DWPF PROCESS CONTROL[a]

F. M. Heckendorn, II
E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808

ABSTRACT

The Defense Waste Processing Facility (DWPF) for waste vitrification at the Savannah River Plant (SRP) is in the final design stage. Instrumentation to provide the parameter sensing required to assure the quality of the two-foot-diameter, ten-foot-high waste canister is in the final stage of development. All steps of the process and instrumentation are now operating as nearly full-scale prototypes at SRP. Quality will be maintained by assuring that only the intended material enters the canisters, and by sensing the resultant condition of the filled canisters. Primary emphasis will be on instrumentation of the process.

INTRODUCTION

The process for immobilizing Savannah River Plant (SRP) high-level liquid waste (Fig. 1) consists of vitrifying the material with borosilicate glass. The previously stored waste is retrieved from the large storage tanks in sludge form, which contains most of the long-lived radionuclides, or as the concentrated radioactive portion of the waste supernate, which contains most of the cesium. The composite material is transported to the DWPF "canyon" where it undergoes further processing and mixing with glass frit. The viscous sludge/frit mixture is fed directly to a Joule-heated ceramic glass melter. The hot (1150°C) molten glass is then poured into stainless steel canisters. The canisters are then welded shut and held in interim storage facilities prior to subsequent transport to a Federal repository.[1]

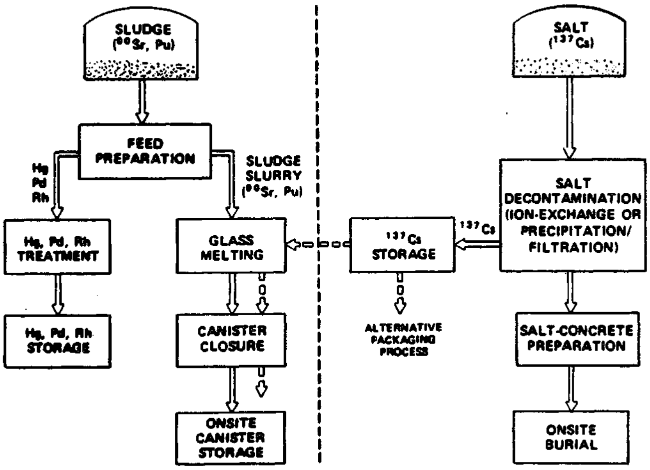

Fig. 1. DWPF Process Flow Sheet

DWPF PROCESS FLOW SHEET

The quality of the final DWPF waste canisters will be assured in a variety of ways, one of which is to control glass quality using a variety of instrumental methods.

Instrumentation development for the DWPF has been extensive due to the limited quantity of suitable, demonstrated instrumentation. For example, the two existing "canyon" types (remote operation and maintenance) facilities at SRP utilize only "bubbler" level indications, limited temperature measurements, and no automatic valves. The instrumentation requirements of DWPF "canyon" are being held as moderate as possible, but are still rather elaborate when compared to existing canyon instrumentation. All parameters which affect the long-term integrity of the waste canister will be measured and controlled as the canisters are produced.

GENERAL REQUIREMENT

Instrumentation for the DWPF is composed of two diverse parts. All components external to the canyon vicinity will be state-of-the-art control equipment similar to that used in other parts of the chemical industry. Primary emphasis of this report is directed at the second portion of the instrumentation, that which is specific for the within-canyon requirements. This latter involves sensing and control of parameters in the hostile radiation environment by either placement of equipment directly in the canyon or by indirect sensing from a shielded area immediately adjacent.

DWPF CROSS SECTION

The DWPF canyon (Fig. 2) is characterized as an approximately 30-foot-wide by 30-foot-high, thick-walled trench or "canyon" which is several hundred feet long. All high-level waste is transported by underground double-walled pipes, in slurry or solution form, into the canyon after preliminary processing in the waste storage tank. All subsequent operations through the production of glass-filled, sealed, and decontaminated waste canisters are carried out within this environment. The exiting canisters are ready for transport and storage.

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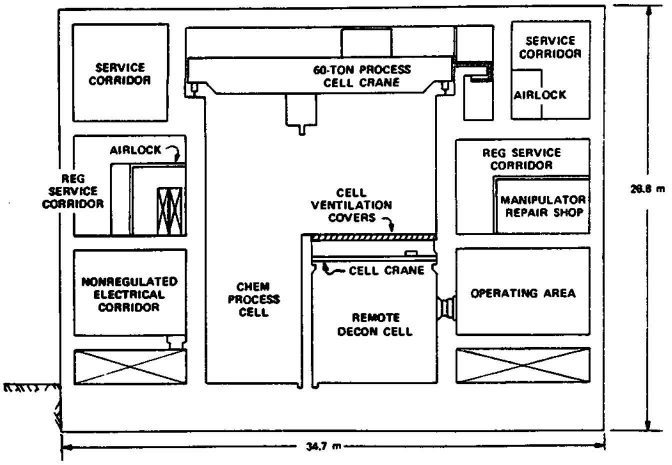

Fig. 2. DWPF Cross Section

The environmental factors that any instrumentation must contend with include high radiation levels, high temperature zones, and remoteable wiring. Of the radiation present (i.e., alpha, beta, and gamma), gamma will be the prime concern of instrument survivability. The radiation fields vary widely from a few thousand rads/hr to thirty thousand rads/hr immediately adjacent to a filled canister. One additional ground rule was that direct contact of the radioactive fluid with any plastic or elastomer was to be avoided if at all possible, due to a severe alpha and beta particle effect.

SLURRY RECEIPT ADJUSTMENT TANK/SLURRY MIX EVAPORATOR

Once high-level waste enters the DWPF, it is initially processed in the slurry receipt and adjustment tank (SRAT) and the slurry mix evaporator (SME) (Fig. 3). These two similar vessels concentrate the incoming sludge, process it with formic acid, and blend it with borosilicate glass frit (very finely powdered glass).

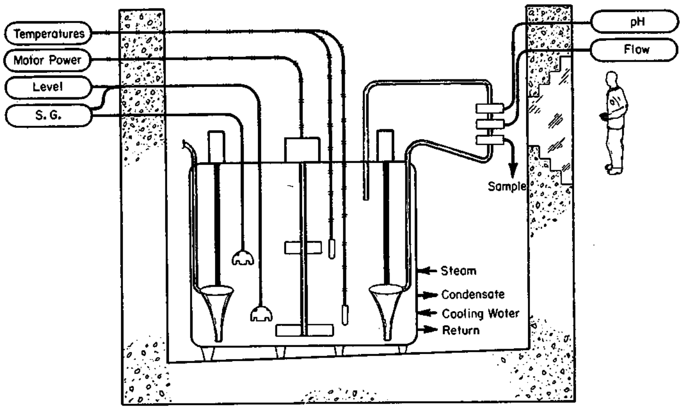

Fig. 3. Slurry Receipt Adjustment Tank Slurry Mix Evaporator

Control of the glass quality begins with the processing and characterization of the waste in the waste tanks, and continues through careful processing by the SRAT and SME. The waste received into the DWPF will be fed from a large batch (2- to 3-month supply) of fully characterized and blended waste. No "unknown" material will be processed. This characterization is based on laboratory analysis of direct waste samples drawn from tanks.[2]

The processing in the SRAT and SME is monitored and controlled utilizing both real time instrumentation and off-line analysis. As the waste is processed, it becomes highly viscous, up to a maximum of 250 dynes/cm yield stress, and special techniques must be used to measure, sample, and transport the material. Both vessels process the sludge while the level, specific gravity, and agitator power are continuously monitored. The two former measurements require an "isolated" bubbler technique, since the conventional air bubbler level sensing technique will not work, due to high plugging tendencies of the sludge. An isolating, all metal diaphragm is used to sense level and specific gravity. No direct contacts occur between the air and sludge.

The temperatures in the upper and lower regions of the vessels are carefully controlled. A temperature-dependent rate of heating technique is used to minimize batch processing time while carefully negotiating through several sensitive processing temperatures. The upper/lower temperature differential is an indication of vessel bottom superheating, which is minimized through agitation and temperature increase rate control. Resistance bulb temperature sensing techniques are used for these modest temperature ranges.

A sample loop is operated semicontinuously during batch processing. It provides an at-line pH measurement and representative sample for laboratory analysis. Hardware for both is located in a manipulator serviced sample cell. The pH indication is effectively real time with only a slight lag of the actual process. It is an indicator of the processing chemistry as the highly alkaline waste is processed with formic acid to an end point. Success with ruggedized pH probes in the sludge/frit slurries has been very good, with units designed for manipulator servicing. Most of the electronics are located outside of the cell in the nonradioactive environment.

A multiple grab sampler is cycled repeatedly throughout the batch processing to acquire representative samples. All metal samplers actuated by all metal pistons (i.e., nonmetallic seals) have been suitably demonstrated. The samples are analyzed off-line in the laboratory to confirm proper batch processing. A long lead time between batches (i.e., 72+ hours) allows ample time for any required corrective action prior to proceeding. In each step the emphasis remains on not producing or proceeding with unacceptable material.

MELTER FEED SYSTEM AND MELTER

After the completion and confirmation of processing through the SRAT and SME, the sludge/frit slurry is transferred to the melter feed tank (Fig. 4). Two recirculation loops, fed from submerged, cantilevered pumps, are used to supply feed material to the immediate vicinity of the melter.[3]

The flow to each of two melter feed nozzles is controlled by the pressure in the recirculation loop at the takeoff point. The latter is controlled by varying the speed of the recirculation pump, thus eliminating the need for control valves. Flow meters are provided in both the recirculation line (nominally 2 inch diameter) and the takeoff line (nominally 3/8 inch diameter). Flow monitoring has been demonstrated using glass-lined D.C. type Magnetic Flow Meters, for both abrasion and radiation resistance. The electronics portion of these meters will be located in the nonradioactive areas. Acceptable operation through the new instrument jumpers has also been demonstrated.

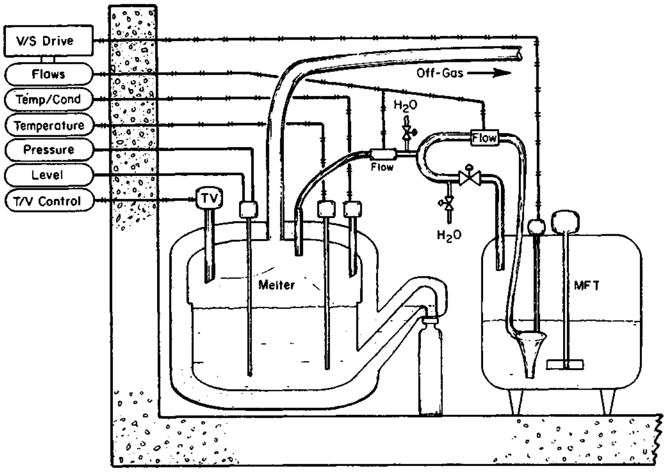

Fig. 4. Melter Feed System and Melter

The internal melter environment is carefully monitored to assure proper temperature control, residence time, and canister pouring. The previously defined feeding will only occur when the melter is under proper control. The level of the material in the melter is continuously indicated by a dip tube bubbler. This has proven a very reliable device through considerable experience. A large diameter dip tube made of Inconel® 690 (Huntington Alloys, Inc.) is provided with side exiting bubble openings. A second pressure sensing point in the melter vapor space provides both a level reference point and the melter pressure. The pressure is maintained by the off-gas system, which also removes any volatile and entrained components and recycles them into the waste system.

A combination high-level probe and vapor space temperature indicator is provided above the glass/vapor interface. The high-level point sensing is accomplished by measuring the voltage between the probe and melter ground. Since the melter is Joule heated, any contact with the probe will be seen as a relatively high voltage (i.e., 40-50 VAC). We have demonstrated that this technique can readily sense glass, cold cap, feed, or foam.

The temperature of the glass is sensed with submerged thick (1/2- to 1-inch wall) thermowells containing multiple thermocouples. Extensive thermocouple testing has demonstrated very good results with Type B thermocouples (platinum - 30% rhodium vs. platinum - 6% rhodium) in platinum - 10% rhodium sheaths. This combination has proven far superior to other combinations of thermocouple type and sheath material, from standpoints of both long-term drift and longeviety.

The melter surface is visually monitored with a pair of T.V. camera/borescope combinations (Fig. 5). An air-cooled and air-purged window borescope is used to penetrate the melter shell and contend with the hot and hostile environment. An externally mounted low light level T.V. camera is coupled through a special electrical jumper to the nonradioactive environment. Additionally, the T.V. camera requires shielding from the high magnetic fields of the melter. All of the above have been demonstrated on large-scale melters, as has the radiation resistance of the T.V. cameras to a level exceeding 5 x 10^7 rads cumulative. The melt surface is an excellent indicator of the overall condition of the melter, both mechanically and operationally. It is one of the most valuable indicators of proper feed rate and melt rate.

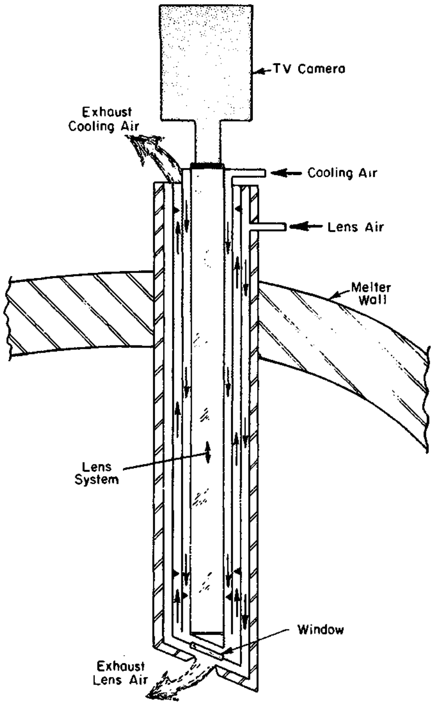

Fig. 5. Melter Boroscope

The glass is poured into the canisters by the differential pressure maintained between the melter vapor space and the chamber above the canister, which is mechanically sealed to the melter. This technique has a beneficial fail-safe effect since the loss of vacuum will always stop the pouring process. Glass samples will be taken at this point by placing a sample container in the mouth of a canister and pouring out a small quantity of glass, with any excess overflowing into the canister. This will be the final quality checkpoint on the glass product, with all appropriate laboratory analysis made.

CANISTER FILLING AND TEMPERATURE MEASUREMENT

The level within a canister (Fig. 6) must be carefully monitored to (1) maximize the glass stored per container, and (2) eliminate potential overfilling. An additional concern is to prevent the formation of a stalagmite of glass in the center of the container, which can block the nozzle and plug the melter pour spout. The latter can occur with the incorrect combination of colder glass and low pouring rate.

Provision has been made for measuring the glass level in a canister. Three methods of level detection have been demonstrated and will be used in the DWPF.

Canister weight is the most straightforward and normally simplest technique that will be used. But weight is insensitive to stalagmite formation and there remains some uncertainty concerning long-term reliability of detecting devices. Within the canyon environment, the weight sensors must contend with high heat, vibration, and radiation effects.

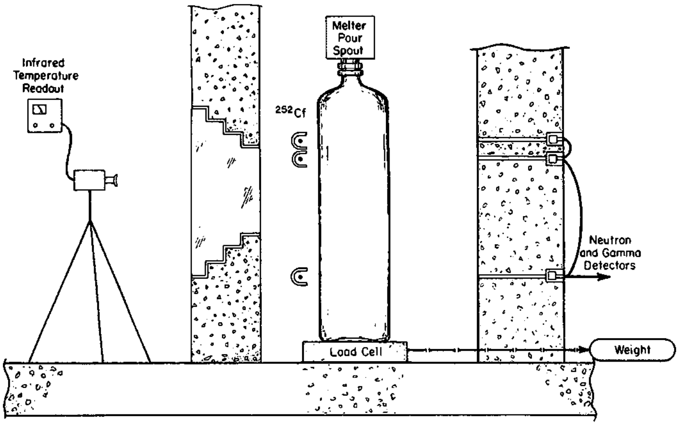

Fig. 6. Canister Level and Temperature

A point level detection technique has been demonstrated using the absorption of fast neutrons. The waste is relatively neutron free due to its age. The borosilicate glass is an excellent neutron-absorbing agent. Californium (^{252}Cf) sources, coupled with BF_3 detectors, show a continuously varying response up to approximately 15 inches of glass path length. This makes them not only a good level detection device, but also an excellent stalagmite detector. They will be used at 50%, 95%, and 100% full positions.

A third technique will be used to both detect the level and to partially characterize the glass contents. The gamma emission of the glass, when carefully collimated, will indicate the level. This technique can be implemented relatively inexpensively along or with the neutron technique. Additionally, it will be useful in stalagmite detection.

The canister surface temperature must be known prior to its leaving the melter for surface decontamination. Undesireable building contamination could possibly result from wet decontamination of a thermally hot canister.

A technique has been demonstrated for measuring the temperature without physical contact or entry into the canyon environment. A specially designed infrared temperature sensor is used from outside of the thick (approximately 5 foot) canyon wall windows. Utilizing a near infrared region of the spectrum to which glass is transparent, the temperature can be read directly. This allows all of the electronics to remain outside of the radioactive environment, and thus avoid damage.

CANISTER WELDING

The final sealing of the canister is important to the overall canister integrity (Fig. 7). A high current D.C. upset welding process has been demonstrated extensively to assure high weld quality.

The welding process virtually assures there will not be any bad welds, due to its very forgiving design (i.e., insensitivity to momentary perturbations of control). Weld quality will be assured on the basis of monitoring while the weld is made, rather than the impractical technique of destructive testing.

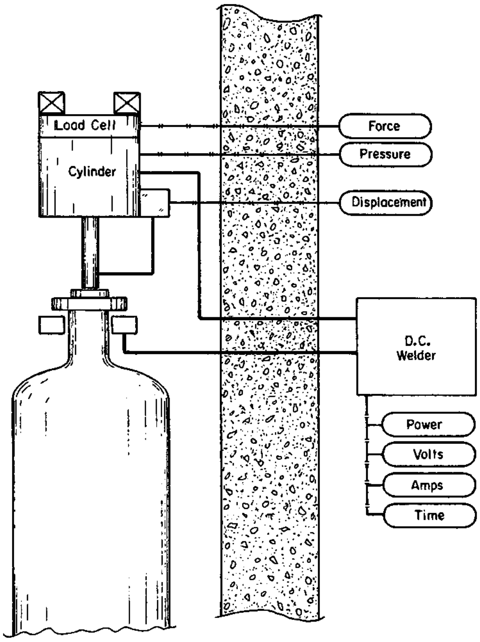

Fig. 7. Welding Process

The canister is fitted with a self-centering, oversized, 1/2-inch-thick plug. A high force (approximately 75,000 lb) is applied to the top of the plug and high current is applied between the plug and canister flange (approximately 240,000 amps). Metal softening occurs at the plug/canister interface lasting about 1 1/2 seconds, completing the weld.

Multiple monitors of the weld parameters are made including:

- piston pressure to ram
- net total force on plug
- displacement of plug during weld
- duration of weld
- power, volts, and amps of each power pak.

The failure of any of the four power packs will not affect a weld in progress. The mechanical components retain sufficient potential energy that anything short of a catastrophic failure will not adversely affect a weld under way. To date, no bad welds have been produced.

FINAL INSPECTION IN THE DWPF

The completed waste canister will undergo a final inspection prior to departing the DWPF. This is both a quality check and a contents characterization (Fig. 8).

The canister surface will be scanned for temperature average and gradient. The technique of infrared emission temperature sensing from outside of the canyon window will be used, as previously described.

The gamma emissions from each canister will also be scanned for both level and spectrum. This information will help characterize the type and distribution of radionuclides contained within.

A clean canister surface is assured by a surface smear test which traverses the entire canister. Freedom from surface contamination is a prerequisite to exit from the DWPF.

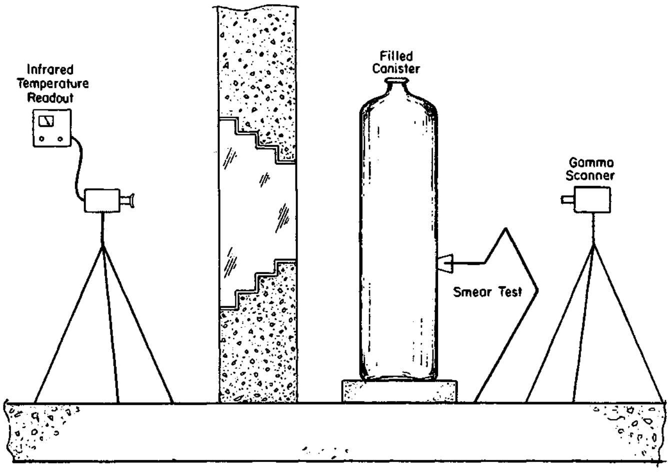

Fig. 8. Final Inspection

SUMMARY

Control of the quality of the waste canisters produced by the Defense Waste Processing Facility (DWPF) relies on control of what enters the canisters, and by testing of filled canisters. Well instrumented control of each critical step in the process is being demonstrated as the route to the final product quality.

Full-scale demonstration of the required instrumentation is either under way or has been completed at the Savannah River Laboratory test facilities. The suitability of all required instrumentation to the canyon environment and the appropriate level of redundancy will be demonstrated prior to its inclusion in the DWPF.

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