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MATERIALS PERFORMANCE IN A HIGH-LEVEL RADIOACTIVE WASTE VITRIFICATION SYSTEM (U)

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ABSTRACT

The Defense Waste Processing Facility (DWPF) is a Department of Energy Facility designed to vitrify highly radioactive waste. An extensive materials evaluation program has been completed on key components in the DWPF after twelve months of operation using nonradioactive simulated wastes. Results of the visual inspections of the feed preparation system indicate that the system components, which were fabricated from Hastelloy C-276, should achieve their design lives. Significant erosion was observed on agitator blades that process glass frit slurries; however, design modifications should mitigate the erosion. Visual inspections of the DWPF melter top head and off gas components, which were fabricated from Inconel 690, indicated that varying degrees of degradation occurred. Most of the components will perform satisfactorily for their two year design life. The components that suffered significant attack were the borescopes, primary film cooler brush, and feed tubes. Changes in the operation of the film cooler brush and design modifications to the feed tubes and borescopes is expected to extend their service lives to two years. A program to investigate new high temperature engineered materials and alloys with improved oxidation and high temperature corrosion resistance will be initiated.

INTRODUCTION

Approximately 125 million liters of highly radioactive waste solutions, from the production of nuclear materials at the United States Department of Energy's Savannah River Site (SRS), are presently stored in large underground carbon steel tanks (referred to as interim storage). The waste solutions contain approximately 35 to 40 weight percent dissolved solids in liquid supernate and about 5 to 10 volume percent insoluble solids or sludge. The dissolved solids are mainly sodium salts of nitrate, nitrite, hydroxide and aluminate. The insoluble solids are primarily precipitated oxides and hydroxides of iron, manganese, and aluminum. Waste handling operations separate the waste into three parts: highly radioactive insoluble sludge, highly radioactive precipitate slurry, and decontaminated aqueous phase of dissolved salts. The decontaminated salt solution is being immobilized by incorporation into a concrete waste form. In preparation for long-term storage to allow for controlled decay of long-lived radionuclides, the highly radioactive sludge and slurry is being vitrified and encapsulated in stainless steel canisters in the Defense Waste Processing Facility (DWPF). This vitrification process is expected to take approximately 25 years to complete. The stabilized solid radioactive waste is currently being held at the Savannah River Site until a suitable long-term storage site is identified and approved.

Feed Processing System

Figure 1 shows a simplified schematic of the DWPF feed process. The precipitate slurry is processed by a hydrolysis reaction of cesium and potassium tetraphenylborate with formic acid in the Precipitate Reactor (PR) Tank to remove mercury and organics. Washed sludge is reacted with nitric acid in the Sludge Receipt and Adjustment Tank (SRAT). Bottoms product from the Precipitate Reactor is then added to the sludge and further processed in the SRAT. The sludge/slurry is then sent to the Slurry Mix Evaporator (SME) where it is mixed with glass frit and concentrated to the proper solid content for the melter. The adjusted slurry is then contained in the Melter Feed Tank (MFT) until it is ready to be fed into the glass melter.

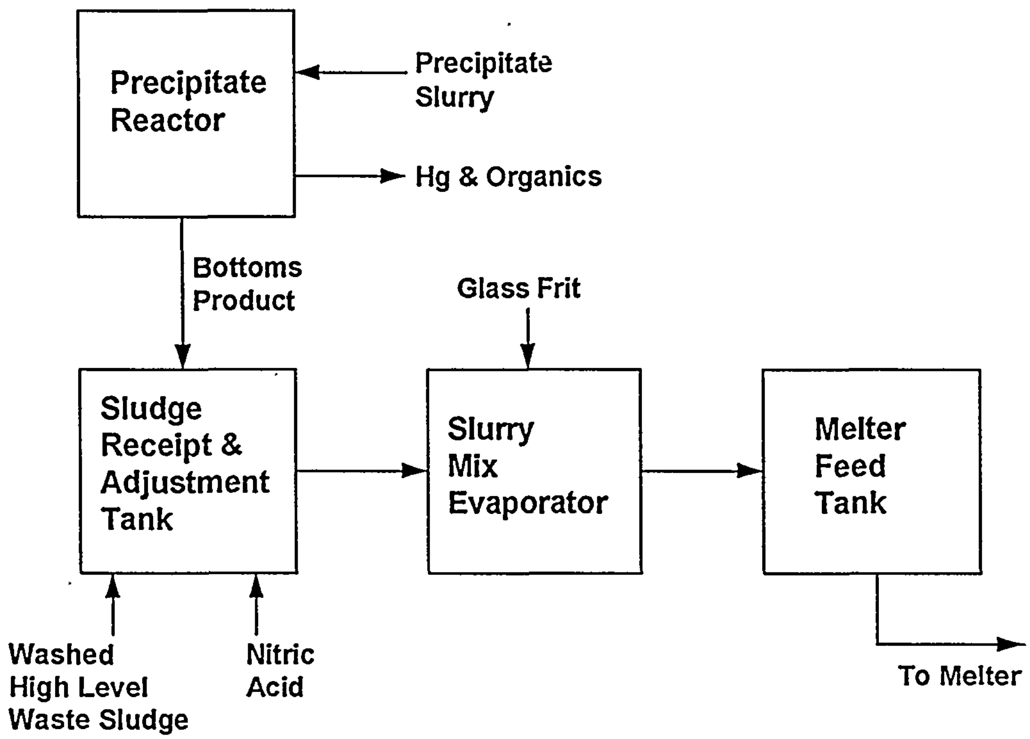


Figure 1. Schematic of DWPF Feed Processing System.

The DWPF feed process vessels, approximately 46,000 liter capacity each, are constructed of Hastelloy C-276, which is a nickel-base alloy. This alloy was selected based on corrosion studies performed by Bickford, et al. in 1984 (1). Alloy C-276 was found to perform exceptionally well under the expected DWPF conditions. AISI Type 304L stainless steel was determined to be unacceptable for processing solutions derived from sludge due to the combined effects of elevated temperatures and concentration of corrosive species such as halides and mercury. Agitator blade assemblies constructed of alloy C-276 are used in the feed processing vessels to adequately mix the highly viscous frit/sludge/slurry mixtures for proper sampling and processing. Heating and cooling assemblies constructed of alloy C-276 are used to maintain process temperature.

Melter and Off-Gas System

The frit/sludge/slurry mixture is vitrified in a Joule-heated continuous melter. A schematic of the DWPF melter is shown in Figure 2. The melter is water cooled, constructed from 304L stainless steel, and is lined with Monofrax K-3 fused cast refractory brick. The glass temperature is maintained between 1050 - 1170 °C by four electrodes, two located at the bottom of the melter and two at the melt line. The melter vapor space is heated to 600 - 900 °C by four resistance type heater rods to ensure the combustion of organic gases. Selection of materials compatible with the aggressive chemistries and elevated temperatures expected in the DWPF melter system required that numerous bench top laboratory tests be performed. In addition coupon studies and component performance evaluations in actual scale melter systems were performed (1-3). Based on these tests, the material of construction chosen for the melter electrodes, lid heaters, dump valve, pour spout, and top head and off-gas components was Inconel 690.

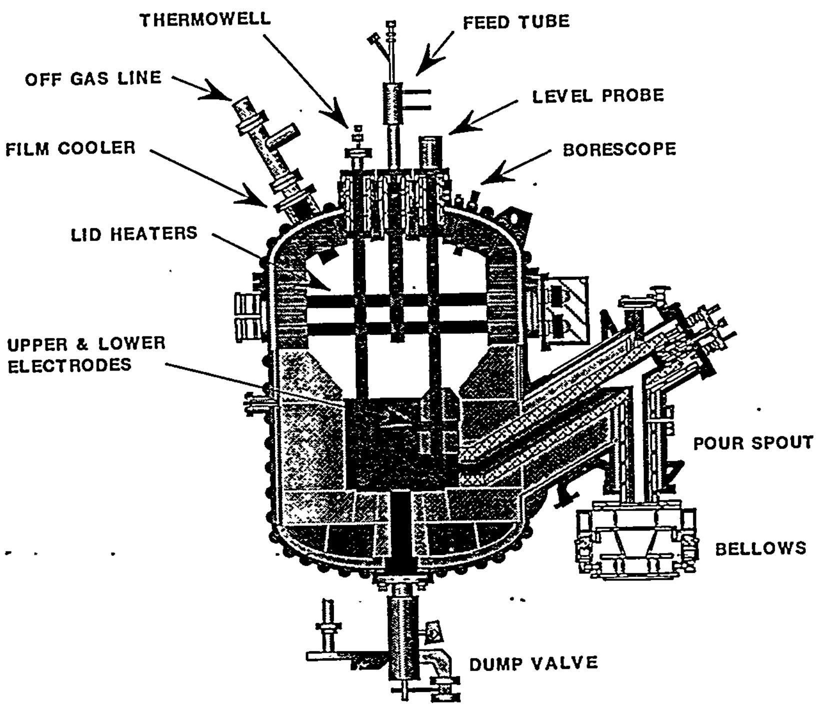


Figure 2. Schematic of the DWPF Melter.

Materials Evaluation Program

The DWPF has operated with non-radioactive simulated waste solutions for approximately twelve months. As mentioned previously, extensive initial testing was performed to determine the appropriate materials of construction for the DWPF. However, because of the erosive nature of processing frit/sludge/slurry mixtures and several process changes since the materials of construction were selected, an erosion/corrosion evaluation program was performed on the DWPF prior to introducing radioactive material in the process. The purpose of the evaluation program was to confirm the suitability of the materials of construction and verify operating lifetimes of key components within the system. The design life of the major process vessels, the melter, and the off gas and top head components are twenty, five, and two years, respectively.

The evaluation program included visual inspection of critical or representative pieces of equipment, ultrasonic thickness measurements in critical wear areas, analysis of process streams for chemical composition, and analysis of corrosion coupons installed in key areas of the process. The following provides a summary of the results of the materials evaluation program.

VISUAL AND METALLURGICAL OBSERVATIONS

Feed Preparation System

Fourteen feed process vessels and related components (pumps, jumpers, piping systems, and sample lines) were inspected for degradation by UT measurements and remote and direct visual inspections, after approximately twelve months of cumulative operating time. Direct visual examination of the interior of the SME was performed because this tank is the most susceptible to erosion/corrosion due to the combination of high temperature (100 °C), glass frit, and higher levels of corrosive species. Radiography was performed on selected recirculating sample lines. Liquid and vapor space corrosion coupon racks were removed from the PR tank and SRAT and inspected after twelve months of exposure. Flat (autogenously welded and unwelded) with crevice washers, galvanically coupled, and U-bend coupons were used for this evaluation.

Table I shows the typical ionic compositions of solutions processed in the major feed processing tanks during nonradioactive simulated waste runs. Only components that are most likely to affect corrosion of alloy C-276 are shown.

TABLE I. Typical Ionic Compositions in ppm of Simulated DWPF Feed Process Solutions in the Various Tanks

Component	PR	SRAT	SME	SMECT*
Fluoride	100	100-	250	100
Chloride	150	100-1000	100-1000	100
Nitrate	nm	350	100-500	100-3000
Nitrite	400	200	100	100
Sulfate	150	400	100-1000	100
Formate	nm	300	500	nm
Phosphate	nm	100	100	nm
Copper	300	nm	nm	nm
wt% glass frit	---	---	40-50	---
pH	9	4-6	4-6	1-2
Process Temp. (°C)	~100	~100	~100	30

nm - denotes not measured.
* - SMECT = Slurry Mix Evaporator Condensate Tank

Based on the inspection results, none of the process tanks showed evidence of any significant degradation after twelve months of operation. No evidence of significant erosion/corrosion was detected in process lines, pumps, jumpers, or recirculating sample lines. The examination of the corrosion coupons also revealed no evidence of significant general corrosion, localized corrosion, or stress corrosion cracking.

Agitator blade assemblies from the major feed process vessels were inspected after approximately twelve months of operation. Figure 3a shows a picture of the agitator blade assembly (constructed of alloy C-276) used in the SME tank. The assembly has four lower rectangular blades and four upper hydrofoil blades. The lower blades are connected to the hub by a connecting tab. Significant erosion was observed on the backside of the lower blades at the step change between the connecting ear and blade. Wear patterns, approximately 50% through wall, were observed emanating from the corners of the tab on all four blades (See Figure 3b). Similar wear patterns, but less severe, were also observed on the MFT lower agitator blades. No significant erosion was observed on the SRAT agitator blades.

Erosion was also observed on the bottom cooling/heating coils and coil supports in the SME and MFT. The erosion was adjacent to the bottom agitator blades. The maximum wall thinning that occurred in the coils was approximately 40%. No significant erosion was observed on the bottom floor or side walls of the SME tank. No significant erosion was observed on the SRAT coils.

Melter

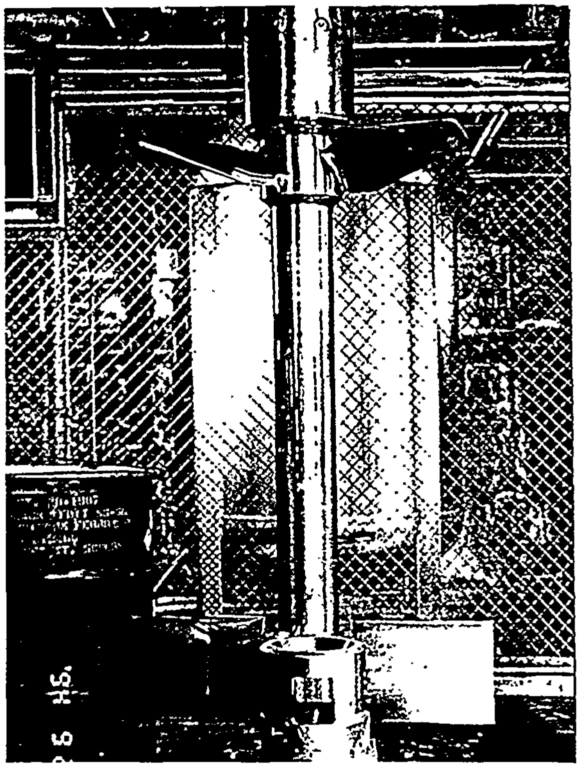
At the time of this inspection the melter had been in service for approximately eight months with over 85% of the time spent in idle mode (melter not being fed). Air is being injected into the melter through the borescope and the backup film cooler to control redox in the melter vapor space. Melter vapor space temperatures have ranged from 650°C during feeding to 900°C while the melter is idled. Temperatures are lower during feeding because a cold cap (unmelted feed material) forms on top of the melt. Temperatures in the off gas line are lowered to approximately 350 °C by the addition of air though the film cooler and the dilution air system. Finally the temperature is lowered to 90 °C by the primary quencher.

Melter Top Head Components

The inspection included the following top head components: two melter borescopes, level probe, two feed tubes, center, side and vapor space thermowells. All components were fabricated from Inconel 690. These components are replaceable and have a design life of 2 years.

Borescopes: Two melter borescopes were visually examined after approximately five months of service. The borescope outer housing protrudes approximately 25 cm into the melter vapor space (Figure 4a). Both borescopes outer housings were in similar condition containing a thick scale and deep pits. The largest pit near the bottom of the outer housing was approximately 75 mm wide and 4.8 mm deep (nominal wall thickness 9.5 mm) (Figure 4b). Deposits containing sodium chloride and potassium sodium sulfate were removed from the surface and identified by X-ray Diffraction (XRD). Sulfate and chloride concentrations were quantified by Ion Chromatography (IC) and found to be approximately 20,000 ppm and 9,000 ppm, respectively. Numerous small pits were observed along the entire length of the outer housing. The orifice below the camera lens, where the purge air exits, was also covered with a thick scale. In some areas the scale had spalled off revealing the metal substrate. Radial cracks in the substrate were observed emanating outward from the inner diameter of the orifice in all directions (Figure 4c). Point scans performed with Energy Dispersive Spectroscopy (EDS) indicated a severe depletion of chromium in the near surface region around the orifice. Internal void formation characteristic of high temperature oxidation was also evident in this region. The inner diameter of this tube, except for the portion around the orifice, did not show any signs of oxidation (spalling or chrome depletion) or corrosion. The original machining marks were still visible on this surface.

(a)



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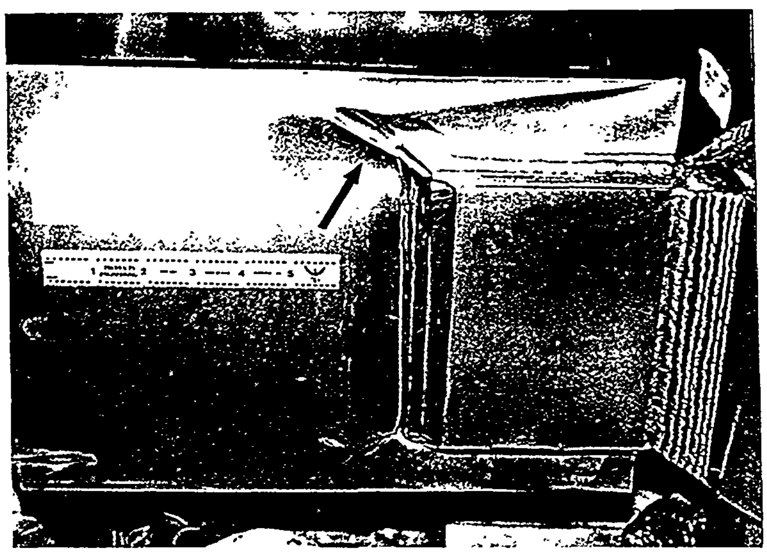
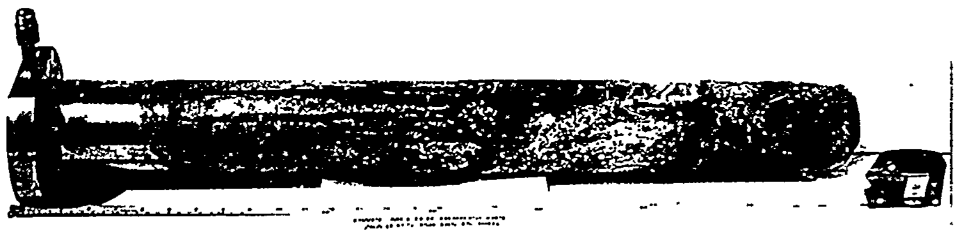
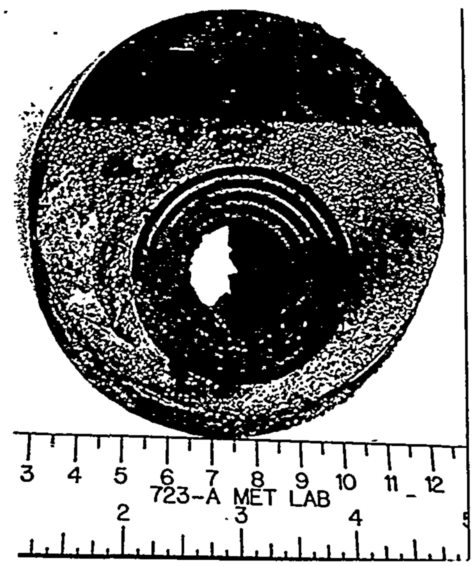


Figure 3. Photograph of SME Agitator, (a) Entire Assembly, (b) Back of Lower Blade (arrow indicates wear scar).



(a)

(b)



(c)

Figure 4. Photograph of DWPF Melter Borescope, (a) Outer Housing, (b) Large Pit, (c) Orifice.

Thermowells and Level Probe: Inspections of the center, side, and vapor space thermowells and the level probe showed no evidence of significant degradation. Components that contacted the molten glass were covered with a thick (2 to 3 mm) glass coating in the region below the melt line. The surface below this glass coating appeared to have a crystalline appearance consistent with an intergranular attack (IGA). The attack was more severe at the end of the components where end grains are exposed. Similar attack has been observed in other melter components from scale glass melter systems at SRS. Some minor attack at the glass - air interface was observed. A thin black coating was observed on these components above the melt line. No evidence of corrosion was observed in the vapor space region.

Feed Tubes: Feed tubes consist of a center tube which is surrounded by a water cooling jacket. Severe degradation of the beveled edge at the bottom of the feed tube was observed (Figure 5). Material loss in this region appeared to be significant, approximately 2.3 mm deep. Several small metallurgical pieces were removed from the outer housing and the bottom area around the orifice adjacent to the bevel. No evidence of intergranular attack was observed in either of the specimens. The area surrounding the feed outlet was in excellent condition and showed no evidence of pitting. Similarly, the entire length of outer housing, including welds, was in excellent condition.

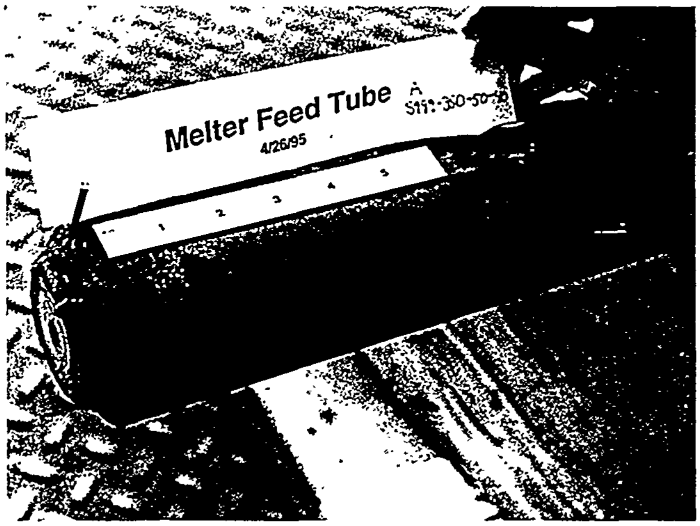
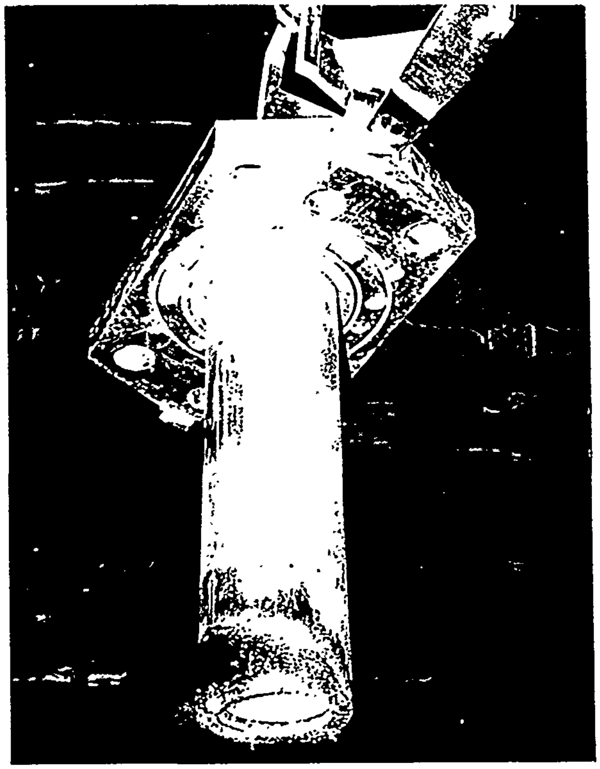


Figure 5. Photograph of DWPF Melter Feed Tube Showing Severe Degradation Around Core End Piece (see arrow).

The following primary off gas components were inspected: film cooler, film cooler brush, off gas line up to and including the isolation valve, and quencher; backup off gas system; film cooler, film cooler brush, off gas line up to and including the isolation valve. All components were fabricated from Inconel 690 except the isolation valve and the primary quencher, which were fabricated from CW7M, a cast version of Hastelloy C-276, and Allcorr, respectively. All the components are replaceable and have a design life of 2 years.

Film Cooler: Visual inspection of the primary film cooler showed oxidation of the lower portion of the outer lip. Oxidation was most severe in a region encompassing approximately 1/3 the circumference of the outer lip (Figure 6a and b). Internal components including the baffles and second lip were in excellent condition. A thin grayish black film was observed on the inner surfaces and contained only sulfates. The outer diameter of the film cooler was in excellent condition i.e., free of pitting or general corrosion, with only light deposits observed.

(a)



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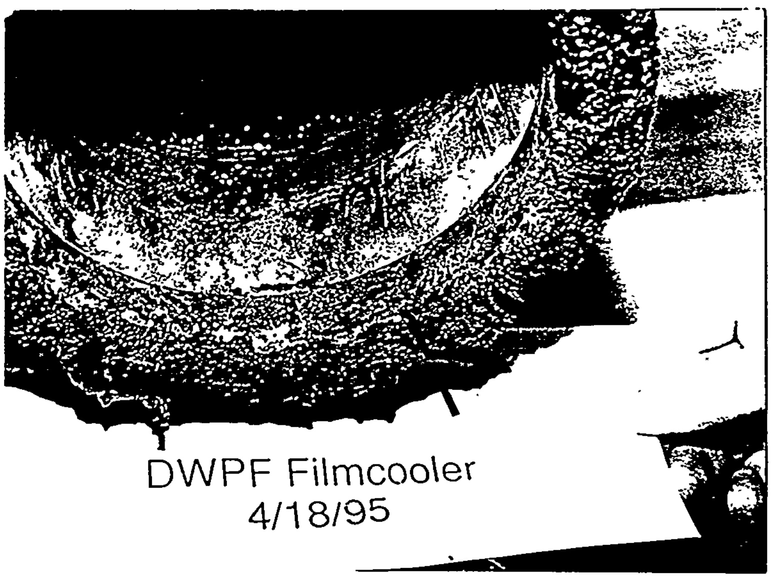


Figure 6. Photograph of DWPF Film Cooler, (a) Film Cooler and Flange, (b) Degradation of Lip (see arrow).

Film Cooler Brush: Severe pitting of the Inconel 690 brush block and degradation of the Hastelloy X bristles was observed (Figure 7). Approximately 25 percent of the bristles from the four holders were missing. The remaining bristles were severely thinned, very brittle and /or partially broken. This region was covered with a grayish black deposit containing sodium chloride and potassium sulfate. Concentrations were approximately 4000 and 21000 ppm, respectively. Metallography revealed a characteristic wrought structure with some grain growth. Large broad pits were observed in both the brush block and in weld fusion zones which attach the bristle holders to the brush block. Bristles still remaining attached to the brush were severely corroded and X-ray Fluorescence (XRF) analyses did not detect the presence of molybdenum. Hastelloy X contains 9 wt% molybdenum.

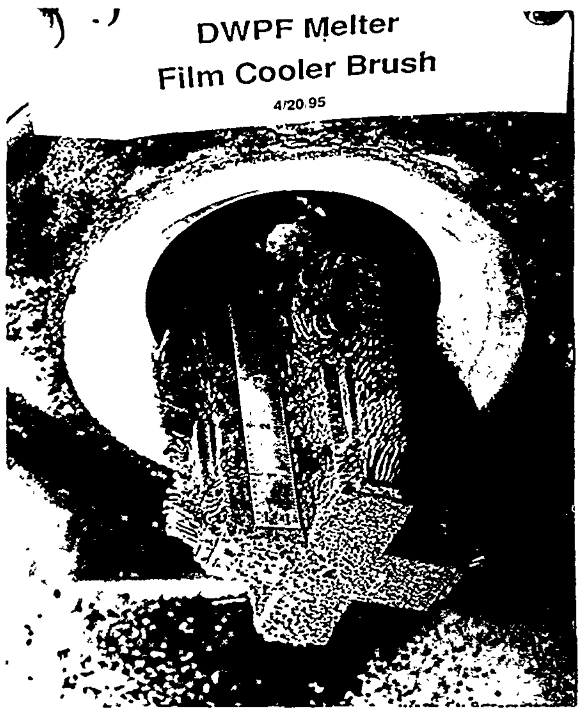
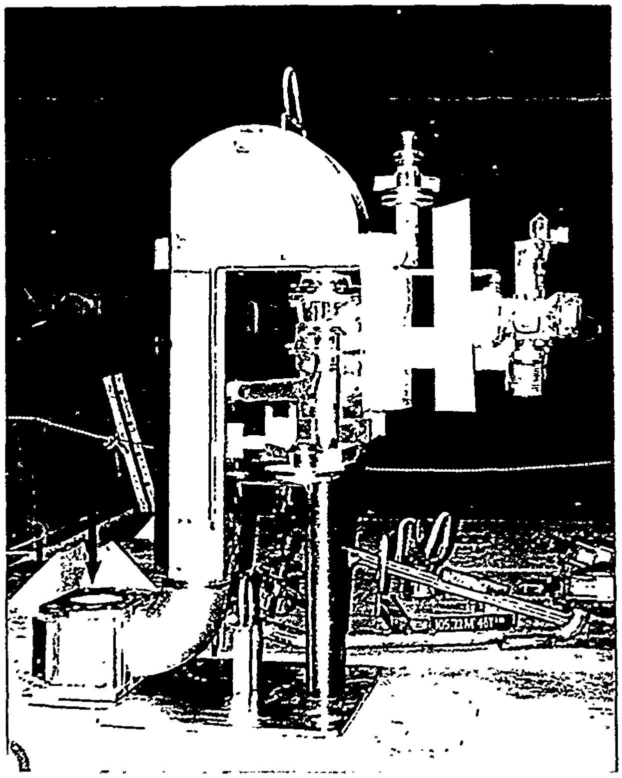


Figure 7. Photograph of DWPF Film Cooler Brush Showing Degradation of Brush Block and Bristles.

Primary Off Gas Line: The melter off gas (MOG) line from the film cooler to the isolation valve was visually inspected for evidence of degradation and deposit build up (Figure 8a). Severe pitting was observed in the 8 inch diameter pipe just below the film cooler brush flange (Figure 8b). The pits were numerous but generally less than 1.5 mm deep. The metal surface in this region was covered with a very thin, light gray deposit. Metallic scrapings taken in this region were analyzed using XRF and indicated a chromium concentration of 12 wt%, which is significantly less than that specified (30 wt%) for the Inconel 690 DWPF melter components. Deposits from this region were found to contain high concentrations of chloride and sulfate bearing salts. Some minor pitting was observed up to the isolation valve. The isolation valve, which is fabricated from CW7M (a cast version of Hastelloy C-276), exhibited no evidence of pitting or corrosive attack. Deposits collected from the off gas line outlet contained chlorides and sulfates in excess of 9000 and 28000 ppm, respectively.

(a)



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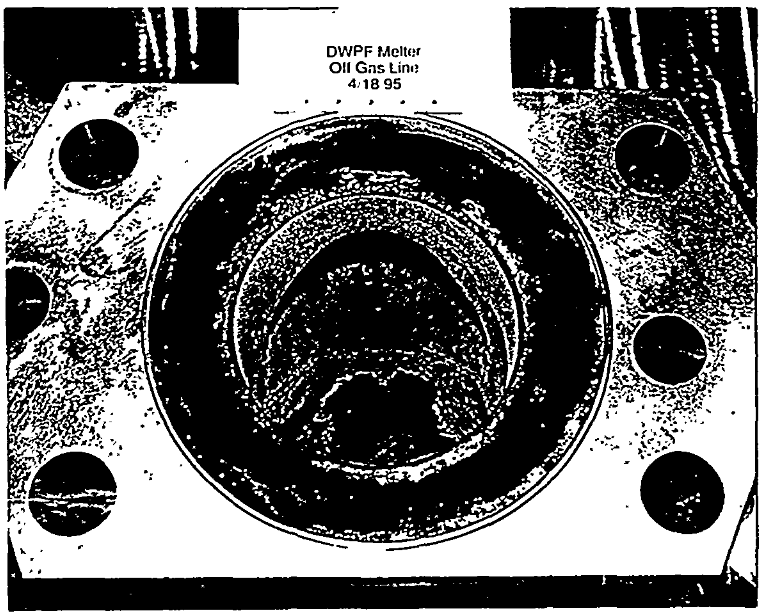

Figure 8. Photograph of DWPF Off Gas Line, (a) Off Gas Line Showing Flanges Where Film Cooler Brush Would Be Installed (see arrow), (b) Off Gas Line Below Film Cooler Brush With Severe Pitting (see arrow).

Primary Quencher: The primary quencher was the only off gas component fabricated from Teledyne Allvac Allcorr. A black loosely adhering deposit was sampled from the inlet region of the quencher and a white crystalline deposit was scraped from the bottom of the outlet pipe. The black deposits contained sodium chloride and sodium sulfate while the white deposits contained only sodium chloride. The quencher showed no evidence of corrosive attack.

Backup Off Gas System

The backup and primary off gas systems perform similar functions; however, they are slightly different in design. The major difference is that the back up quencher is fabricated from Hastelloy C-276. The film cooler brush was coated with a thick off white/pale yellow deposit. Analysis of this deposit revealed significant amounts of lead chloride (> 1 wt%). Lead chloride was not found in the primary system. Sulfate concentrations were lower than that found in the primary system approaching 11000 ppm. Examination of the film cooler brush did not indicate any pitting of the Inconel 690 brush block, although some thinning of the bristles was observed. Degradation of the bristles was not as extensive as that observed in the primary system. The Inconel 690 backup off gas line and Hastelloy C-276 ball in the isolation valve did not show any evidence of corrosion.

DISCUSSION

Feed Preparation System

In general, very little evidence of significant corrosion was observed in the feed processing vessels and related equipment after twelve months of processing nonradioactive simulated waste solutions. This is consistent with results obtained from a corrosion coupon evaluation in the feed preparation system of a 1/10 scale vitrification system (4). Significant erosion was observed on the SME agitator blades and cooling/heating coils. High wear areas on the SME coils have been repaired with alloy C-276 weld filer metal and hard faced with Stellite to increase wear resistance. The SME and MFT agitator lower blades have been redesigned to minimize the step change between the connecting tab and blade. The lower blades have also been hard faced with Stellite.

Based on the material evaluation program, the major DWPF feed processing system components are expected to achieve their respective design lives. Design life for the major equipment are defined to be:

1) Twenty years for major process vessels (i.e. tanks, etc.)

2) Twenty years for permanent piping systems (i.e. sample lines, etc.)

3) Five years for replaceable equipment such as pumps, coils, and agitators

Melter Top Head Components

Varying degrees of degradation were observed on top head and primary off gas components. More severe attack occurred in the hotter regions of the melter vapor space and off gas system. Chloride and sulfate bearing compounds i.e., sodium sulfate, and sodium chloride, present in the off gas condense and concentrate on the colder top head and off gas components. These compounds break down the protective chromium oxide layer resulting in severe degradation of the metal substrate. Generally degradation was more severe in the higher temperature regions of the melter and off gas system.

Results from the metallurgical evaluation of the borescope outer housing indicated that the spalling around the orifice resulted from high temperature oxidation. The significant depletion of chromium deep into the metal substrate, internal void formation, and thick loosely adhering scale are characteristic of high temperature oxidation. Normally alloy 690 would form a stable chromium oxide (Cr_2O_3) layer which would protect the metal from further oxidation or corrosion. However, thermal fluctuations caused by frequent purges of steam (once every half hour) and the constant flow of air through the orifice accelerated spalling of the protective chromium oxide layer and further oxidized the metal. Chloride and sulfate containing salts also contributed to the degradation of the protective oxide layer. Furthermore, elevated temperatures, approaching 900°C, in the melter vapor space during idle mode, accelerated the diffusion of chromium from deep within the metal substrate to the surface.

Oxidation around the orifice of the borescopes may be minimized by reducing the amount of air passed through the orifice and by minimizing the frequency of steam purges. Both solutions would require redesign of the borescope. Oxidation in this region could also be eliminated by using an inert gas purge such as argon but the effects of the gas on the glass chemistry, off gas, and system integrity would need to be evaluated.

The large pit observed on the side of the outer housing near the core end piece resulted from Type II hot corrosion. The morphology in this region was dramatically different from that observed around the orifice only inches away. This type of corrosion results in a non-uniform pitting attack with little or no chromium depletion from the metal substrate (5). Here internal void formation was minimal indicating that only the chromium close to the surface had sufficient time to diffuse to the surface and combine with oxygen to form Cr_2O_3. The extremely high concentrations of chloride and sulfate bearing salts combined with thermal cycling of the outer tube contributed to the degradation and spalling of the Cr_2O_3 layer. A corrosion rate in excess of 7.5 mm/yr was estimated (6).

Chlorides are known to cause severe "breakaway" corrosion in chromium and nickel based alloys (7); however, small additions of aluminum to Ni/Cr alloys have been shown to increase the chlorination and oxidation resistance (8, 9). A duplex chromium and aluminum diffusion layer was applied to one of the replacement borescope outer housings and an inspection was performed after several months of service. Although a thin loosely adhering scale containing alumina was detected, severe pitting was not observed on the housing. The service life was conservatively estimated at one year. Another inspection is planned to assess its performance after one year of service. Alternate alloys containing 2 to 3 wt% aluminum or silicon (VDM alloys 602 CA and 45 TM and Inconel 690 modified with 3 wt% Al) have also performed well in scale glass melter and incinerator coupon tests and are being considered for use on this and other DWPF melter components (10-12).

Degradation of the feed tube core end piece resulted from pitting attack of the beveled region which is between the main outer tube and the bottom flat orifice plate. No significant attack was observed in the outer tube or around the orifice plate. Metallurgical specimens sectioned from the orifice plate and the main tube adjacent to the beveled region did not show any evidence of intergranular attack. Exposed end grains in the beveled region and the lack of adequate cooling may have contributed to the observed localized attack. The degraded regions of the tubes were weld repaired and machined to original specifications. Spare feed tubes were also buttered with matching filler material. A visual inspection of a weld repaired feed tube after approximately 5 months of continuous service indicated a significant improvement in performance. The repaired feed tubes are expected to perform satisfactorily for their two year design life.

Thermowells and the level probe were in good condition. Only a minor melt line attack and intergranular attack (IGA) below the melt line were observed. These components were designed with adequate wall thickness, and therefore, should not be seriously affected by the IGA. Degradation of the portions of these components exposed in the vapor space was not observed. The thermowells and level probes should also perform satisfactorily for their two year design life.

Degradation of the portions of these components exposed in the vapor space was not observed. The thermowells and level probes should also perform satisfactorily for their two year design life.

Primary Off Gas System

Failure of the primary film cooler brush bristles resulted from oxidation of the Hastelloy X, a nickel base alloy containing 9 wt% molybdenum. Molybdenum reacts with the oxygen and forms a corrosive liquid phase at 795 °C or a volatile corrosive gas (MoO_3) at slightly higher temperatures (8). Temperature data from the film cooler region was not available; however, it may approach 850 °C when the melter is idled for extended times. In addition to the degradation caused by the MoO_3, chloride and sulfate salts that deposited on the brush also contribute to the corrosion of the bristles and brush block. Laboratory tests have shown that the chloride and sulfate salts will adversely affect the stability of the protective oxide layers at lower temperatures (7). The acidic nature of the salts fluxes away the protective Cr_2O_3 layer exposing fresh metal which then repassivates. The breakdown of the protective oxide layer can occur very fast resulting in catastrophic corrosion. In the case of the film cooler brush block, degradation was in the form of numerous broad pits. Evidence of sulfidation was not observed. To extend the service life of the film cooler brushes, they will only be installed when needed to clean the film coolers. Alternate materials and designs are currently being considered.

Degradation observed on the end of the film cooler most likely resulted from a combination type II corrosion and oxidation. Metallurgical sections were not removed from this component and therefore, the exact corrosion mechanism could not be determined. Approximately 30% of the bottom edge of the film cooler was affected; however, the degradation was not severe enough to warrant removal at this time. The film cooler will be operable for its intended design life although its efficiency may be reduced. Alternate materials will be evaluated for this component.

Pitting of the off gas line inlet just below the film cooler brush may have been due to the evolution of MoO_3 from the film cooler brush, and therefore, may be mitigated by the current operating procedure described above and possible redesign. Pitting attack past the dilution air nozzle was minimal and was attributed to the reduction of temperature to 350 °C. The off gas line, isolation valve, and the primary quencher should perform satisfactorily for their two year design life.

Backup Off Gas System

The back up off gas system components were in excellent condition; however, operating time on this system was limited. Air injected through this system at approximately 195 kg/hr effectively lowered the operating temperatures (significantly lower than those in the primary side), thereby eliminating the pitting attack. The high chloride and sulfate containing deposits observed throughout this system may pose a serious corrosion problem if this system is used for extended periods of time.

Back up off gas components have seen only limited service. Components from this system would be expected to perform similarly to the primary off gas components if they are used continuously. Although the DWPF back up quencher, which is fabricated from Hastelloy C-276, was not inspected, performance of this material in this environment should be satisfactory. The Hastelloy C-276 quencher from the 1/10 scale melter system at SRS showed no evidence of degradation after approximately seven years of continuous operation.

CONCLUSIONS

The melter feed preparation portion of the DWPF facility has performed satisfactorily during the past 12 months of non-radioactive simulated waste runs. The only component to have experienced erosive attack was the agitator and cooling/heating coil from the SME and MFT; however, design modifications should mitigate the erosion. All other vessels, jumpers and pumps were in excellent condition and should perform satisfactorily for their design lives.

The following melter top head and off gas components showed no evidence of degradation or only minor attack: the level probe, the side center and vapor space thermowells, the primary quencher, the primary and melter off gas (MOG) line isolation valves, the back up MOG line, and the back up film cooler brush. Components that have shown signs of moderate attack but should perform satisfactorily for two years were the primary off gas film cooler, the primary MOG line.

The most severe attack occurred in the hotter regions of the melter vapor space and off gas system and was associated with high temperature oxidation or corrosion resulting from high concentrations of chlorides and sulfates. The components that suffered significant attack were the borescopes, primary film cooler brush, and feed tubes. Changes in the operation of the film cooler brush and design modifications to the feed tubes and borescopes are expected to extend their service lives to two years.

Extension of the current design lives of the various melter top head and off gas components is desirable because:

1) remote handling in a radioactive environment is difficult,

2) outages for component replacement results in unnecessary production downtime,

3) long term disposition of radioactively contaminated components is costly,

4) high alloy materials are expensive, and

5) procurement and fabrication lead times are long.

Therefore, a program will be initiated to develop and evaluate new high temperature engineered materials and alloys having improved oxidation and high temperature corrosion resistance.

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