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Project Summary

Bench-Scale Studies to Identify Process Parameters Controlling Reburning with Pulverized Coal

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The report addresses the evaluation of a technology which is a combination of two technologies used to control the atmospheric emission of NO_x by stationary sources: (1) combustion modification (controls flame temperature and maximizes fuel-rich residence time to minimize NO_x formation); and (2) flue gas cleaning (uses a reducing agent with or without a catalyst to remove NO_x from combustion products). The combined technology uses fuel as a reducing agent to remove NO_x. The process (referred to as in-furnace NO_x reduction, reburning, and staged fuel injection) can be applied to many types of combustion systems. In fact, reburning is the process which allows the "in-furnace NO_x reduction" to take place.

This Project Summary was developed by EPA's Air and Energy Engineering 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

This report summarizes the results of a small theoretical and experimental study which was undertaken as part of the EPA's Fundamental Combustion Research Program to investigate in-furnace NO_x reduction (reburning). In simple terms, the reburning concept involves the use of a heat release zone (via staged fuel addition) to convert NO formed earlier in the main combustion zone into some form which will ultimately produce N_2. The process takes place in two discrete zones.

1. *NO Reduction Zone*. Here fuel is added to produce CH radicals which reduce part of the NO from the main combustion zone to N_2, HCN, and NH_3.
2. *XN Oxidation Zone*. Here the final combustion air is added and a percentage of the total fixed nitrogen (TFN) pool (HCN + NO + NH_3) and char nitrogen (if any) are oxidized to NO as the remaining fuel fragments burn to CO_2 and H_2O).

Thus, NO can produce N_2 in both zones and the key to reburning is to provide the species and temperatures which allow this to happen. The first zone forms N_2 but also converts NO into species which can also be converted to N_2 in the second zone.

Data Available

Figure 1 shows data obtained with coal firing, demonstrating the overall potential of the reburning concept (referred to as Mitsubishi Advanced Combustion Technology, or MACT). This figure also shows data obtained in the boiler simulator furnace (BSF) at Energy and Environmental Research Corporation. Both sets of data indicate that it is possible to achieve extremely low levels (50 ppm NO_x at 6% O_2) under ideal combustion conditions; in general, it has been possible to reproduce the Japanese results under similar test conditions in the U.S. However, the application of reburning to large-scale commercial systems in the U.S., burning a wide range of bituminous and low-rank coals, is not as simple as Figure 1 suggests. In the reburning process NO can produce N_2 in both zones and, to optimize the process, it is necessary to provide the species and temperatures which maximize the rate of N_2 formation. Some NO is reduced to N_2 in the first zone, but the remaining NO either remains as NO or is converted into species which are capable of being reoxidized in the second stage.

To investigate the optimization and application of reburning, experimental studies were conducted in two facilities: a 5.7 cm ID, 7.38 MJ/hr (2kW), back-fired, laboratory reactor firing doped gaseous fuels and a 15.2 cm ID, 73.8 MJ/hr (21 kW), tunnel furnace firing pulverized coal. The reburning fuels used in this investigation included propane, North Dakota lignite, bituminous coals from Utah and Alabama, and Australian coal.

Conclusions

The principal conclusions of the work relate to both the NO reduction zone and the XN oxidation zone.

NO Reduction Zone

1. The optimum rich-zone stoichiometry (SR_2) is approximately 0.9 because of the tradeoff between NO reduction and increased concentration of easily oxidizable N species. Figure 2 compares the data from several sources and attests to the consistency of the overall conclusion. At stoichiometries leaner than 0.9, the initial NO is not reduced as effectively perhaps because of a lack of CH radicals. At rich-zone stoichiometries below approximately 0.9, large amounts of TFN species (particularly HCN and NH_3) are produced and ultimately oxidized to NO in the final stage. As Figure 2 indicates, this problem is greatly enhanced with coal, where the reburning fuel nitrogen becomes more significant as additional reburning fuel is added.
2. The primary zone stoichiometry (SR_1) has little influence on the exhaust NO at the optimum reburning conditions. Increasing SR1 only slightly decreases effectiveness of the reburr concept in spite of a large incre in the available reactive nitroge the rich zone (due to increa reburning fuel).
3. The nitrogen content of reburning fuel has only a s effect on the reburning efficienc optimum combustion conditi but at lower rich-zone stoic metric ratios, it can be of m importance. Figure 3 shows obtained with doped prop flames and indicates that at zone stoichiometries be approximately 0.8, the nitrc content of the reburning fuel gr influences the effectiveness of reburning concept. This i particular importance becaus large-scale utility system w inevitably have a distributio rich-zone stoichiometries ac the combustion chamber in reburning zone.
4. The effectiveness of rebur depends strongly on

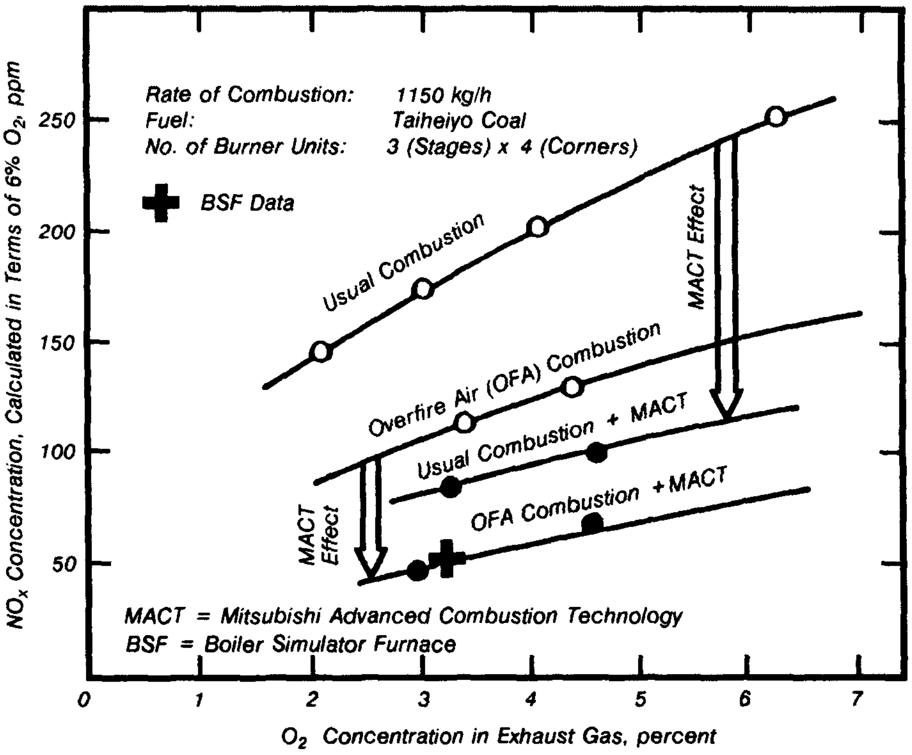

***Figure 1.** NO_x removal effect for coal firing.*

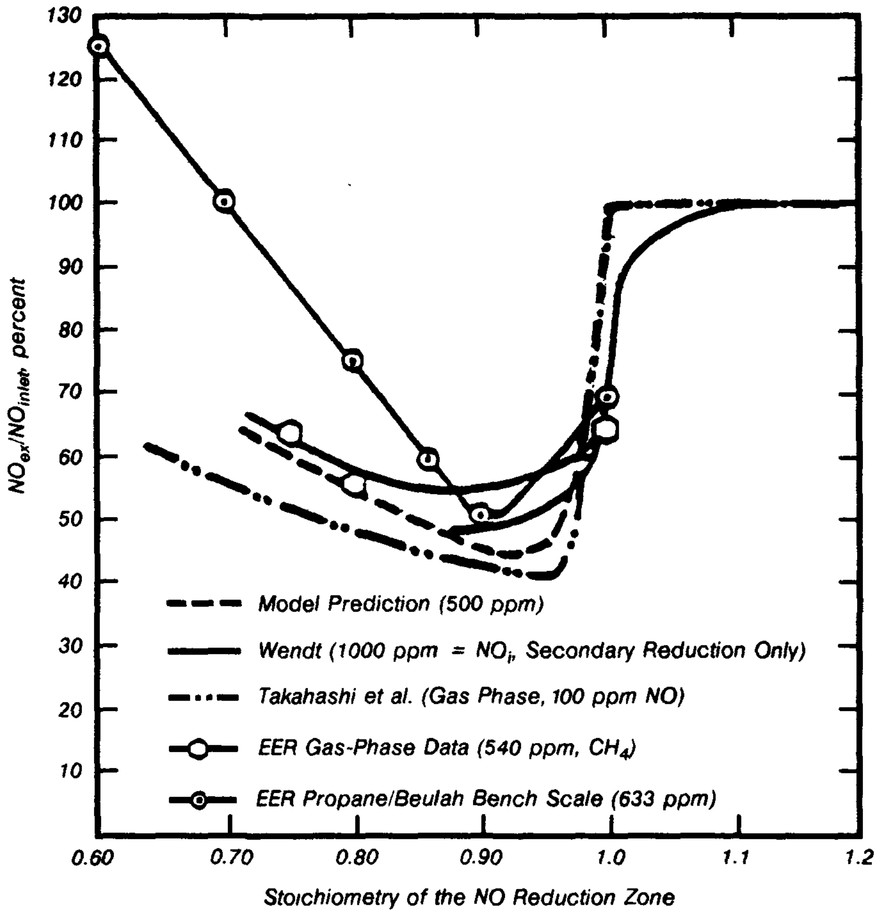

Figure 2. *Effectiveness of reburning--subscale data.*

relationship of the initial NO concentration to the amount of reburning fuel nitrogen added to achieve an overall rich-zone stoichiometry of 0.9. Figure 4 shows that, even with optimum combustion conditions at low initial NO levels, reburning may actually increase exhaust NO emissions. With an initial NO level of approximately 150 ppm and a typical coal as the reburning fuel, the reactive nitrogen available in the *rich zone increases almost* fivefold when the reburning fuel is added to acheive an overall stoichiometry of 0.9.

5. Coal composition is important because it influences char burnout, the initial NO level, and the freburning fuel nitrogen content and speciation. Many coals commonly used in the U.S. for power generation may prove to be relatively unsuitable for reburning, particularly in retrofit applications, because it will not be possible to effectively burn out the coal char in the available time.

XN Oxidation Zone

1. The TXN (total fixed nitrogen, including char N) conversion depends on the XN speciation, the XN concentration, the hydrocartbon content at the rich-zone exhaust, and the thermal environment.
2. Low XN conversions can be achieved by tailoring the temperature profile to obtain selevtive reduction of NO by NH_i species in the final, oxygen rich stage. Figure 5 summarizes the results obtained in the tunnel furnace and shows the dramatic influence of thermal environment on the effectiveness of the reburning concept for two initial NO levels. This effect is believed to be directly related to a large decrease in the TFN conversion in the final stage of the reburning process.

In summary, the overall processes controlling the reburning phenomena have been relatively well-identified and characterized. Although the elementary reactions are not fully understood, the key parameters have been identified and the overall mechanisms defined. Further work could define the influence of mixing rates and establish the potential impacts of applying reburning to boilers and furnaces.

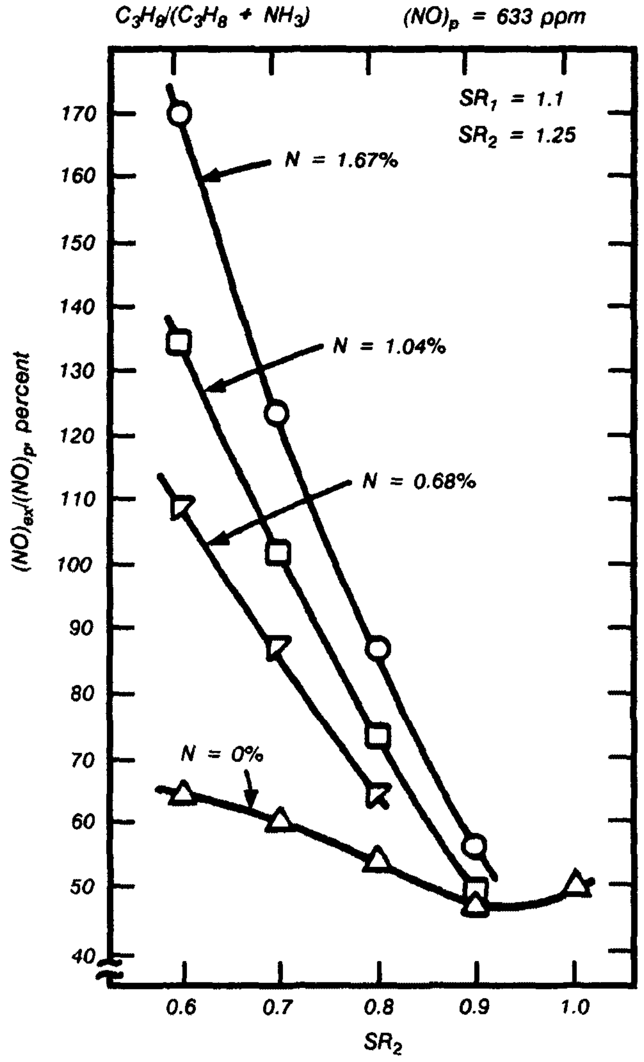

Figure 3. Effect of SR_2 and reburning--fuel nitrogen content (tunnel furnace).

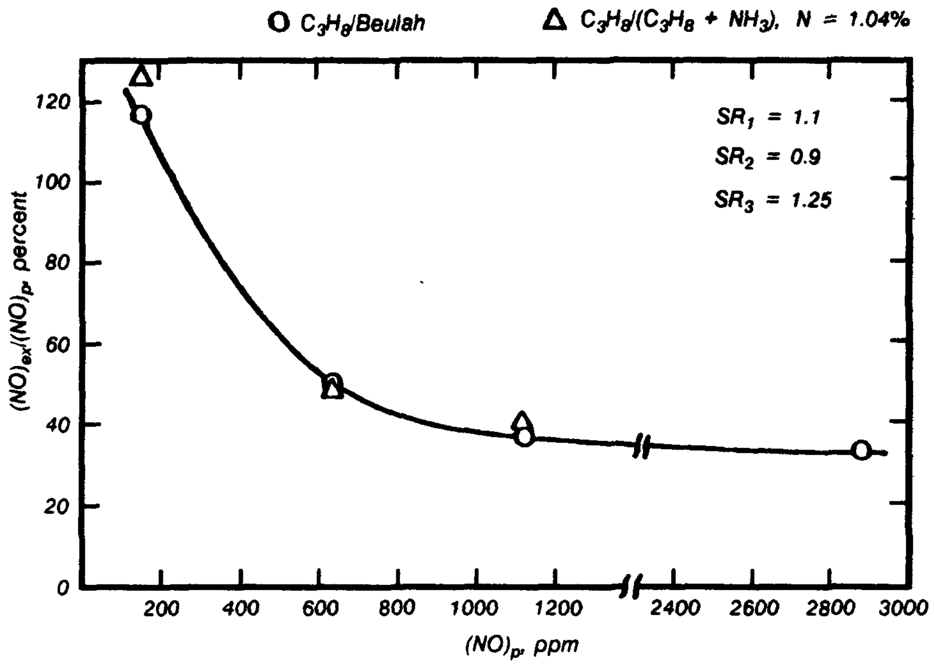

Figure 4. Influence of reburning fuel type and primary NO level.

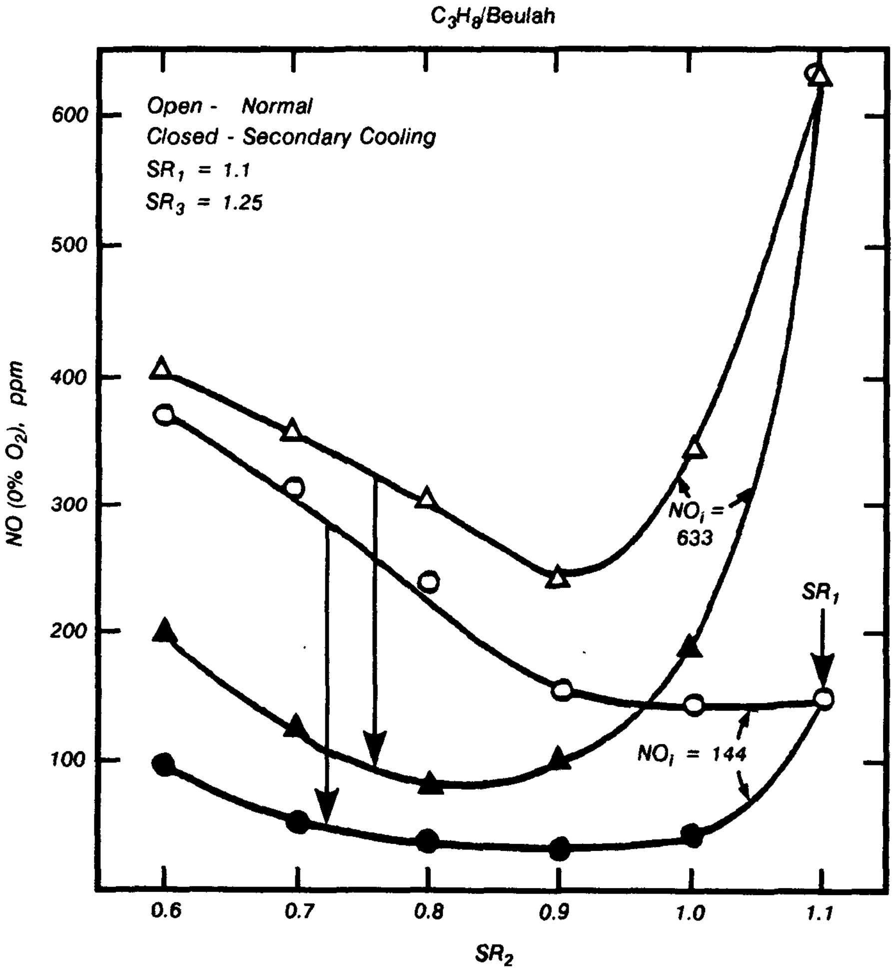

Figure 5. Effect of secondary cooling on exhaust NO emissions.

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***W. Steven Lanier** is the EPA Project Officer (see below).*

The complete report, entitled "Bench-Scale Studies to Identify Process Parameters Controlling Reburning with Pulverized Coal," (Order No. PB 89-200 810/AS; Cost: $21.95, subject to change) will be available only from:

National Technical Information Service
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