

**Operation of Bubblers in the Savannah River Site
Defense Waste Processing Facility Melter - 12166**

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ABSTRACT

Savannah River Remediation (SRR) LLC acquired the liquid waste contract at the Savannah River Site (SRS) in the summer of 2009. In order to achieve the main goal of the contract, closing of High Level Waste (HLW) tanks, it was necessary to process more waste throughout the SRS liquid waste facilities. The Defense Waste Processing Facility (DWPF) would need to increase its production rate of radioactive waste glass filled canisters as a part of the plan to achieve this commitment. To attain the increased production rate, four bubblers were installed in the DWPF Melter in September 2010 to agitate the DWPF Melter glass pool. The four bubblers were designed to be installed in existing nozzles on the top-head of the DWPF Melter. The design and fabrication of the four (4) bubblers was accomplished through SRR critical subcontractor *EnergySolutions* LLC. In addition to the existing bubbler design, a new design concept has been approved and is in the process of fabrication. The new design will allow for the lower end (inside melter) of the bubbler to be replaced while the upper end (outside melter) of the bubbler is reused to minimize cost and waste at the DWPF. The bubblers have been operating in the DWPF Melter for approximately 1 year. The originally installed bubbler set was replaced in January 2011. The bubblers were visually examined once removed from the melter and showed minimal signs of wear. Material testing of the Inconel 690 is being performed to determine if the bubblers operational life can be extended. The use of the bubblers has changed the dynamics within the melter glass pool. This is shown through indications that the bubblers have increased the glass pool circulation. Overall, performance of the bubblers has been encouraging and the DWPF Melter has seen a significant improvement in its ability to process waste since the bubbler installation.

INTRODUCTION

The DWPF has been in radioactive operations since 1996. During this time frame, approximately 3250 radioactive glass filled canisters have been processed through the facility. Waste glass production has been accomplished using two separate Joule heated melters. Melter 1 was in service from 1996 to October 2002, while Melter 2 is currently in service after beginning operation in March 2003. The waste glass is vacuum poured from the melter into stainless steel canisters which hold approximately 1815 kg (4000 lb) of the glass. Although several process improvements had been made to the DWPF Melter to increase attainment and melt rate, Fiscal Year canister production had averaged 215 canisters with the two most recent years (2009 and 2010) only producing 193 and 192 canisters respectively. To achieve the contract goal of closing HLW tanks at a more aggressive rate, it was necessary to increase this production rate.

The direction taken to increase the canister production rate was to increase the melt rate of the DWPF Melter. Historically the melter has been the “bottleneck” of the DWPF process due to the limitations of the previous melter arrangement. It was determined that bubblers would create more convection/mixing within the glass melt pool, thereby increasing the heat transfer to the melt pool

cold cap. The cold cap is a layer of unmelted feed that is on the top of the melt pool after being fed into the melter as a slurry of waste, glass frit, and water. This increase in heat transfer would provide higher melt rates and the increase in canister production needed to meet the contract goals.

The DWPF Melter bubblers were designed and fabricated in partnership with SRR critical subcontractor EnergySolutions, LLC. The design called for four bubblers be installed in place of already existing components (glass level probe, feed tubes, thermowell) installed in the melter top-head. This required that two of the bubblers, C2 and C4, have functions (plenum pressure, glass level, and temperature measurement) in addition to the agitation function. The remaining two bubblers, B1 and B2, would provide the agitation function only. The retrofit also called for the reduction from two feed tubes to one centrally located feed tube. The redesign of the feed tube to allow for its installation in the center top-head nozzle was accomplished in collaboration with Savannah River National Laboratory (SRNL) with modification work performed at SRS. After completion of the pre-conceptual design, final design approval, testing, and fabrication, the bubblers were installed in September 2010. [1] Fig 1 shows the orientation of the relocated/redesigned center feed tube and the B1 and B2 bubblers.

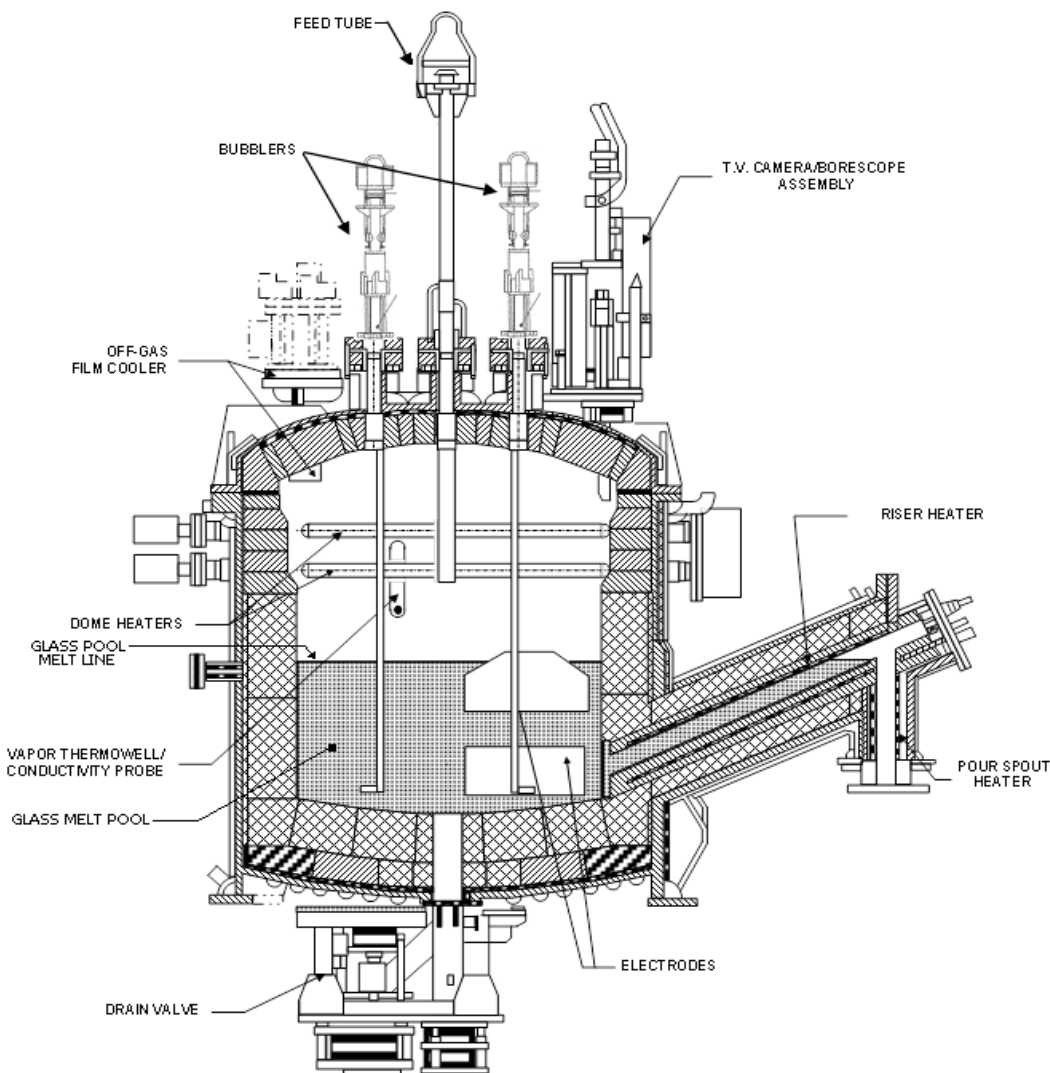


Fig 1. Cross-section of melter showing center feed tube as well as the B1 and B2 Bubblers.

The melter glass melt pool has a surface area of 2.63 m² (28.3 ft²) with a nominal depth of 81.3 cm (32 inches). The glass pool is kept at a temperature of 1100 to 1150 degC. Prior to bubbler installation the melter was able to achieve a two year average glass production of 54 to 57 kg of glass/hour (120 to 125 lbs of glass/hour). During this same two year period the melter was fed at a slurry feed rate of 2.27 to 3.03 L/min (0.60 to 0.80 gal/min).

BUBBLER OPERATION

The DWPF began processing with the bubblers installed at the end of September 2010. Initial bubbler start-up and operation followed specific set of guidelines so that the melter could be easily evaluated as changes were made to slurry feed rate and bubbler gas (argon) flow rate. [2] These guidelines were generated by combining SRR's operational knowledge of the DWPF Melter with EnergySolutions' experience in the use of bubbler technology.

DWPF Melter processing began with the slurry feed rate set at 3.03 L/min (0.80 gal/min), the feed rate prior to bubbler installation, and a bubbler argon flow rate of 14.2 L/min (0.50 ft³/min). The bubbler flow rate and slurry feed rate were systematically increased while observing specific melter parameters (glass pool temperature, vapor space temperature, pressure, etc.). Once these parameters stabilized following a change, the bubbler flow and/or the slurry feed rate would be increased. The bubbler flow rate was raised to 34.0 L/min (1.20 ft³/min) and the slurry feed rate was raised to 4.54 L/min (1.20 gal/min) over a several day start-up period.

A change in glass pool dynamics was observed, as expected, when bubbler operation began. The most notable observation was the convergence of the upper and lower glass melt pool temperatures. This was definitive evidence of the increased glass circulation within the melt pool. In addition, there was a decrease in the power needed to maintain the melter dome heaters temperature setpoint. This provided evidence of the bubblers helping to turn over the cold cap and increasing the heat transfer from glass pool to cold cap. This heat transfer increase was vital to increasing the melt rate and subsequently the glass production rate. The nominal glass melt pool temperatures have also risen, both upper and lower glass temperatures in the 1130 to 1140 degC range, making the increased heat transfer more effective in increasing melt rate. One thing of note is that due to these changes, the bubblers are placed in an idle state, argon flow set to 1.42 L/min (0.05 ft³/min), when the melter is not processing feed. This is done to prevent excessive heat from entering the vapor space and to prevent melted glass from "splashing" onto the upper portions of the bubblers and possibly the opening of the feed tube.

Currently the bubbler flow rate is set in the 36.8 to 39.6 L/min (1.30 to 1.40 ft³/min) range while the slurry feed rate is in the 4.16 to 4.54 L/min (1.10 to 1.20 gal/min) range. The slurry feed rate prior to operating the melter with bubblers was in the range of 2.65 to 3.03 L/min (0.70 to 0.80 gal/min). The increase in slurry feed rate operating range has provided a high canister output. The new feed rate range along with the corresponding bubbler flow rate range has allowed the DWPF to maintain a balance in cycle time in relation to the other processes within the canister production cycle. Process improvements have also been completed in the feed preparation area of the DWPF to support the increased glass production rate. It has been the approach of the DWPF to operate at the fastest rate possible without having to enter an idle state within the melter. The process rate of the melter and the feed preparation areas are dependent upon the characterization of the incoming waste from the Tank Farm area. The current bubbler and slurry feed rate ranges could vary as new sludge batches are processed through the DWPF.

BUBBLER INSPECTION

The design life of the DWPF Melter bubblers is six (6) months. This design life is based on EnergySolutions and Vitreous State Laboratory corrosion testing with Hanford WTP high level waste glass. [2] The decision was made prior to initial bubbler installation that there would be a preliminary visual inspection (via video) by DWPF-Engineering at the 3 month period. This preliminary inspection was performed in January 2011 to make certain that no unexpected material failure/corrosion. Two bubblers were selected (B2 and C2) for the inspection as representative samples of the single function and multifunction designs. The inspection showed minor bending at or below the melt line of both the single function (B2) and multifunction bubbler (C2) tubes (see Figure 2). Additionally, the C2 bubbler displayed a spreading of the tubes used to perform its dual functions (see Figure 2). These issues were not significant enough to prevent the bubblers from being re-installed in the melter top-head. Further, the inspection did not reveal any excessive material loss or corrosion after the three months of service. Due to these observations, it was determined that the bubblers were adequate to reach the six month design life. [3]

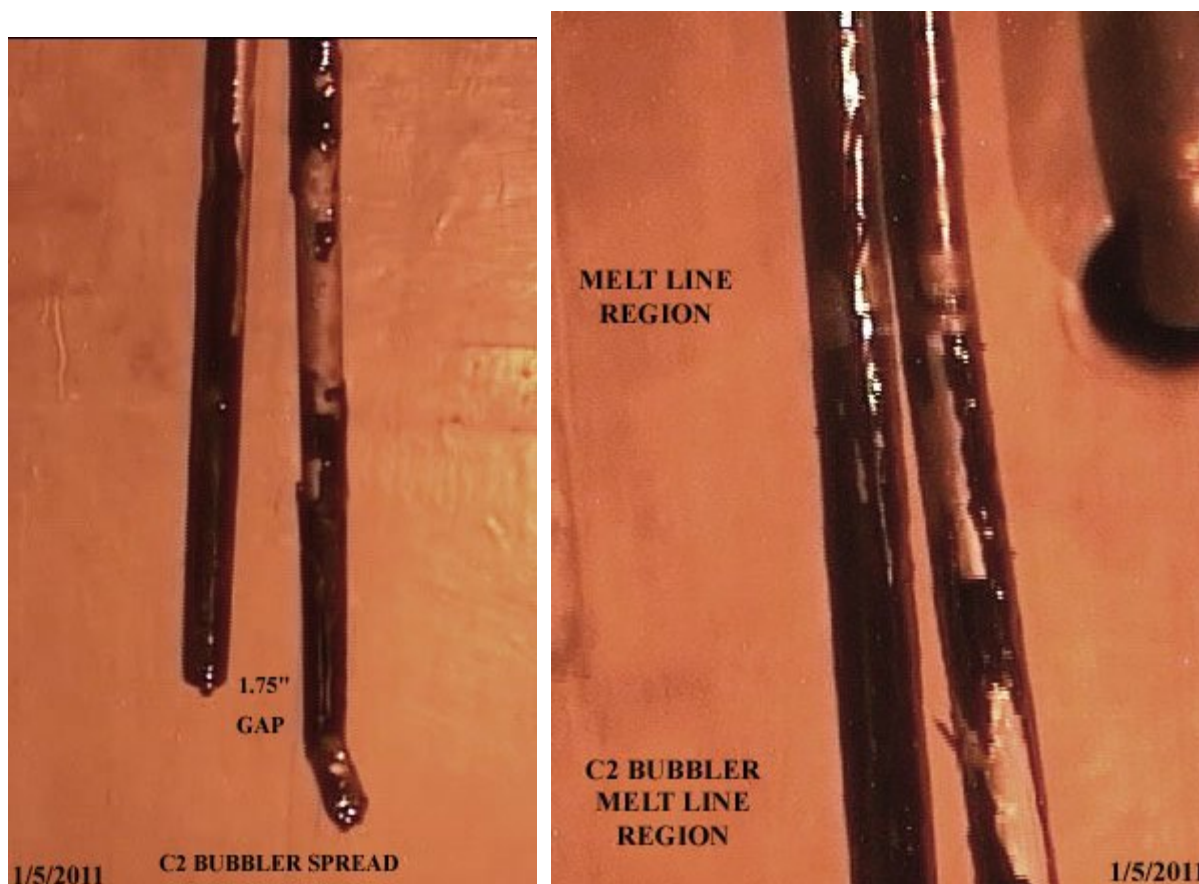


Fig 2. C2 bubbler inspection photo showing bending and spreading of dual function tubes.

To address the spreading of the bubbler tubes, a design change was made to add two attachment points on the tubes. This design change affected both the C2 and C4 multifunction bubblers and was made on bubbler set number 2 and all subsequent sets fabricated through EnergySolutions. The tubes were attached by welding blocks at two separate locations along the vertical length of the tubes.

The complete first set of bubblers was removed in early April 2011, close to the six month design life, and a visual inspection was performed as they were removed from the melter. There were no significant differences in the condition of the bubblers. There was more pronounced bending and spreading of the bubbler tubes, however this did not inhibit the bubblers from being removed from the melter. One of the single function bubblers was chosen to have sections of the bubbler tube removed so that they could be sent to SRNL for metallurgical evaluation. Metallographic examination of the bubbler sample showed little material loss on the outer diameter (OD). However, intergranular attack and internal void formation were noted near the OD surface. Total depth of attack near the glass melt line ranged from 1 to 2 mm (0.04 to 0.08 in). This degree of attack does not imply that the bubblers are in jeopardy at 6-months exposure. However, at this time the 6 month design life will not be extended. Preparations are underway to collect samples from another bubbler at locations below the melt line, at the melt line and in the vapor space. Analysis of these samples will be used to confirm the previous evaluation and to help determine methods to increase bubbler life beyond 6-months.

PRODUCTION RESULTS WITH BUBBLERS

The installation of bubblers has allowed the DWPF to produce at a higher rate than at any other time in the past. The highest canister output prior to bubbler installation at the DWPF was 260 waste glass filled canisters in Fiscal Year (FY)2004. FY2011, the first year of bubbler operation, produced 266 canisters. Of note is that the higher canister output was achieved at a lower melter attainment (time feeding the melter) percentage. This is due to the melter's ability to achieve a higher glass production rate, lbs. of glass / hour, with the bubblers operating versus without. In comparison to the previous two years, the melter has taken a dramatic step forward in canister production. This best illustrates the overall positive effect the bubbler installation has had on the canister production capability of the DWPF (see Figure 3).

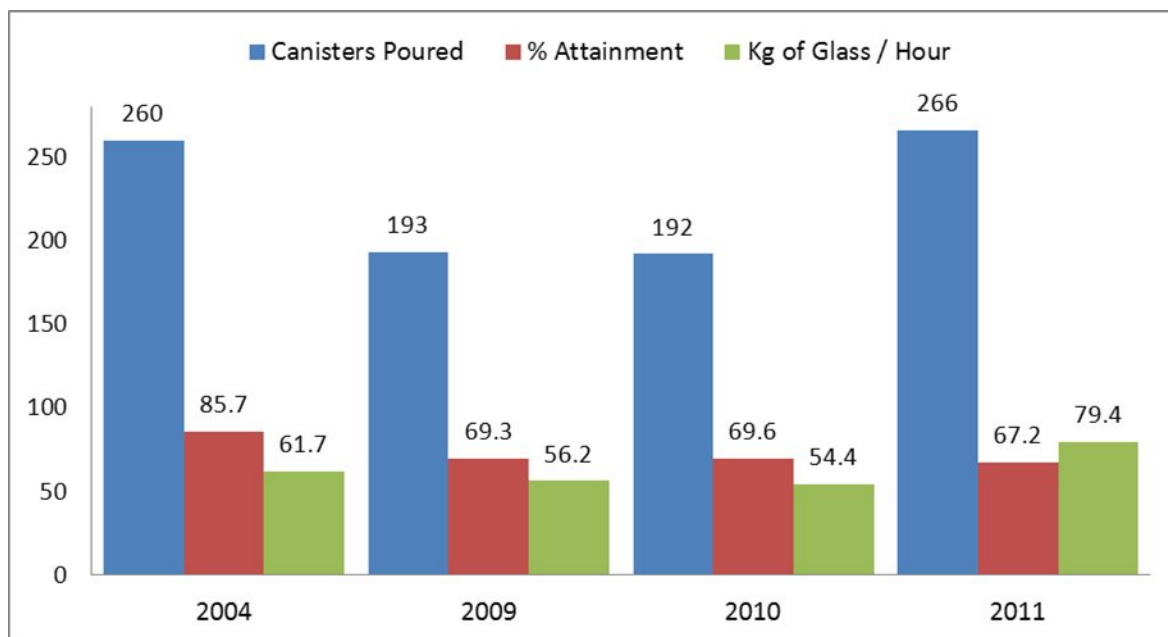


Fig 3. DWPF operating data; past three years of production versus the previous best production year (2004).

It should be noted that the glass production for FY2011, 79 kg. of glass/hour (175 lbs. of glass/hour), is skewed low due to the DWPF having to process extremely dilute feed in May 2011. This month resulted in a glass production rate of approximately 32 kg of glass/hour (70 lbs. of glass/hour). Removing this month of production raises the FY2011 average glass production rate to 84 kg of glass/hour (185 lbs. of glass/hour) further supporting the positive effect the bubblers have shown. The highest glass production rate seen for Melter 2 prior to bubbler installation was 77 kg of glass/hour (170 lbs. of glass/hour); in contrast, 9 of the 12 months for FY2011 have been over this threshold. Further, of those nine months, five have been over 86 kg of glass/hour (190 lbs. of glass/hour) (see Figure 4).

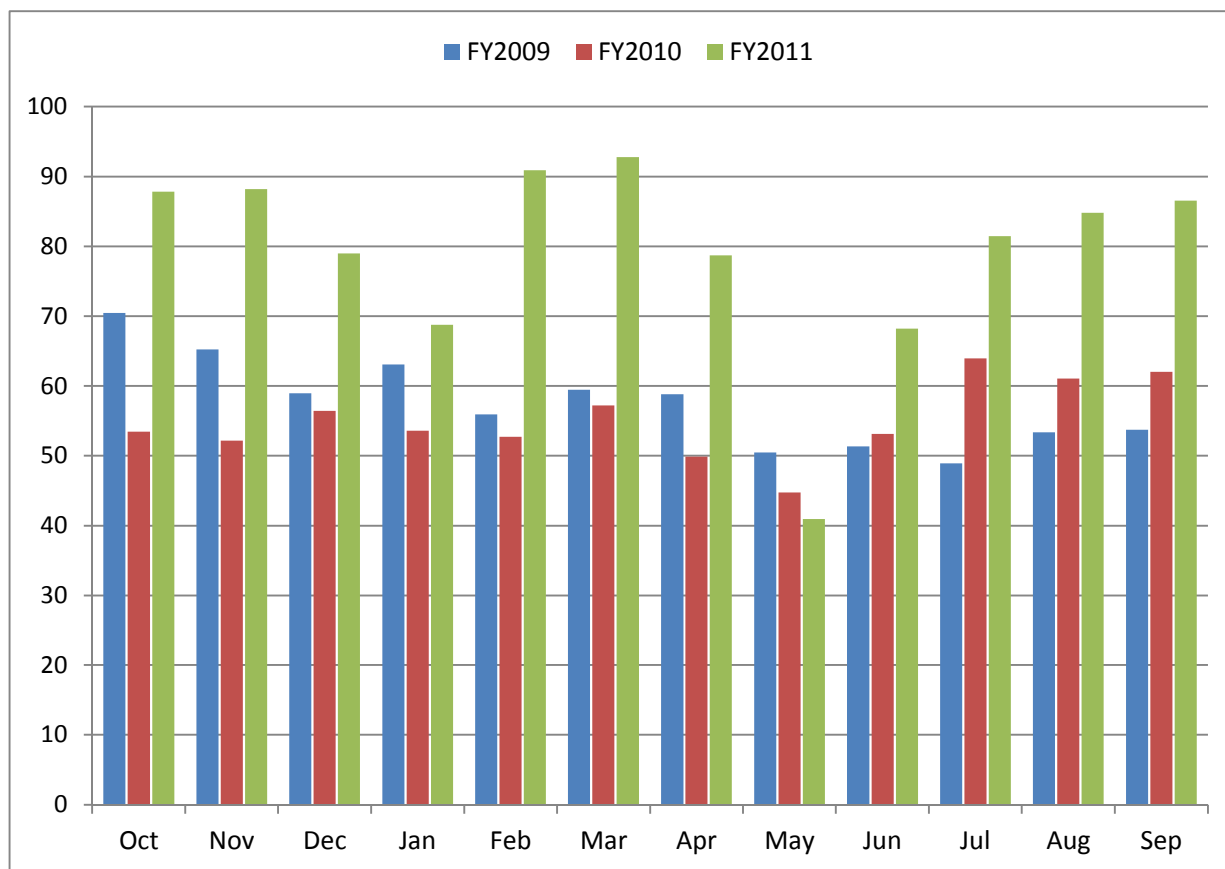


Fig 4. Glass production rate in kilograms of glass per hour for Fiscal Years 2009, 2010, and 2011.

Over the life of DWPF Melter 1 and 2, the DWPF had produced 30 or more canisters three times (all in 1998) prior to FY2011. In FY2011 alone, production exceeded 30 canisters three times (February, July, August). February was very efficient as the DWPF produced 31 canisters in 28 days. Additionally, the DWPF achieved the highest monthly canister production total (32) in August 2011.

CONCLUSIONS / PATH FORWARD

The installation of the bubblers accomplished the goal of increasing the glass production capability of DWPF Melter. Currently the DWPF Melter is producing glass at a rate of 91 to 93 kg of glass/hour (200 to 205 lbs of glass/hour). As a result of this increased glass production rate the

DWPF has been able to produce the most canisters since radioactive operations began in 1996. These accomplishments can be directly attributed to the bubblers ability to increase mixing/convection within the glass melt pool thereby improving the heat transfer from melt pool to the cold cap. Further, this has helped SRR take a significant step forward toward closing the HLW tanks at the aggressive pace set forth in the most recent liquid waste contract at the SRS.

As a path forward, the DWPF is continuing work with SRNL to complete the final metallurgical examination of the bubbler samples to help determine methods to increase the design life of the bubblers beyond the current 6-month restriction. Also, the DWPF is continuing work with *EnergySolutions* on a new bubbler design concept to minimize cost and waste at the DWPF. The new design will allow for the lower end (inside melter) of the bubbler to be replaced while the upper end (outside melter) of the bubbler is reused. This new design is currently in the final design approval phase and *EnergySolutions* will be selecting a fabricator to begin the work to build bubbler sets 5 and 6 using the new design.

REFERENCES

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