Optimization Efforts at DWPF to Ensure Waste Tank Closure by 2037 – 24404

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ABSTRACT

At the Savannah River Site (SRS) in Aiken, South Carolina, the Defense Waste Processing Facility (DWPF) produces a glass-form product by processing high-level liquid waste (HLW) with borosilicate glass in a high-heated Melter, then putting the vitrified waste into stainless-steel canisters. Since 1996, DWPF has performed this vitrification process for the liquid waste mission at the SRS; the overall objective for this mission is to reduce the volume in the upstream waste tanks, so those tanks can be emptied and operationally closed. This mission seeks to eliminate the single biggest environmental risk in the state of South Carolina, which requires a robust processing strategy within the DWPF, along with optimal interface between the other facilities in the liquid waste organization (LWO). As of the end of July 2023, DWPF has safely remediated 63.7 MCi of HLW, and filled 4,319 canisters (We project that about 4,000 more canisters are needed to be filled to reach the closure goal.)

One of the upstream facilities that sends HLW to DWPF is the Salt Waste Processing Facility (SWPF). After this facility became operational in 2020, the LWO mission gained the capability to accelerate our closure processes. This was due to the marked increase in production capacity of the SWPF. As of fiscal year 2023, SWPF had a production goal of receiving 4.1 Mgal of raw salt solution (RSS) from the waste tanks. In the coming years, that goal will be increased to 9 Mgal. Such a significant increase in waste throughput not only reduces the amount of time needed to process the volume in the waste tanks, but it also reduces the risk to the surrounding areas communities.

The downstream facilities from SWPF (namely, DWPF) will need to handle the large increase in output volume from SWPF to accommodate our closure goal. As a result of the age of DWPF (compared to SWPF), along with the larger production volumes, DWPF has undergone a myriad of macro and micro changes to our processing philosophy to ensure we can support the increased salt waste processing. Our company values of Safety, Reliability, Mutual Respect, and Continuous Improvement are emulated in the various strategies employed to facilitate the 2037 closure date for the liquid waste mission. This paper seeks to cover these changes from a past, present, and future perspective.

INTRODUCTION

As stated, the LWO at SRS seeks to reduce the volume of waste in our tanks to reduce the significant environmental risk. The LWO is comprised of the DWPF and the SWPF, along with the Concentration, Storage, and Transfer Facilities (CSTF, also denoted as the "Tank Farms"), the Saltstone Production Facility (SPF), the Saltstone Disposal Facility, and the Effluent Treatment Facility (ETF). Waste is stored in the Tank Farms, where it is chemically treated, concentrated, and large batches are formed to be sent to the downstream facilities. Generally speaking, two different types of waste are produced from the Tank Farms: sludge, and raw salt solution (RSS). The sludge material goes to the DWPF, while the RSS goes to SWPF. At the SWPF, the raw salt solution is further processed via chemical adjustments, filtration, and stripping processes, yielding three waste streams: monosodium titanate/sludge solids (MST/SS), strip effluent (SE), and decontaminated salt solution (DSS). The DSS is transferred to the Saltstone facilities, where it is immobilized in a grout-form in large concrete monoliths. The other two waste streams (along with the sludge material from earlier), are sent to the DWPF for processing.

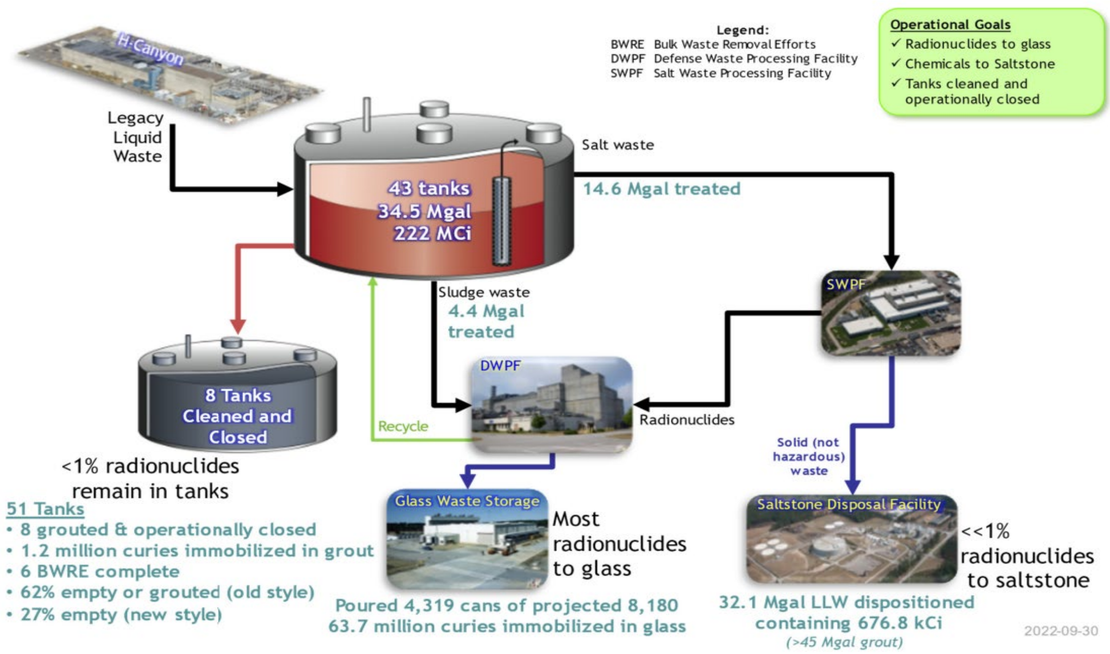

Figure One: Overall LWO diagram[1]

To date, of the 51 waste tanks in the Tank Farm, 8 have been operationally closed. As shown in Figure One, each facility at the LWO must work in concert to achieve the overall goal of reducing waste volume at the Tank Farm. The LWO mantra of *Power As One* ® builds upon the already existing cohesiveness between the facilities, ensuring that everyone understands the impacts imposed by other facilities, and how these can help or hinder the overall mission. If even one facility is unable to keep up with the throughput, it not only slows down our overall waste reduction goal but can potentially cause other facilities to stop processing. Over the years, our facilities have been able to manage our production goals by continuously improving. Such improvements will need to be bolstered to reach our 2037 closure date.

DESCRIPTION

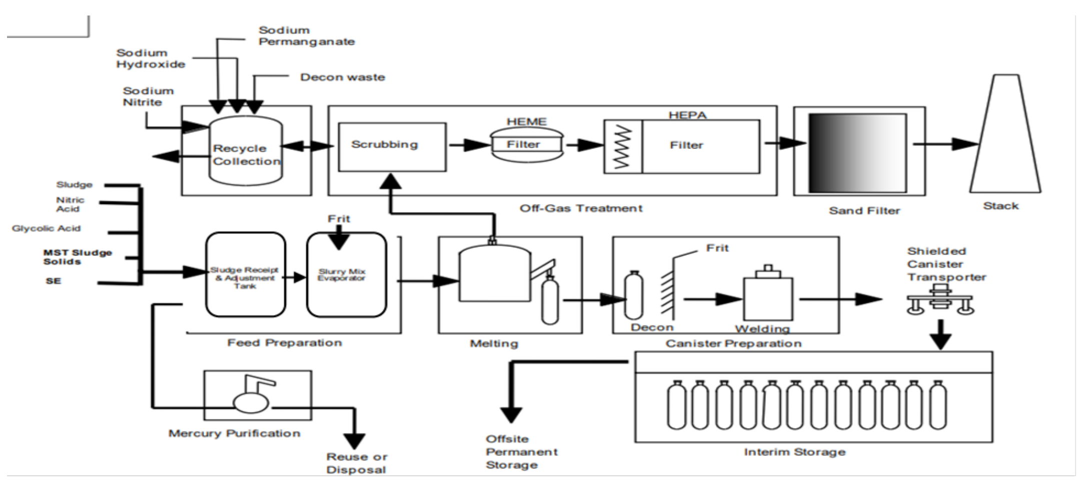

Figure Two: DWPF process diagram

Figure Two gives a general overview of the DWPF process. As stated, the DWPF receives three different waste streams from upstream facilities: sludge, MST/SS, and SE. Sludge from the Tank Farms is received at our Low Point Pump Pit (LPPP) facility, where it is then sent to our first processing vessel, the Sludge Receipt and Adjustment Tank (SRAT), which has a volume of about 41.6 m^3. The SE material from SWPF is transferred to our Strip Effluent Feet Tank (SEFT), which also has a volume of about 41.6 m^3, and the MST/SS from SWPF is also sent to the LPPP, and then sent to our Precipitate Reactor Feed Tank (PRFT), which has a volume of about 26.5 m^3.

Concentration and Adjustment Processing

Once the sludge is received in the SRAT, the PRFT contents are added to the SRAT, followed by chemical additions of nitric acid and glycolic acid. The glycolic acid addition is a very recent facility implementation, which will be covered later in this paper. Adding these chemicals helps with the processability of the waste material (e.g., assists in the removal of mercury, improves general rheology, and ensures the material will be safe to vitrify later in the process). Steam utility is piped to the SRAT via heating coils, which assists with reflux and concentration cycles during the process. Note that condensate from the SRAT is collected in the Slurry Mix Evaporator Condensate Tank (SMECT), which has a volume of about 41.6 m^3, and is eventually sent back to the Tank Farms via the Recycle Collection Tank (RCT), which has a volume of about 41.6 m^3. Finally, the SEFT contents are added to the SRAT, after which a product sample is pulled for analysis. This vessel is now ready to be transferred to the next vessel: the Slurry Mix Evaporator (SME).

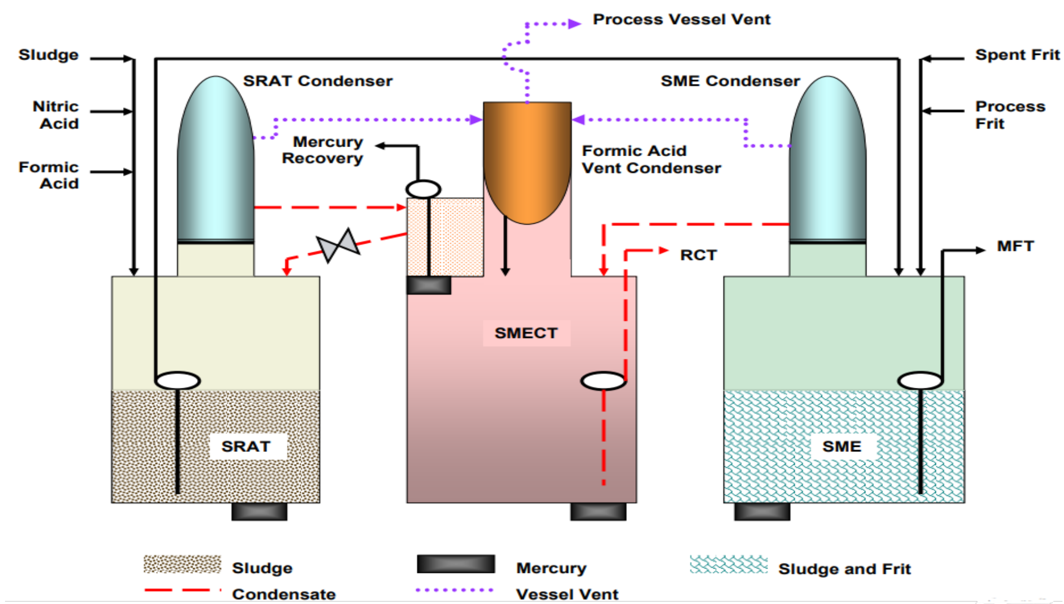

Figure Three: SRAT, SME, and SMECT flow diagram

Once the SRAT material is transferred to the SME, which has a volume of about 41.6 m^3, DWPF undergoes two different types of additions of borosilicate glass (also known as frit) additions to the SME: One such addition involves decontamination frit material to the SME, and the other involves process frit material to the SME. The *decontamination* frit material is used to clean the filled canisters later in the process, to ensure the outside of the canisters are free from radiological material. Once this frit has been used in the cleaning process, it can then be added to the SME, in a type of recycling strategy. The *process* frit material is clean frit material that is added in larger batches to the SME. To ensure the safety of the canister contents, a certain ratio of frit material must be in each canister; this ratio depends on many factors, such as the amount of sludge processed in the SRAT, and the amount of MST/SS material in the SRAT (The SRAT product sample analysis gives the amount of frit required.) As with the SRAT, steam is piped to the SME via its heating coils to assist with concentrating the contents of the tank. Condensate from the SME is also collected in the SMECT, as shown in Figure Three. Once the SME product has been sampled and analyzed to ensure regulatory requirements are met, it can be vitrified in the Melter.

Melter Processing and Canister Production

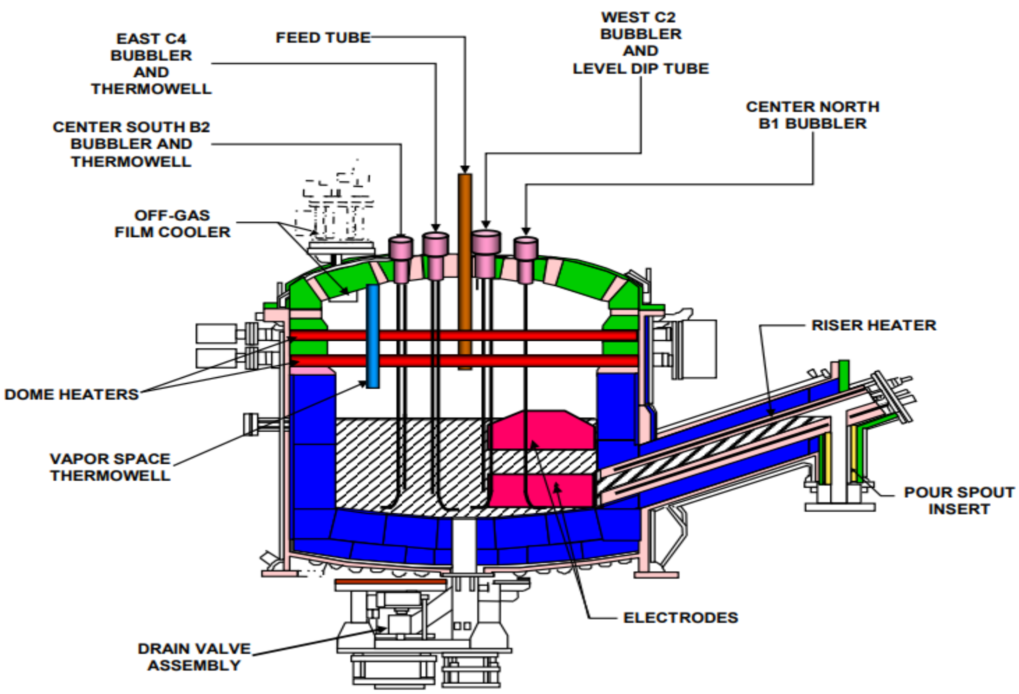

Figure Four: Cross-section of Melter

SME product material is transferred to the Melter Feed Tank, which has a volume of about 41.6 m^3; this vessel acts as a repository to continuously feed the Melter when needed. The Melter itself, which has a volume of about 3.15 m^3 (shown in Figure Four), is comprised of various metals, and includes electrodes, dome heaters, argon bubblers, and dedicated off-gas treatment systems. The Melter electrodes ensure that the melt pool is hot enough to instantly evaporate any water in the material coming from the MFT, along with turning the incoming slurry material into melted glass. The dome heaters ensure that any flammable effluents that are produced when the slurry material is melted are instantly combusted before entering the off-gas train. The argon bubblers increase the mixing capacity of the melt pool, which helps to ensure that the temperature profile is uniform throughout the melt pool. The off-gas treatment trains ensure that any particulates and other harmful components are removed before being discharged to DWPF's primary ventilation system.

A slight vacuum (relative to the Melter vapor space, which is also at negative pressure) is pulled on the pour spout of the Melter, giving the glass pool a path of least resistance. This produces a pour stream, which leaves the Melter and is transferred to a stainless-steel canister. After the canister has been filled (about 1800 kg of the vitrified material), a plug is inserted into the neck of the canister (which aids in keeping foreign material and moisture from entering the canister), and the canister is leak-checked using helium. Next, the canister is cleaned using the decontamination frit material and dried. Finally, the canister is taken to be welded. This final plug weld ensures that material is permanently sealed inside the canister. Once the canister has passed its final inspections, it is taken from the DWPF building to the Glass Waste Storage Buildings, where it awaits transport to a final repository.

DISCUSSION

The DWPF process is very robust and produces a high-quality glass form that immobilizes HLW, which essentially prevents any negative impacts this material could have on the environment. With the accelerated liquid waste mission, DWPF needed to undergo significant improvements to accommodate the 2037 closure goal. As discussed, these macro and micro changes are geared toward improving processability, reducing process cycle time, and proactively addressing risks to ensure the process is not stopped unexpectantly. Changes to the process that have been recently implemented will be covered, followed by in-progress upgrades, and finally, future improvements that are being scheduled.

Glycolic Acid Flowsheet Implementation

One of the most recent upgrades to the process was the implementation of the glycolic acid flowsheet. In the SRAT, the sludge material from the Tank Farms will also be comprised of varying amounts of mercury compounds (namely, mercury oxides) from legacy liquid waste (see Figure One). Mercury poses a processability issue in the SRAT and downstream vessels, so DWPF's process adds a reducing acid to the SRAT to convert the mercury oxide compounds to elemental mercury. After this chemical addition, the SRAT is taken to a reflux boil mode, which aids in stripping out the elemental mercury. In the past, DWPF has used formic acid as its reducing acid. Formic acid poses various safety risks, such as personnel exposure, emergency preparedness thresholds, and it also increases hydrogen generation in the SRAT via catalytic generation. All these risks required additional controls to ensure the formic acid was maintained safely. However, we've recently implemented the glycolic acid flowsheet, which greatly reduces the impact of catalytic hydrogen generation, reduces the risks to personnel if exposed, and does not require emergency preparedness measures if a large amount of it is spilled. For these reasons, safety is heightened, and general costs have been reduced.

It should be noted that the glycolic flowsheet produces a byproduct called glycolate, which can be flammable in large quantities. This poses a risk to the Tank Farms, which receives the DWPF condensate. To address this risk, DWPF also implemented a process change where sodium permanganate, an oxidizer, is added to our RCT. The SMECT collects the glycolate that is generated in the process, and the SMECT is transferred to the RCT, which is eventually transferred back to Tank Farms. However, before this transfer occurs, sodium permanganate is added to the RCT, so that the glycolate compound can be oxidized before being transferred, thus eliminating the risk of this component to the Tank Farms.

Steam Generator Repairs and Upgrades

The SRAT and SME vessels use steam to reflux and concentrate as needed. Because of the safety implications when adding SEFT/PRFT to the SRAT, steam flowrate is a very crucial processing parameter. In the recent past, the steam generator reliability has been less than adequate due to equipment issues and some tuning parameters. Because of this, the facility underwent a large outage to improve the capability of the steam generator. This outage included improving the gap control of the steam generator valves, replacing various valves and the condensate pump, and improving the tuning parameters. After the outage, a large amount of testing of the generator (while the facility performed its general processing) was performed to measure the increased performance of the steam generator (see Figure Five). This testing showed that the steam generator can now steam both the SRAT and SME simultaneously (which was an issue before the outage); the new modifications to the steam generator will also allow the facility to implement a new strategy of transferring SEFT material to the SME, which will be covered later.

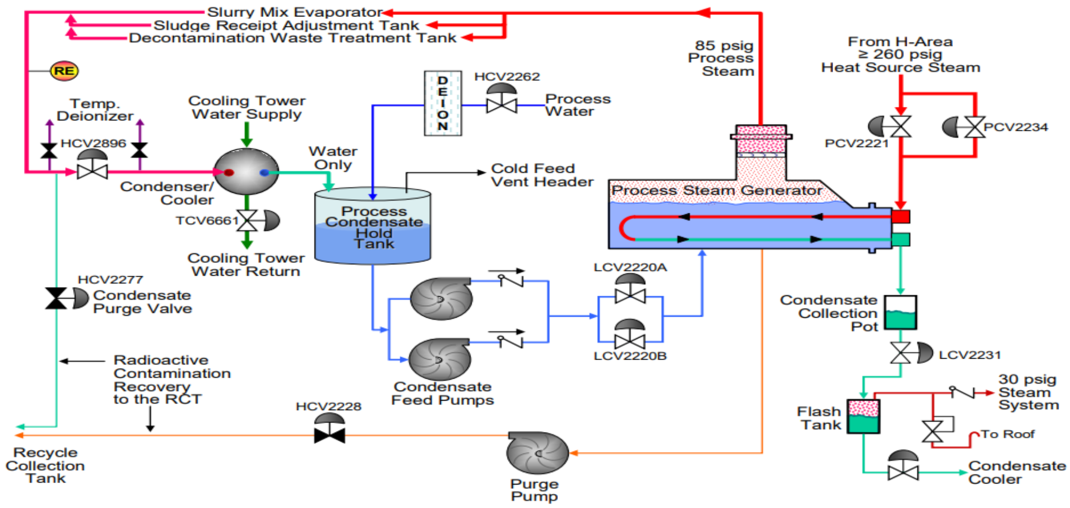

Figure Five: Process Steam Generator System

Process Cycle-Time Improvements

Some of the more in-progress process improvements are aimed at reducing process cycle time, idle time, and strategically minimizing the waste tank volumes. The SRAT process has been optimized by implementing the following:

- increasing the amount of sludge volume received from the Tank Farms to the SRAT;
- only adding one full SEFT volume to the SRAT (in lieu of two or three, as was done in the past);
- increasing the steam flow to the SRAT to meet mercury stripping requirements faster;
- lowering the amount of PRFT material added to each SRAT;
- increasing the acid addition rates of nitric acid and glycolic acid; and
- communicating with upstream facilities proactively to ensure DWPF has enough freeboard space for upcoming transfers.

For the SME, the cycle time has been reduced by strategically approaching the timing for canister cleaning evolutions to become more harmonious with the ongoing SME processing needs and ensuring that at least 5 canister cleaning frit additions are added to each SME batch (which allows the facility to make more space available for new, full canisters). Within the vein of proactive communication, we have also started communicating to the Tank Farms that the SME is ready to be transferred to the MFT, which gives the Tank Farms time to prepare for sending sludge material to the SRAT. In the past, we typically waited until the SRAT to SME transfer was in progress, but adjusting the strategy this way saves at least 8 hours of process cycle time.

Procedural Improvements

DWPF's various work groups work harmoniously to ensure process optimization is given the proper prioritization; added to the diverse backgrounds of our personnel, the ever-changing age ranges also contribute to our constant striving for continuous improvement: more senior employees have a deeper knowledge of our processes, have likely "seen something similar" in the past, and can educate the less-experienced workforce on these aspects. The less-experienced employees bring a "green eyes" approach to the table, questioning the status quo, and generally finding those obvious enhancements that are constantly looked over because "that is how we have always done it." With these perspectives in mind, we have also increased our focus on procedures and how they guide our processing. DWPF operations personnel perform processing functions via procedures (every step of the way), and there are times where these procedures can be better optimized to ensure processing cycle time is reduced efficiently. Below are a few examples of procedure changes we've recently made, along with their estimated reduction of process cycle time:

- Changed SME sampling procedure to allow agitator to remain in HI speed: Previously, the procedure directed operations to take the agitator to LO speed, but the very next procedure has operations to ensure the agitator was in HI speed for 2 hours. This reduced SME cycle time by 2 hours.
- Changed location of 2-hour agitation for SEFT/PRFT transfer procedures: These transfers require their respective agitators to have run for at least 2 hours prior to transfer to the SRAT. These procedures were adjusted so that the 2-hour agitation start time is earlier in the procedure, so that some of the required calculations and field checks run in parallel with the agitation time. This reduced SRAT cycle time by about 2 hours (1 hour for SEFT and 1 hour for PRFT).

Other In-Progress Optimizations

As of this writing, there are other in-progress changes to DWPF's process that will complete soon:

Canister Decontamination Chamber (CDC) #1 Restoration: As mentioned, the filled canister goes through a cleaning cycle to remove any adhered radiological material from the outside of the canister. Historically, DWPF operated two decontamination chambers separately, which allowed for up to 4 canisters to be cleaned within a 12-hour period. However, the first chamber has been out of commission for many years due to broken equipment. The facility is prioritizing the maintenance needed for this chamber, which will drastically increase our canister decontamination capabilities.

SEFT/PRFT Orifice: Flow rate from the PRFT to the SRAT maximizes at about 8 gpm, and the SEFT to the SRAT flow rate maximizes at about 4.5 gpm. The facility is making changes to increase the flowrate of these transfers by removing the variable frequency drive (VFD) from the pumps and increasing the orifice sizes for these transfers to 14 and 16 gpm, respectively. This will increase the transfer rate from these vessels to the SRAT, which will drastically reduce SRAT cycle time.

Proactive Staffing Solutions: DWPF is adjusting its rehiring practices by ensuring personnel are hired for positions in a manner to combat attrition and facilitate proper knowledge transfer. Instead of hiring for a position after someone has made it known they are about to retire, management is now staffing these positions as a person gets closer to announcing their retirement/leaving, which gives a longer time for knowledge transfer, and reduces the risk of these positions going unfilled for unknown amounts of time.

Future Improvements for DWPF

While the facility has made significant headway into optimizing the process, more efforts to improve efficiency are being planned. These changes are a combination of battling aging infrastructure, along with thinking outside of the box when it comes to how our facility processes HLW. While these changes are complex in nature, they will further drive home our intention for closing the waste tanks by 2037 and improve upon the already well-balanced relationships between our various work groups. Brief descriptions of these upcoming changes are shown below.

SEFT to SME transfer: As mentioned, the SEFT is transferred only to the SRAT with our current facility configuration; however, after various regulatory updates and process changes, DWPF will gain the capability to transfer this vessel to BOTH the SRAT and the SME. This will increase our flexibility of processing SEFT material.

Main Process Cell Crane (MPC) modifications: Our MPC is vital for adjusting facility configuration, removing/reinstalling remote equipment, and assisting with a variety of maintenance endeavors. As stated, the DWPF facility is about three decades old, and many of our frequently used equipment (such as the MPC) are showing the effects of time. The facility is currently planning to make major updates to the MPC, upgrading to new programmable logic controller controls, a new crane camera, and new console hardware. Various hardware and software designs will be provided, and new fiber optics will also be installed. New training will be provided to personnel to ensure the new functionality is understood before using the improved MPC crane system.

Optimization of Procurement of Critical Spare Parts: Working with our procurement work groups and staying within our governing obligations, DWPF is seeking out past vendor relationships to facilitate acquiring new critical spares. Given that these previous (sometimes past 20 years ago) companies have fabricated and provided DWPF top-quality equipment, these relationships should be able to be leveraged to ensure we have the appropriate spare parts that are needed for the future.

Repurposing Late Wash Facility (LWF): In the past, DWPF processed and received its PRFT material via the LWF, a satellite facility in the area. However, once SWPF came online, the MST/SS material that is sent to the PRFT is processed there, leaving the LWF dormant and empty. Plans are now in-place to repurpose this facility to store SEFT material within the next two years. This will ensure that the risk to SWPF of not being able to have a place to send SEFT material is very low.

CONCLUSION

Safety, Reliability, Mutual Respect, and Continuous Improvement: These SRMC values not only provide the framework for our continued successes, but they are a testament to our ability to break through milestone after milestone, and hurdle after hurdle. The aging infrastructure of the DWPF, coupled with increasing processing needs and employee turnover, provide quite the challenge to our 2037 closure date. However, we have demonstrated a successful track record of macro and micro changes to our processes, which have improved our processing capabilities by leaps and bounds. Yet, we are still posturing ourselves to take advantage of future endeavors and to improve our processes even further.

Our process optimizations have been of a wide variety, from the implementation of glycolic acid, steam generator improvements, and reduction of process cycle times; and even our future goals of adjusting process configurations and repurposing facilities, while seemingly disjointed from one another, all come together to improve not just DWPF processing, but the throughput of the entire Liquid Waste Organization. This Power As One® value will ensure that South Carolina's biggest environmental risk is eliminated, protecting the health and welfare of future generations. The Department of Energy complex can use some of these lessons learned from the DWPF to address the complex-wide issues of attrition, aging infrastructure, and to support processing goals. In DWPF's future, we seek to continue down this path of continuous improvement, while keeping safety as our top value.

REFERENCES

1. D. P. CHEW and A. W. JUNG, *Liquid Waste System Plan, Rev. 23-P*, 36 (2023).