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Project Summary

Characterization of Emissions from a Fluidized-Bed Wood-Chip Home Heating Furnace

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Emissions from a residential wood-chip combustor, operated in both a fluidized-bed and a cyclone-fired mode, were measured and are compared to emissions from a conventional woodstove and industrial wood-fired boilers. In general, the combustion efficiency of the fluidized-bed and cyclone-fired wood-chip burner is higher than that of conventional woodstoves. Concomitant with this increase in efficiency is a decrease in most emissions. For the fluidized-bed tests, significant reductions of total hydrocarbons and CO were observed, compared to woodstove emissions. The cyclone test showed PAH levels far below those of conventional woodstoves, approaching levels measured in industrial wood-fired boilers. A baghouse, installed during two fluidized-bed tests, was extremely effective in reducing both particulate and PAH emissions. Method 5 samples from above the fluid bed suggest that appreciable PAH is formed in the upper region of the furnace or in the watertube heat exchangers. In general, the cyclone-fired mode was more effective in reducing emissions from residential wood combustion than the fluidized-bed mode.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, 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

Funded by the U.S. Department of Energy (DOE), ETS, Inc. of Roanoke, VA, has designed and constructed a novel home heating unit that is fired on wood chips instead of the cord wood that is normally used in wood stoves. The device was developed for three reasons: (1) by increasing combustion efficiency, the device can significantly reduce air pollution from wood combustion; (2) using wood chips enables the design and construction of automated fuel handling facilities, greatly increasing the potential convenience of heating with wood chips instead of cord wood in fireplaces and wood stoves; and (3) wood chips are cheaper than cord wood and promise more efficient use of timber resources, because the entire tree, rather than just the main wood portions, can be chipped and used for fuel. This study was undertaken to measure the atmospheric emissions from this novel residential wood chip combustor and to compare these emissions with those from both a residential wood stove and industrial wood-fired boilers.

Procedure

The wood-chip-fired furnace used during this study consists of five basic components: (1) a wood feed conveyor, for feeding wood into the unit; (2) a furnace with a 36 cm (14 in.) diameter bed, a gas/water heat exchanger, and a forced-draft fan (interchangeable burner assemblies for the lower portion of the

furnace enable it to operate as a fluidized-bed combustion unit or a cyclone-fired combustor); (3) a fabric filter using a 13 cm (5 in.) diameter inside-outflow shaker-cleaned filter bag, removable ash container, and induced draft fan; (4) a hot water heater to supply domestic hot water to the house; and (5) an auxiliary heater for supplying space heat to the house when the wood system is not operating.

During fluidized-bed operation, wood is fed through a tube in the center of the bed and dropped onto particles of the fluidized bed where combustion takes place. In the cyclone mode, wood is fed through a forced-draft fan and blown into the cyclone burner where it is combusted.

Fuel used in these tests was chipped pine; chips were about 0.6 cm (1/4-in.) to 1.3 cm (1/2-in.) long. Fuel characteristics include an average moisture content of 11.2 percent, a bulk density of 0.24 g/cm^3 (15 lb/ft^3), and a heating value of 17.7 J/kg (8,500 Btu/lb) on a dry basis.

During this study, emissions were measured during four sets of duplicate test runs of the experimental furnace. Gaseous emissions measured during these test runs included nitrogen oxides (NO_x), measured continuously using a photoluminescent detector, and CO, CO_2, and light organics measured using discrete gas samples and gas chromatography. A modified Method 5 sampling train was used to sample particulate and organic emissions during each duplicate test run. Total particulates and water were measured using standard Method 5 procedures. Glass capillary gas chromatography was used to measure the concentration of polycyclic aromatic hydrocarbons (PAHs) in modified Method 5 sample extracts. Gas chromatography and gravimetric analysis was used to measure total organics collected by the modified Method 5 sampling train.

The experimental furnace was operated and sampled in four test modes, the first three of which involved sampling at the flue gas outlet of the baghouse: (1) with the fluidized-bed burner and fabric filter bag in place; (2) with the fluidized-bed burner in place and no fabric filter bag; (3) with the cyclone burner in place; and (4) with the fluidized-bed burner in place, but with samples taken just above the fluid bed in the furnace chamber. Duplicate runs were conducted at each test point, resulting in eight test runs. NO_x measurements were continuous during each test run, and one or two discrete gas samples were taken during each test. The modified Method 5 sampling commenced as soon as steady-state conditions were reached during each test run, and continued until over 2 m^3 (70 ft^3) had been sampled or until particulate loading on the filter reduced the gas flow through the system so that no more sample could be taken.

Results and Discussions

In general, the residential wood-chip combustor tested in this study was successful in reaching its goals of higher efficiency and lower emissions than conventional wood-fired heating appliances. Efficiencies ranged from 62 to 77 percent during the tests. Consumption of the chipped pine fuel ranged from 3.0 to 5.6 kg/h.

The following observations are based on emission data from the wood-chip-fired furnace:

1. Both the fluidized-bed and cyclone-fired combustion units produced lower emissions of particulate, total hydrocarbons, and CO than those from a conventional residential wood stove.
2. PAH emission factors for the cyclone-fired combustion test were significantly lower than those for conventional wood stoves. However, PAH emission factors for the fluidized-bed combustion tests were similar to those from wood stoves for the lighter PAHs, and were higher than residential woodstoves for the heavier PAHs. Lower total hydrocarbon emission factors for fluidized-bed combustion tests, compared to those for wood stoves, imply that a larger fraction of the total hydrocarbons from fluidized-bed combustor are being converted to PAHs.
3. The baghouse on this fluidized-bed combustion unit proved extremely effective in reducing total suspended particulate emissions from the unit. In addition, collection of partially burnt carbonaceous wood particles in the baghouse resulted in significantly lower emission factors for heavier PAHs during the fluidized-bed combustion tests.
4. Hydrocarbon emission sampling just above the bed for the fluidized-combustion mode indicates that most of the significant formation of heavier PAH compounds is occurring above the bed at the inlet of the watertube heat exchanger or in the watertube heat exchanger itself.
5. Overall the cyclone combustor is superior to the fluidized-bed combustor in reducing all emissions except NO_x. NO_x emissions are only slightly higher for the cyclone combustor than for the fluidized-bed combustor. From an emission standpoint, therefore, the cyclone-fired wood-chip combustor appears to be superior to the fluidized-bed wood-chip combustor. This is especially true for PAH emission factors: the cyclone combustor emission factors for PAH compounds were almost as low as those measured from industrial wood-fired boilers. This is a result of very low levels of total hydrocarbon emissions from the cyclone furnace which precludes significant PAH formation.

Conclusions

Compared to woodstove emissions, emissions from the residential fluidized-bed combustion unit were significantly reduced with respect to particulate, total hydrocarbons, and CO. PAH emission factors were similar to those of wood stoves for lighter PAHs, but higher by approximately an order of magnitude for the heavier PAHs. Thus, significant PAH formation is occurring in the furnace above the fluid bed. Using a filter bag for particulate control reduced the air emissions of heavier PAHs for the fluidized-bed tests. Except for NO_x, the cyclone-fired tests showed significant reductions in all emissions measured, over those from a residential wood stove. Cyclone furnace emissions were also lower than those measured in industrial wood-fired boilers. Cyclone-firing thus appears to be superior to fluidized-bed firing, as presently designed, in reducing emissions from the combustion of wood in residential home heating units. However, although not tested for, introducing the wood chips into the fluid bed rather than on top of it may cause more complete combustion and hence lower emissions in the fluidized-bed mode.

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The complete report, entitled "Characterization of Emissions from a Fluidized-bed Wood-chip Home Heating Furnace," (Order No. PB 84-179 878; Cost: $10.00, subject to change) will be available only from:
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