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DWPF GLASS AIR-LIFT PUMP LIFE CYCLE TESTING AND PLANT IMPLEMENTATION

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ABSTRACT

Due to the accelerated cleanup at the Savannah River Site (SRS), efforts are underway to increase the glass melt rate and hence the high level waste processing throughput at the SRS Defense Waste Processing Plant Facility (DWPF). One of the proposed process/equipment improvements is a glass air-lift pump. The use of a glass air-lift pump to increase melt rate in the DWPF Melter has been investigated via several techniques including lab scale testing on various melters. The final test before implementation in DWPF was a long-term life cycle test (several months in duration) on a full size pump. The air-lift pump was successfully tested and no major problems were found. Based on this test a unit was designed and fabricated for DWPF and was installed in the DWPF Melter in February 2004.

INTRODUCTION

A DOE Tank Focus Area program to access possible means of increasing the Defense Waste Processing Facility (DWPF) Melter melt rate was initiated in 2001. A lumped parameter comparison of DWPF data with earlier pilot plant scale data indicated that melt capacity for a given feed was limited by overheating of the glass immediately under the reacting feed (cold cap). Pumps were considered as a means of increasing glass circulation and opening a vent hole in the cold cap to allow increased electrode power, and thus increased melter total power. Limited locations for a pump in the DWPF melter top head, and glass pumping limitations of traditional pumps lead to the development of a system utilizing air-lift pumping.

The air-lift concept was tested with glycerin and an Inconel proof-of-principle air-lift was tested in molten glass and found to be an effective pump. In addition, small scale air-lift pumps were tested in the Slurry Fed Melt Rate Furnace

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(SMRF) to evaluate the overall behavior of the cold cap with an air-lift pump. Details of these tests and others are given elsewhere[1,2]. Prior experience with traditional pumps in glass, and evaluation of this performance with the lumped parameter heat transfer model has indicated that significant melt rate increases were possible from a single air-lift pump unit[1].

Due to the success of these tests and modeling work, a full-scale Inconel 690 unit was fabricated and installed in a glass hold tank at the Clemson Environmental Technologies Laboratory (CETL) facility in 2002. The main purpose of this test was to evaluate the expected unit life. To the extent possible, the test was performed to also provide information on air-lift design details and foam collapse rate. Design details of glass discharge height and nozzle design were also tested, as they require full scale testing in molten glass. This pump was designed to operate with a gas flow rate up to 850 standard liters/hour. In addition, it was used to provide initial indication of the interactions with the cold cap during a one day slurry feeding test[2].

Problems with the initial glass hold tank (glass foam buildup due to small glass hold tank diameter and heater failures) required a new test stand. Testing was completed in August 2003. A total of 72 days of operation (non-slurry feeding except for one day) were completed before the pump was removed. Most of the test time (48 days) was in the new test stand.

Anticipated benefits to DWPF of the air-lift pump were:

- Enhanced melt rate from direct action of increased overall glass circulation rates improving transfer of electrode power to the bottom of the cold cap. This may be the result of increased overall glass velocity or improved venting of cold cap gases trapped under the cold cap. This is the mode of melt rate improvement of traditional pumps operated with modest gas flow rates. However in the present case, the efficiency of the pumping action is improved, so that lower gas flows are required, and the gas is not forced to accumulate under the cold cap. (Gas bubbles generated by the melting process still have to vent from under of the cold cap.)

- Additional increases to melt rates from enhanced power available to the cold cap and slurry indirectly by heat transfer from the pumped glass to the melter plenum. It increases total power available to the melter by allowing additional electrode power to be applied without overheating of the glass under the cold cap.

- More uniform glass pool temperatures, making it easier to stay within temperature operating limits at the top and bottom of the glass pool.

- For Sludge Batch 2 feed processed until early in 2004, evaluation of the heat transfer across the surface of the glass in DWPF suggested that a barrier layer may form. The pumping action of the hot glass from an air-lift may push aside or raise the temperature of viscous layers or un-dissolved material floating on top of the glass pool, causing them to dissolve or dissipate.

This report discusses the full scale air-lift pump tests at the CETL. This includes the non-destructive and destructive evaluations performed on the pump after the test. It also discusses the implementation of the air-lift pump in the DWPF Melter.

LIFE CYCLE TEST DESCRIPTION

A full-scale Inconel 690 air-lift pump was fabricated at SRS for the performance testing in the Pour Spout Test Stand (PSTS). The pump has an outer diameter of 8.9 cm and an inner diameter of 6.4 cm (see Figure 1). The pump has two nozzles near the bottom that can either be run singularly or together. A thermocouple was installed in the pump to monitor glass temperature as well. The initial plan was to place it in the PSTS with simulated DWPF glass and then run it (without slurry feeding) for several months. Air flow of 566 standard liters/hour was targeted for one nozzle at the beginning of the test. The PSTS reservoir has an inner diameter of about 20.3 cm.

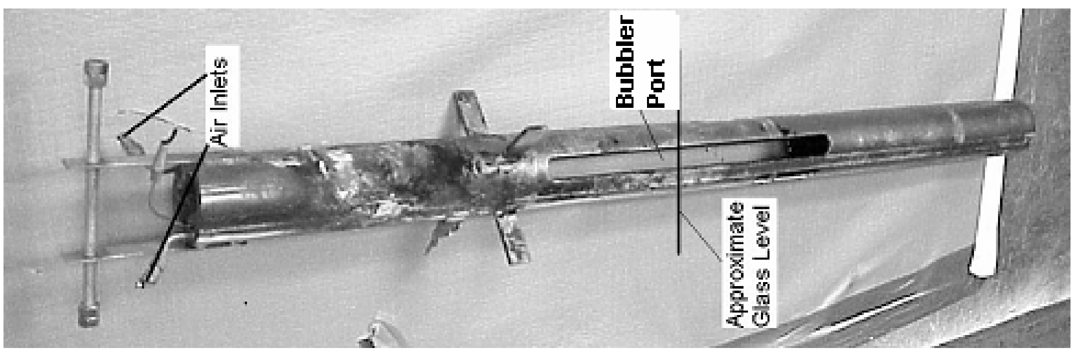

Figure 1. Air-lift pump

The pump was installed in the PSTS in September 2002. The glass temperature was maintained above 1100°C as indicated by the pump thermocouple. Due to excessive glass foaming over the top of the PSTS reservoir that was threatening to damage heaters, the pump was removed and the upper heated zone of the PSTS was extended to prevent this glass from foaming out. However, several other heater failures occurred during subsequent testing. Therefore, a new, more robust test stand was fabricated and used for the remainder of the test. It had 38.1 cm inner diameter Inconel 690 pot (127 cm tall) with more durable heaters.

The new test stand was charged with DWPF black startup frit and heated to an operational temperature of about 1120 °C. The pump was installed the next day. The glass level was 76 cm and the pump was submerged in the glass 61 cm. Unlike before, both nozzles were operated at 283 standard liters/hour. These flow rates remained fairly constant for the remainder of the test. Glass temperature, as indicated by the pump thermocouple, was maintained at about 1120 °C for the duration of the test. No foaming buildup was observed and therefore the theory that the previous foamy buildup problems with the PSTS were due to the small PSTS inner diameter which allowed the foam to “climb up” the PSTS reservoir wall was confirmed.

Throughout the duration of the test the number of bubbles was counted for one minute each day. This number was in the range of 100 - 120 per minute. In addition, glass samples were taken weekly to determine if the glass composition was changing (alkalis being volatized). Subsequent analyses of these glass samples showed that the alkalis were not volatizing. Being a startup glass, the glass did not have corrosive components such as chlorides.

At the end of the test SRS personnel performed a short term slurry feeding test that was videotaped (see next section). The air-lift pump was removed the next day after a total of 72 days of operation time (48 days in new test stand). One of the air lines was disconnected prior to removing the pump from the molten glass. The second air line, which supplied air to the other nozzle, remained attached and functional until the pump was lifted out from the molten glass.

SHORT TERM SLURRY FEEDING EVALUATION

Air flow to the air-lift pump was maintained at 566 standard liters/hour. Simulated DWPF Macrobatch 2 slurry was fed into the melter using a peristaltic pump. The feed rate was measured at 0.133 liters/minute and feeding was maintained for ~90 minutes. After feeding, the pump continued to operate until the cold cap was completely melted. The two diametrically opposed exhaust ports on the pump will be referred to as ports A and B.

During the first 45 minutes of feeding, the feed tube was positioned so that the slurry flowed onto the glass exiting exhaust port B of the air-lift pump. Since the direction of the glass was from the center of the melt pool toward the wall of the Inconel pot, the slurry also flowed away from the pump tube and began forming a cold cap along the Inconel wall. Glass flow from the two exhaust ports of the pump remained uniform during the initial forming of the cold cap. As the cold cap grew, the glass flow from the pump exhaust port adjacent the slurry feed began to decrease, and glass flow from the pump became preferential to exhaust port A, 180° opposite the slurry feed, until exhaust port B became closed 25 minutes into the feeding cycle (see Figure 2).

The feed tube was then positioned so that the slurry was introduced 90° to the exhaust ports on the air-lift pump. Over the next 45 minutes of feeding, the cold cap continued to grow to a thickness of ~2 inches. The vent in the cold cap maintained by the glass flow from pump exhaust port A slowly closed and glass flow from the pump became preferential to exhaust port B, causing a vent to be re-formed in the cold cap at this location.

The opening and closing of vents in the cold cap continued throughout the remainder of the feeding cycle requiring ~15 to 20 minutes for the glass flow from a given pump exhaust port to be blocked and re-opened. Once feeding stopped, the cold cap began to melt and the glass flow from the two air-lift pump exhaust ports became more uniform (see Figure 3). Throughout feeding, the pump air was readily vented to atmosphere and no adverse effects on cold cap stability or increased foaming were observed.

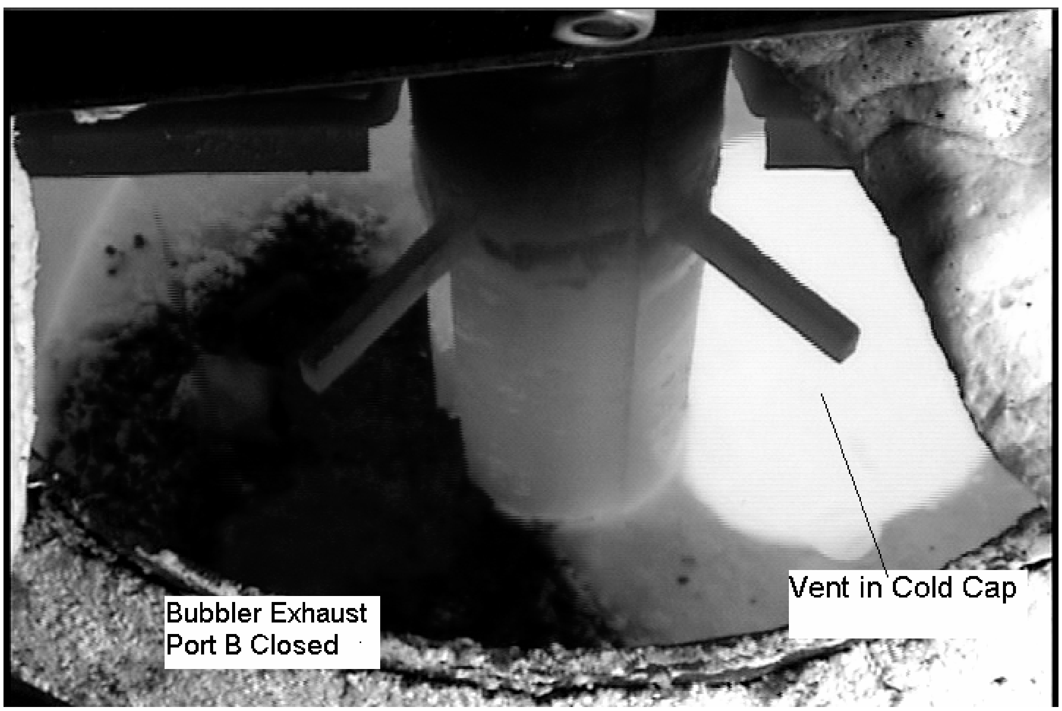

Figure 2. Air-lift pump exhaust port B (visible port on left) shown closed after 25 minutes of melter feeding at 0.133 liters/minute. Glass flow out of the pump is preferential to exhaust port A due to blockage of exhaust port B.

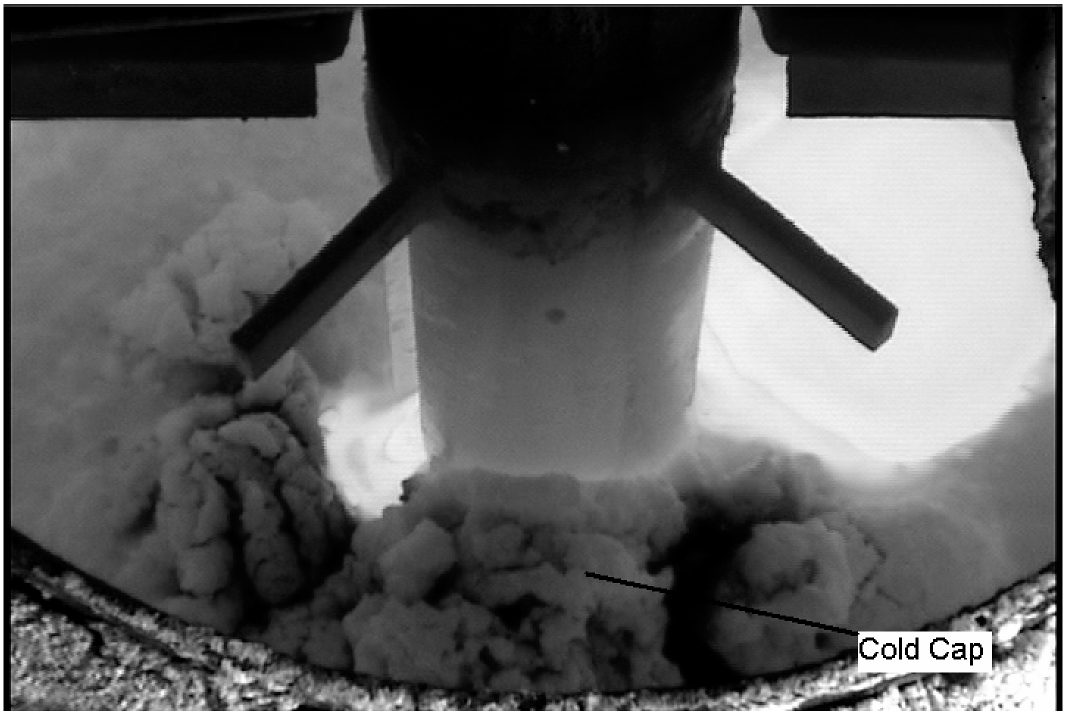

Figure 3. Glass flow out of air-lift pump exhaust port B (visible port on left) reopening cold cap vent (slurry feed had been stopped for ~2 minutes)

POST TEST NONDESTRUCTIVE AND DESTRUCTIVE EXAMINATIONS

Overall the air-lift pump was in excellent condition after 72 days of operation. Visual and metallurgical evaluation did not reveal any significant degradation, material loss or internal attack of the Inconel 690 portion of the pump. Even regions in high flow areas around nozzles or at the glass discharge point at the air/ glass interface did not reveal any observable degradation. Minimal internal attack, internal void formation and depletion of chromium in the near surface regions due to oxidation, were observed in the air passage and glass contact regions.

Degradation rate based on internal attack would predict a rate of approximately 1.27 centimeters per year, but movement of this interface would require material loss to occur. Material loss could not be estimated because significant local variations in wall thickness (from fabrication techniques employed) made comparison of UT readings before and after the testing impossible. Welds were examined and did not show any significant molten glass attack. Minimal degradation of the Inconel 690 may have resulted because the glass chemistry (DWPF start-up frit) was not very corrosive. In addition, the melter pot was fabricated entirely from Inconel 690 and the glass may have been saturated in chromium and nickel. Because the data obtained is not fully representative of what would be expected in DWPF, degradation of the production pump should be carefully monitored during operation and a thorough metallurgical evaluation should be performed after it is removed from service.

Some glass has seeped into the thread gaps between the nozzles and the Inconel housing. Increasing the area of the sealing surface on the nozzles should help minimize glass intrusion into the thread gaps. There was also some oxidation of the Inconel 690 threads most likely resulting from air in leakage around the threads.

Spinel formation was noted at the inlet of each nozzle. The deposits were large enough to completely cover the air passage at the inlet of the nozzle. Although the deposits were extensive, they were porous and did not impede the air flow for the duration of the test. The propensity of the glass to form various spinel phases during the test at Clemson may have been increased because the melter pot was made entirely from Inconel 690.

Even minimal corrosion of the Inconel 690 in this system may have increased the concentration of transition metals in the glass because of the large surface (Inconel 690) to volume (glass) ratio. However, to minimize spinel formation during the operation of the DWPF production pump, argon should be used rather than air to minimize oxidation of the Inconel 690 air passage. Disruptions in gas flow should also be avoided in order to minimize glass intrusion into the air passage. These operational controls should minimize the formation of spinel deposit and extend the life of the pump.

IMPLEMENTATION OF AIR-LIFT PUMP IN DWPF

With the findings of the life cycle tests, an air-lift pump was designed and fabricated for use in the DWPF Melter. The center melt pool thermowell nozzle located in the middle of the top of the melter was chosen as the nozzle in which the pump was to be installed. The melt pool thermowell was removed and the new pump was put in place on February 10, 2004.

Initial observations indicate that the pump is helping to increase glass circulation. These observations include an increase in the lower melt pool temperature readings and the increase in total available electrode power. Due to unrelated off-gas instability problems, the overall impact on melt rate has not yet been determined. Process parameters are currently being systematically varied to determine the optimum operating conditions to maximize waste throughput in the DWPF Melter.

CONCLUSIONS

Based on the results of the life cycle air-lift pump tests, the one day slurry feeding test, and the subsequent metallurgical evaluation of pump, the following conclusions can be made:

1) The air-lift pump was successfully operated for a total of 72 days and provided sufficient flow to pump glass from the bottom of the melt pool without excessive foaming.
2) No problems were observed with the cold cap during the one day air-lift pump slurry feeding test.
3) No significant degradation of the Inconel 690 was observed even in the high flow regions or the air/melt interface.
4) Argon gas should be used with the Inconel 690 pump to minimize oxidation.
5) Significant spinel formation at the nozzle inlets was observed but because it was relatively porous it did not disrupt the flow of air through the nozzles.
6) Operation of the pump in the DWPF Melter has increased glass circulation and increased melter bottom glass pool temperatures as expected and therefore should improve melt rate. The actual impact on DWPF melt rate has not yet been quantified.

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