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Project Summary

Application of LIMB to Pulverized Coal Boilers - A Systems Analysis

Limestone Feed and Boiler Systems

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The report gives results of a systems analysis of the application of Limestone Injection Multistaged Burner (LIMB) technology to pulverized coal boilers. This study was conducted as part of a larger U. S. EPA program to develop the LIMB technology. The report evaluates alternative limestone handling, preparation, and injection methods and boiler system impacts associated with LIMB applications. Downstream emission control systems are not addressed.

LIMB simultaneously reduces sulfur oxides (SO_x) and nitrogen oxides (NO_x) emissions from pulverized coal boilers. It is based on using low NO_x combustion techniques in combination with dry limestone injection into the furnace for simultaneous SO_x control. Study aims were to evaluate alternative concepts for application of the technology, assess potential system problems related to its application, and identify engineering solutions to those problems. Further goals were to identify information needs and recommend studies to acquire this information.

Conceivably, all new boilers could be designed to handle any foreseeable impacts associated with LIMB; however, the practicality of LIMB as a retrofit technology depends on its compatibility with existing boiler systems. Sufficient information is not yet available to accurately gauge its applicability as a retrofit technology; however, the study identified potential system impacts, situations where the impacts will likely be minimized, and design or operating procedures for dealing with them.

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).

Introduction

EPA's LIMB program is an effort to develop an effective but inexpensive emission control technology for pulverized coal boilers that will simultaneously reduce sulfur oxides (SO_x) and nitrogen oxides (NO_x) emissions. The technology is based on using low NO_x combustion techniques in combination with dry limestone injection into the furnace for simultaneous SO_x control.

The need for effective low-cost techniques for control of SO_x and NO_x

emissions has become apparent in recent years because of increased public awareness of the problems associated with acid rain. The long-range transport and transformation of SO_x and NO_x are believed to be major factors contributing to acid rain formation. In addition, these pollutants also degrade local air quality, present health hazards, and participate in photochemical smog formation. To address these problems, effective low-cost control techniques are needed that are applicable to both new and existing sources of these pollutants. The LIMB program seeks to develop such a technique for pulverized coal boilers which represent a major source of SO_x and NO_x emissions.

The multiyear LIMB program, initiated in fiscal year 1981, is based on the results of earlier studies conducted on low NO_x combustion techniques and dry sorbent injection. The program is planned to result in a complete LIMB technology design package. To accomplish this objective EPA has initiated research and development activities including fundamental studies and bench- and pilot-scale experiments.

Along with these research activities EPA also initiated a systems analysis task that includes this report. A major objective of the analysis task is to evaluate alternative concepts for application of the technology to pulverized coal boilers, to assess potential system problems related to its application, and to identify engineering solutions to those problems. This includes analyses of alternative limestone preparation and injection schemes, boiler system impacts associated with LIMB, and impacts on downstream emission control systems. (The current report does not include analyses of downstream control systems.) Additional goals are to identify information gaps related to system impacts and to recommend studies or experiments to acquire the needed information.

Project Analyses

The report gives detailed results of several investigations/evaluations carried out as part of the project.

To form a basis for later technology evaluations, investigations were first made of the physical and chemical properties of coals commonly burned in U. S. boilers and of the types of limestones potentially available for use with LIMB. These properties are summarized and discussed in the report for a range of coal and limestone types.

Investigations were also conducted into the design and operation of various types of raw material handling, preparation, and injection equipment. The report describes how the equipment design and operation are influenced by such factors as raw material grindability, hardness, moisture content, and desired ultimate particle size. Based on this information, evaluations were made of several potential limestone preparation and injection schemes and their relative advantages and disadvantages were compared. The basic schemes analyzed were:

(1) Crushed limestone and raw coal mixed, pulverized together, and injected through the burners.

(2) Ground limestone and raw coal mixed, passed through the coal pulverizers together, and injected through the burners.

(3) Ground limestone pneumatically mixed with pulverized coal and primary air and injected through the burners.

(4) Separate furnace injection of ground limestone through combustion air ports or other ports in the furnace walls.

Also, several variations of these four basic schemes were considered.

Investigations were also conducted into the design and operation of various types of pulverized coal boilers in use today. The influence of such factors as design coal type and boiler age on various design variables (e.g., furnace size, convection pass spacing, sootblower design, and ash removal system design) is described in the report. Also described are the likely influences of LIMB on boiler operation, taking into account such factors as coal type and boiler design. This includes evaluations of the impacts of LIMB on the boiler ash loading and ash removal system operation, slagging and fouling tendencies, and energy requirements. Critical information needs and methods of dealing with potential operating problems were also identified.

The analyses described above led to several major conclusions and recommendations.

Conclusions

Conceivably, all new boilers could be designed to handle any foreseeable impacts associated with LIMB; however, the practicality of LIMB as a retrofit technology depends on its compatibility with existing boiler systems. To be compatible, technology application should not require major boiler design modifications or severe boiler operation impairments. LIMB is still under development so sufficient information is not yet available to accurately gauge its applicability as a retrofit technology; however, the study identified potential system impacts associated with LIMB, situations where these impacts will likely be minimized, and design or operating procedures for dealing with these impacts.

The major factors influencing the compatibility of LIMB appear to be the coal properties and designs of the boiler furnace, convection section, and ash removal systems. Depending on these factors, potential problems arising from LIMB applications include increased furnace slagging, plugging of tight convection section passes, overloading or plugging of ash removal systems, and incomplete coal combustion. If not severe, these problems can be dealt with through alterations in boiler operating procedures or minor system design modifications.

No major system problems are expected with application of limestone handling, preparation, and injection equipment other than potential space limitations at some existing facilities. Limestone feed systems will have to handle limestone feed rates of about 10-30% of the coal feed rate. Several potential limestone preparation and injection schemes are possible which would allow injection through the burners, secondary or tertiary air ports, or other ports installed in the furnace walls Any one of these schemes could prove best for a particular application depending on SO_2 control considerations and the existing coal feed system design. Not much data are available on the dry grinding characteristics of limestone, but measurements of limestone properties should ensure adequate limestone feed system design.

Applications where LIMB appears most compatible with existing boiler systems are those which fire low rank coals. In these applications, the coal properties and designs of the furnace, convection section, and ash removal system all appear well suited for LIMB.

However, system impacts will be larger with bituminous coal units. Bituminous coals generally have higher sulfur levels than lower rank coals, and hence require injection of larger quantities of limestone. These larger injection rates require larger limestone feed system capacities, result in larger feed system power requirements, increase boiler thermal losses, and increase ash loadings handled by the boiler and ash removal systems. Also, limestone injection in these units may increase the tendencies for furnace slagging, convection pass erosion, and plugging of convection passes and ash removal systems.

The potentially most critical problems of those mentioned above concerning the application of LIMB technology to bituminous coal units result from interactions between limestone and ash particles. These interactions may result in decreased ash fusion temperatures which, together with the increased ash loadings, may cause increased furnace slagging and plugging of tight convection passes. This effect is not likely to occur with low rank coals due to differences in ash chemistry. Another related problem is that many older bituminous coal units remove economizer ash with wet sluicing systems. With LIMB, this ash will contain large quantities of calcium and sulfates. When exposed to water it will likely exhibit cementitious properties causing plugging of sluicing systems. Wet sluicing systems for economizer ash are not typically used on units firing low rank coals.

Thus it appears that LIMB will be most easily retrofit on units firing low rank coals. However, about 75% of the existing boiler population on a total capacity basis were designed to fire bituminous coal. Further, bituminous coal units account for an even larger percentage of existing SO_x emissions. For these reasons, LIMB must be applied to bituminous coal units in order to have a large impact on existing SO_x emissions. In this study, some potential problems were identified concerning the application of LIMB to bituminous coal units. Further evaluations are needed to define the magnitudes of these problems and to engineer solutions to them.

Recommendations

Recommendations from this study include: (1) research and development activities that might be undertaken to better understand and respond to system impacts associated with the application of LIMB technology; and (2) additional engineering analyses which would further define system impacts and problems, engineering solutions to those problems, and the compatibility of LIMB with the existing boiler population.

Research and Development Needs

Several research needs related to the limestone feed and boiler systems were identified in this study: measurements of limestone grinding characteristics and of the impacts of LIMB on boiler slagging and fouling tendencies, ash entrainment, ash physical properties, and convection section erosion.

The most critical research need is to determine the effect of LIMB on slagging and fouling, especially in bituminous coal units. Limestone injection tests in some bituminous coal units have resulted in severe deposit buildup and plugging in the convection passes. This buildup could result from a combination of increased solids flow, reduced ash fusion temperatures, and tight tube spacings. Some reports from these tests indicated that the deposits were sticky at normal gas temperatures but became friable when cooled, indicating that the ash melting properties were important.

Correlations of ash fusion temperatures with composition and various slagging indices are available to predict the effects of increased calcium content on ash slagging tendencies. Also, direct laboratory measurements have been made of the impacts of increased levels of limestone on the fusion temperatures of ash/limestone mixtures. However, these types of tools or tests presume 100% interaction between the ash and injected limestone particles. None of them model the dynamics of limestone/ash interactions in the furnace. The true extent of interaction is unknown, but is probably related to the conditions under which the limestone and ash particles come into contact

As a result, bench- or pilot-scale tests should be considered in which limestone particles are injected into a furnace operated so that a variety of peak flame temperatures and time/temperature relationships occur. These tests should include injection through the burners and through ports located at other furnace temperature zones. Air cooled probes can be placed downstream in various temperature zones reflective of radiant and convection sections in order to measure ash deposition rates. Also, various ash strength and friability tests can be conducted on the deposited samples.

Other research objectives should include measurements of the influence of LIMB on total ash entrainment and ash physical properties since these factors can influence ash removal system design and operation. Tests should include collection of ash samples from various points in the furnace and convection section. The samples should be analyzed for calcium content and mixed with water to determine the ash settling and cementitious properties, both of which are especially important in the operation of wet ash removal systems (the degree of ash entrainment determines the necessary ash removal system design capacity). Entrainment and physical properties should be measured as functions of both injected limestone particle size and combustion gas flow rate.

Another useful test objective is to determine the influence of LIMB on erosion in the convection passes, but this would require relatively long term testing. Limestone injection will significantly increase the total flue gas solids loading. Also, limestone inerts include those compounds thought to contribute most to erosion (SiO_2 and Fe_2O_3). Testing would involve measurement of the change in weight of metal probe samples in the convection section of a pilot unit.

Other research needs include studies of limestone grinding characteristics. As indicated in the report, simultaneous grinding of coal and limestone may be a desirable alternative at facilities with excess pulverizer capacity. However, the effects of simultaneous grinding are relatively unknown. Tests might be considered of simultaneous grinding for ranges of coal and limestone types, inlet limestone rock sizes, and pulverizer designs. The test objective would be to observe: the adequacy of mixing of coal and limestone; the effects of limestone addition rate on pulverizer capacity, power requirements, and reliability; and the effects of simultaneous grinding on resulting coal and limestone particle size distributions. A related research need (which may prove valuable in design of limestone feed systems) is to develop a data base of Hardgrove Grindability Index, hardness, and particle specific gravity values for a range of commercially available limestone types.

Engineering Analysis Needs

Several areas have been identified in which additional engineering analyses would be useful. These include additional analyses of the boiler system, analyses of downstream emission control systems, and overview type analyses of the system as a whole.

Important information for assessing the usefulness of LIMB as a retrofit technology includes the design profile of the existing boiler population. Limited material on this subject is presented in the report; however, more specific data are available. Specifically, computer data bases containing substantial information on utility boilers are available. Conceivably, this information could be cross-referenced with information from available FGD system data bases or survey reports to provide a fairly complete picture of the existing boiler population and the nationwide potential for LIMB retrofit applications.

An additional worthwhile effort would be to research the furnace dimensions, plan areas, or heat release rates of the existing boiler population. This information would provide insight about potential unit derating resulting from retrofit of LIMB technology. Such derating may be brought about by the large flame volumes and/or burner dimensions of the low NO_x burner techniques instrumental to the application of LIMB technology.

For a complete systems analysis, engineering evaluations are also needed of the impact of LIMB on downstream particulate control systems. Flue gas solids loadings are greatly increased and the particle characteristics are altered by LIMB. Analyses should be conducted to evaluate which particulate control systems are best suited for LIMB applications and to choose the best methods for upgrading existing control systems in LIMB retrofit applications. A related need is to evaluate alternatives for recovering unused sorbent from the fly ash and recycling it to the boiler.

Finally, overall system material and energy balances and cost analyses should be conducted for a number of cases involving different coal types, system sizes, limestone injection rates, injection system designs, and particulate control system designs. These analyses would serve to summarize total system impacts resulting from LIMB application and to highlight areas of technological and cost benefits associated with LIMB.

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The complete report, entitled "Application of LIMB to Pulverized Coal Boilers—A Systems Analysis: Limestone Feed and Boiler Systems," (Order No. PB 83-114 553; Cost: $17.50, subject to change) will be available only from:
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