APPLICATION OF LOW-LEVEL RADIOACTIVE WASTE INCINERATION TO NON-RADIOACTIVE HAZARDOUS WASTE

R. N. McGrath

Introduction

The safe isolation of low-level radioactive wastes (LLRW) from the environment has been the object of much regulatory and process development activity for the past decade. Incineration systems have been developed that reduce the volume of LLRW and put it in a form that can be easily encapsulated in a binder prior to safe disposal. This paper focuses on the applicability of an incinerator system developed for low-level radioactive wastes to the disposal of non-radioactive hazardous waste, which can also be reduced significantly in volume and weight in a safe manner by thermal decomposition.

The quantity of non-radioactive waste generated yearly in the U.S. is approximately 2033 million ft^3(1) as compared to 1.8 million ft^3(2) of LLRW generated yearly by nuclear power plants and through the practice of nuclear medicine. The isolation of low-level radioactive waste from the environment is of primary importance to the safe disposal of these wastes. Shallow land burial has been the primary disposal technique for these radioactive wastes. Recently, decreasing burial space, regulations requiring improved packaging and higher transportation and burial costs have caused a rapid increase in the cost of LLRW disposal. These disposal costs can be lowered and the remaining burial space used efficiently by reducing the volume of LLRW to be packaged and shipped for burial. As the isolation of hazardous waste from the environment is at least as important as the isolation of LLRW, the greater volume of hazardous waste to be disposed of yearly makes the hazardous waste problem very serious.

Incineration of Hazardous Waste

There are several parallels to the processing of the LLRW in the destruction of non-radioactive hazardous waste. The essential factors for achieving the desired incinerator performance are exposure of the waste to sufficient time, temperature, oxygen and turbulence. The United States Enviornmental Protection Agency has required that thermal decomposition of hazardous waste be carried out with a destruction efficiency of 99.99%(1). Based on experience, it has been estimated that 60% of the existing hazardous waste can be disposed of by incineration (1). It is estimated that exposure of volatized waste to a minimum of 1832^{o}F for 2 seconds in a properly designed combustor will result in the required destruction efficiency (1). For solids, the required destruction efficiency can be achieved by increasing the exposure time. The increase in time allows volatization of the organics from the solid followed by combustion of the vaporized organic material. Testing of a full size prototype of the Combustion Engineering Waste Incineration System (CE-WIS) with simulated LLRW (non radioactive equivalent) has demonstrated all of these incineration factors required for hazardous waste incineration.

Low-level radioactive waste is generally in one of four forms:

1. Miscellaneous combustible and non-combustible solids (e.g. paper, clothing, wood, tools)
2. Ion exchange resin slurries
3. Inorganic salt solutions
4. Organic liquids

Non-radioactive hazardous waste can be in one of five forms[2].

1. Solids
2. Organic vapor laden gases
3. Organic liquids alone
4. Organic liquids in solution with water
5. Slurry of organic solids in water

Combustion Engineering has designed and tested a waste incineration system (CE-WIS) which effectively reduces the volume of all four types of LLRW. Figure 1 depicts a process flow diagram for the CE-WIS. The system consists of a combustor vessel followed by a spray drying tower. An off-gas cleanup system next removes contaminants from the combustor discharge prior to release to the environment. Combustion air is provided to the combustor through the use of an induced draft fan which maintains the complete system under negative pressure.

Miscellaneous combustible solids are first shredded and then charged to the combustor vessel. Ion exchange resins are essentially polystyrene beads which are injected into the incinerator with water. Contaminated organic liquid is injected into the incinerator and can be used to replace incinerator supplemental fuel. In all three cases, the hydrocarbon ignites when exposed to the temperature of the combustor. The hot off-gas from the combustor is used to spray dry the inorganic salt solutions.

Figure 2 depicts a cross-section drawing of CE-WIS combustor. Primary air enters the top of the combustor along with the waste and supplemental fuel. Near the bottom of the cylindrical combustor, first stage, secondary air is introduced in a tangential manner as is primary air so as to impart a high degree of swirl to the waste/fuel/air mixture. As shown on Fig. 2, the waste/fuel/air mixture next enters a secondary chamber where cross-section area is increased and turbulence reducing baffle is placed so as to induce the fall of heavier particles to a grate. A small amount of tertiary air introduced from under the grate enhances volitilization of the organics contained in the solids on the grate. Combustion proceeds to completion in a third stage prior to exit of combustion products from the incinerator.

Figure 3 shows the degree of turbulence in various zones of the combustor as visually observed during the CE-WIS prototype testing. Turbulence is high in the first stage due to the tangential introduction of combustion air. Turbulence is significantly reduced in the secondary chamber by a baffle positioned radially to the tangential flow present in the first stage. Solids were observed falling to the grate at this point in the combustor. As the baffle does not extend into the third stage, relative turbulence of the gases increase as they flow through the increasingly sized third stage of the combustor.

Figure 4 shows how the CE-WIS meets the time and temperature criteria for hazardous waste incineration. The measured temperature profile of the waste/air mixture is shown as it passes through the combustor. Combustor outlet temperature was controlled at 1500°F through the modulation of supplemental fuel and air flow was maintained constant so as to convey the waste/air mixture through the combustor in 2.7 seconds. As can be seen in Fig. 3, the waste/fuel/air mixture enters the combustor and is quickly raised to the maximum temperature of the process (1900°F) in the primary combustion chamber. Additional combustion air is introduced at the beginning of the secondary chamber where the additional air essentially completes the combustion of the waste/fuel/air mixture.

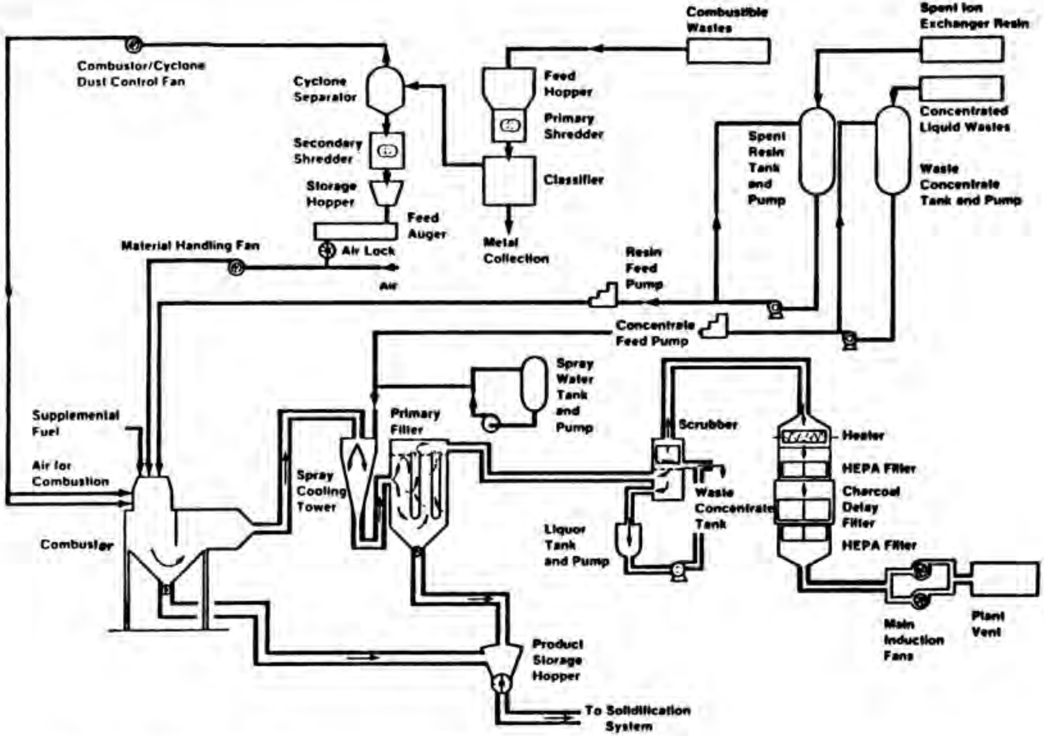

Fig. 1. Combustion Engineering Waste Incineration System (C-E/WIS).

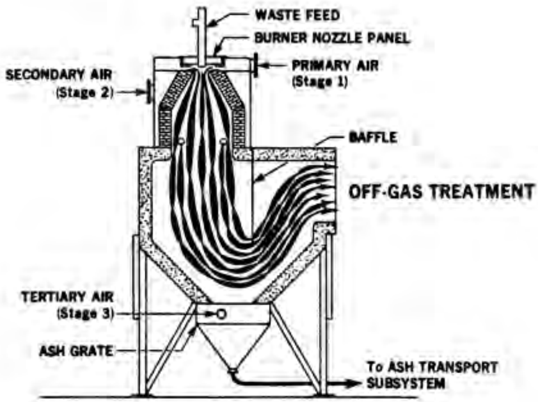

Fig. 2. CE-WIS Combustor.

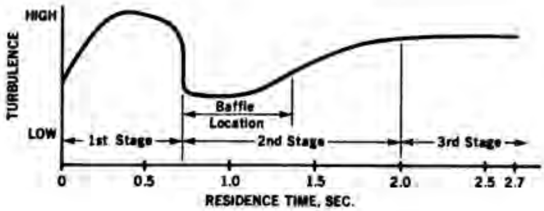

Fig. 3. C-E-WIS Turbulence vs. Residence Time.

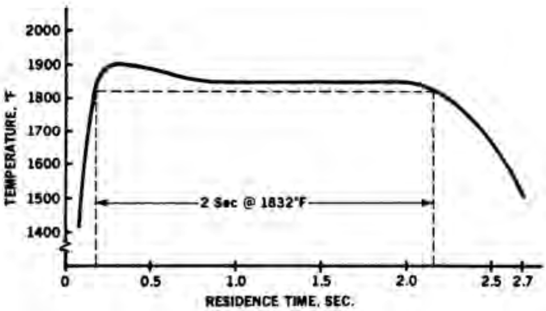

Fig. 4. C-E-WIS Temperature vs. Residence Time.

Of primary importance is the time at which the waste/air mixture is exposed to the temperature recommended for "complete" destruction of organic materials (1832°F) as shown on Figure 4. For the CE-WIS combustor, this exposure time is approximately 2 seconds. By the EPA definition, the CE-WIS combustor exposes the waste to sufficient temperature for sufficient time to bring about the required destruction efficiency for hazardous waste. In the case of solids, some of these were observed burning on the grate (second stage) during CE-WIS prototype testing. Sufficient oxygen for complete combustion is provided by maintaining the combustor in excess air condition at all times. The minimum oxygen concentration at the combustor outlet was 16 volume percent (dry basis).

The prototype of the CE-WIS has been tested for over 600 hours at C-E's Windsor, Connecticut facility. Effective burning of combustible trash and ion exchange resin slurries has been achieved. In both cases, the majority of the combustible solids incinerate while passing through the combustor with a few heavier particles requiring longer residence time falling onto the grate where they burn to completion. Average weight reduction of the waste in the system has been:

Waste Type	Weight Reduction Factor (Feed/Product)
Miscellaneous Combustible Waste	41
Bead Ion Exchange Resin (Dewatered)	57

Hydrocarbon destruction efficiency has been measured at 99.99% for the CE-WIS prototype. The residual ash is due to inorganic constituents of the feed material. It is expected that commercial versions of the CE-WIS will thermally decompose organic solids, gases and liquids with a destruction efficiency which meets the performance requirements set by the U.S. EPA for a hazardous waste incinerator.

Factors effecting the combustibility of hazardous waste are the physical properties of the waste. The following factors are very important to the determination of how the waste should be treated:

a) Carbon to Hydrogen ratio;
b) Presence of H_2O in the waste combined with the hydrocarbon; "inherent water"
c) Presence of H_2O in the waste free of the hydrocarbon; "free water"
d) Quantity of oxygen present in the waste
e) Presence of halogens in the hydrocarbon molecules of the waste;
f) Presence of light metals such as sodium and potassium in the waste
g) Size distribution of solid waste material;
h) Viscosity of the waste;
i) Volatility of the material
j) Heating Value
k) Flame Temperature
l) Ash content

To determine whether a particular hazardous material can be incinerated with the required destruction efficiency, the important physical properties of the material are compared to those of wastes that have been successfully incinerated. When incineration appears feasible, a trail burn in a pilot plant or full size incinerator is performed to verify that the waste is destroyed with the required destruction efficiency.

In conclusion, the CE-WIS has shown that an incinerator designed for LLRW incineration has the proper combination of time, temperature, oxygen and turbulence to thermally decompose different hazardous waste materials with various physical properties.

Treatment of Off Gas From the Incineration of Hazardous Waste

Parallels also exist between the treatment of the off-gas from a radioactive waste incinerator and the off-gas from a hazardous waste incinerator. The filtration train for the CE-WIS begins with a primary filter for the removal of the majority of the particulates in the off-gas. Particulate loadings are heavy during the drying of inorganic salt solutions. The next component is a wet scrubber for the removal of fine particles and gaseous radionuclides. The final stage of off-gas cleanup is a bank of high efficiency particulate air (HEPA) filters and iodine absorbers. The HEPA filters remove very fine particles from the off-gas while the charcoal delay filter temporarily holds radioiodine such that radioactive decay can render these radioisotopes as stable species. Prototype testing supports the following expected overall efficiency for particulate:

Waste Feed Type	Overall Particulate Removal Efficiency
Miscellaneous Combustible Solids	99.98%
Bead Ion Exchange Resin	99.98%
Inorganic Salts	99.993%

Expected off-gas removal efficiency for gaseous radioiodine is 99.993%. Verification testing with tracer radioiodine are planned.

Current and proposed regulations set the removal efficiency of contaminate from the off-gas resulting from incineration of hazardous waste at:

Contaminent	Required Removal Efficiency
Particulate	90%
Gaseous Halogens	99% (when the halogen content of the waste feed is 0.5%)

CE-WIS prototype testing along with manufacturer testing has shown that the wet scrubbing portion of the off-gas cleanup system alone can achieve these required removal efficiencies for particulates and halogens.

Conclusion

The demonstration test program for the CE-WIS has shown that incineration techniques proven sufficient for volume reduction of low-level radioactive wastes are expected to be applicable to hazardous waste incineration in the following areas:

1. Thermal destruction of organic hazardous waste with an efficiency of 99.99%. This destruction efficiency can meet EPA performance requirements indicating a combustion chamber designed with a sufficient combination of time, temperature, oxygen and turbulence.

2. Using only the wet scrubbing portion of the CE-WIS off-gas treatment system particulate and halogen contamination can be removed with sufficient efficiency for hazardous waste incineration.

Acknowledgements

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