Assessing Technological Readiness and Maturity on the Waste Treatment and Immobilization Plant - 8271

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ABSTRACT

There are many challenges in the design and construction of Department of Energy's (DOE) Waste Treatment and Immobilization Plant (WTP) at the Hanford site. The plant is being built to process some 53 million gallons of radioactive waste from 177 underground tanks. Engineering and construction are progressing on this largest project in the DOE complex. The technologies employed to accomplish the waste processing and immobilization have undergone various levels of development over a number of years. In some cases, the treatment approach involves extrapolation or novel applications of existing technologies. Because of the time schedule for the WTP, it is desirable, in some cases, to mature the technologies in parallel with design and construction. From the outset, the project plan has included an assessment and adjustment of the performance and design of the key technologies through an extensive research and testing program.

This paper describes two review programs pioneered on WTP to further assess the technical readiness and maturity of the design: an External Flowsheet Review process and a Technology Readiness Assessment process. Although the results of the two reviews have a good degree of similarity, the two approaches differed in a number of ways and therefore allowed some issues to surface in one review and not in the other. It is concluded that the two reviews provide greater confidence to DOE on the readiness to proceed with design, fabrication, and construction and that the facilities will function as performed.

INTRODUCTION

On the Hanford site, a few miles west of the Columbia River 53 million gallons of radioactive and chemical waste from cold war plutonium production are stored in 177 underground tanks. At least a million gallons of this waste has leaked. Design and construction of the world's largest radioactive waste treatment plant is underway to immobilize the waste into glass and place it in stainless steel canisters for safe and permanent disposal.

The WTP is comprised of three main facilities: the Pretreatment (PT) facility performs separation and concentration of the waste received from the underground tanks. The High Level Waste (HLW) vitrification facility immobilizes the high level fraction of the waste in glass using melters. Similarly, the Low Activity Waste (LAW) facility vitrifies the low-level waste fraction. A large separate analytical lab performs all the process chemistry analyses necessary to ensure good glass is being produced.

Construction on the facilities started with first concrete pour for LAW in July 2002. Design is currently about 75% complete and construction is about 40% complete. The WTP is planned to be commissioned in 2019.

The project design/build plan included development of key parts of the process design in parallel with design and construction of the plant. This approach was taken to support the established schedule to bring the facility online and start reducing the hazards posed by the waste. At the beginning of this phase of the project in 2001, an assessment of the advanced conceptual design that had been supplied by DOE to the WTP contractor, Bechtel National, Inc (BNI), was made as part of a due diligence activity. BNI also commissioned a “challenge team” to look at the project plan and design. These reviews helped assess uncertainties in the technologies to be deployed, among other things. Going forward, the project published a technology roadmap and a research and technology (R&T) plan that outlined the necessary testing required to confirm and advance the design. Although considered largely confirmatory, the R&T work also provides input to the design, and in some cases, results in adjustment of the design. As the project proceeded, internal design reviews, regulatory reviews, and DOE design oversights helped to continue to confirm the adequacy of the design and to identify areas where added attention and activity is warranted. As new issues or requirements are identified testing, analysis, or evaluation work is added to the project scope.

In the fall of 2005, DOE tasked BNI with commissioning an external flowsheet review team (EFRT) to review the design of the facilities. The overarching intent of the review was to provide further assurance that the right facility was being designed and built and that any significant gaps in the R&T program, design, or commissioning/operations were identified and addressed as construction proceeded. About a year later, and after the EFRT effort had been completed, DOE began another, similar review, using a different approach, the Technical Readiness Assessment (TRA) methodology developed by the Department of Defense (DOD) (and later advocated by the Government Accountability Office (GAO)). A comparison of the two programs is provided in Table I below.

TABLE I: COMPARISON OF WTP TECHNOLOGY REVIEW PROCESSES

	EFRT	TRA
Management	Contractor	DOE
Type	External, independent	External, independent
Focus	Critical technical elements	Critical technical elements
Quantitative assessment	No	Yes, rule-based
Scope	Broad: technology selection, R&T design, procurement, commissioning, operations	Narrow: design and supporting R&T
Membership	Industry, national labs, academia	DOE staff and consultants supported by WTP Contractor staff
Number of reviewers	40	5
Duration of review	6 months	6 months

EXTERNAL FLOWSHEET REVIEW

BNI initiated a comprehensive Flowsheet Review as requested by the Department of Energy Office of River Protection (DOE/ORP). A team of nationally recognized technical experts was assembled. Since WTP is a radiochemical processing facility, the review team was largely populated by those who had chemical plant experience and/or radioactive operations experience. Primary areas of interest were analytical modeling, systems design for waste evaporation, ion exchange, waste filtering, and the spatial arrangement and features of the PT and HLW black cells and hot cells. Several spatial model (3D) reviews were made depicting the mechanical handling components of the PT and HLW cells. Both HLW and LAW melters, melter maintenance, the canister and container finishing line design were areas of focused review. The final report was issued in March 2006 [1]. A complete description of the review is given in Reference [2].

The initial technical areas reviewed were based on a judgment of the key operations and processes in the facility, and the judgment of the relative risk represented in the selection criteria. Since the EFRT was independent, it was not constrained by the initial topical areas, and other areas could be added. As an example, the potential for line plugging by from transfers of the high solids process streams surfaced during the review and was identified as a major issue to be addressed.

The EFRT was asked to report back on whether the flowsheet, as a result of its design implementation (technology, operability/maintainability, and engineering) was adequate to meet the contract throughput requirements.

The EFRT reported out 17 major issues and 11 potential issues that would in their opinion prevent the plant from meeting DOE specified waste treatment rates. Not all the issues were technical: about one-half the issues related to commissioning, operations or other non-design topics. Table 2 summarizes the issues.

TABLE 2: CATEGORIZATION OF ISSUES IDENTIFIED BY THE EFRT

Technology/Design	Commissioning	Operations	Miscellaneous
Line plugging (M)	Limited remoteability demonstration (M)	Feed variability (M)	Critical equipment purchases (M)
Erosion (M)	Comprehensive feed testing (M)	Feed prequalification (M)	Loss of WTP expertise base (M)
Pulse jet mixing (M)	Plugging of film cooler (M)	Process operating limits (M)	Incomplete process control design (P)
Inadequate ultrafilter area and flux (M)		Inconsistent long-term focus (M)	
Undemonstrated leaching process (M)		Availability (M)	
Instability of baseline ion exchange resin (M)		Mis-batching of melter feed (M)	
Undemonstrated evaporator DF (P)		Inadequate ion exchange process development (P)	
Recycle effect on evaporator capacity (P)		Potential gelation/precipitation (P)	
Adequacy of evaporator control scheme (P)		Glass formers analysis at silos (P)	
Questionable ion exchange column design (P)			

Questionable ion exchange cross-contamination control (P)			
Complexity of ion exchange valving (P)			
Undemonstrated sampling system (P)			

(M) - major issue (P) potential issue

It is interesting to note that the EFRT did not identify any misapplied or unfamiliar technologies or new, first-time process chemistry applications. They did identify risks in scale-up of selected technologies and heavy reliance on modeling.

TECHNOLOGY READINESS ASSESSMENT

In the fall of 2006, DOE/ORP began a technology readiness assessment (TRA) of the WTP, complementing the prior EFRT work described above. The process used was an adaptation of a process developed by the DOD for development and acquisition of major and technically advanced defense systems. Later, in a report, the GAO has assessed the relationship between technological maturity and project cost growth and schedule extension in 12 DOE projects, and concluded that implementing immature technology in the design was part of the reason for cost growth [3]. The WTP was included in the GAO assessment.

The first step in the TRA process was to adapt DOD concepts to DOE waste treatment design-build projects. This recognizes that major DOE projects can, and must, complete the process technology development and confirmation process while the project proceeds with design and construction to achieve a reduced schedule objective. The TRAs performed by DOE/ORP were patterned after the methodology described in Reference [4]. The principal steps were as follows:

- Identification of critical technology elements (CTEs)
- Completion of a technology readiness level (TRL) assessment of each CTE
- Development of a Technology Maturation Plan (TMP) for technologies with a TRL less than 6 TRAs for the 3 major facilities were reported in References [5] through [7]. The TMP was published in Reference [8].

The technology readiness level scale is provided in Figure 1 below. The DOE goal is to mature technologies to a TRL 6 prior to initiation of design:

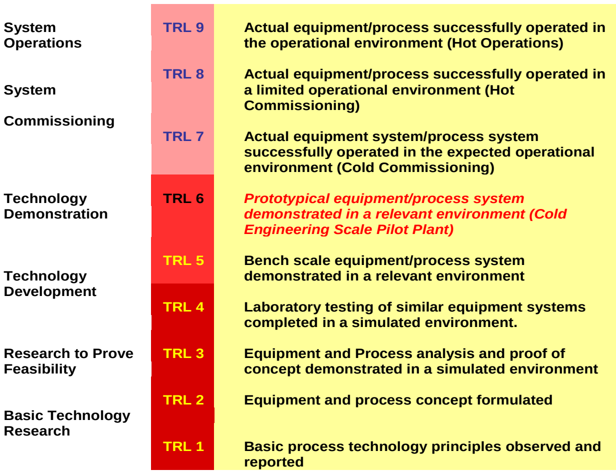

Fig. 1. The Technology Readiness Level Scale is defined at a Summary Level in the above diagram.

The TRA process review identified 186 potential CTEs, of which 21 were selected for detailed evaluation. That review identified 8 technologies (4.3%) that needed further maturation. These are listed below along with the currently assessed TRL and associated facility:

- Rapid analysis of radioactive waste samples (TRL 5, Analytical Laboratory)
- Waste solids separation and treatment (ultrafiltration and leaching) (TRL 3, Pretreatment)
- Radioactive cesium removal by ion exchange (TRL 5, Pretreatment)
- Cesium and nitric acid management (TRL 3, Pretreatment)
- Waste slurry mixing (TRL 4, Pretreatment and HLW)
- HLW melter offgas (TRL 5, HLW)
- LAW container closure (TRL 5, LAW)
- LAW container decontamination (TRL 4, LAW)

DOE, with the assistance of the WTP contractor, prepares a technology maturation plan that defined the activities, schedule and costs to mature the CTE's identified above. The detailed plans for maturing the technologies were included in issue response plans, with the same scope and content as those prepared and approved to resolve the 28 EFRT issues.

Of the 8 items above, the existing ongoing R&T efforts for the first two were considered adequate to advance the maturity to level 6. For the remaining six items, issue response plans were prepared to identify the actions, estimated cost, and schedule to resolve the issue. All of the technologies will have achieved a TRL of 6 well before the equipment is required in the field.

A value engineering (VE) approach was used to define the technology maturation strategies. In the TRA process the existing performance criteria was not questioned; instead the TRL was assessed against the issued and approved criteria In the VE effort, the performance criteria was reevaluated as a potential strategy to rapidly mature the technologies thereby reducing the project risk and potentially reducing the requirement for additional testing or re-work of the design..

It should be noted that the assignment of TRLs was based on an approach wherein not satisfying all criteria to qualify for a given TRL results in the assignment of the next lower level. On that basis the maturation of a TRL may not involve as significant an effort as might appear from the specific TRL scores.

All of the technologies will have achieved a TRL of 6 well before the equipment is needed in the field.

COMPARISON OF RESULTS

Table IV lists the technologies assessed in the EFRT and TRA reviews as well as other key technical topics.

TABLE IV: COMPARISON OF TECHNOLOGY REVIEWS AND PROGRAM PLANS

	Technical Development Needs Addressed or Added		
Technology/Topic	R&T Program	EFRT	TRA
LAW container closure[a]			Yes
LAW container decontamination[a]	Yes		Yes
LAW melter feed[a]	Yes		
LAW melter[a]	Yes		
LAW melter off-gas[a]	Yes		
Laser ablation/inductively coupled plasma/atomic emission spectrometer[a]	Yes		[b]
Autosampling[a]	Yes	Yes	
HLW melter f[a]eed[a]	Yes		
HLW melter[a]	Yes		
HLW melter offgas[a]	Yes		Yes
HLW and Pretreatment radioactive drains[a]			
Newtonian waste pulse jet mixing[a]		Yes	Yes
Non-newtonian pulse jet mixing[a]	Yes		
Cesium nitric acid recovery[a]			Yes
Cesium ion exchange[a]	Yes	Yes	Yes
Waste feed evaporation[a]	Yes	Yes	
Waste feed receipt (exclusive of pulse jet mixing)[a]			
HLW feed storage and blending (exclusive of pulse jet mixing)[a]			
Ultrafiltration and leaching[a]	Yes	Yes	[b]
Treated LAW evaporation	Yes		
Erosion resistance beneath pulse jet mixers		Yes	
Line plugging		Yes	
Antifoam agent performance	Yes		

[a]CTE in the TRA process
[b]Identified as requiring further maturation, but existing R&T/EFRT plans are adequate to address.

As can be seen, both the EFRT and TRA reviews identified areas that were believed to require additional work to adequately develop the technology or design. In some cases, the TRA review identified activities beyond what the EFRT response entailed. It should be noted that resolution of technical adequacy or maturity issues does not necessarily require testing in the R&T program; a number of issues are being addressed through analysis and studies. In some notable cases, such as melter performance, no gaps beyond the R&T program were identified.

The EFRT review went well beyond examination of technologies and designs and, as noted above, found areas in commissioning and operations that it believed needed to be addressed. The TRA and R&T format and process would not have identified those items.

CONCLUSIONS

The challenge to developing and finalizing key technologies in parallel with design and construction is significant, particularly for a project as advanced and complex as the WTP. A well thought-out R&T program, along with ongoing design and technology reviews, is a must. The EFRT and TRA experience on WTP demonstrate that these two types of diverse external reviews can be valuable in confirming that the technologies have been adequately developed before implementation and in identifying gaps where more attention is needed to provide reasonable assurance of successful plant operation.

REFERENCES

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