AN OPERATING RADIOACTIVE LIQUID-FED CERAMIC MELTER SYSTEM

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ABSTRACT

Under sponsorship of the Department of Energy's Nuclear Waste Treatment Program (NWTP), a high-level radioactive waste vitrification system has been installed in the Radiochemical Engineering Facility at Hanford, Washington. The pilot-scale radioactive vitrification system consists of a melter, canister-handling turntable, glass-level detection system, and supporting waste preparation, off-gas treatment and condensate treatment systems. During the past year, radioactive shakedown testing of all the systems has occurred, preparing it for production-type operating campaigns in 1986. This paper discusses the results of the radioactive shakedown completed in 1985.

INTRODUCTION

Since 1973, the liquid-fed ceramic melter (LFCM) process for converting high-level liquid wastes (HLLW) to borosilicate glass has been under development and testing in the United States. Its early success, inherent simplicity, and ease of operation and maintenance led to its adoption as the reference HLLW vitrification process in the U.S., Japan, and the Federal Republic of Germany (FRG). Currently the LFCM is the Department of Energy's (DOE) reference process for planned defense and commercial nuclear waste solidification facilities, including the West Valley Demonstration Project (WVDP), the Hanford Waste Vitrification Program (HWVP), and the Defense Waste Processing Facility (DWPF) at the Savannah River Plant. Because of the LFCM's wide acceptance as the reference waste vitrification process in the U.S., the DOE requested that PNL design, construct, and operate a prototypical radioactive pilot-scale waste solidification facility employing the LFCM process. The pilot-scale radioactive testing is to provide design and operating data that can be applied to production-scale projects. The RLFCM equipment was installed in 1984, and high-level radioactive waste was fed to the melter in October 1984, making it the first large-scale LFCM process to be run in a radioactive environment. The RLFCM underwent shakedown testing in 1985, with increasing levels of activity used in each successive test.

GENERAL SYSTEM DESCRIPTION

The pilot-scale RLFCM is a radioactive testing facility consisting of a vitrification system and supporting equipment systems for preparation of liquid waste, off-gas treatment, and condensate treatment. The vitrification system, which comprises an RLFCM, a canister-positioning turntable, and a glass-level detection system, is depicted schematically in Fig. 1.

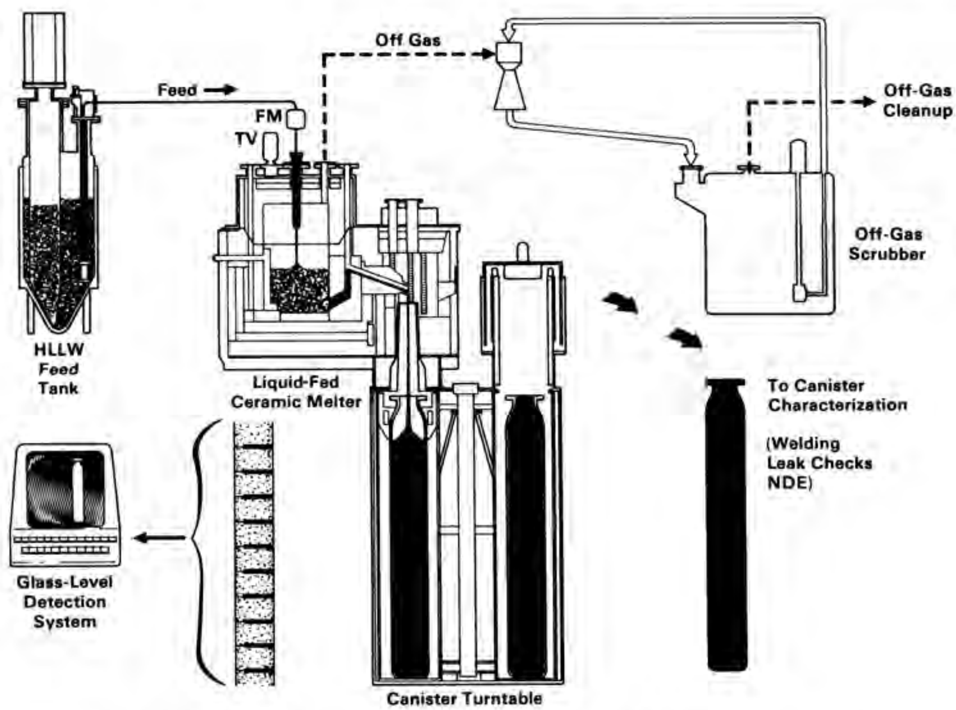

Fig. 1. Schematic Flow Diagram of the Pilot-Scale RLFCM Vitrification System.

Radioactive waste slurries are prepared by blending radioactive waste and glass-forming chemicals in the waste preparation equipment. These are fed from a feed makeup tank to the RLFCM using a slurry feed system. In the RLFCM, the liquid waste is dried and melted to form a borosilicate glass. The temperature of the bulk glass in the RLFCM is maintained at 1100 to 1200°C during operation and at ~1050°C during idling. Off-gas from the vitrification process, consisting of inleakage air, steam, chemical decomposition products, and some entrained particulate, is treated through successive stages of scrubbing, quenching, filtration, and absorption. The decontaminated off-gas is then discharged to the building stack.

The molten-glass product formed in the RLFCM overflows into stainless steel canisters positioned underneath the RLFCM by a turntable, which holds as many as three canisters. The glass level in the canister being filled is monitored by a gamma-detection system. Once filled, the canister is rotated away from the filling position while another is rotated into the filling position. The filled canister is allowed to cool and then is removed from the turntable.

TESTING RESULTS

Several experiments were completed during shakedown testing in 1985. In total more than 300 hours of feeding the melter were logged as over 3200 liters of radioactive slurry were processed. The most significant shakedown test was a 175-hr experiment vitrifying 75,000 curies of activity in 300 kg of glass.

Feed System Performance

The originally installed feed delivery system required several changes in the course of shakedown testing.

The feed-tank mixing system was modified to correct the unreliability of the pulse agitation system. While nonradioactive testing was encouraging from the standpoint of adequate mixing, once the system was installed in the hot cell the mechanical problems became too prevalent. The mechanical reliability of the drive pistons was poor, and the unstable tank pressure during the pulsing process was troublesome for the existing off-gas vacuum system installed in the facility. A more conventional mechanically-driven blade mixer has replaced one of the pulser units.

Good performance was obtained with the air displacement slurry (ADS) pump (Fig. 2). The only difficulty was with the control drive system, which originally used a constant-air-volume piston to drive the pump. As this system was intolerant of small air leaks at in-cell remote connections, it was replaced with a constant-pressure air-delivery system. Initial tests in FY 1985 were very good, and further evaluation of this system will occur in 1986.

The final modification to the feed delivery system was to eliminate an in-line mass flowmeter that monitored feed rate to the melter. The flowmeter's specific design made adequate flushing difficult, thus causing frequent feed line blockages. Tank dropout is currently the primary method for determining feed rate. This is adequate; however, redundancy is desired. In 1986 a radiation-resistant magnetic-type flowmeter will be installed and tested.

Ceramic Melter Performance

The melter has performed flawlessly since its startup in August 1984. Since then it has been at its operating temperature (>1000°C) essentially 100% of the time. Resistive feedback temperature control is used during the vitrification experiments. No significant deterioration of any melter component has been noted.

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Fig. 2. Air Displacement Slurry Pump.

It is interesting to note that an in-cell TV camera for viewing the surface of the interior melting cavity was originally intended. However, it has not yet been installed, and the melter has been operated satisfactorily using nonvisual sensors totally. Process readings from temperature, pressure and glass-level dip tubes can be used to reliably monitor and perform the experiments. The in-melter TV camera will be installed in 1986.

A distributed microprocessor-based control system has worked very well in operating and controlling the melter system.

Effluent System Performance

Development of gas sampling for the RLFCM during the past year has aimed at providing equipment and methods for characterizing emissions at least as well as has been accomplished during nonradioactive testing. Various sampling loops, as depicted in Figs. 3 and 4, allow the sampling of condensible and noncondensible streams. Only limited data were obtained during the shakedown testing as the primary goal was to install and prove the functional aspects of the sampling components. It was shown, however, that the behavior of volatile and semivolatile effluents can be established with orders of magnitude more sensitivity using nuclear analytical techniques. Preliminary results show good removal efficiency for ^{106}Ru using the venturi scrubber. Much more quantified data will be obtained in production experiments currently ongoing and planned for 1986.

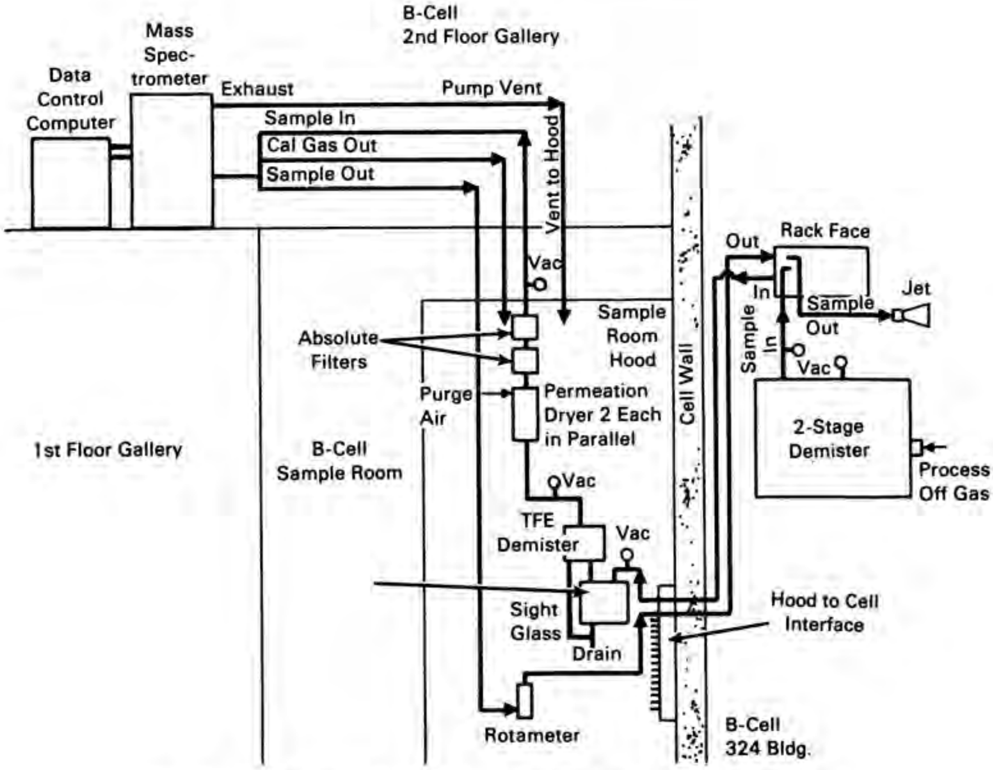

Fig. 3. RLFCM Gas Analysis System for Noncondensible Gases.

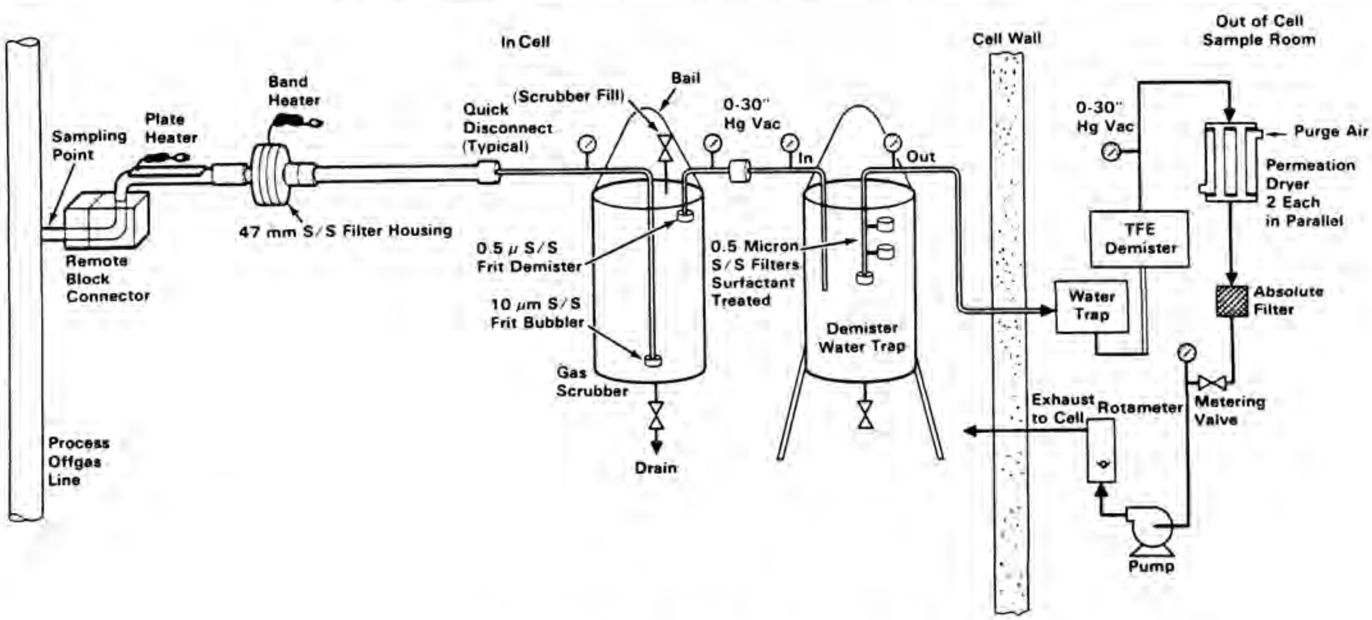

Fig. 4. RLFCM Gas Analysis System for Condensible Gases.

A major concern with the RLFCM system is the behavior of ^{137}Cs, especially during idling. Movement of cesium through the off-gas system and past HEPA filtration units has been observed. Various abatement techniques are being evaluated to further understand the mechanisms for this transport.

Glass-Level Detection System

The RLFCM glass-level detection system is composed of a translatable in-cell gamma-ray source, out-of-cell gamma-ray detection/analysis equipment, and a microprocessor controller/interpreter (Fig. 5). Functionally, the microprocessor sequentially positions the gamma ray-transmission source adjacent to 11 fixed, out-of-cell detectors with the melter canister interposed. At each detector elevation, a 1-min count is automatically initiated; the resulting counting rate is transferred to the microprocessor, where the value is compared with a previously established background rate. This comparison serves to establish both the presence of the glass level and the extent of canister cross-sectional fill. Since out-of-cell detector response is functionally dependent on the source positioning as well as interposed glass, the diagnostic abilities of the level system is limited by the ability to reproduce positioning of the source. Reproducibility to ±2% (an equivalent to ~1/16 in. glass) has been demonstrated, with positional displacements detectable to the nearest 0.1 in. This system has very successfully determined filling heights and can also provide qualitative determination if nonuniform filling of cans occurs, such as the presence of voids or "glass" hair in the canister.

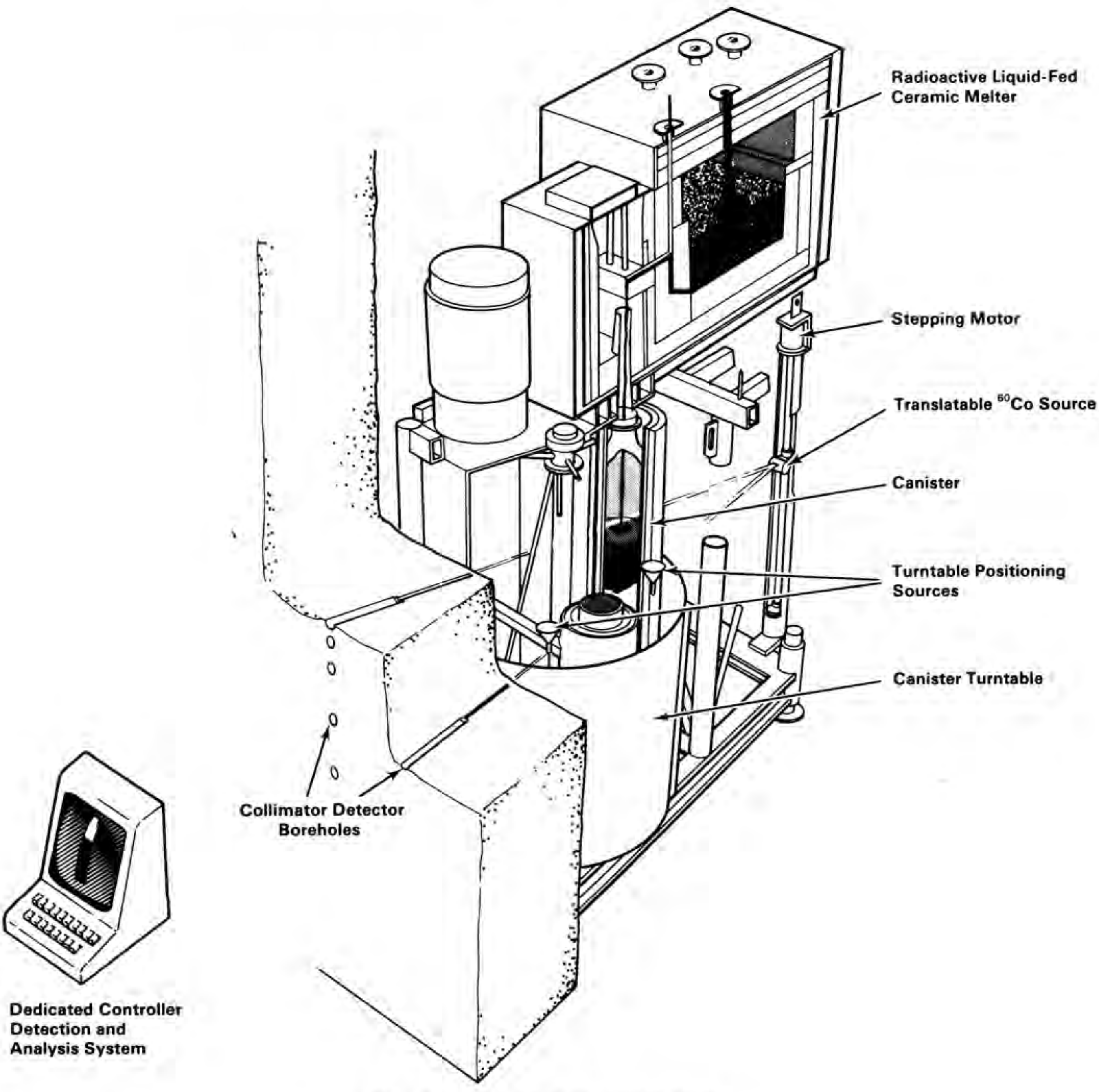

Fig. 5. Glass-Level Detection System.

CURRENT AND FUTURE PROCESSING ACTIVITY

At present the RLFCM system is being used to prepare isotopic heat and radiation sources for the Federal Republic of Germany's repository test in the Asse salt mine. Thirty canisters (Fig. 6), containing up to 2 kW of decay heat with a surface dose of >5 x 10^5 R/hr, are needed for this test. The canisters are supplied by the FRG, and DOE is filling the cans using the RLFCM system. To provide the heat and radiation, nitrate solutions containing ~8 million curies of ^{137}Cs and 5 million curies of ^{90}Sr are being concentrated for spikes to be added to glass-forming chemicals which are then fed to the melter. At this date, ten canisters are being produced, and the remaining 20 will be filled by the end of 1986. After filling, the canisters will be stored at PNL awaiting shipment to Germany in 1987. The Radiochemical Engineering Facilities are currently being modified to allow the canisters to be welded and leak-checked, and to be decontaminated by electropolishing before shipment to Germany.

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Fig. 6. FRG Canister.

SUMMARY

Pacific Northwest Laboratory has installed a Pilot-Scale Radioactive Liquid-Fed Ceramic Melter (RLFCM) System for converting high-level liquid wastes to borosilicate glass in a shielded manipulator cell located in the 300 Area at Hanford, Washington. The pilot-scale system consists of a liquid-fed ceramic melter (LFCM), canister turntable, glass-level detection system, waste preparation, off-gas treatment, and a condensate-treatment system. The RLFCM system is being operated with radioactive wastes to test remote handling, process control, product characteristics, and maintenance of the melter and supporting equipment, and to determine the reliability of this process in a radioactive environment.

The RLFCM is designed to operate at a liquid feed rate up to 40 L/hr and a glass production rate up to 15-20 kg/hr. Since startup, the melter and support systems have undergone "shakedown" testing to prepare the system for planned major tests. These include manufacture of isotopic heat and radiation sources for the FRG's Asse Salt mine test and for radioactive testing support of the West Valley and Hanford Vitrification programs. The FRG canisters will be high-heat, high-gamma sources made by adding high levels of ^{137}Cs and ^{90}Sr to borosilicate glass.

Plans call for operating the RLFCM during 1986 through 1989, initially with a HLW formulation that represents the West Valley Demonstration Project flowsheet. Future tests will be made in support of the Hanford Waste Vitrification Project as well as DOE's Nuclear Waste Treatment Program.

To complement the radioactive melter facility, a canister storage and evaluation facility is being prepared in an adjacent hot cell. Following canister closure by welding in the processing cell, this cell will provide leak-checking, canister decontamination, and various nondestructive evaluation tests of the glass and canister. Its first use will be in preparing the FRG canisters for shipment to West Germany.

The RLFCM activities also support the DOE's longer term goals of completing the documentation of LFCM system design and operation and of providing production specifications for vitrification of HLW. An objective is to verify that an acceptable waste glass can be produced by control of melter process variables so that little or no destructive examination will be required in a production facility.