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Recent Process and Equipment Improvements to Increase High Level Waste Throughput at The Defense Waste Processing Facility (DWPF) - 8366

Richard J. O'Driscoll, Allan B. Barnes, James R. Coleman, Timothy L. Glover,
Robert C. Hopkins, Daniel C. Iverson, Jeff N. Leita
Defense Waste Processing Facility
Washington Savannah River Co. (WSRC)
Aiken, SC, USA 29808

ABSTRACT

The Savannah River Site's (SRS) Defense Waste Processing Facility (DWPF) began stabilizing high level waste (HLW) in a glass matrix in 1996. Over the past few years, there have been several process and equipment improvements at the DWPF to increase the rate at which the high level waste can be stabilized. These improvements have either directly increased waste processing rates or have desensitized the process to upsets, thereby minimizing downtime and increasing production. Improvements due to optimization of waste throughput with increased HLW loading of the glass resulted in a 6% waste throughput increase based upon operational efficiencies. Improvements in canister production include the pour spout heated bellows liner (5%), glass surge (siphon) protection software (2%), melter feed pump software logic change to prevent spurious interlocks of the feed pump with subsequent dilution of feed stock (2%) and optimization of the steam atomized scrubber (SAS) operation to minimize downtime (3%) for a total increase in canister production of 12 %.

A number of process recovery efforts have allowed continued operation. These include the off gas system pluggage and restoration, slurry mix evaporator (SME) tank repair and replacement, remote cleaning of melter top head center nozzle, remote melter internal inspection, SAS pump J-Tube recovery, inadvertent pour scenario resolutions, dome heater transformer bus bar cooling water leak repair and new Infra-red camera for determination of glass height in the canister are discussed.

INTRODUCTION

Washington Savannah River Corporation (WSRC) operates the Savannah River Site's (SRS) Defense Waste Processing Facility (DWPF). DWPF is the world's largest operating high level waste (HLW) vitrification plant. It began stabilizing about 140 million liters (37 million gallons) of SRS's radioactive HLW sludge into a borosilicate glass in 1996. Through calendar year ending 2007, the DWPF had filled 2434 canisters with over 4.3 million kg (9.5 million pounds)) of radioactive glass. Interim storage for the canisters is provided in glass waste storage buildings (GWSB). GWSB #1 was filled with 2251 canisters while GWSB #2 had 171 stored at fiscal years end.

The SRS continues to manage and disposition about 400 million Curies of HLW, which is stored in 49 large, shielded, and partially underground tanks grouped into two "tank farms." H Area has 29 tanks while F Area has 20 Tanks. All SRS tanks are built of carbon steel inside reinforced concrete containment vaults. The major waste streams in the H Area and F Area tank farms include transfers from the chemical processing facilities (canyons) and a low activity waste recycle stream from the DWPF.

High level waste (HLW) is highly radioactive liquid waste that results from the processing of nuclear materials. The waste contains both transuranic waste and fission products in concentrations requiring permanent isolation from the environment.

The DWPF is presently immobilizing HLW sludge in Sludge Batch 4 (SB4). The first four sludge batches averaged about 2.08 million liters (550 thousand gallons) of HLW and produced approximately 580 stainless steel canisters per batch. Each canister is 0.6 meters (2 feet) in diameter by 3 meters (10 feet) tall and is filled with about 1770 kg (3900 pounds) of borosilicate HLW glass. More than 9.2 million liters (2.43 million gallons) of HLW and 15.4 million Curies of radioactivity have been removed from the SRS HLW tanks and immobilized with the first two DWPF glass melters.

The first DWPF melter ran for over eight years, including non-radioactive cold runs. During its 6.5 year radioactive life, 1333 canisters were produced while immobilizing 4.99 million Curies. Through 2007, the amount of HLW immobilized by Melter #2, during its 4.75 year life to date, has surpassed that of Melter #1. This is due to increased waste loading per canister and "hotter" HLW being processed. Melter #2 has poured 1.95 million kg (4.3 million pounds) of glass into 1100 canisters while immobilizing 10.3 million Curies of radioactivity and 4.65 million liters (1.23 million Gallons) of sludge.

MELTER AND ASSOCIATED EQUIPMENT

The purpose of the melter and its associated equipment is to convert a chemically balanced feed of treated high level liquid radioactive waste mixed with a borosilicate frit (fed from the melter feed tank to the melter) to a molten glass form and pour the glass into storage canisters.

The melter includes the melter assembly and the melter heating system. The melter cooling water (MCW), melter feed (MFD) and melter off-gas systems (OGP) are important to the operation of the melter. The melter assembly consists of a refractory lined vessel supported on a frame (and support beam) with riser and pour spout. A pour turntable (PTT) is located below the pour spout and is used to facilitate canister filling during normal operations. There is a pour spout bellows assembly (PSBA) with heated bellows liner (HBL) for canister pouring located between the pour spout and the canister. The drain turntable (DTT) is located directly below the melter assembly and may be used to fill canisters during the draining of the melter. Combustible gases and steam generated in the melter are exhausted by the OGP.

The melter is equipped with a dip-tube bubbler for glass pool level indication and thermowells for glass and vapor space temperature indication. All components which contact molten glass and the jumpers to these components are electrically insulated to preclude the creation of a ground path. A canister positioning arm (CPA) is attached to the lower melter frame to hold the neck of each canister in the pouring position prior to the lower pour spout bellows contacting the canister. The CPA also houses the pour stream viewing camera. A telerobotic manipulator (TRM) is used to remotely maintain the pouring section of the melter.

The melter electrical supply has to be available at all times in order to keep the glass molten. Melter production is based upon being able to receive feed from the MFD System. MFD availability has been around 85% with Melter #2. Any gases (including steam) generated during feeding have to be combusted, diluted and exhausted by the OGP System. If the OGP is down, feeding is not allowed. Many of the melter components are exposed to temperatures in excess of 1100 degrees Celsius and need to be kept cool. The melter has its own closed loop cooling water (MCW) system with redundant cooling water pumps and redundant heat exchangers.

PROCESS IMPROVEMENTS

Increased HLW Loading of the Glass and Optimization of Throughput

Maximizing the amount of waste per canister and maximizing the glass production rate (GPR) are desirable objectives. However, these objectives can be competing. The balance between GPR and waste loading (WL) has to be carefully evaluated in the field. As shown in Figure 1, WL can have an adverse impact on both melt rate and waste throughput. While glass frit development efforts attempt to develop frit compositions in terms of GPR, a concern is that targeting the maximum WL allowed by model predictions may not lead to optimum GPR or waste throughput [1]. In fact, higher WL can have a negative impact on GPR above some critical WL value [2]. The concept that "reduced melt rates at higher WL is unacceptable" should be tempered with an evaluation of the total waste throughput.

With higher WL, some definitions were in order. The prior "standard" canister was termed a "discrete" canister at 28.1% targeted waste loading. An "equivalent canister" would be determined based upon the increased amount of waste in the canister above the standard of 28.1%. The SME batch analyses would provide the WL number used to determine the "value" for the equivalent canister produced. To minimize batch to batch fluctuations, it was agreed between the Department of Energy (DOE) and WSRC, that a 10 batch average WL would be used. Frit formulations allowed the WL to be increased to 45 %, compared to the previous standard of 28.1 %, based upon liquidus temperature constraints.

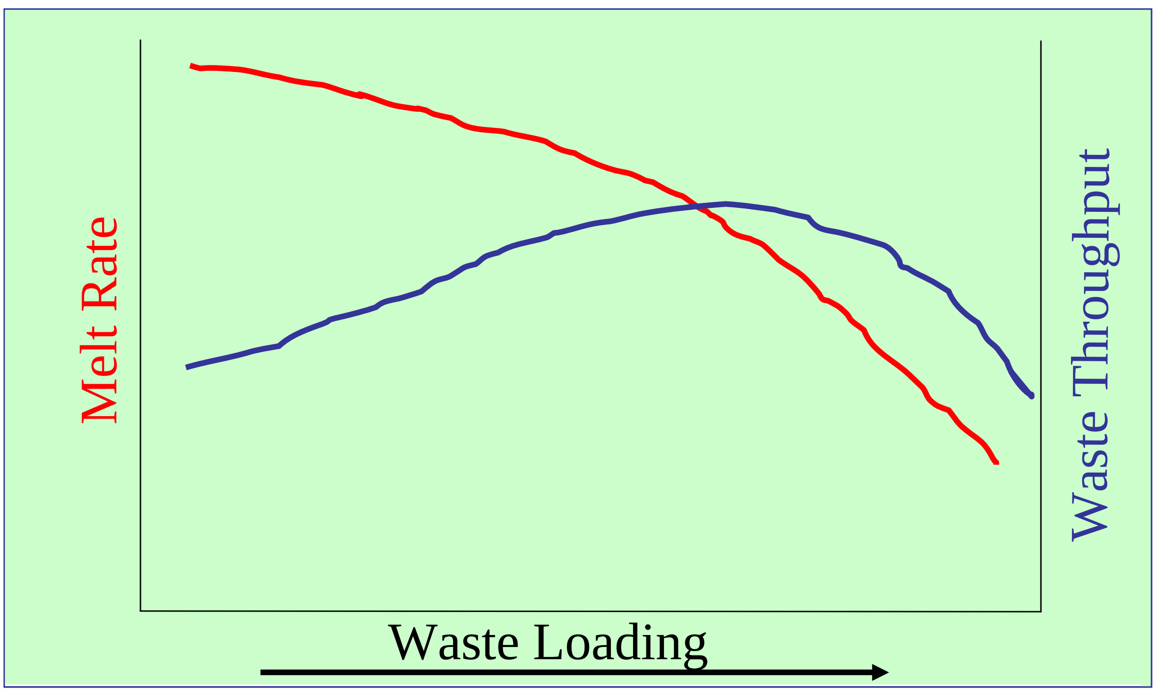


Figure 1: Impact of Waste Loading on Melt Rate and Waste Throughput [3]

DWPF Engineering evaluates actual GPR vs. WL daily. By February of 2006, it was recognized higher WL had resulted in lowering overall waste throughput from the melter system. Evaluation of melter performance indicated a higher waste vitrification rate was achieved at 38% WL (~ 23.6 kg/hr (52 lbs/hr)) than that achieved at 40% WL (~ 22.23 kg/hr (49 lbs/hr)). DWPF Engineering recommended decreasing the WL target so that 38% WL was not exceeded [4]. The 38% WL maximum target was successfully implemented with an estimated 6% increase in waste throughput.

Heated Bellows Liner

During the first few months of melter operation, a remotely replaceable 304L stainless steel liner was installed within the upper PSBA to protect it from glass adhesion. The liners were later fabricated with nickel to improve glass shedding qualities. A nickel sheet metal awning was added over the viewing window in February 1999. These changes showed improvements over the original design but pluggage of the bellows assembly still persisted. Glass production had to be stopped periodically so the assembly could be cleaned out. These cleanouts, which took about six hours, were occurring as often as every 36-48 hours.

DWPF Engineering worked with the Savannah River National Laboratory (SRNL) to design a heater for use within the upper bellows assembly. Engineers worked closely with multiple vendors to further design and assemble the HBL. The objective of the HBL was to reduce pouring interruptions by providing a heated surface inside the bellows assembly. The heated surface allows glass that may have otherwise stuck to the liner, to continue to flow into the can.

Prior to implementation, heat transfer and stress analyses were performed to evaluate the effect of the HBL on the DWPF melter pour spout. Review of the results showed that deflection of the reclamation plate at the base of the pour spout would be small. It was concluded the sealing between the pour-spout flange and the bellows to minimize air in-leakage would be retained after the installation of the heated bellows liner [5].

Basic construction of the HBL includes the outer 304L stainless steel (SS) shell and an interior funnel of Inconel ® 690. A 2.8 kW resistance heater surrounds the funnel. The heater is surrounded by specially molded ceramic fiber insulation and in turn by Micro-therm insulation to protect the PSBA from high temperatures. Heat is generated by an upper and lower heating unit. Each heater is supplied with two (2) thermocouples. The electrical power supply and controls box contains SCR power supplies and dedicated temperature controllers. A separate independent controller is provided for over-temperature protection. The electrical power and thermocouple wires were passed from the third level through a spare embedded conduit in the reinforced concrete wall to a lower holder in the melt cell. From that point, a flexible jumper connects to the HBL located on the bellows assembly.

Initial heat up of the HBL requires approximately three (3) hours. Melter pouring operations are not initiated unless the HBL temperatures are above 930 ^{o}C. The pour stream is viewed from the control room monitors, however minor adjustments to the pour stream camera were required to accommodate additional shine from the heated liner.

Installation of a HBL occurs via remotely operated crane. Power and instrument cables are attached remotely via Master Slave Manipulators (MSM) and the TRM.

Use of the HBL has lowered the average pour spout cleanout rate from seven per month to four per year, resulting in a substantial attainment increase.

A schematic view of the glass flow path through the riser, pour spout, the pour spout insert, dropping through the HBL, the lower (unheated) bellows, the canister throat protector, and into the canister is shown in Figure 2.

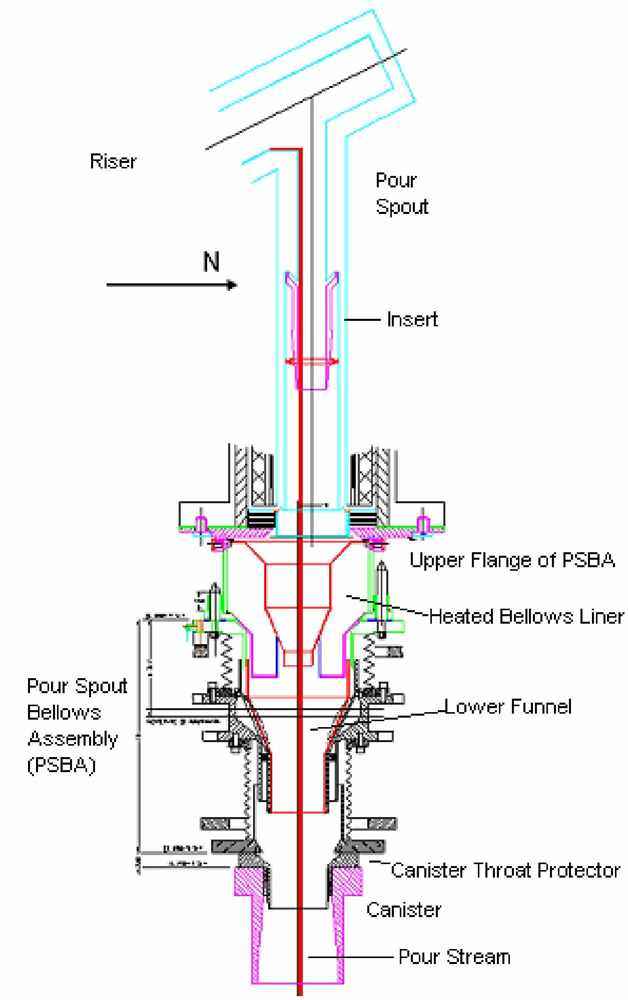


Figure 2: View of the Glass Pour Stream Passing From the Riser into the Canister

The pour spout heated bellows liner has increased production by decreasing downtime and accounts for an estimated 5% increase in canister production.

DWPF Melter Siphon Detector

The melter has periodically experienced pour stream surges, resulting from unpredictable pressure spikes within the melter vapor space. This has caused melter siphon events, which can result in a surge of molten glass nearly 40 times the standard pour rate. There was a significant potential to overfill a canister (can), especially if the surge were to occur when the can was nearly full. Several melter glass siphons were experienced prior to implementing Siphon Detection software logic. These uncontrolled transfers of glass from the melter to the can resulted in hundreds of pounds of glass transferred in just a few minutes. A means of identifying siphons and taking timely corrective actions was necessary to minimize the chance of overfilling canisters.

A siphon is defined as an uncontrolled transfer of glass from the melter to the canister which is caused by molten glass completely filling the riser and pour spout such that the excess weight of glass in the pour spout applies sufficient force to carry additional glass over the apex of the riser and sustain a continuous flow. Essentially, the pour spout fills with glass which falls into the can. The falling glass pulls more glass out of the melter and continues the chain reaction. Unchecked, this chain reaction will continue until the melter level falls so much that the suction generated by the falling glass can no longer pull glass up the riser.

All melter siphons observed had been preceded by a spike in melter vapor space pressure. However, not every pressure spike will cause a siphon. Some melter pressure spikes simply push a ‘slug’ of glass (between 22 to 68 kg (50 to 150 lb) into the can and then the glass pour rate drops to normal in less than 1 minute. Other pressure spikes have pushed over a slug of glass that started a siphon which continued for several minutes and transferred up to 725 kg (1600 lb) of glass into the can. It is possible for the Distributed Control System (DCS) to detect glass siphons and to take actions to stop them. The DCS also evaluates the can weight change vs the melter glass level change to determine if a siphon may be in progress.

The flow is inferred by computing the change in melter level per unit time and the change in can weight per unit time. The greater the glass flow, the greater the change in can weight and the greater the loss in melter level. Unfortunately, due to the high noise on the weight and level signals, computing the flow rate requires large signal filters which delay the computation.

With sustained flow rates exceeding 550 kg (250 lb) per minute, it is clear that a siphon must be stopped rapidly, particularly when the canister is nearly full. During the analysis, it was noted that almost every siphon event was preceded by a melter pressure spike. While not all pressure spikes caused siphons, the higher the pressure spike, the more likely it was to cause a siphon.

A team of engineers implemented a software modification for the DCS that interrupted siphon events. The result was the ability to mathematically detect, and take automatic action to stop the siphon event, by promptly raising the pressure in the pour spout. This substantially decreased the risk of overfilling a can, while increasing the speed of detection and interruption.

Any of three separate conditions can trigger the siphon alarm and interlock. Once the siphon alarm and interlock is triggered, the DCS immediately increases the set point of the pour spout pressure controller, from its normal value of about -4 inwc to +4 inwc. This rapid increase in bellows pressure stops the siphon.

No sustained siphons have taken place since the implementation of the DCS software change. This accounts for an estimated 2% increase in canister production.

DWPF Melter Feed Pump Software Logic Changes

In order to maintain a constant flow in the melter feed loop, the controller constantly adjusts its output to maintain set point. Periodically, the feed loop continually increases its output in order to maintain set point. It has been assumed the increase in output is required to overcome some increasing resistance or “clog” in the piping. Eventually the “clog” breaks free, allowing the flow to increase with a resulting decrease in the pump speed to maintain set point. While the nature of the “clog” is unknown, the cyclic behavior has been observed for years. When the problem worsens, and the “clog” does not break free, an interlock stops the feed pump. When recognized soon enough, the control room operator (CRO) can rapidly increase pump speed which forces the “clog” to break free, restoring the system to normal.

Because the operator can not always monitor and respond to this condition, an automatic response was desired. A software solution was developed which monitors the feed flow rate. When a feed flow sufficiently lower than set point is detected, the speed of the pump is ramped up for a preset period of time and then returned to the speed it was at prior to the ramp up.

With every pump stop, a restart is needed. To restart the pump requires about 265 liters (70 gallons) of prime water, which dilutes the contents of the melter feed tank (MFT), thereby decreasing productivity. The clog detection software logic installed has been shown to successfully prevent the shutdown of the feed pump when the line is “clogged”. This accounts for an estimated 2% increase in canister production.

SAS Operation to Minimize Downtime vs. Reduced Recycle Water

In an effort to reduce the volume of recycle wastewater transferred from DWPF to the tank farm while an evaporator was out of service, an engineering study was performed to consider the impact of isolating the steam to the Steam Atomized Scrubber (SAS) stages. The reduced wastewater generation would be offset by decreased Decontamination Factor (DF) for the off-gas system and an increased particulate loading on the High Efficiency Mist Eliminator (HEME) filters causing not only increased frequency of change out, but loss of production during the change out time period. In addition, dissolution of the HEME filters added caustic and siliceous recycle (increases fouling potential) to the evaporator. The Environmental Compliance Group and DOE approvals were obtained prior to implementation of the plan.

Isolating the flow of steam to both primary and backup SAS stage 1 and stage 2, reduced the recycle wastewater to the tank farm by 15,135 liters (4,000 gallons) per day or 5.525 million liters (1.46 million gallons) per year. This was done in an incremental manner, and evaluated at each step. The DF of the off-gas system was calculated to be decreased by a factor of fifty, with all SAS units steam off, from 8.0×10^8 to 1.6×10^7. This was acceptable for sludge only operations.

Sampling of stack emissions was normally conducted once a month. The sample frequency was increased to weekly and gradually reduced to the original monthly sample after a number of weeks of analysis showed there was negligible impact on the DWPF emissions.

Particulate matter, which had previously been removed from the off-gas stream by the steam scrubbers, was now collecting on the HEME filters. Engineering monitored and trended the differential pressure (DP) across the HEME filters to ensure they were replaced before the DP became too large. The increased particulate loading had required the HEME filter elements to be changed about every three months, compared to no change outs during the first five plus years of operation with steam on to both SAS stages. There are three filters per HEME assembly. The dissolution of the HEME filters in a caustic solution added ~ 37,800 liters (10,000 gallons) of liquid per change out. It was returned to the tank farm as more recycle waste, containing more caustic and siliceous material than normal. It required about two days worth of down time per change out, or eight days (and cans) of potential glass production per year.

Following a series of plugged HEME's, efforts focused on running only the first stage primary SAS with less than the standard 168 kg/hr (370 Lbs/hour) steam. These efforts attempted to run a SAS and at the same time minimize recycle water by throttling steam flow as low as possible. Pluggage of HEME's continued until steam to the first stage primary SAS was increased to the standard 168 kg/hr (370 Lbs/hour) with no steam to the second stage.

One limitation with the above operating scenario, steam to the first stage primary SAS and no steam to the primary second stage SAS or either backup SAS stage, is when cesium (Cs) from coupled operations (salt feed with sludge vs the present sludge-only operation), is received in DWPF feed. The Cs concentration will be increased when the Modular Caustic Side Solvent Extraction Unit (MCU) feed is introduced. No change to SAS operation strategy is expected, however engineering continues to evaluate the need to operate both SAS units when MCU strip effluent is introduced to melter feed stock. It is projected the emission level will remain up to 3.5 times less than our current permit limit of 0.1 mrem/year from DWPF [6]. This accounted for an estimated 2% increase in canister production.

PROCESS RECOVERY EFFORTS

Off Gas System Pluggage and Restoration

In December of 2006, melter engineering evaluation of trends indicated there was pluggage in the primary off gas (POG) system between the offgas condensate tank (OGCT) and the exhauster. A systematic approach was laid out in an engineering path forward. [7]

The melter offgas system pressures and flows began to change following the October/November 2006 outage. SRNL personnel concluded that flow in the system was being restricted due to pluggage in the system. Field measurements were taken to determine the location of the flow restriction. It was determined the problem was between the OGCT and the POG condenser. Components between the two points were removed in late December 2006. Extreme blockage was found in the inlet jumper to the SAS and the inlet of the SAS. Due to the limited ability to clean and test the SAS offline, it was decided to replace the SAS with the spare SAS unit. The inlet and outlet jumpers were flushed and installed. Following the restoration of the system, POG pressures and flows did not return to normal. A further systematic approach was developed to determine the cause of the flow restriction in the POG system.

During this evolution, it was determined that water had accumulated in the SAS causing increased dP in the primary offgas system. The SAS was approximately 75 % plugged. After a number of evolutions, it was determined that the SAS drain return jumpers and return dip tubes within the OGCT were at least partially obstructed. A series of cleaning evolutions with water and nitric acid ensued which eventually cleared the blockages. For this process, a flex jumper was designed, built and connected to a process water (LPW) source in the cell with the other end placed into the inlet of the POG SAS. The LPW isolation valve was closed prior to opening the control valve. The isolation valve was throttled open and the drain on the 1st stage of the POG SAS was monitored while flushing. A similar method was used to flush and monitor the 2nd stage of the POG SAS. The OGCT was emptied and the return legs and drain pipes were inspected visually.

While the POG SAS inlet and outlet jumpers were removed, they were inspected using a remote camera on the crane hook. It was determined the inlet to the SAS butterfly damper was severely (90 %) blocked. As the vacuum break valve sits slightly upstream and above the damper, a tool was successfully used to mechanically abrade the material off the damper. Cleaning the SAS components returned exhauster DP and SAS DP to lower and more acceptable values.

Slurry Mix Evaporator (SME) Tank Repair and Replacement

In April of 2007, DWPF entered an outage to replace the Slurry Mix Evaporator (SME) located in the Chemical Process Cell (CPC). The SME is one of the two primary vessels used to prepare the sludge feed for vitrification. The SME is used to mix treated waste with glass frit to form a sludge-frit slurry. The SME is also used to accept the canister decontamination stream. The slurry is then concentrated to adjust the solids/liquid ratio. From there, the slurry mixture is transferred to the Melter Feed Tank and fed into the Melter at a controlled rate.

The original SME began slurry operations in the early 1990’s during cold runs, with radioactive operations beginning in March of 1996. In the fall of 2002, a SME tank heating coil was removed for repairs. The replacement coil was not able to be “landed” within the coil guides of the tank. An evolution ensued which wound up with de-inventorying the SME vessel, deconning it and repairing both the SME coil guides and a hole that had developed in the vessel bottom during the above mentioned evolution. The original coil guides had eroded to the point they were unable to fulfill their intended function. A removable coil guide (called the 'stop sign' because it is shaped like a stop sign) was designed and installed in the original SME.

In early April of 2007, another leak developed in the SME steam coil necessitating an outage for repairs. The failed coil was removed and attempts were made to install a refurbished coil into the vessel. The refurbished coil would not fully seat in the SME vessel. The SME was then pumped down and inspected with cameras to determine the interference. The inspection identified that the tabs that hold the stop sign coil guides in place had eroded and were no longer anchoring the removable stop sign coil guide. In fact, the removable guide had shifted out of position and had become lodged under the original guide tabs that are welded to the tank. Attempts to remotely dislodge the removable guides were unsuccessful. The inspection also identified that erosion of tank internals and permanent coil guides had ended the SME's operational life. The SME had been in service for 15 years.

It was decided to replace the SME vessel with the onsite spare. A number of design modifications that had been made over the course of startup and operation of the original SME were then incorporated into the spare SME vessel. This was accomplished within a four week time frame.

Remote Cleaning of Melter Top Head Center Nozzle

While attempting to replace a component in the melter top head center nozzle, the replacement unit would not completely re-enter the nozzle. An electrical isolator on the component was apparently encountering interference within the nozzle. Video inspection of the nozzle revealed that glass deposits had adhered to the inside diameter of the nozzle, preventing the component from fully entering. As an interim measure, a second replacement component was modified to decrease the diameter of the electrical isolator. The modified component was then successfully installed. A parallel effort resulted in development of a rotary "flail" cleaner for the nozzle intended to abrade the deposits away. The cleaner was designed to be installed in place of one of the main process crane (MPC) impact wrenches and operated using the impact wrench controls.

At the next scheduled replacement of the center nozzle component, the cleaner was first temporarily installed in the center nozzle. It was operated for several minutes and successfully removed the deposits. A gauge was then installed to verify the successful cleaning of the nozzle. After that, the original replacement component was successfully installed on June 26, 2007.

Remote Melter Internal Inspection

A remotely deployed video camera was developed for internal inspection of DWPF Melter #2 while at elevated (operating) temperature. Two conditions prompted this development. First, as Melter #2 has aged, power provided by the dome heaters during operation has diminished slightly. One proposed explanation for the observed drop in power is that waste material has accumulated on the heaters, limiting their ability to dissipate heat. An inspection of the heaters would be necessary to confirm the presence, size and appearance of deposits. Second, an attempted removal of a glass level bubbler from the melter was unsuccessful. The component stopped upward movement when only partially removed. The cause was assumed to be a buildup of waste/glass on the upper portion of the component, preventing passage through the melter nozzle. Inspection would be necessary to evaluate the buildup.

A system was developed that consists of a small pan/tilt video camera in a double walled, insulating, fused silica dome on the end of a telescoping boom. Forced air is used to provide cooling. The camera and boom diameters are small enough to enter the melter through an unused top-head nozzle. The camera was designed to be deployed using the Main Process Crane (MPC) with the video signal replacing one of the normal crane cameras.

After placement of the camera assembly in the facility and during preparation for use, the insulating dome was broken. Evaluation revealed that the dome could not be replaced remotely so it was decided to use the assembly as-is, accepting a potentially shortened camera life. Upon installation in the melter the camera provided a good picture for approximately 40 seconds at which point it was removed. An example of the view obtained is shown in Figure 3. After a short cooling period it was reinserted for a similar time period. This was repeated numerous times. The internal melter video showed that material buildup on the dome heaters was not excessive and that the glass level bubbler did not have heavy deposits. The general condition of melter internal components was very good.

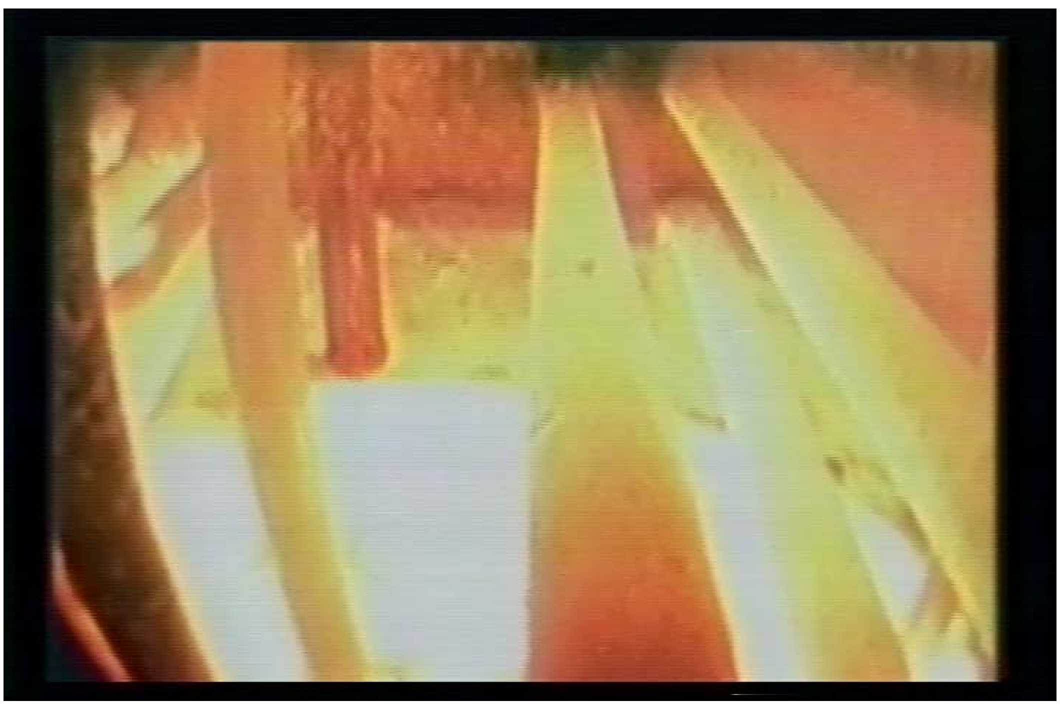
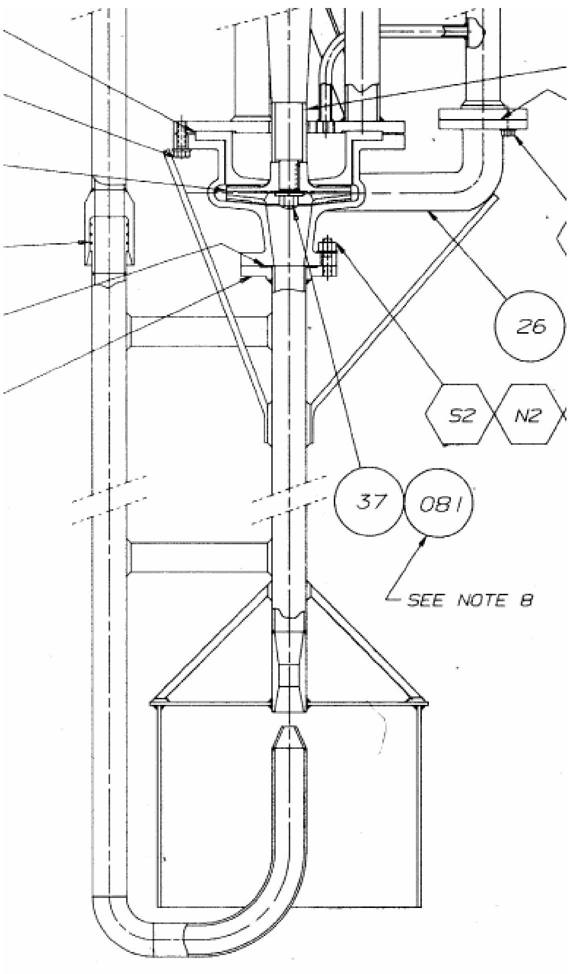


Figure 3: Interior of DWPF Melter, Dome Heater Tubes, Feed Tubes, Glass Level Dip Tube, etc.

The BUOGCT SAS Transfer Pump (TE3) J-Tube Recovery

The backup offgas condensate tank (BUOGCT) SAS Transfer Pump (TE3) had been in service since the beginning of DWPF operations (1994) before it failed in March of 2007. The TE3 was later inserted into the Decon Waste Treatment Tank (DWTT) in 12% nitric acid in June of 2007 to soak prior to a planned rebuild in the CDMC. Upon removal from the DWTT, it was discovered that the entire prime line J-tube was missing from the pump assembly. See Figure 4. Cameras were then lowered to evaluate the DWTT and the J-tube was spotted standing straight up in the tank. Based on the orientation of the separated J-tube, it was decided by Engineering and Operations to attempt a recovery using the crane and an extended hook. The hook was lowered into the DWTT and engaged the support brace between the two parallel vertical pipes. The J-tube was then slowly lifted out of the tank and a full recovery was completed. The path forward for the TE3 pump involves the fabrication and welding of a coupling on each run of vertical pipe. The cause of the failure is being investigated. The TE3 pump is being repaired at the present time.



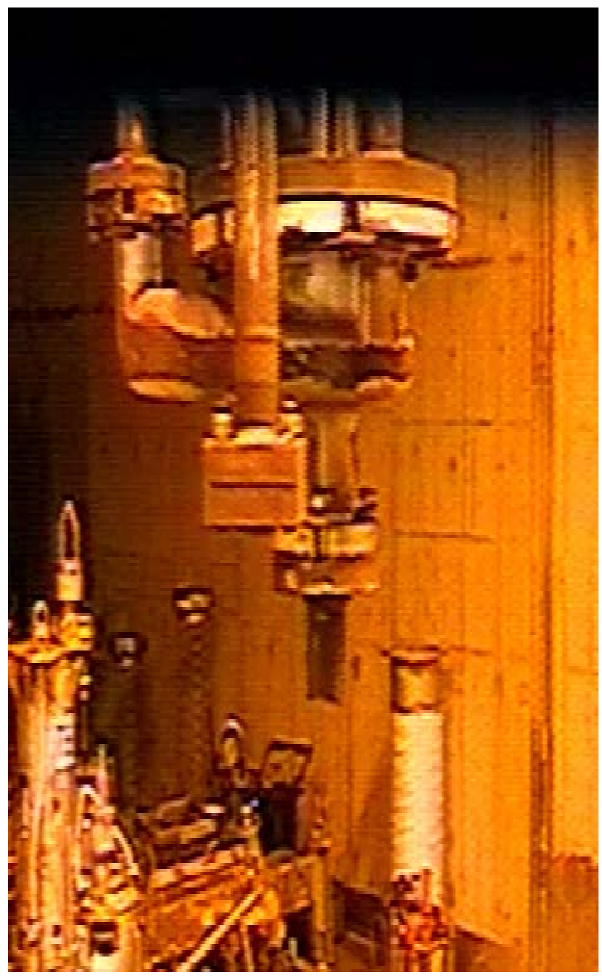


Figure 4: Cross Sectional View of the J-Tube on the left while the right side shows the missing J-Tube which broke off just below the connection flange on the prime leg side and the volute flange on the suction piping.

Inadvertent Pour Scenario Resolutions

The Control Room Operator (CRO) issues a permissive via the DCS for the first level operator to begin canister change operations after which, he operates without CRO direction. The operator on first level raises and lowers the PSBA lower bellows. Likewise, the CRO instructs, via phone or radio, the third level operator to commence the bellows blow down procedure by manually manipulating valves to perform a PSBA blow down. This blows high pressure air through the PSBA to clear air intake slots. While various valves are in the blow down position, the pour spout and PSBA air pressure and flow are outside normal ranges. The blow down must take place with the bellows raised but there is no indication on third level that the bellows is up and there is no indication on first level that the blow down is in progress. It is up to the CRO to coordinate these activities while minimizing the time between cans.

Bellows Blow Down With Bellows Not Retracted

There had been occasions where the bellows had been lowered during the blow down procedure resulting in pressurization of the bellows and air blowing back through the pour spout into the melter, resulting in a subsequent melter pressure spike.

Using available DCS indications, an alarm was added to indicate that the bellows is down while a blow down is in progress. This permits the CRO to contact the first and third level operators and take immediate mitigating actions to prevent accidental pouring of glass.

Pour Initiation Protection Logic

During this evolution, if the CRO were to initiate melter pouring activities, it could result in an inadvertent pour. By monitoring the pour spout pressure control air flow and PSBA air pressure, DCS indications were configured to prevent the CRO from placing a portion of the pouring process in AUTO if preset limits were exceeded. If attempts were made to select AUTO for the controller when the above "prestart" conditions were true, a message was sent to the CRO's console stating why the controller was not permitted to enter AUTO mode. Pour initiation was prevented if valve alignments were not correct.

Dome Heater Transformer Bus Bar Cooling Water Leak Repair

The melter is cooled by its own cooling water system with redundant pumps. Following a routine swap of the running pump in August of 2005, it was recognized that the Melter Cooling Water Hold Tank (MCWHT) was decreasing at a rate of 38 – 58 liters (10 -15 gallons) per day with a corresponding increase in the Melt Cell Sump level. An attempt to view the leak site was made using the MPC crane and the Sputnik camera. This effort was only partially successful due to visual interferences from the Melter Frame. It was determined the leak was near either Transformer B or D which are above each other [8].

Several efforts were initiated in parallel. SRNL was tasked to develop a smaller camera that would allow access between the Melter frame and the Seal Pot in order to determine the exact location of the leak. SRNL was also contacted to do a study on alternatives to the leak sealant Bronz-Seal which was used on Melter #1 as Bronz-Seal was no longer commercially available. An effort was also initiated to ready the Internal Sealant Application System (ISAS) Cart in case an attempt was made to seal the leak using the small quantity of Bronz-Seal still on-hand.

Engineering performed a water hammer study because the leak could have been caused by pressure excursions (water hammer) during the swapping of the pumps. It was determined the reason for the transient during the pump swap was that the standby pump was being started in parallel with the running pump and then the running pump de-energized. This allowed the check valve downstream of the de-energized pump to be slammed shut by the running pump. Engineering determined this situation could cause a large pressure transient 21 – 28 kg/cm (300 - 400 psig) compared to the normal system operating pressure 3.5 – 4.2 kg/cm (50 – 60 psig).

A number of options were considered to resolve the problem. It was decided to discontinue swapping the pumps until the leak rate became greater than 320 liters (85 gallons) per day. Over the course of the next two years, the leak rate increased in various steps. After each step increase in leak rate, an evaluation was made as to its cause. Procedures (such as the cooling water system purging procedure) were changed and new equipment (such as the "Micro" Sputnik camera) was developed.

In November of 2005, the new "Micro" Sputnik camera provided by SRNL was used to determine that the leak was coming from Dome Heater Transformer Bus Bar (DHTBB) B. These bus bars have cooling water passages drilled into them to remedy the cause of similiar leaks on Melter #1 DHTBBs which had external cooling piping soldered to them. These connections pulled away due to differential thermal expansion causing leaks on three of the four DHTBBs on Melter #1. This information allowed SRNL to mockup the leaking bus bar for testing with the alternative sealants using the ISAS cart.

As the bus bars for both Melter #2 & #3 were drilled at the same time, the integrity of the spare Melter #3 DHTBB cooling passages were suspect. Research revealed the only testing performed on these bars was a hydro test to 6.33 kg/cm (90 psig) and that no radiography or ultrasound had been performed to verify integrity of these passages and/or presence of possible laminations. Non-Destructive Examination (NDE) personnel were contacted to perform ultrasonic testing (UT) of the Melter #3 bus bars. The results indicated there were no laminations present, but the passages did not all meet the design requirements for diameter or concentricity. The worst location found (area with the smallest amount of metal left between the outer diameter of the passage and the edge of the bus bar) was still three times thicker than the wall thickness of the copper tubing supplying the bus bar. The procurement specifications for Melter #4 were revised to ensure that NDE is performed on the bus bars to ensure passage integrity before being accepted at SRS.

SRNL Testing of alternative sealants determined that Cargo Seal-Up (Cargo) performed well but had issues with conductivity. An excessive extended flush was needed to lower the conductivity to acceptable levels for DWPF. Another option suggested was to add a demineralizer to the ISAS Cart. It was ordered and successfully tested. The cart was then modified to allow mounting of the demineralizer and changes necessary for the conversion from Bronz-seal to Cargo.

When the MCW leak exceeded 320 liters (85 gallons) per day, DWPF used the ISAS Cart. On August 18, 2007, the cooling water lines to the DHTBB B were isolated and the leak sealant, Cargo, was introduced into the MCW system while visually monitoring the leak with the small remote camera. Within a short period of time (less than two minutes), the leak stopped completely (and remains stopped through December of 2007). The system was flushed of the sealant and returned to normal service. The repair was successful at stopping the 320 liters (85 gallons) per day MCW leak.

New Infrared Camera

The legacy technology used in the DWPF canyon for remote infrared (IR) imaging of DWPF canisters was re-designed, as the existing system can no longer be supported. New technology IR viewing devices have been identified, specified, procured, and received. The technology to control them over long distances by Ethernet, over non-ethernet wiring, has been demonstrated.

IR imaging continues to be used to view the level of glass loaded in the DWPF canisters by external viewing of the canister temperature profiles. Due to the nature of IR, the viewing must use the sensitive infrared equipment mounted inside of the DWPF canyon melt cell. IR image viewing equipment used in industrial environments involves very expensive and sophisticated technology that is similar to military night vision devices but is significantly more complicated. DWPF style IR viewing sensors add the dimension of high precision readout of temperature data from all portions of an image and false color representations of color gradients, typically with the coldest portions blue progressing through the hottest portions red.

The legacy equipment was designed for the DWPF canyon in the mid 1980's and can no longer be duplicated or repaired. A decision was made to upgrade the technology as replacements were identified. The original manufacturer had been adsorbed by a competitor and spare parts are not attainable.

The new IR device requires different wiring technologies and control techniques. The existing hot to non-radioactive side of canyon wiring will now be required to handle Ethernet signals through existing wiring which was not intended to handle this type of signal. Also the wiring from the non-radioactive side of the canyon wall, at the melt cell window, will have to handle Ethernet signals to the main DWPF control room.

There was a strong desire by DWPF engineering to not have to re-pull all of the above wiring. The long run of Ethernet over an existing non-ethernet wiring has been demonstrated at SRNL. Three hundred meters (1000 feet) of the existing wire (multi-conductor non twisted) has been used to demonstrate an "Ethernet over phone lines" technology using VDSL (a modulated technique used for DSL). The demonstration used generic computer equipment and will be repeated with the actual IR devices in the near future.

CONCLUSION

The DWPF melter is fed radioactive material from the large macro-batches of approximately 2 million liters (~ half a million gallons) prepared in the SRS tank farm. From each macrobatch, smaller batches are fed to the DWPF. Each of these small batches, averaging 18,900 liters (5,000 gallons), produces about 5.5 canisters. The facility undergoes batch change effects weekly.

Improvements due to optimization of waste throughput with increased HLW loading of the glass resulted in a 6% waste throughput increase based upon operational efficiencies. Improvements in canister production included the pour spout heated bellows liner (5%), glass surge (siphon) protection software (2%), melter feed pump software logic change to prevent spurious interlocks of the feed pump with subsequent dilution of feed stock (2%) and optimization of the steam atomized scrubber (SAS) operation to minimize downtime (3%) for a total increase in canister production of 12 %.

The DWPF continues to resolve operational challenges in a remote environment due to the resourcefulness of its people.

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