	Project Leader, DNFSB 94-1 R/D Core Technology
Mar 1995 – Jul 1996	Technical advisor, High Level Waste Tanks/DOE-RL
Mar 1994 – Mar 1995	Program Manager, High Level Waste Tanks Characterization Technology Development/PNNL
Oct 1990 - April 1994	Operable Unit Project Leader, LANL ER program
Jan 1989 - Sep 1990	Deputy Group Leader, INC Division
Jan - Jun 1988	Visiting Research Fellow, Superacid Chemistry (Melbourne University)
Jul 1987 - Jan 1989	Section Leader and Project Leader, INC Division
Jun 1985 - Jul 1987	Associate Group Leader and Project Leader, INC Div.
Oct 1976 - present	Staff Member, INC Division
Jul 1974 - Oct 1976	Postdoctoral Associate, Director Funded, CNC Div.

Other Professional Experience

Jan 1972 - Jun 1974	Postdoctoral Associate, Georgia Institute of Technology
Summer 1967	Chemical Technician, Mobay Chemical Company
Summer 1966	Chemical Technician, PPG Industries

Teaching Experience

1982 - 1986	Adjunct Professor, Univ. of New Mexico
1973	Chemistry Lecturer, Georgia Institute of Technology
1969	Teaching Assistant, Ohio State University

Primary Professional Interests

- Actinide, environmental and fluorine chemistry R/D
- Nuclear materials/waste and site remediation

Fellowships/Awards

1994	TWRS/TDPO Outstanding Achievement Award
1986	DOE Weapon Recognition of Excellence Award, Los Alamos
1983	Distinguished Performance Award, Los Alamos
1971–1973	Director's Funded Post Doctoral Fellow, Los Alamos

1970–1971	Lubrizol Industrial Fellow, Ohio State University
1967–1970	NDEA Title IV Fellow, Ohio State University
1963–1967	PPG Foundation Fellow, West Virginia University

Committtees/Service (examples)

DOE Tanks Focus Area Review Group (current)
Savannah River Salt Processing Alternatives Evaluation (current)
Frequent organizer or panel member for national ER/WM symposia
Referee for PRF, NSF, DOE proposals and numerous scientific journals
Argonne Natl. Lab. Chem. Div. advisory committee (current)
National Academy of Sciences panel member (1999)
LANL ER public outreach program (1992)
Director of Research, Cave Research Foundation (1971-1973)

Current Professional Associations

American Chemical Society; American Nuclear Society

Publications

Author of more than 100 refereed journal articles, 2 book chapters, 3 review articles, 3 patents, and numerous Los Alamos reports. Edited two books. Principal author of or major contributor to four RCRA RFI Work Plans and primary author of major sections of Hanford Tank Waste Remediation System Integrated Technology Plan and long-term Pu storage standard DOE-STD-3013-99.

Other Information

Outstanding leadership, organizational, management, and written/oral communication skills.

Extensive experience in staffing diverse laboratory and field programs ranging from basic research to RCRA field cleanup and closure.

Extensive experience in managing technology development and remediation programs having estimated life cycle cost up to $200M.

Significant direct experience with Defense Nuclear Facilities Safety Board.

Developed and directed numerous basic and applied actinide/fluorine and environmental chemistry programs (projects up to $7M/yr).

Proven record of national and international collaboration with academic, industrial, government and national laboratory communities.

Extensive experience complex-wide working with staff ranging from high level HQ management to undergraduate students and field labor.

Direct experience with nuclear accident investigation boards and other safety-related activities

Formal training in public relations, systems engineering, negotiation and program management.

Consistently outstanding performance appraisals.

Broad experience in modern synthetic and analytical techniques, including highly air sensitive and oxidizing materials and highly radioactive materials.

Presented many invited papers at national and international meetings.

Marital Status – Married, two children

Outside Interests – Guitars, whitewater rafting, fishing.

JOSEPH A. GENTILUCCI

Profession: Chemical Engineer

Education

1953 B.A. – Chemical Engineering, Lafayette College, Easton, PA.
Magna Cum Laude
Rank: 1st. of 16 Chemical Engineers
3rd. of 125 Engineers
8th. in Class of 315
Honorary Societies:
Phi Beta Kappa
Tau Beta Pi

Professional Experience

Sept 1993 – Present	Independent Contractor JAG Tech Services, Inc. 127 Savannah Drive Aiken, S. C. 29803-5833
May 1978 – Mar 1994	Westinghouse Savannah River Company and E. I. du Pont de Nemours and Co., Inc. Savannah River Site Aiken, S. C. 29808 Supervisor: J. F. Ortaldo
Jan 1975 – Jan 1978	Inland Chemical Corporation P.O. Box 36, 1702 Winter Street Fort Wayne, Indiana 46801 Supervisor: R. R. Elston, President
June 1953 – Jan 1975	E. I. du Pont de Nemours and Co., Inc. Orange, Texas and Niagara Falls, N. Y. Supervisor: D. Sanders Low Density Polyolefins Division Superintendent (Orange, Texas)

Patent

Patent No. 3,502,734 – Process for partially chlorinating methyl chloride and/or methylene chloride, R. M. Baird, P. K. Baumgarten, J. A. Gentilucci (assigned to E. I. du Pont de Nemours and Co.)

Amplification of Resume of Joseph A. Gentilucci

Employment Highlights

Sept 1993 to Present
JAG Tech Services, Inc.

Established JAG Tech Services, Inc. as an S Corporation to provide consulting services associated with the preparation and/or review of technical programs and procedures and perform independent evaluations of existing technical programs. Past contracts have been associated with:

- Two with Los Alamos Technical Associates relative to the Hanford Double Shell Tank Program and the Tank Waste Remediation System Process Configuration Alternatives Review.
- A fiscal 1995 through 1997 contract with Westinghouse Hanford Company on Down Selection of High Level Melter Alternatives, Redirection of Development Programs for Low Level Melter Alternatives and technology liaison with the Savanna River Site.
- Consulting services to the Lockheed Martin Hanford Company on their waste treatment programs and technology liaison with the Savannah River Site through fiscal year 1998.
- SGN Eurisys Services Corporation on vitrification and technology programs
- Mississippi State University on development of test facilities for establishing an accredited test facility.
- A short term contract with PNNL in 1998 on a DOE sponsored technical review of the Phase 1 submittals from private industry on the Privitization of Hanford Waste Disposal.
- COGEMA Engineering on canister storage costs and concepts
- Lockheed Martin Hanford Company on review of Cs and Sr processing concepts.

Current contracts are in place:

- With Pacific Northwest National Laboratories to participate in the Technical Review Group for Immobilization associated with the Tank Focus Area program through December 1999.
- With Westinghouse Savannah River Site on technology programs related to the operation of the Defense Waste Processing Facility through December 1999.
- With Concurrent Technologies Corporation to participate in an External Independent Review of the Readiness of the Office Of River Protection and their contractors to Privatize the disposal of nuclear wastes at the Hanford Site.

May 1978 to Mar 1994
Westinghouse Savannah River Company & E. I du Pont de Nemours Co.

For the sixteen years I was associated with the Defense Waste Processing Facility (DWPF). During that time, this multi-billion dollar program for the vitrification of highly radioactive waste, was brought from the conceptual phase though design, construction and is currently in operation. My participation in this program started with the writing of the first basic data report on the conceptual facility including the tank farm requirements for feed prreparation and its relationship to DWPF operation. I then went to San Francisco to open the liaison office with Bechtel National who was the Architectural Engineer on the Project. I later returned to the Savannah River Site where I continued as liaison and then assumed responsibilities for construction liaison and establishing the construction quality verification program. I then initiated the first phases of the field component testing program and established the basic testing requirements for bringing the facility through simulated feed operation to radioactive operation. These assignments not only covered the testing and operating requirements but also involved demonstration of glass product quality to meet the Federal Repository requirements. I later assumed responsibilities for

Technical Advisor to the Joint Test Group in the Start Up Organization which was assigned to direct the testing of the facility. My last assignment was Manager of Process Engineering for the DWPF. In this assignment, I was responsible for maintaining the overall technology assurance and configuration of the process including directing technical experimentation programs required to support operations. In addition, I was responsible for technology exchanges with the Hanford Waste Vitrification Plant and other vitrification facilities such as Pamala, Cogema and Sellafield. During this period I also directed and participated in many operational activities such as establishing manpower requirements, job assignments, presenting overview training, future project budgeting and resolution of technical problems.

Jan 1975 to Jan 1978
Inland Chemical Corporation

Inland Chemical Corporation was a privately owned corporation specializing in the reclamation of solvents from waste streams. As Director of Process Development, I was responsible for improvement of process equipment, procedures to maximize the yield of recoverable solvents and plans to optimize the throughput capabilities of the plants. As new waste streams were uncovered, I was responsible for evaluating the potential for recovery within the existing equipment or determining modifications to permit recovery. On large waste streams, I was responsible for developing overall process schemes including sizing of major equipment and evaluating the economic potential for the process. These assignments required coordination between sales, manufacturing and the customer.

June 1953 to Jan 1975

E. I. du Pont de Nemours and Co., Inc.

In my last assignment, assistant division superintendent, at du Pont, I was responsible for supervising more than 100 men including wage roll, foremen and supervisors in the manufacture of polyolefin resins on a multi unit installation. These responsibilities included; personnel administration, estimating production capabilities and costs, manufacturing the desired products to specification at the desired rates in a safe and economical manner, determining the adequacy of proposed expansions to meet future commitments, and obtaining the necessary support from other organizations such as technical and maintenance to accomplish these objectives.

Other assignments (in reverse order with time) with du Pont were:

Sr. Technical Supervisor, Elvax Liaison
Sr. Technical Supervisor, Chlorine Products
Sr. Engineer, Chlorine Products Expansion and Startup
Supervisor, Startup of Chlormethanol Process
Engineer, Chlorine Products Expansion and Startup
Supervisor, Step I and II THF and ZFC Catalyst
Supervisor, Step II THF and ZFC Catalyst
Supervisor, Sodium Perborate and Per Compounds
Staff Engineer, Sodium Products Construction Liaison
Supervisor, Sodium Peroxide
Supervisor, Chlomethanol Products
Engineer, Chlorine Products

RUSSELL L. TREAT

Education/Qualifications

1969 B.S. Chemical Engineering – Washington State University,
Over 30 years of experience in project and program management, line management, engineering, including 24 years in the analysis, design, testing, and operations of Hanford single-shell tank (SST)/double-shell tank (DST) systems and associated retrieval, treatment, and closure technologies. Pioneered the development of the joule-heated glass melting process, the Hanford grouting process, and a patented barrier for closing SSTs. Have "hands on" experience in the retrieval of waste from Hanford SSTs and in operating a plutonium processing facility.

Professional Experience

Associate with Dade Moeller & Associates (Specializing in Occupational and Environmental Sciences)
1845 Terminal Drive, Suite 140
Richland, Washington 99352
(509) 946-0410 Extension 120
Fax (509) 946-4412

Most recently Mr. Treat managed the $50 million/year Waste Feed Delivery System Definition Program in support of the River Protection Project at the Hanford Site.

He managed the $7 million/year, 100 full-time equivalent Hanford Waste Technology Program for Pacific Northwest National Laboratory (PNNL), which included the grout, performance assessment, SST characterization, SST ferrocyanide studies, and DST Waste Retrieval Programs. Also he served as project manager of Foster Wheeler's $25 million Environmental Restoration and Waste Management (ERWM) support project for Westinghouse Hanford Company (WHC), overseeing activities such as the $2.5 million design of a hydrogen mitigation test assembly for tank SY-101. Mr. Treat started Foster Wheeler's office in Richland in 1989 and managed up to 31 staff.

His experience is divided between DOE contractors (Atlantic Richfield Hanford Company [ARHCO], PNNL, and MAC Technical Services [MACTEC] for 18 years) and commercial enterprises (ALCOA, Foster Wheeler, and Dade Moeller for 12 years), providing understanding and balance in the methods employed by both the DOE and commercial sectors.

Mr. Treat served on numerous expert panels, including SST/DST technologies, Hanford grout, and design of the Idaho National Engineering and Environmental Laboratory PREPP facility, and has more than 35 technical publications and presentations, most relating directly to SST/DST wastes. In addition he authored a chapter on in-situ vitrification in a book on waste solidification and stabilization technologies published in 1997.

Accomplishments

Program Manager for Hanford Tank Waste Feed Delivery Program. Mr. Treat developed and implemented management systems for the Tank Waste Retrieval and Disposal Program (TWRD), including the strategy for satisfying the needs for both Defense Nuclear Facility Safety Board (DNFSB) 92-4 specifications and project-level specifications.

Mr. Treat developed the strategy for the Program's reliability, availability, and maintainability evaluation, including the failure modes and effect analysis, recovery mode analysis, and Monte Carlo analysis of schedule risks.

Project Engineer for the Commercial High-Level Waste Vitrification Project. Mr. Treat designed, procured components for, oversaw the construction of, and operated two joule-heated glass melters. The largest of the melters, the pilot-scale melter (with modifications) was recently in use at PNNL. Completed successful startup and operation two weeks ahead of schedule and $500,000 under budget. The melter worked as designed on the first startup attempt. Also led a $1 million preconceptual design and cost study of a high-level vitrification process against ten other high-level waste (HLW) processing alternatives.

Project Manager/Engineer for the Savannah River Vitrification Project. Mr. Treat served as project manager of a $300,000 project that involved the calcination/vitrification and liquid-fed vitrification of simulated high-level Savannah River Plant waste. Vitrified high-iron, high-alumina, and average composition wastes using the joule-heated and in-can melting methods. Canisters of glass were destructively examined to evaluate the homogeneity of the vitrified product.

Project Engineer for the Hanford HWVP. Mr. Treat developed remote sensors and a liquid waste feeder for the Hanford pilot-scale joule-heated melter. Remote sensors included (1) a differential resistivity sensor capable of monitoring for the presence of unacceptable levels of floating molten salt phases, (2) a conductivity probe capable of sensing glass foam in the melter plenum, and (3) a conductivity/temperature probe capable of indicating glass pouring rates. He also developed the Air-Displacement System (ADS), a remote-designed pulse pump capable of reliably delivering thick waste slurries to the glass melter. The ADS is the reference Hanford Site and West Valley Demonstration Site (WVDS) pump.

Project Engineer for the Commercial High-Level Waste Alternative Waste Form Solidification Project. Mr. Treat designed, built, and operated several pilot-scale HLW processing systems including (1) glass marble machine; (2) disk pelletizer; (3) chemical-vapor-deposited coatings and plasma-torch-deposited coatings on marbles and pellets; (4) elevated temperature and pressure autoclave for curing grouted waste; (5) furnace for sintering ceramic pellets; and (6) uniaxial hot press for ceramic pellets. The waste forms resulting from these processes were analyzed for leachability, volume-reduction effectiveness, and other parameters, which were compared to those for glass.

Project Manager for the Rocky Flats Plant Transuranic Waste Solidification Alternative Project. Mr. Treat developed preconceptual designs and life-cycle cost estimates for eight solidification processes, including joule-heated glass melting, in-can glass melting, glass marbles, drummed concrete, cold-pressed hydraulic cement, cold-pressed sintered ceramic, and basalt glass-ceramic.

Project Manager for the Hanford Environmental Restoration Support Programs Project. Mr. Treat provided technical oversight and review of four Best Available Radionuclides Control Technology (BARCT) and Toxic BACT (TBACT) evaluations, including those for HWVP. Also developed data and documentation on radioactive air emissions and treatment for the Plutonium-Uranium Extraction (PUREX) and U/UO_3 Plant to comply with the Washington Statement Department of Health Radioactive Air Emissions Program. Also, Mr. Treat contributed to the conceptual design bases and successful fair-cost estimate for the 200 East Area Effluent Treatment Facility (ETF) to be used by BNFL Inc., for treating secondary liquid effluent waste, and provided cost estimating assistance to WHC in support of the construction change control process. He led the design and procurement of the initial vapor extraction system for Hanford's successful Expedited Response Action that removed several hundred tons of carbon tetrachloride from the soil.

Task Leader for SST Leak Detection, Monitoring, and Mitigation (LDMM). Mr. Treat developed the strategy and criteria for determining the level of risk-based allowable leakage from SSTs during sluicing. In addition, he developed a decision logic for selecting Tank Waste Remediation System (TWRS) retrieval, LDMM, and closure technologies. The selection was based on the projected risk associated with leakage, the current condition of the tanks and waste in each tank, and the cumulative impacts of other waste sources gradiently aligned with the tank and other factors.

Task Leader for TWRS Waste Treatment Testing Options Study. Mr. Treat evaluated four options involving differing levels of testing of TWRS baseline pretreatment and vitrification technologies prior to initiating detailed design. The evaluation included an innovative assessment of technology risk based on the likelihood and consequences of technology failure of the various levels of technology testing assumed. The cost impacts of these evaluated risks were compared to the cost impacts of the schedule delays necessary to accommodate the various testing levels. The conclusions of the study were presented to and supported by the DOE Pretreatment Sub-Technical Advisory Panel.

Project Manager for U.S. Nuclear Regulatory Commission (NRC) Volume-Reduced Waste Forms Project. Mr. Treat led a team of scientists and engineers who developed data on bitumen and cement waste forms to demonstrate compliance with the requirements of the NRC branch technical position on waste forms. Work focused on solidified low-level waste (LLW) incinerator ash.

Project Manager for Best Available Treatment Evaluation of Project C-018H Waste Water Treatment Alternatives. Mr. Treat evaluated 15 different low-level radioactive waste water treatment technologies and processing and disposal options for the secondary waste produced during operation of the 200 East Area ETF. Technologies evaluated included reverse osmosis, ion exchange, precipitation, flocculation, evaporation, granular activated carbon, ultraviolet oxidation, drying, cementration, and French drains.

Process Control Engineer for ALCOA. Mr. Treat served as process control engineer for a high-capacity (500 tons per day) commercial aluminum smelter. The aluminum smelter included 774 smelting vessels, each heated electrically to approximately 1,000°C and coupled to central off-gas cleaning systems. The heating occurred as a consequent of passing current through molten salt, a concept similar to joule-heated glass melting. Design and implemented several mechanical improvements, saving several million dollars per year.

Project Manager for the Hanford Grout Program. Mr. Treat led PNNL's $7 million grout project for five years. During this time, conceived the grout mixing and pumping system that became the heart of the Hanford Grout Facility constructed in Hanford's 200 East Area. To demonstrate the feasibility of this system, designed, procured, built, and tested a quarter-scale prototype of the grout system. Operated the prototype around the clock, producing 22,000 gallons of simulated grouted waste. The grout was fed as it was produced to a trench where its flow properties could be measured. Also conducted the risk assessment for disposed radioactive grout. This risk assessment served as the basis for the risk assessment included in the Part B Permit Application for the Hanford Grout Facility.

Process Engineer for Hanford Tank Farm Process Engineering. Mr. Treat developed and demonstrated a modified waste pump in an SST. The use of the pump increased retrieval of waste heels by 30 percent. He also developed a remote radiation sensor that enabled real-time feedback to the effectiveness of waste retrieval operations. In addition he designed a restricted intake pump that minimized vortexing and loss of positive suction head. The pump was successful in retrieving 7,000 gallons of liquid waste from a leaking SST that could not be recovered using conventional pumps.

Process Engineer/Supervisor for Z Plant (now Plutonium Finishing Plant [PFP]) Process Engineering. Mr. Treat was responsible for all process engineering related to Miscellaneous Treatment Operations at Hanford's Z Plant, now PFP. These operations included preparation of feed for subsequent solvent extraction and ion-exchange operations for recovery of plutonium, uranium, and americium. Specified radiochemical and chemical analyses at Z Plant's Analytical Laboratory as a means of verifying the level of process control and conformance to operating specifications and standards. He participated in two startups of plutonium oxide line operations. He prepared safe operating procedures (SOP) for these operations and audited conformance to the SOPs. In addition he supported the causal assessment of the explosion of Z Plant's americium-241 ion exchange column in 1977.

Project Engineer for the Underground Storage Tank Integrated Demonstration Project. Mr. Treat evaluated the engineering and remote-operable feasibility of three candidate pretreatment processes for TWRS waste: Cs-137 ion exchange, the nitrate to ammonia and ceramic process, and the nitrate biological destruction process. He was the lead author of a feasibility study of 14 alternatives for the remote retrieval of wastes from SSTs, with emphasis on the use of subsurface barriers to minimize leakage during retrieval by sluicing.
The feasibility study included an assessment of life-cycle costs (total present net worth) and a risk assessment based on projected groundwater contamination. Related the costs and risks in an innovative cost benefit analysis. The work was presented to and endorsed by a review panel that included members of the National Academy of Sciences. The work was subsequently presented to the Washington Statement Department of Ecology (Ecology), resulting in a reversal of Ecology's position on the need for subsurface barriers. WHC was granted an award fee for the work by the U.S. Department of Energy, Richland Operations Office, which noted that the effort "exceeded expectations." He also planned and contributed to the development of a TWRS technology screening model that evaluated new technologies against the TWRS baseline based on life-cycle cost, risks, and operations safety.

Publications

Mr. Treat has more than 35 technical publications and presentations.

E. THOMAS WEBER, Ph.D.

Current Address

[redacted]

Education

1964 Ph.D., Ceramic Science, Rutgers University, New Brunswick, N.J.
Thesis Title: "Viscoelastic Properties of Alkali Silicate Glasses"

1960 B.S., Ceramics, Rutgers University

Professional Experience

1995 to present Consultant

Since 1995, a variety of technical consulting activities have been performed, primarily related to nuclear waste immobilization. This work has included technical program reviews, process technology reviews and vitrification project assessments, performed primarily for Battelle-Pacific Northwest National Laboratory and the Department of Energy.

1970 to retirement 12/1994 Westinghouse Hanford Company

Transferred to Westinghouse Hanford Company (WHC) in 1970 as Manager of Reactor Ceramics, with responsibility for laboratory research support to fast reactor fuel fabrication, design and in-reactor testing. This involved operational responsibility for plutonium laboratories. Development work also included non-fuel nuclear ceramics such as neutron absorbers, insulators and oxygen meter solid electrolytes.

From 1976 to 1987, responsibilities increased to management of multiple functions, leading to a department level position, directing organizational components performing research, conducting irradiation testing programs and operating nuclear facilities. Management cognizance included: hot cell facilities, fabrication laboratories, high temperature research and plutonium laboratories, off-site irradiation testing programs, FFTF core component performance testing and several DOE international cooperative research programs. Technical cognizance included: design and development of hot cell testing and examination equipment; fuel, absorber and tritium breeder/blanket materials properties studies and fabrication technologies; experimental assessment of higher actinide incineration in reactors; reactor fuel safety performance analysis and testing; core assembly and materials behavior under reactor accident conditions; breeder reactor fuel and absorber assembly performance assessments; irradiation performance testing of advanced liquid metal reactor and space reactor fuels.

From 1987 to 1989, management assignments involved responsibilities for reactor and nuclear facility safety features of the new Westinghouse Hanford consolidation contract at Hanford. This included managing evaluation of lessons from the Chernobyl accident for Hanford's N Reactor. Managed WHC programs providing direct support to Department of Energy Headquarters for updating and revising their nuclear safety policies and Orders.

From 1989 to 1993, held the position of Manager, Applied Technology for the Hanford Waste Vitrification Plant (HWVP) project. This position focused on providing the technological base for vitrification processes and plant engineering work. Responsibilities addressed identification of domestic and foreign technology sources to meet HWVP process and facility systems needs. This included defining technology development requirements and providing technical direction to performers, primarily Battelle-Pacific Northwest Laboratory. Managed interfaces and monitored developer performance leading to data application in design, process qualification, and waste form qualification. Responsibilities also included definition of HWVP waste compliance plans, interfaces with the high level waste geological repository program and technical interfaces with other DOE and foreign vitrification programs. Chaired Westinghouse Corporate GOCO coordination group for sharing experience and technology between DOE high level waste sites. Led evaluation of foreign vitrification technology as alternatives to DOE technologies for HWVP. Member of DOE delegation for vitrification technology exchange with Russia in 1991 and participant in US-Japan and US-German exchanges.

From 1993 to 1994, managed Vitrification Development for the Hanford Tank Waste Remediation System (TWRS), following close-out of HWVP. Responsible for replanning Hanford waste vitrification technology requirements and approach to fulfill 1993 Tri-Party Agreement milestones. Managed low-level waste melter technology evaluation, vendor contracting and requirements for supporting technology. Coordinated replanning of high-level waste technology requirements and assessments to meet TWRS higher capacity vitrification plant needs.

1965 to 1970 — Battelle Northwest Laboratory

Became a Battelle employee in Hanford contractor change, performing research in properties, synthesis, and fabrication of ceramic fuels, including plutonium compounds. Led a team initiating irradiation testing of uranium-plutonium nitride fast reactor fuel pins.

In 1968 assumed a management position with responsibilities for oxide fuel processing and test fuel fabrication for development of fast breeder reactor cores, especially the Fast Flux Test Facility at Hanford.

1964 — General Electric Corp. at Hanford

Started at the Hanford Laboratory with General Electric in September 1964 as a Senior Research Scientist engaged in development of ceramic fuels and materials for nuclear reactors.

Professional Societies

American Ceramic Society: Fellow - 1976; Nuclear Division Program Chairman - 1975; Nuclear Division Chairman - 1978; Trustee - 1980 to 1983; Vice President for Engineering and Technology - 1990/91

American Nuclear Society: Member

American Chemical Society - Industrial and Engineering Chemistry Division: Member

CHRISTINE A. LANGTON

Work Address
Westinghouse Savannah River Company, Inc.
Savannah River Technology Center
Building 773-43A
Aiken, SC 29802
(803) 725-5806
(803) 725-4704 FAX

Education

1980 PhD, Materials Science and Engineering (Solid State Science), The Pennsylvania State University, University Part, PA

1976 MS, Geochemistry, The Pennsylvania State University, University Park, PA

1972 BS, Geosciences/Geochemistry, The Pennsylvania State University, University Park, PA

Professional Experience

1989 – Present Westinghouse Savannah River Company, Inc
Savannah River Technology Center
Savannah River Site
Aiken, SC

1982 – 1989 E.I. duPont deNemours
Savannah River Laboratory
Savannah River Plant
Aiken, WC 29802

1980 – 1987 Gulf Mineral Resources Co.
Denver, CO

Exploration Geochemist – For base metals and precious metals

List of Projects Successfully Completed while at the Savannah River Site

Corporate Awards

1993 SRS Environmental Awareness Award
1992 George Westinghouse Signature Aware of Excellence (2nd highest award for technical accomplishments)
1991 George Westinghouse Corporate Award of Excellence (highest corporate award for technical accomplishments)
1989 Westinghouse Savannah River Total Quality Award
1990 Westinghouse Savannah River Total Quality Award
1992 Westinghouse Savannah River Total Quality Award
1993 Westinghouse Savannah River Total Quality Award
1987 E.I. duPont Award of Excellence

Other Awards

1993	Nominated for Fellow of the American Ceramic Society
1993	Invited Participant in National Science Foundation
1988 and 1989	Participated as an invited member of the American and Ceramic Society technical exchange delegations to Australia and Scandinavia
1981	Organized and participated in an international expedition to Greece, Cyprus, and Turkey to collect and study ancient building materials – jointly sponsored by the Smithsonian Institution and the Office of Nuclear Waste Isolation
1978 through 1980	Office of Nuclear Waste Isolation Fellowship

Patents

SRS-91-207	M-Area Waste Filtration and Stabilization Process (FIST)
SRS-91-206	One-Step Filtration/Stabilization Process for M-Area Waste Treatment (FIST Alternate B)
SRS-91-243	Filtration/Stabilization Process for M-Area Waste Treatment (FISH Alternate A)
SRS-91-310	Macroencapsulation of Radioactively Contaminated Lead Waste with Vinyl Ester Resins
SRS-92-035	Additives for Improving the Leachability and Flammability of Polymer Stabilized Waste forms
SRS-93-018	A Method to Reduce Contaminant Release Rate from Saltstone by Viscosity Reduction

WALLACE W. SCHULZ

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PROFESSIONAL OBJECTIVE

Nuclear Consultant: Provide valuable, authoritative counsel on nuclear waste management/disposal and chemical separations technology to government, industrial, and academic organizations.

OUTSTANDING STRENGTHS

Recognized world-class authority on nuclear chemical separations and waste disposal technology.

48+ years broad experience in all parts of back-end of nuclear fuel cycle.

Experienced technical consultant to management.

Creative/innovative. An idea person. Twenty-one patents.

Prolific writer. Eleven books, 100+ journal papers and research reports.

Excellent communicator and mentor.

Highly qualified technology evaluator and analyzer.

OVERVIEW OF PROFESSIONAL EXPERIENCE

Dates	*Organization*	*Highest Position*
1988-Present	W2S Co., Inc.	President/consultant
1987-1988	Westinghouse Hanford Co.*	Advisory Scientist
1977-1987	Rockwell Hanford Co.*	Sr. Scientific Advisor
1969-1977	Atlantic Richfield Hanford*	Principal Chemist
1965-1969	Battelle Pacific Northwest Laboratory*	Sr. Research Scientist
1950-1965	General Electric Co.-Hanford*	Research Scientist

*Prime contractors to the U.S. Department of Energy (or its predecessor agencies, e.g. Atomic Energy Commission) at the Hanford Site.

WALLACE W. SCHULZ RESUME, page 2

EDUCATIONAL BACKGROUND

University of Nevada
Reno, Nevada

B.S. (1949), M.S. (1950)
Major: Chemistry

Other Training: Joint Center for Graduate Study, Richland, WA (1950-1975), completed coursework equivalent to Ph.D. degree.

HONORS AND AWARDS

Rockwell International Corporation "Engineer of the Year", 1987.

Glenn Seaborg Award in Actinide Separations, 1987.

IR-100 Awards, 1984 & 1987.

Westinghouse Hanford Co. "Signature Award", 1990.

American Chemical Society-Richland Section, "Chemist of the Year", 1986.

Plenary Lecturer, International Solvent Extraction Conference, Moscow, USSR, 1988.

Member Phi Kappa Phi Honorary Society.

Listed in American Men of Science.

MEMBERSHIPS AND AFFILIATIONS

American Nuclear Society

American Chemical Society: Industrial & Engineering Chemistry Division (Technical Program Chairman 1991-Present; Chairman, 1988); Separation Science & Technology Subdivision (Chairman, 1985).

The Metallurgical Society

Sigma Xi

References and publications available on request.

John Swanson
[redacted]

E-Mail: [redacted]

Education

Reed College: B.A., Chemistry

Occupation

Consultant - Richland, Washington

Representative Skills and Experience

During his 44-year career at the Hanford Site, Mr. Swanson worked extensively in the areas of nuclear fuel reprocessing and radioactive waste management. His activities in these areas covered the span from basic separations chemistry to flowsheet development and interaction with plant process engineers. His waste management activities also included study of the chemistry of actinide elements in the environment and the effect of organic complexing agents on the mobilities of toxic elements in soils.

He has also contributed to the technology aspects of systems studies comparing the costs and risks of various radioactive waste treatment and disposal options. Mr. Swanson has three patents.

Publications

Mr. Swanson has authored or co-authored 46 published papers, articles, and technical reports.

Affiliations

American Chemical Society and American Nuclear Society

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LAWRENCE L. TAVLARIDES

CURRICULUM VITAE

Professor of Chemical Engineering

Syracuse University

Syracuse, NY 13244

HISTORICAL DATA

Education

Ph.D. Chemical Engineering, University of Pittsburgh 1968
M.S. Chemical Engineering, University of Pittsburgh 1964
B.S. Chemical Engineering, University of Pittsburgh 1963

Postdoctoral, Hogeschool of Delft, Holland, Laboratorium Voor Chemische Tech. with Professor P. M. Heertjes on photochemical reactions, 1968

Continuing Educational Studies-7001, University of Pennsylvania, Enzyme Technology and Its Engineering Applications, Summer 1970

Academic Experience

Associate Dean, Graduate Affairs and Research, L.C. Smith College of Engineering & Computer Science Syracuse University	1995 - 1996
Professor, Department of Chemical Engineering and Materials Science, Syracuse University	1985 - Date
Chairman, Department of Chemical Engineering and Materials Science, Syracuse University	1981 - 1985
Professor, Department of Chemical Engineering, Illinois Institute of Technology	1980 - 1981

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Associate Professor, Department of Chemical Engineering, Illinois Institute of Technology	1975 - 1980
Faculty-Research Fellowship, IIT, Academic Year	1974 - 1975
Assistant Professor, Department of Chemical Engineering, Illinois Institute of Technology	1969 -1975

Industrial Experience

Research Engineer, CPC International, Moffett Technical Center, Argo, IL	Summer 1971
Research Engineer, Gulf Research and Development Center	Summer 1968
Engineer, Gulf Research and Development Co. Hamarville, PA	1964 - 1966
Process Engineer, Mobay Chemical Co. Pittsburgh, PA	Summer 1962

Consulting Experience

Battelle, Pacific Northwest Laboratories — 1995 - present
(Member, Tank Focus Area - technical advisory committee. This committee is to advise the National Tank Focus Area committee on technical issues in regards to the clean-up of radioactive nuclear waste stored in tanks throughout the Department of Energy Complex, viz, Hanford Site in Richland, WA, Savannah River Site in Aiken, S.C., Oak Ridge National Laboratories in Oak Ridge, TN and Idaho Falls National Laboratories in Idaho Falls, ID)

Battelle, Pacific Northwest Laboratories — 1993-1995
(Member, Waste Processing Architecture Group (WPAG): This committee is to guide the Tank Waste Remediation System Technology Development Office for the Department of Energy to develop technologies to remediate the nuclear

waste stored in the Pacific Northwest Laboratories at the Hanford Site in Richland, WA. The project is expected to cost $20-200 BILLION over the next 30 years.)

Martin Marietta Energy Systems, Inc. - 1995 (Reviewer for D.O.E., Efficient Separation Program, Office of Environmental Management and Technology Development)	1993
Dow-Corning, USA	1994 - present
Dow Chemical Co. Inc.	1993 - 1994
Exxon Research and Engineering Company, Florham Park, NJ	1988 - 1992
Hercules, Inc., Radford, VA	1988 - 1989
Agway Inc., Syracuse, NY	1985 - 1986
EXXON Research and Engineering Company, Florham Park, NJ	1984 - 1986
CPC International, Moffett Technical Center, Argo, IL	1971 - 1978
Illinois Institute of Technology Research Institute, Chicago, IL	1974 - 1977
Daubert Chemical Co., Chicago, IL	1976 - 1977
Institute of Paper Chemistry, Appleton, WI	1977 - 1979
Kraft, Inc., Kraft Court, Glenview, IL	1979 - 1980
ARCO, Inc., 400 E. Sibley Blvd., Harvey, IL	1979 - 1980

HONORS AND RECOGNITIONS

Chancellor's Citation Award for Excellence in Academic Achievement 1994
Syracuse University

Pacific Northwest Laboratories, Affiliate Staff Scientist (PASS)	1994 – 1997
Anaren Microwave Award for Excellence in Scholarship L.C. Smith College of Engineering and Computer Science, Syracuse University	1993
Fellow, American Institute of Chemical Engineers	1990
Shell Postdoctoral Fellow, Technical University of Delft	1968 -1969
Certificate of Recognition by AIChE National for serving as Chicago Section Chairman	1976
National AIChE Award for Excellence to IIT Student Chapter: L.L. Tavlarides, Chapter Advisor	Nov. 1972
Who's Who in Science and Engineering, Listed	June 1997

CONTRIBUTIONS TO TEACHING

Undergraduate Courses Taught

Introduction to Chemical Engineering, Material and Energy Balances, Fluid Flow and Heat Transfer, Mass Transfer Operations, Unit Operations Laboratories, Chemical Reaction Engineering.

Graduate Courses Taught

Mass Transfer Operations, Chemical Reaction Engineering, Mass Transfer with Reactions in Liquid Dispersions, Enzyme and Biochemical Engineering, Graduate Seminar.

Research Projects

28 Masters of Science Theses supervised, 25 Doctoral Theses supervised, 11 Post Doctoral Associates, 1 Research Fellow, 1 Research Assistant.

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Research Specialization

Supercritical Extraction and Water Oxidation for Soil Decontamination
Metal Ion Separations from Waste Streams by Inorganic Chemically Active Beads and Impregnated Ceramic Membranes
Mass Transfer and/or Reactions in Dispersions
Accoustical Instrumentation Development for Measurements of Liquid-Liquid/Liquid-Solid Dispersions
Metal Ion Interfacial Reactions and Equilibrium in HSE
Plasma Reaction Models of Electrostatic Corona Discharge Reactors
Ceramic Membranes for Gas Separations and Catalytic Reactors
Dispersed Phase Mixing Effects on Selective Metal Extraction
Turbulence Models for Two Phase Flows
Kinetics of Fischer-Tropsch Synthesis Reaction
Biochemical Separations with Solvent Extraction

CONTRIBUTIONS TO RESEARCH

Books

1. L.L. Tavlarides - Process Modifications for Industrial Pollution Source Reduction, Lewis Publishers, Inc., Chelsea, MI (1985).

Co-Editor for Symposium Volume

1. T.W. Chapman, L.L. Tavlarides, G.L. Hubred, R.M. Wellek, editors, "Fundamental Aspects of Hydrometallurgical Processes," AICHE, Symposium Series, Vol. 74 , 173 (1978).

2. L. L. Tavlarides, J. D. Miller, "Fundamental Aspects of Solvent Extraction," section editors in Hydrometallurgical Recovery of Metals from Ores, Concentrates, and Secondary Sources, AIME, Inc., New York, p. 86 (1981).

Other Publications/Patents

13 Patents, 98 Research Publications, 37 Non-Refereed Publications, 6 Recognition of Published Works, 199 Papers Presented and Invited Seminars, 29 Co-Chairman of International, National, and Regional Symposia.

6

Professional Activities

Department of Energy - Independent Panel Evaluation (IPE); Member: June 1998-present

Evaluate Westinghouse Savannah River Company, Engineering Team method to select a process alternative for Cs removal from salt solutions for treatment of radioactive waste. This IPE was commissioned by the Deputy Secretary of the U.S. DOE.

Tank Focus Area - Review Group Committee; Member: 1995 - Date
Battelle, Pacific Northwest Laboratories, DOE
(This committee is to assist the Tank Focus Area of the Office of Technology of the Environmental Restoration and Waste Management Departinent of the Department of Energy. The Tank Focus Area is responsible to develop a technical program to solve the problem to dispose/contain the high-level nuclear wastes stored in tanks throughout the DOE complex.)

Waste Processing Architectural Group (WPAG) Committee; Member: 1993 - 1995
Battelle, Pacific Northwest Laboratories, DOE
(This committee is to guide the Tank Waste Remediation System Technology Development Office for the Department of Energy to develop technologies to remediate the nuclear waste stored in the Pacific Northwest Laboratories at the Hanford Site in Richland, WA. Prof. Tavlarides is the only academic participant. The project is expected to cost $20 - $200 BILLION over the next 30 years.)

American Institute of Chemical Engineers: Chicago Chapter

Member of Board of Directors	1970 - 1980
Director-at-Large	1977 - 1978
	1978 - 1979
Past Chairman	1979 - 1980
Chairman	1976 - 1977
Chairman Elect	1975 - 1976
Secretary	1974 - 1975
Vice Chairman of Program Committee	1973 - 1974
Technical Program Chairman for Annual	1972 - 1973
	1972

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One Day Symposium	
Student Relations Conimittee, Member	1971 - 1972
Student Relations Committee, Chairman	1970 - 1971
Audit Committee, Chairman	1971 - 1978
Fermentation Lecture Series Committee, Member	1977 - 1978

American Institute of Chemical Engineers: National

Interfacial Phenomena Committee, Area 1C, Member	1969 - Date
Mixing Committee, Area 3A, Member	1986 - Date
Counselor's Workshop 64th Annual AICHE Meeting	Nov. 1974
Counselor's Workshop, Chairman	1974
Student's Chapter Committee, Member	1973 - 1974
Technical Program Committee, 69th Annual AIChE Meeting, Chicago, Member	1976
House Committee, 60th Annual AICHE Meeting, Chicago, IL	1970
Member, AIChE Separations Division	1998

International Committee for Solvent Extraction (ICSE)

Board Member	1994 - Date

Illinois Engineering Council

Board Member, Alternate	1970 - 1971
Board Member	1971 - 1972

Solvent Extraction and Ion Exchange Journal

Editorial Board Member	1984 - 1986

The North American Mixing Forum

Chairman	1997 - 1999
Chairman Elect	1995 - 1997
Founding Member	1990 - Date
Executive Council Member	1990 - Date

November 15, 1997

RAYMOND G. WYMER

Dr. Wymer was born on [redacted]. He received his B.S. degree from Memphis State University, and his M.S. and Ph.D. degrees from Vanderbilt University.

Dr. Wymer was employed by Oak Ridge National Laboratory in the Chemical Technology Division from 1953 until his retirement in 1991. During his employment at ORNL he was involved in research and development in all aspects of the nuclear fuel cycle. He became Director of the Chemical Technology, a chemical engineering division employing about 300 chemical engineers, chemists, technicians and support staff.

Dr. Wymer has consulted extensively since 1991 in the areas of radioactive waste management and site remediation for DOE and its contractors. He has had direct consulting experience at Hanford with the TWRS program, and assists DOE/EM-50 in its Efficient Separations and Processing Crosscutting program review.

Dr. Wymer serves on four National Academy of Sciences committees that deal with DOE's waste management and site remediation and closure activities, and is chairman of one of the committees.

Dr. Wymer serves on the Advisory Committee on Nuclear Waste for the Nuclear Regulatory Commission.

Dr. Wymer's other activities have included consulting with DOE, the U.S. Department of State and the IAEA on matters of nuclear non-proliferation in the areas of nuclear fuel reprocessing and uranium enrichment by chemical exchange processes. He is a member of the Chemistry Working Group of the Nuclear Energy Agency, which is an agency of the Organization for Economic Cooperation and Development.

Dr. Wymer is co-author of a book "Chemistry in Nuclear Technology" and edited a book on "Light Water Reactor Fuel Reprocessing." He was an editor of the journal Radiochimica Acta for over ten years until his retirement. He has written numerous reports and open literature publications on all aspects of the nuclear fuel cycle and has contributed technical articles for incorporation in encyclopedias. He has organized and contributed to numerous symposia and workshops in his areas of expertise.

Dr. Wymer has received recognitions for his contributions in the nuclear area, including the Robert E. Wilson Award in Nuclear Chemical Engineering from the American Institute of Chemical Engineers. He is a Fellow of the America Nuclear Society.

[redacted]

APPENDIX C

Uncertainties and Assumptions

Appendix C: Uncertainties and Assumptions

Key Programmatic Uncertainties[a]

1. Can sodium bearing waste (SBW) be declared by citation to be incidental to reprocessing?
2. Can the operating permit for the Waste Isolation Pilot Plant be modified to accept U-134 listed code?
3. Will the criteria for onsite disposal of stabilized low-level waste be available?
4. What will be the effect of public dissatisfaction over implementing separations?
5. What will be the potential for an alternative to cause stakeholders to file a lawsuit?
6. Large surge tanks are not an option; therefore, will there be tanks large enough to transfer waste out of the existing tank farm to meet the 2012 deadline?
7. Can the existing calcine facility be started up after being down for 9 years?
8. Will it be possible to acquire a permit to operate?

Assumptions Identified by the Review Team

1. Adequate funding for treatment facilities will be available for development and deployment.
2. Compliance with Settlement Agreement 2012 and 2035 Milestones is strongly preferred.
3. Future operations of unpermitted Calciner are very unlikely.
4. Adequate Waste Isolation Pilot Plant capacity will be available for RH-TRU and CH-TRU.
5. A high-level waste repository will be opened and have the volume available to accept INEEL waste.
6. The mixed-waste disposal issues for the high-level waste repository will be resolved.

(a) "Overview of EIS Technology Down Selection" by Keith Lockie. Presented at the Tanks Focus Area EIS Review Meeting on June 19, 2000.

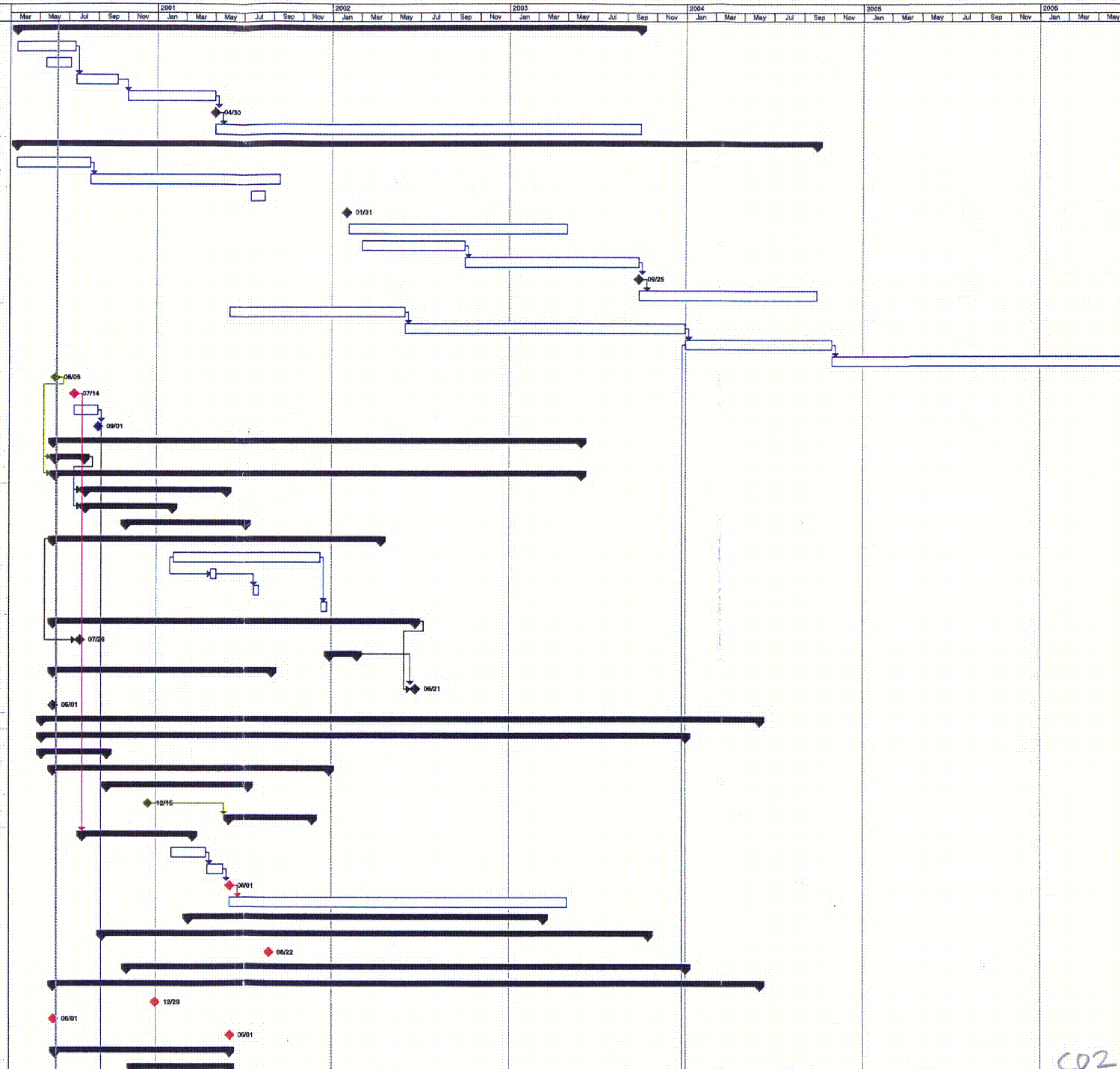
APPENDIX D

INEEL HLW Treatment Roadmap for SBW Separation Options

Appendix D: INEEL HLW Treatment Roadmap for SBW Separation Options

(Only hardcopy available.)

ID		ID	Task Name	Duration	Start	Finish	Predecessors
1		1	**Liquid Waste Treatment Pilot Plant**	184.6 wks	03/16/00	09/29/03	
2		2	LWT PP Conceptual Design	17.4 wks	03/16/00	07/14/00	
3		3	LWT Environmental Checklist	7.6 wks	05/15/00	07/05/00	
4		4	LWT PP Title Design	62 days	07/17/00	10/10/00	2
5		5	LWT PP Cold Pilot Construction	129 days	11/01/00	04/30/01	4
6		6	Issue test plan for initial campaign of LWT PP	0 wks	04/30/01	04/30/01	5
7		7	LWT PP Cold Pilot Testing	126 wks	05/01/01	09/29/03	6
8		8	**Liquid Waste Treatment Demo**	236.6 wks	03/16/00	09/27/04	
9		9	LWTD Conceptual Design	109 days	03/16/00	08/15/00	
10		10	LWTD Environmental Checklist NEPA Doc	283 days	08/16/00	09/14/01	9
11		11	LWTD Advanced Conceptual	22 days	07/16/01	08/14/01	
12		12	LWTD - DOE Project Authorization	0 wks	01/31/02	01/31/02	
13		13	LWTD Cell Demolition	323 days	02/04/02	04/30/03	
14		14	LWTD Title Design	151 days	03/04/02	09/30/02	
15		15	LWTD Hot Prep/Constr/Install	258 days	10/01/02	09/25/03	14
16		16	LWTD Construction Complete	0 wks	09/25/03	09/25/03	15
17		17	LWTD Hot Pilot Testing	262 days	09/26/03	09/27/04	16
18		18	Conceptual Design	52 wks	06/01/01	05/30/02	
19		19	Advanced Conceptual Design	82.6 wks	05/31/02	12/30/03	18
20		20	Title I	43.4 wks	12/31/03	10/28/04	19
21		21	Title II	87 wks	10/29/04	06/29/06	20
22		22	**Tank Farm Management Scenario Receipt**	0 days	06/05/00	06/05/00	
23		23	**Liquid from WM-180**	0 days	07/14/00	07/14/00	
24		24	**Characterization of Liquid from WM-180**	36 days	07/14/00	09/01/00	
25		25	**WM-180 Characterization**	0 days	09/01/00	09/01/00	24
26		26	**CHARACTERIZATION**	156.4 wks	06/01/00	05/30/03	
27		27	**Perform Modeling**	9 wks	06/05/00	08/04/00	22
33		33	**Prepare Mass Balances / Flowsheets**	156 wks	06/05/00	05/30/03	22
40		40	**Experimentaly Validate Scenario**	42 wks	08/07/00	05/25/01	27
51		51	**Develop/Prepare Waste Analysis Plan**	26 wks	08/07/00	02/02/01	27
58		58	**Develop method to get samples out of tanks to represent jetting**	36 wks	10/30/00	07/06/01	52
65		65	**Characterization**	97.2 wks	06/01/00	04/11/02	
73		73	Operations performs TFMScenario	220 days	02/05/01	12/07/01	45
74		74	Sample 2nd Tank	10 days	04/23/01	05/04/01	73SS+11 wks
75		75	Sample 3rd Tank	10 days	07/23/01	08/03/01	74FS+11 wks
76		76	Sample 4th Tank	10 days	12/10/01	12/21/01	73
77		77	**Prepare Recipes / Simulants for TD Experiments**	107.4 wks	06/01/00	06/21/02	
88		88	Solids quantity and physical properties unknown, overloads S/L separation equipment.	0 days	07/26/00	07/26/00	65SS+8 wks
89		89	**Validate Simulants**	8 wks	12/28/01	02/21/02	69SS+4 wks
93		93	**Tank Heel Characterization**	65 wks	06/01/00	08/29/01	
100		100	Data available for testing/validation	0 days	06/21/02	06/21/02	89,77
101		101	Characterization of Waste in Tanks desired by Engineering	0 days	06/01/00	06/01/00	
102		102	**CsIX**	212.6 wks	05/08/00	06/03/04	
103		103	**Sorbent Selection**	190.6 wks	05/08/00	01/01/04	
104		104	**Sorbent Selection Preparation**	19.6 wks	05/08/00	09/20/00	
108		108	**Batch Contacts**	82 wks	06/01/00	12/26/01	
159		159	**Small-scale Column Test**	42 wks	09/20/00	07/11/01	107
200		200	**WIR Determination**	0 wks	12/15/00	12/15/00	
201		201	**Disposability**	25 wks	05/30/01	11/21/01	160SS+16 wks,200,251,252
217		217	**Ease of Handling (Cold)**	32.8 wks	08/01/00	03/16/01	23,105
222		222	Data Analysis	52 days	02/01/01	04/13/01	
223		223	AT Review, HLW, DOE Reviews	5 wks	04/16/01	05/18/01	222
224		224	Validate that Sorbent(s) meet Specs, Sorbent Recommendation from AT	0 days	06/01/01	06/01/01	223,227,252
225		225	Cold Mockup	100 wks	06/01/01	05/01/03	224
226		226	**Chemical Stability**	105 wks	03/07/01	03/12/03	
250		250	**Radiolytic Stability**	161.6 wks	09/11/00	10/15/03	
275		275	Loading Tests	0 days	08/22/01	08/22/01	109,160,110,204
276		276	**Full Scale Test Need**	165.2 wks	11/01/00	01/01/04	
329		329	**Grouting**	209 wks	06/01/00	06/03/04	
330		330	Alternative Binders for SBW (Metalplex) desired by Engineering	0 days	12/29/00	12/29/00	
331		331	Corrosion of CS Drums by Grout desired by Engineering	0 days	06/01/00	06/01/00	
332		332	Full Scale Grout Mixing desired by Engineering	0 days	06/01/01	06/01/01	
333		333	**Storage Requirements**	51.8 wks	06/05/00	06/01/01	
341		341	**In-drum vs Out of drum**	28.8 wks	11/13/00	06/01/01	



Project: ChooseSorbent
Date: 06/07/00

Task | Split | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Split | Rolled Up Milestone | Rolled Up Progress | External Tasks | Project Summary

ID		ID	Task Name	Duration	Start	Finish	Predecessors
346		346	**Waste Formulation Selection**	74 wks	12/11/00	05/10/02	
351		351	CsIX - Neut&Grout Integrated Treatability Study	34 wks	12/08/00	08/03/01	334
362		362	Meet with WIPP/DOT to determine acceptable formulations	0 wks	03/01/01	03/01/01	
363		363	Cold Pilot-plant testing	390 days	05/01/01	10/26/02	
364		364	Full scale Testing Must Be Complete Per Engineering	0 days	06/03/04	06/03/04	363
365		365	**SLS**	195.4 wks	09/04/00	06/01/04	
366		366	Small Demo on SpinTech	4 wks	09/04/00	09/29/00	
367		367	Preliminary Feed Specs for IX	3 wks	09/04/00	09/22/00	24
368		368	Evaluate/Consolidate Existing Data	6 wks	09/25/00	11/03/00	367
369		369	SLS Method/Technology Evaluation	8 wks	11/06/00	12/29/00	368
370		370	Choose Method/Technologies for Testing	0 wks	12/29/00	12/29/00	369
371		371	Develop Discriminating Creiteria to Test To	6 wks	09/25/00	11/03/00	367
372		372	Perform Bench Scale Testing	35 wks	01/01/01	08/31/01	371,370
373		373	Downselect SLS Technology	0 wks	08/31/01	08/31/01	372
374		374	**Perform Larger Scale Testing**	62 wks	09/03/01	11/08/02	373
379		379	Choose Filter Type	0 days	08/31/01	08/31/01	373
380		380	Additional TechD work on SLS must be complete	0 days	06/01/04	06/01/04	20SS+22 wks
381		381	**Post IX Filtration**	67 wks	05/31/01	09/11/02	
382		382	Post IX Filter Testing	67 wks	05/31/01	09/11/02	160
383		383	Choose post IX filter	0 days	09/11/02	09/11/02	382
384		384	**Solvent Extraction**	229 wks	06/01/00	10/20/04	
385		385	**Solvent Selection**	187 wks	06/01/00	12/31/03	
386		386	**Waste Treatment**	27.4 wks	06/01/00	12/08/00	
390		390	**Bulk Volume**	27.4 wks	06/01/00	12/08/00	
391		391	**Grout Formulations**	27.4 wks	06/01/00	12/08/00	
394		394	**Operability**	32 wks	06/01/00	01/10/01	
399		399	**Availability of Solvent**	58 wks	06/01/00	07/11/01	
411		411	**Preconceptual Design Additional Input Parameters**	187 wks	06/01/00	12/31/03	
419		419	**Solvent Grouting**	101.4 wks	06/01/00	05/10/02	
436		436	**Neut&Grout Integrated Treatability Study**	34 wks	06/01/00	01/24/01	
447		447	Meet with WIPP/DOT to determine acceptable formulations	0.2 wks	06/01/00	06/01/00	
448		448	Cold Pilot-plant testing	390 days	06/01/00	11/28/01	
420		420	**Storage Requirements**	43 wks	06/05/00	03/30/01	
426		426	**In-drum vs Out of drum**	18 wks	11/13/00	03/16/01	
431		431	**Waste Formulation Selection**	74 wks	12/11/00	05/10/02	
402		402	**Mercury Treatment**	24 wks	12/11/00	05/25/01	
403		403	**UNEX Sulfide in Grout matrix equivalency**	24 wks	12/11/00	05/25/01	
405		405	**TRUEX Sulfide treatment equivalency**	24 wks	12/11/00	05/25/01	
407		407	**Engineering Cost Analysis**	30.6 wks	05/28/01	12/26/01	
410		410	Solvent Selection	0 days	12/26/01	12/26/01	406,409
449		449	2. Identify and demonstrate the methods to control the solvent composition under oper	17 wks	06/01/00	09/27/00	
459		459	3. Measure the degradations products of the solvents for affect by radiolysis or chemic	30 wks	06/01/00	12/27/00	
470		470	5. Flowsheet optimization-Identify the engineering design data for the operation of the	42 wks	06/01/00	03/21/01	
481		481	8. Develop expected waste composition across feed variations for waste form developr	9 wks	06/01/00	08/02/00	
488		488	18. Provide spent solvent for incineration testing and waste determination	13.5 wks	06/01/00	09/04/00	
497		497	SOLVENT - MERCURY PRECIPITATION	104 wks	06/01/00	05/29/02	
498		498	Solvent - Hg Precip RCRA treatment requirement evaluation	2 wks	06/01/00	06/14/00	
504		504	Solvent - Hg Precip Define the Chemistry	52 wks	06/01/00	05/30/01	
515		515	Solvent - Hg Precip Characterize Precipitation Solids	52 wks	06/01/00	05/30/01	
526		526	Solvent - Hg Precip Hot Demo	22 wks	06/01/00	11/01/00	
537		537	Solvent - Hg Precip Reactor & Engineering Scale-up	104 wks	06/01/00	05/29/02	
548		548	SOLVENT - LAW EVAPORATION	229 wks	06/01/00	10/20/04	
549		549	Solvent - LAW Evap	229 wks	06/01/00	10/20/04	
564		564	Solvent - LAW Evap Evaporation hazard analysis	7 wks	06/01/00	07/19/00	
570		570	SOLVENT - HAW EVAPORATION/CRYSTALLIZATION	229 wks	06/01/00	10/20/04	
571		571	Solvent - HAW Evap / HEDPA Destruction	229 wks	06/01/00	10/20/04	
496		496	Solv X - Flowsheet Verification Testing	24 wks	09/04/00	02/19/01	488

C03

Project: ChooseSorbent
Date: 06/07/00

Task | Split | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Split | Rolled Up Milestone | Rolled Up Progress | External Tasks | Project Summary

APPENDIX E

DOE-ID Review of SBW Processing Alternatives

Objectives and Associated Considerations (criteria)

1 – Maximize Meeting Schedule Commitments

1.1 Schedule – Date SBW is processed out of tank farm – qualitative

1.2 Facilities timely completion of treatment activities and facilities disposition consistent with legal commitments, such as the Settlement Agreement and consent orders. – P1-qualitative

1.3 SBW Disposal Completion Date – When has the SBW actually left the site bound for disposal. – qualitative

2 – Minimize Cost

2.1 Projects and operational costs – qualitative

2.2 Disposal Cost – qualitative

3 – Minimize Technical Risk

3.1 Technical Maturity – Minimize time to starting Conceptual Design (CD-0) – semi-qualitative

3.2 Risk of technical failure – Stability of product and process operability – qualitative

4 – Minimize ES&H Impacts

4.1 Safety and Health (worker) – How do the relative concerns with construction and employee risk differ for each alternative? – qualitative

4.2 Shipment Risk (most cost effective mode) – qualitative

4.3 Meets DOE's long-term stewardship obligations to maintain controls, institutions, information, and other mechanisms to ensure protection of people and the environment upon completion of cleanup – P3-qualitative

4.4 The alternative is protective of workers, public health, and the environment. – P8-qualitative

4.5 Environmental Justice?

5 – Maximize Operability

5.1 Permitting – What is the ease of obtaining the permits necessary to operate the alternative (RCRA, air, etc.) – qualitative

5.2 **Repeats 3.2** Risk of technical failure – Stability of product and process operability – qualitative

Objectives and Considerations, con't

6 – Maximize Utilization by Other Wastes

6.1 Maximizes use of existing HLW Processing Facilities to the extent it is cost effective. – M2-qualitative

6.2 Provides flexibility for future decisions and utilization of DOE resources. – M4-qualitative

6.3 Process ability with NGLW Mission – How effectively can the smaller generation rate be processed through by the respective alternative – qualitative

6.4 Calcine Mission – Are the unit operations used on the SBW usable in the mission of calcine treatment. – qualitative

6.5 Heel Solid Mission – Can the SBW treatment system be able to treat the Heel Solids (considered HLW at this time). – qualitative

7 – Maximize Ability to Dispose

7.1 **Repeats 1.3** Closes Disposal Loop – When has the SBW actually left the site bound for disposal? **(repeat)** – qualitative

7.2 The treatment process selected minimizes the amount of secondary mixed (hazardous and radioactive) waste generated. – P2-qualitative

7.3 The alternative minimizes reliance on Yucca Mountain – P7-qualitative

7.4 NAS 6 – Maintains interim storage of HLW calcine in the bin sets until it becomes clear (1) where the material will be sent; (2) what disposal forms are acceptable, and (3) that an approved transportation pathway to the disposal site is available. (NAS/NRC) – A1-qualitative

7.5 D&D Factor from Facility Disposition should be qualitative

8 – Minimize Program Risk

8.1 Line Item Costs – Not considered additionally to project and operational costs under costs-qualitative Cost Profile Spikes – not considered additionally to project and operational costs can be – qualitative

DMT-2 Consumer Reports

DOE-ID View Criteria	Calcine MACT to WIPP	WIPP Focused Separations	Hanford Focused	2 Stage Evaporation	Direct Vitrification	Silica Gel	Steam Reforming
1.1 Schedule	4.00	5.00	4.00	3.00	3.00	3.00	3.00
1.3 SBW Disposal Completion Date -	4.00	5.00	5.00	4.00	5.00	3.00	5.00
2.1 Projects and operational costs	4.00	5.00	2.00	3.00	1.00	2.00	3.00
2.2 Disposal Cost	2.00	5.00	4.00	2.00	5.00	1.00	4.00
3.1 Technical Maturity –	4.00	4.00	3.00	1.00	3.00	1.00	2.00
3.2 Risk of technical failure -	4.00	5.00	3.00	2.00	4.00	2.00	3.00
4.1 Safety and Health (worker) -	5.00	5.00	5.00	5.00	4.00	5.00	5.00
4.2 Transportation Risk	5.00	4.00	4.00	5.00	5.00	4.00	4.00
5.1 Permitting -	1.00	3.00	3.00	4.00	5.00	4.00	3.00
6.3 Process ability with NGLW Mission -	1.00	4.00	4.00	4.00	4.00	4.00	4.00
6.4 Calcine Mission -	1.00	3.00	4.00	1.00	5.00	1.00	1.00
6.5 Heel Solid Mission - Assume Non-HLW	2.00	3.00	3.00	4.00	5.00	2.00	3.00
7.2 Minimize secondary waste	1.00	4.00	3.00	5.00	4.00	5.00	2.00
7.5 D&D Impact	5.00	4.00	4.00	5.00	4.00	5.00	y

Worse ⟷ Better

1.8 - 2.6 | 2.6 - 3.4 | 3.4 - 4.2 | >4.2

C04

Summary Data Used to Score Consumer Reports

	Calcine MACT to WIPP	CsIX Separations	UNEX Separations	(2 Stage) Evaporation	Direct Vitrification	Silica Gel	Studsvick
1.1 Processing Complete on SBW, year	2013	2012	2014	2015	2015	2015	2015
1.3 SBW Disposal Completion	2021	2019	2018	2021	2018	2025	2019
2.1 Project / OPS costs, millions	474	371	608	569	761	640	571
2.2 Shipping and Disposal Costs at WIPP, millions	291	104	135	291	118	537	151
3.1 Technical Maturity to Begin Conceptual Design(yr)	1	1	2	3-4	2	3-4	2-3
3.2 Technical Risk of Failure	low to medium	Low	medium	medium to high	low-medium	medium to high	medium
4.1 Safety & Health (Worker)	170 REM, 155 Lost work days	129 REM, 129 lost work days	274 REM, 249 lost work days	285 REM, 259 lost work days	618 REM, 561 lost work days	177 REM, 161 lost work days	184 REM, 168 lost work days
4.2Transportation Risks, deaths	worker:0.003, Public 0.00021, accident	worker:0.008, Public 0.003, accident 0.06 total .071	worker:0.0026, Public .000072, accident .02	worker:0.003, Public 0.00021, accident 0.0049 total	worker:0.00071, Public 0.0051, accident 0.0035 total	worker:0.006, Public 0.00042, accident 0.0097 total 0.016	worker:0.00081, Public 0.0058, accident 0.004 total 0.011
5.1 Permitting	thermal,flame	non-thermal	non-thermal	non-thermal	thermal, flame secondary burner	non-thermal	thermal, flame secondary burner
6.3 NGLW Mission	no	yes	yes	yes	yes	yes	yes
6.4 Calcine Mission	no	yes, need to change equipment	yes, need to scale up	no	yes, mostly usable asis	no	no
6.5 Heel Solids Mission	maybe	yes	yes	maybe	yes	maybe	yes
7.2 Minimize Secondary Waste	-9	3	0	6	3	6	-6
7.5 D&D	9.8 Million	111 M	113 M	16 M	102 M	25M	70M

Relative Performance Scores	Performance	Investment	Robustness (low programmatic uncertainty)	Low Technical Uncertainty
Good	CsIX Seps	CsIX Seps MACT to WIPP	UNEX Seps Direct Vit. Silica Gel	CsIX Seps MACT to WIPP Direct Vit.
Mod.	Direct Vit. UNEX Seps MACT to WIPP Steam Reform 2 Stage Evap.	2 Stage Evap. Steam Reform UNEX Seps Silica Gel	CsIX Seps 2 Stage Evap. Steam Reform	UNEX Seps Steam Reform
Poor	Silica Gel	Direct Vit.	MACT to WIPP	2 Stage Evap. Silica Gel

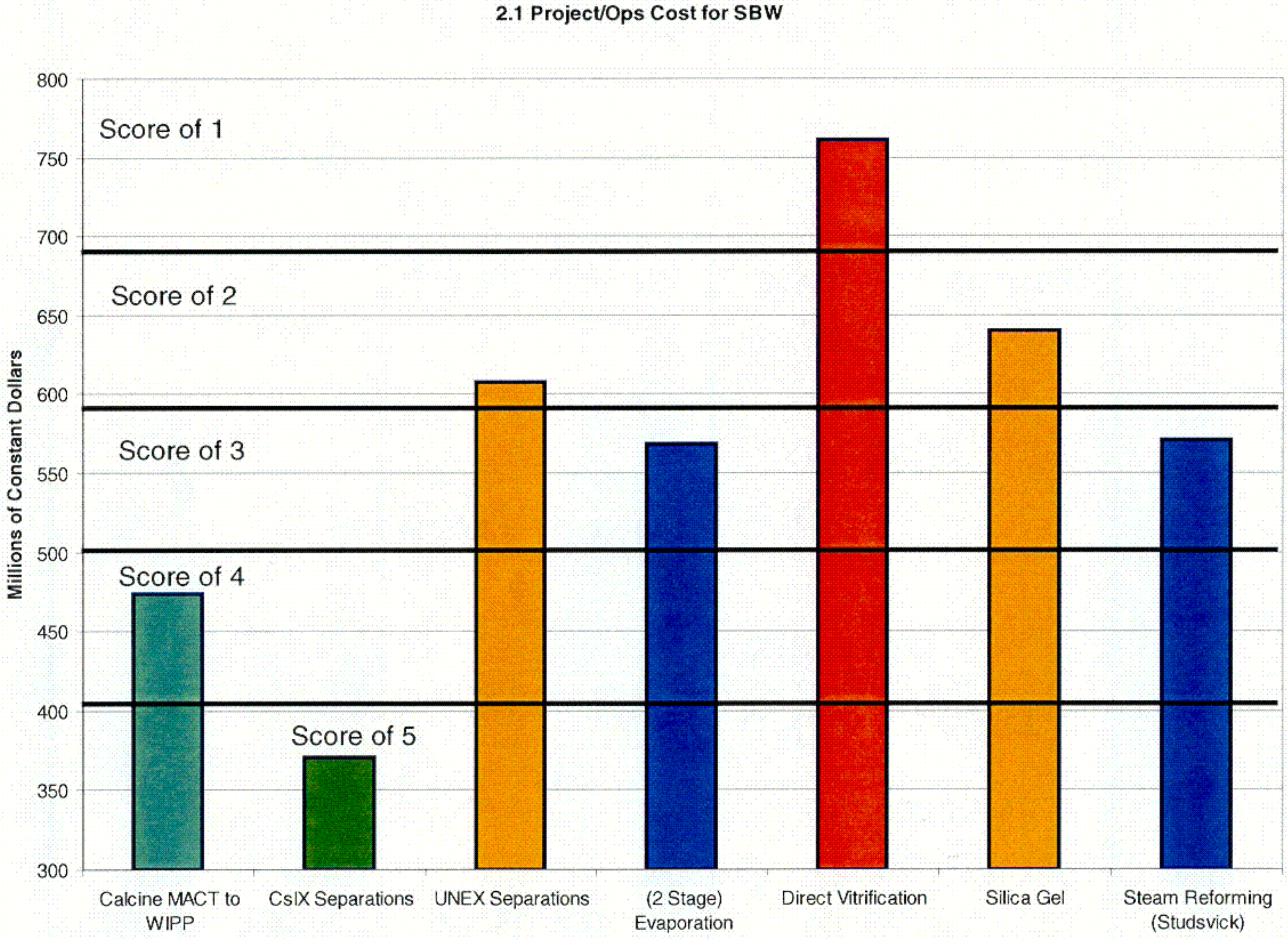
Elimination Reasons
- Primary
- Supporting

E.5

C05

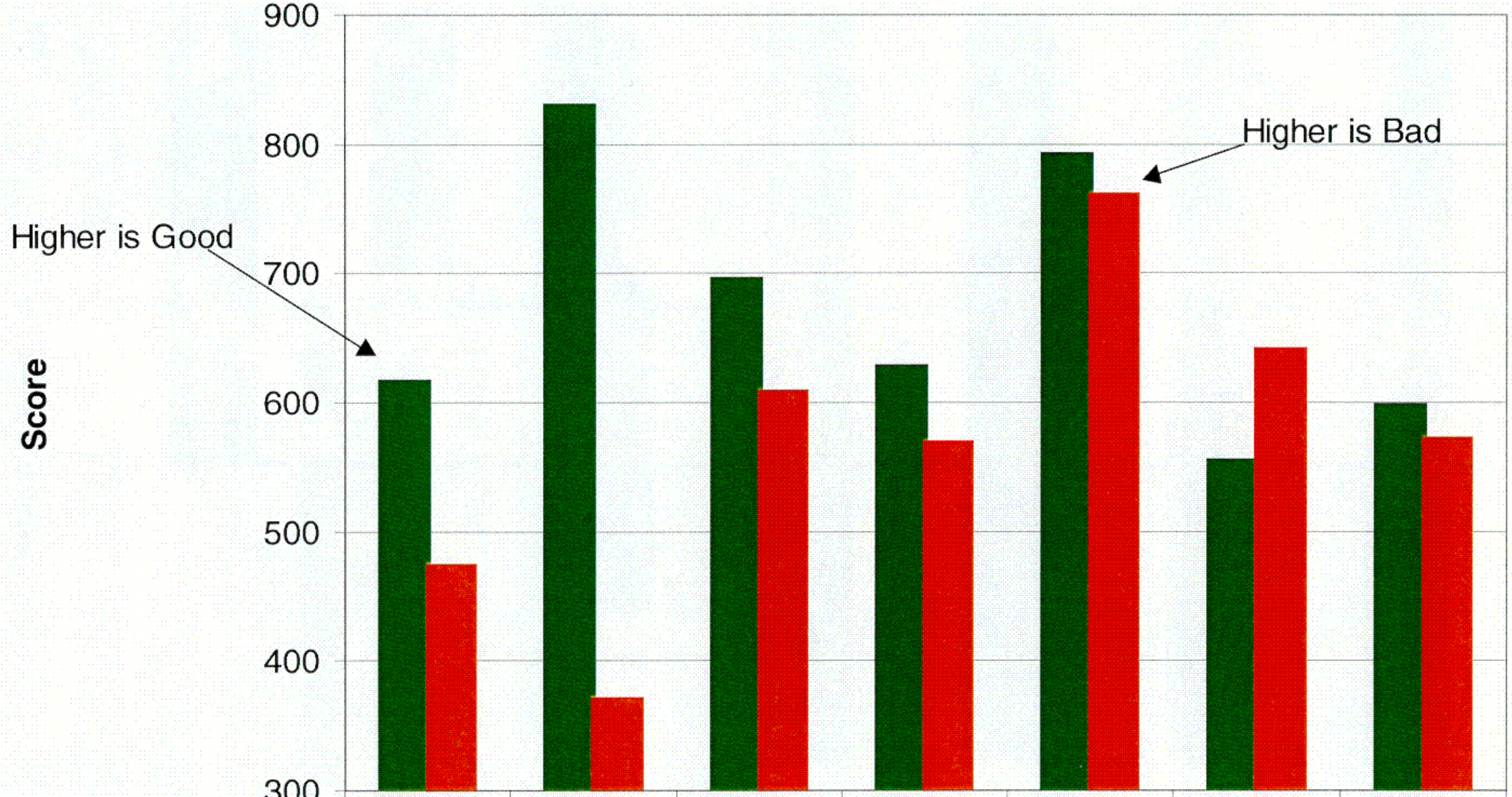
Project/Operations Cost

Score Divided Into 100 Million Dollar Increments



C06

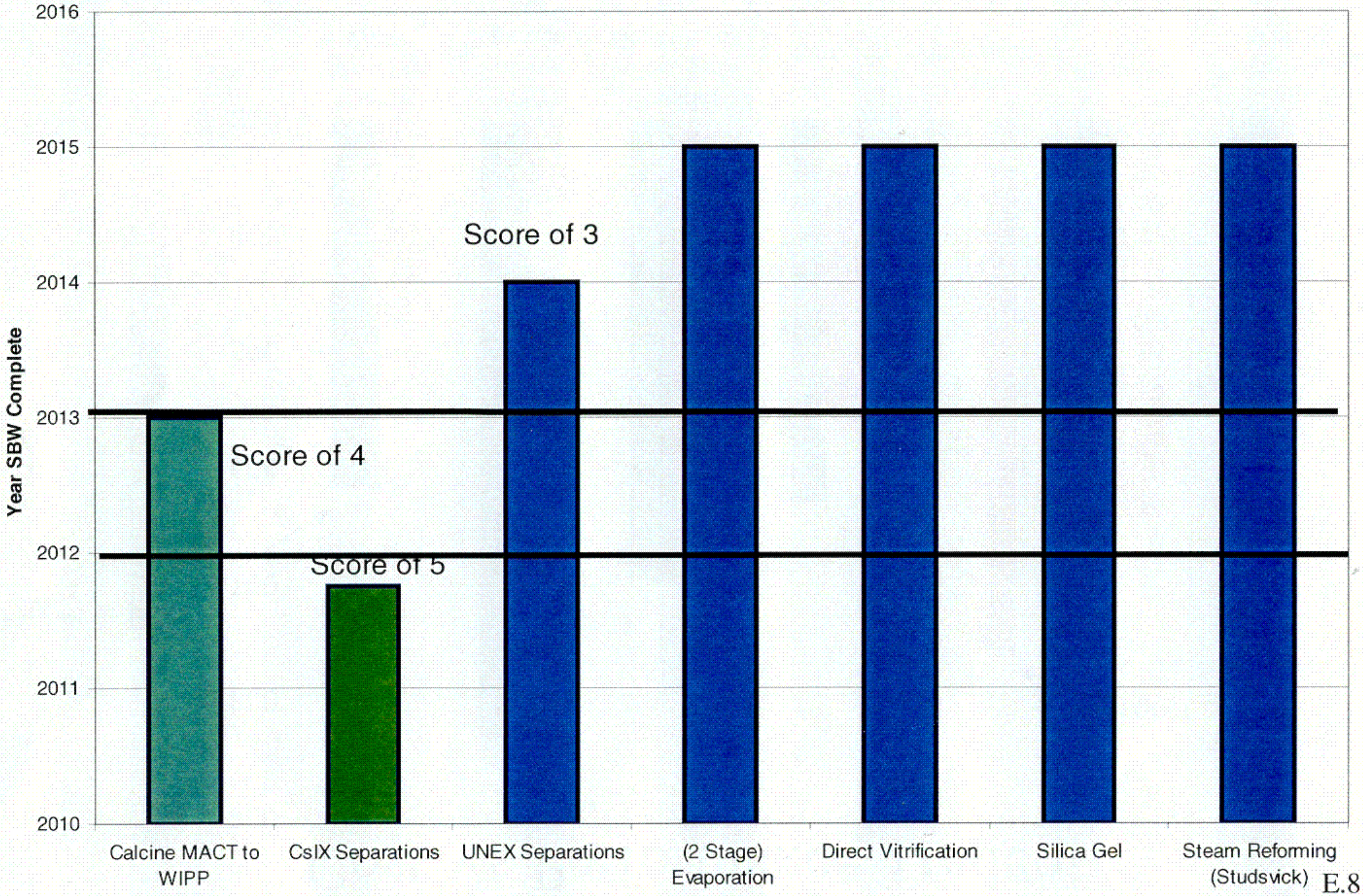
Cost Vs Performance Tradeoff



	Calcine MACT to WIPP	WIPP Focused Separations	Hanford Focused Separations	2 Stage Evaporation	Direct Vitrification	Silica Gel	Steam Reforming (Studsvik)
Performance Score	615	829	695	628	792	554	597
Project/ops,$M	474	371	608	569	761	640	571

C07

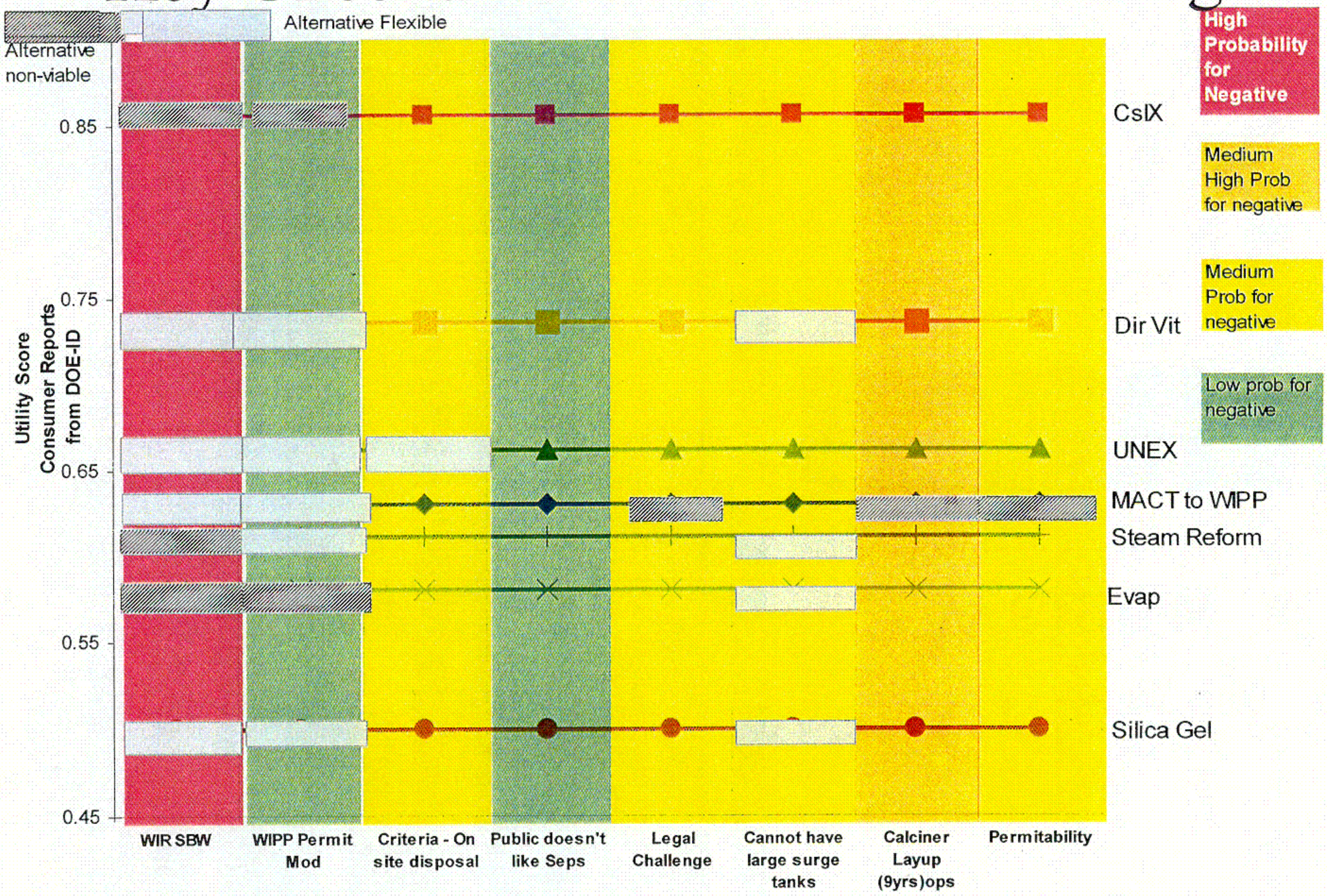
Schedule to Complete SBW Processing



E.8

C08

Key Uncertainties for SBW Processing



Criteria Weights

Example score sheet

Redundant and non-discriminating criteria are crossed off and have zero weighting factor.

Name	Description	Weighting	Weight Value
1.1 Schedule	Date SBW is processed out of tank farm	Low ☐ ☐ ☐ ☐ ☒ High	0.08
~~1.2 Facilitates timely completion~~	~~for treatment activities and facilities disposition consistent with legal commitments, such as the Settlement Agreement and consent orders. – P1~~	Low ☐ ☐ ☒ ☐ ☐ High	0.00
1.3 SBW Disposal Completion Date -	When has the SBW actually left the site bound for disposal.	Low ☐ ☐ ☐ ☐ ☒ High	0.08
2.1 Projects and operational costs	The total cost to construct and operate SBW treatment facilities.	Low ☐ ☐ ☐ ☐ ☒ High	0.08
2.2 Disposal Cost	Costs for shipping and Disposal	Low ☐ ☐ ☐ ☐ ☒ High	0.08
3.1 Technical Maturity–	Minimize time to starting Conceptual Design (CD-0)	Low ☐ ☐ ☐ ☐ ☒ High	0.08
3.2 Risk of technical failure -	Stability of product and process operability	Low ☐ ☐ ☐ ☐ ☒ High	0.08
4.1 Safety and Health (worker) -	How do the relative concerns with construction and employee risk differ for each alternative?	Low ☐ ☐ ☐ ☐ ☒ High	0.08
4.2 Transportation Risk	(most cost effective mode)	Low ☐ ☐ ☐ ☐ ☒ High	0.08
~~4.3 Meets DOE's long-term stewardship obligations~~	~~other mechanisms to ensure protection of people and the environment upon completion of cleanup –P3~~	Low ☐ ☐ ☒ ☐ ☐ High	0.00
~~4.4 protection of workers, public health, and the environment. – P8~~		☐ ☐ ☒ ☐ ☐	0.00
5.1 Permitting -	What is the ease of obtaining the permits necessary to operate the alternative (RCRA, air etc)	Low ☐ ☐ ☒ ☐ ☐ High	0.05
~~6.1 Maximize use of HLW Facilities~~	~~Maximizes use of existing HLW Processing Facilities to the extent it is cost effective. – M2~~	☐ ☐ ☒ ☐ ☐	0.00
~~6.2 Future Decision Flexibility~~	~~Provides flexibility for future decisions and utilization of DOE resources. – M4~~	☐ ☐ ☒ ☐ ☐	0.00
6.3 Process ability with NGLW Mission -	How effectively can the smaller generation rate be processed through by the respective alternative	Low ☐ ☐ ☐ ☐ ☒ High	0.08
6.4 Calcine Mission -	Are the unit operations used on the SBW usable in the mission of calcine treatment.	Low ☐ ☐ ☐ ☐ ☒ High	0.08
6.5 Heel Solid Mission - Assume Non-HLW	Can the SBW treatment system be able to treat the Heel Solids (considered HLW at this time).	Low ☐ ☐ ☐ ☐ ☒ High	0.08
7.2 Minimize secondary waste	The treatment process selected minimizes the amount of secondary mixed (hazardous and radioactive) waste generated. – P2	Low ☐ ☐ ☐ ☐ ☒ High	0.08
~~7.3 Minimize reliance of Yucca Mtn~~	~~The alternative minimizes reliance on Yucca Mountain – P7~~	☐ ☐ ☒ ☐ ☐	0.00
~~7.4 Minimize treatment of wastes without clear disposition~~	~~NAS 6 – Maintains interim storage of HLW calcine in the bin sets until it becomes clear (1) where the material will be sent; (2) what disposal forms are~~	☐ ☐ ☒ ☐ ☐	0.00
7.5 D&D Impact	Waste volumes and types and square footage of facility disposition	Low ☐ ☐ ☒ ☐ ☐ High	0.05
~~8.1 Line Item Costs –~~	~~Not considered additionally to project and operational costs under costs~~	Low ☐ ☐ ☒ ☐ ☐ High	0.00

APPENDIX F

Documents Reviewed

Appendix F: Documents Reviewed

Reports

AEA Technology. 1999. *Cementation of INEEL Type 2 Waste*, AEAT-6095 Issue 1, Charlotte, North Carolina.

Bechtel BWX Technologies Idaho. 2000. *HLW Program, Sodium Bearing Waste Processing Alternatives Analysis,* Compact Disc, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Bechtel BWX Technologies Idaho. 2000. *Sodium Bearing Waste Technology Roadmap,* Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Gibson, P. L., and K. J. Perry. 1999. "Calciner Operations Path Forward Facilitated Problem Solving Session," Appendix C.1, "Calciner Meeting Report," Pre-decisional draft (not for public dissemination), *Sodium Bearing Waste Processing Alternatives Analysis*," Idaho Falls, Idaho.

Idaho National Engineering and Environmental Laboratory (INEEL). 1998. *Hot Isostatic Press Waste Option Study Report,* INEEL/EXT-98-01392, Idaho Falls, Idaho.

Idaho National Engineering and Environmental Laboratory (INEEL). 1999. *Idaho Nuclear Technology and Engineering Center Low-Activity Waste Process Technology Program FY-99 Status Report,* INEEL/EXT-99-00973, Idaho Falls, Idaho.

Idaho National Engineering and Environmental Laboratory (INEEL). 2000. *Idaho Nuclear Technology and Engineering Center Newly Generated Liquid Waste Demonstration Project Feasibility Study,* INEEL/EXT-2000-00141, Idaho Falls, Idaho.

Murphy, J., B. Palmer, and K. Perry. 2000. *Sodium Bearing Waste Processing Alternatives Analysis,* INEEL/EXT – 2000-00361, Pre-Decisional Draft, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

National Academy Press (NAS). 1999. *Alternative High-Level Waste Treatments at the Idaho National Engineering and Environmental Laboratory*, Washington, D.C.

U.S. Department of Energy (DOE). 1997. Interim Guidance, *US DOE Standard Operating Procedures – OST Technology Decision Process*, Office of Environmental Management. As shown at http://www.oakridge.doe.gov/em/td/sop-r7.pdf on June 29, 2000.

U.S. Department of Energy (DOE). 1999. *Process for Identifying Potential Alternatives for the Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement, Revision 1*, DOE-ID 10627, Idaho Falls, Idaho.

U.S. Department of Energy (DOE). 1999. *Idaho High-Level Waste & Facilities Disposition Draft Environmental Impact Statement Summary,* DOE/EIS-0287D, Idaho Falls, Idaho.

Presentations

Technology/Performance Sub-Team Activities Since DMT #1, Presented at the Decision Management Team Meeting #2, Keith Lockie, May 31, 2000.

Idaho High-Level Waste and Facilities Disposition Environmental Impact Statement, Briefing for Principal Deputy Assistant Secretary for Environmental Management, March 20, 2000.

Letters

Cogema, Inc. Letter to Mr. Wichmann from Rhonne Smith, Cogema, Inc. Comments on the *Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement* (EIS).

Studsvik Comments, Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement (DOE/EIS-0287D), Dated April 12, 2000.

Studsvik, Letter to Darryl Siemer from Brad Mason, Transmittal – Studsvik Denitration Process, Dated March 12, 1998.

Excerpts

Following excerpts from:

Technical Alternatives to Reduce Risk in the Hanford Tank Waste Remediation System Phase I Privatization Project, September 1999 (DOE/EM-0493)

- Table 4.4.1 Evaluation Criteria for Alternatives Assessment
- Table 2.3.3 Summary Evaluation for Pretreatment Unit Operations.

Handouts

Handouts for Presentations made at the June 19-23, 2000 Meeting.

Herbst, A.; Acid Side Direct Evaporation/Solidification

Poloski, A. P.; Tank Farm Solids Observations

Olsen, A.; Solid/Liquid Separations

Todd, T. A.; J. D. Law; and R. S. Herbst; SBW Solvent Extraction Alternative

Musick, C. A., R. R. Kimmitt, and J. J. Quigley; Vitrification

Murphy, J.; Calcine Disposition Path Forward

Carteret, B.; TFA Scope of Work

Lockie, K; Overview of EIS Technology Down-Selection

Waste Characterization

Palmer, B.; INEEL Waste Retrieval, June 20, 2000

Murphy, J.; SBW Technology Path Forward

Objectives and Associated Considerations

INTEC Waste Streams, INEEL

Cs Ion Exchange

INEEL Memo: Inventory Estimates for the Tank Farm and CSSFs, MD-01-00/Mil-01-00,

Letter from M. D. Staiger and C. B. Millet to J. T. Beck, dated February 18, 2000, revised March 29, 2000.

Holtzscheiter, B; Immobilization Development for Idaho FY97–FY00, Idaho EIS Review, June 19–23, 2000.

McGinnis, C. P.; Pretreatment Development for Idaho FY96–FY00, Idaho EIS Review, June 19–23, 2000.

Miscellaneous

National Research Council Report on a recent review of INEEL plans and options for HLW treatment.

Technical Feasibility.

Technical Risk Analysis.

Solidification of Acidic, High-Sodium Low Level Waste at the Idaho National Engineering and Environmental Laboratory, September 1998.

Abbreviated Treatment Alternative(s) Descriptions.

APPENDIX G

EM Stage Gate Description

5. PROCEDURE

The OST Technology Decision Process represents a series of stages and gates, from basic research through implementation. The scope of the process emphasizes all activities from basic research through, and including, the actions required for implementation/use of a technology or a technological system that meet a defined performance requirement or that address a clearly defined set of problems. The OST Technology Decision Process Gate Requirements and Deliverables, Attachment D, provides specific informational requirements that must be addressed for a technology to pass through a gate. The intent of the process is to (1) facilitate the collection of information; (2) specify the standard format for information; and (3) facilitate sound and timely decision-making based upon three major actions: GO forward, HOLD for specific action, or STOP do not proceed. The FA/CC/IP will use this document to perform a review of every technology as it passes through a gate. At Gate 4, the information will be submitted to the review group as defined herein. The requirements and deliverables matrix (Attachment E) outlines the requirements at each gate. Technologies developed in the private sector and brought into the DOE-EM system for consideration of research, development, or implementation must be subjected to the stage/gate criteria by the FA. Consideration for a commercial-scale demonstration to obtain performance and cost-of-performance data on a real-world environmental management problem may be appropriate.

5.1 STAGE AND GATE MINIMUM PROCEDURE REQUIREMENTS

Attachment C is a diagrammatic description of the OST Technology Decision Process. The following procedure defines the related specific minimum goals, objectives, measures of effectiveness, actions, and responsibilities associated with each stage and gate.

5.1.1 STAGE 1: BASIC RESEARCH

This stage represents fundamental scientific research for building and documenting core knowledge not tied to a specific, defined need. It includes basic laboratory experimentation, development of theory and analytical models, and proof of principle.

Stage Goal: Generate new ideas.
Objectives: Identify new environmental technology/use of good science.
Measures of Effectiveness: Satisfy programmatic driver criteria (technology end user need, technical merit, costs, and safety/health/environmental protection/risk).

5.1.2 GATE 1: ENTRANCE INTO APPLIED RESEARCH STAGE

Research/studies addressing environmental performance needs. TD/PI addresses programmatic driver criteria (technology end user need, technical merit, costs, and safety/health/environmental protection/risk).

5.1.3 STAGE 2: APPLIED RESEARCH

At this stage, directed scientific/engineering research is conducted that has a link to environmental management needs. Included are proof of principle and laboratory-scale experimentation.

Stage Goal: Conduct systems studies to address DOE-EM high-priority needs.
Objectives: Define data requirements, prepare experimental designs, determine material requirements, and determine business attributes.
Measures of Effectiveness: Satisfy experimental design plan acceptance criteria and programmatic driver criteria (technology end user need, technical merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.4 GATE 2: ENTRANCE INTO EXPLORATORY DEVELOPMENT STAGE

- Linked with clearly defined DOE-EM priority performance needs.
- Satisfied experimental design criteria.
- TD/PI initiates baseline comparison.

- TD/PI addresses gate programmatic driver criteria (technology end user need, technical merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.5 STAGE 3: EXPLORATORY DEVELOPMENT

In this stage, technical feasibility in terms of potential applications is evaluated (i.e., can the technology be sufficiently developed to solve the problem). Included are laboratory-scale prototyping, analysis of user needs, estimates of life-cycle costs, and identification of functional performance requirements and operational concepts.

Stage Goal: Conduct system study to address FA/CC/IP and/or STCG identified priority needs.
Objectives: Verify concept linked to specific needs.
Measures of Effectiveness: Continues to satisfy experimental design plan acceptance criteria and experimental performance meets program expectations and programmatic driver criteria (technology end user need, technical merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.6 GATE 3: ENTRANCE INTO ADVANCED DEVELOPMENT STAGE

- Linked with clearly defined DOE-EM/private sector priority performance needs.
- TD/PI continues baseline comparison.
- TD/PI addresses gate programmatic driver criteria (technology end user need, technical merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.7 STAGE 4: ADVANCED DEVELOPMENT

In this stage, proof of design is required. This includes full-scale laboratory testing, preliminary field testing, technical specification development, and infrastructure development plans.

Stage Goal: Specific DOE-EM application of product, concept, or subsystems that includes studies, advanced analysis, and laboratory-scale models.
Objectives: Review group application validation, specifications assessment.
Measures of Effectiveness: Satisfy external assessment of application specifications and programmatic driver criteria (technology end user need, technology merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.8 GATE 4: ENTRANCE INTO THE ENGINEERING DEVELOPMENT STAGE (MAJOR DECISION POINT INCLUDES REVIEW GROUP INTERACTION)

- Review group completes review of information supplied by FA/CC/IP, TD/PI, and others.
- Technology assessed as being the right technology, at the right place, at the right time.
- TD/PI addresses gate programmatic driver criteria (technology end user need, technology merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.9 STAGE 5: ENGINEERING DEVELOPMENT

This stage includes systematic use of the knowledge gained from research and development to develop a detailed approach for full-scale design. Components include documentation such as drawings, schematics, and computer codes; construction and demonstration units; prototypes and pilot-scale systems; system evaluation; reliability testing; infrastructure plans; and procurement specifications.

Stage Goal: Classified as a technology or system likely to exceed DOE-EM baseline or likely to meet select government performance requirements or a problem set.
Objectives: Scale-up and refine detailed design for prototypes and pilots; clarify DOE deployment strategy and schedules to meet internal/external performance needs.

Measures of Effectiveness: Completed and documented preliminary test results and satisfied test plans and programmatic driver criteria (technology end user need, technology merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.10 GATE 5: ENTRANCE INTO THE DEMONSTRATION STAGE

- DOE-EM deployment schedule established.
- Completed and documented preliminary test results and satisfied test plan requirements.
- An Innovative Technology Summary Report referenced herein is issued unless a full-scale demonstration is to be performed in Stage 6.
- TD/PI addresses gate programmatic driver criteria (technology end user need, technology merit, costs, safety/health/environmental protection/risk, stakeholder/regulator/tribal, and commercial viability).

5.1.11 STAGE 6: DEMONSTRATION

At this stage, the product or technology is subjected to a "real world" demonstration, either at a DOE site or at another location, using actual or simulated waste streams and/or anticipated operating conditions to verify assumptions made to this point.

Stage Goal: Verification of design through test and evaluation of full-scale system.
Objectives: System suitability, full-scale testing, system testing and market conditioning.
Measures of Effectiveness: End user accepts the technology and programmatic driver criteria (technology end user need, technology merit, costs, safety/health/environmental protection/risk, stakeholder/ regulator/tribal, and commercial viability) are met.

5.1.12 GATE 6: ENTRANCE INTO THE IMPLEMENTATION STAGE

- Results of technology/system test is fully documented and a final Innovative Technology Summary Report is issued. A Cost and Performance Report for environmental remedial projects shall also be prepared at this gate for EM-40-funded technologies.
- Technology partner is fully invested (i.e., procurement path defined).
- Implementation and commercialization viability have been clearly defined according to accepted business standards.
- Gate programmatic driver criteria have been fully engaged (technology end user need, technology merit, costs, safety/health/environmental protection/risk, stakeholder/ regulator/tribal, and commercial viability).

5.1.13 STAGE 7: IMPLEMENTATION

The product or technology has been proven to be viable, cost-effective, and applicable to required needs and is put into service by the end user. The technology must be available for transfer to the private sector or already commercially available for commercial use.

5.2 STAGE AND GATES PROCEDURE OPERATIONS MANAGEMENT

Attachment D depicts the OST Technology Decision Process Gate Requirements and Deliverables. Attachment E is the Requirements and Deliverables Matrix.

5.2.1 STAGE PROCEDURE OPERATIONS MANAGEMENT RESPONSIBILITIES

The FA/CC/IP—through the assigned TD/PI and others, as appropriate—is responsible for documentation of all the requirements defined in Sections 5.1.1 through 5.1.13 and as outlined further in Attachment D. The FA/CC/IP in concert with the TD/PI will plan, arrange, and carry out activities and responsibilities according to the stage conditions/requirements for purposes of presenting, justifying, and meeting each of the gate criteria.

5.2.2 GATE PROCEDURE OPERATIONS MANAGEMENT RESPONSIBILITIES

THE FA/CC/IP IS RESPONSIBLE FOR EVALUATING THE DOCUMENTATION AT ALL GATES IN ACCORDANCE WITH THE LISTED GATE CRITERIA. IF THE FA/CC/IP PROGRAM DETERMINES THE TECHNOLOGY WARRANTS PASSING THROUGH THE GATE, THE TD/PI, THE SITE DOE MANAGEMENT, AND OTHERS, AS APPROPRIATE, WILL BE NOTIFIED AND THE TECHNOLOGY MATURATION PROCESS WILL CONTINUE. IF THE EVALUATION INDICATES THE TECHNOLOGY DOES NOT WARRANT FURTHER CONSIDERATION, THE TD/PI, THE SITE DOE MANAGEMENT, AND OTHERS, AS APPROPRIATE, WILL BE NOTIFIED THAT FURTHER SUPPORT FROM THE FA/CC/IP WILL NOT BE FORTHCOMING. IF THE EVALUATION REFLECTS UNCERTAINTIES ABOUT THE TECHNOLOGY, THE FA/CC/IP MAY HOLD FOR RECONSIDERATION. AS A CHECK FOR CONSISTENCY OF THE DECISION PROCESS ACROSS THE OST ORGANIZATION, AT GATE 4 THE FA/CC/IP WILL SUBMIT THE DOCUMENTATION REQUIREMENTS TO THE DECISION PROCESS COORDINATOR FOR CONSIDERATION BY THE REVIEW GROUP. THE REVIEW GROUP WILL THEN MAKE GO, HOLD, OR STOP RECOMMENDATIONS TO THE FA/CC/IP AND OST MANAGEMENT.

5.3 GATE PROCEDURE AND PEER REVIEW

AN OST PEER REVIEW SYSTEM DISCUSSED IN THE *Technical Peer Review Program Provisional Guidance* HAS BEEN ESTABLISHED AND WILL BE USED TO FACILITATE ASSESSMENT OF THE TECHNOLOGY. THE PEER REVIEW INFORMATION, HOWEVER, WILL BE SHARED WITH OST MANAGEMENT AND THE OST TECHNOLOGY DECISION PROCESS REVIEW GROUP. OST HAS DETERMINED THAT A PEER REVIEW MUST BE CONDUCTED BEFORE A TECHNOLOGY PASSES THROUGH GATE 4. THE FA/CC/IP AND THE PEER REVIEW GROUP ARE RESPONSIBLE FOR PEER REVIEW ACTIVITY IN ACCORDANCE WITH THE GUIDANCE DOCUMENT REFERENCED PREVIOUSLY. THE PEER REVIEW GROUP DOES NOT ADDRESS ALL THE CRITERIA IN THIS DOCUMENT. IT FOCUSES ON THE TECHNICAL MERIT OF THE TECHNOLOGY.

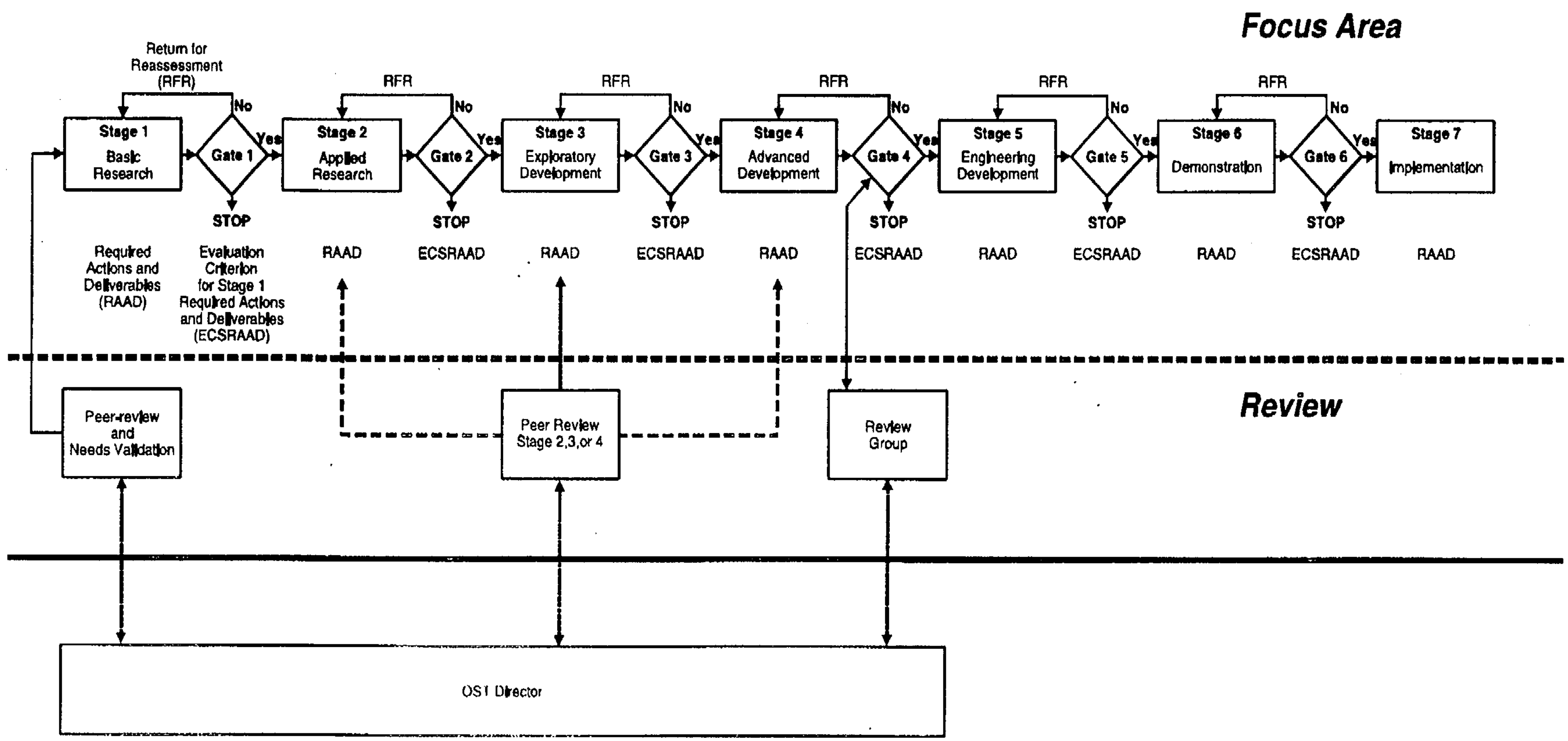
5.4 OFFICE OF SCIENCE AND TECHNOLOGY REVIEW GROUP

THE OST REVIEW GROUP MEMBERS ARE IDENTIFIED BY THE DECISION PROCESS COORDINATOR AND ARE TO ENSURE THAT NEW AND/OR INNOVATIVE TECHNOLOGIES ARE ASSESSED AND MANAGED IN A CONSISTENT MANNER IN ACCORDANCE WITH CRITERIA LISTED HEREIN. THIS GROUP WILL CONVENE TO REVIEW ALL TECHNOLOGIES THAT THE FA/CC/IP SUBMIT FOR PASSAGE THROUGH GATE 4 AND AT OTHER TIMES AS REQUESTED BY THE FA/CC/IP.

THE SIZE OF THE REVIEW GROUP SHALL BE APPROPRIATE FOR THE NUMBER OF TECHNOLOGIES TO BE EVALUATED. THE MINIMUM NUMBER OF MEMBERS SHALL BE THREE. MINIMUM CRITERIA FOR MEMBERSHIP ON THE REVIEW GROUP IS AS FOLLOWS: (1) MUST BE A FEDERAL EMPLOYEE, (2) MUST BE KNOWLEDGEABLE OF THE EM PROGRAM, (3) MUST BE AVAILABLE WITHIN THE REQUIRED TIME FRAME OF THE REVIEW, AND (4) MUST HAVE THE APPROPRIATE TECHNICAL BACKGROUND AND EXPERIENCE, AND (5) MUST BE INDEPENDENT FROM THE SITE THAT IS BEING REVIEWED.

ATTACHMENT C

OST-TECHNOLOGY DECISION PROCESS CHART



ATTACHMENT E
REQUIREMENTS AND DELIVERABLES MATRIX
(NEW GATE REQUIREMENTS ARE BOLD)

Requirement	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5	Gate 6
TECHNOLOGY END-USER NEED						
Project must be relevant to a defined high-priority DOE environmental management need.	**Yes**	Yes	Yes	Yes	Yes	Yes
Research will yield results within a time frame consistent with implementation/deployment needs.	**Yes**	Yes	Yes	Yes	Yes	Yes
Research has been linked to specific end-user needs.		**Yes**	Yes	Yes	Yes	Yes
End-user performance requirements have been incorporated into the project and implementation issues defined.			**Yes**	Yes	Yes	Yes
The end user of the technology must be committed to deployment if the demonstration performance requirements are met.					**Yes**	Yes
The end user of the technology must be a partner in the demonstration of the technology.					**Yes**	Yes
The technology must have been proven applicable to identified end-user needs.						**Yes**
TECHNICAL MERIT						
The scientific and/or technical merit of the project mustbe well founded.	**Yes**	Yes	Yes	Yes	Yes	Yes
The likelihood is high that the research will lead to new discoveries or have substantial impact on progress in that field.	**Yes**	Yes	Yes	Yes	Yes	Yes
Proposed methods or approach for demonstration and implementation are scientifically based.	**Yes**	Yes	Yes	Yes	Yes	Yes
Potential technical advantage(s) over baseline and alternative technologies must be well defined.	**Yes**					
Potential technical advantage(s) over baseline and alternative technologies are defined and documented.		**Yes**	Yes	Yes	Yes	Yes
Evidence must be provided that technical feasibility has been demonstrated and that it will meet performancerequirements. This evidence should include summaries of proof-of-principal and/or laboratory-scale experimentation.		**Yes**	Yes	Yes	Yes	Yes
Proof of the design of the technology application is required.				**Yes**	Yes	Yes
The system to demonstrate the technology in the field must be fully engineered.					**Yes**	Yes
The technical performance requirements have been met.						**Yes**
COST						
The proposed budget for research is reasonable.	**Yes**					
Proposed budget for the research is reasonable and appropriate.		**Yes**	Yes	Yes	Yes	Yes
Preliminary cost estimates reflecting advantages over the cost of baseline and alternative		**Yes**	Yes	Yes	Yes	Yes

Requirement	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5	Gate 6
technologies must be provided.						
There must be a cost benefit associated with continued investment in the research and development of this technology.			**Yes**	Yes	Yes	Yes
Life-cycle cost estimates reflecting the advantages of this technology over the baseline and other emerging technologies must be provided.				**Yes**	Yes	Yes
Capital costs associated with the full-scale demonstration system must be provided.					**Yes**	Yes
Cost factors including return on investment (ROI) and budget estimates have been verified.						**Yes**
Funds must be appropriated for implementation/ deployment of the technology.						**Yes**
SAFETY, HEALTH, ENVIRONMENTAL PROTECTION, AND RISK						
The research must present a solution that meets or exceeds current safety, health, and environmental protection levels and meets or reduces the risk to the public, workers, and the environment during operation in comparison to baseline and alternative technologies.	**Yes**	Yes	Yes	Yes	Yes	Yes
Safety, health, and environmental protection issues have been defined and are incorporated into the research and development documents and activities.			**Yes**	Yes	Yes	Yes
Failure scenarios must be defined and contingency plans developed.				**Yes**	Yes	Yes
All safety, health, environmental protection, and risk documentation and plans have been successfully completed in accordance with the appropriate requirements.						**Yes**
STAKEHOLDER, REGULATORY PROTECTION, AND TRIBAL ISSUES						
Stakeholder, regulator, and tribal issues associated with similar technologies have been identified and assessed.		**Yes**	Yes	Yes	Yes	Yes
Appropriate notification and permitting requirements must be identified.		**Yes**	Yes	Yes	Yes	Yes
Stakeholder, regulator, and tribal issues for this technology have been identified.			**Yes**	Yes	Yes	Yes
Strategies for resolving stakeholder, regulatory, and tribal issues and permit requirements must be completed.				**Yes**	Yes	Yes
All required notifications, documentation, and permits for the full-scale demonstration and deployment of the technology in the field have been completed.					**Yes**	Yes
All relevant stakeholder, regulatory protection, and risk issues have been successfully addressed. All documents and permits, including appropriate National Environmental Policy Act requirements, have been completed.						**Yes**

Requirement	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5	Gate 6
COMMERCIAL VIABILITY						
A preliminary product concept has been defined.		**Yes**	Yes	Yes	Yes	Yes
Invention disclosure and intellectual property issues have been identified and protected as appropriate.		**Yes**	Yes	Yes	Yes	Yes
A preliminary commercialization plan for government and commercial utilization of this technology must be completed.			**Yes**	Yes	Yes	Yes
Private sector partners should have been identified and formal relationships implemented for commercialization of the technology.				**Yes**	Yes	Yes
Transfer of the technology to the private sector must be completed.					**Yes**	Yes
The product concept must be clearly defined via specifications drawings, etc. All intellectual property, including patent and license agreements, have been completed. A commercialization plan that includes a market assessment and a summary of competing technologies must be completed. A private sector partner must be in place.						**Yes**