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Project Summary

An Evaluation of the E-SO_X Process on the EPA Pilot Electrostatic Precipitator

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The E-SO_x Process makes use of an electrostatic precipitator (ESP) for combined sulfur dioxide (SO_2) removal and particulate collection. The concept of spray drying is introduced to the inlet and/or first section of the ESP in which electrical components are removed. Because of the many ESPs at coal-fired power plants, the process is well suited to retrofitting. The work described in this report was a small pilot-scale evaluation of the process to obtain the information needed to undertake a planned 5 MWe field pilot demonstration. The results from this evaluation indicate that a 50 - 60% removal of SO_2 at a calcium to sulfur ratio of 1.2 - 1.4 can be obtained. Furthermore, this reduction in SO_2 can be achieved without degrading the particulate emissions even though the process requires a reduction in the collecting surface of the ESP. The utilization of a temperature-controlled electrode precharger to compensate for loss of collecting surface is also described.

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

E-SO_x is a retrofit process for coal-fired boilers, which combines in a single unit electrostatic precipitator (ESP) technology for collecting particles and spray dryer technology for sulfur dioxide (SO_2) removal. The process uses a modified existing ESP equipped with an auxiliary system for preparation and injection of a lime slurry into the ESP. The front end of an existing ESP is converted to a spray chamber where contact is made between gaseous SO_2 and lime slurry droplets. Water also evaporates in this converted section of the ESP so that the reaction product, excess lime, and fly ash that enter the remaining portion of the ESP are sufficiently dry for efficient ESP operation. A dry solid waste product containing reaction products, unreacted lime, and fly ash is collected. That portion of the ESP not converted to a spray chamber is left with electrical components intact to operate as a particle collector. However, to provide the contacting chamber sufficient space for a finite drying time of 1s or greater, the ESP will lose 25 to 30% of its collector plate surface. At the same time, the particulate load will increase by a factor of 3 or more. This particulate, a large fraction of which is calcium based, has an extremely high electrical resistivity at normal ESP operating temperatures. The sorbent reaction with SO_2 will eliminate the effects of sulfur trioxide (SO_3) that would lower this resistivity. On the other hand, lowering the gas temperature by the water spray will more than compensate for resistivity increases due to ash composition. Advanced ESP technology to aid in maintaining good particulate collection performance is available for E-SO_x retrofitting if required. Cooled pipe precharging, for example, can be introduced in retrofit ESPs to compensate for less collector surface or changes in resistivity characteristics of the particulate.

The concept of E-SO_x appears to offer an attractive option for acid rain mitigation. An economic evaluation of E-SO_x based on reasonable rates of SO_2 removal and lime utilization has indicated that it can be cost effective. A large pilot-plant evaluation is underway at Ohio Edison's Burger Station sponsored by the U.S. Environmental Protection Agency (EPA) and the Ohio Coal Development Office. Preparation for that pilot plant evaluation started in 1987 and the actual testing is being carried out in 1989. This report covers work that was performed in-house at EPA to verify the original results and to define the parameters that control SO_2 removal. The work reported was completed and the technology transferred for use in starting up the field site evaluation.

The E-SO_x concept raises two fundamental questions which can be answered only by experiment. The first question concerns the feasibility of removing substantial SO_2 by contacting the rapidly moving gas with slurry droplets and drying the droplets within the space of one ESP section. The second question has to do with maintaining an acceptable level of ESP performance under a reduced collector area and an increased particulate loading. The results of experiments to partially answer these questions are reported here.

Test Facility

All the experiments were conducted in the ESP pilot-plant located at EPA's Air and Energy Engineering Research Laboratory (AEERL). The pilot-plant consists of a four-section, single-lane ESP operating at a flue gas capacity equivalent to 0.47 m^3/s*.Outside air is heated to 149°C by a natural gas heater. Gaseous SO_2 is injected into the heated air to the desired concentration (usually 1,500 to 2,500 ppm) to simulate burning of moderately high sulfur coal. The ESP is operated under about 0.5 kPa negative pressure so that no SO_2 is released to the room. Fly ash is aspirated counter currently into the simulated flue gas stream just before the cocurrent injection of the lime slurry. Lime slurry containing 10 - 20% solids is pumped through a spray nozzle designed to provide an oval spray pattern in the 1.27 x 0.381 m contact chamber. The atomized slurry droplets have a 1.5 - 2 s residence time in the chamber to evaporate most of the water. The evaporation causes a flue gas temperature drop and results in a relatively dry, powder-like product which contains the unused lime, the absorbed and reacted SO_2, and fly ash. The spray chamber consists of the entrance section and the first of four ESP sections with all the electrical internals (i.e., discharge electrodes) removed. The electrical configuration of the ESP is flexible but, for most experiments reported, two cold pipe prechargers were used: one in the connecting space between sections 1 and 2 and one between sections 3 and 4. Conventional wire-plate electrodes were assembled in sections 2 and 4.

*Readers more familiar with nonmetric units may use the conversion factors at the back.

Summary of Results

The primary objectives of the E-SO_x experiments carried out at EPA using the 0.47 m^3/s modified pilot ESP were to verify E-SO_x as a competitive retrofit process for SO_2 removal and to determine the critical parameters which influence the degree of SO_2 removal. Once the critical factors were determined, they could be adjusted within limitations of the process to give the best conditions for SO_2 removal and sorbent utilization. To meet these objectives, experiments were planned to investigate impacts of indirect variables as well as those directly influencing the lime slurry/SO_2 reaction.

SO_2 Removal Dependence on Critical Factors

A number of tests were performed in which only concentration and rate of injection of slaked lime were varied. In essence, this permitted an examination of the effect of the two most critical parameters on SO_2 removal; the temperature of approach to saturation ($\Delta T_A S$) and the stoichiometric ratio of calcium to sulfur (Ca/S) in the slurry/gas mixing. When other parameters are held constant, including spray chamber geometry, gas flow rate, SO_2 concentration in the gas, and the inlet gas temperature, these injection parameters can be manipulated to give a $\Delta T_A S$ and Ca/S combination. There is a lower limit on $\Delta T_A S$ for adequate droplet drying and an upper limit on the solids concentration for consistent spraying. The fixed conditions are listed in Table 1.

Table 1. *E-SO_x Fixed Conditions for SO_2 Removal Studies*

Air Flow	28 m^3/min
Inlet temperature	149°C
SO_2 concentration	2000 ppm
Fly ash concentration	1.9 g/l
Nozzle configuration	Single two-fluid CasterJet oval spray pattern
Inlet chamber	1.5 m spray chamber plus 1.2 m ESP section

The removal of SO_2 as a function of approach temperature for various stoichiometric ratios is shown in Figure 1. This correlation between approach to saturation and SO_2 removal shows that good removal is possible at very low stoichiometric ratios, but only at very close approach temperatures. At these close approaches the droplets are not completely evaporated and excess moisture will pass into the ESP. The lower practical $\Delta T_A S$ is believed to be between 16 and 17°C. Stoichiometric ratios of 1.3 to 1.4 produced a removal of 50% or better at a 17°C approach to saturation. Results indicate a marginal improvement in SO_2 capture at a ratio of 1.4. The leveling off of removal rate with increasing Ca/S is also reflected in the plot of percent removal as a function of Ca/S in Figure 2.

Particulate Removal

The second fundamental question about E-SO_x as a retrofit concerns maintenance of an acceptable level of particulate removal. In conjunction with the SO_2 removal testing, the ESP electrical configuration was varied to determine effects of the increased load and change in characteristics of the particulate matter collected by the ESP. With sections 2, 3, and 4 energized and containing 0.32 cm wires, the ESP has an 18.8 s/m (96 SCA). With only two of the sections energized, the ESP was reduced to 12.5 s/m (64 SCA). Cold pipe prechargers, between sections 1 and 2 and between 3 and 4, could be activated, but the SCA would remain the same. The data in Table 2 °show that high mass efficiencies were obtained during a 4-fold increase in particulate loading and a 50% reduction in the SCA. There appears to be no significant change in efficiency with the amount of particulate as long as some moisture is present. The ESP

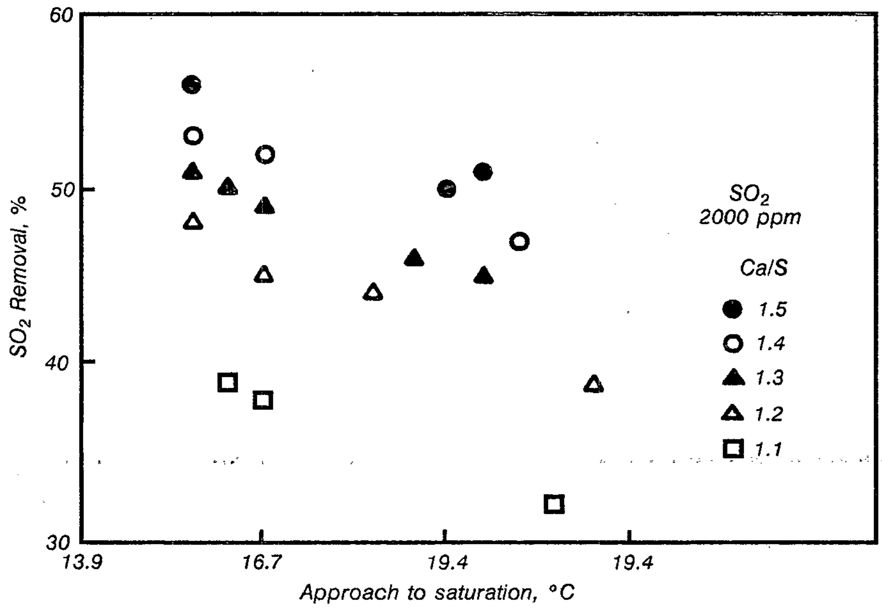

Figure 1. *Effect of approach temperature on SO_2 removal at several stoichiometric ratios.*

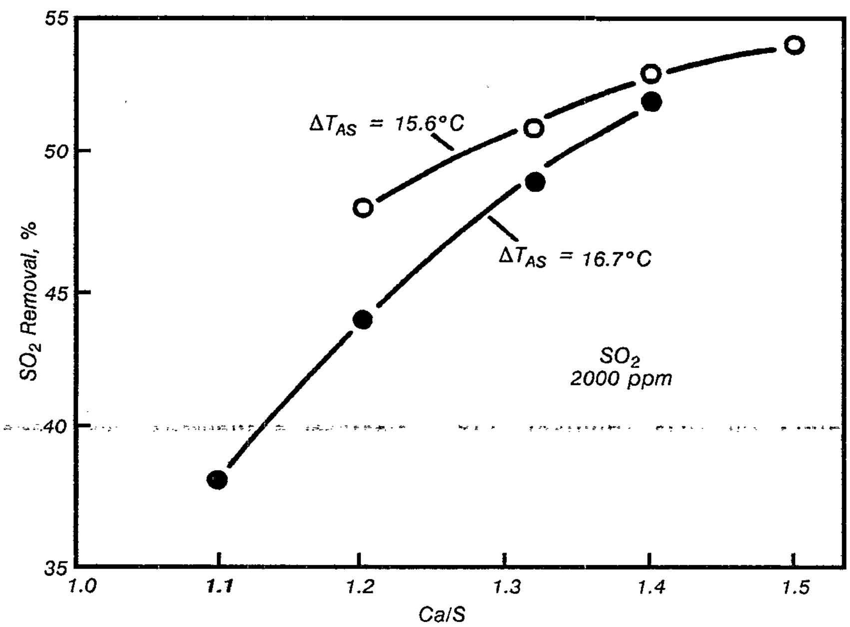

Figure 2. *Effect of stoichiometric ratio on SO_2 removal at two approaches to saturation.*

emission rates listed in Table 2 also indicate that under E-SO_x conditions the ESP can meet or exceed the NSPS standard of 43 ng/J. For fly ash only, the efficiency was reduced severely without moisture addition. In this case, the 38 kV could be maintained on the cold pipe precharger, but not on the wires because of back corona. Evaporation of water during the drying step lowers the temperature which accounts for the low resistivity of the lime sorbent/fly ash mixture in the E-SO_x process. As a consequence of the low resistivity, back corona is not a problem.

Future Work

The primary immediate E-SO_x follow-up will occur at the Burger Plant of Ohio Edison where the EPA, Ohio Coal Development Office (OCDO), Babcock & Wilcox Research Division and Southern Research Institute are evaluating the process. The evaluation is being carried out in a 5 MWe pilot ESP which is connected by a slipstream off of the main ducts between the boilers and the plant ESP. The work plan at this site has been designed to verify the SO_2 removal results and the ESP efficiencies that have been obtained in the in-house process and reported here. The work, having been done on a larger unit, should provide experience in design that will be more meaningful for a full-scale demonstration. The pilot evaluation is slated for completion in late 1989 with results to be reported in the spring of 1990.

Table 2. E-SO_x Particulate Removal Efficiencies for Various ESP Electrical Configurations

Sections Energized 38 kV	Cold Pipe 38 kV	Approach Temperature (°C)	Particulate	ESP Efficiency (%)	Emission Rate (ng/J)
2, 3, 4	Yes	17	E-SO_x & fly ash	99.5	7.319
2, 3, 4	No	17	Fly ash	97.9	13.776
2, 3, 4	No	17	E-SO_x & fly ash	98.5	12.915
2, 3	No	17	E-SO_x & fly ash	98.6	37.884
2, 3	No	19	Fly ash	95.6	24.969
2, 3, 4	No	56	Fly ash	97.6	12.915
2, 3, 4	Yes	56	Fly ash	97.8	16.359
2. 3. 4	Yes	89[a]	Fly ash	89.0	55.104

[a]No moisture injection

NONMETRIC EQUIVALENTS

Readers more familiar with nonmetric units may use the following conversion factors:

Metric	Multiplied by	Yields nonmetric
°C	9/5 x °C + 32	°F
°C (app to sat.)	9/5 x °C	°F (app to sat.)
cm	0.394	in.
g/l	0.526	gr/ft^3
kPa	4.00	in. H_2O
m	3.28	ft
m^3/s	2128	cfm
MWe	3000	acfm
ng/J	0.0023	lb/10^6 Btu

The EPA author, **Louis S. Hovis**, also the EPA Project Officer (see below), is with Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711.

The complete report, entitled "An Evaluation of the E-SO_x Process on the EPA Pilot Electrostatic Precipitator," (Order No. PB90-216 441/AS; Cost: $17.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:
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