Independent Technical Review at Savannah River
A Key Step in Developing a Safe and Effective Path Forward

J.C. DeVine, Jr.
Polestar Applied Technology, Inc.
Washington Savannah River Company
P. O. Box A, Aiken, SC 29808
USA

R.L. Kaltreider
U.S. Department of Energy
19901 Germantown Road, Germantown, MD 20874
USA

L.T. Ling
U.S. Department of Energy, Savannah River Operations Office
P. O. Box A, Aiken, SC 29802
USA

V.G. Dickert
Washington Savannah River Company
Building 766-H, Aiken, SC 29808
USA

ABSTRACT

Radioactive Liquid Waste Tank 48 at the Department of Energy Savannah River Site (SRS) is interconnected with the site tank system and integral to the removal and processing of high level waste in the years ahead. The tank is currently isolated from the tank system and unavailable for use because the salt solution within the tank contains Cesium and other radioisotopes contaminated with significant quantities of tetraphenylborate (TPB) which can release benzene gas in the tank space and produce a potentially flammable condition. The purpose of the Tank 48 Independent Technical Review (ITR) was to assess the viability of the preferred technical path forward for resolution of the TPB problems and ultimately, a return of the tank to service. The review team consisted of a well balanced mix of academia and industry experts tasked to perform detailed reviews of the technology approach alternatives and down selection process, and identify technical as well as programmatic risks attendant to those alternatives.

INTRODUCTION

For over ten years, one of the large high level waste (HLW) storage tanks at Savannah River Site (SRS) has been unavailable for use in processing and disposition of high level waste because it contains significant quantities of tetraphenylborate (TPB). In an effort to select a safe, technically sound, and practical solution to this problem, the U.S. Department of Energy (DOE) and the Washington Savannah River Company (WSRC), the prime contractor at SRS, assembled a team of experts to conduct an independent technical review and to recommend a course of action.

DISCUSSION

The Problem, in Summary

Safe management, retrieval, processing and ultimate disposition of the ~36 million gallons of high level waste at SRS is a matter of very high priority to the local community, to the State of South Carolina and to the U.S. Government. With DOE, the South Carolina Department of Health and Environment and Control

(SCDHEC) and the U.S. Environmental Protection Agency (EPA) are signatory to a Federal Facilities Agreement (FFA) which commits to an aggressive schedule for emptying and permanent closure of non-compliant SRS HLW tanks by 2022.

Tank 48[a] is a large (1.3 million gallon tank), one of the "new style" tanks at SRS with full secondary containment, located and interconnected within the tank system such that it will play a very important role in removal and processing of HLW in the years ahead. However, the tank is currently isolated from the system and unavailable for use, because its contents - approximately 250,000 gallons of salt solution containing Cesium and other radioisotopes - are contaminated with significant quantities of TPB, an organic material which can release the benzene vapor into the tank.

Tank 48 has been in that condition since 1995, when the TPB was added (as part of a salt processing system called In-Tank Precipitation). While there have been numerous studies and plans for removal of the tank contents, none has been selected for implementation to date.

Plans for SRS HLW processing, as needed to meet FFA commitments, call for return-to-service of Tank 48 by January 2010, an aggressive schedule that places very high importance on successful resolution of the TPB problem. Early in 2006, WSRC established a Tank 48 path forward comprising development and application of one of two processes - Fluidized Bed Steam Reforming (FBSR) and Wet-Air Oxidation (WAO) - with a third method, called Aggregation, as a backup. Each of these methods, however, was recognized to present significant technical challenges, so timely success was not assured.

In light of the importance of successfully resolving the TPB problem, in a way and on a time frame that supports overall SRS commitments for tank closure, WSRC recommended and DOE directed the establishment of a formal Independent Technical Review to examine the problem and its planned resolution, to identify technical and programmatic risks, and to formulate recommendations to maximize prospects for success.

Structure and Approach

Early in the planning phases, an ITR Charter was developed and approved by DOE and WSRC. The Charter outlined the objectives of the Tank 48 ITR, the size and requisite capabilities of the ITR team, the methods to be employed, and the evaluation time frame. Included in the Charter are eleven lines of inquiry, addressing specific issues to be addressed by the ITR team.

The Tank 48 ITR team consisted of eleven members, with extensive collective experience and capabilities in chemistry, chemical engineering and nuclear management. Seven members are currently or retired senior scientists, engineers or executives and four are university professors. Several members have had some professional involvement at SRS, but individually and collectively the team fully met the "independence" criterion established in the ITR Charter.

The ITR team convened at SRS on June 6, 2006. Over the subsequent ten weeks, team members reviewed extensive documentation of previous WSRC work on this issue, were briefed by or interviewed WSRC personnel, toured the tank site, conducted literature search for information pertinent to the problem, visited facilities where equipment comparable to that anticipated for use at SRS was being operated or tested, and participated in numerous inter-team discussions on this topic.

In the course of its work, the ITR team conducted detailed reviews of the methods and processes (including backups) comprising the current WSRC path forward for Tank 48, along with several alternative approaches. They identified technical and programmatic risks attendant to each, and on that basis formulated a recommended course of action.

The Tank 48 ITR team completed its work and issued its formal report[1], with conclusions and recommendations, on August 10, 2006, as scheduled.

---

[a] The tank's full designation is 241-48H, indicating its presence in the H-Area Tank Farm. For simplicity it is referred to herein as "Tank 48".

Technical Issues

There were two major sets of technical issues confronting the ITR Team, including the selection of an effective primary treatment process for the TPB-contaminated material in Tank 48 and the broader set of issues germane to reuse of the tank such as method for removal and disposition of the residual heel, the criteria for release of tank for other service, and the compatibility of the current plans with FFA schedule commitments.

Regarding treatment processes, the ITR team first reviewed the prior WSRC work in down-selecting several preferred concepts from a very wide range of candidates. The team agreed with the WSRC selections, and from that point applied its primary attention to the three methods considered most viable by WSRC, as follows:

Fluidized Bed Steam Reforming (FBSR)

In principle, steam reforming thermally reacts a high sodium content slurry and potassium tetraphenylborate followed by oxidation of off-gases. The reaction takes place between solid and gas phases in a series of two fluidized beds, the first operating at 650-725C and the second at 800-900C (both at one atmosphere). Steam reforming under the planned operating conditions will normally produce exhaust gas (predominantly CO_2, N_2 and H_2O) and a solid product (predominantly $Na_2CO_{3,}$).

Energy is provided to the fluidized bed reactors in the form of a solid fuel (e.g., coal), with residual fuel or carbon compounds potentially remaining in the solid product. The solid product then would be slurried through addition of water and transferred for blending with other wastes as feed for vitrification, via the SRS Defense Waste Processing Facility (DWPF). Additional processing may be required if residual elemental and organic carbon in the solid product is not in sufficiently low concentration to meet limits imposed by DWPF processing requirements.

Wet Air Oxidation (WAO)

Wet air oxidation removes organic constituents from the feed slurry through oxidation at lower temperature but higher pressure. Wet air oxidation is typically operated at approximately 300°C and 100 atm. Oxygen or air is injected to the process, resulting in three phases within the reactor: gas, solid (from insoluble components in the waste feed), and aqueous solution.

The extent of oxidation of organic constituents depends on operating conditions, with residual organic constituents that may include benzene, phenol and acetates. The primary process effluents are exhaust gas and an aqueous slurry. The aqueous slurry effluent from wet air oxidation may require further treatment if the concentrations of organic constituents exceed limits imposed by DWPF processing requirements. High pressure reactor conditions are a concern because high pressure operating conditions are not common at SRS.

Aggregation

The third method evaluated by the ITR team has been termed Aggregation. Aggregation is not a processing method per se, but rather a disposition alternative by which the TPB-contaminated material from Tank 48 would be blended with other waste streams suitable for on-site disposal in solid (cement-based) form in the SRS Saltstone facility. Although such an approach could be attractive from a schedule standpoint, it would effectively constitute permanent disposal at SRS of a substantial amount of radioactivity (~400,000 Curies of Cs-137). For that reason it is considered acceptable by DOE and the State of South Carolina only as a backup approach for potential use in the event that no other viable processing method is found.

The ITR team also examined numerous other technical issues related to the removal of TPB from Tank 48, and the cleaning and release of the tank for reuse, including the following:

Pre-Concentration of Processing System Feed

The team identified potentially significant advantages to concentration of the Tank 48 material prior to processing and/or temporary staging. The Tank 48 bulk contents could be concentrated by a factor of about three (form ~3 wt. % to ~10 wt%) using well understood and readily available filtration systems. Increasing the concentration of the material to be processed could improve processing efficiency and shorten overall processing time, and it would also allow staging of the total quantity of Tank 48 bulk material in a substantially smaller tank (less than 100,000 gallon capacity).

Heel Management

Heel management - the sequence of tasks necessary to remove the residual material (the bottom ~2") from Tank 48 after bulk material removal, followed by tank flushing and cleaning to render that tank suitable for reuse - presents both significant technical challenges and uncertainties. Moreover, it is the last major step on the critical path to tank release, and therefore the potential adverse schedule impact of risks and uncertainties is magnified.

The ITR team examined a variety of methods for tank flushing and cleaning and options for disposition of the heel and tank flush fluids.

Criteria for release of Tank 48 for Reuse

A central element to successful heel management is the establishment of end point criteria for Tank 48 cleanliness that are both appropriately conservative (in terms of effects of tank residuals on down-stream receivers) and practically achievable. The team assessed the achievability and technical and schedule implications of the current limit for residual TPB (12 Kg), and developed a rationale for an alternative limit.

Processing Sequence and Timing

The team evaluated the likelihood that the January 2010 schedule could be met based on current SRS HLW processing plans and the significant technical challenges involved. The team then examined alternative approaches, particularly with respect to sequence and timing of key steps.

The current Tank 48 path forward is essentially sequential - a processing system is designed, built and tested, the bulk material is then removed and processed, after which the tank heel is removed. The tank is then cleaned and once it is demonstrated that the cleanliness criteria have been met, the tank is released for further use. This approach is simple and straightforward, but the composite of complex sequential tasks and schedule risks associated with each will make it difficult, if not impossible, to achieve the 2010 schedule.

In concept, an earlier Tank 48 return-to-service could be achieved by taking the TPB processing task - a multi-year duration activity involving significant technical challenges and uncertainties - off the critical path. This "parallel" approach would involve removing the bulk tank contents from the tank as soon as possible to a different storage location (one or more tanks) that would serve as the feed system for subsequent processing. From that point, the heel removal and tank cleaning activities could proceed independently and in parallel with the TPB processing work.

In comparison with the current sequential processing strategy, the parallel path approach offers high potential for both schedule acceleration and schedule risk reduction - but it would require a technically suitable interim storage location for the TPB-laden waste material currently in Tank 48. Such a location is not readily available. The ITR team evaluated both the prospects and implications of this approach, in comparison with the current path forward.

ITR Conclusions and Recommendations

In its formal report, the ITR team articulated numerous conclusions and recommendations. Among the foremost of these:

1. Selection and Implementation of a Tank 48 Processing Technology

   The ITR team judged FBSR to be the most mature of the candidates, particularly for radioactive material applications, considering the advanced design work for FBSR remote operations currently in-progress for treatment of sodium bearing tank wastes at Idaho National Laboratory. Its processing products meet SRS needs. While adaptation and testing for the Tank 48 requirements is needed, the team found no fundamental obstacles to success.

By comparison, WAO is also a strong candidate, but it is less developed than FBSR for this application and is lacking demonstrated performance in radioactive material processing. Its very high pressure operating regimen also poses a challenge. None of these obstacles is considered by the ITR Team to be insurmountable, but it is the team's judgment that it would take longer (in comparison to FBSR), by a year or more, to achieve WAO operational status at SRS.

On that basis, the ITR team concluded that FBSR is the preferred method for bulk treatment of the Tank 48 material, and recommended specific tasks that should continue, on a high priority basis, to confirm its viability. Wet air oxidation should be carried as a backup, but developed only to the degree necessary to confirm its technical viability.

Also based on the strong prospects for both FBSR and WAO, the ITR team recommended that Aggregation no longer be considered as a primary treatment method. The team did consider disposition via Saltstone to be a suitable tank heel and/or flush liquids, given the relatively small curie and TPB content involved, but recognized that even that approach may not garner DOE or SCDHEC acceptance.

2. Pre-Concentration of Tank 48 Wastes

   The team recommended further technical evaluation of concentration mechanisms, for use if beneficial, depending on other aspects of the selected path forward.

3. Heel Management

   The ITR team recommended that heel removal and tank cleaning be accomplished by means of a flushing regimen involving an initial series of water flushes, followed by a second series of flushes with salt solution chemically similar to the solutions to be reintroduced to the tank after it is returned to service. Depending on the observed effectiveness of those flushes, a third flushing step, utilizing stronger chemical cleaning solutions, may also be necessary.

   The team also recommended that the effluent liquids from the initial water flush be collected for treatment via the same system (steam reforming with pre-concentration) to be employed for bulk TPB processing and that consideration be given to treating and disposing of subsequent flushes via Saltstone.

4. Criterion for Tank Return-to-Service

   The ITR team proposed a fundamentally new end point model wherein the tank could be accepted for return to service based on demonstration that TPB concentration in salt solution flush effluents (as distinct from quantities of material remaining in the tank) are lower, with substantial margin, than levels that could cause flammability or other problems for downstream processes.

5. Processing Sequence and Timing

   It was the team's collective judgment that January 2010 is not realistically achievable by the sequential processing approach currently envisioned by WSRC, utilizing either FBSR or WAO as a primary processing technology. The team believes that Tank 48 return-to-service by one year or longer after that date is a more likely outcome.

   However, recognizing that HLW processing plans involve some inherent unpredictability, it may be possible to meet FFA tank closure commitments with a Tank 48 return-to-service a year or more later than the currently projected need date of January 2010. In that the team was not in a position to judge the implications or acceptability of a schedule slip of that magnitude (nor was that evaluation part of the team's charter), the team noted that WSRC and DOE management must make that call based on regulatory, stakeholder and other programmatic considerations.

   On that basis, the ITR team presented a conditional recommendation regarding sequential vs. parallel path processing. If it is desired by management to maximize chances of achieving Tank 48 return to service by January 2010, the team recommended that the parallel approach be adopted, with an immediate high priority action to select the optimal feed tank system (i.e., modification of an existing tank or construction of a new one).

The team's alternative recommendation, if returning Tank 48 to service a year or more later than January 2010 is considered tolerable by DOE and WSRC management, is to continue with the present course (sequential strategy), with resource allocation and project management actions directed to addressing the SR technical and programmatic risks and accomplishing the development work needed for rapid implementation of FBSR at SRS, as outlined in the report.

Follow-up Work

Immediately following the ITR team's issuance of its report, with attendant presentations and discussions, WSRC embarked on a process of systematic consideration and decision-making regarding the report's conclusions. This culminated in (1) the preparation of a response plan to the ITR recommendations that was approved by DOE and (2) production and issuance of key WSRC documents identified in the response plan, addressing specifically the key elements of the ITR team's recommendations and the Tank 48 path forward.

Two ITR members, the chairman and the leader of the Processing Technology sub-team, were engaged to review and provide comments on the response plan and the subsequent WSRC documents. A DOE team is currently reviewing the resultant WSRC documents and recommendations.

ITR Lessons Learned

In principle, the ITR approach is not new; but in several respects, the approach employed at SRS to address the Tank 48 problem was a departure from previous practice. The following are some of the key elements in the SRS Tank 48 ITR process, which are considered by the ITR team and the authors to have been particularly pertinent to its success:

1. <u>Prior planning and agreement</u>

   DOE requested, and WSRC prepared, a detailed up-front plan for the ITR. The plan addressed all aspects of the effort including the ITR Charter, team members, initial lines of inquiry, schedule, and milestones. The planning document was discussed extensively and approved jointly by DOE and WSRC senior SRS management. This step proved invaluable in setting clear and mutual expectations for the effort, from the outset and served as a guide and template for the ongoing work.

2. <u>Small, diverse and carefully selected team</u>

   Based on careful tabulation of needed skill-sets and screening of identified candidates, an eleven-person team was selected. This relatively small team size added to the workload of the individual team members, but it permitted very effective interactions and communications among team members and with WSRC personnel.

3. <u>Aggressive, well planned and managed schedule</u>

   The schedule set for the Tank 48 ITR was ten weeks, from first meeting to issuance of final report. This was very aggressive - to the point considered unrealistic by some. It required participants to commit to availability for essentially the entire review period.

   The ITR team achieved this schedule, issuing its final report on the exact date planned at the outset. And although challenging, the aggressive schedule actually proved to be beneficial in several respects. It kept all members engaged, from start to finish, with none of the "spin-down" / "spin-up" inefficiencies common to more protracted efforts. The schedule established specific actions and objectives for every week, both during team on-site weeks (four of the ten weeks) and the intervening off weeks. And, because the schedule was established at the outset, and then adhered to throughout, accountabilities and expectations were clear from start to finish.

4. Lines of Inquiry (LOIs) that are meaningful and flexible

   An initial set of LOIs were established and approved to set the baseline for the work, but the ITR charter also called for the ITR team to evaluate the LOIs and propose expansion or refinements as needed. This approach took full advantage of the team members' experience and preempted the possibility of unintentionally omitting some key aspect of the issue resolution. As a result, two new LOIs were added after the review was begun.

5. Real-time assembly of report

   The initial outline for the ITR final report was developed during the very first ITR first meeting, and it became a living document, serving as the structural framework for the entire effort. Draft material was then produced and reviewed by the team throughout the course of the review.

   The benefits of this approach are substantial. It engaged the entire team throughout the effort, yielding feedback and feed forward on a continuing basis, and it secured team concurrence (and revealed unexpected disagreements or uncertainties) on a real-time basis.

6. Open, interactive process

   As standard practice, the ITR team conducted its work in fully open meetings and working sessions. DOE and Defense Nuclear Facilities Safety Board (DNFSB) representatives were welcome to observe all ITR activities and often did so. Also, the ITR made several mid-review progress reports to DOE management. These practices enhanced customer understanding and confidence in the ITR conclusions.

CONCLUSIONS

The ITR process employed for the SRS Tank 48 work was an adaptation of an approach proving to be more and more useful around the DOE complex. It applied elements that have been used successfully in other jobs, with refinements to meet SRS specific needs.

The ITR validated the WSRC path forward in most respects, but pointed out several areas warranting higher attention or redirection. The ITR recommendations were subsequently reviewed and are being considered by WSRC and DOE.

In summary, the SRS process yielded a very successful review - efficient, effective and unusually fast - and therefore deserves consideration for use in other applications.

REFERENCES

1. Washington Savannah River Company, 2006. *Independent Technical Review (ITR) of the Path Forward for Savannah River Site (SRS) Tank 48*, ITR-T48-2006-001, Revision 0, August.