Impacts of Changing Residential Oil Burner Technology

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Introduction

The pressure-atomized flame-retention-head oil burner design totally dominates the current oil-heat market. This burner, originally introduced in about 1970, represented a dramatic improvement relative to the older non-retention designs. There are approximately 5 million flame-retention oil burners in use today representing about 45% of the oil-heated homes in the U.S.A. Current sales in this replacement-dominated market are between 400,000 to 500,000 units per year. Each burner on average represents a 15% reduction in fuel use compared to the conventional burner it replaces, and as high as a 40% reduction if the entire heating unit is replaced. The total accumulated amount of fuel saved just by the flame retention burner technology is estimated at over 0.5 quadrillion Btu (as of 1991) or $3.6 billion or 85 million barrels of oil. The flame retention head burner represents a well accepted technology, proven to save significant amounts of energy, which can operate with very low pollutant emission levels.

Demands for better performance, however, are driving the development of burners which produce even less soot and particulates, less NO_X, even higher efficiency, lower firing rates (thermal output), and greater resistance to adverse venting situations. These will be used in heating systems which are smaller, have tighter, more efficient heat exchangers, and may be sidewall vented. They also enable consideration of cogeneration and heat pump designs. This paper will summarize recent results of a detailed study comparing the emissions and operational performance of currently available and advanced burner designs.

Research Approach

Seven oil burner designs were tested measuring various operational parameters of specific interest including emission rates of particulates, O_2, CO_2, gas-phase hydrocarbons, and NO_X. The seven burners included a conventional retention-head (CR), a high-static retention-head (MR1), a European high-static retention-head (MR2), an air-atomized unit (AB), a prototype pre-vaporizing burner (PV), a surface/recirculation burner (SR), and a low-pressure air-atomizing burner (LA). The burners were fired with No. 2 fuel oil at 0.5 gallons per hour (20.5 kW) into a three-section cast-iron boiler equipped with a lightweight 3/4 inch (18 mm) refractory combustion chamber. Particulate emission rates were measured using an EPA-5 method. Heat exchanger fouling rates were measured with a unique system designed and developed at Brookhaven National Laboratory for this project. This system allows for an accurate and repeatable measurement (in situ) for heat exchanger surfaces under tightly controlled conditions. Tests were conducted under steady state and cyclic conditions including startup/shutdown transients. The heat exchanger fouling rates were measured for selected cases under various operating conditions and with varying fuel qualities.

Results

Figure 1 shows the excess air at the setpoint for all the burners, a first level figure of merit for comparison. A setpoint for emissions comparison was established at 10% over the excess air level corresponding to a #1 smoke, equivalent to a steady state "zero-to-trace smoke." Figure 2 shows the peak transient smoke number for startup and shutdown. Particulate emission rates were measured for selected burners and these are shown in Figure 3. These results indicate the importance of transient phenomena in total particulate emissions.

Figure 4 provides a comparison of NO_X emissions, which vary considerably between burners. The units with the strongest combustion gas recirculation (SR & LA) show the most potential for NO_X emissions reduction. As an example of the work on soot deposition, Figure 5 shows the effect of excess air on fouling rates (deposition) during steady-state tests for the retention head (CR) and the air-atomized burner (AB). Figure 6 shows the effect of fuel sulfur content on deposition rates. Generally this work points out the great importance of sulfuric acid corrosion in the fouling process. To achieve improved performance this can be minimized through fuel selection, burner design, and operating mode.

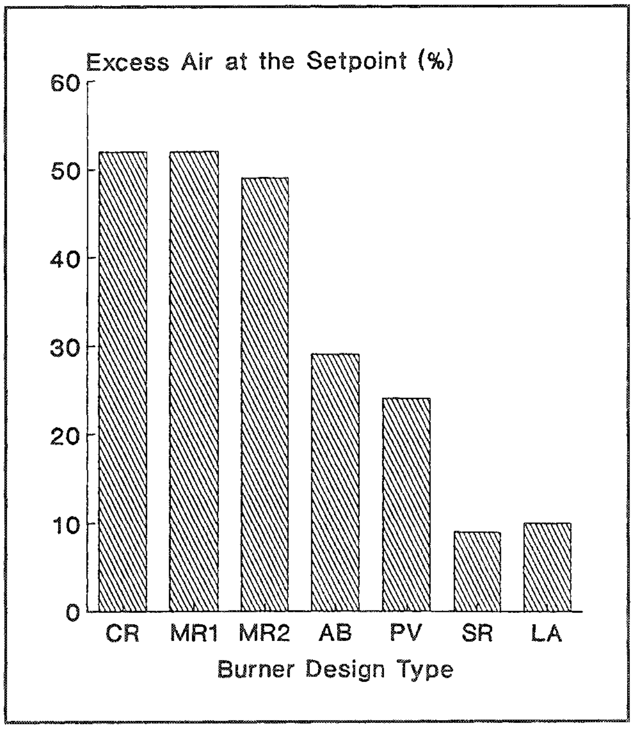

Figure 1. Setpoint Excess Air Levels for all of the Burners

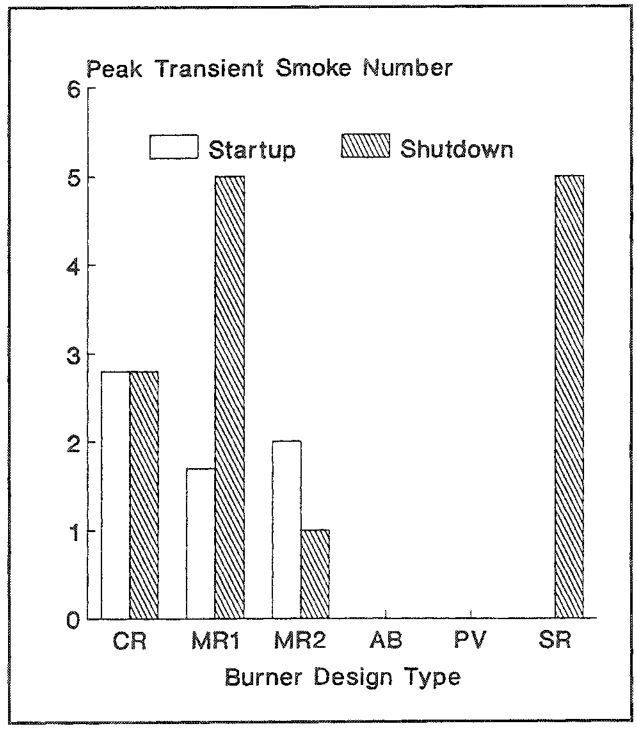

Figure 2. Magnitude of the Startup and Shutdown Smoke Peaks

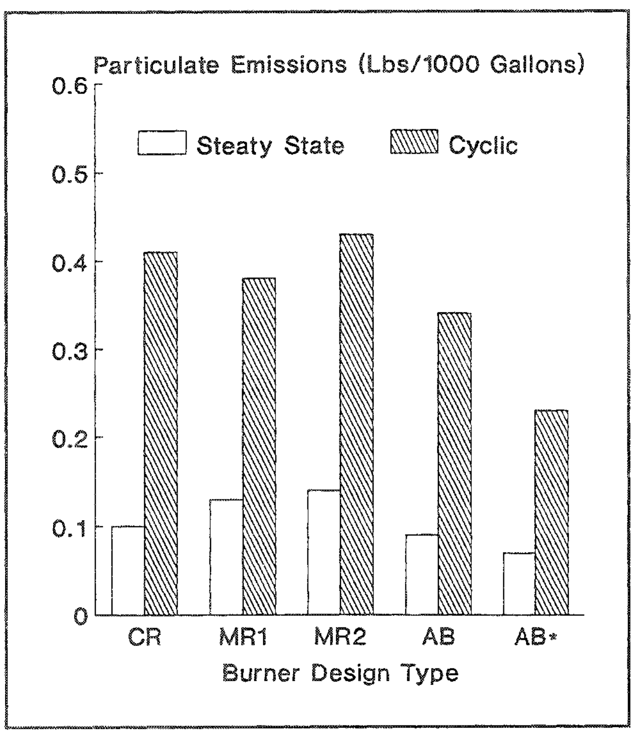

Figure 3. Particulate Emissions in Cyclic and Steady State Operation. Note text AB is at setpoint (30% excess air) and test AB is at high excess air (50%)

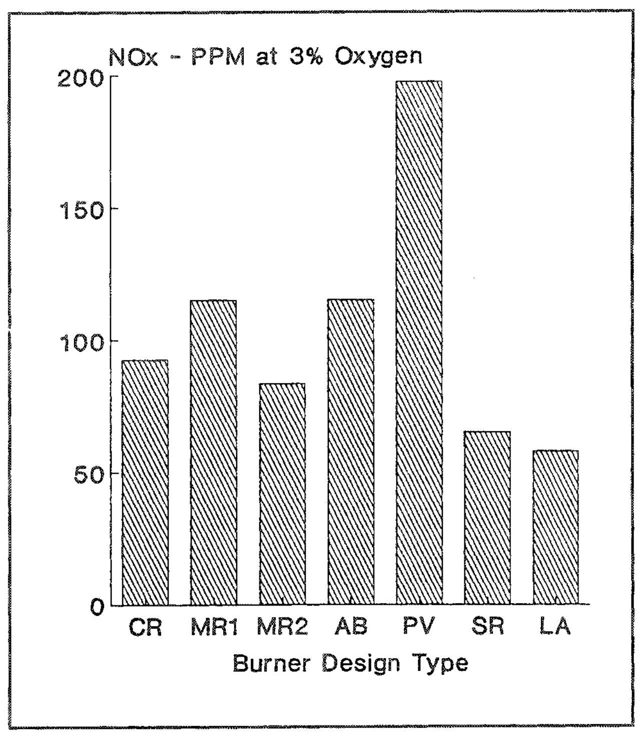

Figure 4. Comparison of Steady State NO_x Emissions

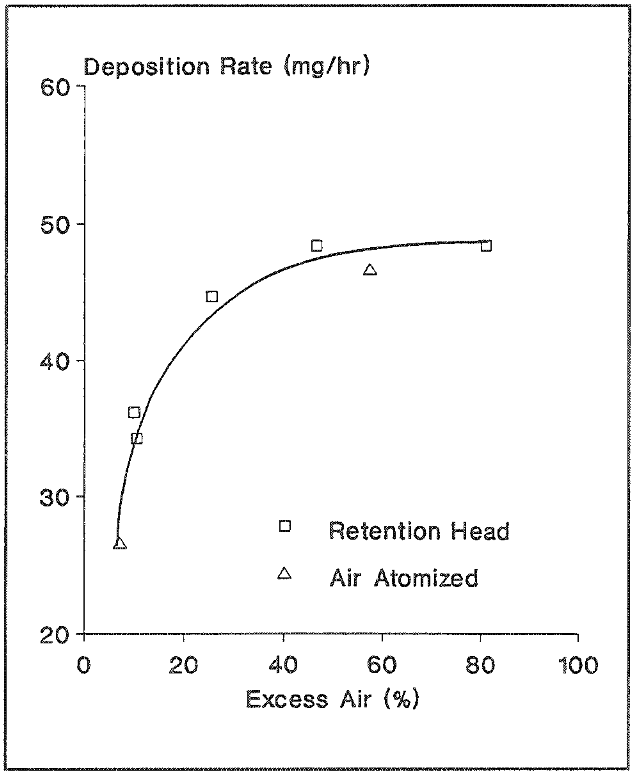

Figure 5. Effect of Excess Air on Steady State Fouling Rate for Two Burners

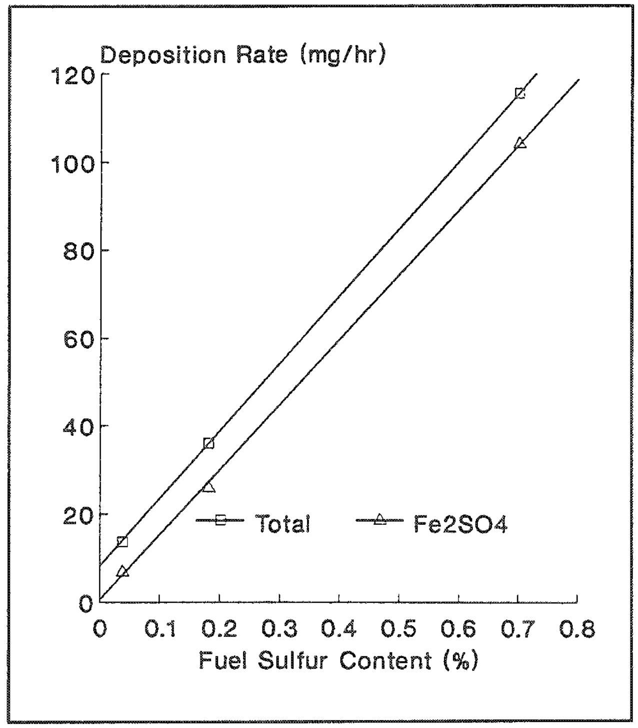

Figure 6. Effect of Fuel Sulfur Content on Deposition Rate at 25% Excess Air and Zero Smoke

Conclusions

Studies of comparative air-pollutant emissions and soot deposition rates in heat exchangers have been performed. Relative to conventional burners the advanced units offer lower excess-air capability, higher efficiency, less NO_X, and somewhat lower levels of particulates. The conventional burners tested were found to have much lower particulate emissions than indicated by the EPA emission factors for these sources. Residential oil burners generally, and modern equipment specifically, are not significant national emission sources. New oil burner designs which can operate with very low levels of excess air will significantly reduce or eliminate deposition and fouling of heat exchanger surfaces. There is also a strong correlation between sulfur content and deposition rates that indicates significant benefits can be obtained by shifting to low-sulfur (0.05% by weight) fuels.

Acknowledgements

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Reference

Krajewski, R., Celebi,Y., Coughlan, R., Butcher, T., and McDonald R. Brookhaven National Laboratory. Emissions Characteristics of Modern Oil Heating Equipment. July 1990, BNL-52249, Upton, New York.