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Project Summary

Emissions Assessment for Refuse-Derived Fuel Combustion

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This project examines the emissions resulting from the combustion of refuse-derived fuels (RDF) and coal. The two RDFs used were Eco-Fuel II, a pulverized product, and a shredded RDF from Americology. Both were pelletized before burning.

The RDF and coal were burned in a small spreader-stoker fired boiler. The parameters that were varied in this program were RDF type and amount of coal burned with the RDF. In two experiments a waste chemical, triethanolamine, was added to the fuel, and its destruction efficiency was assessed.

Analyses of the flue gases identified low levels of hydrocarbons, nitric oxide, carbon monoxide, and sulfur dioxide. The particulate loadings increased as the percentage of RDF in the total fuel increased. More than half of the particulate loading was submicron in size when RDF was fired without coal. Large quantities of polycyclic organic materials were detected in those experiments in which the shredded and pelletized RDF was fired in the furnace. No dioxins were detected in those tests in which it was analyzed. In the experiments in which RDF was the only fuel, lead emissions were several orders of magnitude above the levels detected in the coal base run. Based upon the flue gas analysis, the destruction of the triethanolamine was complete.

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 use of waste materials as a fuel substitute is a concept that has received close examination in recent years. Waste-to-energy combustion systems have been used for many years in Europe. However, the United States' approach is somewhat different from the approach used in Europe. In the United States a major effort has been organized to promote the combustion of RDF in waste-to-energy systems in contrast to the mass burning approach utilized in Europe. An RDF is a processed municipal solid waste which has had as much non-combustible material (sand, metals, etc.) removed as is technically and economically feasible. The combustible part of the waste (paper, plastics, etc.) is then subjected to shredding to reduce the size of the fuel. The final product (RDF) may then be burned in a suspension burning mode, a turbulent well mixed bed, or a fixed bed.

The RDF may also be further processed into a form known as densified RDF (d-RDF) which requires pelletizing, briquetting or otherwise compacting the RDF into larger more dense pieces.

In this study, a pelletized form of RDF was used as a fuel in the emissions assessment program. Two types of RDF (Eco-Fuel II,* obtained from Combustion Equipment Associates, E. Bridgewater, MA, and Americology, obtained from American Can Co., Milwaukee, WI) were fired with and without the addition of coal in a small spreader-stoker fired boiler. A complete assessment of the flue gases was performed by continuous monitors and by batch collection techniques and

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

analysis techniques. Also, analyses were performed on the gaseous and particulate samples extracted by the Source Assessment Sampling System (SASS)

A further addition to the experimental program required an assessment of the destruction of a hazardous waste material that was co-fired with the coal/RDF fuel. The degree of destruction of the waste was determined by monitoring the anticipated by-products of the waste material. This waste material was mixed with the RDF before pelletization, and the resulting pellets were co-fired with coal.

Objective and Scope

The objective of this program was to perform an emissions assessment of the combustion of RDF both with and without the co-firing of coal. The combustion was in a stoker-fired boiler, with most of the combustion occurring in a fixed bed of burning fuel on a grate. The assessment was performed by sampling gaseous and particulate emissions and by conducting analyses on the samples extracted from the flue gas stream. Additionally, chemical analyses were performed on the fuels used, and other effluent solids from the boiler.

The research program included two different RDFs and a low sulfur coal. Each fuel was fired separately and each RDF was co-fired with the coal. The coal was fired separately in one test as a benchmark, permitting comparison of the emissions from the two RDFs with those from coal.

Also, the program included an assessment of the destruction of a hazardous waste material that was co-fired with a coal/RDF fuel. The degree of destruction of the waste was determined by monitoring all of the anticipated by-products of the material. Triethanolamine was used as the hazardous material.

Particulate Emissions

The boiler used in these tests did not have a specific particulate control device such as a cyclone, although small amounts of fly ash settled in the boiler tubes. With Eco-Fuel II pellets burning as the only fuel, the stack emissions were lower than when burning only coal, or when burning both coal and pelletized Eco-Fuel II. Burning the Americology pellets resulted in appreciable higher particulate emissions than when burning Eco-Fuel pellets

The particles less than 1 μm in diameter comprised the largest fraction of the particulate concentration in experiments in which RDF was used. In the coal-only run, the submicron particulates comprised 20 percent of the total loading. In three tests in which coal and Eco-Fuel II were co-fired, the submicron particles comprised approximately 55 percent of the total particulate loading. In the experiment which used Eco-Fuel as the only fuel, the submicron particulates comprised 83 percent of the total loading, although this experiment had the lowest total particulate concentration. The experiments in which the Americology RDF was co-fired with coal and then fired as the only fuel, the submicron particulate loadings comprised 71 percent and 85 percent of the total loading, respectively. Also, these two experiments produced the highest total particulate concentrations.

Based on the data collected, it is evident that both RDFs have a tendency to produce large quantities of submicron particulate matter; more than when burning coal. Also, a pale blue haze was evident at the stack during the two Americology tests, indicating the presence of a large amount of small-sized particulates. The fact that this haze was not observed during the Eco-Fuel tests may be attributed to the lower concentrations of submicron particulates in the gases, the higher strength of the Eco-Fuel pellets, or the chemical/physical processing that produced the Eco-Fuel

Sulfur Dioxide (SO_2)

The SO_2 emissions ranged from a high value of approximately 480 ppm in the coal-only experiment to a low value of approximately 98 ppm in the Americology only experiment. Although the Eco-Fuel II had a lower sulfur content than coal on a weight basis, the sulfur content per Btu was nearly the same. Thus, in comparison of tests with and without coal co-firing, only a small reduction in sulfur emissions was achieved in the Eco-Fuel runs. The fraction of sulfur fired that was emitted as SO_2 varied between 75 and 100 percent of the sulfur fired in all runs

Nitrogen Oxides (NO_x)

The nitric oxide (NO) emissions varied from a low of 150 ppm in tests firing coal + Americology to a high of 260 ppm in tests firing coal + Eco-Fuel II in which triethanolamine had been added to the Eco-Fuel II. Since the addition of triethanolamine raised the nitrogen content of the fuel, it would be expected that the NO emissions would increase. In those tests in which no triethanolamine had been added, the NO levels ranged from 150 ppm to 220 ppm Thus, the addition of the amine had a perceptible but small influence of NO_x emissions.

When the RDF was co-fired with coal, the nitrogen emitted as NO represented approximately one quarter of the fuel-bound nitrogen. Higher emissions of NO relative to the nitrogen in the fuel were observed in the RDF-only test runs.

Chlorides

As expected, chloride emissions increased as the chloride concentration in the fuel increased. The lowest stack concentrations, 12 6 ppm were recorded in the coal-only test. The highest concentrations, 245 ppm were recorded in the Americology test.

A chloride mass balance was achieved in only two tests, one in which the Americology + coal was the fuel, the other in which the Americology was the only fuel In the test in which Eco-Fuel II was the only fuel, 10 percent of the total chloride was accounted for in the flue gases and flyash. In the coal and the coal + Eco-Fuel II tests, 36.7 and 67 0 percent, respectively, of the chlorides entering the boiler with the fuel were accounted for in the flue gas.

Total Hydrocarbons

Total hydrocarbon emissions, as measured by the on-line monitoring instrument, were quite low (<20 ppm) for all tests. The hydrocarbon analyzer sampled gases that had been filtered through a trap and were heated to 200°F. It is possible that some hydrocarbon species were scrubbed out of the sampled stack gases before the gases were analyzed, however, flame ionization gas chromatography analyses supported the low hydrocarbon emissions.

Organic Species

Gaseous organic materials extracted from the flue gas were noticeably higher when the Americology was burned than when the Eco-Fuel II was burned. The burning of both RDFs resulted in higher organic emissions than when coal was the only fuel. Measureable organic material was observed in the respirable particle emissions only when burning Americology as the only fuel, and the concentration per cubic meter of the flue gas was about a factor of 50 below the concentration of organics collected from the gas stream itself.

Polycyclic Organic Materials (POM)

POMs were detected and measured in three tests, both in the flue gas and in the suspended particulates The Americology RDF fired without coal appeared to result in higher POM emissions than the Eco-Fuel II RDF fired without coal Also, the Americology RDF fired without coal produced more POMs than when co-fired with coal.

Dioxins

The emissions from the burning of RDF without coal were analyzed for the dioxin 2,3,7,8 TCDD. No positive identification of this species was made in either the suspended particulate or the gaseous emissions.

Emissions Analyses

This section summarizes the emissions measured and analyzed for seven tests. The distinctions between tests were primarily related to the different compositions of the fuels fired, although the physical properties of the RDF fuels presumably also affected the emissions and cannot be overlooked. Other than fuels, there were no major changes in feed system or boiler operation during the test program. When coal and RDF were co-fired, each fuel provided half of the total heat input to the furnace.

The seven tests conducted were:

- Coal fired only
- Coal co-fired with Eco-Fuel II (50/50 by heat content)
- Eco-Fuel II fired only
- Coal co-fired with Americology (50/50 by heat content)
- Americology fired only
- Coal co-fired with Eco-Fuel II + 10 wt percent hazardous waste
- Coal co-fired with Eco-Fuel II + 5 wt percent hazardous waste

The weight fraction of hazardous waste that is reported is the weight of hazardous waste contained in the Eco-Fuel II pellets, not the weight fraction of waste in the coal + Eco-Fuel II.

Table 1 summarizes the emissions that were observed. The average carbon dioxide (CO_2) measured in the stack is shown for each test The excess air in each test was maintained at a level just sufficient to reduce carbon monoxide (CO) in the stack gas, and the average CO during all tests was less than 20 ppm.

Applications of Test Results

The principal value of the results of these tests lies in their comparison with two related programs using laboratory scale systems. This comparison should demonstrate the effects of type of RDF burning on stack emissions more accurately than a direct comparison of these laboratory-scale data with full-scale RDF co-firing data. The temperatures, mixing, fuel compositions and fuel preparations, and firing obtained in these small laboratory-scale systems can be more directly related to larger systems than the residence times involved. The residence time in full-scale industrial RDF burning is much longer, especially in the gas phase reactions that occur above a bed in a stoker-fired boiler.

Table 1. Summary of Emission Measurements Burning Coal and Densified RDF in Stoker Fired Boiler

Test No.	1	2	3	4	5	6	7
Fuel Fired[1]	Coal Only	Coal + Eco-Fuel II	Eco-Fuel II Only	Coal + Americology	Americology Only	Coal + Eco-Fuel II + TEA[2]	Coal + Eco-Fuel II + TEA[2]
Stack Emissions							
CO_2, percent	8 5	9 4	8.5	4.9	8 5	8 7	9 7
Particulates, mg/M^3	145	167	111	323	417	186	206
SO_2, ppm	477	462	403	271	98	394	388
NO_x, ppm	200	175	170	150	220	260	251
Cl^-[3], ppm	37	67	12	115	245	ND	ND
Organics[3], mg/M^3	?	576	965	1170	2870	ND	ND
POM[3], mg/M^3	ND	ND	12.1	19.9	55.0	ND	ND

ND—not detected.
(1) Coal + RDF runs used as fuels on a 50-50 basis based on heating value.
(2) Triethanolamine, simulating a hazardous waste, was incorporated into RDF fuel pellets @ 10 and 5 wt percent in tests 6 and 7, respectively.
(3) Emitted in gaseous form.

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The complete report, entitled "Emissions Assessment for Refuse-Derived Fuel Combustion," (Order No. PB 86-111 218/AS; Cost: $11.95, subject to change) will be available only from:
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