

# Pacific Northwest National Laboratory

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## Tanks Focus Area FY98 Midyear Technical Review

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June 1998

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Prepared for the U.S. Department of Energy  
under Contract DE-AC06-76RLO 1830

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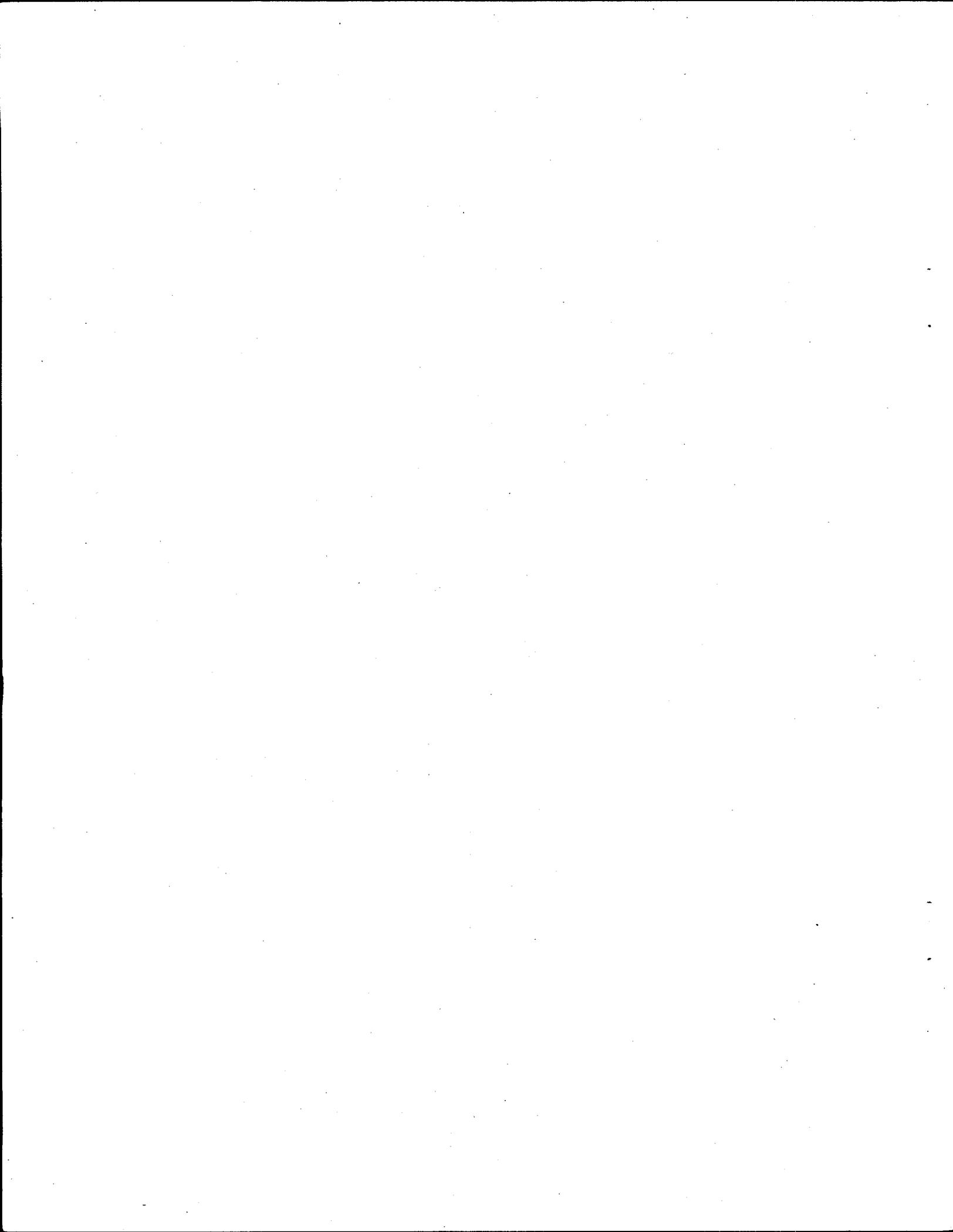
## **Tanks Focus Area FY98 Midyear Technical Review**

S. N. Schlahta  
T. M. Broun  
Tanks Focus Area Technical Advisory Group  
Tanks Focus Area Technology Integration Managers

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Pacific Northwest National Laboratory  
Richland, Washington 99352



## Summary

The U.S. Department of Energy (DOE) continues to face a major radioactive waste tank remediation problem with its present 271 waste tanks containing hundreds of thousands of cubic meters of radioactive waste across the DOE complex.<sup>1</sup> The tanks and the waste they contain present a variety of safety concerns. The tanks must be maintained in a safe condition and eventually remediated to minimize the risk of waste migration and/or exposure to workers, the public, and the environment. However, current regulations are more ambitious than baseline technologies and budgets will support. Science and technology development investments are required to reduce the technical and programmatic risks associated with the tank remediation baselines.

The Tanks Focus Area (TFA) serves as the DOE's Office of Environmental Management's national technology and solution development program for radioactive waste tank remediation.<sup>2</sup> The TFA manages, coordinates, and leverages technology development to support DOE's four major tank sites: Hanford Site (Washington), Idaho National Engineering and Environmental Laboratory (Idaho), Oak Ridge Reservation (Tennessee), and Savannah River Site (South Carolina). Its technical scope covers the major functions that comprise a complete tank remediation system: waste retrieval, waste pretreatment, waste immobilization, tank closure, and characterization of both the waste and tank with safety integrated into all the functions.

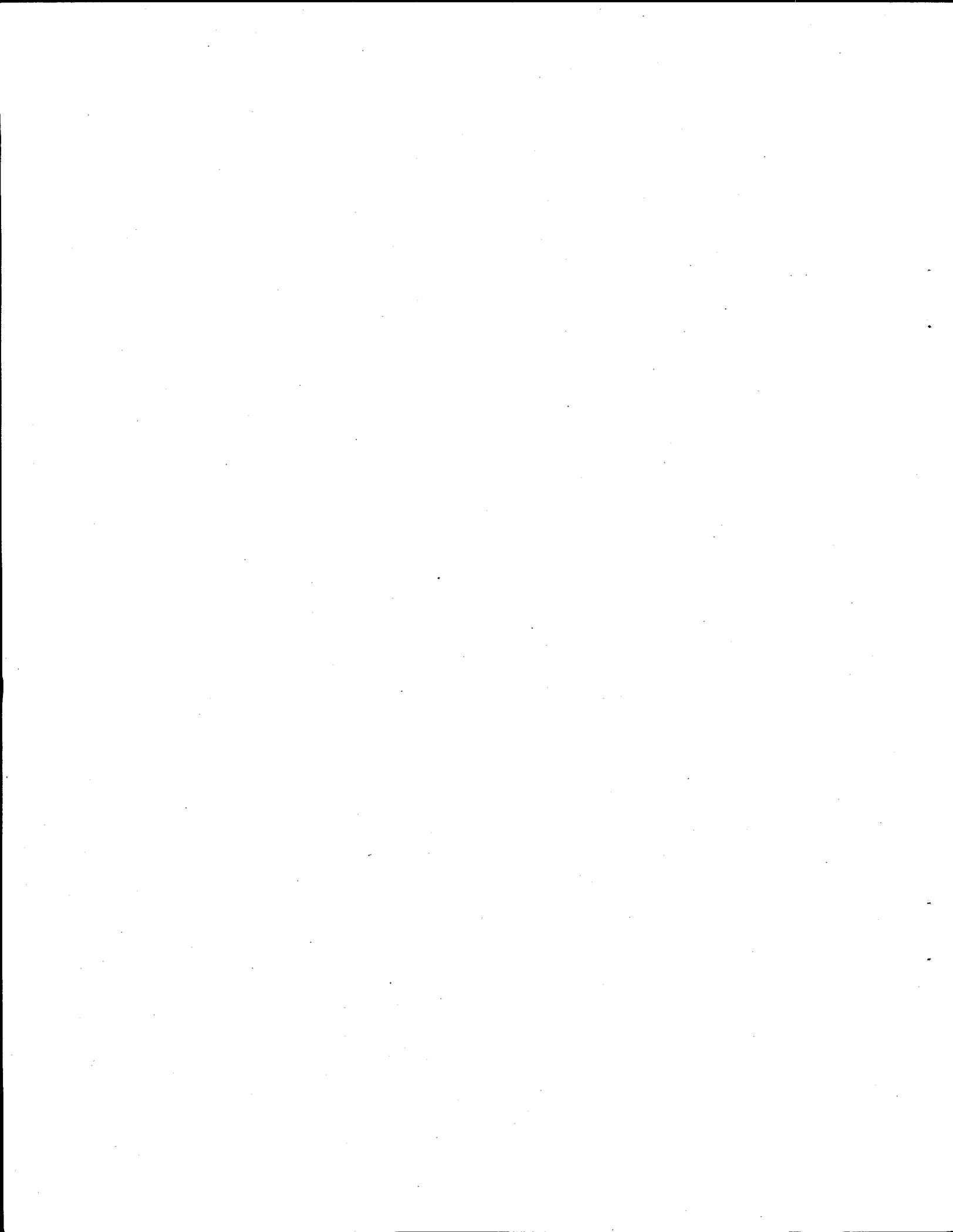
The TFA FY98 Midyear Review took place on March 9 -13, 1998, in Richland, Washington. The midyear review encompassed the need and requirements for several different types of reviews to accomplish technical and programmatic objectives (i.e., review by the TAG, independent peer review, and technology maturity review) into a single meeting. Technologies and technical solutions were selected for review based on three criteria: need for independent peer review, approaching the next stage of development as described in the DOE Office of Science and Technology stage/gate decision process, and the opportunity for technical review to assist in validation of the technical approach to solve complex user needs.

In total, 17 technologies and technical solutions were selected for review. The purpose of each review was to understand the state of development of each technology selected for review and to identify issues to be resolved before the technology or technical solution progressed to the next level of maturity. The reviewers provided detailed technical and programmatic recommendations and comments. The disposition of these recommendations and comments and their impact on the program is documented in this report.

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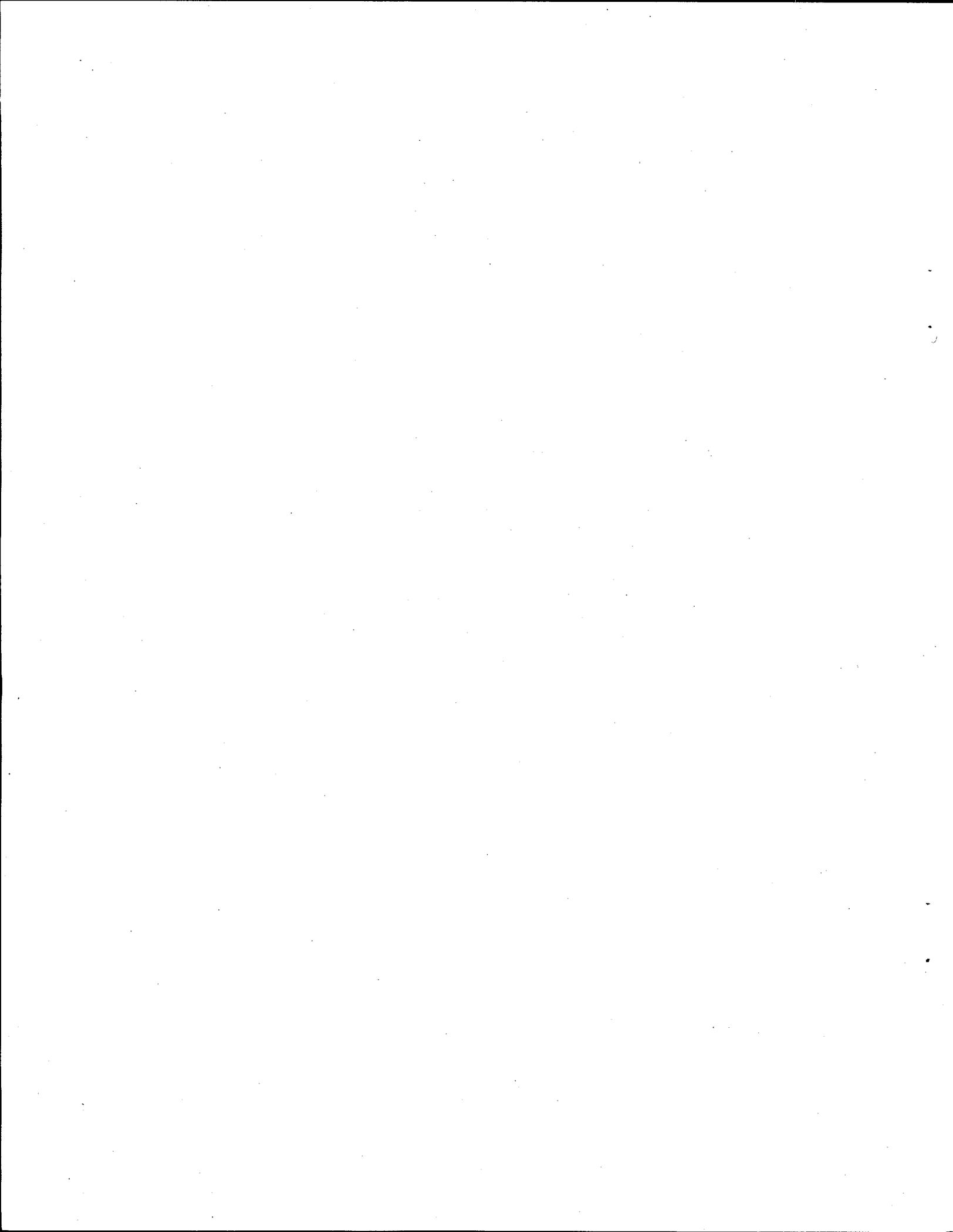
<sup>1</sup> In 1997, two tanks were closed at the SRS, reducing the number of tanks from 273 to 271.

<sup>2</sup> The DOE's Richland Operations Office serves as the lead operations office and program manager of the TFA. The Pacific Northwest National Laboratory, operated by Battelle for the U.S. Department of Energy, leads the TFA's Technical Team, which consists of seven contractors and national laboratories.



## Acronym

BVEST	Bethel Valley Evaporator Service Tank
CPT	Cone Penetrometer Platform
DOE	U.S. Department of Energy
DWPF	Defense Waste Processing Facility
EM-30	U.S. Department of Energy Office of Waste Management
EM-50	U.S. Department of Energy Office of Science and Technology
EN	electrochemical noise
GAAT	Gunite and Associated Tank
HLW	high-level waste
INEEL	Idaho National Engineering and Environmental Laboratory
LAW	low-activity waste
LOD	level of detection
ORR	Oak Ridge Reservation
PA	performance assessment
PI	principal investigator
RCRA	Resource Conservation and Recovery Act
SRS	Savannah River Site
TAG	Tanks Focus Area Technical Advisory Group
TFA	Tanks Focus Area
TIM	Tanks Focus Area Technology Integration Managers
TRU	transuranic
WIPP	Waste Isolation Pilot Plant
XRF	x-ray fluorescence spectroscopy



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## 1.0 Introduction

The U.S. Department of Energy (DOE) continues to face a major radioactive waste tank remediation problem; today, the DOE is responsible for 271 waste tanks containing hundreds of thousands of cubic meters of high-level waste (HLW) and transuranic (TRU) waste. The tanks and the waste they contain present a variety of safety concerns, including generation of flammable gas and leakage of radioactive waste to the surrounding soil. The tanks must be maintained in a safe condition and remediated to minimize the risk of waste migration and/or exposure to workers, the public, and the environment. However, programmatic drivers are more ambitious than baseline technologies and budgets will support. Science and technology development investments are required to reduce the technical and programmatic risks associated with the tank remediation baselines.

### 1.1 Tanks Focus Area

The Tanks Focus Area (TFA) serves as the DOE's Office of Environmental Management's national technology and solution development program for radioactive waste tank remediation.<sup>1</sup> The program was formed to increase integration and realize greater benefits from DOE's technology development budget. The TFA manages, coordinates, and leverages technology and solution development to support DOE's four major tank sites:

- Hanford Site in Washington
- Idaho National Engineering and Environmental Laboratory (INEEL) in Idaho
- Oak Ridge Reservation (ORR) in Tennessee
- Savannah River Site (SRS) in South Carolina.

The TFA's technical scope covers the major functions that comprise a complete tank remediation system: waste retrieval, waste pretreatment, waste immobilization, tank closure, and characterization of both the waste and tank with safety integrated into all the functions. The TFA integrates program activities across organizations that fund tank technology development, including the DOE Offices of Waste Management (EM-30), Environmental Restoration, and Science and Technology (EM-50).

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<sup>1</sup> The DOE's Richland Operations Office serves at the lead field office and program manager of the TFA. The Pacific Northwest National Laboratory, operated by Battelle for the U.S. Department of Energy, leads the TFA's Technical Team, which consists of seven contractors and national laboratories.

## **1.2 FY98 Midyear Review**

The TFA FY98 Midyear Review took place on March 9 -13, 1998, in Richland, Washington. The midyear review encompassed the need and requirements for several different types of reviews to accomplish technical and programmatic objectives (i.e., review by the TFA Technical Advisory Group [TAG], independent peer review, and technology maturity review) into a single meeting. Technologies and technical solutions were selected for review based on three criteria: the need for independent peer review, approaching the next stage of development as described in the DOE Office of Science and Technology stage/gate decision process, and the opportunity for technical review to assist in validation of the technical approach to solve complex user needs.

In total, 17 technologies and technical solutions were selected for review. The objectives for each review were to understand the state of development of each technology selected for review and to identify issues to be resolved before the technology or technical solution progressed to the next level of maturity.

The format used differed from past TFA midyear reviews to incorporate multiple reviews and to receive in-depth comments on the technologies and solutions. The TFA Technology Integration Managers (TIMs), with input from the TAG and DOE users, identified a set of questions to be addressed during each review session. The questions were crafted in such a way as to assist in identifying the state of development for each technology vis-à-vis the EM-50 stage/gate decision process. Principal investigator (PI) teams were directed to answer each question fully before a review group consisting of selected members of the TAG and both DOE and contractor site users. Following each PI team presentation, which included an opportunity for questions and answers, the review group discussed its findings, recommendations, and comments in an executive session (the executive session included only the reviewers, a facilitator, and a recorder).

## **1.3 Contents of This Report**

This report includes a complete section for each of the 17 technologies or solutions that were included in the midyear review. Each section includes a brief description of the technology or solution, findings (which include both the questions asked and the reviewers' analysis of the information given by the PI team to answer these questions), recommendations, and comments of the reviewers' and the TFA's responses.

## **1.4 End Result of Comments**

In addition to assisting the TFA in improving the current and future technical management of these activities, the results of these reviews will comprise the technical input to the upcoming stage/gate reviews for each of these technologies.

## 2.0 Corrosion Probe for Hanford and SRS Technology Stage: Advanced Development

### 2.1 Technology Abstract

Liquid HLW at the SRS and Hanford is stored in carbon steel tanks that are susceptible to nitrate ion-induced corrosion cracking. Monitoring and maintaining adequate nitrate, nitrite, and hydroxide ion levels prevents this. At the Hanford Site, leaks began to appear in the single-shell tanks shortly after nitrate-based waste was added to the tanks in the 1950s. Leaks are now confirmed or suspected in 67 single-shell tanks. The tanks may be leaking as a result of localized corrosion of the steel tank wall. This corrosion could result from nitrate stress corrosion cracking and pitting. Historically, tank waste samples and process knowledge were used to ensure that the waste was within chemistry specifications to avoid corroding the tanks. The sampling and analysis techniques used to ensure the waste stays within specifications are expensive and do not provide timely data.

Thus, another method was needed to monitor the waste. A 2-year laboratory study was started at the Hanford Site in 1995 to provide a technical basis for using electrochemical noise (EN) to monitor in-tank corrosion. Electrochemical noise consists of low frequency (< 1 Hz) and small amplitude signals that are spontaneously generated during corrosion by electrochemical reactions. Based on this study, a prototype system was built and then deployed in Hanford Tank 241-AZ-101 in August 1996. A more complex system – the first-generation probe – was designed and then installed in Tank 241-AN-107 in September 1997.

Now, the TFA and its partners are incorporating the lessons learned from deploying and using earlier probes. The corrosion probes are simple in design and relatively inexpensive, compared to the costs of tank sampling and laboratory chemistry analysis. Using this technology for corrosion monitoring, which is a site requirement, could significantly reduce the downstream costs by providing real-time data that would limit the amount of inhibitor added. The prototype second-generation probe has been developed and tested on Tank 241-AZ-101 at the Hanford Site. The monitor consists of a three-electrode array, one immersed in the waste liquid, and two exposed to the vapor space above the waste. Instantaneous variations in electrochemical corrosion current and potential among the electrodes can be analyzed to identify the extent and rate of corrosion, and to discriminate among corrosion mechanisms (e.g., uniform, pitting). The EN corrosion probe potentially applicable to monitoring waste storage tanks at the Hanford Site and SRS for corrosion-induced leakage.

### 2.2 Findings

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

### **2.2.1 Is the Application of this Technology to the HLW Tanks Appropriate?**

Yes – but see detailed comments below and Sections 2.3 and 2.4.

- (a) Have the user's performance requirements been established, and is the technology adequate for the intended purpose?

More precise performance requirements need to be developed by the user to define what constitutes successful operation. This includes, but is by no means limited to, how data can be converted into information that is useful to plant operators.

- (b) Is the approach to applying the technology sound?

Electrochemical noise sensors, especially when deployed with alternative sensors to minimize false positives and negatives, have been used commercially for about twenty years. However, it appears that this project would benefit substantially from more effective interface with industrial users, especially those who have developed algorithms for converting data into process control decisions. It also is essential and timely to engage tank farm operators in developing useful algorithms.

- (c) Are there any stakeholder or regulatory issues that need to be considered?

Regulators and stakeholders seem favorably disposed.

### **2.2.2 Is the Technology Sound and Appropriate?**

Yes – but see detailed comments below and in Sections 2.3 and 2.4.

- (a) Is the EN technology applicable and appropriate to monitoring tank corrosion caused by HLW? Have alternatives been considered?

The deployed device actually will be a corrosion-sensing system including near-real time but not continuously operated devices (linear polarization) and devices that are retrieved and analyzed off-line on a schedule or as needed (coupons). This type of redundancy is ideal when a new sensor is deployed and substantial operating experience has not yet been achieved. This is particularly true for high-sensitivity sensors such as EN, in an environment in which false negatives and positive indications could lead to significant incorrect actions (or inactions).

As mentioned earlier, effective software systems to translate huge amounts of EN data into information for operating decisions is critical. The first order of business should be a thorough check of industry to see if well-tested software already is available and can be adapted to HLW tanks applications.

A good strategy to corrosion is ensuring that the underlying chemistry is well enough understood so that the controlling chemical constituents are known with high confidence. This is the underlying

premise for grab sampling to determine specific parameters such as nitrate, nitrite, and hydroxide and would be the basis for deploying in situ probes such as Raman spectroscopy. However, technical success of implementing chemically specific methods such as Raman (for example) in the tank environment has substantial uncertainty and the tank chemistry is very complex. Again, the best strategy appears to be using several complementary corrosion indicators, as each has some limitations and the consequences of incorrect indications is high.

- (b) Is the design robust enough for applications in both double-shell and single-shell tanks?

EN is clearly deployable in double-shell tanks, but it is unclear how they could be used in single-shell tanks with little liquid content. Deployment in mixing vessels, process lines, etc. seems quite feasible and could be the greatest value since quick reaction time is needed, i.e., response time for the sensors should relate to reaction time for process upsets. For materials in storage in tanks, the acceptable reaction time is weeks, months, or (apparently) even years.

- (c) Is the corrosion-monitoring equipment reasonable and adequate for use in the tank and tank farm environment?

The use of EN in the tanks clearly is very desirable but should be combined with other corrosion indication methods, at least until substantial in-tank experience has been gained. Surveying other users for data-handling algorithms and working closely with tank operators to define the operating envelope in which the sensor packages will have to operate is recommended.

### 2.2.3 Is the Technology Cost Effective?

Yes, but...

- (a) Is the development cost appropriate and reasonable for the application?

The effort to date appears to be among the most cost-effective endeavors TFA has funded. Essential steps such as data handling software, user interface, and longer term testing in more varied environments are going to require additional effort. The investigators should be applauded for accomplishing a lot in a short time and on a limited budget.

- (b) Do the projected cost savings appear to be achievable, and great enough to justify deployment, data evaluation, and changes in tank farm operation?

While the cost savings could be substantial, the analysis that was presented seemed superficial and the presentation was uncomfortably "evangelical" in flavor. An accurate cost/benefit analysis will not be straightforward, and certainly should include factors such as the cost of false negative and positive indications. This has potential for being one of TFA's "best buys," but more rigorous cost/benefit assessment and operating experience will be necessary to confirm this with high confidence.

## 2.3 Recommendations

1. This has been a highly cost-effective development project to date and the EN work to date is sound. The PIs deserve praise.

**TFA Response:** Thank you for the compliment. The TFA believes that the PIs and others who have worked on the project have done some excellent work in the development, the design, and working on data evaluation.

2. The ultimate cost effectiveness of EN corrosion monitors, while very promising, needs more rigorous examination to quantify the cost benefit.

**TFA Response:** The TFA performed a cost-saving analysis in FY97. The details of cost savings are difficult to quantify, although cost data was presented in the review. The costs fall in two areas: those that can be quantified (cost of sampling versus cost of probes and operations) and those that are difficult to quantify (cost of a new tank versus providing corrosion protection). Additional cost analysis will be considered if it is determined that the information is needed for user decisions to deploy.

3. Identification of user requirements and integration of the sensor package into the user working environment is essential to success. In particular, this project has work to do on converting voluminous data into information that is useful for actions by process operations personnel. Surveying industry in this regard is strongly recommended. Redundancy of probes is highly desirable.

**TFA Response:** Agree. The TFA needs to survey the industrial efforts in the data reduction area. The TFA has made initial contact with one corrosion consulting firm that is active in the data reduction area but who currently are not working on this area. Data reduction is probably the next big effort that the TFA needs to work on. The TFA also agrees that redundant probes need to be deployed. The next probe is to be deployed in Tank 241-AY-102, which will be receiving the Tank 241-C-106 waste when it is retrieved. This appears to be a high priority for Hanford and has immediate cost benefits. The TFA is looking at the FY99 budget to see if another probe can be installed in Tank 241-AY-102.

4. The biggest benefit may not be in stored waste where the required response times are long, but in dynamic process environments where a faster response may be highly desirable.

**TFA Response:** Agree. Currently, the corrosion probe scheduled for Tank 241-AY-102 will be installed before the corrosion inhibitor is added. The addition will be tracked with information from the probe. In addition, the waste received from Tank 241-C-106 will be tracked with the probe. Also, SRS is working on the capability of the probe to look at dynamic processes. Some of these issues will be resolved in FY98 and FY99.

## 2.4 Comments

1. Currently for most tank farms, conditions that promote corrosion are identified by taking a grab sample and determining the concentrations of key analytes. This approach has the advantage of not only detecting potential corrosion conditions but also indicating the corrective action to be taken (e.g., add caustic or nitrite). Note that this approach requires high confidence that the controlling chemical processes are known and measured adequately. For long-term storage where allowable corrective action times are long, the analytical delay may be acceptable, as corrosion under these conditions is a long-term process and sampling at long intervals, such as once per year, may be acceptable. In addition, this approach is relatively immune to the annoyance of false positive indications, which could cause costly and unnecessary corrective actions.

For tanks that are actively receiving waste or for process pipes, valves, and other transport components, the detection of the onset of corrosion may be more time-critical and difficult to detect because the waste dynamics can change rapidly. This clearly is a scenario where real time corrosion sensors that can detect and differentiate corrosion processes can have major benefits.

However, real-time monitoring is a double-edged sword. The downside is the potential for false positive indications that can set off alarms and trigger costly disruption of normal operations. In real life industry, when sensors repeatedly report false positives, they typically are disconnected or simply ignored. It is of paramount importance that the output of the corrosion probe be integrated into standard tank farm operations and that it be highly reliable. In its first in-tank test, the probe indicated active corrosion when water was added to the tank. The PI apparently could not guarantee that the probe was indicating tank corrosion as opposed to gradients in the electrolyte environment. In fact, the probe may be undesirably sensitive to factors other than corrosion. Reliability must be established with respect to both false positives and negatives. It must be demonstrated that the probe can differentiate non-corrosion phenomena (temperature, ionic strength changes, vibration, and electrical noise) from true corrosion indications.

2. **TFA Response:** Agree (the corrosion probe must be highly reliable). Currently, trained data analysts are examining the data. Corrosion monitoring data analyses will need to be developed before the data are used in tank farm operations; this has not been done. Also the corrosion data analyses will need to be highly reliable and sensitive to false positives and negatives.

The corrosion probe has been designed to indicate the occurrence of corrosion-inducing conditions before the tank would experience corrosion. As indicated, long-term tank corrosion is a relatively slow process and would not require immediate action. This makes operator action much less time-critical because decisions would not have to be made immediately.

3. A closely related concern is the manner in which the project approaches data analyses. The approach appears to rely on collaborators in the United Kingdom who develop neural network training models employing statistical moments taken from time windows of the temporal data. While time did not allow us to determine whether the neural networks were used appropriately (e.g., number of hidden layers, number of nodes per layer), it is well known that neural nets can over fit data. As the PIs

indicated, a number of industrial corporations are using EN technology. It is highly advisable that the PIs identify how industry approaches the data analysis problem in an industrial process context, including how the probe output is used to initiate corrective actions.

**TFA Response:** Currently, a neural network has not been developed nor is one being used. The TFA should examine industrial applications, industry's approach to data analysis, and what the data reduction issues are. This work will not be addressed in FY98 but may be initiated in FY99 or FY00. Funding for the data analysis is still under discussion. The TFA has several concerns regarding the amount of data and the time it takes to be evaluated.

4. Process monitoring devices must be integrated with other standard operation systems before they are useful. This involves qualification of the device and its software, operator and maintenance personnel training, and other process qualification. Device integration is a critical issue that must be addressed by the PIs in conjunction with operations personnel who will eventually own (and presumably use) the device.

**TFA Response:** Some of the integration issues have been addressed, such as design of the installation fixtures, training of the crews, layout of the electrical equipment, maintenance procedures, and normal check-out. The one issue that is related to the comment is the data evaluation. Data interpretation is still being done by the corrosion probe developers. As noted previously, automated procedures are available to analyze the data from the probe. This issue will be addressed in the FY99 to FY00 time frame.

5. At the beginning of the presentation, the PIs stated that the corrosion probe would be used in combination with other corrosion detection technology. However, no technical detail was provided for the other probes and the strategy was not presented on how data from the various sensors would be integrated and used as a corrosion sensor system. Multiple independent sensors are a time-tested method in industry for process control and are highly recommended in this case as well. In industry, typically when a critical condition is being monitored (e.g., oxygen in an ethylene plant), three independent probes are used, and action is taken when indications are received from at least two probes. Integration of the sensor package is key.

**TFA Response:** Agree (multiple corrosion probes should be deployed in the waste tanks). Currently, the funding has not allowed this to occur. Several high-priority tanks have not been sampled in years and need inhibitor additions. The only method currently used is taking a sample and performing analytical chemistry to evaluate the ion concentration to determine if corrosion inhibitor needs to be added. The problem is that this process is expensive and results in relatively high radiation doses to workers.

6. Additional thought should be given as to whether placement of several probes laterally (as well as vertically) per tank would be advisable. For example, placing one probe near a wall and one near the center should alleviate some concerns about spatial variations that might not be detected by a single probe array.

**TFA Response:** The current design of the corrosion probe has four measurement locations in the axial direction. This is not a limitation of the design, and more can be installed. This appears to be adequate for the installations in tanks with no transients. The TFA needs to reevaluate the probe design in terms of the number of measurement stations for the transient cases and possibly add more measurements. The lateral or azimuthal direction will need measurements. The TFA considered deploying as many as four probes in a single tank. This will continue to be an option in FY00 to FY01. The constraint has been funding and higher priority tanks that can benefit from corrosion probe installations.

7. This project was presented to the review committee as a Gate 4 review. The review committee felt that state of development was more appropriate for Gate 5 review.

**TFA Response:** The TFA believes that the corrosion probe is somewhere between Gate 4 and Gate 5. The TFA will reevaluate the gate number.

8. The reviewers note some concern about whether the corrosion environment is understood with enough certainty to preclude missing possible ill-defined or unknown corrosion mechanisms (e.g., vapor phase mechanisms). In other words, the reviewers believe the TFA should keep an open inquisitive mind to surprises even after the monitors are "perfected."

Finally, the reviewers feel that electrochemical probes, no matter how perfect, are unlikely to totally replace chemical sampling or chemically specific probes. This is because the response action itself is chemical in nature and is determined by measured deficiencies in the chemical environment.

**TFA Response:** The corrosion probe is designed to detect the onset of corrosion in the tank conservatively. The TFA agrees that chemical sampling will be required in some specific areas. It is the intent to have the probe give an early warning of the onset of corrosion; then a decision can be made on what should be done about evaluating the waste tank owners' options.

## **3.0 Cone Penetrometer: Hanford Tanks Initiative Vadose Zone Characterization Technology Stage: Engineering Development**

### **3.1 Technology Abstract**

To conduct performance and risk assessments in support of tank farm closure, an estimate of residual waste in the tanks and inventory of waste that has leaked to the vadose zone is required. Regarding the leaked waste, scientists need to know three things. What hazardous chemicals and radionuclides are in the vadose zone? What is the concentration of the contaminants? How do the contaminants behave in the soil? Because the tanks are buried under several feet of soil, it is not easy to validate if a tank has leaked. It is even more difficult to determine the quantity of contaminants trapped in the soil and how these contaminants have moved. The Cone Penetrometer Platform (CPT) may provide some of the answers to these questions by providing a rapid, cost-effective method for locating tank waste contaminant plumes and obtaining small discrete soil samples at desired locations and depths for hot cell analysis of contaminant inventories.

The Hanford Tanks Initiative, which is jointly funded by the TFA and the Hanford Tank Waste Remediation System, has developed and plan to deploy a CPT with screening sensors to map the location, extent, and concentration gradients of contaminants in the Hanford vadose zone of Tank 241-AX-104. After detecting and screening the contaminant plume location, a second CPT with a discrete soil sampler will be used to take soil samples at desired locations. The soil samples will be used to analyze and quantify contaminant species.

### **3.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **3.2.1 Is the Application of this Technology to Determine Waste Inventory in the Soils Surrounding HLW Tanks Appropriate?**

The CPT using the spectral gamma and x-ray fluorescence spectroscopy (XRF) sensors may be appropriately applied to collect characterization information at the Hanford Site vadose zone. However, the technology in itself is not sufficient to provide a comparison assessment of the vadose zone source term. The work being conducted under this task is a technology demonstration, full-scale in the field. It is the first application of this technology at the Hanford Site. Information collected during this demonstration will provide input data for the performance assessment (PA) currently being completed. The goal appears to be reduction of the uncertainty in the PA by providing additional data to characterize the contaminant plume.

This technology is characterized as a screening tool and cannot be considered as the sole method for comprehensive vadose zone characterization. The CPT (with appropriate sensors) appears to meet the more limited user need defined by the Hanford Site Technology Coordination Group.

- (a) Do the sensors and probes selected for the AX Tank Farm and for other Hanford vadose zone applications appear to be able to meet the defined performance requirements? Are there performance requirements that should be changed? If so, in what manner?

Specific performance requirements were not well defined and, thus, the review group cannot answer the question. The sensors and probes are intended to detect zones of contamination and differentiate them from background. However, the minimum detection limits may be too high to allow a successful application. For example, the proposed performance specification for cesium-137 using the gamma sensor was set at 100 pCi/g, whereas cesium-137 data from the gamma logging in vadose zone piezometers near Tank 241-AX-104 identified activities of concern less than 10 pCi/g.

Much of the presentation's focus was on detection of uranium using the XRF tool. However, detection of uranium may not be adequate to identify critical source terms for other radionuclides.

The radiological constituent of most concern in the vadose zone has been identified to be technetium-99. The data quality objective set for technetium was 25 micrograms per gram in the soil, which may be above concentrations of concern delimiting the contaminant plume. Detection of cesium using the gamma tool may not be indicative of detection of technetium, which is known to be far more mobile.

However, the selected sensors are appropriate for more limited objectives and succeed within the time frame proposed. Other sensors could be investigated (a number were suggested for a longer term program of technology development).

- (b) Is the program integrated with other vadose zone projects and are there clear advantages to integrating with these projects?

The TFA is attempting to integrate this effort with other vadose zone efforts at Hanford and apparently is integrated with the Hanford Tank Waste Remediation System baseline. However, integration into other site vadose zone efforts is difficult to assess at this time, because a new site-wide integration effort has recently been initiated. The reviewers stress the need for such integration and encourage the TFA to further pursue this integration effort. Tools tested at one site could be applied to others, data on contaminant migration could be shared, etc.

- (c) Are implementation interfaces clear?

Yes, interface organizations were clearly defined at the review; the Hanford Tanks Initiative appears to be experienced in working on similar projects at Hanford and thus are aware of pitfalls and requirements to complete the project successfully.

- (d) Are there unknowns that may impact successful deployment?

A number of unknowns exist that could impact successful demonstration. Because the technology has never been demonstrated at this site with these specific sensors, it is an experiment. In accessing and characterizing the subsurface, significant uncertainty exists. Use of the CPT in Hanford geology is not a slam-dunk. For example, the first time the CPT was demonstrated at Hanford, only the top 8 ft of the subsurface was accessed. However, significant advancements in the instrumentation have occurred since that time. Yet, if large boulders are unexpectedly encountered, the depth of penetration could be severely limited.

Other uncertainties deal with the performance of the sensors, mainly with the minimum detection limits that can be obtained for different radionuclides and elements. If the sensitivity is not great enough, adequate delineation of the contaminant plume may not be possible.

### 3.2.2 Is the Approach Sound and Appropriate?

Yes. However, performance requirements need to be better defined and expectations of the data use need to be clarified.

- (a) How will the technology impact current methods for vadose zone characterization? Does this technology have an advantage over the baseline? If so, what is it?

If the technology is successful, it could be used as a screening tool to detect contamination in the vadose zone and allow for a reduction in subsurface sampling. Plus any piezometers drilled would be better located to provide the optimum characterization information.

Baseline technology that compares to the CPT is conventional drilling and sampling with laboratory analysis. The CPT provides a screening tool to reduce overall characterization costs by providing real-time information in the field. The CPT's advantage over the baseline is that it has potential to significantly reduce characterization costs, while providing real-time data in the field. However, it is unlikely to totally replace installation of piezometers and laboratory analysis of samples.

- (b) Are there other recommended systems that should be considered for backup if the primary probe/sensor package fails, or for future use to provide enhanced capability? What development is needed for these alternative backup sensor packages to be made available to this program?

Other sensors and systems could be considered for backup if the primary probe/CPT fails. For example, Applied Research Associates has developed a sonic-assisted CPT to better access the subsurface under difficult conditions. If the CPT does not progress to the desired depth, it is possible that the sonic-assisted cone could be considered. Other probes, such as Raman and a beta-detector, were presented as possible additions to the sensor system. However, further development over 2 or more years would most likely be required before the new sensors were available to be used in a Hanford tank farm. A compressed xenon gamma sensor was also presented as an alternative, as was an americium-sourced detector for the XRF probe.

### 3.3 Recommendations

1. If the objective of this project is demonstration of the CPT with gamma and XRF probes and not comprehensive characterization of the vadose zone at the AX Tank Farm, the review panel generally supports the project. The panel is split on the construction and purchase of a backup probe before the demonstration is conducted. If the single probe currently built fails, it would be costly to halt operations until a backup probe became available, especially because the demonstration is conducted inside the tank farm. However, no cost data were provided showing how much a delay would cost. Review members that believe no backup should be purchased stress that reliability of the tool is one of the objectives of the project.

**TFA Response:** From the beginning, the objective of this project was to develop new tools and methods via the CPT that could be used to screen for the relative levels of tank waste leak contaminants in the vadose zone and sample selected locations for quantitative analysis. The TFA concurs that in most cases, comprehensive characterization would not be possible due to obstructions that would limit access to the vadose zone, potential inability to access desired depths due to refusal, or potential to miss contamination that may reside directly beneath a tank. However, the TFA also recognizes that the current methods of borehole drilling are limited by obstructions and inability to access the areas directly beneath a tank.

The perceived advantage of the CPT is to augment borehole drilling by providing a mobile CPT that will allow rapid screening for contaminants and discrete multiple soil sampling at desired depths in areas of interests based on screening results. Although neither existing boreholes and gamma logging nor CPT screening and discrete sampling can fully characterize a contaminant plume, the combination of the two should provide a much better understanding of vadose contamination than the TFA currently has. In particular, the CPT tools could be used to screen and sample the suspected areas of contaminants that have been plotted via "shape factors" using gamma logging in existing boreholes.

Although TFA and Hanford Tanks Initiative would prefer to have a backup screening probe, insufficient funding is available to build a second probe. Some redundancy is built into the screening probe as it has two detectors. If, for example, the XRF detector failed, the probe still has the capability to screen for cesium-137 and possibly strontium-90 (via Bremsstrahlung radiation) using the gamma ray detector. If the gamma ray detector failed, the probe still has the capability to screen for uranium and possibly gross gamma (via Compton scattering) with the XRF detector.

2. The review panel also recommends that clear performance requirements be set so that expectations for the demonstration are well understood and not set too high. The specific application of the technology and the scope of the demonstration must be clearly communicated. The reviewers believe that the CPT demonstration can provide additional screening characterization data to assist with minimizing the uncertainty in the PA to predict migration of contaminants in the vadose zone and groundwater at Hanford. The focus for the PA will have to turn towards remediation alternatives and what data needs to be collected to make remediation decisions.

**TFA Response:** The TFA accepts that the value of the CPT demonstration will be partially lost if expectations and objectives are not adequately communicated. The TFA will work with Hanford Tanks Initiative to communicate the objectives and performance requirements for this work before and after the demonstration to ensure that the technology's benefits and accomplishments are recognized. Based on the line of questioning by the review panel, the greatest concern appeared to be that performance requirements were not driven by the eventual user of the vadose zone characterization data. The user in this case would be Jacobs Engineering, who is responsible for modeling the PA of tank farm closure options and risk to future generations, which is partially based on the estimates of contaminant source terms. The TFA concurs that no PA has been done to state that a minimum level of detection (LOD) of 100 pCi/g for cesium-137 or a minimum LOD of 100 ppm for uranium is adequate sensitivity to determine where the main body of a contaminant plume may reside for risk assessment purposes. One could also state that no PA has been done to determine if cesium-137 levels discernable by gamma logging (about 1 pCi/g) suffice to determine the main body of a contaminant plume, especially given that a borehole is locked into one position and only effective if the contaminant plume intersects it at some point.

Although the performance requirements of the screening probe were not based on a PA, the expectation of the screening probes were based on the potential ability of the probe to find the tank leak contaminants by setting the LOD of the detectors several orders of magnitude below the source term of the contaminant in the tank. The cesium-137 levels in Tank 241-AX-104 are about  $10E9$  pCi/g, which is 7 orders of magnitude above the LOD. The average uranium concentration in all single-shell tanks is about 2000 ppm, which is about a factor of 100 above the LOD. Given the limited selection of detectors and their state of development for CPT application, it was judged that these two detectors would optimize the potential to find the main body of a contaminant plume. However, the main objective of the screening sensors is to locate the plume and its boundaries within the LODs of the detectors to conduct a follow-up discrete soil sampling campaign. One could also sample beyond the LOD regions (and almost certainly would) to look for lower levels of contaminants.

The overall objective is still to develop new screening and sampling tools that will augment current characterization technology and provide a better understanding of vadose zone contamination than either TFA or the user currently has.

### 3.4 Comments

1. The panel is concerned that the project team has not defined the objectives of this project clearly enough, although the panel appreciates that this is a fast-evolving project. It appears that this task deals with demonstration of a technology that has the potential to be used to collect characterization information in the AX Tank Farm and eventually elsewhere at Hanford. The extent that the technology will be used, the scope of the data collected, and the ultimate use of these data in both transport analysis and plume delineation in PA and retrieval decisions is vague, based on the information presented at the review.

**TFA Response:** The TFA concurs that this task deals with a demonstration of a technology that has the potential to be used to collect characterization information in the AX Tank Farm and eventually elsewhere at Hanford. The extent to which the technology and data will be used is vague because this is a demonstration project that must prove its feasibility and usefulness before potential users will accept it. As with any new evolving technology, technological risks must be overcome via good engineering and, above all, a successful field demonstration. As explained previously, the objective is to improve upon and augment current technology for characterizing the vadose zone. In particular, the potential ability to take small (about 50 cc) multiple soil samples at discrete depths in a single push should make the CPT a highly desirable tool to obtain actual field data samples and conduct quantitative analyses to verify assumptions that go into PAs. The Hanford Tanks Initiative is fully engaged in activities at Hanford to define a DOE-integrated program for vadose characterization and to transfer the CPT to potential users once a commitment is made to accept the technology.

2. Other issues previously discussed include:

- depth of penetration
- minimum detection limits for gamma emitters and other contaminants of concern (measured by XRF)
- mapping of constituents that are easily detected but that do not necessarily follow the constituents of most concern
- no backup probe available if first probe fails in the field.

**TFA Response:** *Depth of Penetration.* The Hanford Tanks Initiative goal is to push to 150 ft before refusal. Numerous past pushes at Hanford in the 200 West Area indicate average depths of 75 ft and maximum depths of 120 ft can be obtained. A push in April 1998 at a site in the 200 East Area achieved 160 ft using a 2-inch-diameter push pipe. The results so far are highly encouraging that depths of 100 ft will be easily achievable and in some cases depths to 150 ft can be obtained. Actual field tests are needed to ascertain the rate of success.

*Minimum detection limits for gamma emitters and metals.* As explained previously, the LODs for the gamma and XRF probe should be several orders of magnitude below the source terms in the tank and adequate to find the main body of the contaminant plume. These two detectors were selected based on their LODs for tank waste signatures, availability, and state of development.

*Mapping of constituents that are easily detected but that do not necessarily follow the constituents of most concern.* Both cesium-137 and uranium are constituents of concern. However, the mapping/screening step is for guidance in choosing the best locations to take soil samples. Analysis of the samples will be conducted to determine the concentrations of all constituents of concern.

*No backup probe available if the first probe fails in the field.* As stated previously, funding is not available to build a second probe.

3. Another issue is that the "hottest" portion of the contaminant plume is likely to be present directly beneath an underground storage tank and that this area will not be accessed by the CPT. It is possible that the locations where the CPT can be pushed may not indicate significant contamination. Alternatives such as directional drilling and logging beneath a tank may need to be considered.

**TFA Response:** The TFA concurs that a contaminant plume directly under a tank is a possible plume configuration. The TFA recommendation is a graded approach to a new technology. First, demonstrate the feasibility of CPT sensors and samplers. Transfer the technology to a user. Then, if sufficient interest exists, pursue the more difficult approach of directional drilling. However, one of the major safety concerns facing vertical pushes is to ensure that the CPT cannot veer significantly off of the vertical in such a way as to puncture the tank. This would probably be a greater safety issue for directional drilling.

4. It was not made totally clear that the regulators have approved use of an isotopic source in the CPT. This could present an issue due to possible sticking of the tool downhole. It is also possible that there could be concerns voiced by stakeholders.

**TFA Response:** The TFA concurs that use of a 30 mCi cadmium-109 source could become an issue. The Hanford Tanks Initiative is working that issue with safety people within Hanford contractors, and so far, it is not considered a problem. The use of 30 mCi sources for aboveground applications in XRF detectors is an approved process at Hanford. This is a very small isotopic source with a 470-day half-life and would be considered insignificant compared to existing contamination within the tank farms in a PA. However, one cannot rule out potential institutional resistance to its use at Hanford and that is part of the feasibility evaluation regarding its potential application.

## 4.0 Borehole Miner Technology Stage: Demonstration

### 4.1 Technology Abstract

At the ORR, five tanks that supported a geologic disposal project (the Old Hydrofracture Tanks) are scheduled for remediation. These tanks have capacities ranging from 13,000 to 25,000 gal and contain a total of 6,100 gal of settled sludge and 37,000 gal of supernate with moderate levels of radioactivity. For remediation, the waste must be retrieved from the tanks. The liquid is relatively easy to remove; however, traditional methods lack the energy of the Borehole Miner and are not as effective in removing stubborn wastes. Further, traditional methods, because of the time involved, increase the risk of radiation exposure to workers and the total cost of remediation.

The Borehole Miner can solve several of the problems inherent with traditional sluicing. For tanks with limited riser access, the system can be fitted with an integral pump and deployed down a single 12-inch-diameter riser. The Borehole Miner is an innovative solids removal system that directs a high-pressure, moderate-flow-rate water jet close to the walls, floors, and internal equipment of waste storage tanks. The water jet produces pressures from 500 to 3,000 psi with flow rates of 20 to 200 gal/min. The high-energy water jet is delivered by a nozzle that can be remotely extended 10 ft or more, angled from a horizontal to a nearly vertical position, and rotated about its supporting mast, thus allowing the jet to be directed to any in-tank location. At ORR, a separate pump is used to remove water and dislodged sludge and heel. In addition to the work at the ORR, the Borehole Miner could remediate waste at the Hanford Site and the SRS (with equipment modification).

### 4.2 Findings

The six TAG members and other panel members evaluated the presentations and the responses to the prepared questions by the TIM and the PI. The executive session resulted in a consensus agreement to the responses of the prepared questions. The finding of the review group follow.

#### 4.2.1 Is This Technology Ready for Deployment?

- (a) Have performance requirements, including an adequate definition of the problem and the required deployment schedule, been defined by the user?

The performance requirements were not well defined as statements were given that ORR will do the best that can be done to retrieve the sludge. Another statement was given that greater than 95% waste must be retrieved.

A detailed project schedule with milestones is presented by Lockheed Martin to be implemented to execute the task.

- (b) Are there any issues (technical or institutional) that will likely preclude the system from meeting performance requirements?

Yes. Cold checkout and testing of the system has not progressed as rapidly as originally anticipated. These delays have primarily been related to issues that are common to the set-up and checkout of developmental equipment.

Denaturing of fissile uranium isotopes must be done before waste retrieval. The current plan is to add depleted uranium to the tanks and use the Borehole Miner to mix the solution.

- (c) Has the Borehole Miner capability been adequately demonstrated to justify in-tank demonstration/implementation?

No. Cold testing of the Borehole Miner at high pressures (1500 psi) has not been completed. These tests will be completed before use at the Old Hydrofracture Facility.

- (d) Are there any system weaknesses or feasibility issues that need to be addressed before implementation?

Concerns have been raised that mist production at higher operating pressures will limit visibility in the tanks. These issues will be evaluated during cold testing. Impacts of poor visibility would be interrupted operation of the Borehole Miner, which will slow production rate and may cause additional stress on the equipment, leading to failure.

The potential formation of an aerosol mist causes concern for radiation exposure to personnel during strainer change-out operations in the event of a clogged strainer.

Other concerns are whether the ventilation system is adequate to prevent high-efficiency particulate air filter breakthrough if there is a high rate of mist formation.

Also, the concern is raised whether chemicals will be aerosolized and cause risk to workers. How can this possible occurrence be mitigated?

If no ventilation exists in the tanks, will the system be pressurized and could radiation leakage occur that might affect workers? If so, how will this situation be managed? A potential operational problem may occur if the sludge around the pump inlet cannot be solubilized rapidly and cause a choking operation. How will this be addressed?

- (e) Are there any system weaknesses or feasibility issues that need to be addressed before implementation?

Documentation was not presented to the review group to answer this question.

#### 4.2.2 Have Cost Benefits Been Analyzed and Documented?

Cost data were not provided to the review group to answer this question.

#### 4.3 Recommendations

1. Application of the Borehole Miner to other sites should be given with better defined requirement specifications.

**TFA Response:** The TFA received several comments during the midyear review regarding the adequacy of performance requirements. A separate meeting is being planned between the TAG and Retrieval TIM Pete Gibbons to discuss the definition and adequacy of performance requirements. The TIM feels that the specifications for the Borehole Miner were both extensive and rigorous for quality assurance, interface control, operational parameters, and confinement of contaminated liquids. The performance objectives of the system pertaining to how much waste must be retrieved was based on process testing using simulants. The system is expected to give a similar performance in the tank to the extent that the waste acts like the simulant; whether or not this occurs remains to be seen. Simulant testing at Pacific Northwest National Laboratory shows that suspendable waste will be pumped out. The unknown is how much of the waste is suspendable.

The Borehole Miner is an order of magnitude more energetic than the simple sluicer it replaced in the baseline design. It is expected, therefore, that a system of this kind will be better. How effective it is will be shown in hot testing. It is likely that retrieval pump characteristics will be limiting based on their scavenging ability.

The overall objective is to remove all visible waste. To this end, a crawler will deploy an end effector similar to that being used at Gunite and Associated Tanks (GAATs) to perform final cleaning of the tanks.

2. A number of concerns have been raised because this is the first testing of the Borehole Miner in a hot application. For example, radiation exposure could occur due to aerosol formation in a pressurized tank. Also, what type of failure modes can be anticipated and how will these be recognized to take corrective actions?

**TFA Response:** Agree. The tank ventilation system has been designed to control excess aerosols, and pressures will be monitored. The most obvious failure mode would be a high-pressure leak in the wastewater stream. All high-pressure waste systems are doubly contained, including the pump that sits in a large pan with sufficient capacity to collect a large leak. The high-pressure system contains safety relief valves. The nozzle goes slack with loss of hydraulic pressure so the unit can still be removed from the tank. Hydraulic pressure interlocks are included with the high-pressure water pump to kill pressure upon loss of hydraulics.

3. Efforts should be made to build failure recognition and corrective actions into cold testing.

**TFA Response:** Agree. A test plan for the Borehole Miner was provided to ORR, covering some failure recognition. An extensive Operational Readiness Review has been completed, addressing this comment.

#### 4.4 Comments

1. The TFA wishes to emphasize the need to provide deployment data to the Retrieval Technology Guide (formerly the Retrieval Analysis Tool) and Pacific Northwest National Laboratory researchers to develop a knowledge bank for other applications.

**TFA Response:** Agree. A Retrieval Technology Exchange is scheduled at ORR on June 9 and 10, 1998. One of the topics is the Retrieval Technology Guide. Deployment data from each site will be solicited.

2. The issue of denaturing fissile uranium isotopes by adding depleted uranium to the tanks concerns some members, as depleted uranium is largely soluble in the supernate, whereas the fissile materials are solids. Any separation of solids with supernate in processing steps may negate the denaturing effects expected. The kinetics and equilibration of uranium nitrate between solid and liquid phases should be examined to assess this risk.

**TFA Response:** Agree. This comment was passed on to ORR.

3. The review committee expressed concern as to whether the system will have been sufficiently challenged during Pacific Northwest National Laboratory testing and upcoming cold testing to avoid operational failure during hot testing.

**TFA Response:** The Borehole Miner system is simple. The most complicated feature is the high-pressure mud pump. The mud pump is state-of-the-art oil drilling equipment. However, as with any first-of-a-kind technology, startup problems are to be expected. Some have already been discovered and repaired during cold testing. The system is designed to be flushed for contact maintenance.

## **5.0 Heel Retrieval for SRS Type IV Tanks**

### **Technology Stage: Demonstration**

#### **5.1 Technology Abstract**

In tanks at the SRS, after bulk waste removal is performed, sludge heels remain in the tank. The debris and residual waste include hardened sludge; heavy, possible cohesive sludge deposits; zeolite; silica; reel tapes; and clinkers. The heel and debris must be removed with the waste transferred to a facility for processing. Tank closure requires the bulk of the residue to be removed. For example, Tank 19 is scheduled for closure during FY98; however, a 25,000 gal (estimated) residual sludge and zeolite heel remains, which prevents immediate closure activities. Traditional retrieval methods for bulk waste – installing large slurry pumps in the tank to vigorously mix the contents into solution – with a cost of approximately \$6-10M/tank have been used. Sluicing and local water jets with scavenging pumps were used in Tank 17 heel retrieval. The TFA is exploring methods and developing technologies to improve these methods for more complete removal of the tank heels.

#### **5.2 Findings**

This review addressed an integrated program that SRS has assembled to remove residual material from Tank 19. Their approach includes the use of a Flygt mixer to mix and suspend solids, water monitors to focus a water jet on stubborn materials and to aid in sweeping solids to the transfer pump, a water mouse and crawler to aid in the sweeping process, and a Pit Bull pump to transfer waste from the tank. Only the Flygt mixer and Pit Bull pump were sponsored by the TFA, and our review focused mostly on those components. However, because the entire system will be needed to meet the cleaning objectives, the system was also evaluated as a whole.

Is the technology ready for deployment?

- (a) Have performance requirements, including an adequate definition of the problem and the required deployment schedule, been defined by the user?

Performance requirements have been established as operational objectives or outcomes required. However, these endstates have not been further reduced to describe the performance of the individual technology components. For example, models are used to establish the quantity of residual waste that may remain following retrieval efforts, but the rate of removal, waste conditions required following retrieval, operator requirements, etc., have not been addressed. If any of these considerations would become important to acceptance of the technology, they should be defined at the outset.

Because SRS is combining TFA-sponsored efforts along with some of their own technologies (water monitor, water mouse) to achieve the desired heel-cleaning capability, the performance requirements should probably be defined to reflect the overall orchestration of tools to meet the cleaning objective.

(b) Are there any issues (technical or institutional) that will likely preclude the system from meeting performance requirements?

A number of technical concerns were revealed:

- The Flygt mixer has been used in tanks with weights to counter the thrust developed. However, because the new deployments will be using 50-hp units, up from 15-hp units used before, there is concern that weights alone may not be sufficient to maintain stability. Cold testing is advised.
- A crawler was presented as a means of deploying the "water mouse" or other tools that may be needed to physically move waste piles toward the suction of the transfer pump. No requirements were provided for that crawler, and it appeared that the effort may be attempting to solve a problem that is not yet well defined and that the tools that it would carry have not yet been fully described or tested.
- The waste mound in Tank 19 has not been characterized to determine the strength of the residual zeolite-waste composite. However, the techniques presented to dislodge the material will not be successful if the material is hard and relatively strong. This appears to be a potential fatal vulnerability of the effort, and the schedule does not appear to allow for significant delay.
- The use of the Pit Bull pump to remove the residual material appears to have credible hydraulic performance for the application. However, because it is driven by air displacement, a potential failure mode might allow air into the waste matrix. The trapped gas may generate the basis for an unreviewed safety question.
- The selection of the Pit Bull pump seems to be driven by low cost and apparent simplicity that is expected to be manifested as high reliability. Some testing has been conducted, but there does not appear to be a significant basis to predict equipment life.

(c) Have physical and chemical properties of the heel material been adequately characterized?

The hard material has been chemically characterized only to the extent that a sample could be taken. The material was taken from the surface and was probably softer than the material beneath. Further, no physical characteristics were measured. Without this information, a significant risk remains that the current approach will not be successful if hard material is encountered.

(d) Have implementation plans been developed, and is deployment ready to proceed?

Plans have been developed, and appear to be appropriate given the development nature of this effort. The issues discussed above should be addressed satisfactorily before moving into operations.

### 5.3 Recommendations

1. The stability and effectiveness of the Flygt mixer pump should be verified through cold testing of the prototype. The tests should address the proposed method to secure the pump such that reaction forces are understood and are experienced in an environment that is hydraulically similar to the tank (e.g., same size).

**TFA Response:** Agree. Full-scale, 50-hp Flygt mixers are planned to be tested at the TNX facility at SRS to test full-scale operations, including pump mounting.

2. The use crawlers as a vital component of the system should be further defined.

**TFA Response:** Agree. The current scope of the SRS crawler is to hold a water jet spray nozzle array to sweep the residual waste over to the Pit Bull pump using less water than the sluicer that was used for the same purpose in Tank 17. The use of Houdini and ROV (Brand) crawlers was evaluated. It was decided that a pair of off-the-shelf Inuktun remote-controlled tracks would provide the basis for a fully operational crawler for under \$250,000, which was less than the other choices.

3. The residual heel should be qualitatively measured for strength, or additional flexibility should be introduced to the heel removal approach to allow for failure of the current tools.

**TFA Response:** Agree. The TFA has been and will continue to recommend physical property measurements to support retrieval planning. This type of data would be useful. As was experienced in Tank 17 with the Bingham Plastic material that was left after mixing, the residue will only achieve its final form after the lightweight components have been washed out. The crawler with a 10,000-psi water jet array should be able to move any non-consolidated aggregate. If not, additional tools can be added to the crawler.

4. The Pit Bull pump should be evaluated for safety concerns (such as hydrogen release from the waste matrix) that may be driven by inadvertent sparging of the compressed air used to drive pumping action. Also, the reliability of the pump should be evaluated further using a range of waste simulants (particle sizes, densities, etc.). If the reliability testing is not conducted, data on the first demonstration should be collected to relate wear or failure to the waste conditions.

**TFA Response:** Agree. The Pit Bull pump will undergo the equivalent of an unresolved safety question review before being installed in an SRS tank. The current plans for the pump call for it to be used after a conventional centrifugal transfer pump loses suction, so the sparging action would be negligible (as opposed to placing the unit at the bottom of a full tank). A wide range of particle sizes was tested at Pacific Northwest National Laboratory. The simulant was varied from kaolin to sand, to crushed rock swept up from the parking lot. All were pumped satisfactorily. In fact, one of the objectives of the testing was to see what conditions would clog the pump and then how to free it up remotely. The Pit Bull pump can be filled with clean water that flushes accumulated residue out of the chamber. The wear to the lower flapper valve was noted in the test report with recommendations.

5. The Flygt pump should be tested for instabilities that may occur at low liquid levels.

**TFA Response:** Agree. Examining the Flygt pump for instabilities at low liquid levels was the objective of the Pacific Northwest National Laboratory testing.

#### **5.4 Comments**

No comments were provided by the reviewers.

## **6.0 Salt Removal Systems for SRS Annulus Technology Stage: Demonstration**

### **6.1 Technology Abstract**

The SRS tanks contain salt solution, saltcake, and sludge. In some of the tanks, the salt solution has leaked from the primary tank to the annulus. Within the annulus, the solution has dried to become saltcake. In Tank 16, approximately 1 to 2 ft of residual saltcake remains in the annulus. Ventilation ductwork occupies much of the lower space of the annulus, limiting access to the annulus floor and the salt within the ductwork. It is expected that the annulus and ductwork must be cleaned to meet the regulators' requirements and allow the site to close the tanks.

To date, no proven methods exist for removing the highly radioactive waste from the annulus geometry. The TFA is working with the SRS to analyze the residual material. The purpose is to determine the retrieval performance objectives for tank closure, effective retrieval methods, and to define the available access for retrieval systems. The goal is to adapt an industrially available process, for example, a spray or crawler system, to remove the saltcake from the annulus. If analyses of salt samples dictate that retrieval is required, then existing industrial equipment will be evaluated. This will take advantage of equipment design and operation experience gained from other applications, thus reducing costs. The selected equipment will be adapted to this application in FY99 for deployment in FY00.

The technology selected will be applicable or adaptable to removal of salt from the cooling-coil-filled double-shell tanks at the SRS as well as providing data for retrieval of salt from the single-shell tanks at the Hanford Site. The Hanford Site contains a few dozen salt-filled tanks that may need to be cleaned to meet regulators' requirements. This cleanup could begin to occur during phase 1 privatization and will be completed as part of phase 2 privatization. Hence, the use of industrial technology at the SRS broadens the base of available technology for phase 2 activities.

### **6.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **6.2.1 Is the Approach for Designing the Retrieval System Sound?**

This task was originally designed to support the removal of salt from a tank, not from the annulus as described in the presentation. As the panel was informed, the recent decision at SRS to abandon the In-Tank Precipitation process has cascaded to a decision to delay removing salt from the storage tanks. This task was redirected to apply essentially the same effort, albeit with significant change in focus, to remove salt from the annulus from Tank 16 to facilitate tank closure. The flexibility on the part of TFA and the SRS was commendable and necessary to preserve this effort.

The planning has been well developed for characterization of the waste in the annulus, but essentially no details have been developed for removal of the material. The characterization effort appears sound.

- (a) Is there a clear path forward for defining the proposed retrieval system? Is the approach appropriate? Is the decision point for retrieval of the residual waste in Tank 16 annulus clearly defined?

The general approach seems to be appropriate, in that the decision to remove the waste must be supported first by the characterization, and that is where all of the technical effort has been focused. However, some questions exist regarding characterization specifics:

- there is no detail supporting the number of samples or sample size that must be taken to achieve an acceptable level of statistical confidence in the results
- the sample physical integrity (for measuring physical or rheological properties) has not been satisfied in the sampling approach. Because the selection of a waste removal approach rides on a determination of the waste being amenable to dissolution, the physical properties and surface conditions need to be preserved, such that laboratory tests are meaningful.
- the dissolution tests need to be conducted in a manner that supports selection of the appropriate approach from the range of candidate waste removal technologies.

- (b) Are features included in the design and testing to ensure that this technology can be adapted or applied to type III tanks? How can the activity be improved to meet this objective?

The sampler system that has been the focus of development to date appears to be generic and applicable to sampling in other tank annuli as well as the tanks themselves. No information was presented on the retrieval system, so no response is provided on that element of this effort.

## **6.2.2 Is the Technology Ready for Demonstration In-Tank?**

The tools to sample the waste have been demonstrated adequately for application in any tank or tank annulus where the objective is to secure chemical information. Because the sampling system does not preserve all of the needed physical or rheological properties, additional methods may be needed where that information is important.

No retrieval technologies have been demonstrated yet, so those technologies are not ready for other applications.

- (a) Have performance requirements, including an adequate definition of the problem and the required deployment schedule, been defined by the user?

The user has identified a clear and reasonable path to deploy characterization equipment and to support a decision on whether (and how much) waste must be removed from the annulus. However, the characterization plan seems somewhat superficial. The core sample planned will probably

retrieve only the surface of waste that may be 2 ft deep, and there is no apparent basis to assume that the surface material is the same as the deeper material. Further, the sampling plan does not support a statistically defensible assessment.

- (b) Are there any issues (technical or institutional) that will likely preclude the system from meeting performance requirements, including when retrieval operations begin?

The most important technical issue for the sampling technology is the lack of physical integrity of the sample. Further, the analysis plan was not detailed enough to assess whether the results would support prediction of dissolution kinetics or other methods.

### **6.3 Recommendation**

The review team recommends that the laboratory test plan address the issue of extending the kinetics of the dissolution process measured under laboratory conditions to the large-scale application (test scale, temperature differences, contact time, change in waste surface condition, etc.). The insight provided by this analysis should be useful in determining what can/should be meaningful measurements of the actual retrieval process in the Tank 16 annulus as various parameters are encountered or applied (e.g., changes in dissolution liquid temperature, rate, force). Unless there is a convincing basis to assume the salt is all of uniform characteristics, the review panel encourages additional samples be taken to add confidence that the results are representative.

**TFA Response:** Agree. This recommendation has been passed on to SRS.

### **6.4 Comments**

No comments were provided by the reviewers.

## **7.0 Transuranic Extraction (TRUEX) and Strontium Extraction (SREX) for INEEL Technology Stage: Peer Review**

### **7.1 Technology Abstract**

Highly radioactive, acidic liquid waste (approximately 1.7 Mgal) is stored at INEEL. This waste is the result of reprocessing activities on spent nuclear fuel from test reactors. The recommended method for treating this waste is to separate specific radionuclides from it, so that the bulk of the liquid, mostly inert materials, can be disposed of as a low-level waste. Disposing of the waste as low level reduces the cost of waste remediation and reduces the risk to waste handlers. Three processes are being developed and demonstrated and deployed to remove the three most active radionuclides – cesium, strontium, and TRU elements.

The TRUEX process is a countercurrent solvent extraction process being developed that separates TRU radionuclides from the waste, using octyl-(phenyl-N,N-diisobutyl carbamoyl) methyl phosphine oxide as a complexing agent in a tributyl phosphate and paraffinic hydrocarbon solvent. The organic phase extracts TRU elements with valences of +3, +4, and +6. The SREX is similar but uses a crown ether as the complexing agent. Cesium removal is being studied but was not part of this review. After extraction or ion exchange, the radionuclides are stripped from the solvent or eluted from the ion-exchange medium and vitrified or otherwise disposed of as HLW. The inorganic phase contains the bulk of the liquid, which can then be disposed of as U.S. Nuclear Regulatory Commission Class A Low-Level Waste, which is far less expensive.

### **7.2 Findings**

Five TAG members and a few panel members reviewed the TRUEX-SREX program. After the TIM and PI presentations, the TAG and panel members met in executive session and reached common agreement in the following discussion.

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **7.2.1 Is the Technology Sound and Appropriate?**

The overall program addresses the removal of TRU elements, strontium, cesium, and technetium, from the bulk of the INEEL tank and calcine waste. The performance requirement set for the program is to prepare a low-level waste stream that meets U.S. Nuclear Regulatory Commission Class A waste requirements. The INEEL has no environmental impact statement for waste treatment at this time. When the environmental impact statement is complete, the performance requirements may be changed.

The technology is sound and appropriate for removal of TRU elements and strontium, but the program seems to be casting about for the appropriate technology for removal of cesium and technetium. A technology decision on cesium and technetium removal probably should await the environmental impact statement.

After the appropriate technologies are decided, it will have included the sequence of the four technologies in the integrated flowsheet. This sequence decision has not received much attention, and it must be immediately included in the program. Only then can the program do what it must do with real waste to prove the sound and appropriate integrated technology, namely an integrated large-scale test.

- (a) Have performance requirements, including an adequate definition of the problem and the required deployment schedule, been defined by the user?

Yes, except for technetium. The final performance requirements will be re-evaluated after the environmental impact statement. However, the panel questions whether or not the low-level waste form, grout, will meet the U.S. Environmental Protection Agency requirements for onsite disposal.

The schedule is in accord with the INEEL 2006 plan.

- (b) Are there other technologies that can separate TRUs and strontium from acidic waste? If yes, have the benefits of these technologies been defined?

Yes, several technologies exist to separate TRU elements and strontium. The benefits of the TRUEX and SREX process have been defined, but the decision, the reasons, and the cost differentials have not been documented in a downselect mode. This documentation should be immediately prepared. It could be done in a 10- to 20-page letter to TFA, which would ensure that the PIs are abreast of these technologies.

- (c) Given TRUEX and SREX produce waste that meets U.S. Nuclear Regulatory Commission's Class A requirements, what additional work (e.g., an integrated demonstration) is needed? If additional work is needed, when should it be done? Is there a good chance of success with this work?

Additional work is needed. The major technical need probably is a sequenced, integrated test of the four technologies with real waste. This test does not need to be continuous, but the different technologies should be sequenced so that the product from the first is the feed to the second, etc. This integrated test should be done after the environmental impact statement is prepared, and after the individual tests are each proven acceptable on simulants.

There is an excellent chance of success for this work.

- (d) The Efficient Separations and Processing Crosscutting Program is developing technologies based on ionic strength that can remove cesium, strontium, and technetium in a single step. What target would a single-step removal system need to meet or exceed to warrant TFA funding demonstrations of this technology?

A single-step process for removal of TRU elements and strontium would be an advantage to the overall integrated flowsheet providing the single-step program can meet the performance requirements and be cost effective. The cost effectiveness must include capital cost, operating costs, and newly generated waste by-products. However, a single-step process, when transferred to TFA, likely will not be developed such that the above requirements can be determined. The determination would require at least a demonstration with simulants.

### 7.2.2 Is the Technology Cost Effective?

A cost-effective pretreatment technology for treating tank waste depends primarily on the relative amounts of low-level waste and high-activity waste where the low-level waste product is contact handled, and the high-activity waste product is remote handled. A tank waste integrated flowsheet that includes vitrification for immobilization of the high-activity waste and grout for the low-level waste will have an overall cost for high-activity waste glass product of about \$5M/m<sup>3</sup>. This number probably is two orders of magnitude greater than the low-level waste grout costs. The implementation of the TRUEX-SREX technologies in the INEEL flowsheet indicates a reduction of about 18,000 m<sup>3</sup> to 1,000 m<sup>3</sup> of high-activity waste glass product, thus, the potential savings of \$5x17x10<sup>9</sup> or \$85B.

- (a) The cost benefits for implementing TRUEX-SREX into the site's total flowsheet must include the design, the construction, and the operational advantages or disadvantages with respect to the total flowsheet. Has the technical feasibility adequately been demonstrated to gather cost and performance data? Is the throughput or the scale of the demonstration adequate for flowsheet development and cost benefit analysis?

No, the realistic cost and performance data can be done only after the demonstration of the total integrated flowsheet with real waste. The demonstration plans to include throughput have not been developed.

- (b) Considering the previous question (Section 7.2.2.a), have the advantages and disadvantages been evaluated and reported? Are the related cost analyses available?

No, the total flowsheet must be demonstrated before this question can be answered.

No, the related cost analyses cannot be done at this time.

## 7.3 Recommendations

Further development of TRUEX-SREX for integration into the INEEL flowsheet for tank wastes needs to consider the following for priorities:

1. Document the downselect to TRUEX-SREX.

**TFA Response:** Agree. INEEL will document the downselect process in the near future. Further action will be pending the final INEEL environmental impact statement.

2. After the environmental impact statement is prepared, review the performance requirements, especially consider if U.S. Nuclear Regulatory Commission Class A is required for low-level waste.

**TFA Response:** Agree. This requirement is already under review. It is believed that the environmental impact statement will include options for Class C and Class A grout.

3. Determine the sequence of the technologies for removal of TRU elements, strontium, cesium, and technetium.

**TFA Response:** Agree. This is very important and needs to be determined as soon as possible. The TFA is unsure when this will occur, but INEEL will make this a priority.

4. Prepare a sequenced integrated demonstration of the four technologies.

**TFA Response:** This was planned for FY99 for tank waste, but changes in the INEEL program to focus on calcine were made, and this work fell below the TFA FY99 funding line. Pending further changes in INEEL program and TFA prioritization, this work will be proposed for future funding.

5. Minimize the individual technology tests.

**TFA Response:** Agree. With very limited INEEL funding, this will be necessary to move the program forward.

6. Demonstrate integrated process with the high-sodium tank waste and then decide if a demonstration with calcine feed is necessary.

**TFA Response:** The current INEEL program states the tank waste will be treated by calcining. No INEEL separations work is being funded on tank waste; therefore, no integrated demonstration will be done on tank waste, unless changes occur in the INEEL program.

## 7.4 Comments

The following comments may be issues, concerns, or questions, and they are numbered but do not appear in any priority.

1. The PIs need some improved chemistry expertise.

**TFA Response:** The INEEL chemists are technically qualified but have limited process experience. INEEL has contracted with W. W. Schultz, J. L. Swanson, and G. Vandergrift over the past 4 years to provide process chemistry expertise. Unfortunately, FY99 funding will not allow for outside chemistry support, and it is very likely that the INEEL separations program will lose most of its chemistry expertise and experience to other programs. It is possible that this loss of personnel will be permanent and that the program may never recover the site-specific technology experience. Future TFA activities, if supported, will strive to address this concern.

2. Decide on cesium removal technology because the technology and the sequence are co-dependent.

**TFA Response:** Agree. This will be a priority for the INEEL program.

3. Consider the Resource Conservation and Recovery Act (RCRA) metal and land disposal restriction requirements for low-level waste.

**TFA Response:** INEEL will incorporate RCRA metal and land disposal restriction requirements into their program, as funding allows.

4. Prepare a short document to support questions on cost effectiveness.

**TFA Response:** INEEL program has performed several system analysis studies that demonstrate the cost effectiveness. These documents will be updated to incorporate new results and cost information.

## 8.0 Control of Leachate Solids Formation Technology Stage: Peer Review

### 8.1 Technology Abstract

The tank sludge at the Hanford Site, SRS, and ORR needs to be pretreated to remove nonradioactive constituents that either add to the volume of the resulting HLW (e.g., aluminum) or impact immobilization processing (e.g., chromium). The sludge can be pretreated by caustic or acid leaching, but for the subsequent processes, the materials in the sludge leachates must remain in solution with no included gels or colloids. Crystalline solids and gels would interfere with pumping and mixing operations, and coat or clog piping, filters, and equipment surfaces. Solids formation can be controlled by chemical additives, by limiting phosphate concentrations, or by controlled reprecipitation using flocculents or seeding. The TFA task to control leachate solids is working to compile and categorize the significant amounts of information on solubility chemistry from past studies at Hanford and other DOE sites and supplement the information with additional studies, where necessary.

### 8.2 Findings

The eight members of the TAG and three DOE User Steering Group members on the review panel discussed and agreed on the responses to the questions. The answers for some questions are not a clear "yes" or "no" so the comments are included here.

#### 8.2.1 Have User Performance Requirements and Data Needs Been Established?

It is unclear from the information presented to the review group that user performance requirements have been clearly established for this work. The large document shown by R. Kirkbride is clearly not a succinct summation of performance requirements for the task.

- (a) The TFA technical community believes controlled solids precipitation is beneficial and gel formation is of concern. These findings have not been incorporated significantly into Hanford Site planning. Is the TFA concern about getting these concepts recognized properly placed?

The review group did not agree with the statement preceding the question (i.e., controlled precipitation is beneficial). Indeed, the group felt that controlled precipitation may not be beneficial, but control or prevention of precipitation and gelation is the preferred path for operations. The concepts of the work appear to be well integrated into site planning. However, the results do not appear to be incorporated into present flowsheets.

- (b) What are the technical phenomena of concern (e.g., settling, packing of solids, gel formation, solubility or supersaturation precipitation, transport mechanisms)?

The review group feels that not all of the technical phenomena of concern have been identified by TFA researchers. The review group feels that kinetics, non-soluble solids, and colloid formation are also important technical phenomena of concern, which should be considered in future work. The presentations did not give enough information to allow reviewers to tell whether these issues have been adequately considered in the work.

### **8.2.2 Is the Technical Approach to Meet the Need Requirements Sound?**

The technical approach being used is not adequate to meet the need requirements because thermodynamics is only part of the answer. It would seem more cost effective and useful to focus on one model rather than two (the reviewers note that the Pitzer parameter database is growing, e.g., for Waste Isolation Pilot Plant [WIPP] PA). For different sludge compositions, thermodynamics models are not reliable; for example, steady-state is not necessarily thermodynamic equilibrium. Input data (characterization data) may not be reliable. Therefore, sampling will have to be done at the time of mixing.

- (a) What technical information currently exists relative to the phenomena of concern?

This question was not answered.

- (b) Is the experimental plan looking at a broad set of conditions? Is the work being done systematically?

The experimental plan was broad but not totally adequate in that the temperature extremes should have been broader and analyses for saltcake dissolution do not include all cations and anions.

- (c) Do the study conditions incorporate the baseline conditions?

The study conditions for both saltcake and sludge incorporate baseline conditions.

- (d) How far below the minimum Na:Al ratio required for solubility are the baseline conditions?

This question could not be answered by the researcher due to the complexities of the system and inadequacies in the information available.

- (e) For saltcake dissolution, is the balance between experimental work and modeling appropriate? Is the selection of the model correct?

The mix of experiments and modeling is appropriate for saltcake. The model is appropriate for saltcake, although more work is needed, as expected at this stage. The model should only be used for diagnostics, not relied on for prediction of operating areas.

- (f) Could the user include the results of the effort into current decision processes (e.g., TRUEX logic diagram)?

The user is including results in decisions and planning.

### **8.2.3 Has the Estimated Cost Benefit of Performing this Work (i.e., estimate the benefit of not plugging a line or creating suspended solids in a feed staging tank) Been Performed?**

Although some cost data were supplied, the data were inadequate to answer the question. It is difficult to quantify cost benefit when results of the work are still uncertain.

## **8.3 Recommendations**

1. The TFA Technical Team needs to exert greater control over that part of the work that deals with formation and control of solids in sludge leachates. In particular, review panel members feel strongly about the need for such action by the TFA Technical Team. The Technical Team needs to get the sludge leachate/solids formation part of the effort properly focused on user needs so as to tell the user how to structure proposed leaching processes to avoid formation of gels and/or solids, and, if their formation is unavoidable, what can be done to still have operable leaching processes.

**TFA Response:** Agree. Funding in FY99 for the candidate solids task is on hold pending a decision to continue. The PI is documenting the results to date for a follow-on review with the TAG this summer to support a decision to proceed. The TFA has also discussed this with the user, and the TFA will work with the user to define needed information. Since the midyear review, the TFA and user have met several times and have clarified the work scope for both the control of leachate and saltcake dissolution tasks.

2. The present technical approach includes development of two thermodynamic models, which use different approaches to estimate activity coefficients. Development of both models does not appear to be cost effective and one of the models should be dropped from the program.

**TFA Response:** The Hanford user has focused on the ESP model as its choice, and the TFA is supporting that decision. Validation of the ESP is one of the TFA goals, and the TFA believes analyzing data using both models is required to help ensure that ESP can adequately represent the equilibrium conditions. The second model is more rigorous and is useful in transforming data for use in the ESP. The cost of using the second model is only the cost of the data preparation—all data generated is used for both models.

3. The review group recommends that more money be added to the task on salt dissolution for complete analysis of all cations and anions. The amount needed was estimated by the PI to be about \$50,000. The data is needed to ensure complete data is available for modeling of the system.

**TFA Response:** Agree. The user also agrees with the recommendation. The TFA has added funds in FY99 for analytical work. This is an analytical capabilities question and involves tradeoffs by the PI on how to allocate funding provided. Even with the current budget, the TFA is gathering data that is useful to the program this fiscal year under the current task.

4. The data on saltcake dissolution shows that sodium oxalate is the least soluble salt in the system. Work needs to be done to determine final disposition of the sodium oxalate.

**TFA Response:** Agree. The saltcake team recently met at Mississippi State University to conduct a workshop on the experimental and modeling results. This oxylate issue is being addressed currently.

5. Kinetics is an important aspect of chemical reactions including precipitation. The review panel recommends that a kinetics model be developed in conjunction with the thermodynamic model.

**TFA Response:** This has been discussed with the user, and all agree that kinetics is important. Data is available from previous work funded by the Efficient Separations and Processing Crosscutting Program and performed at Pennsylvania State University on dissolution rates of alumina in simulated sludge, and this is now being applied to the FACSIMILE model of AEA under the AEA grant. Additional kinetic studies are being planned. The TFA is also discussing the impacts of kinetics on ESP and the work at Mississippi State University's Diagnostic Instrumentation and Analysis Laboratory on saltcake dissolution.

## 8.4 Comments

1. The review panel was impressed by the saltcake dissolution work that has been done to date and what is planned for the future. This work appears to be well planned and executed except for disposition of sodium oxalate. Further attention needs to be given to handling and disposition of sodium oxalate.

**TFA Response:** Agree. See response to recommendation 4 above.

2. Unfortunately, many review team members are disappointed by the presentations on control of sludge leachate solids/gel formation. The members do not see much progress, if any, since the last review (Midyear 1997). The reviewers are particularly concerned that the researchers do not seem to be pursuing an experimental course that will let users avoid formation of undesirable gels/solids, and, if such gels and/or solids do form, how to best deal with them in sludge leaching processes/flowsheets. Perhaps the underlying problem is a big gap in communications and understanding between reviewers and experimenters. In any case, the review panel recommends (recommendation 2) that the TFA Technical Team become more involved in this effort until the reviewers can agree that the technical work is on track.

**TFA Response:** This area has been worked extensively since the midyear review. The focus of the midyear review was to answer questions and to bring the American Society of Mechanical Engineers up to speed. The TIM did not recognize the TAG's need for more detailed technical information and apologizes. A document detailing the status will be published in June, and TFA will work with the TAG to review this work and assist in ensuring the task is moving in the right direction. The TFA has reviewed the direction with the user, and TFA, the PI, and the user agree. The Program Execution Guidance for this task is much more descriptive than the Program Execution Guidance for FY98.

3. Although the researchers recognize that the formation of gels and precipitates are possible and should be avoided during processing, they fail to recognize that gels are metastable and cannot be predicted by a thermodynamic model. In addition, a reaction can be thermodynamically allowed but kinetically hindered. Too little attention has been given to kinetics in this work.

**TFA Response:** See response to recommendation 5 above.

4. The review group feels that for sludge leaching neither of the thermodynamic models being used are appropriate for predictive purposes. The real value of the models may be in defining the data needs and in diagnostics.

**TFA Response:** The TFA has investigated the ESP model being used at Hanford and believes this is a useful tool. The model does have some capability for kinetics, but is principally a thermodynamic model. It is important that the user select a flowsheet and operating condition that are stable due to the uncertainties and chances for delays in processing. The TFA recognizes the need for kinetics, but the thermodynamics model can set the boundary conditions that are also critical for operations.

The TFA is conducting experiments to help fill in gaps for data needs and to expand the model to regions not available but critical to the users. This was discussed in detail at the workshop conducted recently at Mississippi State University Diagnostic Instrumentation and Analysis Laboratory. The TFA has identified regions and is doing experimental runs to gather needed data. The user strongly supports this approach.

## **9.0 Enhanced Sluicing Systems—Nozzles and Pumps Technology Stage: Engineering Development**

### **9.1 Technology Abstract**

The DOE complex has horizontal and vertical cylindrical steel and concrete waste storage tanks that require remediation. Removal of bulk saltcake and sludge, saltcake heels, hard sludge heels, and debris will be required. The baseline methods involve long-range sluicing or mixer pumps. Enhanced approaches are required for retrieving hard sludge, heavy residual waste, bulk waste in leaking tanks where water use is restricted, and debris and contaminated floor and wall segments.

Performance and cost data comparing enhanced retrieval methods to the performance baseline of past-practice sluicing are needed for Hanford's single-shell tanks. Data will be applied to the selection of retrieval systems for 1) Tank 241-C-106 bulk waste removal (W320 Project) 2) retrieval of single-shell tanks during privatization phase 1 (Initial Single-Shell Tank Retrieval System), and 3) concept design technical input to the privatization phase 2 specification.

In addition to single-shell tanks, retrieval of double-shell tanks using the baseline of two mixer pumps is expected to leave a considerable amount of heavy and/or cohesive sludge heel. While this is adequate for initial HLW feed, the program needs assurance that if the effective cleaning radius of the mixers proves insufficient, that a backup method can be deployed to mobilize enough residual waste to complete the mission. Further effort in predicting the effective cleaning radius by characterizing the shear strength, or resistance to mobilization, of the sludge is needed to plan for use of a backup method. Alternative or supplementary methods are needed to better mobilize sludge from double-shell tanks containing HLW feed for phase 1 privatization. Other double-shell tanks may contain hard heels, sludge, and other waste types, waste that mixer pumps will not adequately mobilize. This is another application for a well characterized sluicing system.

### **9.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **9.2.1 Is the Technology Ready for Deployment?**

This "enhancement" to a traditional technology does not appear to be ready to deploy. The consensus of the review group was that it is in stage 3 or 4, in that little testing had been conducted, and most of the work was oriented at modeling hypothetical performance. Plans were presented, indicating several tests at large scale will be conducted, but only relatively primitive tests have been conducted to date.

- (a) Have performance requirements, including an adequate definition of the problem and the required deployment schedule, been defined by the user?

The schedule for deployment was not presented, but generally, the progress toward deployment does not appear to support a near-term deployment (which the reviewers understand Tank 241-C-106 to be). Explicit user needs did not appear to be driving the technology development and were not apparent in the planning. General guidelines or objectives for the "enhancements" existed, such as the ability to selectively remove the upper layer of the sludge waste. However, no evidence was presented that the approach to address these was constrained by existing physical limitations of the Tank 241-C-106 waste retrieval system (nozzle indexing precision, process feedback, etc.).

- (b) Has an implementation pathway been defined?

The remaining activities described to support deployment did not appear to be focused on delivery of a complete package nor on time. There is an obvious parallel between the test setup and Tank 241-C-106, but the instrumentation in the tank will not provide the process control that is available to the testing/development staff working on cold simulants. As such, the actual effectiveness of the enhancements will not be knowable during sluicing.

- (c) Have safety or other institutional issues been considered within the baseline project to ensure implementation of data/techniques from this work?

Little indication was given of an attempt to understand the needs and limitations during operations. Other than the high heat issues that are driving the sluicing project, no safety issues were identified that are influencing the development.

- (d) Do additional technical issues exist that this work should be addressing?

The mathematical model seems to lack some of the key parameters that will influence sluicing performance, such as sludge properties, geometry of sludge during sluicing, and jet penetration of liquid. Further, it is not clear how the operator will get sufficient feedback to control the process. The model and testing were based on a homogeneous solid mixture of consistent and uniform physical properties. If that is not the case in Tank 241-C-106, the operator may not be achieving the rate or extent of solids removal that are predicted by the model.

## 9.2.2 Is the Technical Approach Sound?

- (a) Is the information being generated meeting the user need/performance requirements?

The user apparently needs a method to ensure that the sluicing pattern will support their need to transfer batches of sludge that carry an acceptable inventory of strontium-90 (not too little and not too much). It is doubtful that this approach will achieve that result completely, although the approach may provide some qualitative improvement in sluicing strategy.

- (b) Does the information generated fit into the Hanford Site's ability to use it when sluicing Tank 241-C-106?

The information may be useful, but does not appear to be on a schedule that will meet the user's needs. Significantly more experience with this approach will be needed (by the operators) before it is beneficial.

- (c) Will deployment provide adequate data to judge the benefits from improved sluicing systems?

No, the lack of instrumentation from the actual sluicing campaign will severely limit assessing the effectiveness of this approach.

- (d) Have the advantages of the current approach been defined, and are they acceptable?

The advantages appear to be more wishful than proven. Because there is still significant development and demonstration needed before deployment, it is difficult to assess the likelihood that benefits would be realized.

### 9.3 Recommendations

1. The limitations of the user's equipment should be understood and operational features of the test setup should reflect those same limitations.

**TFA Response:** Agree. The intent of the University of Missouri at Rolla test setup is to duplicate the geometry of the system. It would be good to also duplicate visibility and other parameters and test the sluicing plans and procedures for feedback to the site. Unfortunately, this activity is not funded next year. If priorities change in future years, this recommendation will be incorporated in the testing.

2. Sampling of the sludge being transferred may be needed to support the estimate of strontium-90 that has been transferred.

**TFA Response:** Agree. The W-320 Process Control Plan requires periodic grab samples to verify mass transfer and elemental constituents.

3. The strategy for development should include stopping and restart considerations. Some provision should be made for the operator to assess progress.

**TFA Response:** Agree. The W-320 Process Control Plan enumerates startup and shut down procedures. The process will be determined by mass flow meters and visually.

4. A final field test should be conducted simulating the conditions the operator will face, with the same limitations on visualization of the sludge geometry, liquid level, nozzle position, and material transported. This test would reveal the problems the operator will likely face.

**TFA Response:** Agree. This was recommended for FY99. The activity fell below the funding line for FY99.

## 9.4 Comment

The idea behind this approach appears to be based on relatively sound ideas for creating a pattern of solids removal with the hydraulic jet. However, because so many variables affect performance and so few of them are controllable by the operator, it is more likely that practice and process feedback will be the keys to success than refined mathematical simulation. The reviewers strongly encourage the full-scale tests and suggest that the tests include the same kinds of uncertainties the operators are likely to face.

**TFA Response:** Agree. See recommendation 4 in Section 9.3. In addition, full-scale testing later this year will reveal additional areas for the operators to be aware of, but hands-on training will not be available due to budget limitations.

## **10.0 Solid-Liquid Separations: Melton Valley Storage Tank and Cells Unit Filter for INEEL Technology Stage: Engineering Development**

### **10.1 Technology Abstract**

Separating solid particles from liquid waste is essential at several tank sites. For the Hanford Site, solid-liquid separation is required to meet the privatization contractual maximum of 5% solids in the feed stream to the Tank Waste Remediation System. At the INEEL, separation is critical for removing small, undissolved particles of calcined waste from the melter feed. At the SRS, separation is required for the late wash precipitate or the selected cesium removal technology. At the ORR, various liquid low-level waste streams, including TRU sludge, and strontium and TRU-bearing retrieval solutions are being treated by a TFA demonstration currently underway. Solid particles can damage pretreatment equipment, leading to costly and time-consuming delays, and cause difficulties with immobilized waste forms. Two activities related to solid-liquid separation are being conducted under the auspices of the TFA. The TFA is advancing the development of cross-flow filtration using a cells unit filter and is conducting the large-scale demonstration mentioned. In cross-flow filtration, the feed stream is pumped through a semi-permeable membrane pipe, and the pressure differential generates a shell-side flow of filtrate while the concentrate continues down the pipe.

At the ORR, four technologies were evaluated for separating solids. The four technology options are settling, cross-flow filtration, dead-end filtration, and centrifuging. Settling is simple, inexpensive, and highly effective; it is the method of choice if downstream criteria can be satisfied. Cross-flow filtration is also effective, moderate in cost, and requires no chemical additives. Dead-end filtration works only on dilute streams, requires flocculents and filter aids, and involves elaborate backwash operations. Both filtration methods require periodic chemical cleaning of the filter media. Centrifuging is the most complex method and requires high investment and maintenance costs. By analyzing these solid-liquid separation methods, the site has technical, cost, and risk data regarding the best way to remove solids from liquid waste streams.

### **10.2 Findings**

Each question was given an answer by the presentation team--sometimes with backup of data and sometimes not. The panel discussed each question to reach consensus on what technology was being reviewed and what was meant by the question. Questions were answered assuming that only cross-flow filtration was being reviewed in the context of the questions.

#### **10.2.1 Is the Technology Ready to Deploy?**

In general the appropriate answer is "not applicable." However, cross-flow filtration is ready for deployment where the Cells Unit Filter results have shown a specific feed could be treated by cross-flow

filtration. The technology is in the process of being deployed at the Melton Valley Storage Tank Facility. In a general sense, cross-flow filtration has been ready for deployment before there ever was a TFA; it has wide industrial use. The risk of deployment to a specific waste-stream application is lessened by Cells Unit Filter testing.

- (a) Is there sufficient correlation between the physical properties of the waste stream (e.g., particle size) and cross-flow filtration design parameters to ensure process scale-up using existing results? If not, what information is needed, and what is the most efficient approach to obtain this information? Are additional tests with actual tank waste needed (or of value)?

Deployment of cross-flow filtration to meet any solid-liquid separation need can be done with very little physical data. Risk is lessened by testing treatment in a Cells Unit Filter or similar unit. In general, manufacturers would design the full-scale unit based on feed and on process goals and constraints provided by the customer. Further, manufacturers would test the feed in their own test facility. Because this cannot be done with radioactive feeds, test units, like the Cells Unit Filter, must be present at the DOE sites. They will also be needed during processing to solve operational problems. What the TFA tests have not provided is answers to long-term concerns of deployment – long-term fouling and fouling caused by trace contaminants. Additional tests will be needed by the user, when a specific stream for treatment and specific process goals are identified.

- (b) The general characteristics of waste streams to be separated include settling rates, particle size, density, and rheology. This program has evaluated settle-decant and cross-flow filtration. Are there stream characteristics that TFA has overlooked? Are there technologies that the TFA has overlooked?

The reviewers' consensus is that the TFA has chosen to support testing of the use of cross-flow filtration for specific waste streams at ORR, INEEL, and Hanford. The reviewers are not saying it was a wrong choice to settle on one technology, however. It did act to pass SRS's expertise to the complex and integrate thinking in the area of solid-liquid separations. At INEEL, there is no plan in place to use cross-flow filtration for their specific flowsheet needs; no equipment has been selected. With privatization, Hanford has no solid-liquid steps other than settle-decant in the tanks. The reviewers assume the choice to use cross-flow filtration at ORR was based primarily on what technology was available at no cost.

Very little is gained by having a wealth of basic information concerning the particle characteristics and rheology of the feed. The proof of treatability is the Cells Unit Filter or similar tests. Except for being an inexpensive means for educating experimentalists on the use of the Cells Unit Filters, very little, likewise, is gained by the testing with simulants.

The Cells Unit Filter tests have not been representative of actual operation. In an actual cross-flow filtration operation, the slurry would recycle from 10 to 100 times. In the tests as performed (with permeate returned to the feed), recycle was equivalent to 10,000 times. This made particle shear much worse than expected for actual operation. Future tests by potential users should invest in higher feed volumes.

In general, all solid-liquid separations processes are ready for deployment. What will be needed before deployment is testing programs based on feed and process-goal specifics? At that time, the proper method for that separation will be made based on performance and cost. The reviewers cannot recommend that TFA fund additional testing on cross-flow filtration or any other solid-liquid separation technology.

- (c) Is there a mechanism for transferring the knowledge of the current cross-flow filtration demonstrations to the privatization vendors at Hanford and ORR as well as the management and operations contractor at INEEL?

The mechanism for transferring knowledge is in place. It is in open literature reports by the TFA and its PIs.

- (d) Are commercial providers available? Is the specific performance or unique design data available to vendors so they can design and deliver systems to the sites?

Commercial vendors are available. The ORR unit was designed with close interaction between ORR and the vendor. In fact, a case could be made that the amount of design information given to the vendor for the ORR unit could have been too much --placing little responsibility for the unit's performance on the vendor.

- (e) Are there issues (technical or institutional) that may impact successful demonstration and deployment of the cross-flow filtration system on the ORR Melton Valley Storage Tank waste?

Both technical and institutional issues could impact the success of the Melton Valley Storage Tank deployment. The biggest is the concern about funding for the remaining equipment needed for transfer of the waste to the new tanks. This could cause a serious delay. Technical concerns that could tarnish success would actually be lessons learned. Because of the limited feed used in the Cells Unit Filter tests, this will be the first opportunity to encounter fouling problems due to long-term operations. (However, lessons learned will only be appropriate for treatment of this waste stream under these conditions.)

#### **10.2.2 Have Cost/Performance Benefits of Cross-Flow filtration Been Developed Relative to Alternatives for Both Thickening and Polishing (e.g., removal of dilute solids upstream of ion-exchange columns)?**

No. Cost/performance benefit development was not the focus of the TFA mission. It has given several sites experience in the initial downselected method (cross-flow filtration) and put a team together who can continue to integrate concerns and knowledge on solid-liquid separations in the future.

### 10.3 Recommendations

1. Although this has not strictly been a development activity, the panel commends TFA on the integration aspect of this program. SRS expertise on cross-flow filtration, which was developed for In-Tank Precipitation, was shared with other sites in an effective way. The contacts and pathways made during this activity are likely to be important long after TFA passes.

**TFA Response:** Thank you. The TFA believes the multi-site collaboration exhibited by this task is a strength of the TFA, and the monthly solid/liquid separation conference calls previously suggested by the TAG to assist in coordination were key to its success.

2. The use of TFA funds to fabricate the full-scale cross-flow filtration unit at Melton Valley Storage Tank is viewed as the flagship for a disturbing trend in the TFA. In the need to look relevant to the user, TFA has, in some cases, become a provider of funds rather than a provider of technology. The reviewers recommend that TFA do all it can to halt this trend.

**TFA Response:** This task is part of an effort funded by three programs to demonstrate, deploy, and put into full-time operation a technology brought along by the TFA. The TFA is paying roughly half of the fabrication costs, with the Accelerated Site Technology Deployment Program paying for the remainder of the fabrication and EM-30 paying for operation (EM-30 paid for hot cell tests for the sludge work in FY96). This is the direction that the users are suggesting the TFA move as a program. However, TFA is working to better define a target and limit for the fraction of the program focused on deployment. The effort should help in balancing the TFA portfolio.

3. Because 1) of the high degree of commercial development for solid-liquid separations and 2) picking of the technology for each application will be stream- and process-goal specific, there is no need for further TFA involvement.

**TFA Response:** The TFA is supporting the Accelerated Site Technology Deployment Program where applicable. The installation and operation of a modular skid-mounted cross-flow filtration system for nuclear operations is a novel application. Limitations in sampling and handling of radioactive tank waste limit the extent of characterization, which adds a degree of uncertainty in performance of the technology. Unknown tank waste components could cause short- or long-term fouling of the filter elements. The degree of filtrate flux recovery by chemical cleaning deserves further attention. Funding by TFA will cover data collection, performance evaluation costs, and assist in coordinating the multiple funding sources.

In addition, the application of this compact processing unit at ORR is an opportunity to learn a great deal about the use of cross-flow filtration with a wide range of waste compositions and unknowns. Other sites will be able to use this data as a road map on how to deploy the technology, a function that is recognized as valuable by TFA users.

## 10.4 Comment

Kudos to TFA for an extremely well integrated program that has done much to pass useful knowledge throughout the complex. However, the use of development funds to fabricate a unit for ORR Operations does not merit any praises whatsoever from the panel. The reviewers consider the TFA to be a supplier of technology to EM-30, not just a checkbook.

**TFA Response:** The TFA agrees our job is to be a supplier of technology. The TFA's definition of being a supplier is to provide novel systems useful to the complex. This task can be compared with the Cesium Removal Demonstration and the Out-of-Tank Evaporator, both of which are regarded as successes of the TFA. This demonstration-leading-to-deployment approach is within the scope the TFA was given by the DOE. However, TFA appreciates the TAG comment and is working to address the issue of a "balanced" portfolio. The TFA will continue to support deployments where there are technical reasons to be involved and there is a benefit to the complex. However, TFA hopes to target only a fraction of the budget to this type of effort.

## **11.0 Parametric Studies of Hanford Sludge Washing Technology Stage: Peer Review**

### **11.1 Technology Abstract**

Sludge in certain tanks at the Hanford Site and ORR presents pretreatment, retrieval, and immobilization problems. In pretreatment, the sludge contains high concentrations of nonradioactive components, notably aluminum, chromium, and phosphates. Nonradioactive components 1) add to the volume of the final waste form, increasing cost and schedule, and 2) can have deleterious impacts on the quality of the glass, which allows only small amounts of waste to be added to each glass log, greatly increasing the immobilization and long-term storage costs associated with waste remediation.

Enhanced sludge washing is the proposed method of treating the sludge at the Hanford Site. This process involves a series of "washes," where tank waste is mixed with aqueous solutions containing sodium hydroxide, heated, cooled, and then the liquid, which contains the nonradioactive elements, is decanted. The TFA is performing tests to gather more information on the parameters involved in producing enhanced sludge washing.

### **11.2 Findings**

The PIs answered the questions from their perspectives, but it was apparent from the discussions that, in many cases, those answers were not shared by the reviewers. However, the reviewers did NOT go through a formal vote on each of the questions. Among the reasons for this was the feeling that some of the questions were not appropriate in the context of this review and that insufficient time was available to resolve conflicting interpretations of the meaning of some of the questions. The following set of answers is based on one reviewer's sense of the feelings of the group, based on comments made during the presentations and the thrust of the discussions during the review team's subsequent executive session, and as modified by review of the other team members.

In addressing these questions, the review team is assuming that the term "sludge washing" in the questions is really meant to be "enhanced sludge washing," the term used most frequently by the PIs and in the Technical Task Packages describing the work. In any case, the review comments are made on the basis that the subject discussed and the questions asked were aimed at the LEACHING of components from the solids, and not on the removal of soluble or solubilized materials by simple WASHING.

### 11.2.1 Has the User Defined the Performance Requirements and End Points for Sludge Washing Development/Performance Testing?

The user feels the answer to be "yes." However, the review group feels that this is largely due to the fact that the performance requirement seems to be along the lines of "any data that are obtained are of value," with relatively little consideration being given to cost/benefit considerations (with regard to data collection).

- (a) Has proper consideration been given to the final waste form volume as a function of the total flowsheet?

Regarding the end use of the data towards achieving the user's goal to "prepare HLW sludge that makes a reasonable amount of HLW glass," it is clear that the enhanced sludge washing approach is not being weighed against any other approach, and that whatever amount of HLW glass can be achieved by that approach has been judged to be "reasonable." In addition, the introduction of the privatization approach to tank waste remediation has led to uncertainties in the perceived focus and needs.

The user stated that the final waste form volume was a key metric in his evaluation but did not indicate what amount of HLW glass would be "unreasonable," or whether the impact of this approach on the volume of low-level waste glass was a concern. The review group feels that the answer to this question is --"sort of."

The preceding paragraphs regarding the "reasonable amount" of HLW glass apply to question b (next section), as well.

- (b) The targets for removal of aluminum, chromium, and phosphate are all in the 70-80% range at Hanford. Can these be achieved? For what streams is this a problem? Are the options for treating those wastes well defined and achievable in the currently envisioned operating scenarios?

There are several parts to this question. The review group was shown the results of a data treatment exercise indicating that 70-80% removals can be achieved on a weighted average basis. However, the exercise was evidently not a part of this project, so no details were presented for the team to evaluate. The question "For what streams is this a problem?" was answered by listing those tanks and SORWT groups in which removals of <70% were observed. Those listings also provided estimates of the inventories in those groups, so that the team could identify for itself which (tested) streams provide a problem. The presenters did not address the last two parts of this question.

- (c) Are the proper experimental approaches and techniques being used to meet the user's need?

The review team's answer is "the reviewers don't really know," even though the presenter felt the answer to be "yes." With some difficulty, the review team determined that the experimental approaches and techniques being used by one site are substantially different than those being used by the other two sites. It was not clear why this was the case, other than personal preference. From the

verbal descriptions given to the team, it appeared that both approaches might be valid, but insufficient detail was available to be judged. The majority of the review team was surprised that the "enhanced sludge washing team" had not resolved the differences within itself. Members of the TAG would be happy to assist in such resolution, if needed.

- (d) Have other considerations been given to final determination of optimal removal levels for aluminum, chromium, phosphate, and sulfate?

In addressing this question, the presenter described efforts to investigate kinetic and solubility effects as well as chromium oxidation methods. If the intent of the question was aimed at INCREASING removal of these materials, then the answer to the question would appear to be "yes." However, OPTIMAL removal level is not necessarily MAXIMUM removal level, so in this context the apparent answer is "no." One example of the difference in these concepts noted by the review team is that some sludge types could be low enough in the listed components that caustic leaching would have no impact on the amount of HLW glass; in that case the optimal removal on a cost/benefit basis would be zero (no leaching) and efforts to increase removal would be pointless.

### **11.2.2 Is the Technical Approach to Addressing the Sludge Washing Need Sound?**

The review team feels that the answer is "yes, in general." Use of a wide variety of tank wastes, leaching under a variety of conditions, and considering both kinetic and solubility effects are all desirable features. However, the details of how the tests are actually performed and how the data are summarized, interpreted, and presented are sometimes open to question (as discussed elsewhere).

- (a) Given the results to date, should future work evaluate continuous versus batch processing, and at what scale?

For this question, the review team feels that results of the planned kinetic experiments should be very valuable in evaluating whether sludge leaching should be done in a continuous or a batch mode. Regarding scale of future work, the team sees little benefit in going to a larger scale at this time because 1) limited resources would be better utilized in investigating a larger number of small samples than in investigating a smaller number of large samples, and 2) a large-scale demonstration unit could not be ready in time to provide information to phase 1b of the privatization effort. For simple sludge WASHING, as opposed to sludge LEACHING, the review team feels that sufficient data are likely already available for evaluation of continuous or batch operation of a settle/decant system.

- (b) Have sufficient sludge-washing tests been completed to respond to user requirements?

The user's response to this question was "Yes for some requirements, No for other requirements." The review group does not differ with that assessment.

### 11.3 Recommendations

1. This work should be continued, but with a better focus, aimed at answering more specific questions. Some of the issues discussed by the review team in this regard were:

- (a) More effort should be directed at selection of meaningful samples to be subjected to testing. Experimental testing should center on samples of most relevance to refining the estimates of the process effectiveness for the overall waste inventory; that is, the samples thought to represent large tank inventories of aluminum, chromium, and phosphorous, especially samples representing waste types that have not yet been examined or types where results to date indicate the desirability of more extensive removals. Consideration should also be given to the impacts of potential retrieval and/or blending activities on the types of samples needed for this study.

**TFA Response:** Agree. The TAG realizes the difficulty of getting samples from Hanford Tank Waste Remediation System, and that the TFA has been working around available samples. The TFA has worked closely with the Hanford Tank Waste Remediation System to ensure the TFA is wisely using the available samples. For instance, as ORR is using a hot cell, ORR has been working with more radioactive samples. Waste high in chromium has been directed to Pacific Northwest National Laboratory and tests with these samples are specifically directed at the priority issue regarding chromium removal. As to the impacts of retrieval and immobilization, the TFA has recently conducted pretreatment-retrieval and pretreatment-immobilization workshops, and the various PIs are now discussing interface issues in more detail. Currently, the sludge washing activities are unfunded for FY99. Should this task restart, selection of meaningful samples will be included as an important activity.

- (b) With a given sample, there should be a focus on the specific tests and analyses that are of most value. This recommendation implies the need for obtaining at least partial results before deciding whether to do more extensive analyses on the samples of the one test (e.g., microscopy studies) and/or before deciding whether/which other conditions should be tested (e.g., if rapid and complete leaching of the important components is observed with 1 M sodium hydroxide at a low temperature, there is no need to complete the test matrix at higher concentrations and temperatures).

**TFA Response:** One of the drivers for continuing this work in FY98 was the need to provide more information on a broad operating envelope than a simple analytical chemistry task (e.g., the previous prescriptive enhanced sludge washing testing matrix) would provide. The PIs met with the users and developed the parametric approach, which can allow optimization over a range of time, temperature, and concentration. These tests are conducted in parallel for efficiency. Recent studies have revealed that under certain conditions the volume of HLW actually goes up if the processing envelope is not carefully controlled. This result might not have been recognized using the standard enhanced sludge washing analysis approach.

In practice, the design of the experiments is based on "near-real-time" analysis, and this is not practical. A significant delay exists from the time laboratory tests are complete until analysis results are received. This problem is found at all three laboratories. Waiting for analytical results would lengthen the schedule. Developing the capabilities to obtain faster results could be done but would increase the cost substantially.

- (c) Testing procedures (the mechanics of doing the tests) should be better standardized, but the flexibility to adjust to unexpected results must be maintained.

**TFA Response:** The TFA believes the PIs are working on a standard approach, and data is transferable from site to site. The PIs have flexibility to follow and further delve into results, and the results are being incorporated into a unified report for FY98. Future efforts, if supported, will be better standardized.

- (d) The workers' understanding of the importance of their results in terms of the "big picture" (e.g., the effect of the treatment on the amount, and quality, of HLW glass that would result, and on other overall flowsheet matters) should be improved. This would be a key factor in improving the focus of efforts in the areas discussed in (b) above.

**TFA Response:** The TFA has recently emphasized the issue of the pretreatment-immobilization interface and the need for a better integrated flowsheet from the user to define the appropriate performance requirements for the sludge washing operations. Enhanced sludge washing requirements do not appear to always match the overall objectives. The TFA believes this has been partially the result of integration issues within the user organization. The PIs for this task are experienced, have a good understanding as to where they fit, and were active participants in the pretreatment-retrieval workshop and the pretreatment-immobilization workshop, helping improve the dialog about impacts at the interface.

The TFA will continue to strengthen the interfaces and performance requirements definition to ensure the PIs' efforts are focused appropriately.

With the currently projected sample load and funding level, the work on this project should be consolidated at one site instead of being distributed across three sites as is currently the case. This will lead to efficiencies of operation and will also increase standardization of test and analysis procedures. None of the reviewers disagreed with this recommendation. Strong feelings were expressed by several reviewers that the one site should be Pacific Northwest National Laboratory, based on factors such as proximity to the wastes, greater competence of the investigators, track record of obtaining and reporting meaningful results, and degree of understanding of the overall problem; no support was expressed on technical grounds for any of the other sites.

**TFA Response:** Historically, the TFA and the users benefited from the team of performers working together on the enhanced sludge washing testing. However, given current budget constraints and the nature, extent, and priority of the sludge testing remaining, the TFA agrees that changes will be

needed. Currently, all of the sludge activities are below the funding line and will not continue in FY99. If future budgets allow these activities to be restarted, the TFA will work to streamline the efforts consistent with the recommendations.

## 11.4 Comments

1. While several review team members believe that the results obtained in this project have been of substantial value, several other team members were quite skeptical of that fact (one specific comment was "The basic data package is very shaky"). A large factor in this divergence of opinion is likely the fact that there was general agreement that the "story" presented to the team was difficult to follow and was deficient in the areas of need, background information, relevance to the "big picture," and end-point definition.

**TFA Response:** See response recommendation 1.d (Section 11.3). The TIM takes responsibility for the poor organization of the data for the midyear review. Results generated in this work have been used to fulfill a major *Hanford Federal Facility Agreement and Consent Order* milestone (M-50-03). Based on that fact alone, the data generated has been of substantial value and is recognized by the user as being valuable. In addition, the results are valuable. The TFA now has a better understanding of how various sludge types respond to washing with dilute sodium hydroxide and leaching with several molar sodium hydroxide. The TFA has a better understanding of the gaps in our knowledge of sludge washing and leaching. Observations as to kinetics of aluminum dissolution, the conversion of chromium(III) to chromium(VI), and the formations of gels and precipitants are important to planning treatment flowsheets. The parameters being investigated in this work (temperature, concentration, time) will allow the process engineers to pick the conditions they need to achieve the specific process objectives. The TFA feels this work has added value to the program since it was transferred to TFA from the Hanford Tank Waste Remediation System. The better collaboration of various PIs, the improved communication via the conference calls, and the idea to do parametric studies have all contributed to a more broadly based program. Results of this integrated testing will be reported as testing concludes this fiscal year.

2. Two areas of significant concern regarding terminology were noted. The first area is in the meaning of terms such as "sludge washing," "enhanced sludge washing," and "caustic leaching." It was obvious in the review session that the terms mean different things to different presenters, and that loose and variable usage of the terms lead to unnecessary confusion. Similar comments apply to the second area of concern, which is the use of the word "sludge." The presenters generally used this term for the SAMPLE as they received it, whereas to several members of the review team feel the word should be reserved for something like "the water-insoluble portion of the sample." This can be a very important distinction in consideration of what the actual "sludge compositions" and "sludge leach factors" are, and it is important that those who apply the data from this work understand that the "sludge" data from this project may not be on the same basis as the "sludge" data in tank inventory estimates and in flowsheet modeling activities. Greater involvement of the workers in this task in interpreting the significance of their experimental results to the "big picture" could/should assist in avoiding such misinterpretations of the data.

**TFA Response:** The TFA believes this may be a communication issue during the midyear review and will use the comment to help in preparation of future presentations and publications. The PIs and users do have a common understanding of the results and the application of the terms. The PIs use the as-received material as “sludge” to determine the properties. The term the team uses for the water-insoluble portion of the sample is “washed sludge.” Leached sludge is the term referring to solids after leaching with caustic or oxidant, then washed with dilute caustic. The TFA does not believe confusion exists regarding term usage by the PIs and the users.

3. Several reviewers feel strongly that this “enhanced sludge washing” project is too isolated in its method of operation, without proper regard for the effects of/on operations that precede it (retrieval and/or blending) or follow it (immobilization). This project appears to be part of a parcel of “too many small tasks,” with nobody taking overall responsibility.

**TFA Response:** See responses to comment 1 and recommendation 1d. This task is well integrated within the pretreatment team. Significant work has been done to get the interface issues with retrieval and immobilization recognized and understood. The PI team has been the driving force behind the workshops with the retrieval and immobilization teams, and the other teams are now recognizing how interrelated these tasks are. The TIMs discuss this issue frequently and have identified specific actions with the users to strengthen the definition of interface-driven performance requirements.

4. Several reviewers support a more extensive analysis of the existing data, using statistical methods, if appropriate.

**TFA Response:** Agree. A need for more extensive statistical analysis has been recognized and recommended. If the sludge processing activities regain funding in the future, the TFA will work with the users and TAG to prioritize activities required, including statistical analysis, to meet the data requirements.

## **12.0 Waste Form Product Acceptance Testing Technology Stage: Engineering Development**

### **12.1 Technology Abstract**

The Hanford Site will process its HLW through the privatization process. Current plans are to separate the low-activity waste (LAW), process it into glass, and dispose of it onsite. The HLW fraction will also be vitrified and stored for ultimate disposal in a national HLW repository. The HLW process will be patterned after those of the SRS and the West Valley Demonstration Project, and the final waste form will comply with the waste acceptance criteria established for HLW disposal.

The composition of the waste at the Hanford Site has a wide variability due to Hanford's processing history and contains organic compounds, components with low solubility in glass, components that tend to form separate phases, and RCRA metals. The waste is currently listed RCRA; this requires product performance that not only results in immobilization of the radioactive components, but in stabilization of the listed metals. The approach used to address these issues will also provide insight into processing requirements for INEEL and should increase the glass performance database for the HLW program relevant to SRS, West Valley Demonstration Project, and INEEL.

The LAW glass form must be formulated to have long-term stability in the Hanford Site disposal facility. In support of the HLW glass disposal, an international glass burial program was established that included the United States. Currently, the data generated by the TFA is being evaluated for applicability to the Hanford LAW disposal task, and a review of the literature on international long-term glass testing, performance, and interaction with disposal systems is being completed. The results of these evaluations and the performance requirements that will result from the Hanford Site's PA of the disposal system will be used to design an approach to predicting long-term performance from the glass composition. The rationale for tying to composition is because composition is the only significant glass parameter measurable in an operating plant. Therefore, the plan is to define a test or suite of tests that can be used to identify a composition region that meets the long-term leaching performance required to support the Hanford's PA and to meet the privatization contract requirements. Once defined, the acceptable performance region can be used by the DOE to evaluate glass compositions throughout private glass production to ensure that the glass will meet disposal system requirements (the glass compositions will vary widely due to waste feed composition).

### **12.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

### **12.2.1 Will TFA Technical Results Fulfill Definable Needs for DOE's Waste Acceptance Process Under the Hanford Privatization Contracts?**

The review group sees the effort to identify viable glass waste form composition regions as a necessary technical element of the Hanford privatization effort. This "yes" response is highly qualified because of the timing for Hanford privatization contract commitments. This work is expected to define glass composition ranges, which are viable for disposal performance and processing. Results of the work can support DOE's assessment of the waste form product DOE will receive from vendors under phase 1b. But, the major application of TFA-funded work is expected to support privatization phase 2 planning and contracting.

- (a) Are there additional elements that need to be included in the strategy? Is the technical approach adequate?

The technical approach is logical. TFA and Hanford investigators have positioned themselves to be responsive to Hanford needs. However, it is difficult to state whether additional elements are needed because no clear definition is available for a DOE strategy on acceptance of vendor waste products. It is prudent for DOE (via TFA) to support independent capability to obtain relevant data to assist DOE's critical evaluation of vendor process and product qualification activities.

- (b) Are there additional specifications that need to be developed and/or added to the Hanford specification? Have deployment (transfer to the user) and performance objectives been adequately defined by the user?

Reviewers do not see any additional specification items needed near term (relative to Hanford Phase 1 Privatization Request for Proposal).

Deployment of the strategy adopted by TFA to support Hanford privatization procurement involves a daunting field of glass "composition space." TFA investigators will need to be very judicious in selection of composition ranges for detailed investigations. Reviewers strongly encourage focus of early efforts on glass composition fields identified in vendors phase 1a proposals. The TIM expressed this intent.

- (c) What is the current thinking on how to address long-term performance and the interaction with the PA process?

Reviewers understand and applaud a combined effort that includes Hanford-funded work on PA measures and TFA-funded work on viable glass composition ranges. At this early stage, there appears to be good synergism. The objective, to link long-term waste form performance capability to both test protocols with reasonable durations and to glass composition influence, is a complex undertaking.

The approach of filtering out what parameters in PA tie directly to glass compositions will require considerable resources. There could be value in using "expert assessment" approaches to highlight fruitful hypotheses for initial emphasis in the investigations.

It appears to be too early in the program to select a specific test (e.g., pressurized unsaturated flow test) or test conditions for screening long-term glass performance relative to the PA. The importance of disposal system (container walls, groundwater chemistry, level of saturation, etc.) needs to be scoped early in the process to understand the necessary conditions for testing waste form (glass) compositions. Also, it will be important to develop a strong rationale for selection of glasses to be used in evaluating test methods and the relationships to PA. This deserves a broad base of expert consensus/peer review.

The desirable outcome of this work is both a test appropriate to qualification/acceptance of specific vendor waste form products and an understanding of composition ranges that minimize risk of unacceptable or unprocessable waste forms.

### **12.2.2 Has the Hanford Need for Development and Documentation of Analytical Test Standards for Immobilized LAW Been Satisfied?**

If the purpose of a glass standard is to qualify a testing laboratory, the available results fall short. More than one standard is needed to qualify a laboratory based on industry standards. The status for this question is detailed further in the discussion on question a in this section.

The work performed by Argonne National Laboratory included in the review is well done and appropriate. It is a necessary first step in addressing the need identified in this question. The logic for selecting the glass composition for the initial standard is sound. The round robin planned with this standard glass and the quantity procurement will be valuable.

- (a) Has it been determined how analytical glass standards will be utilized in the interface between DOE and privatization vendors regarding waste form acceptance?

No definitive information was available in this review on how DOE intends to utilize glass standards and product qualification and testing in the privatization vendor interface. It is not possible to address adequacy of the TFA work without additional information. Reviewers are concerned that TFA needs a better definition from DOE of the strategy (and related technical needs) for acceptable product qualification and over-check.

While the vendors are required to produce a product that meets specifications, the ultimate responsibility for providing an appropriately immobilized waste belongs to DOE. Therefore, DOE will need verification that the delivered product meets specifications. Two approaches are available, both requiring the availability of standard materials. One approach is to check the vendor laboratory quality by submitting blind standards for analysis at periodic intervals. Note that the true test results must not be known (blind) by the laboratory and that multiple and different standards are highly desirable. The second approach is to qualify an independent laboratory under contract with DOE.

This procedure would also include the periodic submission of multiple blind samples with a request for reporting analysis uncertainties. Several model protocols are available that could be followed such as the one the U.S. Environmental Protection Agency uses to certify regional testing laboratories or the certification of clinical laboratories or the standardization of industry test labs. The selected protocol should be designed to be cost effective.

(b) Is the technical approach of this task responsive?

Yes, the TFA scope and results to date from Argonne National Laboratory certainly appear responsive to a generic need. The lack of a more definitive acceptance and over-check process logic for the DOE-vendor interface precludes any additional near-term response.

(c) Are the compositions selected for glass standards and the tests included in round robins reasonable for use in vendor interface activities?

The composition selected for the standard is logical. Argonne National Laboratory did a good job of relating the selected standard to other glasses used in prior LAW glass exploratory work. This selection, and the possible need for another standard composition(s), should be reassessed when information can be obtained from the privatization vendors concerning the glass compositions they want to use.

The initial round-robin testing will focus on the acceptance test in the privatization request for proposal. Results of work to date suggest additional guidance be provided on performing this test. The LAW specifications call for product consistency test results at 20°C. However, because leach rates are low, the concentrations of analytes found in test solutions at 20°C are near the analytical detection limits. Therefore, it would be best to run the tests at a higher temperature to ensure analyte concentrations would be measurable with acceptable confidence levels. Results could then be extrapolated back to 20°C. As the presentation showed, the extrapolation would be conservative. In general, analyte levels should be a minimum of  $4\sigma$  above detection limits, with  $10\sigma$  as the optimum.

(d) What further work will be required in this area once the round robins are documented?

Not enough information is available on a DOE strategy for handling the privatization vendor waste acceptance interface to answer this question.

If laboratories need to be formally qualified to certify testing data, either in product/process qualification or actual waste product testing, much more work will be needed.

Also, it is currently not clear whether glass standards will be needed to support the specifications on reporting glass composition and selected radionuclide content (technetium-99, cesium-137, and strontium-90). The TFA has prudently held off commitment of resources to radioactive glass standards until DOE further clarifies the needs under the privatization contracts.

## 12.3 Recommendations

1. The TFA plan for determining viable glass composition ranges to support Hanford privatization includes evaluation of both glass durability and properties important to processability. The reviewers recommend that TFA management critically evaluate commitment of resources to measurement of processability properties (viscosity, liquidus, etc.), due to vendor discretion on melter processing. If new property data are essential, screening methods may be more appropriate than rigorous measurements.

**TFA Response:** Agree. The processability evaluation will only be screening in nature except for the liquidus. The liquidus analysis is part of the scope required to determine onset of crystallization related to nepheline and chromium solubility, especially for phase 2, where details of the pretreatment scope and strategy still must be developed. Otherwise, processability considerations will be only to ensure that the data being developed are in a generally acceptable processing envelope.

2. Results to date justify providing supplemental guidance on product consistency test application for compliance to the Hanford LAW specifications. Recommendations on test temperature, washing of glass samples, and minimum analyte concentrations are desirable, especially in the context of planned round robins.

**TFA Response:** Agree. Argonne National Laboratory work scope includes added input from the user.

## 12.4 Comments

The presentations and organization of material provided by the PIs and TIM Bill Holtzscheiter were well done and addressed the questions.

Reviewers could not relate this activity to the gate review context. The planned integration of work on PA-relevant testing to determine viable glass composition fields is in the initial stages. This review was, therefore, focused on the merit of technical plans rather than on technical results.

1. It is difficult to provide judgements on the value of detailed work in this task in the absence of clear logic from DOE on waste acceptance strategy. The reviewers have product specifications from the privatization request for proposal but no road map or criteria as to what constitutes adequate compliance.

**TFA Response:** Agree. Requirements for additional user input have been communicated and the Program Execution Guidance for FY99 requires definition of this road map.

2. Given the lack of definitive disposal performance criteria for Hanford LAW, it is prudent to develop data compilations that show viable glass composition fields. DOE reduces its risks by maintaining independent capability to assess proposed vendor waste forms. The primary focus should be on LAW glasses, because these have the onsite disposal PA obligation. The logic for carrying out equivalent work for high-activity waste glass needs further refinement and review.

**TFA Response:** Agree. The work scope in the Program Execution Guidance is consistent with this comment.

3. The intent to select a test for glasses that has meaning in the PA context was clear and is endorsed. The programmatic arrangement to address this involves important collaboration between TFA-funded glass work and Hanford-funded test assessment in the PA context. The specific pathway chosen to accomplish integration will require strong collaboration among performers. The selection of applicable tests will need objective and critical review work, as the performing experts are also the inventors of several candidate test methods.

**TFA Response:** Agree. The process of ensuring strong collaboration is continuing but is incorporated into the technical response as a required user interface.

4. The approach in this task to assemble existing glass data from diverse sources is commended. Using basic glass property and reaction data developed for high-activity waste and other waste glasses will effectively reduce the need to develop new data for evaluating many potential LAW glasses.

**TFA Response:** Thank you. The FY99 Program Execution Guidance reflects this approach.

## **13.0 Pulsed Air for GAAT Retrieval Technology Stage: Demonstration**

### **13.1 Technology Abstract**

To remediate tanks, waste containing suspended solids must be removed from certain tanks and pumped (in some cases, several miles) to other tanks that have longer design lives or are staging tanks for immobilization activities. To keep the solids in suspension and avoid plugging the transfer lines, the waste must be staged, i.e., collected in a holding tank and mixed, and then conditioned to separate the smaller particle sizes for transfer, all to avoid plugging the lines. Plugged transfer lines are usually abandoned because of the risks involved in unplugging the lines using conventional methods; this requires new lines to be built, a very costly proposition.

Pulsed air mixing offers cost and operational advantages over conventional baseline mixing methods (jet mixer pumps) for keeping the waste mixed and the light-weight particles separated in holding tanks (conditioning for transfer), thus avoiding plugged lines. In pulsed air mixing, large bubbles are produced periodically by gas-pulsing valves that feed air through horizontal, circular plates positioned just above the tank floor. The rapid growth of the pulsed air bubbles near the tank floor and their subsequent rise through the fluid lift the solids and maintain them in a uniform suspension. Pulsed air mixing requires little addition of water, involves no moving parts, and does not add heat to the waste slurries. It has been successfully tested at the Hanford Site and will be deployed in an ORR tank in FY98. It also could be used to alleviate flammable gas generation in selected Hanford tanks.

### **13.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **13.2.1 Is the Technology Ready to Deploy?**

(a) Has the user defined performance requirements, problem definition, and deployment schedule?

There is apparently enough performance requirement information, but it is not apparent that this information has been documented and been accepted by the users nor does there seem to be a common understanding of the information. The volumes, the likely transfer schedule times and rates, the amount of solids, and a characterization of solids have not been fully defined for either the supply resulting from tank clean-out or the discharge to the Melton Valley Storage Tanks. However, as long as on-line particle size and slurry concentration measurement (supported by Accelerated Site Technology Deployment Program) and continual removal of +100 micron particles are successfully employed along with the pulsed air technology, the requirements definition is not critical. Technology for grinding accumulated +100 micron particles may also be required, longer term.

This is a fully scheduled hot demonstration with a firm deployment schedule, ready for transfer at ORR according to a site schedule. Evaluation of the hot demonstration will support further deployment, but probably within comparable size limitations.

- (b) Are there technical or institutional issues that preclude meeting performance requirements?

Answering this requires additional information from Mike Powell regarding 1997 tests to determine how he knew he met requirements. This would include a comparison of the simulant used to the expectation for the actual solids in the slurries to be pumped.

This technology has never been tested on real slurries. As solids from different actual "hot" tanks are suspended and pumped to this holding tank, which uses pulsed air, there is the potential that small amounts of emulsifiers could cause foaming, which may be a serious challenge to successful operation.

Bubble collapse may cause entrained particulates to increase significantly. There is some concern this will overload the high-efficiency particulate air system.

Tiny bubbles may be entrained with the solid-liquid slurry. The presence of small bubbles can interfere with solids Dp or weight percent analyses that are central for successful operation.

- (c) Will the system be ready for transfer to ORR according to site schedule?

Yes. The schedule delivery of the system near the end of March is consistent with the ORR schedule.

- (d) Are there any system weaknesses or feasibility issues that need to be addressed before implementation?

ORR has built in flexibility to the system so that it may not be critical to know exact requirements. However, without specific requirements, it will be hard to gather data to allow deployment elsewhere. It is appropriate to apply the ORR information as a pilot for other sites. However, the majority of the tanks and volumes at the other sites are much larger and, thus, will create new challenges.

### **13.2.2 Have Cost Benefits of Pulsed Air Over Alternative Technologies for this Application Been Documented?**

Not enough data were provided to evaluate this question. An answer should be forthcoming after hot testing has been completed.

### **13.2.3 Will/Can the Demonstration Provide Data to Support Other Applications of the Pulsed Air Technology?**

Linkage with other sites should be established. No need or performance requirements have been transmitted for the technology by other sites. After testing, if complete, the data obtained can be used to evaluate the application at other sites if the sites are interested.

### **13.2.4 Is It Necessary for this System to Have Decontamination and Reuse Design Features to be Considered for Use at ORR, SRS, and Hanford?**

Decontamination is not a major concern for the GAAT application at ORR because the equipment will remain in one tank until completion of operations. SRS and Hanford must identify the particular requirements for their sites.

## **13.3 Recommendations**

1. An analysis of the impact of the air input by pulsed air in addition to the air draft required to maintain vacuum upon the air handling systems was not presented. It is assumed that the system air pressure will not be allowed to go positive; thus, this additional air may be a serious problem. This possible occurrence should be examined and a contingency plan developed if necessary.

**TFA Response:** This issue has been addressed. The volume of air passing through the pulsed air system, including possible aerosols generated, were matched with the capabilities of the tanks ventilation systems. The vent system is calculated to be able to handle the mixer air while maintaining a proper air balance.

2. Key issues are on-line monitoring of slurry Dp and weight percent and the ability to ensure +100 micron particles are recycled. Assuming these two pass hot tests, the pulsed air technology should work. Cold testing should include these two critical supporting technologies. (This may have already been done.)

**TFA Response:** Cold testing is complete on the sensors selected for the Tank W-9 hot test loop. Hot testing should show that the sensors will function in actual waste with the pulsed air system operating. Will bubbles interfere with the instruments? Will the instrument results match lab analyses?

3. The potential to cause foaming due to small amounts of emulsifiers will require continual monitoring, particularly when changing to a new source of slurry. Additional equipment to alert for emulsions may be required.

**TFA Response:** Agree. It is expected that video surveillance will warn operators as wastes are agitated in the source tank and dumped into Tank W-9.

## 13.4 Comments

1. There were several references to optimizing the system by "tuning" the air pressure controls (delta P and/or duration of pulse). Performance requirements for this are not defined, and the robust capability, created by the use of +100 micron particle removal and slurry analysis, render this optimization unnecessary and not a useful demand on operator attention.

**TFA Response:** Agree. The factory presets will be used unless analysis of the slurry shows that particles outside of the accepted size are being lifted.

2. The properties of the tank waste are unknown, and to the extent needed or possible, they should be evaluated.

**TFA Response:** Agree. There will be characterization, but the integrated physical properties of the slurry will be tested by the pulsed air mixer in combination with the sensor loop and grab samples. Similarly, the sludge left behind after a transfer of the light-weight constituents will need analysis.

## **14.0 Waste Loading Improvements for High-Activity Waste Glass Technology Stage: Engineering Development**

### **14.1 Technology Abstract**

Both the SRS and the Hanford Site have technical needs regarding waste loading in vitrification. The SRS's Defense Waste Processing Facility (DWPF) complies with Waste Acceptance Product Specifications and process control requirements by demonstrating, to a high confidence, that melter feed will produce glass meeting all quality and processing requirements. This method requires that uncertainties – associated with sampling, sample analysis, and property estimation models – be determined and that sufficient allowance is made for the uncertainties when controlling feed composition.

The existing model for liquidus temperature has a large uncertainty associated with it, and its application has reduced allowable waste loading, increasing the overall cost of waste immobilization. Some constraints on the application of the durability model can cause acceptable glasses to be rejected, because the durability is indeterminate (i.e., the applicability of the model is not certain). New or improved property models for liquidus temperature and durability are needed. The model tolerances need to be identified. The models should apply to the entire range of plausible glass compositions produced from glass formers and washed sludge waste (“sludge only glass”) or glass formers, sludge, and processed washed precipitate.

The Hanford Site users identified waste loading issues associated with chromium and crystallization. Currently, HLW glasses are formulated to ensure that little or no insoluble phases exist in the HLW melter. Insoluble phases are caused by chrome minerals, spinels, noble metals, and other problem constituents. Currently, these issues result in lower waste loadings, which is an expensive alternative. The TFA is exploring an alternative to allow problem constituents to remain insoluble in the glass matrix. This approach is acceptable as long as the insoluble phase does not adversely affect the waste processing or the quality of the waste form. Information is needed on the technical viability of producing HLW glasses with insoluble phases.

### **14.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **14.2.1 Is the Work Being Performed in this Task Focused on the Most Significant Factors Affecting Waste Loading Limits for High-Activity Waste at Tank Waste Sites?**

The presentations clearly defined that phase separation is the singularly most important aspect for defining the zone where the product consistency test is valid. The liquidus temperature measurement was defined as the most probable source for increasing waste loading, because it currently is the biggest error

band in defining the acceptable operating area. Liquidus temperature and associated crystal formation are also key issues in evaluating waste loading uncertainties at Hanford. Other process operational considerations such as viscosity, resistivity, and durability were not presented; however, on discussion, it was stated that all the processing requirements were considered when the analysis of impacts (relevant to DWPF) were evaluated.

- (a) Liquidus temperatures testing has been completed for DWPF glasses. The glasses will be analyzed and included in the DWPF process control models. Are the glasses and test matrixes selected appropriate? Are there issues that need to be considered before deployment?

It appears that sufficient effort was expended in selecting a representative range of compositions that represent DWPF feeds. No other issues appear obvious considering the range of parameters verified as indicated in the response to question 1 above (Section 14.2.1).

- (b) The model for durability is based on homogeneous glasses. Will this approach provide definitive data to improve the homogeneity constraint?

The DWPF durability constraint program is evaluating both homogeneous and phase separated glasses. The selected test matrix should result in a more definitive boundary constraint that will meet durability requirements. The information presented strongly indicated that boron-rich continuous phases are detrimental to durability; however, the nature and extent of acceptable dispersed boron-rich phase is unquantified.

- (c) How important are kinetic effects? Is it essential to include the DWPF canister cooling cycle? How sensitive is the onset of phase separation to the accuracy of the expected cooling cycle? Can phase separation be eliminated by adding a minimal amount of some component, such as aluminum?

The impact of kinetics on phase separation have not yet been quantified. If phase separation occurs, then it may be important to evaluate it over a range of expected cooling cycles. The effect of addition (or controlling the minimum content) of aluminum oxide ( $Al_2O_3$ ) on phase separation is being evaluated.

- (d) How are the compositional differences between DWPF and Hanford wastes being handled in the test matrix (i.e., range of compositions that may occur)?

Because the DWPF database is smaller than the Hanford feed variations, these data will be added to some existing Hanford data and expanded to cover the wider range of compositions and key components. Some additional emphasis on clearly defining the combinations and relative concentration ranges of problem components likely to occur at Hanford and INEEL would be valuable to planning future work.

## 14.2.2 Is this Technology Enhancement Cost Effective and Timely in Meeting User Needs?

This task has been concentrating on the DWPF, which is currently in its second year of operation. Improvements in the waste loading would result in consuming more feed earlier, thereby having the largest impact on operational duration.

- (a) Have the cost benefits been determined and documented?

Based on a predicted increase of 2% in waste loading by reducing the liquidus temperature uncertainty, in excess of \$500M savings is estimated. This savings estimate was verified by an independent computation.

- (b) Have users at SRS committed to incorporate new data into process controls and implement improvements?

SRS has provided co-funding for these efforts and is providing funds to improve the liquidus model in the DWPF process control system. A similar approach is planned by SRS to support the phase separation deployment. User representatives indicated a strong commitment to utilize the new data.

- (c) Will these improvements be utilized at Hanford relative to the privatization plans?

Current indications are that DOE will support this effort in FY99. Potentially significant impacts result from improved loading of difficult constituents and understanding the phase separation boundary.

For DOE to understand the possibilities of the waste form and to ensure that it does not pay for glass volume that is not required, they must have a clear baseline for waste oxide loading, and information that allows them to establish appropriate incentives for the private contractor to provide a product at the highest possible waste loading. With a contract that makes payment based on number of canisters at a minimum waste loading, there would be little incentive for the private contractor to reduce the number of canisters produced by increasing the waste loading.

It is not clear at this point what level of Hanford Site funding will be applied to analyzing and using the data. Also, a need exists for clarification on how TFA plans to relate to issues associated with selection of melter technologies that might tolerate more solids.

- (d) Is the TFA overlooking anything critical? Have risks been identified and contingencies been established (i.e., data quality, implementation into the operating basis)?

It appears that a thorough review of thermodynamic and operational parameters have been made and that the limiting conditions were included in the task. The program has been developed on a sound technical and statistical basis to support refinement of current process control systems.

## 14.3 Recommendations

1. Evaluate whether the quantity of boron-rich dispersed phase or the creation of a continuous boron-rich phase is the critical value for meeting durability constraints. Some level of nonhomogeneity may be acceptable without seriously impacting waste form durability. Defining the level of acceptable nonhomogeneity could produce a wider operating envelope.

**TFA Response:** Agree. This objective is included in the technical response and will be a part of the task.

2. A detailed, statistically designed experimental test program should be developed for expanding the existing databases to the Hanford and INEEL compositional ranges. This should give priority to key elements such as noble metals, zirconium, phosphorus, and chrome.

**TFA Response:** Agree. The test matrix work is in progress.

3. Kinetic effects on phase separation and/or crystallization should be evaluated to determine if it has a significant impact on durability. Numerous full-scale canisters were produced during DWPF glass qualification. Analysis of the data obtained during this qualification should be reviewed before developing a test program.

**TFA Response:** Agree. This is a part of the current and planned FY99 scope.

## 14.4 Comments

1. The presentations made by the TIM Bill Holtzscheiter and PIs were well prepared and responsive to the TFA questions. The detailed experimental program is technically sound and focused on the objectives, which can be efficiently applied. There is obviously good integration across sites.

The continuation of this effort is considered essential for long-term understanding of SRS, Hanford, and INEEL vitrification operations, with or without privatization. The "user" at SRS is DWPF and the specific technical staff supporting process control systems are clearly involved. For Hanford, it is not clear who the technical staff users of the data will be. There is incentive to identify and involve the cognizant Hanford staff in the interface with TFA on this task. Similar considerations apply to INEEL.

**TFA Response:** The users at Hanford are diverse; however, the focus is to support the privatization team. The TFA is currently expanding the site coordination to include the PA interfaces as well. INEEL users have been consistent and the objectives are defined to support the baseline process definition in light of the long timeline for INEEL.

2. One area that might be considered is the impact of reducing the confidence level of the operating area on a cost/risk analysis bases. For example, if precipitation of materials in the melter is the failure mode, what is the cost/risk if a 90% confidence level was used versus 95% confidence level? Considerations such as the blending aspects of the feed tank and melter should be incorporated to evaluate the true risk.

**TFA Response:** Agree. The TFA believes that this is a good approach; it is early in the program on melter improvement to address this as the FY99 task is limited to improvement of the DWPF melter and fundamental parameters for INEEL. This approach will be incorporated in the FY00 program.

## **15.0 GAAT Closure and Isolation Technology**

### **Stage: Engineering Development**

#### **15.1 Technology Abstract**

Site plans at the ORR call for the GAATs to be closed. To close the tanks, the waste must be removed, the tanks must be cleaned, and the slurry transfer pipes must be blocked. The slurry transfer lines are a series of pipes ranging from 1.5 to 3 inches in diameter that were used to deliver slurry waste to the tanks when they were operational. Today, rainwater falls through the pipes to the tanks and then must be disposed of as radioactive waste, increasing the cost of tank closure. Capping the pipes above the ground surface poses risks to the workers.

Thus, two efforts are underway to plug the GAAT slurry transfer lines. The first task involves developing and demonstrating an end effector to clean the pipes and prepare them for plugging. The end effector will be deployed by the Modified Light-Duty Utility Arm or the Houdini vehicle. Another end effector is being tested to cut pipes inside the tank, especially those that run from the surface through the tank roof to the floor so that they can be accessed for plugging. This end effector is a portable band saw. The saw will be designed for deployment using the Light-Duty Utility Arm. This mechanical sawing approach was selected because the saw is lightweight, it can be deployed easily, it cuts cleanly and quickly, the blades are easy to change, and radiation exposures are acceptable.

The second task is to develop an appropriate pipe sealing fixture. A test stand was assembled to evaluate the pipe cap design, the sealing ability of an epoxy sealant, and other pipe plugging concepts. Additional tests are planned to modify the pipe cap design, if necessary. This isolation and closure technology may also be applicable to waste tanks at the Hanford Site and at INEEL.

#### **15.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

##### **15.2.1 Closure: Is the Technology Ready to Be Demonstrated In-Tank?**

The multi-point injection technology is ready to be demonstrated in-tank. The characterization technology is at stage 3 (exploratory) and is not ready for demonstration. Questions 1b-1d and 2a-2c (represented as Sections 15.2.1.b-d and 15.2.2.a-c, respectively) are not applicable for the characterization technology.

- (a) Are the performance objectives clearly defined or is there a path forward for defining the objectives? Is there a technical approach likely to meet desired performance objectives or provide timely input to development of the objectives?

The performance requirements are specified for the grouting by multi-point injection technology in that it has to be completely mixed and homogeneous. The technical approach has been demonstrated based on soft sludge. If hard sludge is encountered the technical approach may not meet desired performance objectives.

There are no performance objectives specified for the characterization of the grout and the timing of the development of the objectives was not clear. The capability of this technology needs to be determined and considered in discussions with regulators and stakeholders.

- (b) Are there important issues (technical or institutional) that may impact the schedule and success of the activities?

The multi-point injection technology may be impacted if the sludge in the tank is not soft sludge or if the regulatory/stakeholder groups do not support grouting in place. If the sludge is hard, complete mixing may not occur and it may not be possible to drive the plastic casing/jetting tool through the sludge layer.

- (c) Have regulatory and potential stakeholder issues been considered? Are there any issues that are likely to cause problems that will impact the technology deployment?

The stakeholder/regulatory groups have not approved grouting waste in place. Success may also be impacted if the regulatory/stakeholder groups require confirmation by grout homogeneity that cannot be proven by grout characterization technology. It would be prudent to await final approval by the regulators/stakeholder groups before grouting.

- (d) Are the key technologies required for GAAT closure commercially available for use by other appropriate sites?

The recommended grout delivery and mixing process is commercially available from Ground Environmental Services and the high-pressure pumping systems can be leased through the oil industry.

### **15.2.2 Closure: Is the Technical Approach Sound and Appropriate?**

- (a) Has information/technology from other sites been applied to closure of the ORR GAATs?

Yes, the ORR personnel have reviewed what SRS has done.

- (b) Have leaks and leaked material, arising from before the tanks were cleaned or while they are being cleaned, been addressed from a closure perspective?

This was not well addressed by the presenters and therefore cannot be answered.

- (c) Can the results of this closure effort benefit other sites' tank closure efforts? How, specifically, and what should be done to enhance that benefit (e.g., are cost and risk reduction data being developed through this work)?

The grout formulation can be evaluated and potentially used by other sites provided the chemical and radionuclides of concern are the same. The grout delivery system may only be selectively used. It is not clear what the benefits would be for larger tanks because the number of openings for injecting the grout is not available. There is not enough information on needs or costs to understand the benefits or evaluate extending technology to other sites.

### **15.2.3 Isolation: Is the Technology Ready to Deploy?**

Yes, the pipe cutter and pipe isolation tools are ready to deploy.

- (a) Are performance requirements/drivers clearly defined, and does the technical approach appear to be sound?

Performance requirements and drivers are defined. The plan to cut and isolate from inside the tank was reviewed. Water intrusion into these tanks occur, and it is desirable to prevent this from happening. The approach is to deal with the issue from within the tanks since the Modified Light-Duty Utility Arm and Houdini are available. This was preferable to cutting and isolation from outside the tanks, as the contamination level in the soil is unknown, and cutting could result in potential exposure and contamination. This is logical if the concern is addressed while the waste is being removed from the tank. However, it was not demonstrated that the water that would build up in the line after it was plugged would not back up above the surface somewhere and cause a personnel concern. The plans or schedule for dealing with these lines/pipes was not reviewed. The lines should be removed as soon as possible after they are cut.

- (b) Have alternatives been adequately evaluated/considered?

Yes.

- (c) Have contingency plans been developed and utilized to minimize technical and schedule risks?

The contingency plan would be to cut and isolate outside the tanks but the plan was not developed; therefore, schedule risks exist. If the pipes have degraded or if the pipes are cut too close to the tank wall it may not be possible to apply the pipe cap. Additionally, if the pipe cap is not applied to encompass the entire length of pipe in the tank, future corrosion of the pipe remaining in the tank may cause water intrusion again.

## 15.3 Recommendations

1. Samples were only taken from Tank TH-4 in one location because there was only one entrance into the tank. However, for the multi-point injection technology to work additional risers will be cut into the tank. An additional riser should be considered for sampling. It could be cut in a location being planned for the multi-point injection technology.

**TFA Response:** Based on current sampling data and waste process history, Tank TH-4 contains only a few curies of radionuclides, well below what ORR believes will be the regulatory compliance level. Hence, additional sampling may not be needed to meet regulatory requirements. As additional risers are cut into the tank to support the multi-point injection technology, ORR does plan to validate its procedures before hot deployment. As noted in the FY99 Program Execution Guidance, "this is envisioned to include placement of injection pipes through harder sludge and use of in-pipe inspection equipment to monitor the character of the sludge."

2. There are several issues on the technical adequacy of the grout formulation. It was not apparent from the material presented that adequate testing had been completed to demonstrate compliance with the assumptions and conclusions in the PA. Additionally there may be additional requirements imposed by the regulators and stakeholders that may have to be confirmed. Lastly, toxicity characteristic leach procedure was listed as the determination method for uranium and this is questioned as the correct method.

**TFA Response:** Agree. Grout testing was not finished at the time of the TFA midyear review. During the remainder of FY98 ORR has an activity to conduct hot laboratory grout tests using some actual sludge from Tank TH-4. Data from these tests will be used during FY99 to prepare a proposed deployment plan for submittal to regulators for their concurrence. SRS has demonstrated that state-approved tank closure can be achieved without a PA; instead, they used a less costly performance evaluation.

3. Additional evaluations/PAs need to be completed for varying amounts of homogeneity of the waste and the grout to validate need for complete homogeneity.

**TFA Response:** The cold demonstration test performed during FY98 used sand as a sludge simulant because this material was considered more difficult to mix than the actual sludge material in Tank TH-4. The mixing achieved was deemed acceptable by ORR personnel. During FY99, results from the cold testing will be provided to the regulators for their concurrence that hot-testing can be done during FY00. If regulatory concurrence is not achieved, then either an improved mixing technology or additional evaluations will be done.

4. Plans should be developed to cut and isolate the pipes from outside (if there are integrity problems with the pipe) so as to minimize schedule risks.

**TFA Response:** Agree. The FY99 Program Execution Guidance allows for two GAAT demonstrations of the ORR pipe plugging system. At this point, ORR is to evaluate the success of the pipe-plugging effort and determine the need for other pipe-plugging contingencies, such as external-tank activities. A letter report is to be provided to the TFA summarizing the conclusions of this evaluation.

5. An evaluation should be done to ensure each isolated pipe will not result in an above ground release (due to water backing up in the pipe) resulting in a personnel safety issue.

**TFA Response:** ORR decided to isolate the pipes from within the tank rather than externally to the tank partially because they do not know the location and source of all the pipes entering the GAATs. The FY99 Program Execution Guidance requires ORR to evaluate the success of their in-tank pipe-plugging effort after two GAAT deployments and to assess whether other contingencies, such as external tank activities are necessary. A letter report is to be provided to the TFA summarizing the conclusions of this evaluation.

6. Verification should be provided that if the jets are misdirected they will not penetrate the gunite wall.

**TFA Response:** Verification of jet orientation will be part of the operational procedures governing the Tank TH-4 hot demonstration. A task of the FY99 Program Execution Guidance is for ORR to assess the applicability of the jet-grouting technology for other larger GAATs. One element of the report is "the prospect that grout jetting may damage tank walls."

7. Verification that there is not an aerosol misting problem during the mixing should be done and plans should include increased monitoring of the ventilation system.

**TFA Response:** These concerns will be addressed during the Operational Readiness Review process used by ORR before performance of the Tank TH-4 hot demonstration.

## 15.4 Comments

1. The efforts by TFA to identify low-pressure jets to mobilize and mix waste and grout should continue to reduce the grouting cost and increase the flexibility as the availability of high-pressure pumping systems can be limited.

**TFA Response:** Agree. ORR's FY99 Program Execution Guidance includes a task to assess the applicability of the Tank TH-4 technology for in-situ grouting of tank heels in larger ORR GAAT, SRS, and Hanford tanks. Specifically mentioned in the Program Execution Guidance description for this task is "also to be provided is information regarding availability of high-pressure grout pumping systems for the different tank sites and relevant cost information that would support future site decisions regarding the deployment of the technology." Moreover, Pacific Northwest National Laboratory is planning to do some low-pressure jet grouting tests during the latter part of FY98.

2. Polymer mixing is similar to grout/waste mixing, and the American Society of Plastics Engineers may be able to provide help in verifying homogeneity.

**TFA Response:** ORR's current plans are to use its cold demonstration test results to illustrate to the regulators that the multi-point injection technology achieves sufficient homogeneity. If the regulators require more verification, various approaches, including those recommended by the American Society of Plastic Engineers, will be evaluated for use at ORR.

3. The use or need for a high-pressure grouting system versus lower-pressure grouting systems was not presented by ORR.

**TFA Response:** For closure of Tank TH-4, ORR is currently committed to the use of the high-pressure grouting system of Ground Environmental Services. In spite of contrary perspectives, high-pressure systems are viewed by ORR's contractor, Ground Environmental Services, as readily available around the complex. Moreover, the turbulence produced during the pulsed application of the high-pressure injection is viewed to achieve good mixing.

ORR's perspective is that full characterization of the sludges in the waste tanks is not practical. Samples will be taken to characterize the waste as much as is practical; however, there will always be some degree of uncertainty in the sludge characterization (consistency, density, depth, viscosity, etc.). Therefore, it is wise to have the grout delivery system designed with as much excess pumping horsepower available as possible. If a tank closure job is begun with a low pressure system and a hard pan layer or stratified sludge is encountered, as found in GAAT W-4, then chances of successfully homogenizing the waste and grout will be very low.

## **16.0 Pulse Jet Fluidic Mixer Technology Stage: Demonstration**

### **16.1 Technology Abstract**

Research and previous nuclear missions at the ORR have created radioactive waste that is stored in tanks, with 500,000 gal of waste produced annually and 600,000 gal held as a result of historical activities. The site uses evaporation to manage the waste. The evaporator feed is held in the Bethel Valley Evaporator Service Tanks (BVESTs). In the evaporator, the generated steam is purified and released. The remaining liquid and solid particles are sent back to the BVESTs. Over the years, feeding the waste back to the tanks has created a sludge layer in the tanks. The sludge is taking up valuable evaporator feed tank space. However, no technology currently available in the United States could cost effectively retrieve the sludge from the horizontal tanks, which contained numerous obstructions and limited access.

Working with the United Kingdom's AEA Technology, the TFA secured a pulse jet fluidic mixer to remove waste from the BVESTs. The concept of pulse jet fluidic mixing is to add liquid waste or water to the heavier sludge. By adding the lighter material and mixing, the weight of the sludge is reduced, making it easier to pump out of the tank. From September through October 1997, the pulse jet system removed about 78,550 gal or 98% of sludge from BVEST W-21. In the spring of 1998, the technology was deployed in BVEST W-23. The mixer offers a near maintenance-free system for removing the tank sludge, because it has no moving parts inside the tank. The mixer can be used where in-tank equipment or flammable gases would eliminate other technologies. Also, the mixer has a proven record of operation in the United Kingdom. The technology could also be used at INEEL.

### **16.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **16.2.1 Is the Technology Ready to Deploy?**

The technology has been deployed at ORR. For future deployments the vendor, AEA Technology, would have engineer-customized applications.

- (a) Have performance requirements, including an adequate definition of the problem and the required deployment schedule, been defined by the user?

This question is not applicable because the deployment has already occurred.

- (b) Are there any issues (technical or institutional) that will likely preclude the system from meeting performance requirements?

The system performed well for the ORR application; however, physical limitations have been recognized. The system is designed for mixing a certain set of waste characteristics in certain geometric applications. For example, vacuum lift distance is a physical limitation.

The technology has apparently been developed primarily to maintain suspensions of solids. In the ORR application, a part of the requirement was to mobilize solids that had remained settled for years. This proved somewhat difficult, and was not optimized by the system that was deployed (partly because of limitations imposed by the existing physical setup). Mobilization of solids may present a more difficult challenge than maintaining a suspension, and this deployment does not necessarily provide the basis for mobilization of different solids in other configurations.

- (c) Are there any changes to the system that could make it useful in another application? Is it clear which mixing applications are appropriate for this technology and which are not?

Changes would have to be made for other applications. All mixing applications are site specific and depend on waste and tank characteristics. Proper modifications using an off-the-shelf technology were made for the ORR deployment.

- (d) Are there system weaknesses or feasibility issues that need to be addressed before implementation?

For any particular application, system requirements must be addressed and modifications made to the pulse jet technology system.

### **16.2.2 Have the Cost and Technical Benefits of the Pulse Jets Been Documented?**

Total costs for the ORR deployment were presented. However, cost benefits and comparisons to other mixing technologies were not presented. Technical benefits may need additional documentation so that the technology is compared to alternatives.

## **16.3 Recommendations**

1. The review panel recommends that documentation of the ORR deployment be prepared comparing this technology to alternatives in terms of performance, applicability, and cost. Additional work identifying potential sites for future deployment should also be completed. The PI and the TIM should focus on lessons learned and transfer of the technology to other applications.

**TFA Response:** Agree. ORR has issued a performance report on the deployment of the AEA system in Tank W-21. These lessons learned will be catalogued in the Retrieval Technology Guide (formerly the Retrieval Analysis Tool). ORR will be deploying a more robust system in BVESTs C-1 and C-2, after which the full efficacy of the concept will be made manifest and comparisons and applicability recommendations can be made.

2. Where mobilization of solids is a part of the performance requirements, some flexibility should be allowed for the uncertainty in the performance of the system (potential to add or move jets, increase the time allowed, increase jet velocity, etc.).

**TFA Response:** Agree. This is the principle of the AEA system for BVESTs C-1 and C-2 that will be deployed in FY99.

## 16.4 Comments

1. One of the major issues occurring during the ORR deployment was that only 88% of the waste was removed using the pulse jet fluidic mixer, while the performance requirement was set at 95%. The deployment was successful, however, because additional retrieval tools were built into the system to ensure that the deployment would meet the performance requirements.

**TFA Response** The original performance goal was 90%. After that was achieved, more was desired and achieved at a small incremental cost.

2. The technology will also have to be customized to meet a particular application. As a result of only a single deployment at a DOE site, the reviewers were not presented information on AEA Technology's ability to scale and revise equipment for other DOE applications.

**TFA Response:** Agree. This will be remedied by their deployment in the C Tanks (BVESTs) in FY99.

3. One of the major benefits of the pulse jet fluidic mixer was that its deployment allowed use of the existing infrastructure.

**TFA Response:** Agree. This is a very strong point because the original Melton Valley Storage Tanks also share this unique geometry.

## **17.0 GAAT Retrieval Systems Technology Stage: Demonstrations**

### **17.1 Technology Abstract**

The Tanks Focus Area has combined new and existing technologies to remove radioactive sludge from the ORR GAATs, 12 underground tanks constructed of gunite (a concrete-like material) and 4 of stainless steel. The waste is being removed from these tanks so that they can be closed under the Comprehensive Environmental Response, Compensation and Liability Act. The GAATs were sluiced in the early 1980s, and contain only a residual layer of sludge. Sludge removal is difficult in the GAATs, because accessibility to the tank interiors is limited and small objects and debris that can interfere with some retrieval systems are often found at the bottom of the tanks. The GAAT cleaning system consists of the Modified Light-Duty Utility Arm, Confined Sluicing End Effector, and the Houdini, a multifunctional remotely operated vehicle.

The Modified Light-Duty Utility Arm is a mobile robotic arm on a telescoping mast, which provides a flexible and adaptive multi-axis positioning system to deploy inspection, characterization, and retrieval tools through existing risers in the underground waste storage tanks. The Confined Sluicing End Effector is an end effector that uses three rotating water jets to cut and slurry the sludge, which is removed from the tank by a three-phase jet pump. The Confined Sluicing End Effector can be deployed by the Modified Light-Duty Utility Arm or by the Houdini vehicle. Houdini, a hydraulically operated track-driven vehicle, assists in removing sludge from the tank bottom or retrieving small objects. Houdini can be fitted with a camera, a plow, a grasping tool, another robotic arm, or other tools, depending on its task. The GAAT retrieval system may also be applicable to the Hanford Site.

### **17.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **17.2.1 Is this Technology Ready to Deploy and Transfer?**

The integrated system has already been deployed at ORR and used to clean tanks. For transfer to other sites the system integration may be different depending on the individual site needs.

##### **(a) Did the technology system meet its performance requirements?**

The retrieval system consisted of different tools/components that ORR integrated into an overall system. TFA supported some of these tools (Confined Sluicing End Effector, Gunite Sluicing End Effector, Modified Light-Duty Utility Arm, Houdini, Decon System) and not others (Floor Cleaning End Effector, Coring End Effector, Characterization End Effector). ORR specified a performance requirement for the system that at least 90% of the remaining waste be removed. This was restated to

remove solid waste to the extent practical and remove all visible sludge. ORR represented the system as having performed to these requirements. However, no performance requirements were specified or reviewed for the individual components.

- (b) Are there technical issues identified from the initial implementation that warrant continued development/improvement by TFA?

There are areas for continued development/improvement, but this is not necessarily by the TFA. These areas are:

- Jet pump erosion improvements. No clear performance requirement was stated except "anything better than what is available now."
- Further development of the Modified Light-Duty Utility Arm to be more user-friendly (less operative-intensive and more forgiving) and an improved ease of maintainability
- Floor cleaning equipment to remove material that does not mix into a slurry
- Tether management issues (improvement, specifically) for the Characterization End Effector
- Improved positioning at a fixed stand-off and perpendicular to the wall
- Tool to cut pipes larger than 3 inches in diameter.

Additional improvements have all ready been made to Houdini reliability and maintainability resulting in development of Houdini-II.

- (c) Is the system ready for unassisted site use?

At ORR, no additional assisted use is needed. The integration by ORR may not be applicable at other sites. Assisted use will be necessary, but it is not clear that TFA has the capability to provide the assistance to address operational needs to make it work. It is also not clear that all the components used by ORR on small tanks can be used on large tanks for retrieval. The operator cost may also be prohibitive on a larger scale.

- (d) Is performance data available and applicable for other sites to use?

No performance data was presented, but it was stated that performance data is or will be available. It is uncertain whether it will be applicable to other sites because performance requirements were not provided and therefore may not have been determined for each component.

- (e) Are systems commercially available for future use? Is there a path to future use and deployment?

The integrated system used by ORR is not commercially available. Individual components are commercially available and could be adapted for specific site use. Through the TFA, the tools have been provided/demonstrated so the sites can develop a path.

### 17.3 Recommendations

1. It is unclear how TFA intends to assist technology transfer from one site to another. The development of performance requirements and evaluation of components against these requirements has to occur versus just an overall evaluation against the system performance requirements. This will require additional data collection by the sites. Additionally, the technology transfer should include the lessons learned (both positive and negative), the understanding of the operational needs to make it work and the total cost (both development and implementation costs). TFA needs to evaluate their program for technology transfer of the above types of data.

**TFA Response:** Agree. This is the intent of the Retrieval Technology Guide (formerly the Retrieval Analysis Tool). Performance data is gathered on each deployment, including lessons learned. This information will be published in cleared reports and placed on the Web in the Retrieval Technology Guide. In addition, a Retrieval Technology Exchange will be held in June to discuss, capture, and publish retrieval issues and lessons learned from across the DOE complex. Performance requirements will be a topic for discussion between the Retrieval TIM and the TAG at an upcoming meeting. This forum should serve to support a better definition of attributes for technology transfer.

2. Specific performance requirements need to be defined for the jet pump development. Development should also include measurement/estimation of nozzle erosion so that potential impacts on subsequent processing can be evaluated/addressed. Even if ORR does not need this data, it will be needed at other sites.

**TFA Response:** A performance requirement has been defined that is focused on balancing the pump's suction performance with both air and water to improve the current pump's measured performance. In addition, a requirement for replaceable parts located at the point of pump erosion has been specified. Specific performance characteristics for the new jet pump will be determined and made available to all potential users. This will include abrasion resistance and comparison to commercially available units.

### 17.4 Comments

1. The TFA has resulted in an increased dialogue between the sites and sharing of information with and without the TFA personnel involved. This sharing and dialogue will benefit all sites.

**TFA Response:** Thank you. Agree.

2. The GAAT Retrieval System was identified as a gate 6 technology, which is not correct as implementation has occurred. The technology is at gate 7. The benefit of a technology review at gate 7 should be evaluated by TFA.

**TFA Response:** The TFA believes that reviewers of demonstrated and deployed technologies provide value in terms of lessons learned and identification of future required actions to support other sites' use or follow-on implementation. Full implementation will not be in force until operational life expectancy is established. The GAAT retrieval systems are still prototypes and not commercially available equipment. The TFA expects that by the time GAAT remediation is complete that the equipment could be considered for gate 7. Initial deployment has occurred, but implementation (i.e., routine use) has not.

## **18.0 Grout/Glass Waste Forms for ORR Technology Stage: Engineering Development**

### **18.1 Technology Abstract**

Radioactive waste in underground tanks at the ORR is being consolidated into one set of double-contained tanks, the Melton Valley Storage Tanks. This waste will then be provided to a private vendor to process. After the vendor has processed the waste, DOE will purchase the immobilized form and ensure that it is disposed of in an appropriate repository. For the selection of the immobilization process, DOE needed information on the relative cost and performance of the most likely waste forms. The goal of this task is to provide information to make this decision. Preliminary information was provided by simulating and testing different sludge types from various tank farms, developing robust grout and glass formulations to accommodate the wide range of sludge compositions in the ORR tanks, evaluating the impact of various sludge compositions on waste processing operations, studying waste form acceptability and volume, evaluating waste disposal costs, and analyzing life-cycle costs. The preliminary information was provided before vendor selection. The final report will be useful to other sites (Hanford, ORR, SRS, and INEEL) that will address low-level waste containing levels of activity and TRU components over the next decade.

### **18.2 Findings**

The review team members attempted to answer the questions provided as described below, based on information presented at the review.

#### **18.2.1 Are the Waste Forms Assessed in this Task Suitable for Application by ORR in Melton Valley Storage Tanks?**

Yes, considering the ORR wastes as a whole and the individual tank farms, but not separate individual tanks, either glass or grout could yield a product that meets the Waste Acceptance Criteria for the WIPP. All the wastes from the various tank farms will be staged through the Melton Valley Storage Tanks, but the extent of mixing, if any, between tank farms is not specifically planned.

- (a) What is the maximum waste loading of sludge in glass/grout that can be processed and still produce an acceptable waste form (to the WIPP and to ORR)?

The maximum waste loading in glass appears to be around 45-50 wt% sludge oxides (dry weight). The maximum waste loading in grout is not firmly established, but appears to be around 15% wt% dry sludge oxides (~ 60% wet) or somewhat higher. It is important to make comparisons of waste loading between different waste forms on a consistent basis, i.e., as either wet sludge (of specific solids content) or dry sludge oxides.

- (b) What are the factors that limit waste loading?

In the case of glass, limiting factors are sludge composition and Fissile Gram Equivalents. In the case of grout, the limiting factors are free water, loss of strength with lighter loading, and capability to pass toxicity characteristic leach procedure (an ORR requirement) at these loadings due to heavy metals content. There may be a potential issue with hydrogen gas generated by radiolysis of water or organic compounds, if present, in grouts. It was noted that the WIPP canister is vented. However, transportation regulations will probably require a sealed package. These issues may or may not be factors in waste loading with grout.

- (c) The consolidation of tank waste creates uncertainty in the composition variability of the waste feed for privatization. What factors and precautions are required to ensure waste form production?

A range of glass compositions has been studied that maps out a composition area that should permit vitrification of most wastes. Surrogates and actual waste samples are being tested in grouts; sensitivity testing is exploring performance within a  $\pm 10\%$  composition window for the surrogates.

Based on this review, it is advisable for ORR to have a plan in place for sampling waste batches staged for processing when process transfers start. It would be prudent for ORR to plan for process testing of samples (or surrogates) from actual waste batches staged in Melton Valley Storage Tanks for processing, especially if sampling of the waste composition shows it to be outside the envelope of previously tested compositions.

- (d) Have all the viable immobilized waste forms been addressed (e.g., direct drying) by this task? Have user performance requirements been defined and met?

Yes, all the viable immobilized waste forms been addressed given the available time and resources. Vitrification and grout were selected for this study because they are both being used for various wastes at SRS and they are the alternatives under consideration for LAW at Hanford and INEEL. There could be considerable uncertainty introduced in ORR schedules due to development and qualification lead time for a different type of waste form.

### **18.2.2 Is There a Basis to Assess What Technology Features Would be Most Cost Effective in Relation to Various Risks?**

No presentation on costs was given due to procurement sensitivities. (See the following sections covering recommendations and comments).

- (a) Which parts of the immobilization process most significantly affect costs?

No presentation on costs was given due to procurement sensitivities. (See the following sections covering recommendations and comments).

- (b) Are the technical bases for the waste form cost analysis sufficient for comparison of the waste forms versus the ORR privatization specification?

No presentation on costs was given due to procurement sensitivities. (See the following sections covering recommendations and comments).

### **18.2.3 Are ORR Needs Defined in a Manner that Allows Results from this Task to be Applied?**

Yes, however, ORR has asked vendors to propose processes and waste forms that could be used to immobilize all the low-activity tank waste on the site. The results from this task should be a key part of assessing the viability of vendor proposals and monitoring vendor performance. It is clear that requirements added by ORR related to onsite interim storage are more restrictive than for WIPP's waste acceptance.

- (a) Are there user performance requirements that should drive waste form selection or the selection process?

Yes, the privatization request for proposal calls out WIPP waste acceptance criteria and toxicity characteristic leach procedure requirements. The request for proposal also factors in the cost drivers. It is not clear to what extent requirements associated with meeting transportation regulations applicable to shipment to WIPP have been factored into the ORR request for proposal. There could be differences in the degree of difficulty associated with compliance that depend on the waste form.

- (b) This is a short-term implementation (~ 2 years). Is this a candidate for mobile units like the Transportable Vitrification System even though the waste form is expected to be "remote handled" TRU waste?

Yes, ORR demonstration projects for treatment of mixed wastes indicate that modular, mobile vitrification processing units are feasible. Contact maintenance has proven feasible when the system can be flushed to remove waste materials. Modular shielding will be necessary and waste form shielding will be necessary; waste form handling systems must be designed for remote operations. It must be noted, however, that the Transportable Vitrification System has never been operated with higher activity classifications of LAW.

- (c) Have all institutional/stakeholder or other constraints be identified and resolved (e.g., public acceptability of grout)? Are there other sites/applications for this work?

Not enough information was presented to answer the first part of this question. The ORR users did indicate that major efforts have been made to ensure public awareness of the plans for immobilization and disposal of ORR tank wastes.

For the second part, Hanford, INEEL, and SRS may benefit from waste form development and low-level waste information in planning of low-level waste immobilization. The experience with various formulations and the comparison methodologies developed for the ORR situation should also be useful in determining immobilization for other waste sources, such as mixed wastes, pond sludges, evaporator bottoms, etc.

### 18.3 Recommendations

1. Waste (or sludge) loading data needs to be stated on the same basis – either wet or dry weight of sludge oxide – whenever comparisons of waste forms are made. It could avoid confusion if a primary standard way of stating waste loading were adopted in the program. For example, using a dry oxides equivalent could be applied for both grout and glass, with loading of wet sludge of specified solids content stated as a secondary or supplementary indication.

**TFA Response:** Agree. The TFA will ensure that the reporting provides a consistent and/or understandable basis for waste loading if the TFA is comparing to contract specifications.

2. ORR should consider a limited, practical program of tank mixing or controlled sequencing of wastes from specific sources into the Melton Valley tanks. This should address the cost issues associated with decreased waste loadings for some waste sources due especially to Fissile Gram Equivalent limits. Early modeling to assess where limitations for glass/grout loading and related problems with ranges for glass/grout compositions might be quite cost effective. At the moment, the investigations on grout and glass formulations seem to be performing all ranges of waste loading, so there is probably some overkill and wasted time/money.

**TFA Response:** The final report will include the recommendation above. The direct application to ORR will depend on the technology selected by the ORR privatization, but some of the cost and mixing opportunities above could apply to other waste forms as well.

3. In view of the problems associated with tank sampling (limited risers, incomplete samples, etc.), the value of  $\pm 10\%$  composition variability selected by ORR program for processability studies has associated risks. Such risks should be assessed with the assistance of a qualified statistician. Performing a sensitivity analysis of a model is often used to determine how uncertainties in the model inputs are propagated to the model outputs. The results of the analysis are only valid when the input uncertainties are accurately characterized by accepted statistics, along with some mathematical form of an error distribution. The concern is that, due to the limited number of samples, some waste components might vary by far more than  $\pm 10\%$  from the nominal.

**TFA Response:** This recommendation is outside the scope of the current FY98 TFA program; however, the recommendation will be passed on to ORR for their consideration in their preparation of feed to privatization.

4. ORR should establish contacts with Los Alamos National Laboratory investigators, who are evaluating packaging for disposal at WIPP, to review the issues on hydrogen generation when water is present. The implications of this hydrogen issue for meeting transportation packaging and shipping regulations should also be evaluated.

**TFA Response:** This recommendation is outside the scope of the current FY98 TFA program; however, the recommendation will be passed on to ORR for their consideration in their preparation of feed to privatization.

5. Although the reviewers were not given specific cost information for the ORR waste form options, general discussion of important factors led to several recommendations. Be sure to include full capital and operating costs for vitrification and grouting equipment/facilities, based on experience from other sites.

**TFA Response:** Due to the limitation of funding on this task, a comprehensive cost estimate is not possible. However, the team will ensure that the cost estimate is sufficient to allow confidence in the comparison and in areas where specific costs dominate, the basis for the estimate will be included in the documentation.

6. Determine the actual waste form to be placed in canisters as soon as possible, e.g., will molten glass be cast into the canisters? This could drive the canister material from carbon steel (\$2,000) to stainless steel (\$10,000) with resulting cost increase.

**TFA Response:** Agree. This is extremely important; however, it is outside the TFA scope. The intent of the comment will be provided to ORR.

7. Factor cost for demonstrating compliance to WIPP acceptance criteria and transportation compliance into overall costs for each candidate waste form and process. Consider the cost of reworking or reprocessing a waste form that does not comply. Assess the costs of re-qualification(s), which may become necessary as waste feed compositions or formulations change.

**TFA Response:** This will be included in the final report due to limits of the available funding.

## 18.4 Comments

This session was well focused on the questions. It was an excellent series of presentations by the PIs under leadership of TIM Bill Holtzscheiter. It was helpful to have some ORR experts in the executive session to clarify issues.

The experimental designs employed are entirely appropriate, and the glass PI should be commended for seeking the help of a statistician. Building on the data set that has been acquired in this study to handle new situations that might benefit from the use of SIMPLEX (a statistical software package) optimization to find optimal regions of the multi-dimensional composition space. SIMPLEX has the

advantage of requiring fewer experiments and would be particularly effective for making changes to the first compositions already established by extensive experimental design.

1. Interest has been expressed in whether there might be a simpler process (than grout or vitrification) that could prepare ORR sludge for disposal at WIPP. Direct drying by wiped-film evaporator was evaluated in the early 1990s using surrogate sludge by EM-30. Toxicity characteristic leach procedure performance tests were not performed, but it is likely that this waste form would not have adequate leach resistance to qualify for temporary storage and shipping. There are some alternative waste form studies being performed for preparing Rocky Flats wastes for disposal in WIPP. TFA and ORR could check the Rocky Flats program (which has Pacific Northwest National Laboratory staff performing some waste form work) to see if any options might be of interest.

**TFA Response:** The alternative waste form work will be reviewed and included or referenced in the final report for ORR. In the initial phase of the design, the key variables were still being identified and funding limited the work to a phased approach that built on each year's accomplishment, which provided the justification for continued work. However, for future work, the TFA will test the SIMPLEX optimization for applicability.

2. It was stated that a commercial vendor would take over the contents of the Melton Valley Storage Tanks, yet it was not absolutely clear to the reviewers whether some final clean-out wastes would be part of this activity. Specifically, plans for "scabbling" the concrete walls of the gunite tanks were mentioned, but it was unclear how this or other "hard heel" residual materials would be combined with other wastes or transferred to the Melton Valley Storage Tanks. The potential implications for waste form processing of unique "scabbling" residues or tank heels should be clarified. Successful processing of these materials may require additional development work not in current plans.

**TFA Response:** This recommendation is outside the scope of the current FY98 TFA program; however, the recommendation will be passed on to ORR for their consideration in their preparation of feed to privatization.

## **19.0 Summary**

At the FY98 Midyear Technical Review, TAG members, site users, and independent reviewers provided detailed technical as well as programmatic comments on 17 of the TFA's technologies and site solutions. As appropriate, the comments will be incorporated into the program during FY98 and beyond.

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## **Appendix A**

## Appendix A

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