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Project Summary

Environmental Assessment of a Waste-to-Energy Process, Burlington Electric's Wood and Oil Co-Fired Boiler

Mark A. Golembiewski, K.P. Ananth, T. Sutikno and
Harry M. Freeman

In July 1978, Midwest Research Institute conducted a series of emission tests at the Burlington Electric Department's power plant in Burlington, Vermont. The study was designed to provide multi-media emission data for the purpose of identifying potentially adverse environmental impacts, and to identify pollution-control technology needs.

The No. 1 boiler at Burlington Electric, which was tested for this study, is fueled by a combination of wood chips and No. 2 fuel oil. Approximately 82% of the heat input (9.3 tons/hr) was provided by the wood fuel and the remaining 18% by the fuel oil (175 gal/hr). Electrical power generated from this boiler system was about 8 MW. The air pollution-control system consists of two mechanical collectors in series.

Four effluent streams were sampled and analyzed for this assessment program: bottom ash, primary collector ash, secondary collector ash, and stack emissions. Common to all streams were characterizations for elemental composition and potentially hazardous compounds such as polychlorinated biphenyls and polycyclic aromatic hydrocarbons. In addition, the boiler exhaust gases were analyzed for particulate, NO_x, SO_2, CO, and total hydrocarbon concentrations. The Source Assessment Sampling System was also used, following guidelines established by EPA's Level 1 environmental assessment protocol.

This publication is a summary of the complete project report, which can be purchased from the National Technical Information Service.

Introduction

Under the sponsorship of the U.S. Environmental Protection Agency's Fuels Technology Branch in Cincinnati, Midwest Research Institute (MRI) is presently conducting multi-media environmental assessments of various waste-to-energy conversion systems. This paper will discuss the results of one such effort at the Burlington Electric Department's power plant in Burlington, Vermont. The Burlington plant was selected for study because of the renewed interest in wood and wood waste as a primary boiler fuel in certain regions of the country. The Burlington plant is the only facility in the U.S. presently firing oil with wood waste to generate electric power.

The sampling and analysis program at Burlington was designed to provide multi-media emission data for the purpose of identifying potentially adverse environmental impacts and assessing pollution-

control needs. In the following sections of this paper, we will briefly describe the test facility, the sampling and analysis procedures that were used, and the results of the test program. An assessment of the results using EPA's Source Analysis Model (SAM-1A) is also presented.

Description of Boiler Test Facility

The No. 1 Unit at the Burlington Electric plant was originally a coal-fired boiler that was modified to fire wood chips with supplementary oil injection. Steam produced to power a 10 MW turbine generator is rated at 100,000 lb/hr.

Wood chips are conveyed from the storage bin to four gravity-fed chutes. From the base of the chutes, the chips are injected into the boiler using compressed air. The wood chips fall onto a horizontal, traveling grate which is supplied with underfire air. Because of the high moisture content of the chips, the boiler cannot provide the needed steam output from wood alone; therefore, supplementary fuel oil is used. No. 2 fuel oil, along with overfire air, is introduced above the grate bed from both sides of the firebox, thus insuring adequate steam production. Residual ash is discharged at the end of the grate into a hopper, from which it is removed pneumatically to an outdoor storage silo.

The flue gases leaving the boiler are ducted to an emission control system consisting of two, high efficiency mechanical collectors in series. For a flue gas flow rate of 60,000 acfm at 330°F, the collectors were designed for an overall pressure drop of 6.5 in. H_2O and a collection efficiency of 97.75%.

Sampling and Analysis Methodology

The sampling and analysis test matrix that was used is shown in Figure 1. The input fuels, bottom ash, primary and secondary collector ash, and air emissions at collector inlet and outlet were sampled. Three complete sets of samples from each of these streams were taken over a two-day period. The sampling and analysis procedures used were either EPA methods or those approved by the EPA project officer. Results of the sampling and analysis efforts are discussed below.

Results

Input Fuels—The wood/oil feed ratio during the MRI tests was approximately 80% wood and 20% oil, on a heat input basis. The average composition of the wood was 4.3% ash, 70% volatile matter, and 25.7% fixed carbon (dry basis). The average sulfur content was 0.35% and the average heat of combustion was 5,870 Btu/lb (as received) and 9,480 Btu/lb (dry basis). The sulfur content of the oil was 0.35%, while its heat of combustion average was 19,500 Btu/lb (138,100 Btu/gal).

Bottom Ash—Analysis of elemental composition in bottom ash indicated that most elements were more concentrated in the bottom ash relative to the fuel inputs. Those elements exhibiting the largest increases in concentration were Ba, Zr, Sr, and Li. No PCB materials were detected in the bottom ash samples above the 0.05 μg/g detection limit. One PAH compound, phenanthrene, was identified at a concentration of 0.89 μg/g.

Analysis for PCB materials at 0.05 μg/g detection limit was negative in the ash samples. No PAH compounds were identified in the primary ash sample extracts.

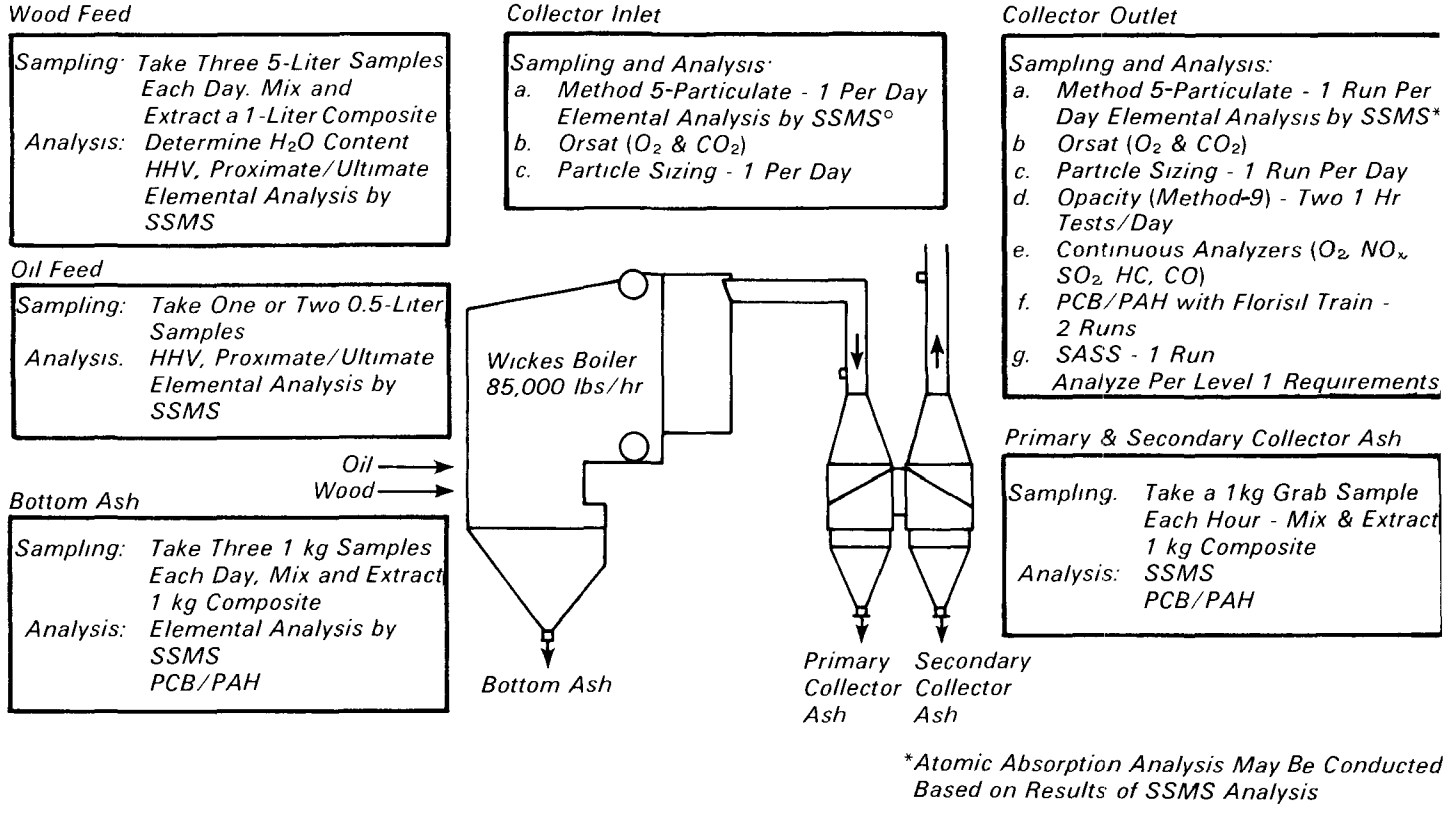


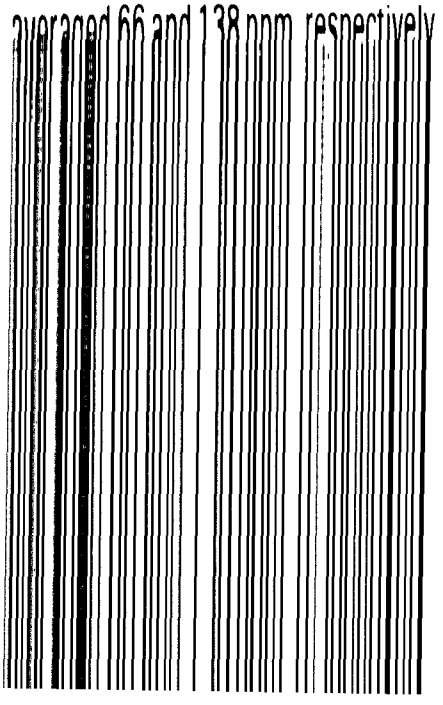
Figure 1. Test matrix for Burlington Electric's wood and oil-fired power plant

However, several compounds were confirmed in the secondary ash samples, including acenapthylene, phenanthrene, fluoranthene, and pyrene. One sample contained 10 μg/g of phenanthrene, which was the highest PAH concentration observed.

Uncontrolled Air Emissions—The average uncontrolled particulate concentration was 2.96 g/dscm (1.30 gr/dscf) as measured by EPA Method-5. On the basis of heat input, uncontrolled particulate emissions averaged 1.47 g/MJ (3.43 lb/10^6 Btu). Oxygen and carbon dioxide contents averaged 12.3% and 8.2%, respectively. Filter samples from the Method-5 particulate tests were analyzed for elemental composition. The elements emitted at concentrations greater that 10 μg/dscm were Pb, Ba, Sr, As, Ga, Zn, Cu, Fe, Mn, Ti, and P.

An optical/diffusional particle counting system was used to measure the particle size distribution of the uncontrolled emissions. Particles in the range of 0.005 to 0.10 μm were counted by a diffusion battery/condensation nuclei counter arrangement, while those in the 0.3 to 2.6 μm range were counted by an optical counter. Because the dilution system consistently became plugged with larger particles during operation, no particle counts could be obtained in the size region above 2.6 μm. Therefore, the mean particle size could not be determined. Within the size range of particles counted (0.005 to 2.6), the majority of the particles appeared to be between 0.3 to 0.5 μm in diameter.

Controlled Air Emissions-Using continuous gas analyzers, concentrations of O_2, NO_x, SO_2, CO, and total hydrocarbons (THC) were measured in the stack gas. NO_x, and SO_2 concentrations averaged 66 and 138 ppm respectively



and V were in the range of 1 to 75 μg/dscm. The remaining elements had concentrations which were less than 1 μg/dscm.

Particle size data was obtained by the same method used at the collector inlet (optical/diffusional particle counter). As with the inlet measurements, data for particles > 2.6 μm in diameter could not be obtained. The number of small particles (< 2.6 μm) appeared to increase in the controlled gas stream relative to the uncontrolled emissions. The reasons for this increase are not clear.

Plume opacity data, obtained using EPA Method-9, averaged about 20% on both test days. Samples for analysis of PCB and PAH materials were collected in a special sampling train utilizing impingers and a Florisil adsorbent trap. PCB analysis did not produce any responses greater that the 1 μg/sample detection limit of the GC/MS analytical technique. Similarly, no PAH compounds were identified at levels which permitted structural confirmation.

Organic analysis of the Source Assessment Sampling System (SASS) components, in accordance with Level 1 guidelines, revealed low levels of organic constituents. Characterization of the organic emissions was difficult, although they appeared to be composed mainly of carbonyl-containing groups.

Source Assessment Model (SAM-1A)

The EPA's SAM-1A methodology was applied to the four effluent streams as a means of interpreting the emission results. The SAM-1A analysis results indicated that the secondary collector ash contained the highest degree of hazard, although all three ash streams were similar in the magnitude of their hazard values. Stack emissions showed a relatively low degree of hazard.

The primary collector ash stream had the highest Toxic Unit Discharge Rate (TUDR) which would seem to indicate that this effluent should receive the first priority for control measures. However, because of certain limitations which are inherent in the SAM-1A methodology, this observation should not be regarded as being definitive.

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Controlled Air Emissions–Using continuous gas analyzers, concentrations of O_2, NO_x, SO_2, CO, and total hydrocarbons (THC) were measured in the stack gas. NO_x, and SO_2 concentrations averaged 66 and 138 ppm, respectively. CO readings averaged 213 ppm and THC concentrations were only 9 ppm.

Three Method-5 particulate runs were made simultaneously with the sampling runs at the collector inlet. The average particulate concentration was 0.18 g/dscm (0.08 gr/dscf). The particulate emission rate averaged 0.09 g/MJ (0.17 lb/10^6 Btu), on the basis of heat input. The average efficiency of the two-stage mechanical collection system, as determined from the simultaneous inlet/outlet tests, was 94.2% for total particulate.

Elemental analysis of the Method-5 particulate filters indicated moderately high elemental concentrations. Pb, Ba, Sr, Zn, and Ti were present at the highest concentrations, approaching 100 μg/dscm, while Hg, Sb, Zr, Br, Se, As, Ga, Cu, Ni, and V were in the range of 1 to 75 μg/dscm. The remaining elements had concentrations which were less than 1 μg/dscm.

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***Harry M. Freeman** is the EPA Project Officer (see below).*
The complete report, entitled "Environmental Assessment of a Waste-to-Energy Process, Burlington Electric's Wood and Oil Co-Fired Boiler," (Order No. PB 80-220627; Cost $12.00, subject of change) will be available from:
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5285 Port Royal Road
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