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Project Summary

Demonstration of Sorbent Injection Technology on a Wall-fired Utility Boiler (Edgewater LIMB Demonstration)

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This document summarizes results of the full-scale demonstration of Limestone Injection Multistage Burner (LIMB) technology conducted on the coal-fired, 105 MWe, Unit 4 boiler at Ohio Edison's Edgewater Station. Developed as a technology aimed at moderate levels of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions control for relatively low-cost retrofit applications on older plants, LIMB operation at a calcium to sulfur (Ca/S) molar ratio of 2.0 is shown to be capable of achieving approximately 55 to 72% SO_2 removal at capital costs significantly lower than wet flue gas desulfurization systems for units under 300 MWe and equal or lower operating costs. The removal depends upon the specific sorbent in use and the degree of flue gas humidification employed. Sorbents tested include a commercial calcitic hydrated lime, both with and without a small amount of calcium lignosulfonate, a material added to improve reactivity. Results are presented for humidification of the flue gas both to an 11°C approach to the saturation temperature (where an increase of 10% [absolute] in SO_2 removal efficiency is obtained), and for minimal humidification (where water is added solely to maintain adequate electrostatic precipitator [ESP] performance). The performance of the DRB-XCL™ low-NO_x burners, with an overall average emission of 206 ng/J (0.48 lb/10^6 Btu), is also presented.

The document also discusses the impact of LIMB technology on boiler and plant operations. The effects are related primarily to the increased quantity of particulate matter that must flow through the boiler, ESP, and ash handling equipment. The need for effective sootblowing is seen as the single most important requirement when considering application of the technology: without it, the increased particulate loading can decrease heat transfer efficiency between sootblowing cycles. The other effects discussed in some detail result from the quicklime component of the ash and the precautions that must be taken to avoid the potential for deposits at wet/dry interfaces and for high pH conditions associated with ash handling.

Finally, the application and economics of the technology are discussed in terms of a hypothetical LIMB system on a 150 MWe boiler. This forms the basis for a comparison of the capital and operating costs of the technology with those of a conventional limestone wet scrubbing system.

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

With the growing concern about acid rain and the improved understanding of its origins, an active program has been underway in the U.S. for many years to develop and utilize technology for acid rain control. The focus of this effort has been on control of sulfur dioxide and nitrogen oxides, (SO_2 and NO_x), from coal-fired utility boilers, since they represent the major source of these acid rain precursors. National point source SO_2 and NO_x emission standards were established for utility boilers in the 1970s; however, these standards apply only to newly constructed boilers. There exist today many coal-fired boilers built before establishment of these regulations. Many of these units have 20 to 30 years of remaining useful life, and the new acid rain legislation recently enacted by Congress will require some level of control for older units.

The SO_2 emission standards for new boilers are based on the use of flue gas scrubbing technology, an option that may not be technically or economically feasible for existing boilers. Space for locating the scrubber or disposing of its waste may not be available and/or the high capital cost may not be justified for a boiler with a relatively short remaining lifetime. As a result, there is a need for low capital cost, easily retrofitted, control technologies. The proposed acid rain legislation suggests that such technologies, which do not achieve the high removal efficiencies of scrubbers, can still be important in meeting overall removal goals for existing boilers.

One technology which could play a role in a utility's compliance with new acid rain legislation is LIMB (Limestone Injection Multistage Burners), which is based on the injection of a dry sorbent into the boiler for direct capture of SO_2 in the flue gas, combined with the use of low-NO_x burners for reduction of NO_x emissions. LIMB is a control technology for coal-fired boilers which requires low capital investment and is easily retrofitted to existing boilers. Although it achieves removal efficiencies lower than flue gas scrubbers, the cost per unit of SO_2 removed is much lower than that for scrubbers. Research and development work by the U.S. EPA and others in the late 1970s and early 1980s established the technical foundation for the design and operation of a LIMB system on a coal-fired boiler.

In 1983 the LIMB process was considered sufficiently developed to plan a full-scale demonstration of the technology on an operating utility boiler. EPA formally initiated the demonstration in 1984 with matching co-funding by the Ohio Coal Development Office. Babcock & Wilcox (B&W) was selected as the primary contractor and Ohio Edison's Edgewater Station in Lorain, Ohio, was selected as the host site; both of these organizations provided funding support. The system was designed for Edgewater's 105 MWe Unit 4 boiler, a coal-fired unit burning a nominal 3% sulfur Ohio coal.

The LIMB system was started up in July 1987 after a thorough review of the research and development data base and subsequent design and installation. Initial operation showed that LIMB was highly effective in removing SO_2, but that the system could be operated for only a few hours at a time due to the inability of the electrostatic precipitator (ESP) to control particulate emissions. This problem was diagnosed as being due to the inordinately high electrical resistivity of the LIMB ash. This situation made long-term, continuous operation impossible due to the need to maintain particulate emissions within the mandated opacity limit of 20% and 43 ng/J. The Edgewater LIMB system was operated for several weeks intermittently in a series of 2 to 5 hour runs to gather SO_2 removal data; then the system was shut down until the particulate removal problem could be resolved. A maintenance shutdown of the Edgewater boiler had already been scheduled at this time, so little project time was actually lost.

At about this time B&W's dry scrubber experience and dry sorbent injection work by Consolidation Coal indicated that humidification of a flue gas stream in the presence of an active sorbent resulted in additional activation of the sorbent and enhanced SO_2 removal from the gas stream. For LIMB, humidification offered the promise of increasing overall SO_2 removal and sorbent utilization at a relatively small increase in cost. Flue gas humidification was also shown to solve the LIMB particulate problem, since moisture in the gas reduces the electrical resistivity of the ash, reduces the volume of the gas, and improves other electrical conditions. With the promise of increased SO_2 removal beyond what was originally projected and resolution of the ESP operating problems, a developmental program was initiated to design and install a first-of-a-kind flue gas humidification system for Edgewater.

A bypass arrangement was used at Edgewater due to the uncertain reliability of the humidifier at the time. Humidification in existing ductwork is envisioned for a commercial system, if site-specific limitations and design parameters permit suitable residence time.

The system started up again in September 1988 and operated until June 1989 under a variety of test conditions, including some relatively long, steady-state, operating periods. The remaining portions of this document give results of the tests performed, and describe operating experience with the Edgewater LIMB system.

Results and Discussion of SO_2, NO_x, and Particulate Emission Control

The original project goal for SO_2 capture, based on extensive bench and pilot scale tests, was 50% using sorbent at a calcium/sulfur (Ca/S) molar ratio of 2.0. During the initial test runs of LIMB in September 1987, SO_2 removal was approximately 55 to 60% at a Ca/S of 2.0. With start-up of the humidifier in 1988, extended LIMB run times could be realized because of improved ESP operation, and the system could be adjusted and optimized. The humidifier added a potential complicating factor in the determination of LIMB SO_2 removal, since SO_2 could also be captured in the humidifier itself. It was soon confirmed, however, that this removal occurred only at close approach to the adiabatic saturation temperature of the flue gas (about 52°C). Data taken while the humidifier was operated at high temperatures, typically about 135°C where ESP operation improved but no SO_2 removal occurred, were used to determine SO_2 removal in the furnace. Later tests with humidifier outlet gas temperatures approaching the saturation point were used to define the incremental removal in the humidifier. However, unlike the 1987 trials when tests were limited to only a few hours, humidification stabilized ESP operation and thus permitted continuous operation and rigorous test periods with no significant changes in operating conditions extended to as long as 15 hours.

The September 1987 tests included some runs using commercial, hydrated calcitic lime treated with calcium lignosulfonate, an additive that appeared to improve SO_2 removal in earlier bench scale studies. Additional tests with more extensive use (1518 metric tons over two periods of 10 and 25 days each) of the modified sorbent were included in the 1988-89 demonstration. Tests were conducted with commercial hydrated calcitic lime both at "minimal humidification" and at an 11°C approach to saturation. The former term covers results obtained both before the humidifier was installed and when the humidifier was used just to maintain a suitable flue gas temperature and humidity for effective electrostatic precipitation, normally about 135°C. Corresponding tests were performed using lignosulfonate-doped sorbent. The data indicate that the modified sorbent increases SO_2 removal from 55 to 63% with minimal humidification, and from 65 to 72% at close approach to saturation, when operating at a Ca/S of 2.0. The increase is believed to be due to a combination of the finer size and the nonagglomerating properties of the modified sorbent, as well as the sorbent's ability to resist sintering.

SO_2 Capture in the Furnace

SO_2 removal is determined by measuring SO_2 at the stack and comparing this level with an uncontrolled calculated SO_2 level based on the coal sulfur content. Typically the SO_2 concentration falls rapidly when sorbent is first injected into the boiler, and then continues to decrease gradually to a steady state value within about 30 minutes. This incremental increase in SO_2 removal is thought to be due to supplemental reaction of sorbent that settles out on boiler surfaces. After this initial acclimation of the boiler, the SO_2 levels remain relatively unaffected by sootblowing and other boiler operations since normally there is a continual renewal of the deposits throughout such activities.

Since pilot scale tests had indicated that SO_2 removal was particularly dependent upon the temperature at the injection point, limited parametric optimization tests were conducted to quantify the effects at full scale. The variables, all of which are related to the temperature, included injection at different elevations in the furnace, momentum flux ratio (essentially injection velocity and furnace penetration at a given load), the angle of injection (nozzle tilt), and boiler load. The results show that these parameters have little effect on SO_2 removal in the Edgewater boiler over most of the ranges tested, indicating that the system is very insensitive to minor changes, if the initial design parameters enable near-optimum operation.

The only factors that influenced SO_2 removal significantly were those related to sorbent injection at the low end of the 1260 to 871°C sulfation temperature window or with a gross reduction in injection velocity. These conditions occurred when sorbent was injected at the upper elevation in the furnace, and during periods when the boiler was at minimum load and/or when the top row of burners were off. Under such conditions the estimated temperature at the injection point was 1038°C or lower and the increased residence time did not appear to be sufficient to compensate for the difference.

At one point outside of the test period, the booster air was turned off entirely, leaving the lime transport air as the sole means of conveying the lime into the furnace. A dramatic loss in efficiency resulted, indicating that there is a point at which the momentum flux ratio becomes important. The condition was beyond the range of control on the booster air flow, however, and could not be readily tested. Injection into higher temperature zones was attempted in the form of tilting the injection nozzles at elevation 181 down 15° from horizontal. No appreciable change in SO_2 capture was apparent. While this was not expected to lead to a dramatic difference, it leads one to suspect that elevation 181, where the temperature is about 1260°C, was very close to an optimum injection point for this boiler. Injection ports could have been located at a lower elevation where temperatures are higher; however, recirculation in the lower furnace would probably have resulted in sintering and decreased efficiency.

SO_2 Removal by Humidification

The Edgewater project demonstrated that LIMB SO_2 removal could be enhanced by humidification of the flue gas. Most of the tests conducted at close approach to the flue gas saturation temperature were limited to a period of 8 to 12 hours so that the baseline removal could be certified. The longest continuous run with no interruption was 29 hours. Subsequently, however, the humidifier has been operated continuously for as long as 11 days at an 11 to 14°C approach temperature as part of the Coolside process tests under the U.S. Department of Energy-sponsored LIMB Demonstration Project Extension.

Humidification to an 11°C approach temperature increases SO_2 removal from 55 to 65% at a Ca/S of 2.0. The tests run at 22 and 33°C approach temperatures suggest that the enhancement is lost somewhere slightly above a 33°C approach. However, the few data points obtained are not considered sufficient to define a truly representative curve. Pilot work and dry scrubber experience predict an exponential increase in SO_2 removal when approaching the saturation temperature.

NO_x Emission Control

In order to reduce NO_x emissions, the existing circular burners were replaced with B&W's DRB-XCL™ burners as part of the demonstration project. Discrete baseline tests with the older burners had shown emission levels of about 301 and 387 ng/J at 63 and 97 kg/sec main steam flow (mid and peak load conditions, respectively). The DRB-XCL™ burners do not appear to be as sensitive to load conditions. An overall average NO_x emission level of 206 ng/J was obtained over the full range of operating conditions during the January - June 1989 period. Averages of the weighted 24-hour and 30-day rolling averages of 202 and 211 ng/J were calculated for the periods of January 8 to 26 and February 21 to April 22, 1989, respectively.

The DRB-XCL™ burners operate at about 1.0 to 1.2 kPa pressure drop, in comparison to the 0.5 to 0.7 kPa required by the circular burners. The unburned carbon content averaged 1.54 wt % for four LIMB ash samples collected isokinetically while sorbent was being injected at a Ca/S of 2.0 and NO_x emissions were about 206 ng/J. This would equate to about 4.6 wt % in an ash undiluted by reaction products and excess sorbent. It was also noted that there appeared to be no interactive effects between sorbent injection and NO_x reduction.

Particulate Emission Control

An early concern of the LIMB demonstration was the ability of the Edgewater ESP to handle the two- to threefold increase in particulate loading that accompanied sorbent injection. While the loading and the finer size of the particulate are issues that must be addressed, the preliminary tests in 1987 dramatically indicated that the extremely high electrical resistivity of unconditioned LIMB ash was by far the most immediate impediment to continuous operation. As noted earlier, the high resistivity, in particular, precluded continuous operation beyond several hours as the opacity climbed toward the 20% limit at that time. Fortunately, the humidifier installed for the 1988-89 operations proved to be an effective means of conditioning the ash and restoring the efficiency of the ESP to near normal levels.

Although the Edgewater humidifier was designed to accommodate close approach to saturation for SO_2 removal purposes, it was soon found that adding even modest amounts of water (lowering the flue gas temperature to about 135°C) was sufficient to maintain opacity generally in the 1 to 7% range throughout the demonstration. Specific ESP tests included measurement of resistivity *in situ*, operating voltage and current, and inlet and outlet gas flow, mass loading, and particle size distribution. These intensive tests were conducted during the week of May 22, 1989, and cover operation of the ESP with both three and five of the six fields in service while the unit was operating at 75 MWe, due to operational concerns beyond the control of the project. Nevertheless, the conditions were such that the humidifier was operating at the full design flow since repairs to various sources of air in-leakage in the boiler had not been fully successful.

For the tests, the ESP inlet temperature was maintained at 135°C except for one test with an inlet temperature of 74°C. The results of these tests, coupled with those from associated laboratory tests and mathematical modelling, indicate that humidification to 135°C lowered resistivity to 2.3×10^{11} ohm-cm, permitted continuous operation at acceptable opacity levels, and resulted in particulate emissions on the order of 1.7 to 8.6 ng/J or less at the conditions tested.

LIMB Commercial Design and Economics

Two LIMB retrofit systems were designed for a 150 MWe boiler to allow comparison of the costs and impacts with those of a wet flue gas desulfurization (FGD) system. Previous economic studies had shown LIMB to have cost advantages over wet FGD for units under 300 MWe, while wet FGD was more cost effective for larger units. A representative unit firing 2% sulfur coal was used as a basis. Complete costs of the two LIMB system designs were estimated, and the resultant operational changes analyzed. The two systems were selected to cover the range between the high cost when humidification to an 11°C approach temperature is used to obtain maximum sulfur capture and the lower cost system where minimal humidification only restores ESP performance. The main difference between the systems is the inclusion of a humidification chamber for the maximum humidification case, while the minimal humidification design included installation of humidifier lances in existing flues.

Results of the analysis show that LIMB system capital costs are in the range of 30 to 43% of a wet FGD system, and that the costs per ton of SO_2 removed are lower than those of equivalent performance wet FGD systems. Additionally, the advantages of the LIMB systems include: simplicity of operation and ease of maintenance, reduced outage time for installation, shorter lead time for material supply, smaller space requirement, and lower reduction of plant electrical output

Operational Considerations

LIMB Effects on Boiler Operation

The impact of LIMB technology on boiler operation is related primarily to increased particulate loading and depends heavily on the adequacy of the sootblowing system. With sorbent injection in the upper furnace as was done at Edgewater, LIMB technology results in a higher rate of ash accumulation on tubes and other available surfaces, roughly in proportion to the additional particulate matter. Virtually all of the sorbent appeared to follow the gas stream through the convective pass, rather than being reported as bottom ash. Thus injection at the elevation of the nose and above avoids the potential for sintering and slagging conditions that would probably have resulted had the sorbent been introduced at a higher temperature and/or a lower elevation. The four new steam sootblowers added in the primary superheat area as part of the project were effective within their range, but did not make up for limitations elsewhere.

The LIMB ash that did accumulate on the tubes was found to be about as easily dislodged by sootblowing as is normal coal fly ash. The most notable difference was that, instead of operating on a normal once-per-shift basis, the sootblowers were run about three times as frequently, effectively in almost continuous cycles. As one might expect, this strained the capacity of the compressed air system at Edgewater, to the point that all but the four air heater blowers were converted to a steam-driven system for the LIMB extension work to follow. This is not to say that an air system would not work, only that the capacity of the Edgewater system could not keep up with the heavier duty cycle.

The overall effect of ash accumulation on the tubes was a decrease in heat transfer and higher flue gas temperatures throughout the boiler. Heat transfer rates through the tubes appeared to return to normal immediately after being blown, only to begin the cycle once more. Because of this and the relatively low capacity of the air-driven sootblowers, the net result was a flue gas temperature of about 177°C at the air heater outlet, compared to a more normal temperature of about 149°C under steady state conditions. However, effective sootblowing is expected to reduce this temperature rise significantly.

The other source of energy loss necessarily associated with LIMB is the excess air used both for sorbent dispersion in the furnace and water atomization in the humidifier. At Edgewater, ambient air was used for both, although preheated air, recirculated flue gas, or even mechanically assisted devices could be used for sorbent dispersion in another installation. While the data have not been reduced in terms of a specific energy loss, the "booster air fan" arrangement at Edgewater used about 3.78 kg/sec of air to feed 1.51 kg/sec of sorbent into 126 kg/sec of flue gas. Humidification to an 11°C approach to saturation required about 2.52kg/sec of air to atomize 5.54kg/sec of water. The atomization system was designed conservatively with an air compressor motor rated at 876 kW, to ensure the production of the fine droplet size required. Close approach to saturation at Edgewater also required flue gas reheat for plume buoyancy. A steam coil reheater with the capability of raising the flue gas temperature 22°C was installed for this purpose at the outlet of the ESP, just before the induced draft fan. In applications where only minimal humidification would be required for ESP operation, the energy penalty associated with high levels of humidification and reheat would be significantly lower.

Humidifier Operation

The humidification system installed at Edgewater proved to be relatively problem-free and achieved the purposes for which it was designed. Early mathematical and plastic flow modelling and quarter-scale simulation tests, all conducted in the early design phase, provided meaningful insight into the flow patterns and evaporation processes involved. For the most part, the wet/dry interface problems were limited to relatively small, manageable areas. The most significant problem was a buildup of material near some of the atomizers. The material would build to several centimeters in length and then fall to the floor of the horizontally configured chamber where material would accumulate. A modified airfoil lance assembly for the atomizer array was designed and installed in 3 of the 22 lance locations for the last 3 months of the program. These modified assemblies had a greatly reduced tendency for deposit formation, and the complete atomizer array was replaced before continuing with the Coolside process tests.

When the humidifier was operated at outlet temperatures 22°C and above the saturation temperature, essentially no difficulties were encountered. Moreover, the presence of unreacted quicklime, CaO, in the ash undoubtedly contributed to favorable conditions by virtue of its exothermic reaction with water. Although the quantity of water vapor present in the flue gas as a result of combustion was more than sufficient for total rehydration of the CaO, the gas/solid reaction kinetics appeared to be quite slow when the humidifier was operated considerably above the saturation temperature. Under this operating condition, much steam evolved when mixing LIMB ash with liquid water just prior to disposal (described in more detail later). Notably less steaming occurred when the humidifier was operated at close approach to saturation, suggesting that, whatever the mechanism(s), the excess CaO has a strong affinity for liquid water.

Predictably, deposits formed in the center area of the humidifier outlet turning vanes after extended operation precisely at an 11°C approach to saturation. The deposits built to a thickness of about 10cm and then sloughed off onto the floor. These deposits are not considered to be a problem because the chamber was being tested at the extreme limit of its design and several remedial alternatives could be used in a commercial system. These include not only operation at a slightly higher temperature, but also intentional capture of large, unevaporated droplets with periodic deposit collection and removal through a hopper system. If site-specific spatial limitations permit, a vertical, down-flow configuration with a hopper for solids collection would be preferred for a commercial humidifier required to operate at close approach temperatures.

Ash Handling and Disposal

LIMB technology also has significant impacts on the power plant's ash handling and disposal practices. The most obvious of these is the sheer quantity of material that must be processed. As implied earlier, operation at a Ca/S of 2.0 with a 10% ash, high sulfur coal almost triples the rate at which ash must be collected by the ESP and then transferred to the ash silo. As long as lines were free of obstructions and the transfer equipment was in good working order, the increased quantity generally did not pose a problem since normal demand and the basic design of the ash handling system could accommodate such amounts. By the same token, it was important to react to upsets quickly since there was less time available to make required repairs.

Beyond the quantity of ash itself, the other major considerations regarding LIMB ash handling and disposal stemmed from the quicklime component and the pozzolanic properties of the ash. At Edgewater, ash is pneumatically conveyed from the ESP hoppers into the ash storage silo. Even during the relatively short tests in 1987, LIMB ash tended to bridge over at the wet/dry interface near the aspirating water jets used to create the vacuum. A device designed to ram through the deposit periodically was successfully designed and installed to overcome this seemingly small, but critical, problem.

Greater difficulty was encountered due to the amount of steam generated by the water/quicklime reaction occurring in the beds of the trucks used to haul ash to the landfill. Water was mixed with dry LIMB ash from the silo in a pug mill that discharged directly into the truck waiting below. As the level rose in the bed, the steam that resulted soon made it impossible for the operator to see how much room remained. As noted earlier, this was true especially when minimal humidification was employed. Although the problem had been anticipated and a large fan had been mounted to blow or suck the steam away, the severity of the steaming was far beyond the fan's capability. After considering a number of alternatives including weighing and sonic techniques, a system was devised that involved the operator's lowering a freely hanging thermocouple to the desired fill level in the empty truck bed. The thermocouple then read ambient temperature up until the time it would begin to sense the hot ash. While not regarded as a permanent "commercial" solution to the problem, it proved to be an expedient, practical remedy for the purposes of the demonstration. In time, a "reference" thermocouple was added in the discharge chute of the pug mill, since some variation in temperature did occur, typically in the 66 to 121°C range, depending on the stoichiometry and degree of humidification.

For future commercial systems, a more sophisticated design including those based on gravimetric, sonic, or even spectrophotometric techniques is envisioned, if treatment is restricted to an ash unloading system such as exists at Edgewater. Assuming that rehydration of the quicklime component is the preferred method of ash disposal, another extreme is possible where there are pre-existing facilities, such as a pug mill and radial stacker at the disposal site, which can readily accommodate steam from the ash. The steam emanating from the surface of the ash presents no sustained problem in that it subsides to faint wisps within about 15 minutes.

Before the steaming problems were brought under control, they gave rise to a further complication that had been underestimated. While underfilling the truck was the norm, on a couple of occasions overfills did occur that had to be picked up with a front end loader. The area then was washed down as a final cleanup measure. When this was done, the lime-rich ash would raise the pH of water draining toward the plant's ash pond. While provision had been made for sensing and neutralizing high pH water that could result from a failure in the pneumatic ash conveying system and from minor yard spills of lime or ash, the amount that spilled from overfilling the truck had not been anticipated. Moreover, sumps that accumulate significant quantities of lime or LIMB ash due to low flow or agitator failure could also produce undesirably high pH. The solution to all of these related difficulties was rerouting all of the potential sources through the neutralization system.

Most of the LIMB ash from Edgewater was placed in Ohio Edison's ash disposal site, adjacent to the normal ash disposal area. Despite apprehensions that the cementitious properties of the ash might cause some difficulty with the bulldozers, no significant problems were encountered, probably because the pozzolanic reactions did not proceed to any appreciable extent at the relatively low water/ash ratios used to produce a material that can be readily dumped from the truck. In addition to the routine LIMB ash disposal, approximately 140 truckloads were placed in two test cells in an isolated area of the disposal site for study over the next several years under a related DOE-sponsored program.

Summary and Conclusions

The results of the LIMB demonstration project on a full-scale, coal-fired utility boiler show that the technology has met or surpassed program goals with respect to SO_2 and NO_x emission control. Moreover, in spite of early difficulty in controlling particulate emissions with the ESP, the design and installation of a full-scale humidification system appears to have overcome the adverse aspects of the increased quantity of fine, high resistivity ash. Specifically, the use of a lignosulfonate-doped hydrated calcitic lime, produced in bulk by a commercial supplier, and operation of the humidifier at an 11°C approach to saturation resulted in SO_2 removal efficiencies of up to 72% at a Ca/S of 2.0, far in excess of the 50% program goal. Even without the lignosulfonate additive, up to 65% capture was possible under the same conditions. Removal efficiencies of about 62 and 55% were obtained in the absence of humidification to the close approach temperature for the modified and unmodified sorbents, respectively. The SO_2 data have also been reduced and presented in a form that characterizes the removal over a range of stoichiometric ratios. At the same time, an overall average NO_x emission level of 206 ng/J was achieved over months of operation with the DRB-XCL™ burners installed to meet a goal of 215 ng/Jor less. Particulate emission control was effectively restored by modest levels of humidification as indicated by opacity measurements at the ESP outlet. Particulate mass emission levels of 4.3 to 8.6ng/J were found to be far below the 43ng/J goal, although the tests had to be conducted at conditions representing approximately 75% of the full boiler load. This load limitation was imposed because long-term loss of refractory material had exposed support beams in the vicintiy of the nose arch to unaccepatably high temperatures.

The designs of two 150 MWe LIMB systems, one with only minimal humidification to restore ESP efficiency and another with the capability of operating at close approach to saturation, were used as a basis for cost comparisons with wet limestone FGD. Economic studies have shown that the capital and operating costs of LIMB technology compete favorably for units up to about 300 MWe. Additional benefits of LIMB include ease of operation and maintenance, relatively simple installation, smaller space requirement, and a lower reduction of the plant's generation capacity.

The overall impact LIMB technology had on boiler and plant operations at Edgewater is particularly notable in a few areas, all of which are considered manageable when viewed from the perspective of further commercialization. The single greatest impact comes simply from increased particulate loading through the boiler, ESP, and ash handling system. Unless restored by effective sootblowing, heat transfer efficiency in the boiler decreases in proportion to the amount of sorbent injected. At higher Ca/S ratios the limitations of the compressed air sootblowing system at Edgewater soon pointed toward the need for future commercial systems to address sootblowing capability more thoroughly than had originally been anticipated for the demonstration project. In comparison with these effects, the impact of increased gas flow from air used to disperse the sorbent and to atomize water in the humidifier is thought to be quite low, especially if only moderate humidification to perhaps 135°C is required to restore ESP efficiency. While the data indicate an overall energy penalty of about 1.5% in boiler efficiency for the combined impacts, it is strongly believed that this can be recovered with more effective sootblowing.

Again because of the increased quantity of material, LIMB technology makes additional demands upon the ash handling system that must be taken into account in the application for future commercial systems. Beyond this, the chemical composition of the LIMB ash, and the quicklime component in particular, should be reviewed carefully in light of possible deposit formation at wet/dry interfaces where the pozzolanic properties of the ash can be important. Likewise the lime component of the ash is important with regard to potentially high pH conditions in any wetting operation that might be used as part of the ash disposal process.

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The complete report, entitled "Demostration of Sorbent Injection Technology on a Wall-fired Utility Boiler (Edgewater LIMB Demonstration)," (Order No. PB92-201 136/AS; Cost: $35.00, subject to change) will be available only from:
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