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Project Summary

Effects of Sorbent Injection for Sulfur Dioxide Removal on Particulate Control Systems for Coal-Fired Boilers

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Various studies were undertaken to quantify the effects of dry SO_2 sorbent injection on ESP operation with a coal-burning utility boiler. The specific dry sorbent operation of interest was EPA's LIMB process. The combination of spent sorbent and fly ash has a higher resistivity, a higher mass concentration, and a finer particle-size distribution than the ash alone; all of these factors diminish the effectiveness of ESP. Also investigated was chemical conditioning to reduce the resistivity concern, the only one of the three concerns stemming from sorbent injection that can be readily mitigated. Other topics studied were: the recycle, disposal, and utilization of waste ash-sorbent mixtures; the selection and modification of sorbents to improve SO_2 capture in the furnace; and the reactivation of spent sorbent by humidification to achieve supplemental post-furnace capture of SO_2.

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

Limestone Injection, Multistage Burners (LIMB) is being developed by EPA as a way to control SO_2 emissions from coal-fired boilers. This technology is one of several based in dry-sorbent injection that are expected to be adaptable in retrofit applications to boilers that predate new-source performance standards. It provides only partial reduction of SO_2 emissions at economical operating costs; however, it requires a lesser capital investment than more efficient conventional processes, such as wet scrubbing, and is thus a candidate for application where old boilers continue in service.

One concern in implementing LIMB technology is the difficulty introduced in maintaining acceptable levels of particulate emissions. The concentration of suspended solid matter that must be removed is greatly increased; moreover, the fraction of the solids consisting of small particles (and thus especially difficult to remove) is substantially increased. These changes in suspended solids will have unfavorable consequences in any particulate-control device. Their impact is most serious, however, in terms of the performance of electrostatic precipitators (ESPs), since most of the boilers where LIMB may be applied operate in conjunction with ESPs for particulate control.

The primary concern of this research was the problem of operating ESPs successfully in utility plants equipped with LIMB. Three of the five major tasks addressed this central issue. A secondary concern was to provide technical support of the full-scale demonstration of LIMB that EPA is undertaking at the Edgewater plant of Ohio Edison at Lorain, Ohio. The two remaining tasks were in this area.

Project Scope and Objectives

The five technical tasks that provided the organization structure of this project were:

1. Development of a predictor of the electrical resistivity of mixtures of fly ash and sorbent that result from sorbent injection into coal-fired boilers.

2. Determination of the effect of high mass loadings of ash/sorbent mixtures on ESPs.

3. Designing and implementing a pilot-scale program of ESP with furnace sorbent injection.

4. Investigation of recycle, disposal, and utilization of LIMB ash/sorbent mixtures.

5. Studies with a pilot-scale combustor to characterize sorbents that may be applicable to the LIMB process.

Tasks 1-3 addressed different aspects of the concern of ESP performance in conjunction with a LIMB-equipped furnace: the high electrical resistivity of the ash/sorbent mixture resulting from the LIMB operation; the substantially elevated concentration of particulate matter to be collected; and the long-term maintenance of a pilot-scale ESP attached to a moderate- or full-size furnace. An objective under Task 5 was the evaluation of sulfur trioxide gas or water vapor as a means of lowering the high resistivity of an ash/sorbent mixture.

Task 4 addressed issues of importance to the LIMB demonstration at Edgewater. Can spent sorbent in the form of calcium oxide be rejuvenated by hydration and reinjected as calcium hydroxide to achieve more complete utilization? Can spent sorbent be disposed of in a landfill without contaminating groundwater? A third question, less related to Edgewater than to the broader future application of LIMB, can a commercial market be found for LIMB wastes?

Task 5 addressed a number of additional issues of concern at Edgewater: the selection of a sorbent from those available in the market; the enchancement of sorbent activity with lignosulfonate (a dispersing agent) as an additive; and the reactivation of spent furnace-injected sorbent by humidification of flue gas in a low-temperature duct, to achieve post-furnace capture of SO_2. This task also addressed the issue of chemical conditioning of ash/sorbent mixtures to lower their resistivity.

Results and Discussion

Task 1. Development of a resistivity predictor for ash/sorbent mixtures. The first step was to obtain a variety of samples of ash/sorbent mixtures and characterize them with respect to mineral composition, particle size, surface area, density, and electrical resistivity. Efforts were then made to establish correlations between resistivity and one or more of the other properties. In particular, an attempt was made to establish a relationship between resistivity and the sum of lithium and sodium contents, which is the basis of an earlier correlation for ordinary fly ash; this attempt failed. During the project, it was discovered that the procedure used for resistivity measurements altered the surface area of the ash/sorbent mixtures and thus altered the resistivity.

The need for a revised procedure for measuring resistivity was thus evident. Work toward that end will be described in the report of another project. The effort to develop the resistivity predictor, however, remains unfulfilled; the prospects for completing this effort successfully cannot be evaluated from the data now available.

Task 2. Investigation of high mass loadings in ESPs. This task was addressed through both experimental and theoretical approaches. The experimental effort centered on the use of a specially instrumented ESP that was operated in conjunction with a pilot-scale combustion facility, which produced an ash of high resistivity (2×10^{12} ohm-cm), an elevated concentration (higher by a factor of three), and a particle-size distribution with a much greater proportion of fine material The primary observations were that: there was an ESP malfunction owing to the high ash resistivity, and there was a strong space-charge suppression of the corona (observable when the ash resistivity was lowered with SO_3) due to the fineness of the particle-size distribution. The data were used in the existing ESP model to project the effect on ESP emissions of adding the LIMB process to a typical boiler, shown in Figure 1.

The theoretical study consisted of development of a revised version of the ESP model, which is responsive to a wider range of ESP operating conditions Comparisons of the revised model with a limited number of field data sets indicate that the revised model functions satisfactorily as a predictive tool Nevertheless, there was an indicated need for certain further refinements in the model.

Task 3. Performance of a pilot-scale program of ESP performance with furnace sorbent injection. Arrangements for pursuing this task at Base Gagetown of the Canadian armed forces in New Brunswick were completed, and certain background data were obtained. Ultimately, however, the pilot facilities assembled at Gagetown were dismantled at EPA's direction before the planned measurement program could be completed. A crucial factor that led to this action was the abnormally high carbon content of the ash produced in the Gagetown burners, which would have had a serious impact on ESP performance, regardless of the impact produced by sorbent injection.

Task 4. Studies of LIMB ash recycle, disposal, and utilization. The results of these studies demonstrate that LIMB ash can be reactivated by hydration and can then be reinjected to achieve further utilization for SO_2 capture A major stumbling block to this approach, however, is the excessive mass loadings that will occur unless the sorbent can be separated from the fly ash. Potential separation methods that deserve further study are based on a cyclone or an ESP, a dense-phase classifier, or a steam elutriator.

Both laboratory and field tests showed that LIMB ash can be safely handled and used for landfilling. Cementitious reactions in the moist ash produce a nearly impermeable product, which has a minimal potential for groundwater contamination. LIMB ash cannot be classified as a hazardous waste under any of the RCRA criteria.

Synthetic aggregates represent one of the most promising uses for LIMB ash. Such aggregates are likely to conform to

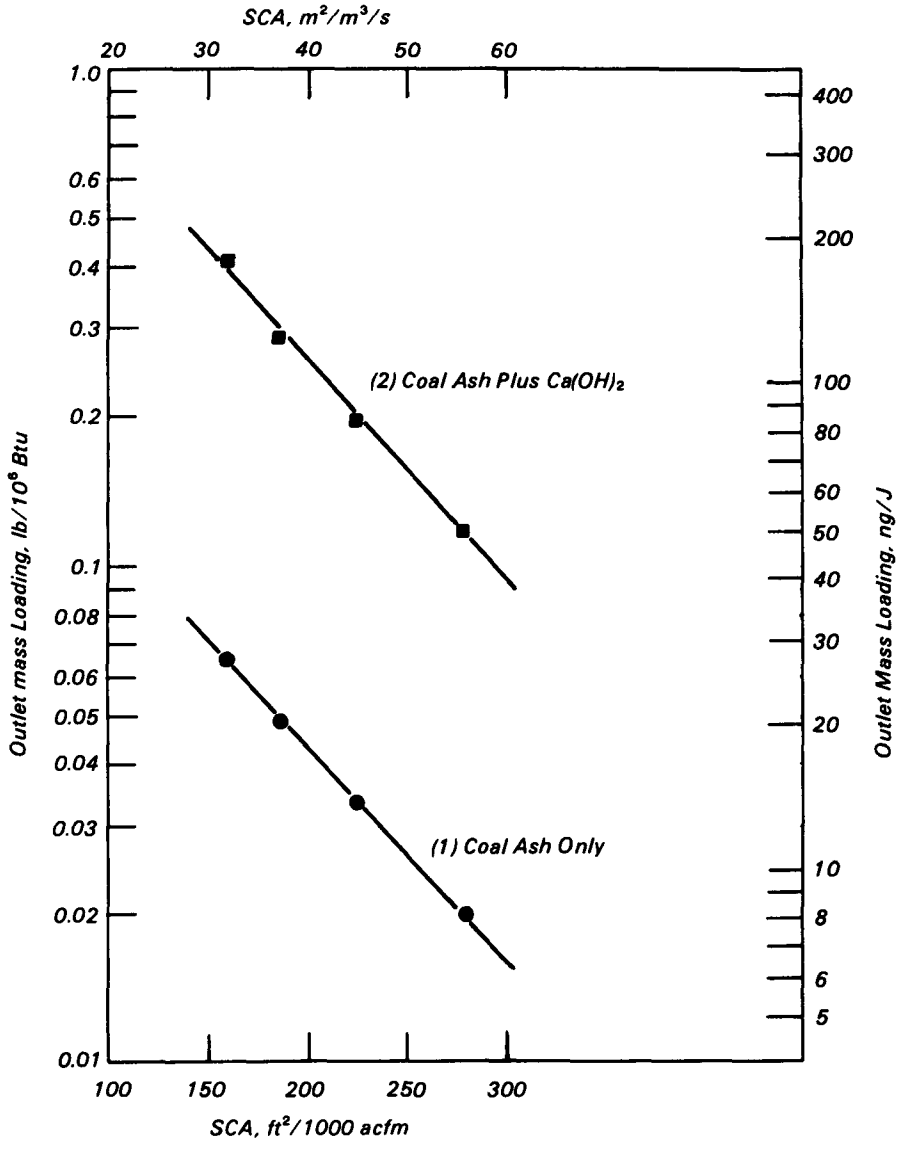

Figure 1. *Outlet mass loading as a function of SCA for an ESP collecting coal ash only or coal ash plus sorbent.*

highway specifications; however, further development of aggregate technology and testing of aggregate in a highway test section are needed.

Task 5. Studies of sorbent characterization in a pilot-scale combustor. Several topics were investigated under this task.

- Commercial hydrated limes were collected and characterized with respect to physical properties and chemical reactivity (with respect to SO_2 capture during furnace injection). Correlations between physical properties and chemical reactivity could not be established, even though significant variations in properties presumed to be important (particle size and surface area, for example) were encountered. The range in furnace utilization was relatively narrow - less than 20% on a relative basis. The economic significance of even such a narrow range, however, justifies ongoing efforts to clarify the relationship of physical properties to utilization.
- The effectiveness of calcium lignosulfonate as an additive in hydrated lime, for increasing utilization during furnace injection, was confirmed, specifically through demonstration of the utility of this dispersant as either a dry powder or an aqueous solute.
- Certain fundamental aspects of SO_2 capture by hydrated lime at low gas temperatures, under the influence of humidification, were studied. A primary conclusion is that water

vapor alone cannot activate the solid appreciably. Physical wetting, on the other hand which occurs when dry entrained sorbent particles and water spray droplets collide, has the potential for strongly activating the solid. The practical limitation of the wetting process is the infrequency of particle-droplet collisions, which allows most of the sorbent particles to remain dry and hence unreactive.

- Charge-augmented sorbent humidification (CASH) was studied briefly. In this process, sorbent particles were charged negatively and water droplet positively, to enhance the collision frequency. Further study of the concept was pursued under another project. In the final analysis, no beneficial result of the process seems to be in the offing.

- The effects of SO_3 gas and water vapor were compared as conditioning agents, to alleviate the concern with high resistivity of ash/sorbent mixtures in an ESP. At concentrations of about 60 ppm, SO_3 was found to be largely ineffective - much less promising than had been indicated by prior studies. At addition levels of around 5% by volume (which gave approaches to adiabatic saturation of 11°C), water vapor, on the other hand, produced a much more promising result - a reduction in resistivity from 1 x 10^{13} to 1 x 10^{1} ohm-cm. The effect of water vapor is shown in Figure 2.

Recommendations

Further research should be done to complete or augment work initiated during this project. Examples of objectives not yet satisfied are the development of a resistivity predictor (Task 1) and the long-term evaluation of a pilot-scale ESP operating with LIME particulate matter generated in a moderate- or full-scale combustor (Task 3). Efforts to complete Task 1 have

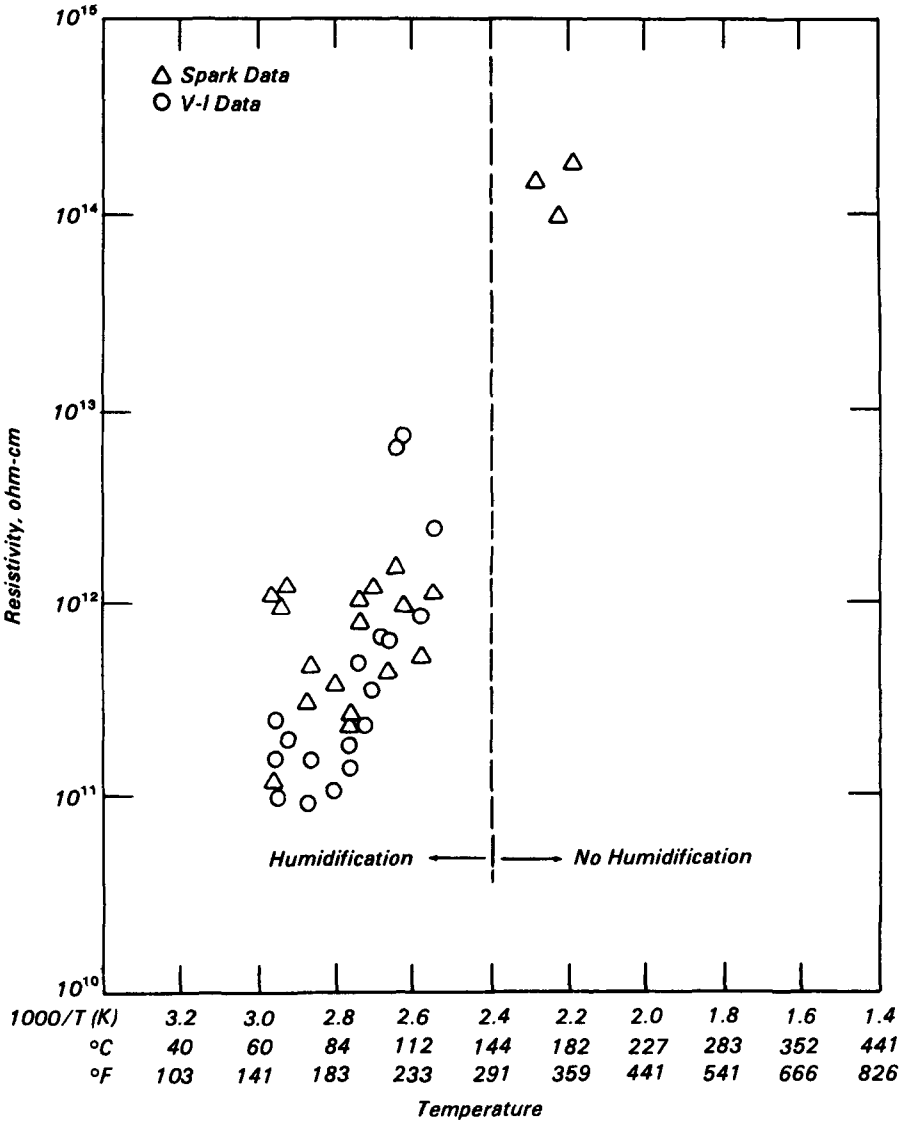

Figure 2. Resistivity of ash/sorbent mixture as a function of temperature and humidification.

been made under another project, but have not yet reached a satisfactory end point. The long-term ESP test is now rescheduled under another project as part of the LIMB demonstration at Edgewater. Further developments of the revised ESP Model from Task 2 have been made under another project.

Certain findings under Tasks 4 and 5 can be implemented at Edgewater if required: The LIMB wastes may be safely disposed of in a landfill; the $Ca(OH)_2$ sorbent selected for Edgewater may be treated with lignosulfonate additive, either in solid or liquid form, to achieve enhanced activity; and the concern with high electrical resistivity of the waste-ash/sorbent mixture may be dealt with adequately with water-vapor conditioning.

Certain results under Tasks 4 and 5 indicate that certain modifications to LIMB (to enhance the process) may require further work. Further work is needed to make the recycle or commercial utilization of LIMB wastes practical and economical. Additional studies are needed to permit effective post-furnace reactivation of spent sorbent by humidification; the data now available, however, reveal that the primary limitation on the effectiveness of humidification is the infrequency of collisions of sorbent particles and water droplets. The charge-augmented humidification process that was investigated seems to offer no benefit.