United States
Environmental Protection
Agency

Hazardous Waste Engineering
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-85/121 July 1986

EPA

Project Summary

Evaluation of Pilot-Scale Air Pollution Control Devices on a Refuse and Coal-Fired Boiler

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This study, funded by the U.S. Environmental Protection Agency (EPA), Hazardous Waste Engineering Research Laboratory (HWERL) was conducted to evaluate prototype air pollution control devices on "waste-as-fuel" processes. The site, Ames, Iowa, cofires pulverized coal and refuse-derived fuel (RDF) in a tangential-fired, suspension boiler. A test program was implemented to evaluate a pilot electrostatic precipitator (ESP), pilot venturi scrubber, and pilot fabric filter in controlling particulate and gaseous air pollutants. Each device was slipstreamed ahead of the plant's full-scale ESP, and operated as a primary control device. The pilot scrubber was also tested downstream of the full-scale ESP, and was evaluated as a secondary control device.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The nature and magnitude of atmospheric pollutant emissions caused by the thermal conversion of waste to energy are not yet well defined. Thus far, pollutants identified in air emissions from various resource recovery operations include particulates, metals, chlorides, sulfur oxides (SO_x), nitrogen oxides (NO_x), and polycyclic organic materials (POMs).

Fabric filters have been successfully applied to preprocessing operations, and ESPs are the most common air pollution control equipment used on cofired boilers and mass-burn incinerators. Full-scale fabric filters have not been applied to waste-as-fuel combustion processes, and wet scrubbers have been used on incinerators with less success than ESPs. Since available information indicated that state-of-the-art devices proved effective in controlling pollutants of concern from waste-as-fuel processes, alternative devices such as wet ESPs, and jet ejector scrubbers were not considered for this study.

Test Plans and Results

Four different pollution control devices were tested. The fabric filter installed at the Ames solid waste recovery plant was sampled to evaluate particulate removal efficiency. The fabric filter treats particulate-laden gas, at in-plant temperature, from seven sources in the plant—the air density separator/RDF cyclone exhaust, primary shredder, secondary disc screen, and a number of conveyor transfer points. Results indicate that the fabric filter effectively controls particulates generated by various sources in the plant. While no attempts were made to optimize operation or collection efficiency of the unit, it removed an average of 97.8 percent of the particulates.

A pilot ESP, pilot scrubber, and pilot fabric filter were also tested. All the devices were controlling combustion gases from the cofired Boiler 7 at the Ames Power Plant. The boiler burns pulverized coal and RDF in a tangential firing mechanism at different fuel ratios ranging from 0 to 25 percent RDF on a

Btu basis. Emissions are currently controlled with an ESP.

Emissions were characterized by simultaneously measuring selected pollutants at the inlet and outlet of each control device. The full range of boiler fuel ratios was studied for each device. Operating parameters that varied during mobile venturi scrubber testing included pressure drop across the venturi throat, gas flow rate, and scrubbing liquor flow rate. The gas flow rate increased with the scrubber liquor flow rate in such a manner that the liquid-to-gas ratio remained constant. Testing was performed at pressure drops of 2.5, 5.0, and 7.5 kPa (10, 20, and 30 in. H_2O).

The operating parameters that were varied during pilot ESP testing included the number of energized fields, specific collection area (SCA), and gas flow rate. Tests were performed at 3, 4, and 5 energized fields and at SCAs of 16.4, 21.9, and 27.3 m^2 per m^3/h (300, 400, and 500 $ft^2/acfm$).

The pilot fabric filter was operated at an air-to-cloth range of 0.46 to 0.91 m^3/min per m^2 (1.5 to 3.0 acfm per ft^2). The unit was equipped with reverse air, mechanical shake, or a combination of the two for cleaning the fabric.

Figure 1 shows the slipstream and sampling locations. All the control devices were slipstreamed into the system upstream of the existing ESP. Additional scrubber tests were performed while slipstreaming flue gas downstream of the full-scale ESP, thus representing a secondary control device. Samples were taken at the inlet and outlet of each pilot control device while boiler conditions, fuel composition, and control device operating conditions were monitored. A Method 5 source sampling train was used to sample each

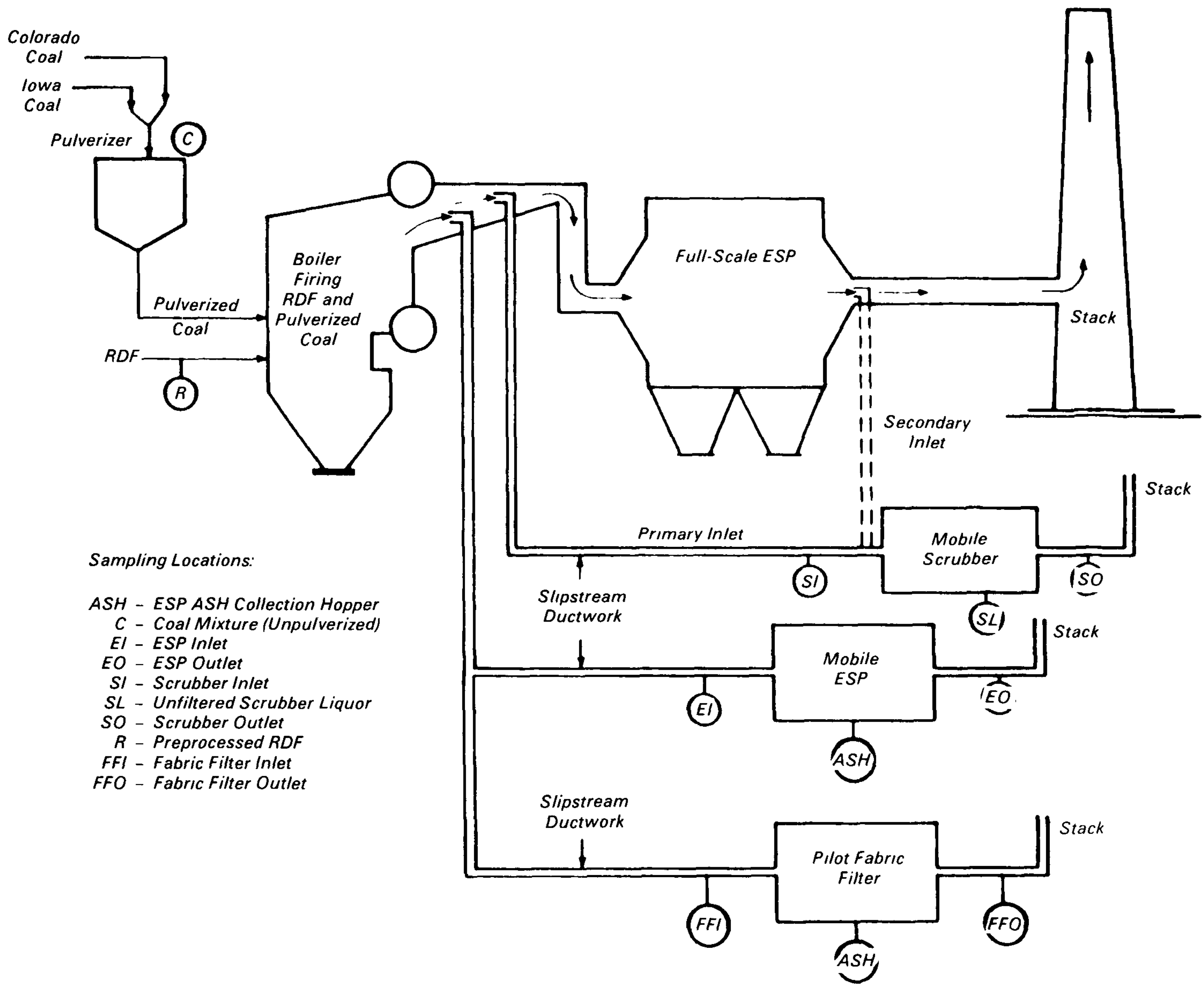

Figure 1. *Schematic of pilot control devices at Ames, Iowa.*

control device at the inlet and outlet. These samples were analyzed for total particulate, halides, elemental analysis (by spark source mass spectrometry), and selected metals (by atomic absorption analysis).

Discrete grab samples of coal, RDF, ESP ash, fabric filter ash, and scrubber liquor were collected at the time of emission testing. Coal samples were taken before the pulverizer, and processed refuse samples were collected at the atlas storage bin before the fuel entered the pneumatic feed to the boiler. Tables 1 and 2 show the ultimate and proximate analyses of coal and RDF grab samples. Table 1 shows the results of samples taken during ESP and scrubber tests and Table 2 shows results of fabric filter tests.

During all primary device tests, the particulate removal efficiency was 99 percent. The efficiency remained roughly the same for coal plus RDF tests at all pressure drops, and efficiency decreased with increasing pressure drop for the tests with coal only. This observation led to the conclusion that an operating parameter other than pressure drop affected removal efficiency to a greater degree. Midwest Research Institute investigated this theory and reported that the observed contradiction in the data "...was due to the longer residence time created by a lower pressure drop and partly due to the fluctuation of particle size distribution..." Pressure drop in the scrubber was maintained by adjusting gas and liquor flow rates, not throat size. The results also suggest that RDF input to the boiler may enhance particulate collection in a venturi scrubber. This observation is somewhat misleading, however, because inlet particulate loading also appears to increase with RDF input. Chlorides were also sampled and analyzed, and the results are as follows:

- Chloride emissions increase when firing RDF, when compared with coal only tests.
- A water/lime solution in a venturi scrubber is highly effective in controlling chloride emissions.

The secondary scrubber tests resulted in particulate removal efficiencies ranging from 75 to 95 percent.

The results of particulate testing on the pilot ESP, specifically the effects of SCA and fuel type on removal efficiency, indicate the following:

- The number of energized fields and SCA, when increased within design limits, tend to enhance particulate

Table 1. *Average Fuel Analyses–Pilot Scrubber and ESP Test Runs Only (Values in Weight Percent Except as Shown)*

	Coal[a]	RDF[b]
Fuel as received		
Proximate analysis		
Water	16.13	13.25
Ash	9.27	12.78
Volatile matter	36.54	61.36
Fixed carbon	38.06	12.61
Heating value, MJ/kg	23.68	15.45
(Btu/lb)	(10,180)	(6,644)
Dry fuel		
Ultimate analysis		
Ash	11.06	14.83
Carbon	73.53	50.31
Hydrogen	1.38	3.97
Oxygen[b]	9.73	30.37
Sulfur	3.13	.38
Nitrogen	1.17	.14
Heating value, MJ/kg	28.21	17.80
(Btu/lb)	(12,130)	(7,654)

[a]*Average of selected grab samples.*
[b]*Calculated by difference.*

Table 2. *Average Fuel Analyses–Pilot Fabric Filter Test Runs Only (Values in Weight Percent Except as Shown)*

	Coal[a]	RDF[b]
Fuel as received		
Proximate analysis		
Water	16.06	5.74
Ash	15.96	9.64
Volatile matter	31.53	70.57
Fixed carbon	36.50	14.05
Heating value, MJ/kg	21.25	17.38
(Btu/lb)	(9,122)	(7,460)
Dry fuel		
Ultimate analysis		
Ash	18.92	10.23
Carbon	61.81	46.83
Hydrogen	4.13	6.16
Oxygen[b]	9.60	36.17
Sulfur	4.38	.27
Nitrogen	1.16	.34
Heating value, MJ/kg	25.32	18.44
(Btu/lb)	(10,869)	(7,913)

[a]*Average of selected grab samples.*
[b]*Calculated by difference.*

collection efficiency regardless of the coal and RDF mixture.

At a specific SCA, RDF input to the boiler tends to decrease ESP collection efficiency; however, a further increase in RDF input does not necessarily continue to decrease ESP performance.

The lead concentrations measured at the ESP inlet and outlet show a definite increase in lead emissions with increased RDF; however, the highest lead emission measured was less than 5 mg/dry std. m^3, and the overall average was 0.71 mg/dry std. m^3.

For fabric filter tests, Figure 2 shows the effects of pressure drop and type of fuel on particulate collection efficiency. Significant trends cannot be recognized within the collection efficiency range shown. Regardless of pressure drop or fuel type, particulate collection efficiency was 99 percent or greater.

The control of lead emissions was shown to be very effective. Only one of five outlet samples was above the detectable limit of 0.007 mg/dry std. m^3, with a concentration of 0.03 mg/dry std. m^3. Lead emissions did, however, increase with increasing RDF input. Chloride emissions, again, increased as RDF increased, with very little control exhibited by the fabric filter (20 to 30 percent removal). Fluoride emissions did not change significantly throughout the range of operating conditions.

Conclusions

Total uncontrolled particulate emissions at the Ames test site were not significantly different in tests of coal only and of coal plus RDF. Some trace elements and gaseous chlorides increased significantly when burning RDF. Lead and zinc emission concentrations were about three times higher and gaseous chlorides about 10 times higher when burning 25 percent RDF (Btu basis). Neither the scrubber, ESP, nor fabric filter particulate removal efficiencies changed as the portion of heat input supplied by RDF increased.

Conventional state-of-the-art air pollution control devices were found to be effective in controlling the pollutants investigated: particulate, trace metals, SO_x, and halides. The fabric filter and ESP were more efficient in controlling particulate emissions than gaseous pollutants. A venturi scrubber was very effective in removing the gaseous pollutants. Specific operating parameters, which were varied on the respective control devices, can optimize pollutant removal efficiencies.

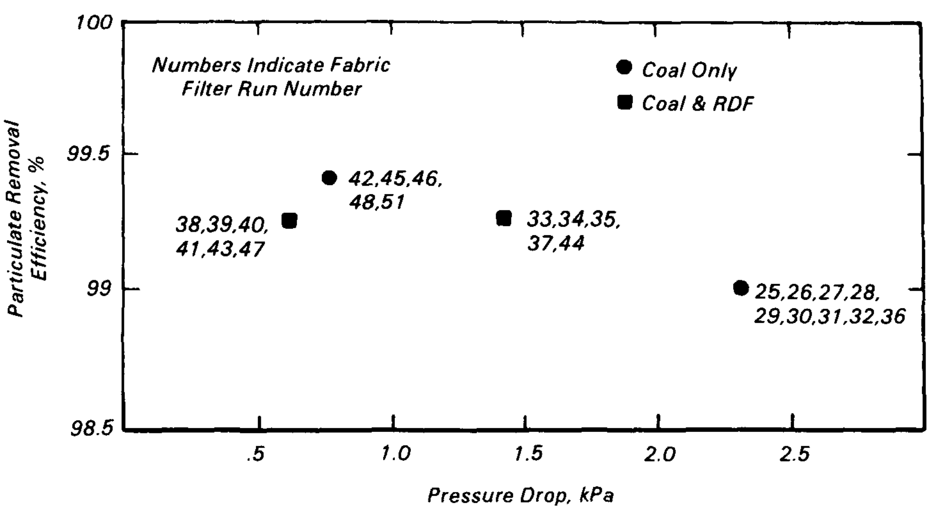

Figure 2. *Particulate removal efficiency as a function of fabric filter pressure drop*