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by

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SRL
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The Savannah River Plant has been operating a nuclear fuel cycle since the early 1950's. Fuel and target elements are fabricated and irradiated to produce nuclear materials. After removal from the reactors, the fuel elements are processed to extract the products, and waste is stored. During the thirty years of operation including evaporation, about 30 million gallons of high level radioactive waste has accumulated. The Defense Waste Processing Facility (DWPF) under construction at Savannah River will process this waste into a borosilicate glass for long-term geologic disposal. The construction of the DWPF is about 70% complete; this paper will describe the status of the project, including design demonstrations, with an emphasis on the melter system.

BACKGROUND AND PROCESS DESCRIPTION

The waste is stored in alkaline form in 1.3 million-gallon carbon steel tanks. Most metal ions precipitate as hydroxides; the alkali metals stay in solution. To conserve storage space, the salt solution is concentrated by evaporation beyond saturation. The waste therefore exists as: sludge, salt cake, and saturated salt solution. Most of the radioactive components are in the sludge; the principal exception is ^{137}Cs which is in both salt cake and supernate.

Because the vast majority of the solids are non-radioactive, a process that will allow separate disposal of radioactive and non-radioactive materials is economically attractive. The DWPF process steps are:

- Dissolution of excess aluminum from the sludge with concentrated caustic.
- Dissolution of saltcake followed by precipitation of Cs and K from the solution using sodium tetraphenylborate.
- Disposal of the filtered wash solution from the sludge and the filtrate from the decontaminated salt solution as a cement grout dubbed Saltstone.
- Solidification of the precipitated ^{137}Cs and the sludge as a borosilicate glass.

Before the tetraphenylborate is fed to the melter, it is hydrolyzed using formic acid to remove as much of the aromatic hydrocarbons as possible to reduce the amount of combustion in the melter. Because nitrite ion interferes with this hydrolysis reaction, it must first be destroyed using hydroxylamine nitrate. The process is shown in Figure 1.

After aromatic removal, the cesium-bearing stream is combined with the sludge from the waste tank farm in the slurry receipt and adjust tank (SRAT). In the SRAT, formic acid is added to destroy NO_2^- and CO_3^{-2} as well as to adjust the pH and redox state of the waste prior to glass formation. One significant species reduced by the formic acid is Hg^{+2}. The reduced Hg is removed from the SRAT by distillation, acid-washed and water-rinsed to produce a decontaminated metallic Hg product which can be recycled to the SRP separations process.

After the waste streams are mixed and the Hg has been stripped, glass frit is added and the slurry is boiled down to 50% solids and fed to the joule-heated glass melter. The waste glass is semi-continuously poured into stainless steel canisters which are cleaned, welded shut, and sent to interim storage awaiting shipment to a repository.

DWPF MELTER

Melter Description

The melter is designed to vitrify a continuous slurry stream of glass frit and chemically treated waste at a rate of 228 lb/hr. A cross-section of the melter is shown in Figure 2.

Two pairs of diametrically opposed electrodes provide power to the glass melt which is maintained at 1050°C to 1150°C. This temperature is selected to produce a melt viscosity low enough and waste dissolution rate high enough to meet feedrate requirements without undue corrosion of the melter materials. Supplemental heat is applied above the glass pool to vaporize the water and maintain a plenum temperature high enough to combust the organics entering the melter; this plenum heat is supplied from eight resistance-heated Inconel® tubes. Glass is discharged into stainless steel canisters through the riser/pour spout channel using a differential pressure control process.

Several design features have proven to be essential to smooth operation of the melter system. First, it is important that no surface temperatures exist where volatile sulfides can condense and pool, as they are extremely corrosive. The transition between the hot melter plenum and relatively cool offgas line is protected using a film cooler which mixes steam or air with the offgas in a way that no intermediate temperature gas contacts the wall. The plenum must be kept above a minimum temperature; to do this requires minimizing air inleakage in all fittings and jumper connections. Also, a uniform pour spout temperature profile is necessary to prevent spout pluggage or glass stream wandering. A sharp-edged disengagement point for the glass also helps eliminate stream wandering. The pouring glass can easily be blown into a fiber form which will plug the pour spout vacuum line; this is prevented with an air baffle in the bellows section that connects the pour spout to the canister.

Because most of the key components of the melter cannot be remotely replaced, materials of construction and fabrication techniques were chosen to minimize the probability of premature melter failure. The design life of the melter is 2 years based on refractory wear estimates. The refractory in contact with the glass pool is Monofrax® K-3. All melter heaters are Inconel® 690 including the 4 electrodes, 8 plenum heaters, riser/pour spout heaters and 5 drain valve heaters. All top head components which protrude into the melter are also of Inconel® 690.

Prior to shutdown, a spent melter will be emptied through a bottom drain valve. The valve is shown in Figure 3.

Melter Assembly

It takes about 3 years to fabricate and assemble a DWPF melter. The first melter is nearly complete and will be installed in the DWPF facility in March 1988. Ordinarily, the melter assembly and installation is in three stages: the melter is fabricated and assembled by the vendor and delivered to SRP; the melter is next fitted up with all its jumpers in a mockup shop to guarantee a precise fit in the DWPF canyon facility; finally the jumpers are removed and the melter and jumpers are remotely installed in the DWPF. In the case of the first DWPF melter, some of the final melter assembly steps were completed in the mockup shop rather than at the vendor to save time.

The equipment installed in the mockup shop included the drain valve, the electrodes, the plenum heaters, the riser/pour spout assembly, and the top head. Piping and wiring from the frame to the melter vessel were completed after the top head was secured. This included cooling water piping, thermocouple wiring, and instrument air piping. Electrical and water flow tests were conducted and documented.

Remotability Studies

All services enter through the top head nozzles; these include two feed tubes, two off-gas lines, three thermowells, two TV camera borescope assemblies and a level probe. All equipment in the melt cell of the DWPF must be remotely installed and removed using an overhead crane. Before installation in the DWPF, it must be determined that all planned remote operations can be performed. In the mockup shop, each jumper will be balanced, adjusted to fit the system and remotely installed. Any interferences will be identified and eliminated. Also, the overall balance of the 80-ton melter and frame assembly will be checked to ensure that it can be lifted into place with the canyon crane. This work will take place in the mockup shop (Figure 4).

KEY DESIGN AND PROCESS DEMONSTRATIONS

Feed Preparation

The hydrolysis of tetraphenylborate, including nitrite destruction using hydroxylamine nitrate, has been demonstrated on a 1/5-scale and the subsequent treatment with formic acid and frit addition have been demonstrated on a full-scale. All of these melter feed processing steps work well. Hg reduction is the only step not demonstrated on an engineering-scale; that will be done in early 1989 in a new 1/10-scale integrated melter/feed prep facility.

Melter

Several specific key melter design concepts were successfully demonstrated using a 2/3-scale non-radioactive melter; two years of operation of this melter have provided confidence in the DWPF design. These concepts include the use of differential vacuum to control glass pouring, side entering electrodes, and an integral riser/pour spout heater assembly. It was shown that the temperature control of the pour spout and the vacuum pour system were adequate to provide smooth pouring with clean flow termination and no spout pluggage. It was also demonstrated that the lid heaters have sufficient power to start the melter and to maintain the necessary plenum temperature during slurry feeding. The design feed rate of the melter of 8 lb/ft^2-hr has also been achieved.

Melter Drain Valve

A prototype of the DWPF valve has been tested in SRL. It has been shown to be operable: it can stop and start flow, and its probe is capable of pushing through a layer of spinel on the bottom of a melter and draining the fluid glass above the layer.

Canister Handling

The cleaning and closure of the stainless steel canisters have been demonstrated on a full-scale. The canisters are decontaminated with an air-injected frit slurry blasting process. The device, shown schematically in Figure 5, uses an 8% slurry of glass frit driven by a 100 psig air stream that is sprayed in a helical pattern covering the entire canister. The system is completely automatic and the only waste product is a slurry of frit that goes into the melter process. The actual canister decontamination cell has been operability tested by SRL.

After cleaning, the canisters are welded shut using a resistance upset welding technique. The weld plug is inserted into the neck of the canister, as shown in Figure 6, and forced down using 75,000 lb of force and 225,000 amps. A solid state weld between the plug and the canister flange is created, there is no fusion of the metal. The weld process has been demonstrated on the actual DWPF welder. Canisters filled from the 2/3-scale non-radioactive melter and sealed with the DWPF welder will be drop-tested to show that the process meets acceptance criteria.

Glass Sampling

A remote glass sampler, capable of catching a small sample of glass as it is poured, has been demonstrated. The device, shown in Figure 7, is attached to the canister as part of the canister throat protector before it is connected to the melter. During pouring, a retractable sample cup is momentarily inserted into the stream. The sample cools rather quickly making it easy to remove from the cup.

Melter Off-Gas

The melter off-gas system has been demonstrated on the 2/3-scale non-radioactive melter. The system, shown in Figure 8, consists of a film cooler, a quencher, two steam atomized scrubbers and a high efficiency mist eliminator. Tests indicate that the system will meet the design DF of 10^8. The behavior of Hg in the off-gas system will be tested in the 1/10-scale integrated melter/feed prep system mentioned above.

PROJECT STATUS

As of October 30, 1987, construction of the DWPF (Figure 9) was on schedule at 71% complete and design was 98+% complete. The completion strategy for DWPF is for sequential turnover of well-defined facility segments with checkout and run-in of the segments to be performed by Task Teams consisting primarily of Operations personnel but with participation by Design and Construction. A facility segment is defined as a logical, identifiable unit of process, building, or auxiliary equipment which can be turned over for commissioning.

There are 645 facility segments in DWPF. These have been organized into logical groupings for turnover. Turnover packages in four parts are being prepared for all the segments. Part 1 defines major equipment within the facility segment and the relationship to other segments. Part 2 is a detailed definition of components and boundaries. Part 3 lists major checkout and run-in tasks. Part 4 details checkout and run-in procedures. Construction Quality Verification is handled as a separate task prior to turnover using specific checklists. Each Task Team leader is the contact for his group of facility segments.

The construction schedule and sequential turnover was integrated with Operations activities to produce an Integrated Schedule which has as its endpoint the hot startup of DWPF. The schedule generated by the Artemis® scheduling program uses early turnover dates, performs manpower leveling, and considers manpower limitations. "What if" scenarios can be run to determine the effect of different strategies or events on the schedule. A project guidance team consisting of representatives from Operations, Construction, and Design manage the schedule. Mechanical completion of S-Area is scheduled for September 1989, followed by one year of cold runs and hot startup in September 1990.

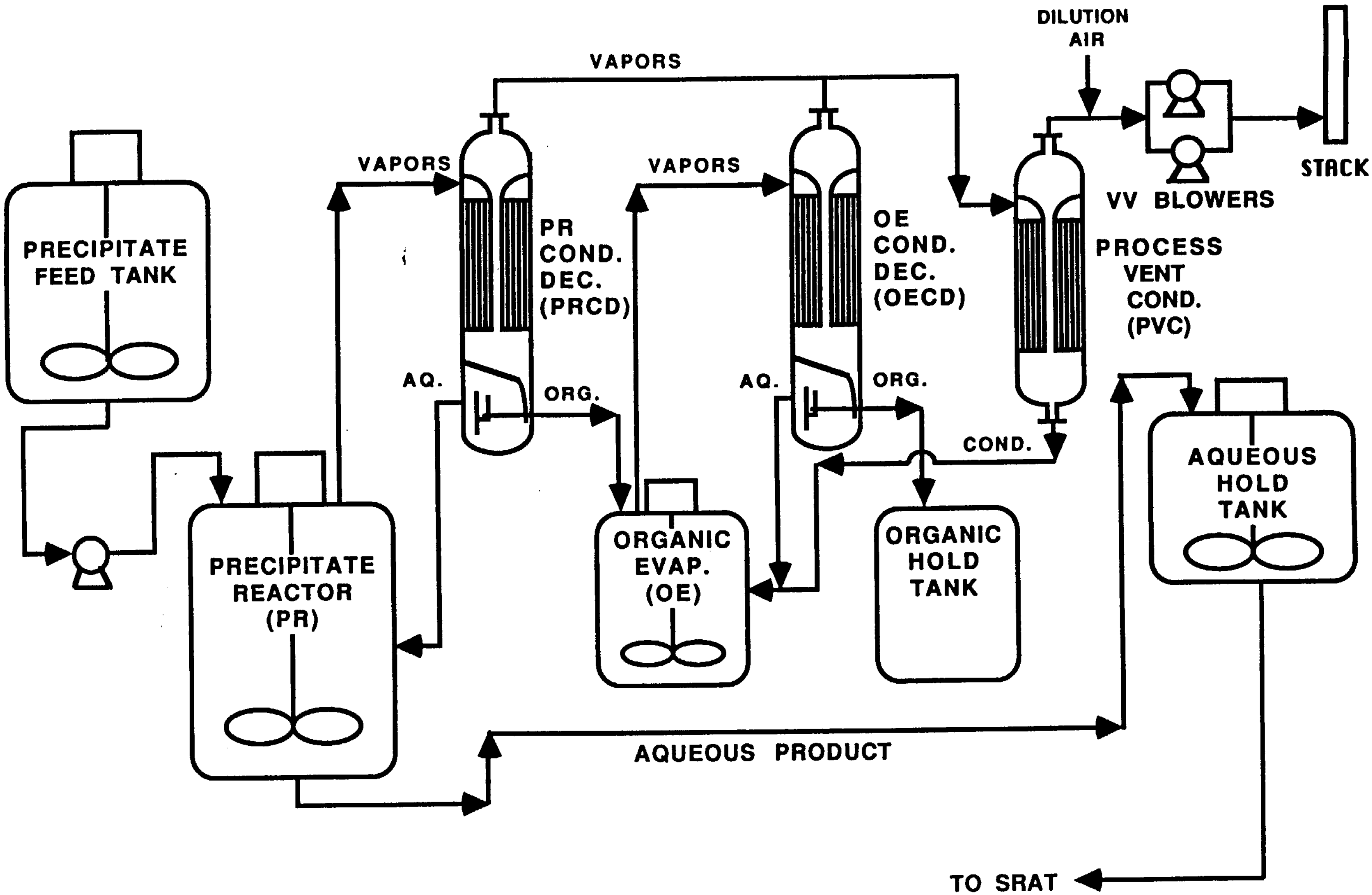

FIGURE 1. Precipitate Hydrolysis Process

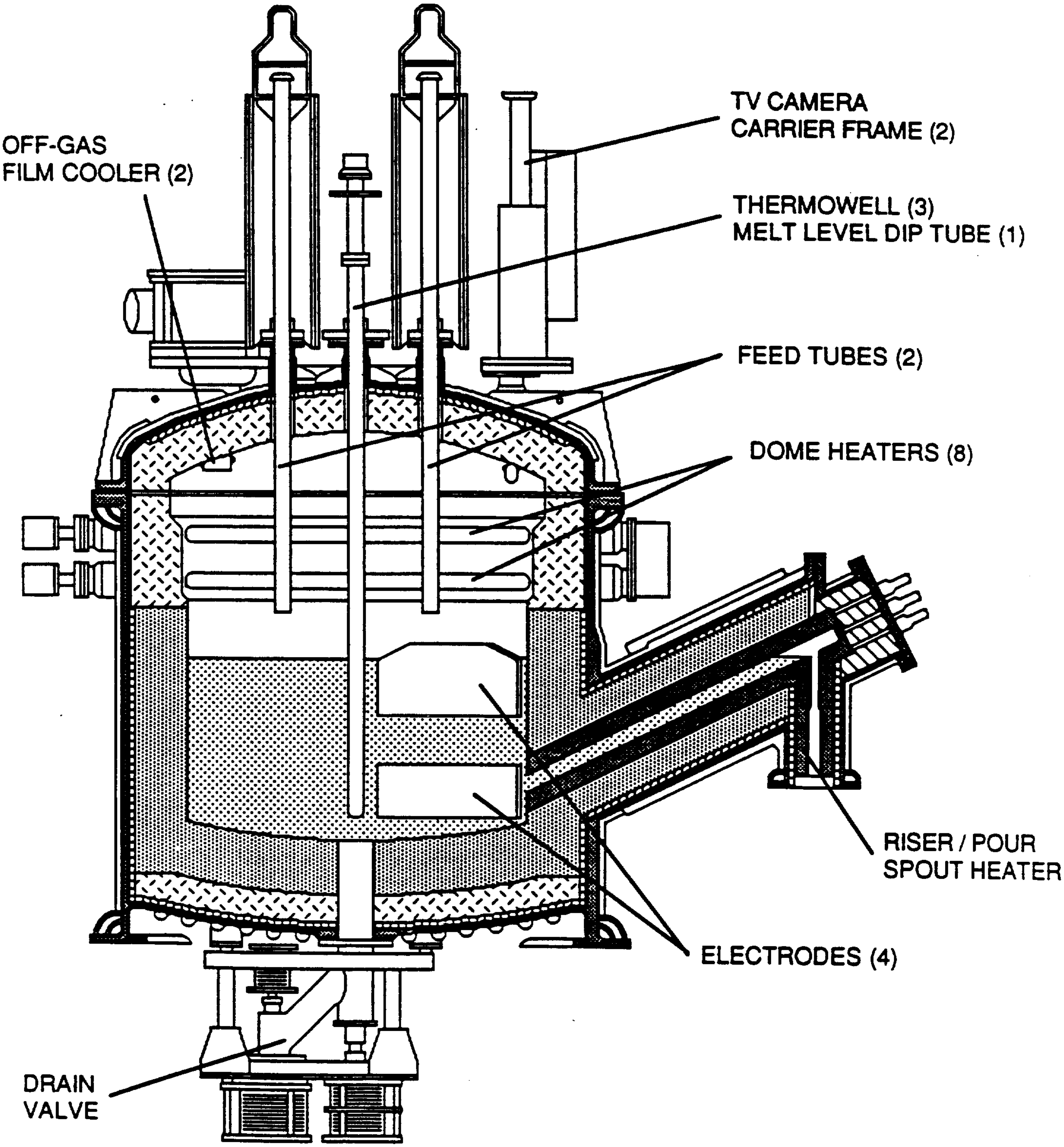

FIGURE 2. DWPF Glass Melter

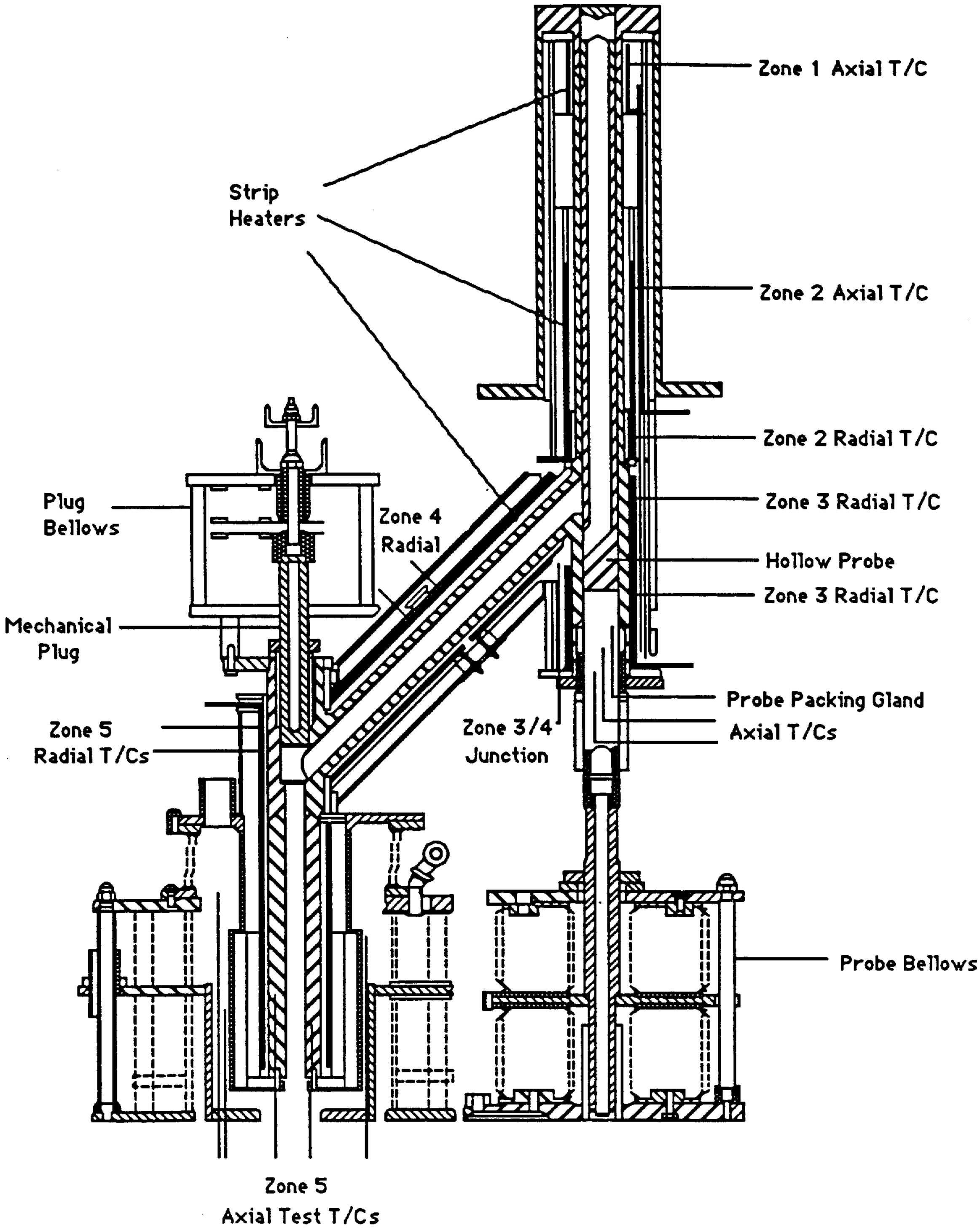

FIGURE 3. Prototype DWPF Drain Valve

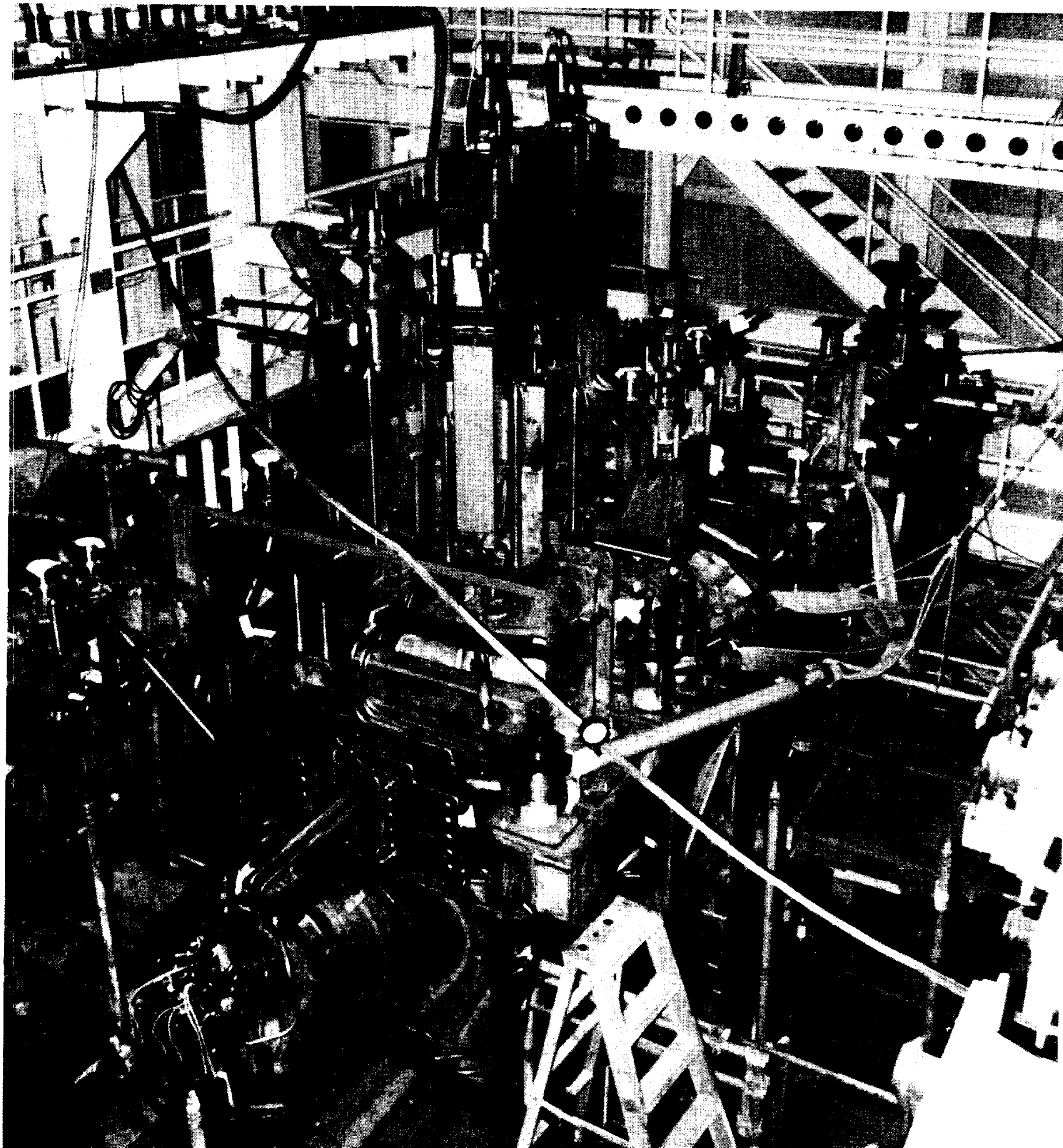

Figure 4. Melter in Mockup Shop

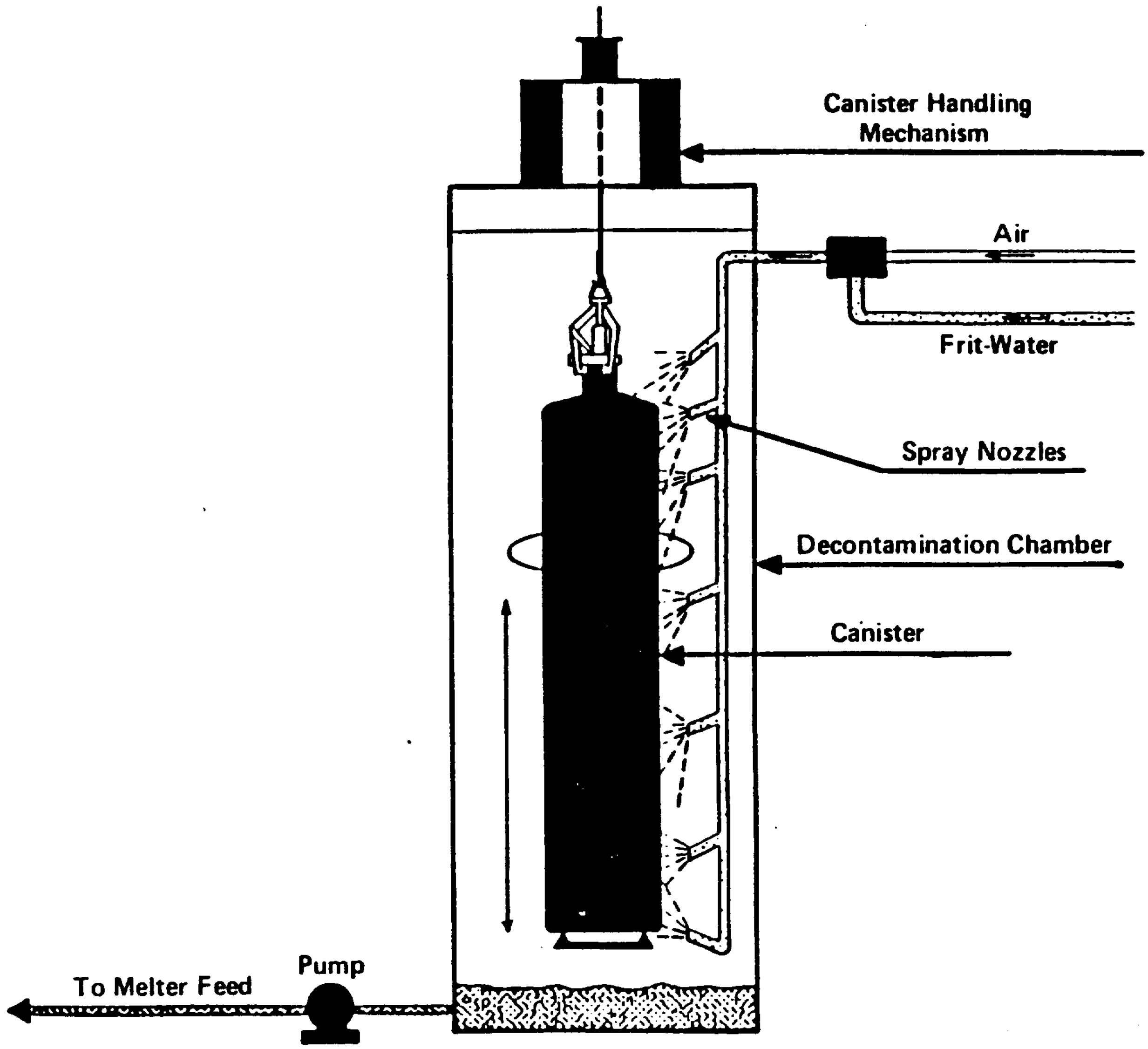

FIGURE 5. Canister Decontamination Method

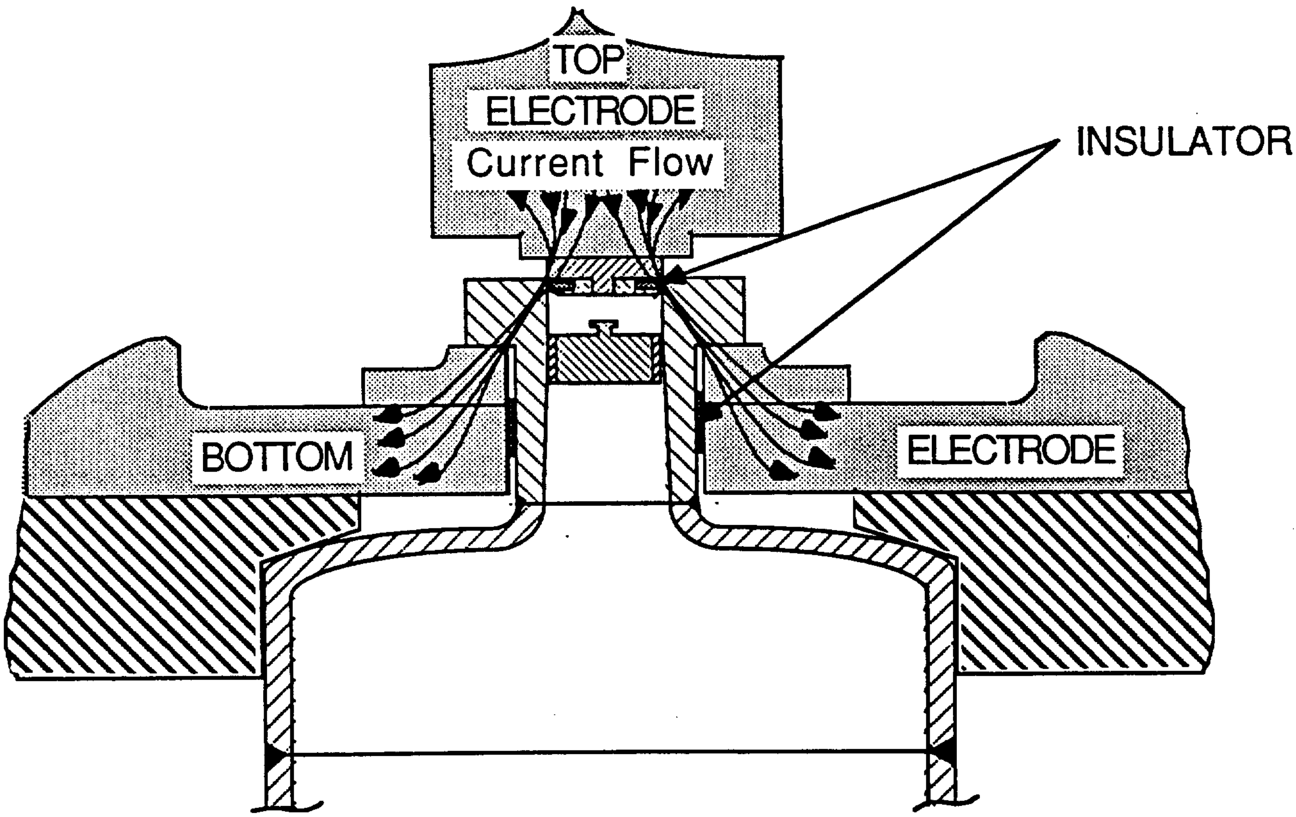

FIGURE 6. Welding Current Flow Diagram

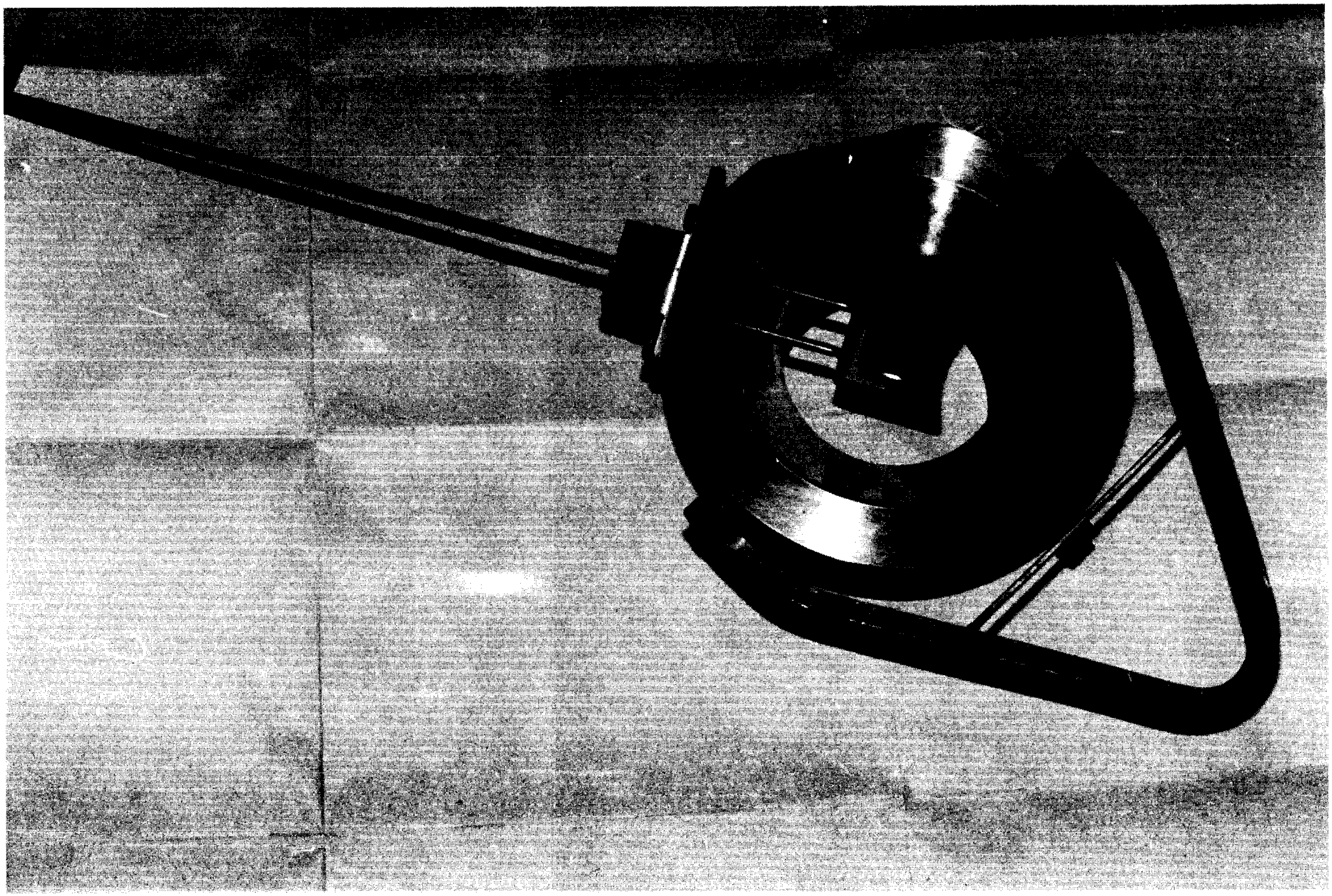

Figure 7. Glass Sampling Device

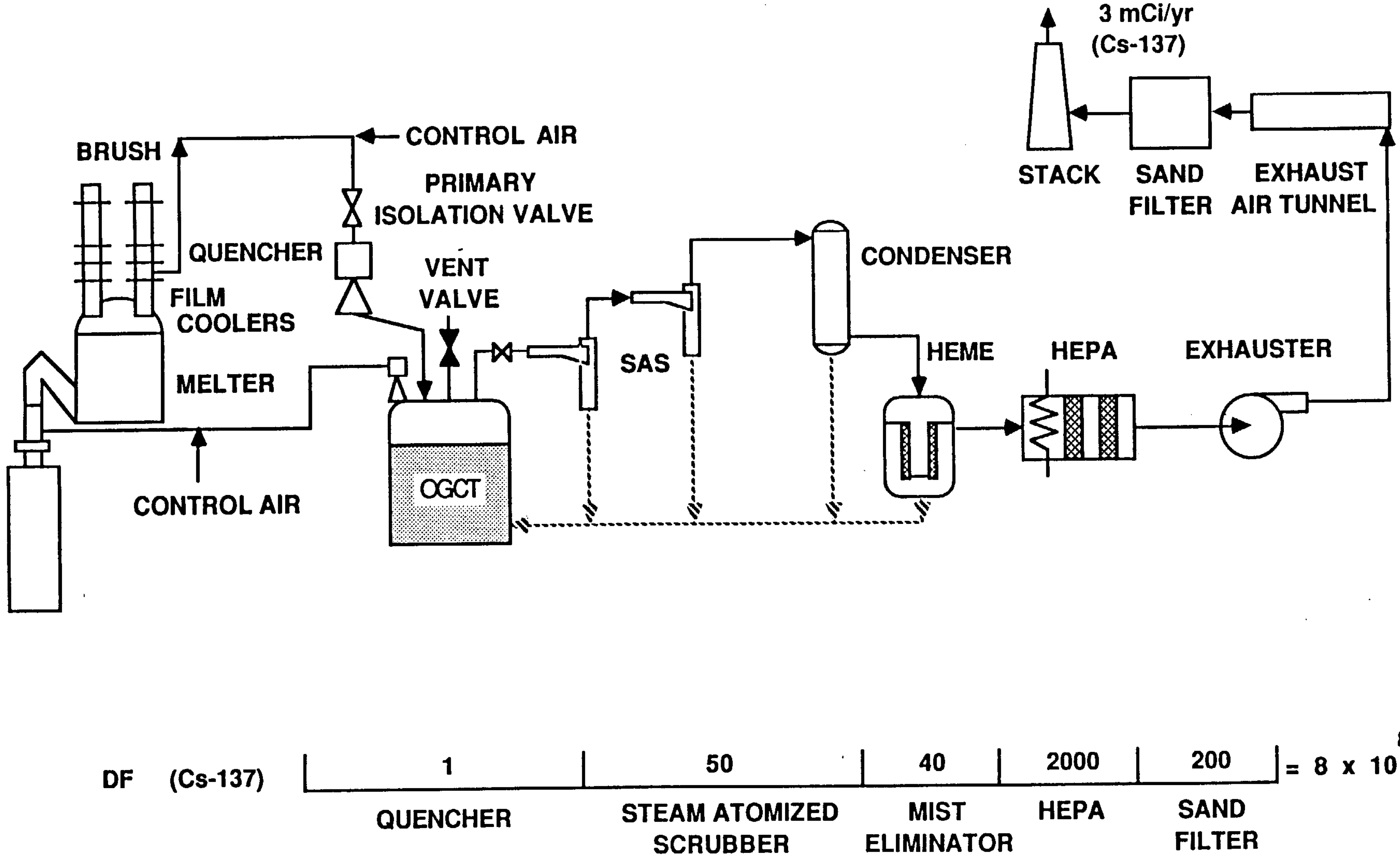

FIGURE 8. DWPF Melter Off-Gas System

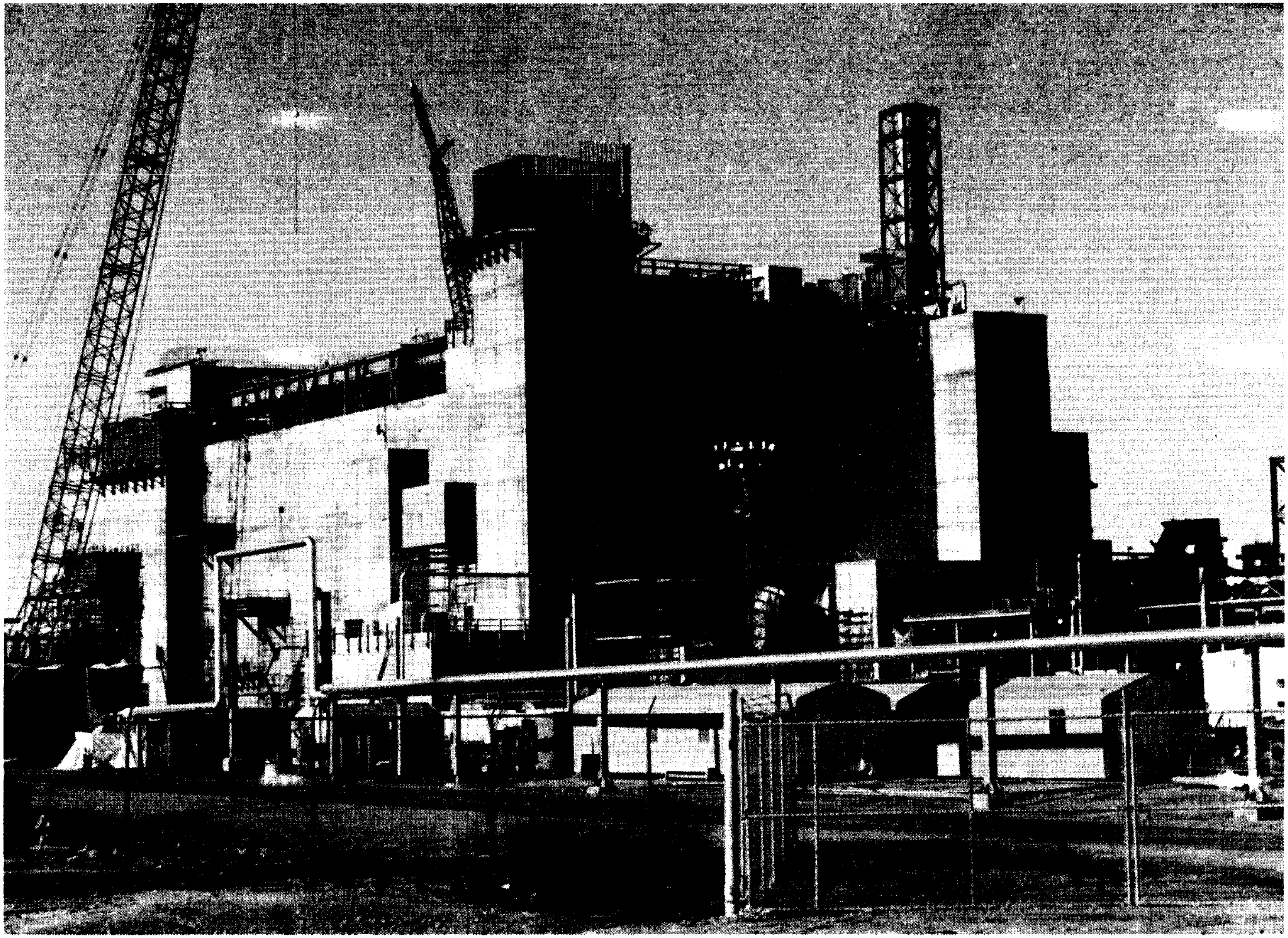

Figure 9. Defense Waste Processing Facility