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Project Summary

Boiler Design Criteria for Dry Sorbent SO_2 Control with Low-NO_x Burners

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A program to develop boiler design criteria for application of dry sorbent control technology with low-NO_x burners on tangentially fired pulverized-coal-burning boilers was conducted under EPA sponsorship. A comprehensive review of past and current research in the area of sorbent SO_x control was performed to provide a basis for evaluating the implications of this technology on boiler design, cost effectiveness, and operability. Historical and projected design trends were analyzed for all tangentially fired pulverized-coal utility boilers built by C-E since 1960, including the effect of coal rank. A candidate host unit was selected for consideration as a site for demonstration of dry sorbent SO_2 control. Dry sorbent process designs, including sorbent preparation/delivery equipment and boiler modifications, were developed and costed for new and retrofit (200, 400, and 600 MWe) high-sulfur coal-fired units and new (200, 400, and 600 MWe) low-sulfur coal-fired units. SO_2 removed was 50% in the boiler for all cases. Spray dryers were incorporated on the new units to achieve overall SO_2 removal (sorbent injection plus spray dryer) of 70% (low-sulfur coal) and 90% (high-sulfur coal). Conventional limestone flue gas desulfurization costs were developed for comparison. Capital costs, cost of electricity, and cost effectiveness per ton of SO_2 removed were developed.

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

Proposed legislation in response to the acid rain question would require at least a portion of existing oil and coal burning plants to limit emissions of sulfur dioxide (SO_2). Due to the possibility of regulation of existing plants, various alternative sulfur oxide (SO_x) removal processes are being examined in addition to the tail-end lime or limestone scrubbing systems predominantly employed to meet NSPS. Because of the combined requirements of retrofitability and moderate sulfur removal efficiency, the concept of furnace sorbent injection has received renewed interest and study as an alternative to tail-end lime or limestone scrubbing systems. Early trials in small-scale furnaces and full-scale utility boilers generally failed to demonstrate sufficient in-furnace SO_2 removal at reasonable sorbent-to-sulfur ratios.

The development of advanced low nitrogen oxide (NO_x) utility boiler combustion technologies may provide new combustion conditions and lower furnace gas temperatures which may be more suited for in-furnace absorption of SO_2 by limestone or other sorbents. The combination of these two technologies has been given the acronym LIMB, Limestone Injection with Multi-stage Burners.

This report presents the results of the EPA contract, "Boiler Design criteria for Dry Sorbent SO_2 Control with Low-NO_x Burners." This study consisted of several tasks: (1) literature survey of state-of-the-art knowledge of SO_2 removal by sorbent injection; (2) review of historical and projected design trends for C-E coal-fired utility boilers; (3) selection of a candidate host site for LIMB demonstration; (4) design of sorbent preparation systems plus definition of boiler and back-end modifications required to incorporate LIMB on new and retrofit units; and (5) economic analyses of these LIMB-related designs, plus, for new units, SO_2 removal via conventional flue gas desulfurization (FGD) techniques.

Results and Discussion

Process Design Criteria

Five factors which most directly determine the effectiveness of sorbent injection on a particular boiler were identified during the literature survey portion of this contract:

Coal type—Ash compositions vary considerably. Laboratory tests have shown that sorbent injection affects the slagging and fouling behavior of some coals. Ash reactivity can affect sorbent capture.

Sorbent type—$Ca(OH)_2$ was determined to be the most effective sorbent, followd by limestone. The most important physical characteristics are specific surface area and porosity which determine the calcination and sintering rates. Limestone was shown to have a maximum specific surface area at 1000°C. CaO absorption falls off sharply above 1200°C, while $CaSO_4$ starts to decompose at 1204°C.

Time/temperature effects—SO_2 absorption is a strong function of the residence time within a critical temperature range. For limestone, this range was found to be roughly 1204 to 927°C. The point at which the sorbent is injected into the boiler is critical in maximizing the residence time within this temperature range and minimizing the exposure to higher temperatures which adversely affect sorbent performance. Maximum SO_2 absorption was obtained when the sorbent was injected in the area of the overfire air ports.

Stoichiometry—SO_2 absorption increases with increasing Ca/S molar ratios. Ca/S ratios above roughly 4:1 were shown to give only small improvements in SO_2 removal.

Gas composition—A reducing atmosphere in the reaction zone does not affect SO_2 absorption. The rate of SO_2 absorption is higher for higher concentrations of SO_2 in the gas stream.

Existing ash collection systems may be adversely affected by sorbent injection. Electrostatic precipitator (ESP) performance was shown to drop off considerably due to the change in particulate resistivity. Wet ash conveying systems were susceptible to plugging. No adverse effects were identified in the performance of mechanical collectors. Operating dry scrubber systems in conjunction with sorbent injection may offer economic advantages in some cases by allowing units firing high sulfur coals to meet NSPS limits.

Process Design

Data for all C-E tangentially fired pulverized-coal-burning utility boilers built since 1960 were reviewed to determine historical and projected design trends for potential retrofit applicability of dry sorbent injection for SO_2 control. From this review, three units (200, 450, and 560 MWe) were identified as candidates for demonstration of dry sorbent injection. These units were used to define the process equipment and boiler modifications which would be required to achieve 50% SO_2 removal in the boiler in a retrofit application with high-sulfur coal.

Similarly, generic process designs were defined for new tangentially fired pulverized-coal-burning boilers at 200, 400, and 600 MWe with low- and high-sulfur coals. An SO_2 removal of 50% in the boiler with sorbent injection was defined, with spray dryers added to achieve NSPS-required overall SO_2 removals of 70% (low-sulfur coal) or 90% (high-sulfur coal).

The sorbent preparation and injection system in all cases was designed for on-site pulverization of limestone to 90% −325 mesh via dedicated roller mills. The sorbent was transported via dilute phase flow (1.5 kg air/kg limestone) to multiple nozzles located in the upper furnace area with a discharge velocity of 61 m/sec. Calcium-to-sulfur mole ratios were defined as 2:1 for high-sulfur coal units and 4:1 for low-sulfur coal units.

The boiler modifications required to incorporate sorbent injection included boiler nozzle penetrations (a retrofit cost only), increased soot blower capacity (new and retrofit units), and surface modifications (new units only). For new high sulfur units, reducing the SO_3 concentration in the gas stream permitted a reduction in the gas outlet temperature, which resulted in costs associated with incorporating larger Ljungstrom air heaters.

Gas cleanup requirements were handled differently for retrofit and new units. Multiclone collectors were added upstream of the ESPs to reduce the solids loading to the existing ESPs. SO_3 conditioning was incorporated to offset the resistivity increase associated with the high calcium content. Baghouses were incorporated on new units as part of the spray dryer systems, but were not included as a sorbent-injection-related cost. Incremental ash removal capacity was added for all units as required.

For the six new unit cases, limestone plus forced oxidation scrubber systems were defined for the purpose of comparing the costs associated with conventional FGD to the costs associated with dry sorbent injection.

Process Economics

Capital and operating costs were developed for the LIMB and FGD process equipment for the new and retrofit cases described above. These costs were developed according to procedures outlined in the EPRI Technical Assessment Guides, and are expressed in December 1985 dollars for a January 1986 start-up.

Retrofit units

The costs of retrofitting sorbent injection to the existing units considered in this study, including sorbent preparation and delivery, boiler and back-end modifications, and low-NO_x burners, ranged from 55.9 to 78.8 $/kW. The effect on first year costs of electricity ranged from 4.15 to 5.72 mills/kW-hr (15-year levelized costs ranged from 5.98 to 8.23 mills/kW-hr).

New high-sulfur units

The cost of incorporating LIMB for 50% SO_2 removal plus spray dryers to achieve 90% overall SO_2 removal on the new high-sulfur units considered in this study ranged from 93.0 to 111.6 $/kW. The effect on first year costs of electricity ranged from 6.20 to 7.05 mills/kW-hr (30-year levelized costs ranged from 11.05 to 12.38 mills/kW-hr).

The cost of incorporating conventional limestone FGD equipment to achieve 90% SO_2 removal ranged from 221.3 to 320.7 $/kW. The effect on first year costs of electricity ranged from 11.17 to 14.84 mills/kW-hr (30-year levelized costs ranged from 18.03 to 23.02 mills/kW-hr).

New low-sulfur units

The cost of incorporating LIMB for 50% SO_2 removal plus spray dryers to achieve 70% overall SO_2 removal on the new low-sulfur units considered in this study ranged from 44.1 to 60.3 $/kW. The effect of first year costs of electricity ranged from 2.29 to 3.03 mills kW-hr (30-year levelized costs ranged from 3.73 to 4.88 mills/kW-hr).

The cost of incorporating conventional limestone FGD equipment to achieve 70% SO_2 removal ranged from 151.1 to 228.2 $/kW. The effect on first year costs of electricity ranged from 5.99 to 8.82 mills/kW-hr (30-year levelized costs ranged from 8.53 to 12.35 mills/kW-hr).

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The complete report, entitled "Boiler Design Criteria for Dry Sorbent SO_2 Control with Low-NO_x Burners," (Order No. PB 86-216 736/AS; Cost: $22.95, 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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