

Facility Improvements and Modifications to Extend the Operational Life of the Modular Caustic-Side Solvent Extraction Process - 16082

Carl Scherman, Annah Garrison, and Earl Brass
Savannah River Remediation, LLC

ABSTRACT

Savannah River Remediation, LLC (SRR) is working to remove, stabilize, and dispose of approximately 36.7 million gallons (138.9 million liters) of liquid radioactive waste currently stored in 43 underground waste tanks, and ultimately close waste tanks. In 2008, as an interim salt treatment system to remove cesium from high level waste salt solutions prior to the Salt Waste Processing Facility start up, the Modular Caustic-Side Solvent Extraction Unit (MCU) initiated the removal of cesium from liquid radioactive salt waste prior to disposal.

The MCU was designed and built for an expected three-year operational life and five-year design life. The first MCU cold runs began in June 2007 and hot startup was completed in April 2008. MCU remains in hot operation to this day, aiding in multiple, high-level tank closures. In an effort to continue liquid waste disposition at the Savannah River Site (SRS), equipment upgrades and operational improvements have been made to extend the life of the MCU beyond the original three years.

Several pieces of fixed equipment have been converted into removable equipment which reduces the downtime associated with equipment change-outs and thereby reduces the dose to workers and processing impacts. Multiple pumps and filters have been upgraded to more robust designs. Process monitoring and controls have been upgraded to improve process performance. Redundant centrifugal contactor vibration equipment has been installed on each contactor in order to better assess the reliability, processing performance, and lifetime of the contactors. A new Solvent Hold Tank (SHT) Sampler has been installed to minimize the organic cross-contamination within the sampler, dose to workers, and sample analysis time. To increase processing availability and aid in visually obtained data, camera port has been added to the Salt Solution Feed Tank (SSFT). In order to decrease the overall background dose to the workers, the Process Vessel Ventilation (PVV) duct work now has the capability to be flushed to remove contamination. The caustic wash addition system has been modified to be a once-through system to improve equipment reliability, decrease downtime, and decrease dose to workers. In addition, the solvent that MCU utilizes to extract Cesium out of salt waste has been upgraded to Next Generation Solvent (NGS) which is based on MaxCalix extractant instead of a BobCalix extractant.

Further, these upgrades and improvements have allowed MCU to be able to process at higher flow rates (up to 8.5 GPM) and with increased throughput (as high as 1.3 million gallons in FY13 and 5.3 million gallons since hot operations initiated) that

have allowed SRR to continue the disposition of nuclear salt waste. The continued operation of MCU ensures more curies are stabilized into a glass matrix at SRS's Defense Waste Processing Facility (DWPF) and less curies are retained within South Carolina at SRS's Saltstone Disposal Facility (SDF). Unique challenges associated with modifying and improving a demonstration plant that is in hot operations and was designed to be temporary with a limited plant footprint have been successfully overcome. Further, creative strategies for removing old equipment have been utilized given the limited decontamination agents available for use that will not interfere with the organic solvent.

This paper presents and discusses the deployment of these upgrades and operational improvements to MCU in order to allow continued, increased salt waste processing beyond the initial design life.

INTRODUCTION

The MCU was designed and built for an expected three-year operational life and five-year design life. The first MCU cold runs began in June 2007 and hot startup was completed in April 2008. MCU remains in hot operation to this day, aiding in multiple, high-level tank closures. In an effort to continue liquid waste disposition at the SRS, equipment upgrades and operational improvements have been made to extend the life of the MCU beyond the original three years. These upgrades and improvements have allowed MCU to be able to process at higher flow rates (up to 8.5 GPM) and throughput (as high as 1.3 million gallons in FY13 and 5.3 million gallons since hot operations initiated) that have allowed SRR to continue the disposition of nuclear waste. The continued operation of MCU ensures more curies are stabilized into a glass matrix at SRS's DWPF and less curies retained within South Carolina at SRS's SDF.

BACKGROUND

SRS Salt Processing

The existing Actinide Removal Process (ARP)/MCU process has been operating at SRS since April 2008 as an interim salt treatment system to remove actinides and cesium from high level waste salt solutions. MCU is the first production-scale Caustic Side-Solvent Extraction (CSSX) process for cesium separation. While the application of this solvent extraction process is unique, the process uses commercially available centrifugal contactors for the primary unit operation as well as other common methods of physical separation of immiscible liquids (i.e. coalescers and decanters). This process enables permanent disposal of the CSSX raffinate, Decontaminated Salt Solution (DSS), at the SDF as cementitious grout, and the Strip Effluent (SE) containing cesium at the DWPF in a vitrified waste form. MCU is operated in series with the ARP, where ARP first removes sludge solids, soluble strontium and actinides from the salt waste solution and then feeds the Clarified Salt Solution (CSS) to MCU for cesium extraction. Figure 1 provides an overview of the SRS Salt Processing Facilities that feed DWPF & SDF.

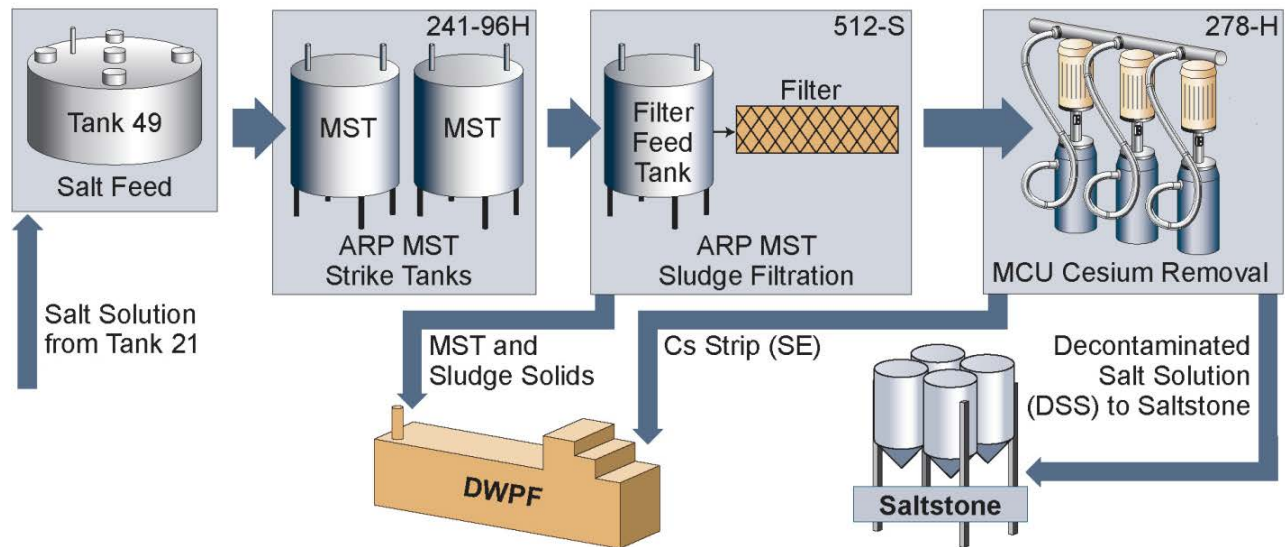


Fig. 1. SRS Salt Processing Facilities

MCU Process

MCU uses a four-part organic solvent developed by Oak Ridge National Laboratory (ORNL) [1], [2]. This solvent is used to extract cesium from the aqueous feed solution in the extraction contactor bank consisting of seven centrifugal contactors. The DSS raffinate is sent to a coalescer and decanter to remove any entrained solvent before transfer to Tank 50 and ultimately to the SDF. The cesium laden solvent from the extraction bank is scrubbed in the scrub contactor bank consisting of two centrifugal contactors. The scrub solution removes ionic impurities in the solvent, and also ensures that the anion pair associated with the Cs⁺ in the solvent is in the optimal anion form for stripping. Cesium is then stripped from the solvent to an aqueous strip solution in the strip contactor bank consisting of seven centrifugal contactors. This concentrated cesium SE is then sent to a coalescer and decanter to remove solvent carried over into the strip effluent. The cesium laden SE is sent to DWPf to be vitrified. The solvent stream exits the strip contactor bank and is sent to the wash contactor bank consisting of two centrifugal contactors to clean the solvent of any impurities. The solvent is then recycled into the system for further use. An MCU process flow schematic is shown in Figure 2.

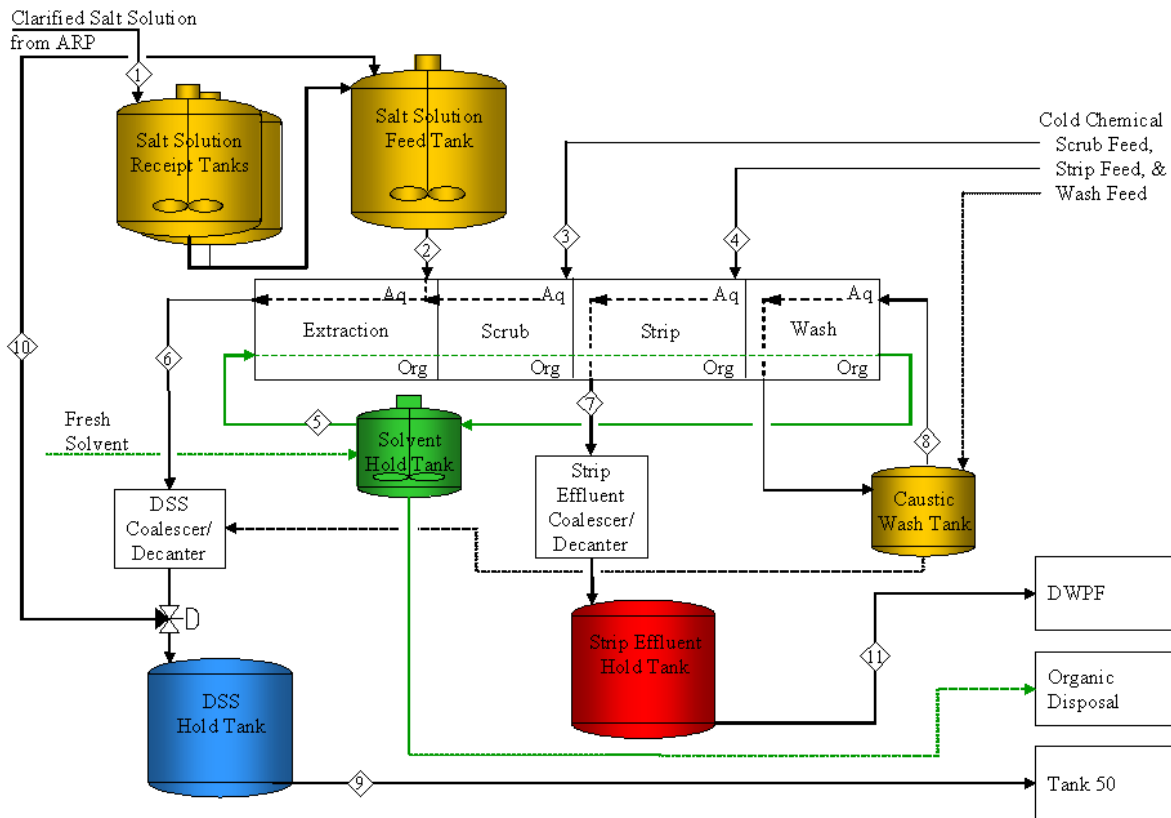


Fig. 2. MCU Process Flow Schematic

DISCUSSION

Coalescer Modifications

Early in MCU processing, it was realized that a filter upstream of the DSS Coalescer would improve the operating lifetime of the DSS coalescer media. In January 2009, a DSS Coalescer Pre-filter was installed up-stream of the DSS Coalescer [3]. This pre-filter utilizes the same Pall coalescer media as the coalescer, but the flow is outside-in instead of inside-out. The purpose of the pre-filter is to reduce precipitated solids passed to the coalescer media, which is designed to facilitate organic droplet growth. This pre-filter utilizes Hanford connectors to allow it to be removed and installed remotely without having any workers enter the MCU Process Cell. The addition of this pre-filter allows the DSS Coalescer to process more gallons between change-out of the coalescer media. This pre-filter is a fully removable jumper that ensures low overall dose to workers and has greatly improved processing time. Due to the success of the remote DSS Coalescer Pre-filter, the SE Coalescer was upgraded in June 2012, to also be removable with Hanford connectors. The Strip Effluent stream carries the Cesium-laden boric acid to the SE Hold Tank (SEHT) before being transferred to the DWPF. Prior to this modification, replacing the SE Coalescer media greatly contributed to worker dose

because workers had to physically enter the MCU Process Cell in order to remove the coalescer media from the housing. After this modification, workers remotely remove a jumper that contains the coalescer media. This coalescer media is then changed in a shop designed for working on contaminated equipment. This modification has decreased the amount of time necessary to replace the SE coalescer media, which directly increases processing time and decreases worker exposure.

Pump Modifications

Many of the MCU pumps were not designed to be used for more than the original three year operating life of the facility. The original design utilized light-industrial Lutz® pumps for many applications throughout the facility. These proved less reliable than desired. There are two more robust designs for each of the applications where the Lutz® pumps were used. These two alternative pumps are Corcoran® pumps and Flux® pumps. The Corcoran® pumps offer a more robust design with a larger shaft and intermediate bearing to better stabilize the shaft. The Corcoran® pumps have been installed in the SSFT [4], SHT [5], and Aqueous section of the DSS Decanter [6]. Corcoran® pumps are also staged and awaiting the next available opportunity for installation in the Contactor Drain Tank (CDT) and SEHT. Due to some small tank nozzle diameters, Corcoran® pumps were not feasible in every location. The SE Decanter Aqueous, SE Decanter Organic, and DSS Decanter Organic pumps have been upgraded to Flux® pumps ready for installation when the current Lutz® pumps fail. These Flux® pumps are similar to the Lutz® pumps but have improved shaft and bearing assemblies. Lastly, the DSS Hold Tank (DSSHT) utilizes Tsurumi pumps. These pumps experienced many gasket failures which required frequent replacement and directly contributed to worker dose. These pumps previously had Nitrile rubber gaskets. These gaskets were upgraded to be Stainless Steel gaskets in November 2013 [7]. No further gasket failures have been noted.

Process Controls Improvements

Many process controls initiatives have taken place to enhance the throughput of MCU. Since process flow rates are essential to the process, it became desired to validate the numerous flow indications. Installing redundant flowmeters would be costly and result in significant worker dose to install. Therefore, the facility installed many Distributed Control System (DCS) calculations that double-check the flow indications from flowmeters in the facility. These confirmatory calculations compare the average rate-of-change of process tank levels to the indicated process flows. These confirmatory calculations have been implemented within the DCS since April 2010 and are a testament to ingenuity by enhancing the process via confirmatory calculations instead of modifications within the facility [8]. In addition to confirmatory calculations, several original Variable Frequency Drives (VFD) have been upgraded. Most of these VFDs were Allen-Bradley® 1336 models which are now obsolete. Therefore, these drives have been upgraded to Allen-Bradley PowerFlex 700 models and have proven to be much more reliable for the facility.

These process control upgrades have resulted in less downtime and greater processing time, while solving a processing problem with zero dose to the workers.

Contactors Vibration Enhancements

The MCU Contactors were originally installed with one vibration sensor. The vibration sensor is installed between two bearings, which does not provide accurate information about any single bearing. Further, this vibration sensor signal is converted multiple times before the signal reaches the DCS. The result is reduced accuracy in the indication of the overall contactor vibration. In July 2012, redundant vibration monitoring was installed on each of the MCU contactors [9]. Each contactor now has a vibration sensor directly on the lower bearing, upper bearing, and motor bearing. Each of these sensors sends a signal to a termination box directly outside of MCU. These signals can be captured and analyzed to get specific degradation trends of each of the three bearings on each of the contactors. This has allowed for predictive maintenance on the individual MCU contactors, which has significantly improved the reliability of the entire contactor bank.

Sampling Capability Improvements

MCU original design had two sample stations. The Sample Station #1 was capable of sampling the SEHT, the SHT, and the CDT. Sample Station #2 was capable of sampling the DSSHT and the Caustic Wash Tank (CWT). During sampling of the SEHT, the waste is recirculated through the sampler for a minimum of 20 minutes. This recirculated stream was sent to the CDT. In July 2012 a modification was installed to route this waste to the SE Decanter (SED) instead of the CDT [10]. Any waste in the CDT ultimately has to be dispositioned to either the SE Decanter or DSS Decanter. Therefore, this modification decreased the amount of waste in the CDT that needed to be dispositioned, increased the overall processing efficiency of MCU, and improved compliance with the Waste Acceptance Criteria (WAC). Another upgrade to MCU sampling was the installation of a dedicated SHT sampler. As discussed, Sample Station #1 was capable of Sampling the SEHT, SHT, or CDT. Braided metal hoses were physically swapped in the sample room in order to change the configuration to allow the Sample Station #1 to sample each of these tanks. MCU was required to be shut down in order to swap these hoses, and a leak check was required every time. This resulted in significant down-time just to get an SHT sample. Furthermore, there was risk that organics from SHT sampling could be contaminating the subsequent sample of the SEHT. For these reasons, a dedicated SHT Sampler (Sample Station #3) was installed in November 2013 [11]. This sampler is only used to sample the SHT and there is no longer a risk of organic contaminating the SEHT sample. Further, there is no downtime needed in order to sample the SHT and the associated dose to workers is nearly completely eliminated.

Process Cell Rain Cover Addition

MCU was constructed such that the contactor room is a fully enclosed room with a shield door for maintenance access. The Process Cells have concrete walls and the roof has interlocking, 3-foot thick concrete cell covers for shielding. There is a

sealant between each of the cell covers to ensure that the air in-leakage between cell covers is minimized. However, this sealant does not prevent rain water from seeping through the cracks into the process cell. Liquid in the sumps could be rainwater or a leak from some portion of the process. For this reason, rainwater routinely shut-down MCU until the sump water could be dispositioned. Therefore, a rain cover was installed over the Process Cells in November 2013 [12]. This has made a dramatic impact on the facility as nearly zero rain water was observed in the the Process Cell sumps since installation. This directly correlates into more processing time for MCU.

Camera Port Addition

Following the discovery of sodium oxalate solids in the MCU Feed tanks in the summer 2014, the facility had a desire to be inspect and sample for solids within the process tanks that did not have sampling capability. At the time, the SSFT pump was being replaced. A tank access tube was welded to the flange that supports two SSFT pumps and a hole was core-bored into the cell cover directly above [13]. A camera port plug has been installed to ensure overall dose to workers is kept to a minimum. This allows a camera to be installed through the cell covers and through the pump flange on the tank into the head space of the SSFT in order to perform visual inspections of the material inside. This camera port has been used many times to inspect the SSFT to ensure normal conditions. This camera port has also been utilized to obtain dip samples of the SSFT material for analysis. Similar camera ports are being planned for each of the other MCU process tanks to enable visual inspections.

Process Vessel Ventilation Flushing Capability

The MCU Process Vessel Ventilation (PVV) prevents the spread of contamination by providing an active air flow path through HEPA filters. Ductwork is internally contaminated upstream of the HEPA filters. Due to space constraints, this PVV duct work is in close proximity to other work spaces that caused background dose to workers. Therefore, it was desired to have the ability to flush each of the PVV ducts. In April 2015 a modification was installed that allows the PVV ducts from each of the MCU process tanks to be back-flushed with domestic water back into the respective process tank [14], [15]. This decreases the overall background dose to the workers.

Caustic Wash System Modification

MCU was constructed with a Caustic Wash Feed and Bleed system. This system pumped clean caustic into a Caustic Wash Tank (CWT) and then part of this caustic was pumped via a second pump into the MCU process. The resulting two-pump setup was unreliable and inefficient, as not all of the clean caustic pumped into the process was actually utilized by the process. In April 2015, a modification was installed that modified this Caustic Wash system such that it is now a once-through system [16], [17]. The more unreliable of the two pumps, which was also within the contaminated Contactor Room, was removed and caustic is now metered into

the process via a single pump that is in a clean, easily-accessed area. This modification has resulted in less dose to maintenance workers, less downtime, and increased process efficiency.

Chemistry Changes

The initial MCU process flowsheet utilized a BobCalix based solvent. The BobCalix solvent is composed of four components. These are BobCalixC6 (0.007M), Cs-7SB (0.750 M), TOA (0.003 M), and Isopar-L (69 wt%). This flow sheet utilized 0.001 M nitric acid as the strip solution, 0.05 M nitric acid for the scrub solution, and 0.03 M sodium hydroxide as the wash solution. In October of 2013, Next Generation Solvent (NGS) was implemented at MCU [18]. The components of NGS are MaxCalix (0.050 M), Cs-7SB (0.500 M), TiDG (0.003 M), and Isopar-L (74 wt%). This flow sheet utilizes 0.01 M boric acid as the strip solution, 0.025 M sodium hydroxide as the scrub solution and 0.03 M sodium hydroxide as the wash solution. The NGS flowsheet was implemented at MCU to increase the cesium removal efficiency, allowing MCU to operate longer, processing more salt waste than initially anticipated, and without impacting the commitments to the state of South Carolina. Further improvements have been to modify the wash solution concentration to 0.025 M sodium hydroxide in order to have the scrub and wash solution concentrations the same to allow for operational flexibility [19].

Future Improvements

The team focus is on increasing worker safety and decreasing dose to workers, continuous improvement, evaluating process performance, and maximizing attainment / minimizing downtime. Additional improvement concepts are generated and prioritized through a System Engineering Evaluation process to ensure cost/benefit commensurate with the current life expectancy and business objectives.

CONCLUSIONS

Many upgrades and improvements have been implemented within the MCU at SRS. These improvements have increased the facility attainment, decreased overall dose to workers, increased plant reliability, and decreased the time to perform maintenance. Many creative strategies have been utilized to upgrade equipment within this unique, radioactive facility.

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8. J-DCF-H-04924, Rev 0, "MCU Confirmatory Calculations"
9. J-DCP-H-11002, Rev 1, "MCU Vibration Monitoring Modification"
10. P-DCP-H-11009, Rev 0, "Reroute SEHT Sample Return Line Going to DCD (MT-21)"
11. P-DCP-H-13001, Rev 0, "An Independent Sampler for Solvent Hold Tank (SHT)"
12. C-DCF-H-04159, Rev 3, "Rain Cover Over MCU Process Area"
13. P-DCF-H-02059, Rev 0, "Salt Solution Feed Tank Pump – Camera Port Modification"
14. P-DCF-H-02083, Rev 0, "MCU PVV Flushing Modification (1 of 2)"
15. P-DCF-H-02084, Rev 3, "MCU Process Vessels (PVV) Flushing Modification (2 of 2)"
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