A Risk Management Approach to Nuclear Waste Inventory Versus Storage Capacity

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**A RISK MANAGEMENT APPROACH TO NUCLEAR
WASTE INVENTORY VERSUS STORAGE CAPACITY**

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ABSTRACT

Nuclear waste is presently stored in 177 underground storage tanks at the U. S. Department of Energy's Hanford Site in Washington State. The storage tanks are of two construction types, 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs). No waste has been added to the SSTs since 1980. However, the DSTs are configured to receive additional waste from site waste generators. The overall waste inventory is time dependent and strongly influenced by present and future tank farm operations. These operations include waste evaporation, retrieval, pretreatment, and processing; waste generated from various site facilities; and SST waste inventory transferred to the DSTs.

A risk-based simulation model was developed to replicate the waste inventory through the year 2015. The DST wastes were divided into three waste types (aging, complexed, and non-complexed) that were simulated in the model. For each of the three waste types, statistical analyses were performed and the time-dependent waste volumes at the "mean" and "90% confidence level" were compared with existing DST capacity. Several "off-normal" operation scenarios were also analyzed using the risk-based simulation model. Mitigating actions or fallback positions were modeled where off-normal scenarios indicated that capacity shortfalls could potentially occur. The results indicated that selected fallback positions were adequate to ensure that the storage capacity exceeded the waste inventory during the affected time periods.

Key Words: Risk-Based Simulation Model

1.0 INTRODUCTION

The Westinghouse Hanford Company's (WHC) Tank Waste Remediation System (TWRS) has traditionally projected double-shell tank (DST) waste storage capacity and waste volume (generation, reduction, and disposal) using deterministic techniques (Ref. 1 and 2). A recent study (Ref. 3) evaluated the Path Forward for the 200 West Area of the Hanford Site using risk-based techniques. The results indicated that waste volume uncertainty could be significant and that a large likelihood exists that adverse conditions, such as leaks, facility upsets, and/or cross-site transfer line failure may result in the need for more free tank space than is currently projected. Based on the results of this 200 West Area risk-based study, TWRS Engineering determined that the entire DST system capacities and waste volumes (both 200 East and 200 West) should be modeled using risk-based techniques to assess risks associated with limited DST waste storage capacity.

This report describes a risk-based methodology that was developed and utilized to evaluate the waste volume versus DST waste storage capacity. The objectives of the risk assessment were, (1) develop a risk-based waste volume versus storage capacity risk assessment process, and (2) demonstrate the risk assessment process, including the use of fallback positions. The scope of the risk assessment focused on a 20-year window (including 10 years to account for lead time for required actions) to support management decisions that might affect either the waste volume or DST capacity.

The following acceptance criteria was utilized in the analysis: *The risk-based waste volume projections through the year 2015 shall be less than or equal to the storage capacity (including handling capabilities and fallback positions) for each of the segregated waste types analyzed with at least a 90% confidence level.*

Risk-dominant contributors with associated uncertainty were identified for both the waste volume projections and the waste tank storage capacity for a base case and selected upset or off-normal conditions. Appropriate fallback positions (management actions) were developed that could be implemented to alleviate the impact of the risk-dominant contributors to the waste volume.

2.0 FUNCTIONAL FLOW DIAGRAM

A functional flow diagram was developed to form the basis of the simulation modeling effort. The first level of the functional flow diagram (Figure I) is very general and was used to establish the basic elements to be considered in the simulation model. A second, and in some instances, a third level of detail was added to the functional flow diagram but they are not shown.

The main part of the waste storage system is 28 DSTs; 3 in the 200 West Area and 25 in the 200 East Area. Also included in the system are the 200 West Area and 200 East Area transfer lines, and the cross-site transfer line. Two DSTs are used as staging and receiving tanks for the evaporator and waste disposal activities.

Figure 1. Functional Flow Diagram of the Double-Shell Tank Waste System.

3.0 SIMULATION MODEL

3.1 Simplified Model

The first step in the simulation study was to build a simple model that captured the essence of the problem to be considered without being overly complicated. The results of the simple model were then used to guide development of, and provide validation for, a more exacting simulation model using Minuteman Software's GPSS(*) simulation computer modeling language.

One of the significant results of the simple model is that uncertainty in waste generation and waste loss information increases with time such that there is an increasing likelihood that specific action will be required in out-years to avoid having the waste volume approach available waste storage capacity. Decisions whose actions would require 8 to 10 years to implement must be made based on increasingly more uncertain information. Therefore, it is essential that uncertainty related to waste generation and waste loss information be considered in detailed simulation analysis.

3.2 Simulation Model

Three separate, related models were developed for waste types that were considered to have the greatest effect on managing future waste storage requirements. The waste types were: (1) high-heat, or aging waste, (2) complexed waste, and (3) all remaining waste, included as non-complexed waste.

(*)GPSS is a registered trademark of Minutemen Software, Stow, MA.

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A simulation model was developed in GPSS to approximate the actual flow patterns existing in the 200 Area tank farms (see Figure II). In summary, Figure II shows 200 West and 200 East Area elements, including SSTs and facility waste sources. The AR-204 Unloading Station is shown to indicate that there are multiple pathways for waste to enter the DST system: some hard-piped and some using rail or truck transportation. Transfer piping segments are also included in the model.

Waste removal pathways in the model include the 242-A Evaporator, through the Liquid Effluent Retention Facility, to the Liquid Effluent Treatment Facility, and the pretreatment and vitrification pathway. The slurry return from the evaporator is also included in the model.

The principal assumptions for the GPSS model are:

- Inflow (25 waste generation streams) and outflow (evaporation, pretreatment, and vitrification streams) are based on the Operational Waste Volume Projection, Rev. 21 (Ref. 2) data.
- Transactions are generated within the model to simulate discrete volumes of waste moving through TWRS functional systems, such as the 200 West Area transfer lines, the 200 East and 200 West Area DSTs, cross-site transfer lines, AR-204 Unloading Station, the Evaporator, and disposal systems.
- A quarter-year time step was used to allow mid-year changes to be modeled (e.g., Evaporator campaigns of less than a year-long duration).

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- Probability distributions were used instead of single-point values for waste generator and waste disposal streams. The probability distributions were based on results of interviews with operators of waste generators and/or engineering judgment.
- The effect of equipment failures associated with the Evaporator was modeled by assuming that the evaporator feed lines failed for one year (i.e., a one year mean-time-to-repair), triggered randomly approximately 10% of the time.

* Included in GPSS model, with waste volume queuing capability deactivated

4.0 RESULTS

4.1 Base Case Results

The results of the base case are based on completion of waste generation and reduction activities per the Planning Baseline Tri-Party Agreement Milestones, and no component failures (except as noted).

The results of the three primary types of waste are presented below. In the following figures, the initial DST waste capacity is shown together with the modeled mean waste volume and the 10% probability that the actual waste volume would exceed the projected waste volume (i.e., the 90% confidence level).

The base case waste volume versus capacity as a function of time for aging waste is shown in Figure III. With a confidence level of 90%, the waste inventory is projected to utilize only a portion of the aging waste spare tank capacity (one tank or 1000 Kgal.) during the years 2008 to 2010. However, because of the relatively short duration of the partial use of the spare waste tank, a fallback position was not considered necessary.

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Figure III. Aging Waste - Base Case Volume vs. Capacity.

The base case waste volume versus capacity as a function of time for complexed waste is shown in Figure IV. The beginning inventory is 4,926 kgal. The complexed waste portion of salt well pumping of SSTs enters the system through the year 2000. SST retrieval will also add to the waste volume during the years 2004 through 2015 and accounts for the small peak shown in 2012. The retrieval of waste from tanks SY-101 and SY-103 is considered as no net increase in waste volume because these tanks are currently included in the complexed waste inventory and the waste in these tanks remain in this inventory, even if it is transferred to other waste tanks. Volume reduction occurs for a small fraction of the complexed waste through evaporation and pretreatment streams.

Figure IV. Complexed Waste - Base Case Volume vs. Capacity With Fallback Position.

The results shown in Figure IV demonstrate that the mean waste volume for complexed waste is projected to exceed the available capacity by 1996 unless two additional non-complexed waste tanks are allocated to receive complexed waste. Adding two waste tanks to receive complexed waste from the set of non-complexed waste tanks will alleviate this projected waste volume shortfall and will not result in the non-complexed waste capacity to exceed volume limits under projected conditions (see Figure V). Because of the gradual decrease in complexed waste inventory through pretreatment and vitrification after the peak value in the year 2000, individual complexed waste tanks can be emptied and released in 2005, 2009, and 2014 to be used again for non-complexed waste.

The base case waste volume versus capacity as a function of time for non-complexed waste is shown in Figure V. SST and DST retrieval add to the waste volume between the years 2004 through 2015. Large waste volumes in the last few years of the projection window are generated by the SST retrieval and the transfer of SST sludge to vitrification. The various peaks and valleys seen toward the end of the time period are from widely varying volumes in the SST sludge sent to vitrification. Volume reduction occurs through the major portion of the period analyzed through evaporation, pretreatment, and vitrification. The significant increase in waste volume toward the end of the period (2011 to 2015) is due to the selective focus on volume reduction using the evaporator, pretreatment, and vitrification facilities to reduce complexed and aging waste inventories. Shortly after 2015, it can be expected that some tanks currently allocated to complexed and aging waste can be released, and become available to hold non-complexed waste. Also, the volume reduction efforts involving these other two waste streams (complexed and aging waste) can then be almost entirely devoted to the reduction of non-complexed waste.

4.2 Off-Normal Scenarios

As part of the risk assessment, a series of off-normal conditions (upsets) were postulated for each of the main waste types. These off-normal conditions were developed based on data received during facility interviews, historical information available in documents, authors' knowledge of Hanford activities, and engineering judgment of uncertainties associated with programmatic issues. These off-normal simulations reflect the authors' best judgment of risks associated with programmatic and off-normal situations that may alter the base case simulation input information.

Figure V. Non-Complexed Waste - Base Case Volume vs. Capacity.

For each of the three main waste streams (aging waste, complexed waste, and non-complexed waste), three major off-normal conditions were chosen that represent a variety of situations considered to dominate the list of candidate events. These off-normal conditions are listed in Table I. Each waste stream was analyzed for three off-normal conditions that represented; (1) a major hardware loss (tank) due to accidentally inflicted damage or a loss caused by programmatic circumstances, (2) a major programmatic disruption (delay of key activities), and (3) a major change in the volume of waste requiring storage. These off-normal conditions represent large impacts to storage capacity and waste volume and, therefore, encompass less significant off-normal conditions. Each of the off-normal conditions was modeled and analyzed for impacts to the base case waste

volume projections.

For the off-normal conditions that result in an unacceptable impact to the waste volume versus storage capacity projections, a fallback position was developed. These fallback positions are also listed in Table I. The off-normal condition and fallback position were analyzed to demonstrate that the adverse consequences are prevented by the fallback position.

In some cases the off-normal conditions did not require a fallback position to be developed, because the available waste capacity was not exceeded. In several cases, the off-normal condition produced a very small likelihood of exceeding the available capacity near the end of the time frame analyzed in this report. In these cases, judgment was used to decide if the potential problem required any near-term action, or if further analysis could wait for better data. In those cases where no near-term action was required, the results were simply noted, and no fallback position was developed.

The eventual use of the proposed fallback positions is dependent on many factors. However, this study demonstrates that appropriate fallback positions can be developed to manage the risk associated with described off-normal conditions. The fallback positions shown here are appropriate and reasonable, but are not purported to be the only fallback positions that could be appropriate to mitigate the effects of the postulated off-normal conditions included in this analysis.

5.0 CONCLUSIONS

The risk assessment methodology described in this report has been shown to be a useful tool to identify and manage the risk of exceeding the DST waste capacity for TWRS. Uncertainties in the data were considered and evaluated using appropriate probability distribution functions. The 90% confidence that a waste volume would not exceed available capacity was used to indicate when an anticipated action should be taken to prevent limits from being exceeded.

The division of the model into three waste streams (aging waste, complexed waste, and non-complexed waste) proved to be an effective method to study the effects of waste volume versus available capacity. These effects were difficult or impossible to observe using a model that combined these waste streams.

Off-normal conditions were postulated that covered a range of accidents and programmatic issues. Fallback positions were developed that would alleviate the effects of each off-normal condition, thus, ensuring that the waste volumes would be within available capacity. The off-normal conditions and associated fallback positions described in this report serve as plausible examples of the perturbations that can be analyzed through the use of simulation modeling techniques. The cases examined identified the sensitivity of the DST waste capacity to variations in input and output waste streams.

Finally, the effort demonstrated the usefulness of simulation modeling in considering uncertainties in waste volume projections and evaluating the sensitivity of the waste volume to input parameters.

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Continued enhancement and integration of the simulation modeling concept should provide a versatile risk management method for TWRS to evaluate DST waste volume versus available capacity.

Table 1. Simulation Model Cases - Base Case, Off-Normal Conditions, and Projected Falback Positions.

Waste Type	Base Case		Off-Normal Conditions (from Base Case) and Projected Falback Positions		
	Case #1	Case #2	Case #3		
Aging Waste Condition	• Falback Position	• Off-Normal Condition	• Falback Position	• Off-Normal Condition	• Falback Position
Complexed Waste Condition	Figure III	None required.	Convert non-complexed tank to aging waste tank.	Dilute the additional cesium waste by 2 times and send to non-complexed tanks.	Pretreatment increases high-heat output by 2 times.
	Includes effects of evaporator line failure. (Figure IV)	Allocate 2 non-complexed tanks to complexed waste in 1996.	Accidental loss of one DST.	Misrouting of complexed waste into a non-complexed waste tank in 1998.	None required.
Non-complexed Waste Condition	Includes effects of evaporator line failure. (Figure V)	None required.	Accidental loss of one DST.	Reduce SST solids retrieval to match the volumes in OVP, Rev. 21.	Continue retrieving beyond 2015.
	None required.	None required.	Accidental loss of one DST.	Retrieval requires additional dilution, doubling SST retrieval stream.	Terminal clean out volumes from B Plant, PUREX, and 100 N are increased by a factor of 10.
		Postpone TCO of PUREX & 100-N, while increasing the use of the 242-A Evaporator through 2006.			

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