LOW-LEVEL RADIOACTIVE WASTE INCINERATION

AT THE IDAHO NATIONAL ENGINEERING LABORATORY DURING 1985

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ABSTRACT

The low-level radioactive waste incinerator at the Idaho National Engineering Laboratory (INEL) has been processing contaminated waste since September 1984 and is now accepting combustible waste from all INEL waste generators. Waste generators at the INEL sending their wastes to the incinerator for processing must comply with waste acceptance limits and supply appropriate packaging. The incinerator operations during the past year have produced very high waste volume reduction factors (100/1 to 250/1), low radioactive emission rates, and low operator dose rates. Changes in the off-gas system operation have been made to extend the life of the bags in the baghouse.

INTRODUCTION

The low-level radioactive waste (LLW) incinerator located at the Idaho National Engineering Laboratory (INEL) has been routinely processing contaminated solid combustible waste since September 1984. The purpose of this paper is to convey the operational results from this operation, the benefits of the operation, and the lessons learned. The incineration system will be briefly described followed by a discussion of the operational results of each of the subsystems. These subsystems include the feed system, the incinerator, the off-gas cleaning system, and the ash removal system.

SYSTEM DESCRIPTION[1]

The following is a brief description of the INEL low-level radioactive waste incineration system located at the Waste Experimental Reduction Facility (WERF). Figure 1 shows a flow schematic of the incinerator.

The combustible waste is received at WERF prepackaged in 0.23 m^3 (2 x 2 x 2 ft) cardboard boxes that are lined with 0.1 mm thick polyethylene bags. These packages provide fixed geometry for the waste feed system, and are sized to allow an adequate waste feed rate through the incinerator.

The waste feed and characterization system consists of a semi-automated roller conveyor with radiation monitors, a standard airport-type x-ray unit for inspection of packages, and a scale to weigh the waste for control of burn rates. A lift and roller conveyor system introduces the waste into the top-loading chute of the incinerator. The loading chute is a triple-door airlock to minimize air leakage to the negative pressure combustion chamber.

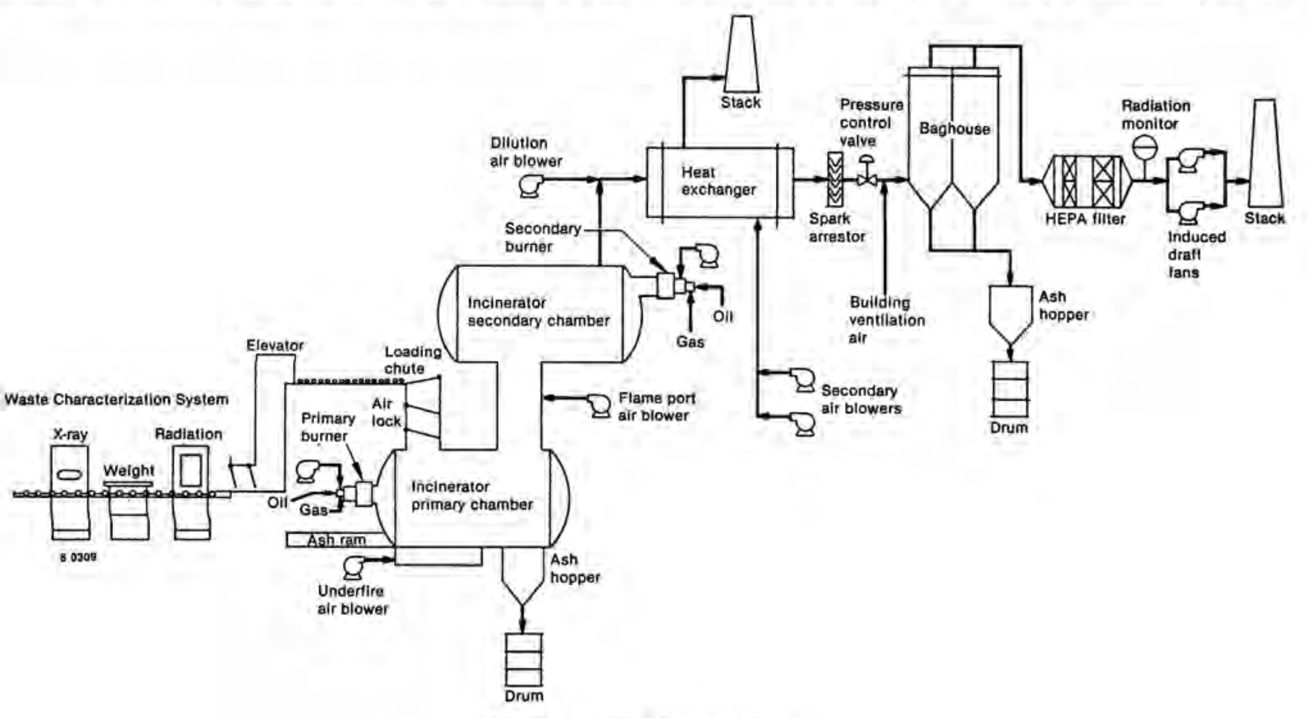

Fig. 1. WERF Incinerator.

The incinerator is a commercially available, dual-chambered, controlled-air incinerator capable of burning 180 kg (400 lbs) per hour of 26,000 kJ/kg (12,000 BTU/lb) combustible material. Principal components include a gravity-feed loading chute for introducing waste to the primary chamber in which the waste is ignited and volatiles driven off; the secondary chamber, which acts as an afterburner for the volatile gases generated in the primary chamber; and an ash ram that periodically strokes partway along the hearth to push residual ash to the rear of the primary chamber into the ash drumming system.

Both incinerator chambers are lined with a high alumina refractory and contain fuel-oil-fired burners to preheat the incinerator system and to maintain the required combustion temperatures. Combustion air is introduced into the primary chamber through a series of underfire air ports. The combustion air is controlled to maintain a slightly-oxygen-deficient condition. As the hot volatile gases exit the primary chamber, excess air is injected to bring about complete combustion in the secondary chamber. The ash ram at the front of the primary chamber periodically strokes, pushing the ash pile slowly toward the rear of the chamber, where it enters the ash drumming system.

The ash drumming system is located in the basement beneath the incinerator. The ash is cooled by circulating air through plenum chambers surrounding and dividing the hopper, and by percolating low-pressure bleed air up through the ash bed. A 200-liter drum with a rigid polyethylene liner is used to receive ash from the drumming system for storage and subsequent shallow land disposal.

The incinerator off-gas treatment system, which is an integral part of the facility ventilation system, was designed to cool and filter the incinerator effluent before release through the main exhaust stack. Exhaust gas exits the incinerator upper chamber at approximately 1100°C. Dilution air is immediately introduced to reduce the temperature to less than 750°C before entering a heat exchanger. The heat exchanger, a tube-in-shell gas-to-air parallel flow unit, reduces the temperature to less than 450°C. Prior to filtration, facility ventilation air is introduced to further reduce the off-gas temperature to less than 175°C.

The cooled gases are passed through a fabric filter baghouse for initial removal of particulate. Periodically, a blast of compressed air is directed down the inside of each bag to remove the dust cake and deposit it into a conical hopper where it is pneumatically conveyed to a drumming station by a vacuum transfer system. This dust transfer system also services the incinerator ash drumming system for cleanup of the system during and after ash drumming operations.

The filtered gases exit the baghouse and pass through a bank of high efficiency particulate air (HEPA) filters consisting of prefilter and HEPA elements in series. The off-gas is discharged through a 15 m (50-ft) main stack which is instrumented to measure exhaust gas parameters such as temperature, flow, opacity, SO_2 content, and radioactive particulate. Two induced draft fans are operated in parallel to provide the facility ventilation. The parallel configuration provides redundancy, with one of the fans powered from an emergency back up generator in case of site power failure.

This incinerator system was designed to require a minimum number of people for operation. One person operates the control panel and another periodically places a number of waste boxes on the semiautomatic waste conveying system. The control console contains all of the necessary indicators, controllers, TV monitors, and annunciators to remotely monitor and operate the system.

FEED PROCESS

Because of the distance between the INEL waste generator facilities and the WERF, all combustible waste must be transported over the road to the WERF incinerator. To accomplish this transport safely, and to facilitate storage during generation of the waste in support of incineration campaign operations, all waste is packaged in polyethylene lined two-foot cube cardboard boxes. These boxes are then placed on pallets (27 to a pallet) which are loaded in cargo containers (3 pallets per cargo container) for transport to WERF.

The WERF waste acceptance criteria includes limits on weight (27 kg), contact radiation (10 mrem/h), and composition of waste within the boxes (no metalics or liquids). With the current radiation limit of 10 mrem/hr at near contact, only 0.3% of the waste boxes have been rejected because of radiation. The x-ray monitor has identified that 3% of the boxes contain items which are prohibited. The prohibited items most commonly encountered are aerosol cans and tools. If a box is rejected because of a single item, the box can be opened and the item removed. If the box contains numerous prohibited items, it is returned to the generator for repackaging.

Since the WERF incinerator is not equipped with a wet-scrub system to remove acidic combustion products, halogenated materials are not accepted at the incinerator. The principal impact of this limitation has been on the use of polyvinyl chloride (PVC) shoe covers at the INEL. A substitute material (polyethylene) has been identified, but because the substitute is more slippery, it has not gained general acceptance. For those generators who found the polyethylene shoe covers unacceptable, the PVC shoe covers are packaged for burial without incineration.

Originally, the WERF incinerator was designed for a waste mix of cloth, plastic, rubber, paper and wood, which has an average energy value of 26,000 kJ/kg (12,000 BTU/lb). Operation to date has indicated that there is a higher fraction of polyethylene than originally assumed. The actual waste mix is estimated to be more than half polyethylene. The balance of the waste is composed of paper, rags and wood. The higher BTU content of the actual waste mix results in a throughput rate of approximately 110 kg/h (250 lb/h) compared to the 180 kg/h (400 lb/h) of the design waste mix.

Mechanically, the feed characterization system has performed well in identifying prohibited waste before it enters the incinerator and also in limiting air in-leakage. Waste boxes have been jammed between the lower feed doors and the chute walls on a few occasions, but the consequences were negligible, and the design has been refined to minimize this occurrence.

ASH HANDLING SYSTEM

The incinerator ash system was carefully designed to cool the ash and allow safe transfer to 200-liter drums for disposal. All ash transfers to date have been accomplished without incident. A major concern during the design was the potential that a large noncombustible item could jam the exit valving system. Careful examination of the incoming waste using the x-ray device has precluded any problems in this area.

The baghouse dust collection and drumming system is similar to the ash drumming system and has also performed without incident.

OFF-GAS CLEANUP SYSTEM

The off-gas cleanup system, composed of a baghouse, a prefilter, and a HEPA filter, removes particulate material from both the incinerator off-gas and the building exhaust gases. The stack line is equipped with a radiation monitor to alarm high radiation emissions. To date, no radiation indication above background (background level 10^4 d/m) has been recorded by this stack monitor which is an indication of the effectiveness of the off-gas cleanup system in removing radioactive particulate.

The baghouse filter bags were specified to be noncombustible fiberglass material. After one and one half years of operation (including noncontaminated incinerator operations), the bags are starting to fail and are being replaced. This is a somewhat shorter life-span than had been expected. Discussions with the bag manufacturer revealed that the bags are brittle when cold and therefore bag life has been shortened by operating the jet-pulse blow back cleaning mechanisms while the bags are cold. The operation will be modified to allow cleaning only during incineration campaigns when the off-gas air temperature is high and thereby avoid any cold blow-back cycles. This change is expected to extend bag life.

The HEPA filters have not been changed since initial operation. The HEPA prefilters have been changed twice. In both cases failed baghouse bags were found to be the cause.

INCINERATOR PERFORMANCE

The incinerator itself has performed very well in providing efficient combustion. Analyses of the incinerator ash have shown low combustible material content (0.5% carbon), which indicates adequate combustion efficiency. The system was originally operated by engineers. The WERF operations staff is now trained and procedures refined so that the system is no longer operated by engineers. The operation positions require formal qualifications.

The primary combustion chamber operates in an air-deficient mode to minimize turbulence and particulate carryover into the off-gas system and the secondary combustion chamber completes the combustion in an excess air mode. The effect of the starved air environment in the primary combustion chamber is that volatile constituents of the waste are quickly driven off, leaving a nonvolatile carbon "heel." After several hours of operation, this heel is burned off by shutting off all fresh feed and slowly changing to an excess air mode. The most efficient operation appears to consist of maximum-rate waste feeding 70% of the time with heel burnoff operations conducted for 2 to 3 hours each shift. Less frequent burnoff operations have resulted in a higher unburned plastic content in the bottom ash, with more slagging on the hearth and formation of larger clinkers. Attempts to slow feed rates to allow continuous heel burnoff result in elevated chamber temperatures and frequent pauses to allow temperatures to recover.

OVERALL SYSTEM EVALUATION

Since the beginning of contaminated incineration, 2400 boxes of waste have been processed in the WERF incinerator. Calculation of an actual volume reduction factor for any given incineration campaign is not straightfoward, because the incinerator ash and baghouse ash are not readily measured for any given campaign. Volume reduction factor estimates have been made based on visual examination of the contents of the hearth and hopper and counting of filled drums; and the estimates range from 100/1 to 250/1, based on the incoming waste volume (uncompacted). This high volume reduction factor is largely attributed to the high polyethylene fraction of the feed which produces almost no ash.

The total waste volume processed by the WERF incinerator is 425 m^3 (15,000 ft^3). Health physics records for the WERF staff show a total estimated dose of .07 rem have been accumulated during this period.

CURRENT EFFORTS

Corrosion coupons have been installed in the off-gas heat exchanger to allow estimates of the effects of acid gas formation and condensation on metallic surfaces. Reports on the samples will be available in mid-1986. A liquid waste burner system has been designed and installed to allow destruction of EPA-regulated hazardous wastes. The associated permit applications have been prepared with late 1986 targeted for the trial burn.

Incinerator ash samples were analyzed for EP Toxic hazardous constituents. No ash samples analyzed to date have shown any toxic element levels of concern. Baghouse dust, however, was found to contain higher levels of cadmium and lead than are permissible for unregulated disposal. All ash, including this contaminated ash, will be solidified to minimize nobility of the radioactivity, secondarily, the solidified ash is being tested to determine if it can be disposed of as LLW. The INEL permit staff is currently pursuing "delisting" of this ash, because there is no permitted disposal site for "mixed" radioactive and hazardous waste.

CONCLUSION

The WERF incinerator was designed and constructed to reduce the volume of combustible waste from the various nuclear facilities at the INEL. In the first year of operation, the generators and the incinerator have gradually attained full operation. Mechanically the system has performed well, providing reliable operation with very good volume reduction, undetectable stack radioactive particulate emission, and low operator radiation doses.

REFERENCES

1. R. L. GILLINS, J. N. DAVIS, R. Y. MAUGHAN, and J. A. LOGAN, "Low-Level Waste Incineration at the Idaho National Engineering Laboratory," American Nuclear Society Conference, New Orleans, June 1985.

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