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Utilizing Commercial Submersible Mixer Pumps for Sludge Removal in Savannah River Site's Tank 26 – 20289

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ABSTRACT

The Savannah River Site (SRS) Liquid Waste System (LWS) safely manages, stores, treats, and dispositions liquid radioactive waste. The LWS consists of 51 underground waste storage tanks (eight of which are operationally closed and filled with grout), waste evaporators, treatment facilities, and solidification facilities, known as the Defense Waste Processing Facility (DWPF) and Saltstone Production Facility (SPF). One of the waste storage tanks, Tank 26, was placed into service in 1980 as an F Tank Farm (FTF) Evaporator Feed Tank. From 1980 to 2013, Tank 26 received F Canyon receipts and dilute supernate that was then transferred to the 242-16F FTF Evaporator for volume reduction. In 2013, the steam tube bundle failed in the FTF Evaporator, and the decision was made not to repair/resume evaporator operation. During operation of Tank 26, solids built up to a level of 2.03 m in the tank with a volume of 1062.9 kL. Due to the evaporator failure and subsequent shutdown, the solids in Tank 26 were selected to feed Sludge Batch 10, which is collected and prepped prior to being sent to DWPF for final disposition. To accomplish solids removal, Commercial Submersible Mixer Pumps (CSMPs) were selected to slurry the solids in preparation to be sent to Tank 51. Four CSMPs were installed in Tank 26 with each one installed in a separate quadrant of Tank 26. This work would mark the first deployment of CSMPs in an SRS waste tank.

The CSMPs were developed in response to operational issues from previous mixing pumps and budgetary constraints. The CSMPs use the concept of modifying commercially available equipment for nuclear waste applications. The CSMPs consist of a 230-horsepower submersible mixing pump (manufactured by GPM, Inc.) joined to a mast fabricated at SRS. For this application, Savannah River Remediation (SRR) design services was challenged to provide a mast design that required no steel superstructure support system on top of Tank 26. Also, SRR design services provided a simplified Tank 26 riser interface that did not require extensive machine parts to adjust height of the suction screen of the CSMP within the tank. Other design improvements include no requirements for tank top radiation monitors and no requirements for flushing of the CSMPs during startup/shutdown operations.

The CSMPs were operated at an initial height of 2.29 m above the Tank 26 bottom for 10 days. After sludge sounding, the CSMPs were lowered to a height of 1.52 m with no issues due to proper work planning and the simplified riser interface. With the CSMPs lowered to a level of 1.52 meters above the tank bottom, the CSMPs were operated for 12 days and another sounding was performed. The sounding level came back matching the disturbance depth results of the first pump run. Chemistry samples were analyzed while the tank was left to settle. The analysis revealed enough weight percent solids to provide good feed to Sludge Batch 10. Also, the results revealed the supernate within the mixture would provide good salt solution feed to Salt Waste Processing Facility (SWPF) Salt Batch 3. So, the plan was modified to let the disturbed solids settle and decant the salt solution for addition to SWPF Salt Batch 3. Then water will be added back to Tank 26, and the CSMPs run in order to wash the solids to decrease settling time prior to being sent to Tank 51 for Sludge Batch 10.

Utilizing CSMPs for waste removal in an SRS Tank has provided a cost-effective means for further waste removal efforts. In addition, the CSMPs are easier to operate by utilizing a robust and simplified design. The CSMPs performed quite well with no process shutdown or delays during operation. As a result, CSMPs are integral to the future of removing radioactive waste from storage tanks at SRS.

INTRODUCTION

The mission of Tank 26 prior to waste removal was to feed qualified material to the FTF Evaporator in order to concentrate liquid into salt. Due to the failure of the evaporator tube bundle, Tank 26 was selected for a feed tank for Sludge Batch 10. CSMPs were chosen for disturbing and mixing solids in Tank 26 prior to transfer to Tank 51 for sludge batching. The CSMPs were developed in response to operational issues utilizing previous mixing pumps and from budgetary constraints. The CSMPs use the concept of modifying commercially available equipment for nuclear waste applications.

DISCUSSION

Tank 26 Overview

Tank 26 is a 4921.04 m^3 (1,300,000 gal) capacity; Type IIIA waste tank located in F Tank Farm (FTF) and was placed into service on January 11, 1980. The tank primary shell is 25.91 m (85 ft) in diameter, and 10.06 m (33 ft) in height constructed from ASTM A516, grade 70 stress relieved steel. Tank 26 has permanently mounted U-shape cooling coils installed prior to completion of the Tank and are supported on the tank bottom. The primary shell is set within a full secondary shell that is 27.43 m (90 ft) in diameter and 10.06 m (33 ft) in height. There have been no leak sites observed for Tank 26. Tank 26 initially stored approximately 2.29 m (80 in) of sludge with the top layer containing approximately 19.05 cm (7.5 in) of salt prior to waste removal operations. Fig. 1 shows the typical Type IIIA arrangement.

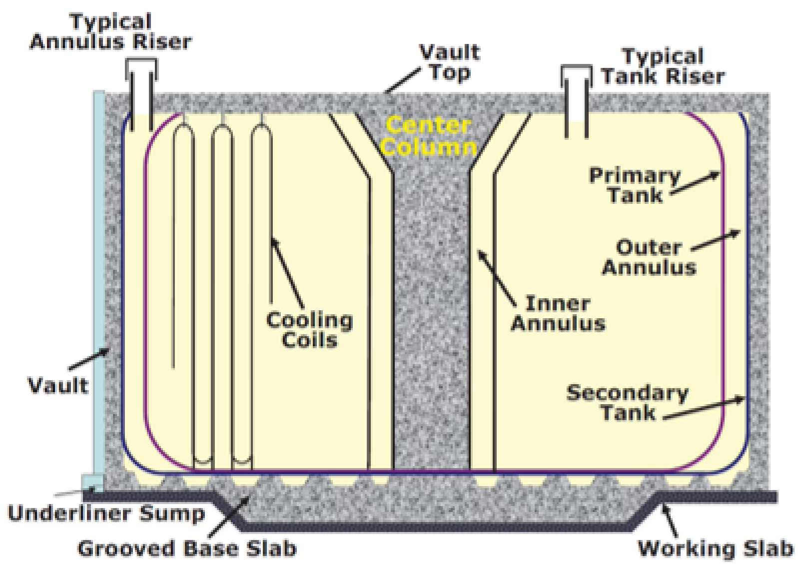

Fig. 1. Typical Type IIIA Tank Diagram

Tank 26 CSMP Riser Selection

Riser selection for CSMP installation included considerations for equipment to be removed and the expected Effective Cleaning Radius (ECR) of the CSMPs. The ECR is determined by calculation in which the discharge velocity of the nozzle is used to determine the depth of solids to be disturbed below the CSMP. Fig. 2 displays a graphical representation of the calculated ECR of 8.9 m (29.2 ft) for the installation of four CSMPs. The combined ECRs of the four mixing pumps leave only 1.9% of the total cross-sectional area in a less than ideal mixing fluid velocity with the calculated value of the ECR equal to 8.9 m (29.2 ft). In addition, cooling coil interferences were not encountered during Tank 26 equipment installation based on designs of the Type IIIA cooling coil designs. Cooling coil designs for Type IIIA tanks specify the cooling coil returns are mounted to the top of the tank with the vertical U-shaped coils angled away from each of the risers.

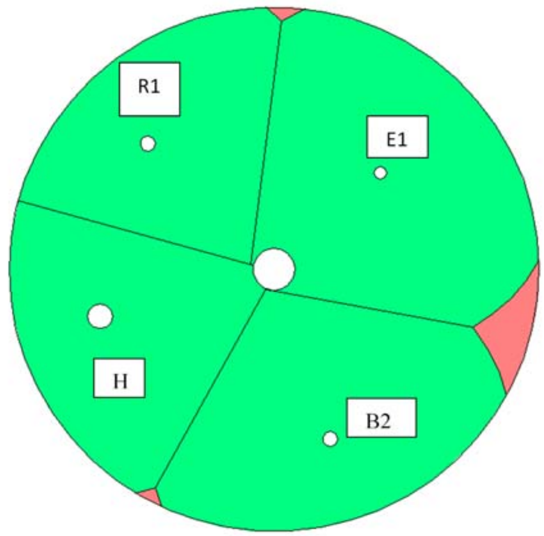

Fig. 2. Tank 26 CSMP ECR 8.9 m (29.2 ft) Coverage Diagram

Tank 26 Modification Strategy

Tank 26 Risers B2, E1, H, and R1 were determined to be the locations for installing four CSMPs. Risers B2 and H required just a shield plug to be removed. The evaporator feed pump/eductor in Riser R2 was removed so that Tank 26 could not feed the FTF evaporator and to remove the riser enclosure covering both Risers R1 and R2. Riser E1 required spare tank level instrumentation to be removed, while Riser R1 required an evaporator feed eductor to be removed. A new Submersible Transfer Pump (STP) was installed in Riser C1. The existing transfer jet, which utilized stream in Riser C1 as a motive force was removed prior to installation of the STP. The STP (Tsurumi LH411) is similar in model to majority of new transfer pumps installed in the Tank Farms for waste removal operations.

Variable frequency drives for the CSMPs, CSMP turntable motors, and STP were installed in 241-18F. Controls for the equipment was added to an existing Distributed Control System (DCS) and operated from a DeltaV console in 241-18F control room. Fig. 3 shows the general layout of Tank 26 equipment installation. In addition, a purge ventilation stack extension was installed to provide an elevated release of potential mercury vapors generated due to waste removal operations.

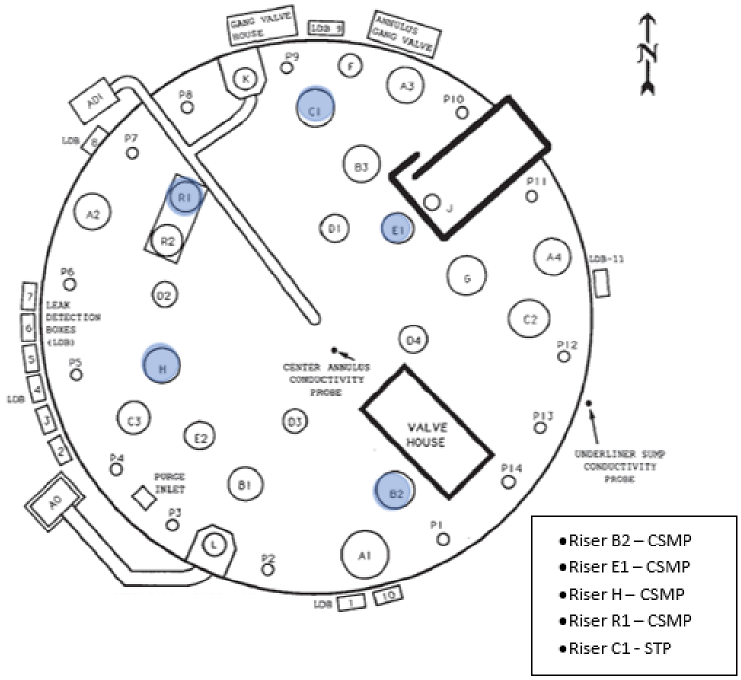

Fig. 3. Tank 26 Equipment Layout

Procurement and Testing of the CMSPs

A procurement specification was generated and provided prospective bidders detailed information relative to the type of pump to be manufactured, critical dimensions, materials of construction and minimum hydraulic performance requirements. The award was based upon a best value approach under a competitive bidding process. [1]

The CSMPs were manufactured by GPM, Inc and the CSMP is designated model SBMX2S200-4T4-15.0. One of the six CSMPs procured was mounted to a test mast and ran for 10 days at TNX area at the SRS. [1] The test was utilized to get baseline data on CSMP operation as well as determine maximum speed and minimum level used to avoid rooster tailing required for the Tank Farms documented safety analysis. Table I lists the speeds and minimum coverage levels to meet rooster tailing requirements.

TABLE I: CSMP Operating Speed vs. Tank Level

Tank Liquid Level Above Bottom of the CSMP Inlet Screen	Maximum CSMP Speed
Greater than or equal to 76.2 cm (30 in)	188.50 rad/s (1800 rpm)
Less than 76.2 cm (30 in) and greater than or equal to 6.5 cm (25 in)	157.08 rad/s (1500 rpm)
Below 6.5 cm (25 in)	Immediate shutdown

Future procurements utilize a datasheet listing the model and part number when ordering to shorten the procurement process.

Design of the CSMPS

The CSMP is constructed with a 149.14 kW (200 HP) motor with N Class insulation. Since the liquid to be mixed in Tank 26 had a high Specific Gravity (spg), the CSMP motor was rerated to 171.51 kW (230 HP) in order to utilize a higher motor nameplate amperage for the VFD. The motor is a sealed motor design and is cooled by liquid contact with the motor casing. Inside the motor casing is a temperature switch that is used to shut the CSMP down when the motor temperature increases above 200 ^{o}C. Also, the pump bearing is cooled by an oil seal that comes with a float switch, which will shut the CSMP down when the oil level is low within the bearing seal. The manufacturer recommends a minimum submergence level of 1.98 m (77.9 in) under normal operation and a maximum of 60 ^{o}C liquid temperature with the rerating of the motor. The maximum diameter of the pump is 56.9 cm (22.4 in). The pump connects to an SRR designed mast with an ANSI 14 inch – 150 LB flat faced flange. The maximum rated flow is 0.12 m^3/s (1950 gpm) with two 5.08 cm (2 in) tangentially opposing nozzles.

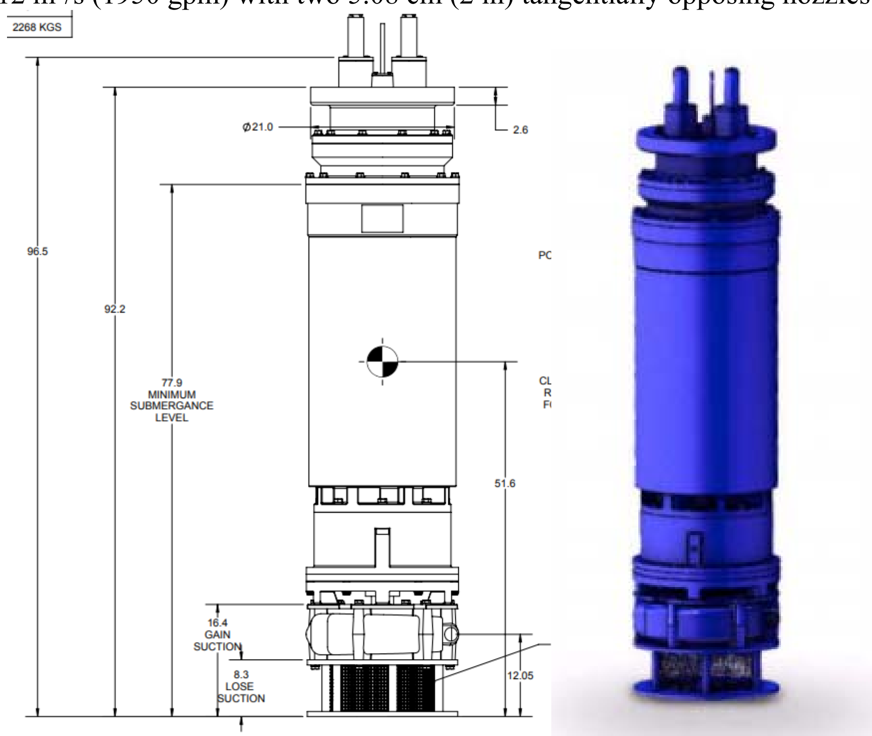

Fig. 4. CSMP Overall Dimensions

Design of CSMP Mast and Assembly

The SRR designed mast is 10.05 m (32 ft) long and can fit through a 58.42 cm (23 in) diameter riser. The mast has 11 rings spaced 25.4 cm (10 in) about which in turn allows for the CSMP to be lowered into the waste tank in 25.4 cm (10 in) increments. The mast is made of stainless steel and was fabricated by SRR Construction. The mast center column is made of a 35.56 cm (14 in) diameter pipe with conduit for the power cable and float/temperature switch cabling running through conduit in the center. The conduit is offset, and the void spaces are filled with controlled low strength material for shielding purposes. The flange connection between the pump and mast are liquid tight although the CSMP motor cable penetrations are liquid tight as well. The provide additional assurance that liquid will not enter the motor cavity through the cable penetrations. The total CSMP/mast assembly is 12.09 m (39.68 ft) long (not including the junction box/support). Fig. 5 shows the flange connection assembly and the complete mast/CSMP assembly.

Fig. 5. Flange Connection and CSMP Mast Assembly

Fig. 6 shows an installed configuration of the mast and shield plate assembly on Riser H. The design requires no structural steel, support cans, and only one turntable assembly. The shield plate is 20.32 cm (8 in) thick and sits directly on the riser lip. Atop the shield plate is the turntable mounting plate along with the slewing bearing. The drive plate mounts to the bearing with the elevation ring split plates providing attachment to the CSMP mast. A motor and gearbox assembly drive the slewing bearing at speeds of 0.052 to 0.105 rad/s (0 .5 – 1 rpm). Limit switches provide method of switching between clockwise and counterclockwise rotation as well as provides overtravel protection.

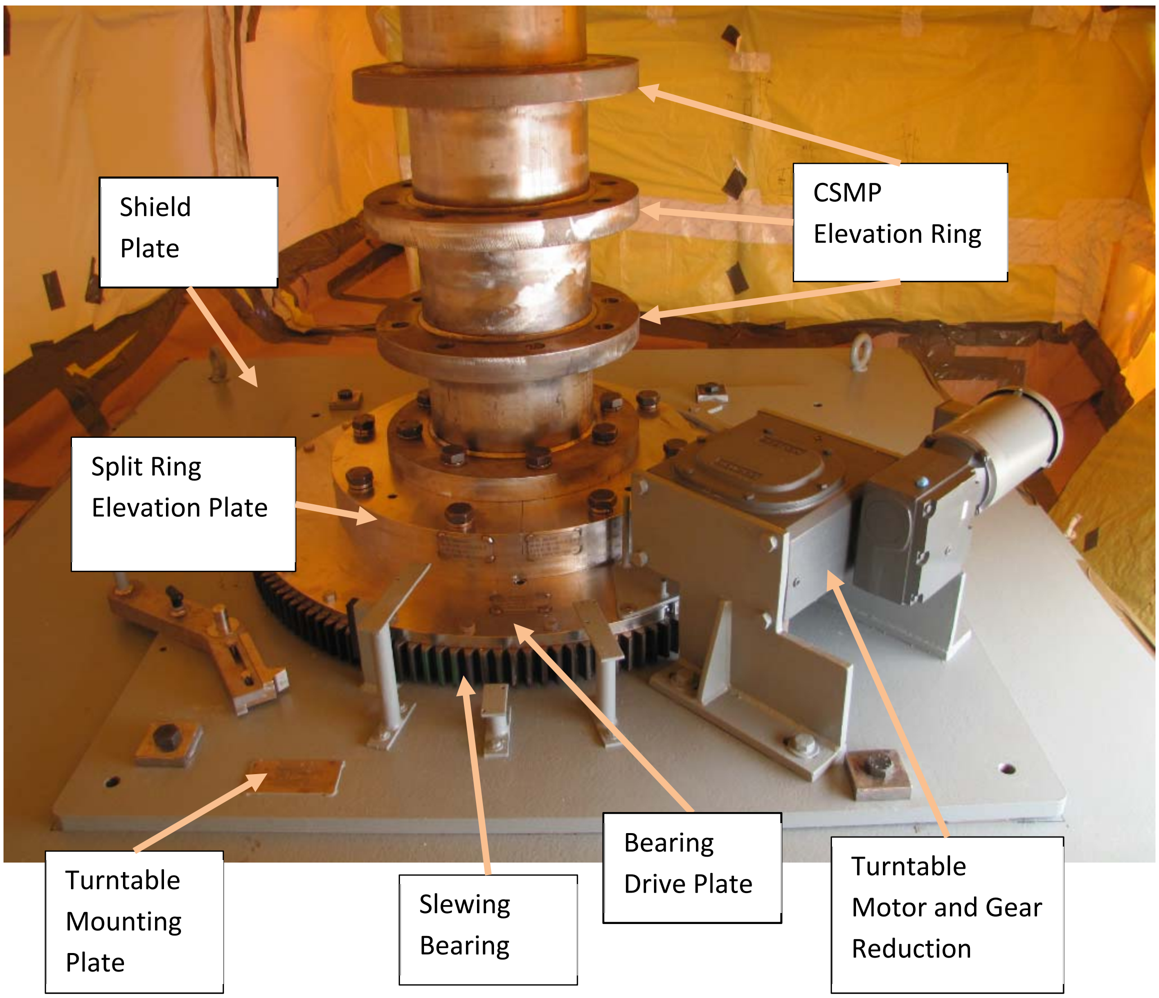

Fig. 6. CSMP Riser Interface

The benefits of this design are decreased installation and operating costs. Decreased installation costs can be attributed to no structural steel is needed to support the CSMP. Also, the mast design and simplified riser interface require no support cans and no second set of slewing bearings. As for operating costs, the simplified riser interface allows for ease of lowering after pump runs. The work instructions only require the CSMP and the elevation spilt ring to be unbolted with the CSMP supported by a crane. The elevation ring split plates are slid aside to lower the pump and repositioned back into place. The bolts are reinstalled, and the rigging is removed. Also, the CSMP does not require flushing upon startup and shutdown like other waste removal pumps in the Tank Farms.

Installation of the CSMPs in Tank 26

Installation activities for Tank 26 waste removal equipment took place from December 2013 to September 2016. Field work included removal of equipment on the tank top, equipment in the tank risers, and electrical equipment in 241-18F. Fig. 7 shows the installation of Riser E1 CSMP (July 2015) after the installation of the first CSMP in Riser H (May 2015). Fig. 8 through 11 show Tank 26 before and after installation of the CSMPs for each riser.

Fig. 7. Riser E1 Installation

Fig. 8. Riser B2 Before and After

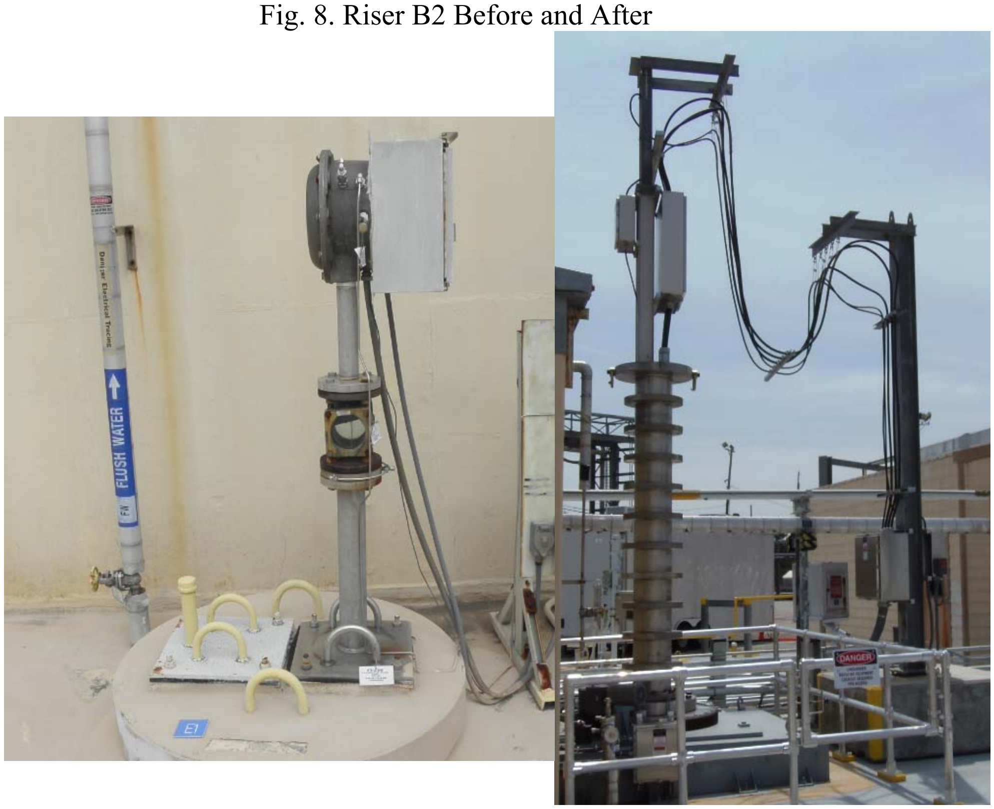

Fig. 9. Riser E1 Before and After

Fig. 10. Risers R1(left) and R2 (right) Before and After

Fig. 11. Riser H Before and After

Operation of the Tank 26 CSMPs

The Tank 26 CSMPs were turned over to SRR Operations in September 2016. Since the HTF 3H evaporator leak had to be repaired, waste removal activities were suspended until the sludge in Tank 26 was needed for Sludge Batch 10. During this time, the Tank 26 CSMPs and STP were run under a preventive maintenance activity. In each run, the pumps were run for less than 5 minutes to protect motor and pump bearings from developing flat spots. This allowed the pumps to be run without utilizing rigorous hydrogen generation controls normally implemented for normal operations. Once the HTF 3H Evaporator was repaired, preparations were made to finalize the operations strategy for Tank 26 waste removal. The Tank 26 CSMPs were lowered from the initial installed position of 2.79 m (110 in) to 2.29 m (90 in) above the tank bottom. Excess supernate totaling 2006.27 m^3 (530,000 gal) was transferred to Tank 32 in preparation for HTF 3H evaporator feed. 690.91 m^3 (182,520 gal) of well water was added to Tank 26 in preparation of initial mixing.

The Tank 26 CSMPs were operated for 10 days from 2/13/2019 to 2/23/2019 at a level of 2.29 m (90 in) from the tank bottom. The CSMP operating speeds ranged from 178.02-188.50 rad/s (1700 -1800 rpm) for the duration of the first mixing campaign without shutdowns. Some CSMPs were slowed down from the maximum operating speed of 188.50 rad/s (1800 rpm) due to amperage approaching the vendor recommended maximum of 246 A to maintain service life of the CSMP given a maximum liquid temperature inside the waste Tank of 60 ^{o}C. The current for the Pumps ranged from 220 to 245 A. The anticipated solids level after the first mixing campaign was estimated to be 1.83 m (72 in) per the Tank 26 flowsheet calculation.

Following the first mixing campaign, a sludge sounding was performed on 2/26/2019 and determined the solids level to be 1.46 m (57.63 in) above the tank bottom. A technical error notification was initiated to determine the cause of a larger than expected disturbance depth of the CSMPs. The solids in Tank 26 were determined to contain more salt than previously anticipated. The higher salt content of the solids allowed the CSMPs to disturb more than 60.96 cm (24 in) below the pump suction screen by dissolving soluble solids with dilute supernate. Evaluations were updated to account for the configuration of the tank to address hydrogen generation and criticality concerns with operating the Tank 26 CSMPs in a tank with a higher amount of salt mixed into the sludge than anticipated. The CSMPs in Tank 26 were then lowered to 1.52 m (60 in) above the tank bottom. No obstructions or solids were encountered, indicating the CSMP disturbed solids evenly within the tank.

Tank 26 CSMPs were operated for 12 days from 5/2/2019 to 5/14/2019 at a level of 1.52 m (60 in) from the tank bottom. The CSMPs were operated at a speed of 178.02-188.50 rad/s (1700-1800 rpm) for the duration of the second mixing campaign without shutdowns. After the pump run was complete, a wafer measurement was performed, which indicated a settled solids layer at 68.91 cm (27.13 in) from the tank bottom. A sludge slurry sample was taken right after shutdown. The sludge slurry mix was found to contain 8.6 wt% insoluble solids. The mixture was found to have a high enough molarity of sodium (8.00 M) for the supernate portion of the mix to be used in a salt batch for SWPF. A subsequent turbidity measurement was taken on 7/23/2019 with a reading of 2.03 m (79.83 in) which indicated there was enough distance between the STP and solids layer to make a transfer from Tank 26 to 35. On 8/16/2019, 936.72 m^3 (247,500 gal) of supernate was transferred from Tank 26 to Tank 35.

The Tank level in Tank 26 will be raised adding 813.86 m^3 (215,000 gal) prior to mixing and sending to Tank 51. The Tank 26 CSMPs will be run for 8 hours prior to the initiation of the transfer to mix the added well water and resuspend the solids in Tank 26. Tank 26 will be transfer 870.64 m^3 (230,000 gal) of sludge slurry to Tank 51 in support of Sludge Batch 10. After the initial sludge slurry transfer, Tank 26 will serve as a receipt tank for Tank 27 dissolved salt solution until further sludge is needed for sludge batch 11.

CONCLUSION

Utilizing CSMPs for waste removal in an SRS Tank has provided a cost-effective means for further waste removal efforts. In addition, the CSMPs are easier to operate by utilizing a robust and simplified design. The CSMPs performed quite well with no process shutdown or delays during operation. The next deployment for CSMPs in the Tank Farms will be salt dissolution in Tank 41. As a result, CSMPs are integral to the future of removing radioactive waste from storage tanks at SRS.

REFERENCES

1. HUBBARD, M., J. E. HERBERT, and P. W. SCHEELE, "Commercial Submersible Mixing Pump For SRS Tank Waste Removal – 15223," Waste Management Symposium, 2015, March 15 to March 19, Phoenix, AZ.