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Time Motion Study for Modular Caustic Solvent Extraction Unit

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ABSTRACT

The Defense Waste Processing Facilities (DWPF) at the Savannah River Site (SRS) is used to process high-level radioactive waste from the Tank Farm into borosilicate glass to immobilize the radionuclides into the glass structure and has processed and vitrified nuclear wastes into canisters for long-term disposal since FY96. All wastes vitrified to date in DWPF are "sludge only" wastes. The old salt waste processing technology, ITP, was suspended in FY98 due to benzene build-up inside the tank. The new selected technologies for treating the salt waste are Actinide Removal Process (ARP) and Caustic Side Solvent Extraction process (CSSX). The Modular CSSX Unit (MCU) is a cesium removal process that will be operated downstream of the ARP. The MCU is a short-term method for cesium removal, which utilizes the same technology as the Salt Waste Processing Facility (SWPF). Once the SWPF becomes operational, the MCU will be shutdown.

The modeling request is from the MCU project to verify the validity of its Conceptual Design Package. The modeling task is not typical because there are five different facilities/projects/processes involved, i.e., Tank Farm, ARP, MCU, Saltstone, and DWPF. Each facility, project, and process has their own management team and organization, with its own fiscal responsibility and performance accountability. In addition, from a task cost perspective, MCU desires to minimize modeling not directly associated with their facility. The balancing of comprehensive analysis with limited granularity is challenging. The customer expectation is the model should be small and delivered within weeks. Modeling a stand-alone MCU will not yield overall meaningful results because it can be expected that most problems will occur at interfaces with other facilities. This paper discusses how we set out our modeling strategy, overcame obstacles, avoided touchy issues, and delivered the modeling result on time and on budget.

INTRODUCTION

The DWPF at the Savannah River Site is used to process high-level radioactive waste from the Separations Area into borosilicate glass to immobilize the radionuclides.

Since FY96, DWPF has processed and vitrified nuclear wastes from HLW Tank Farm into canisters for long-term disposal (Reference 1). All wastes vitrified to date in DWPF are "sludge only" wastes. No salt waste has been treated in DWPF so far. There are three different types of salt waste: low curie salt, low curie with actinide salt, and high curie with actinide salt. A small fraction of the current inventory of salt is low in cesium and low in actinides. This material (referred to as low curie salt) is treated by the removal of the cesium-bearing interstitial liquid, followed by dissolution of the saltcake and transfer to the Saltstone Facility for treatment and disposal. Another portion of the salt is low in cesium but contains actinides. This material can be treated by performing a monosodium titanate (MST) strike to adsorb the strontium and actinides then filtering. This process is called Actinide Removal Process (ARP). The majority of the salt inventory contains significantly higher levels of cesium and actinides. The selected technology for treating this waste is the Caustic Side Solvent Extraction process (CSSX) (Reference 3). CSSX is to be utilized in two separate facilities for the removal of cesium from salt waste. The Salt Waste Processing Facility (SWPF) is being designed to process most of the salt waste in the tank farm. The current schedule shows SWPF ready for processing waste in FY09. There is, however, a need for some cesium removal capability before SWPF comes online. The Modular CSSX Unit (MCU) is a temporary measure to remove cesium from the ARP filtrate before it is sent to Saltstone Facility for treatment and disposal. The MCU is scheduled to be operational by October of FY06 and is currently in the design phase.

The model presented in this study was requested by the MCU project to model MCU operations. The primary purpose of the MCU is to extract Cs from filtrate solution, send the Cs concentrated in an aqueous strip solution to DWPF for vitrification (Reference 2) and supply decontaminated salt solution (DSS) to Tank 50. Refer to Figure 1 for process flow diagram. The primary objective of the modeling effort is to determine whether MCU can meet the minimum throughput requirement of one million gallons per year. In order for the modeling result to be meaningful, the current MCU model includes high level processes for ARP and DWPF. The model is developed with just enough granularities for ARP and DWPF processes for the model to be meaningful.

The material balance and calculation sheets for ARP project

are documented in X-CLC-S-00113, Rev. D (Reference 3). The material balance and calculation sheets for MCU project are documented in "Preliminary Material Balance for the Modular CSSX Unit, Rev. 1" (Reference 4)

WASTE SYSTEM OVERVIEW

The Closure Business Unit (CBU) Waste System is a set of seven different facilities interconnected by pipelines, each of which contains one or more processes, as seen in Figure 1 (Reference 5). The System is operated by a number of different organizations, including Liquid Waste Disposition Projects (LW), Waste Solidification Projects (WS), and Supporting Organizations. The seven different facilities, their physical locations, and their processes are as follows:

Liquid Waste Disposition Projects

- 1) F-Tank Farm – Storage and Evaporation, Sludge Removal, Salt Dissolution, and Low Curie Salt (LCS)
- 2) H-Tank Farm – Storage and Evaporation, Sludge Removal, Salt Dissolution, LCS, Actinide Removal Process (ARP) – strike tanks located in 96-H in conjunction with the filter in 512-S comprise the ARP process which removes Sr and actinides from dissolved salt solutions), and Sludge Washing
- 3) Wastewater Treatment – Effluent Treatment Project (ETP)

Waste Solidification Projects

- 4) Defense Waste Processing Facility (DWPF) – ARP (Future) – Filter located in 512-S in conjunction with the strike tanks in 96-H comprise the ARP process which removes Sr and actinides from dissolved salt solutions and Vitrification
- 5) Saltstone Facility – Saltstone production process and disposal vaults

Supporting Organizations

- 6) Modular Caustic Side Solvent Extraction (CSSX) Unit (MCU) – (Future) cesium removal process for ARP filtrate
- 7) Salt Waste Processing Facility (SWPF) – Salt removal facility with Sr, actinide, and Cs removal capability that will contain its own Actinide Removal and CSSX process

To a large extent, these facilities function independently, and each facility accomplishes several of the functions of the CBU LW, WS, and Supporting Organizations systems. But taken together, these seven facilities function as one large treatment plant that stores and treats waste streams and converts them into forms suitable for final disposal. The

three major waste forms are borosilicate glass in stainless steel canisters, which will eventually be disposed of in a federal repository, saltstone to be dispositioned on site, and treated water effluent that is released to the environment. The seven facilities together are commonly termed the CBU Waste System.

CHALLENGES

Since the events of 9/11/2001, a big portion of the national budget has been diverted toward homeland security and the war on terrorism. As a result, the SRS is under a very difficult fiscal environment in recent years. The Systems Engineering modeling group has no birthright to any jobs. Modeling jobs are solicited from within the SRS complex. Development of an integrated model for the entire CBU waste system is the ultimate goal and vision of the Systems Engineering modeling group. Years of marketing effort finally made an inroad into a piece of CBU Waste System process – DWPF. Word-of-mouth from satisfied modeling customers contributed to landing the modeling job. The DWPF model has been completed. The MCU model is the second piece of the puzzle toward an integrated CBU Waste System model.

The complexity of the modeling request, as mentioned in the Abstract, is that MCU is only a small project within a much greater integrated waste treatment and disposal systems at SRS as shown in Figure 1. Modeling downstream, large size facility, DWPF for example, is not as complicated, as modeling a small facility sandwiched between other facilities. To model a complex facility like DWPF, the facility is willing to wait for several months to get the modeling result. However, for a small MCU project, the expectation is that the model should be delivered within weeks and the project is not going to pay for modeling of interfacing facilities and processes. On the other hand, modeling a stand-alone MCU will not yield meaningful results because it is expected that most of the problems will occur at interfaces with other facilities.

Therefore, in order to satisfy the customer, the modeling team issued a carefully worded Task Plan to emphasize that the team will only model the interfacing facilities, i.e., Tank Farm, ARP, saltstone, and DWPF, at a relatively high level, and only to the extent that yields useful information on the MCU strategy. The MCU process will be modeled in detail. The model will be used to verify the validity of MCU project assumptions and identify potential deficiencies in the MCU system.

ARP, MCU, and SWPF are proposed new facilities to be built at SRS. Westinghouse Savannah River team (WSRC)

is the primary contractor to run CBU Waste System. Parsons is the primary contractor in charge of the SWPF design and construction. ARP and MCU, both in the design phase, are to be built by the WSRC team. Each facility, project, and process has its own management team and organization, with its own fiscal responsibility and performance accountability.

The objective is to develop a very high level operational research model for MCU to verify the throughput requirements specified in the Conceptual Design Package. The model was developed using the Vitech Corporation COREsim[®] application. The model developed in this study does include a limited high level model for Actinide Removal Process (ARP) and Defense Waste Processing Facility (DWPF). However, the MCU model is not tied in with the existing DWPF COREsim model (Reference 6) due to the time constraint.

The boundary and flow diagram of the MCU COREsim model are given in Figure 2.

ASSUMPTIONS

Assumptions are the limitations that constrain the modeled process. Examples of assumptions are resource availability, facility availability, equipment capacities, system cycle times and batch size limitations. The general assumptions imposed on the model are provided in Reference 7.

The Filter Only Case (Maximum Case), Rev. 0 of the MCU material balance assumed the filtrate solution sent from ARP to Salt Solution Receipt Tank (SSRT) will be with sodium concentration of 6.3 molar. The salt solution will be subsequently adjusted to a 5.6 molar sodium solution in order for the MCU contactors to get right chemistry. Rev. 1 of the MCU material balance assumed the filtrate solution will be adjusted in ARP before being sent to the SSRT. An additional 2 hours step was added to account for the adjustment time required for the Filter Only Case.

The ARP project has a requirement to maintain the facility availability at 75%. Therefore, the model assumed that the ARP facility availability is 75%. The same facility attainment requirement is imposed on the MCU. So, the model assumed facility attainment for MCU is 75%. The DWPF has a goal to maintain Melter attainment of 80%. The SRAT, ASRT, PRFT, and Low Point Pump Pit (LPPP) have their own availabilities. Therefore, for the DWPF facility as a whole, a 75% attainment is assumed. It is assumed that ARP, MCU, and DWPF will run 24 hours a day, 7 days a week.

There are three different types of outages: (1) planned outages, (2) short term unplanned outages, (3) long term unplanned outages. The short term unplanned outage is defined as an outage with mean time to repair of 24 hours. The long term outage is defined as an outage with mean time to repair of 72 hours.

Table 2: Outages for Different Facilities

Facility	Planned Outage	Unplanned Outages
ARP	7 weeks/yr	Short = 3 weeks/yr Long = 3 weeks/yr
MCU	7 weeks/yr	Short = 3 weeks/yr Long = 3 weeks/yr
DWPF	7 weeks/yr	Short = 3 weeks/yr Long = 3 weeks/yr

CASE STUDY

Operating scenarios evaluated by this study are defined as cases. Table 3 identifies each case by number and description. These cases evolved as the study progressed. Initially, the three cases (Case 1, Case 2, and Case 3) of MCU process were modeled to reflect the three cases mentioned in the MCU Material Balance Calculation Sheets. Next, three alternative operating scenarios were simulated by changing various set points (e.g. outages planning, number of tanks, and tank size). These cases are Case 4, Case 5, and Case 6.

Table 3: Case Description

Case #	Description
Case 1	Intermediate Case ARP, MCU, DWPF conduct planned outages at the same time. (Baseline: 2 strike tanks in 96-H)
Case 2	Minimum Case ARP, MCU, DWPF conduct planned outages at the same time.
Case 3	Maximum Case ARP, MCU, DWPF conduct planned outages at the same time.
Case 4	Minimum Case ARP, MCU, DWPF conduct planned outages at the different time. (Baseline: SEHT tank working volume = 800 gal)
Case 5	Intermediate Case ARP, MCU, DWPF conduct planned outages at the same time. One Strike Tank in 96-H
Case 6	Minimum Case ARP, MCU, DWPF conduct planned outages at the different time. SEHT tank working volume = 5,000 gal.

Modeling Result

The modeling results are summarized in Table 4.

Table 4. Model Results

Case #	Waste from ARP to MCU	MST Sludge Processed in DWPF
1	1,940,000 \pm 54,000 gal/yr	72,400 \pm 2,600 gal/yr
2	1,357,000 \pm 18,000 gal/yr	50,200 \pm 1,100 gal/yr
3	1,865,000 \pm 46,000 gal/yr	42,200 \pm 2,100 gal/yr
4	984,000 \pm 44,000 gal/yr	37,000 \pm 2,700 gal/yr
5	1,955,000 \pm 83,000 gal/yr	73,100 \pm 2,900 gal/yr
6	1,226,000 \pm 110,000 gal/yr	47,900 \pm 4,000 gal/yr

It is quite a surprise that the Intermediate Case has higher throughput than the Maximum Case. The total filtrate waste volumes sent from ARP to MCU for Intermediate Case and Maximum Case are 1.96 MM gal/year and 1.87 MM gal/year respectively. The reason is that for the Maximum Case, the filtrate has to be adjusted to 5.6 molar of sodium and then sent to SSRT. It would add 2 hours to the filter cycle time.

If ARP, MCU, and DWPF do not coordinate their planned outages (Case 4) to shut down three facilities at the same time, the MCU facility may not be able to meet the minimum annual throughput requirement of 1 million gallons per year. In the conceptual design package, Strip Effluent Hold Tank (SEHT) has a maximum working volume of 800 gal. If SEHT is a tank with 5,000 gal working volume (Case 6), then the MCU facility will be able to meet the requirement of processing at least 1 million gallons filtrate solution through MCU, even if ARP, MCU, and DWPF do not coordinate their planned outages. The MCU annual waste processing rate for Case 4 (800 gal SEHT) and Case 6 (5000 gal SEHT) are 0.984 MM gal/year and 1.226 MM gal/year respectively. The 5000 gal SEHT was randomly selected as a case scenario. The actual optimized tank size will be between 800 gal and 5000 gal. Further study is required to determine the optimum tank capacity. The disadvantage for three facilities conducting the planned outage at the same time is that each facility has to maintain their own maintenance crews and can not share their maintenance resource pool during the planned outages.

If the MST strike time in ARP is 4 hours (Intermediate Case), the striking tank process step is not the bottleneck. Therefore, having two strike tanks (Case 1) provide only slightly higher fresh waste processing capacity compared to

the case with only one strike tank (Case 5). The projected annual waste processing rate for Case 1 (two strike tanks) and Case 5 (one strike tank) are 1.964 MM gal/year and 1.955 MM gal/year respectively.

The MST Sludge batch size (2643 gal per batch) for the Intermediate Case is too big to fit into SRAT if the Sludge Only waste feed is to stay as 6,500 gal per batch as is the current practice.

The water added to the SRAT from Cs-strip solution and MST sludge will be boiled off at a rate of 400 gal per hour. The additional processing time may adversely impact the SRAT cycle time to a point it might become the bottleneck of DWPF canister production process. There is a need to integrate the MCU model with DWPF COREsim model for further study.

CONCLUSION

If the MST strike time is 4 hours, having two striking tanks in 96-H provided very limited benefit compared to one striking tank.

The MCU may not be able to meet the minimum annual throughput requirement of 1 million gallons if the three facilities fail to coordinate their planned outages.

With a larger SEHT, the MCU will be able to meet the minimum annual throughput requirement of 1 million gallons, even if three facilities can not coordinate their planned outages to occur at the same time.

There are a lot of interface issues between MCU and DWPF which need to be resolved through further studies utilizing an integrated model. The issues identified include the size of MST/Sludge batch and impact of water from aqueous process solutions to the SRAT cycle time.

The Intermediate Case has higher throughput than the Maximum Case. The total filtrate waste volumes sent from ARP to MCU for Intermediate Case and Maximum Case are 1.96 MM gal/year and 1.87 MM gal/year respectively. The reason is that 2 hours are added to the Maximum Case to adjust sodium concentration from 6.3 molar to 5.6 molar in ARP.

RECOMMENDATIONS FOR PATH FORWARD

The MCU COREsim model is not integrated with the existing DWPF COREsim model (Reference 6) at this point. The goal is to have an integrated CBU Waste System model to cover operations from Tank Farm to ARP,

CSSX, Saltstone, to DWPF. To integrate the MCU with DWPF Operations-Research models is the next step toward that goal.

CBU Waste System operations are convoluted and highly integrated processes. Without an integrated model, it is impossible to study the impacts of changes made in one facility on other facilities.

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BIOGRAPHY

R.C. Chang has more than 15 years of hands-on chemical engineering and simulation modeling experience. Mr. Chang is a Certified Modeling and Simulation Professional (CMSP). He is a Principal Engineer in Westinghouse Savannah River Company. He received a Master Degree in Chemical Engineering from Oklahoma State University. He has presented several technical papers, holds three patents, and is currently working on developing modeling capability within the Systems Engineering Department of WSRC.

Figure 1: Closure Business Unit Waste System

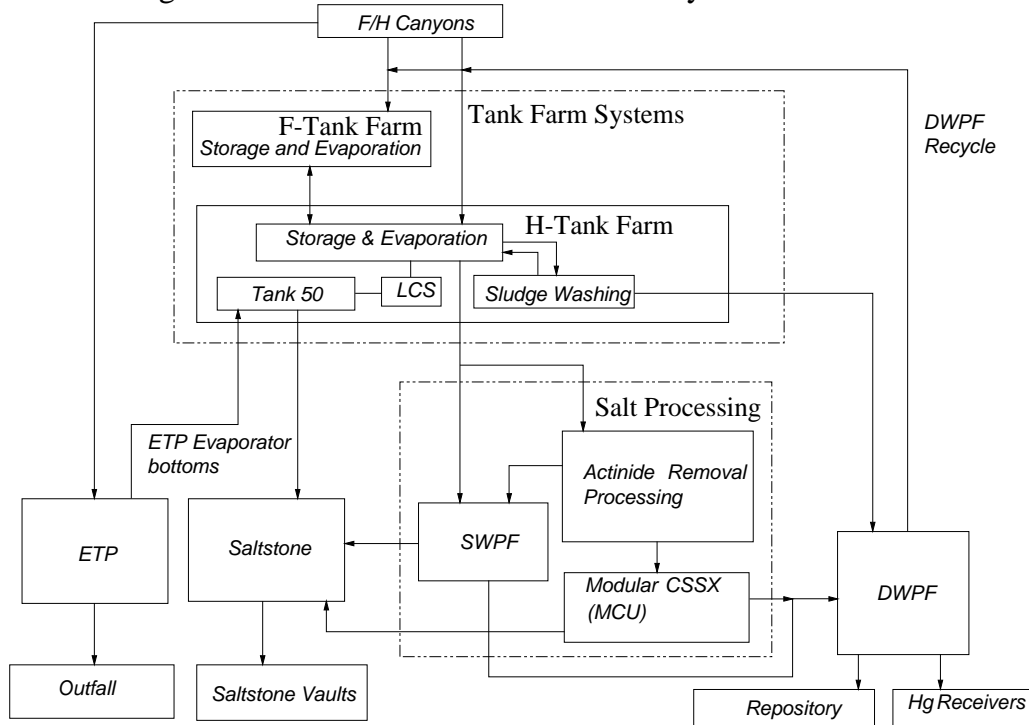


Figure 2: MCU Model Boundary and Flow Diagram

