TECHNICAL PROGRESS AND COMMUNITY RELATIONS ACTIVITIES FOR THE FLUIDIZED BED THERMAL TREATMENT PROCESS AT THE ROCKY FLATS PLANT

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ABSTRACT

A fluidized bed system is being developed at Rocky Flats for the treatment of mixed waste (a mixture of radioactive and chemically hazardous waste). The current program builds on experience gained in the 1970's and 1980's in tests with bench-scale, pilot-scale, and demonstration-scale fluidized bed incinerators. Rocky Flat's fluidized bed system operates at low temperatures (~525-600°C) which eliminates many of the disadvantages associated with high temperature thermal treatment processes. The bed makes use of *in situ* neutralization of acidic off-gases by incorporating either sodium carbonate or a mixture of sodium carbonate and bicarbonate (Trona) in the bed media. This obviates using wet scrubbers to treat the off-gas. It is expected that once in production, the fluidized bed process will yield up to a 40:1 reduction in the volume of the waste feed. The current development program for the full-scale system is a nationwide effort incorporating input from national laboratories, universities, regulatory agencies, and private companies to assure the most current technology is utilized and that regulatory concerns are addressed. In addition to resolving technological issues, the fluidized bed program is addressing public concerns with a proactive community relations program.

INTRODUCTION

The Rocky Flats Plant (RFP), located approximately 16 miles northwest of Denver, Colorado, is one of seven plants in the U. S. Department of Energy (DOE) Weapons Complex. EG&G Rocky Flats, Inc. has operated the plant since 1990 and is responsible for ensuring safe operations, managing environmental restoration and waste management projects, and maintaining the security of the plant and its material.

Since operations began at the plant in 1952, much has changed in world affairs. The primary mission of the plant had been the production of nuclear weapons components from plutonium, beryllium, uranium, and stainless steel. In January, 1992, the President of the United States announced the cancellation of weapons component production at the plant. As a result, the primary mission of RFP was altered from one of nuclear weapons component production to one of transition toward clean-up, deactivation of facilities, decontamination, and future production contingency.

As a result of manufacturing activities over the past forty years, RFP has generated more than 62 waste forms that are categorized as "mixed waste." These are wastes with both radioactive constituents (plutonium, uranium, and americium) and chemically hazardous components (*e.g.,* cutting oils, solvents, and laboratory chemicals). A large portion of these waste forms may be Land Disposal Restricted (LDR), thus falling under the provisions of the Resource Conservation and Recovery Act (RCRA). These wastes consist primarily of commonplace items such as coveralls, papers, booties, rags, plastics, etc. that were either used in the actual production process or have been exposed to the production environment. Many of these wastes have no measurable level of radiation above background, but fall into either the mixed waste or radioactive waste category because of their exposure to the production environment. The majority of RFP's waste is classified as low level waste (*i.e.,* radiation < 100 nCi/g). All remaining waste is classified as transuranic or "TRU" waste (radiation > 100 nCi/g).

A unique problem when considering RFP's waste is that it is primarily contaminated with alpha (α) radiation. Pu^{239}, the isotope comprising weapons grade plutonium, decays by α-emission. These α-particles are readily stopped by a sheet of paper or by the outer layer of the skin. However, if one were to ingest plutonium by breathing dust, swallowing it, or by entry through a wound, it can be absorbed by the organs of the body where it will bombard the surrounding cells with α-radiation. The result is that special precautions must be taken when working in a potentially plutonium contaminated environment. Because of the nature of its work, RFP has unique expertise in dealing with plutonium and α-contaminated environments.

Safely treating these mixed wastes is a challenging problem. For treating the hazardous components of these wastes, the Environmental Protection Agency (EPA) either specifically requires incineration, or incineration is the only proven method to meet all applicable treatment requirements (1). Safely incinerating RFP's waste is complicated by the α-contamination described above. While many processes exist to safely incinerate hazardous waste, they are high temperature processes and are not as well suited to the special requirements of treating α-contaminated wastes.

Research has shown that elevated temperatures can volatilize radionuclides (2,3). This is the topic of continuing research at Lawrence Livermore National Laboratory (LLNL). Also, processes operating above ~800°C require refractory linings in the combustion chamber. These linings are known to be fragile and require routine maintenance and periodic replacement. In addition, refractories absorb radionuclides. This increases the potential for radiation exposure when performing routine maintenance. Another shortcoming of high temperature processes is that they operate under positive pressure or suffer from frequent positive pressure excursions. In the event of a leak in a vessel, pipe, or seal, contamination would leak out into the surrounding environment. Finally, if plutonium is present, it may be desirable to recover. Plutonium oxide formed by high temperature or "high-fired" processes is relatively insoluble and difficult to recover. Plutonium oxide formed at lower temperatures (such as those of RFP's fluidized bed) is more easily recovered.

Rocky Flats developed a fluidized bed incineration process that overcame the problems described above. It operated over the relatively modest temperature range of ~525-600°C, required no refractory lining, and operated under negative pressure. This system was successfully demonstrated in a full-scale test facility, the Fluidized Bed Incinerator (FBI). The program suffered a setback when there was a small fire outside the primary bed. Although damage totalled only $847, this ultimately led to the cancellation of the program. Now, due to the strengths of the technology and the increased need for waste management solutions, the program has been revived. This paper will discuss the advantages of RFP's fluidized bed incineration process, the FBI system, the new Fluidized Bed Unit program, and activities to gain public acceptance.

ADVANTAGES OF THE RFP FLUIDIZED BED PROCESS

RFP began development work or a fluidized bed incinerator in the early 1970's. At that time, the major driving force was to develop a low temperature process that would destroy the combustible components of the waste, but produce a "low-fired" plutonium oxide in the ash. This "low-fired" plutonium oxide would be easier to recover by available processes than that produced by a higher temperature incinerator ("high-fired" plutonium oxide). However, as development progressed, numerous other advantages became evident, as follows:

- Because of its low operating temperature (~525-600°C), RFP's fluidized bed requires no refractory lining. These are fragile, absorb radionuclides, and increase the potential for radiation exposure to maintenance personnel. Further, the spent refractory becomes a secondary waste requiring treatment when replaced.
- Because there is no refractory lining, the system can be started-up and shut-down quickly. Refractories are fragile and have limitations on their heat-up and cool-down rates.
- Low operating temperatures, such as in RFP's fluidized bed process, are not conducive to NO_x formation. This is not true of most other thermal treatment processes.
- Elevated temperatures are known to volatilize radionuclides and other heavy metals (2,3). RFP's fluidized bed system operates at a lower temperature than most other thermal treatment processes and hence is less prone to volatilization concerns. Quantifying plutonium, uranium, and americium volatilities is the topic of ongoing research being performed at LLNL. Preliminary studies show radionuclide volatile species nearly immeasurable over the temperature range of RFP's fluidized bed system (~525-600°C).
- The turbulence of fluidized beds avoids the formation of "hot spots" (isolated regions of superheated material). This makes fluidized beds intrinsically explosion-proof.
- Fluidized beds are unique in their ability to use *in situ* neutralization of acid gases. By incorporating sodium carbonate (Na_2CO_3) in the bed media, any acid gases produced (such as during the combustion of plastics) are quickly neutralized. Other thermal treatment processes do not have the turbulence necessary to exploit this capability and must rely on wet scrubbers. Scrubbers use large volumes of caustic water to neutralize the acid gases and are the source of a large volume secondary waste stream. Preliminary work at LLNL suggests that an indirect benefit of *in situ* neutralization is that it reduces the formation of toxic combustion by-products (including metals) and products of incomplete combustion (PIC's). This results from the immobilization or neutralization of some of the intermediates necessary to form PIC's.
- There are minimal secondary wastes associated with RFP's fluidized bed process. As explained above, *in situ* neutralization is possible which obviates the requirement for a wet scrubber. The only secondary wastes come from catalyst and sodium carbonate attrition. These solids are easily collected with the ash and can be readily solidified by other methods (*e.g.*, polymer solidification, microwave solidification, or cementation). This solidified material would be the final waste form. Other thermal treatment processes require wet caustic scrubbers which produce a high volume aqueous secondary waste stream.
- Fluidized bed thermal treatment is compatible with a wide range of wastes including combustibles, soils, and sludges. That portion of the waste feed which is not combustible is either removed by an extraction screw or eroded by the abrasive action of the bed. In either case, this material is collected and solidified as described above. While it is true that size reduction of the waste feed is necessary, this is easily performed by commercially available shredders. Past experience has shown size reduction to be quick and reliable (4).
- RFP's fluidized bed is designed to operate at a negative pressure. This assures that any unexpected leakage would be from the outside into the FBU system. This fail-safe design assures containment of all wastes, secondary wastes, and exhaust gases. This is a major advantage when considering the radioactive and hazardous components of the waste.

THE FLUIDIZED BED INCINERATOR

Development work on RFP's fluidized bed process began with bench-scale experiments in 1972. By 1973, a 9 kg/hr pilot-scale unit was installed for larger scale testing. In 1977, an 82 kg/hr, 1.5 million BTU/hr (439 kW) Fluidized Bed Incinerator (FBI) was constructed to demonstrate the technology at full-scale. The FBI was intended to serve as a research tool to test the design before proceeding to the design and construction of the actual production facility.

The FBI at RFP was a two-stage thermal treatment process. A schematic of the process is shown in Fig. 1. Solid waste was prepared by sorting in a glovebox to remove large metal or non-combustible components. These components were separated from the FBI feed and stored for appropriate disposal. The balance of the material was fed into a coarse shredder for size reduction. Material from the shredder fell into an air classifier to separate any small metal components from the combustible waste. The combustible waste went

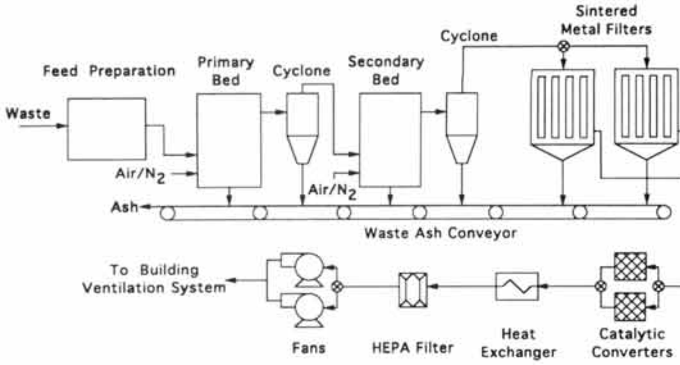

Fig. 1. Rocky Flat's fluidized bed process.

through a fine shredder and into a hopper. A feed screw at the bottom of the hopper fed waste material into the bed.

The first stage of the bed contained a mixture of chromia-alumina oxidation catalyst along with sodium carbonate to neutralize acid gases. This first bed was operated under oxygen deficient conditions to pyrolyze the waste. Any acidic off-gases such as those produced in the combustion of many plastics were quickly neutralized *in situ* by the sorbent. A screw at the bottom of the bed was used to withdraw any small, non-combustible metal components that might have entered the system ("tramp metal"). The combustible off-gases exited the first stage and entered a cyclone. Entrained solids removed by the cyclone were conveyed to the ash disposal drum; combustible gases continued to the second stage bed. The second fluidized bed contained only oxidation catalyst and was operated with excess oxygen. Here the waste destruction was completed. By utilizing the chromia-alumina oxidation catalyst, the entire operation was performed in the relatively modest temperature range of about 525-600 °C. Gases exiting the second stage entered another cyclone, and any entrained solids were conveyed to the ash disposal drum.

Off-gas from the second stage entered the exhaust treatment train. The gas initially passed through a sintered metal filter to remove particulates $>2.8\,\mu$m, and then entered a heat exchanger to reduce its temperature to ~80°C before passing through the High Efficiency Particulate Air (HEPA) filter. A single HEPA filter was located at the exhaust from the heat exchangers. The off-gas then passed to the building ventilation system and through an additional bank of four HEPA filters in series before being discharged to the atmosphere. Each HEPA filter in the system was designed to remove 99.97% of the particulates $\geq 0.3\,\mu$m.

Air pumps on the exhaust end of the FBI drew air through the system and assured continuous operation under negative pressure. Because of the low temperature of the operation, it was possible to fabricate the entire unit out of stainless steel without a refractory lining.

In tests performed through the early 1980's, the FBI demonstration unit successfully destroyed approximately 21,500 kg of low-level solid plant wastes and over 5600 liters of liquid plant waste (4). One of the highlights of the program was a test burn of polychlorinated biphenyls (PCB's) in the smaller, 9 kg/hr pilot unit. This test was performed in 1981 and was monitored by the EPA. Results showed the system achieved a destruction efficiency in excess of 99.9999% ("six-nines") (5).

Development of the FBI was halted in 1981 when there was no economic incentive for further development and it was more cost effective to ship waste to the Idaho National Engineering Laboratory (INEL) for storage. By 1984, the Resource Conservation and Recovery Act (RCRA) had come into effect, and many of the untreated RFP wastes would not meet the Land Disposal Restrictions (LDR's). Compliance with the LDR's was necessary for shipment. Realizing a treatment process was necessary at RFP, the FBI program was revived in 1985.

In 1986, enhancements were made to adapt the FBI to production use rather than as a research-grade technology demonstration unit. These upgrades included adding more instrumentation to the unit and installing a catalytic convertor on the off-gas system to assure complete conversion of carbon monoxide (CO) to carbon dioxide (CO_2) and complete destruction of any residual hydrocarbons. By July, 1987, systems tests were nearing completion and documentation had been completed in preparation for a trial burn for licensing.

As is common engineering practice, during shakedown testing the FBI was operated outside of its normal control limits. This was done to test the performance of various alarms and interlocks in preparation for the trial burn. The system tests were successful; however, after one trial the system was improperly secured for the night. A small amount of diesel fuel seeped out of the vessel and was ignited by its hot surfaces. Damages were estimated at only $847. This figure included cosmetic costs to cleanup and re-paint smoke damage and costs to recharge the fire extinguisher. The FBI was repaired and ready to operate within two days.

Per standard procedure, RFP notified DOE. Because there was less than $1000 in damages, DOE was not required to report the incident to the State of Colorado, but did so anyway. The story appeared in the local media, and there was considerable negative publicity. The FBI had been developed in relative isolation at RFP. As a result, when news of the fire reached the public, there was concern that radioactive waste was being incinerated without their knowledge. There was also concern that the system had not been adequately designed, properly operated, and that quality assurance was inadequate. Although the fire itself was not financially costly nor was there extensive damage, the negative public pressures ultimately resulted in the termination of the program.

THE FLUIDIZED BED UNIT

In 1989, the Colorado Department of Health (CDH), the Environmental Protection Agency (EPA), and DOE signed the Federal Facility Compliance Agreement-I (FFCA-I). In Treatment Plan No. 1 required by FFCA-I, fluidized bed incineration was listed as the top technology for the treatment of combustibles and filters. As a result, development activities are now underway on an improved Fluidized Bed Unit (FBU).

The FBU program is building upon knowledge gained from the FBI to arrive at a robust process that will be accepted by the public. One of the major lessons learned from the FBI experience is the importance of involving public, environmental, and regulatory groups early in the development process. Another is the importance of building a production-grade system for actual waste processing. The original FBI was a research incinerator that was not designed for routine destruction of mixed waste.

The new program is addressing the design, operational, and quality concerns expressed by the public following the fire in the FBI. To ensure the latest technology is incorporated in the design of the unit, the FBU program has sponsored research and technology exchanges with universities, private companies, and regulatory agencies from around the country. This program is depicted in Fig. 2.

A plexiglas Flow Visualization Unit (FVU) has been constructed at the Colorado School of Mines (CSM) in Golden, CO. This system has a computer-interfaced data acquisition and control system. The FVU is used by both EG&G employees and CSM faculty for ambient temperature fluidization studies in support of the FBU Project. Its location at CSM facilitates easy access for demonstrations and briefings to the public.

Los Alamos National Laboratory (LANL) is performing research on techniques to monitor for radionuclides in the off-gas. Lawrence Livermore National Laboratory (LLNL) is studying the volatility of radionuclides and heavy metals over the temperature range of 500-1200°C. Calculations indicate that aerosol formation, particularly of plutonium oxyhydroxide, is minimal at the proposed operating temperature of the FBU, but increases exponentially with temperature.

The Department of Energy's (DOE) Morgantown Energy Technology Center (METC) is expert in the area of fluidization. Along with West Virginia University (WVU), they are providing information on state-of-the-art fluidized bed systems and monitoring techniques. They are assisting in evaluations of bubbling fluidized beds (as was the FBI) versus more modern fast, recirculating beds or hybrid beds (a fast bed above a bubbling bed).

EPA's Risk Reduction Engineering Laboratory (RREL) is the interface for the regulatory requirements for licensing. EPA-RREL has sub-contracted with Energy and Environmental Research Corporation (EER) to perform a study of continuous off-gas pollution control techniques and monitoring technology. The S-Cubed Division of Maxwell Laboratories was sub-contracted by EER to look at existing, state-of-the-art technologies for the monitoring of radionuclides in the off-gas.

The National Institute of Standards and Technology (NIST) in Boulder, CO is working with FBU team members to develop gas separation membranes that may be useful in separating nitrogen and hydrocarbons from carbon dioxide in the off-gas. The NIST facility in Gaithersburg, MD is assisting in accelerated life testing of metals proposed for FBU materials of construction.

Finally, the EG&G Rocky Flats Waste Technical Support Group is designing prototypes of the waste feed system, selecting materials of construction, and providing technical and administrative support for the project.

In FY '93, thermally hot tests of the FBU concept will be performed using an existing fluidized bed incinerator away from the Rocky Flats site. These tests are being coordinated by the EPA-RREL. Initial studies will focus on verifying the effectiveness of the sodium carbonate *in situ* neutralization of acidic off-gases. Later studies will verify the FBU's ability to meet the emissions requirements set forth by the EPA and the State of Colorado.

Realizing that licensing a thermal treatment process for mixed waste may be difficult, Dr. C. C. Lee of EPA-RREL established the National Technical Advisory Committee on Mixed Waste Incineration (NTAC). NTAC has selected the FBU to serve as a case study to determine what is necessary to license thermal treatment processes for mixed waste. The NTAC membership includes a representative from the primary contractor at each of the DOE sites having or contemplating mixed waste incineration, a representative from DOE headquarters, the EPA Offices of Solid Waste, Radiation, and Air Quality and Planning Standards, the EPA Regional Offices, the EPA Risk Reduction Engineering Laboratory, industrial representatives for mixed waste incineration, the Nuclear Regulatory Commission, and representatives from State Environmental Departments in states where mixed waste incineration is under active consideration.

COMMUNITY RELATIONS ACTIVITIES

Community relations is an important part of the FBU program. Several activities are underway to promote public involvement and communication. One such activity is the demonstration of fluidized bed technology using the fluidized bed Flow Visualization Model at the Colorado School of Mines. In addition to serving as a research tool, this has been used for several such demonstrations for various community groups. This model is readily accessible to the public, and provides the opportunity for information exchange in an informal academic environment.

Another activity to promote public awareness is participation with the Rocky Flats Speakers Bureau. This group provides presentations to community groups, businesses,

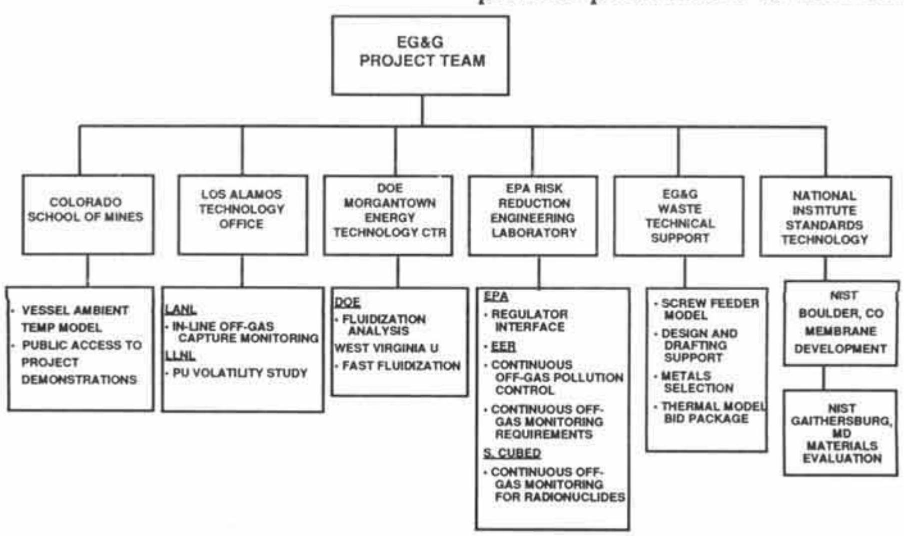

Fig. 2. Fluidized Bed Unit (FBU) National Program.

schools, and others upon request. FBU team members are participating in the Speakers Bureau to enhance public understanding of the FBU.

For information dissemination, EG&G Community Relations publishes the *Environmental Restoration Update* every two months to describe progress in environmental management areas. They also publish fact sheets on an ongoing basis to provide concise definitions of programs and topics. It is anticipated that the FBU will be included in an upcoming issue of the *Environmental Restoration Update*, and a fact sheet on this program is in preparation for public distribution.

Public involvement is also being facilitated through participation with the Citizen Review Group for the Comprehensive Treatment and Management Plan (CTMP). The FBU is one of the treatment technologies described in the initial draft of the CTMP. This document, required as part of FFCA-II signed in 1991, details the various waste streams on-site and how they might be treated. A Citizen Review Group was formed to review the initial draft of the CTMP. This group is comprised of local business leaders, environmental groups, state and local officials, educators, and local landowners. Their primary task has been to thoroughly review the CTMP and participate in detailed presentations and discussions on the information contained in the document. Their goal is to make recommendations to DOE and EPA for clarifications and/or modifications to the document so that it will be more informative for the general public to review. Combined with in-depth briefings on several technologies including the FBU, the group also visited the Flow Visualization Unit for a better perspective on the fluidized bed technology.

Upon completion of the final draft of the CTMP, a 60-day public comment period will be initiated. During this period, a public information workshop will be conducted followed by a public comment meeting.

SUMMARY

The fluidized bed thermal treatment program at Rocky Flats is building on knowledge gained over about twenty years of development activity. The low temperature Fluidized Bed Unit (FBU) has several technical advantages over other thermal treatment technologies for the destruction of mixed waste. Rather than develop the technology in relative isolation at the plant, the FBU program has branched out to involve universities, regulators, and private companies to assure that the most current technology is incorporated into the design. Ultimately, success will be measured in the development of a safe, viable technology that can be licensed. A necessary part of realizing this success is to provide opportunities for public involvement early in the process. The FBU program is striving to work more closely with the community to jointly solve the problem of mixed waste destruction.

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