



Project Summary

Use of Sorbents to Reduce SO₂ Emissions from Pulverized-Coal Flames Under Low-NO_x Conditions (Progress Report)

P. Case, M. Heap, J. Lee, C. McKinnon, R. Payne, and D. Pershing

This summarizes a special progress report that describes data obtained to date under an EPA contract concerned with the use of dry sorbents to reduce sulfur oxide (SO_x) emissions when pulverized coal is burned under conditions which limit the formation of nitrogen oxides (NO_x). The full report both summarizes the data obtained to date, and assesses their significance. However, readers should bear in mind the preliminary nature of the data.

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).

The Problem

Metallic oxides form sulfates under combustion conditions. The goal of this program is to ascertain whether calcium containing sorbents (or other suitable materials) can be used in economic quantities to provide combined NO_x/SO_x control for pulverized-coal-fired boilers without reducing boiler availability. Previous studies with dry limestone injection into utility boilers were not very encouraging. This was attributed to a combination of deadburning and non-uniform distribution of the limestone in the boiler. Early tests were carried out with pre-NSPS high-turbulent burners;

however, when pulverized coal is burned under low-NO_x conditions, peak flame temperatures are reduced and there are enlarged fuel-rich zones. These differences, together with injecting the sorbent with either the staged air or the coal to ensure even distribution, could provide conditions which are conducive to sulfur capture by dry sorbents.

The Approach

Two parallel investigations are underway at different scales to determine whether it is possible to effectively control NO_x and SO_x emissions from pulverized-coal-fired boilers using low-NO_x burners and sorbent injection:

- Bench-scale investigations are being conducted using a boiler simulator furnace (BSF) to determine the phenomena controlling sulfur capture in pulverized-coal flames. In addition, these studies will provide information on the impact of sorbent injection on slagging and fouling.
- Pilot-scale investigations are involving full-scale low-NO_x coal burners tested in an environment designed to simulate the burner zone heat release rate of the small utility boiler being used as the host for the demonstration of EPA's low-NO_x coal burner. The intention is to conduct a program in which the results of the bench-scale studies can be readily transferred to pilot-scale and any anoma-

lies encountered at pilot-scale can be investigated cost-effectively at bench-scale.

Results

Figure 1 summarizes data obtained to date in the study at both scales. Data have been obtained with the EPA prototype at 70×10^6 Btu/hr burning two coals: a low-sulfur (0.6%) Utah coal, and a medium-sulfur (2.5%) Indiana coal. Sulfur capture, as expected, is dependent on coal sulfur content: for the Indiana coal, captures of 50% were possible at full load with calcium-to-sulfur molar ratio of 2. Figure 1 also shows the range of sulfur captures obtained in the BSF for the Indiana coal with the same sorbent used in the pilot-scale studies, a commercial calcium carbonate. The parameters which caused this wide range in captures were: heat extraction in the radiant zone, load, and tertiary (staged) air velocity.

Future Work

The bench-scale studies have been in progress for 3 months, and initial screening studies will be completed within 6 months. These studies will determine the influence of: fuel-rich conditions, detailed temperature history, coal-type, and sorbent type/size.

During this time, pilot-scale studies will be mainly concerned with tests at higher firing densities. After the controlling parameters have been defined by these screening studies, more detailed measurements will be made to enable the results to be explained and to determine whether high captures can ever be obtained in real boilers.

Although coal is the most abundant U.S. source of fossil fuel energy, its use poses several serious problems for society. Mining coal, either from deep or surface mines, involves environmental, safety, and health considerations. Once coal is mined, problems associated with transportation, storage, and energy conversion must be faced. In the foreseeable future, coal will be used primarily for the generation of electricity in thermal power plants which burn coal in suspension after it has been pulverized. Coal is not a pure hydrocarbon, and the impurities can give rise to the generation of atmospheric pollutants when it is burned. Assuming an efficient combustor, atmospheric pollutants are produced from the impurities in coal: nitrogen, sulfur, and inorganic material. The inorganic material forms

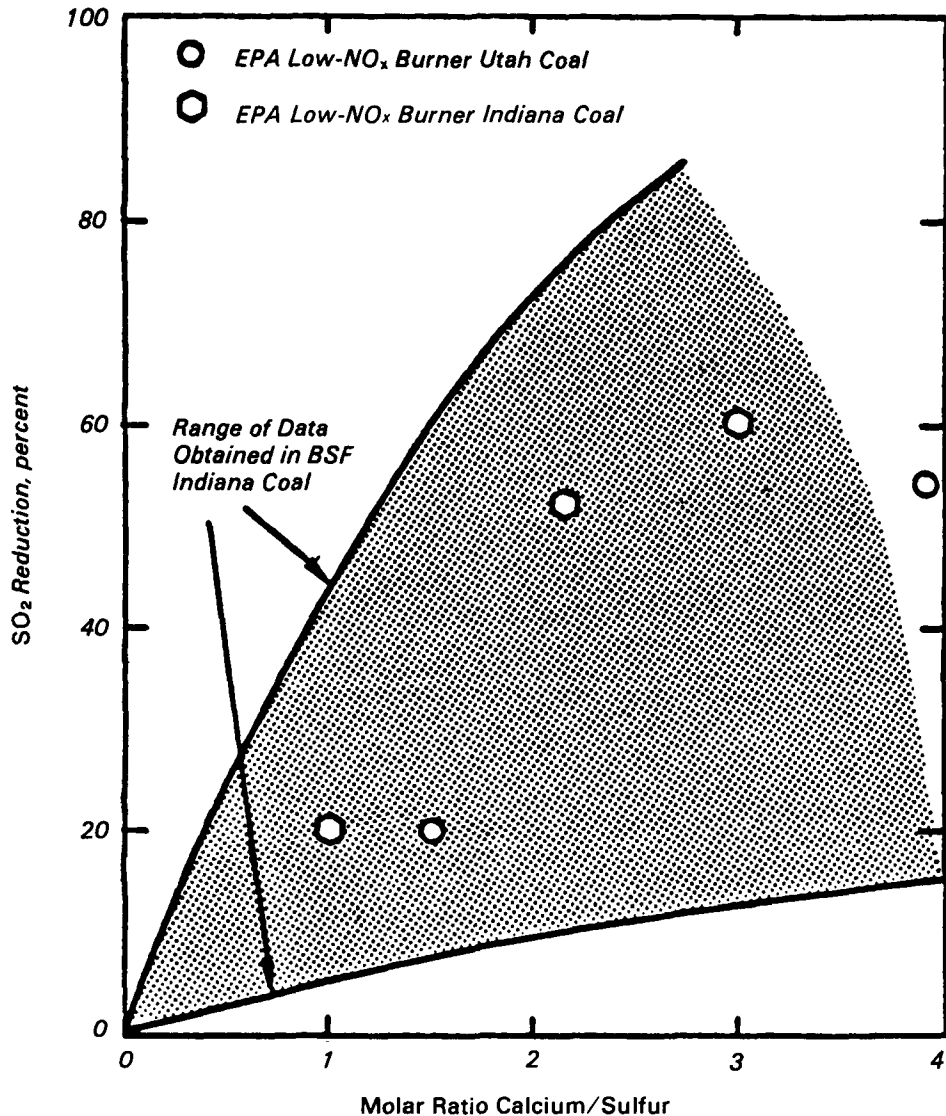


Figure 1. Summary of data from this study using Vicron (CaCO_3) as the sorbent.

fly ash, some of which is deposited in the boiler, but the major portion must be removed in a precipitator or baghouse. Nitrogen and sulfur give rise to oxides (NO , NO_2 , SO_2 , SO_3) which are themselves pollutants, and they may also contribute to the acid rain problem since they are precursors for the formation of nitrates and sulfates.

There are four approaches to the problem of reducing the emission of SO_x and NO_x resulting from the combustion of pulverized coal:

1. Removal of the offending species from the coal. Nitrogen and some of the sulfur is bound in the organic coal matrix. Therefore, physical cleaning techniques which reduce coal ash levels reduce coal sulfur concentra-

tions by removing pyrite, but have minimal impact on coal nitrogen content. Conversion of the solid fuel into clean gaseous (or relatively clean liquid) fuels is potentially more effective (but more costly) for reducing both fuel-bound sulfur and nitrogen.

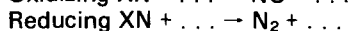
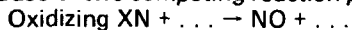
2. Removal of the pollutant species from the products of combustion. Flue gas treatment techniques are available to remove both NO_x and SO_x before the products of combustion are emitted into the atmosphere. Although available, these techniques increase the complexity of power plants and the cost of power generation.
3. Fuel blending. High- and low-sulfur

fuels can be mixed to reduce SO_x emissions; e.g., coal/oil mixtures and coal blending.

- Prevention of the formation of gaseous pollutants. NO_x emissions can be reduced by limiting flame temperatures and controlling oxygen availability in the initial heat release zone. SO_x emissions can be reduced by retaining sulfur as part of the solid effluent. Thus, there is the potential to prevent the formation of gaseous pollutants by optimizing conditions in the heat release zone.

This report describes a series of pilot-scale experiments which were designed to provide information on this final approach: the use of sorbents to reduce SO_x emissions under combustion conditions which also minimize NO_x formation.

NO_x emissions from pulverized-coal-fired power plants are due primarily to the oxidation of fuel-bound nitrogen which is partitioned between the volatile and char fraction when coal is decomposed. The fractional conversion of gaseous nitrogen specie (XN) to NO is controlled by oxygen availability because of two competing reaction paths:



In addition, an optimum gas-phase stoichiometry (about 70% theoretical air) maximizes N₂ production by the second path. In contrast, little is known about the oxidation of nitrogen in the char other than under oxidizing condi-

tions conversion to NO is low but finite. NO_x is also formed by the fixation of molecular nitrogen. This formation path can be restricted by limiting flame and bulk gas temperatures since the rate of fixation is very strongly dependent on temperature. Thus NO_x formation in pulverized-coal flames can be reduced by modifying the combustion process to ensure that the coal reacts initially in an oxygen deficient region and that peak flame temperatures are limited. This can be achieved by dividing the furnace into a fuel-rich and an oxidizing burnout zone. An alternative approach, one that is being supported by the EPA, uses burner design and outboard staged-air ports to provide a flame with a fuel-rich inner core with a complete oxidizing envelope.

For solid-fuel combustion, sulfur in the fuel does not necessarily convert quantitatively to SO₂/SO₃ in the combustion products. Coals with high alkali metal oxides contents retain significant amounts of sulfur in the ash as sulfates. Thus, there is the potential to mix a sorbent with the fuel either prior to or during combustion which will capture gaseous sulfur species and reduce the emissions of SO₂ because some of the sulfur will be removed in the particulate collector as a solid. Figure 2 is a schematic of a combined NO_x/SO_x control system applied to a pulverized-coal-fired power plant. Coal is fired in low-NO_x burners to minimize NO_x emissions, and SO_x emissions are

reduced by a combination of in-furnace capture and downstream cleanup. The sorbent could be:

- Mixed with the coal prior to the pulverizer, or mixed with the coal after grinding and fed to the furnace through the burner.
- Mixed with one of the combustion air streams (secondary or tertiary staged air) and then injected into the furnace.

The addition of sorbent will increase the total solids loading in the furnace and can also cause problems due to slagging and fouling. In Figure 2, a dust collector downstream of the air heater will remove a large fraction of the sorbent which will then be used in a wet or dry contactor to further reduce flue gas SO₂ content.

Figure 3 places the results obtained to date in perspective with other pilot-scale studies. Data are compared from the bench- and pilot-scale tests and data obtained with Steinmuller in a refractory tunnel furnace with an approximate firing rate of 10 x 10⁶ Btu/hr. The data shown in Figure 3 for the BSF represents data obtained with heat extraction in the radiant zone. This figure shows similar captures for various scales; however, it fails to answer two basic questions: (1) What factors will allow data generated at one scale to be interpreted in terms of another scale? and (2) Are these captures possible in real systems?

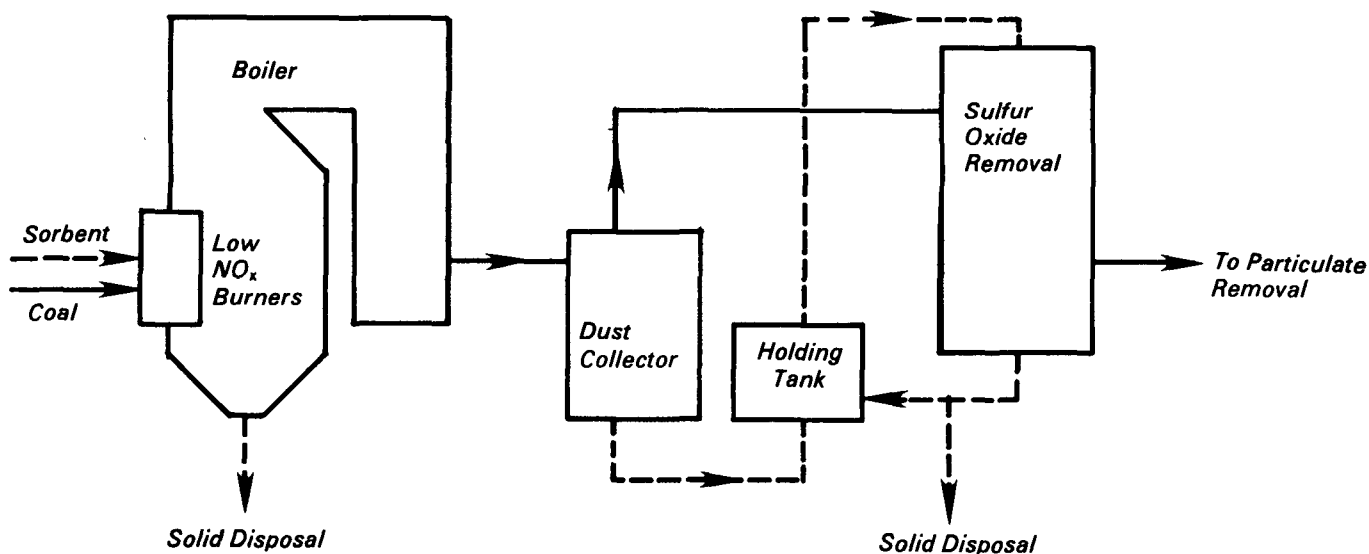


Figure 2. Combined NO_x/SO_x emission control for pulverized-coal-fired boilers.

- LWS
 ○ Prototype Burner - Indiana Coal
 ○ Prototype Burner - Utah Coal
 ◇ Steinmuller Burner - Indiana Coal
- BSF
 △ Indiana Coal
- IFRF (Steinmuller Burner)
 ▲ 1.09% S Coal
 ■ 2.42% S Coal

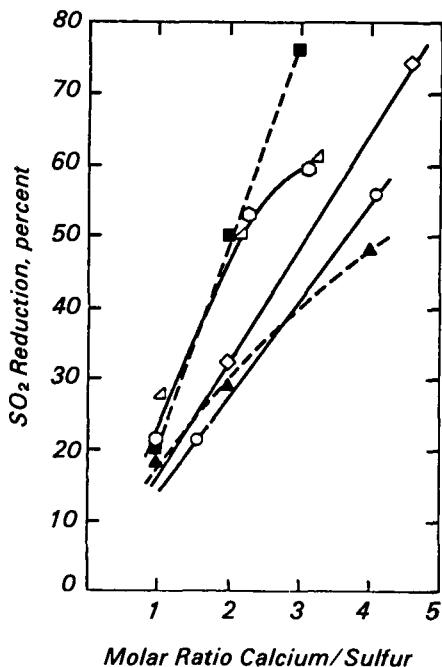


Figure 3. Summary of pilot- and bench-scale data.

Since this is a progress report, it is inappropriate to draw conclusions from a study that is in its infancy. Data have been obtained which show that calcium utilization efficiencies of 25% are possible if the thermal history of the

sorbent is controlled. However, the data obtained to date are limited. The bench-scale studies have not investigated conditions which would allow reactions involving H_2S to become important. The studies have been exclusively cause and effect: no information has been gathered which will explain the observables. Information is required on:

- Sorbent particle temperature as a function of time.
- Sorbent residence time distribution in the radiant furnace.
- Sorbent reactivity as a function of time.
- Gas-phase sulfur speciation and concentration (i.e., related to sulfur evolution from the coal).
- The form of the calcium/sulfur solid (sulfate, sulfide, or sulfide coated with sulfate).
- Decomposition of the sulfide or sulfate producing SO_2 .

This type of information will be obtained after the bench-scale screening studies to determine the effect of fuel-rich conditions, thermal environment, sorbent type, and coal type have been defined.

Further work at pilot-scale must be limited to screening studies which will concentrate mainly on the impact of thermal environment. The EPA burner will be fired in a test tunnel which has a much higher exit temperature and gives total thermal histories which approximate those used in the IFRF studies and in real boilers.

The preceding discussion does not address the impact of sorbent addition on boiler operability. Even though sorbent injection could be used to reduce SO_x emissions, it would be an unacceptable technology if it seriously impaired boiler availability or increased the cost of other pollution control equipment. Thus, further work is needed to assess the impact of sorbent addition on: slagging, fouling rates and the nature of the deposit (i.e., if it can be removed by soot blowers), furnace exit temperatures, and precipitator efficiency.

Even though the results obtained to date are preliminary, they do indicate that the technology is sufficiently promising to warrant more detailed study to establish the precise conditions under which it can be applied in practice.

P. Case, M. Heap, J. Lee, C. McKinnon, R. Payne, and D. Pershing are with Energy and Environmental Research Corp., Santa Ana, CA 92705.

Dennis C. Dreihmel is the EPA Project Officer (see below).

The complete report, entitled "Use of Sorbents to Reduce SO_2 Emissions from Pulverized-Coal Flames Under Low- NO_x Conditions (Progress Report)," (Order No. PB 83-131 045; Cost: \$11.50; subject to change) will be available only from:

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 5285 Port Royal Road
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The EPA Project Officer can be contacted at:
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