Appendix 9.0

MICRONIZED COAL REBURNING DEMONSTRATION OF NO_X CONTROL

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ABSTRACT

The Micronized Coal Demonstration Project is part of Round 4 of the U.S. DOE's Clean Coal Demonstration Program. Originally planned for demonstration at TVA's Shawnee Plant, the demonstration was transferred to Eastman Kodak Company (Kodak) and New York State Electric & Gas Corporation (NYSEG). The project includes the demonstration of micronized coal reburn technology for the reduction of NO_x emissions from a cyclone boiler at Kodak. The cyclone boiler application includes the utilization of a retrofit Fuller MicroMill™ to provide micronized reburn coal.[1] The technology is also to be demonstrated on a 150 MW class tangentially-fired boiler at NYSEG's Milliken Station. Milliken will utilize an existing DB Riley MPS mill with dynamic classifier to provide the reburn fuel. This paper provides an update on the current status of the project with emphasis on test results and operating experiences.

INTRODUCTION

The concept of coal reburning was first demonstrated in the US in 1991-1993 at Wisconsin Power & Light's Nelson Dewey Station on two 100 MW cyclone boilers. Since the compliance date for the Group II boilers (cyclone, vertically fired, wet bottom and cell burners) is January 1, 2000, interests in reburning technology started to surface recently.

In September, 1991, the United States Department of Energy selected a micronized coal reburning

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[1]Micromill is a trademark of the Fuller Company

project for funding in Round 4 of its Clean Coal Technology Demonstration Program (CCTD). The Micronized Coal Reburn Project for NO_x Control on a 175 MW wall fired Unit was to be demonstrated at TVA's Shawnee Plant. The project was subsequently relocated to NYSEG's Milliken Station and Kodak's #15 Boiler in December 1995. Project team members include CONSOL Inc., D.B. Riley, Fuller Company, Energy and Environmental Research Corporation (EER), and ABB Combustion Engineering, Incorporated. Project cofunders include DOE, Kodak, NYSEG, New York State Energy Research and Development Authority (NYSERDA), and Empire State Electric Energy Research Corporation (ESEERCO).

The overall project goals are:

- Demonstration of micronized coal reburning technology on a cyclone boiler with at least a 50% NO_x reduction.
- Demonstration of micronized coal reburning technology in conjunction with low No_x burners on a tangentially fired boiler with a 25-35% NO_x reduction.
- Comparison of mill effectiveness and economics in micronizing coal using a Fuller MicroMill and a D.B. Riley MPS 150 with dynamic classifier.
- Determine effects of coal micronization on electrostatic precipitator (ESP) performance.

The host site for the cyclone boiler demonstration is Kodak's Kodak Park Site Power Plant located in Rochester, New York. #15 Boiler is a 50 MW class cyclone boiler. The host site for the tangential boiler demonstration is NYSEG's Milliken Station, located in the town of Lansing, New York. Milliken has two Combustion Engineering 150 MW pulverized coal-fired units built in the 1950's.

Cost and Schedule

This project was established to meet NO_x emissions requirements for both Milliken and Kodak's #15 Boiler, therefore the schedule was set to complete the project by 1998. The construction period for Kodak lasted from Fall 1996 to Spring 1997. During this period Kodak #15 Boiler was retrofitted with Fuller MicroMill, MCR injectors, overfire air, flue gas recirculation and burner management and controls. The operation and testing phase of the demonstration began in April 1997 and will be completed by December 1998. Milliken Station performed parametric testing on the boiler using existing equipment. The testing began Spring of 1997 and will conclude in the Summer of 1998.

The total cost of the project, including the demonstration program will be $8,683,499 and will include obligated DOE funding of $2,500,000.

Project Description

Cyclone Boiler Micronized Coal Reburn Project

Kodak's #15 Boiler is a Babcock and Wilcox Model RB-230 cyclone boiler commissioned in 1956. The unit was designed to generate 400,000 lbs/hr of 1400 psig, 900°F steam with a rated heat input of 478 MMBTU/hr at maximum continuous rating. The fuel supplied to this boiler is Pittsburgh Seam medium to high sulfur coal with a Hargrove Grind Index of approximately 55 and a high heating value of 13,300 Btu/lb. The cyclone furnaces operate at a very high heat release rate, creating molten slag which is captured on the cyclone walls and flows to a slag tap at the bottom of the furnace. Particulate control is maintained by an electrostatic precipitator.

The baseline NO_x emissions from this unit is nominally 1.25 lb/MMBTU. The MCR retrofit project is expected to lower NO_x emissions from .70 - .60 lbs/MMBTU at 400,000 lbs/hr steam, while limiting the reduction of boiler efficiency.

The design of the technology includes the installation of a Fuller MicroMill coal micronizing system, reburn injectors/burners and overfire air downstream of the main cyclone burners. The MicroMill is unique in that it uses a tornado like column of air to create a rotational impact zone where the coal particles actually strike against each other and thus crush themselves. The typical particles generated by the MicroMill will be approximately 20 microns, whereas normal pulverized coal is about 60 microns. This will increase the surface area by ninefold allowing for more complete combustion in a shorter time period. This is critical to the success of the project, since the boiler is small and has a low residence time.

The reburn system is the core technology that is being demonstrated to reduce NO_x emissions. Reburn has been used principally with natural gas or oil as the reburn fuel. Reburning of pulverized coal has been demonstrated and proven to be advantageous to the alternative fuels. The project will use true micronized coal (80% <325 mesh) for reburn fuel. EER was responsible for the design and supply of the micronized coal injector equipment and overfire air system as well as determining the expected boiler performance and NO_x emissions.

Tangentially-fired Micronized Coal Reburn

NYSEG's Milliken Station has two 150 MW units with CE designed tangential coal-firing single furnace boilers. Both units have been retrofitted with ABB Low NO_x Concentric Firing Systems (LNCFS 3™) and four new DB Riley MPS 150 pulverizers with dynamic classifiers.[2] The combination of the LNCFS-3 and MPS mills has resulted in reducing NO_x emissions from both units from a baseline of .60 lb/MMBTU to less than .39 lb/MMBTU while producing marketable fly ash with a carbon content less than 4 percent.

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[2]LNCFS-3 is a trademark of ABB Combustion Engineering, Inc.

Each pulverizer supplies one elevation of corner burners. To simulate and test a reburn application, the lower three coal elevations were biased to carry approximately 80% of the fuel required for full load. The top burner provided the remaining fuel. The speed of the dynamic classifier serving the top mill was increased to provide a micronized fuel. An incremental NO_x reduction was achieved in addition to the reduction already obtained with the LNCFS-3.

As a comparison to the NO_x reductions demonstrated with the reburn simulation, the burners were arranged to more deeply stage combustion. This simulated the ABB TFS2000R™ combustion system.[3] Whereas the LNCFS-3 utilizes close coupled and separated over-fire air injection zones, the new system has an additional zone of separated over-fire air. The result is a burner that is capable of deeper staging.

TEST PLAN

The test plan was developed to cover all of the impacts of the micronized coal reburn demonstrations at Kodak and Milliken Station. Incremental NO_x reductions obtained by reburn have been determined and will be verified with additional testing. The effectiveness of the two micronizing systems is presently being evaluated. The change in dust loading and precipitator performance caused by the micronized fuel still needs to be determined.

Pittsburgh seam coals were burned during the demonstration testing, with the same coal used as the primary and reburn fuels. Testing was in conjunction with the optimization testing performed by ABB on Milliken Unit 1, and by EER on Kodak #15 Boiler. The boiler and operating settings were determined during the optimization testing and will be verified during future testing planned later this year.

The first phase of micronized coal reburning evaluation was conducted at Milliken Unit 1. This included using the existing top burner to feed the micronized reburn fuel into the upper reaches of the boiler using the existing mill to micronize the coal. Based on additional future testing, if test data demonstrates that a significant benefit can be derived with a separate micronized reburn system, then separate injectors will be installed to replace the existing top coal burner nozzles. Both phases of the project would involve the same tests, and utilize the LNCFS-3 test data from the Milliken Clean Coal Demonstration Project as a baseline.

Baseline and micronized coal reburning tests conducted at Kodak # 15 Boiler were at full load. Testing at reduced loads were kept to a minimum. The micronized reburn fuel was prepared using the Fuller MicroMill.

The operating variables that were modified during the tests are listed in Table 1. The parametric/optimization tests were performed on the reburning system to establish the best operational modes. Also various low and high experimental values for each optimized variable were tested to confirm operational boundaries of the system and to record the effect. The experimental ranges of the operating conditions were adjusted to maintain reliable boiler operation and power generation. In particular, if a set of test conditions could not maintain the required steam conditions, the variables were adjusted or the test was terminated.

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[3] TFS 2000R is a trademark of ABB Construction Engineering, Inc.

TABLE 1. TEST VARIABLES

Milliken Unit 1:

Boiler Load, MW

Full Load, %

Top Elevation Coal Size, % -325 Mesh

Mill Setting, rpm

Economizer O_2, %

[1]Fuel Air Levels 2, 3 and 4 Damper, %

[2]Top SOFA Damper, %

Top Elevation Coal Flow, % Total

Main Burner Tilt, Degrees

SOFA Tilt, Degrees

Kodak Boiler 15:

Boiler Load, MW

Full Load, %

Reburn Fuel Rates (%of total)

Micronized Coal Size, % -325 Mesh

Primary Excess Air, %

Primary Stoichiometry (SR1)

Micronized Coal, %

Reburn Stoichiometry (SR2)

Overall Excess Air

Final Stoichiometry (SR3)

[1]Fuel Air Levels 1 (Top Level) Damper Position is at Minimum

[2]Bottom and Middle SOFA Damper Positions are at Minimum

Overall, the evaluation program included two test programs, corresponding to the micronized coal reburn at Milliken Unit 1 and the micronized coal reburning evaluation at Kodak #15 Boiler. Each test program consists of four test programs:

- Diagnostic
  These tests identify the boiler setting which provides optimized performance while maintaining minimal NO_x emissions and carbon in the ash.
- Performance
  These tests verify that the optimized boiler operation and performance is equivalent to the diagnostic test findings. The testing quantifies the diagnostic test performance.
- Long-Term
  This test monitors the operation and performance of the boiler over a 51 day period to demonstrate that the micronized coal operation of the boiler is sustainable and can maintain overall performance.
- Validation
  This test demonstrates that the optimized boiler operation and performance over a long period of time is repeatable.

Coal Reburning Technology for NO_x control

Coal Reburning is a NO_x control technology whereby NO_x is reduced by reaction with hydrocarbon fuel fragments. A typical application of coal reburning to a coal-fired boiler is illustrated in Figure 1. No physical changes to the main burners are required. The burners are simply turned down and operated with the lowest excess air commensurate with acceptable lower furnace performance when considering such factors as flame stability, carbon loss and ash deposition.

The technology involves reducing the levels of coal and combustion air in the burner area and injecting reburn fuel (micronized coal) above the burners followed by the injection of overfire air (OFA) above the reburn zone. This three zone process creates a reducing area in the boiler furnace within which NO_x created in the primary zone is reduced to elemental nitrogen and less harmful nitrogen species. Each zone has a unique stoichiometric ratio (ratio of total air in the zone to that theoretically required for complete combustion) as determined by the flows of coal, burner air, reburn fuel and OFA. The descriptions of the zones are as follows:

- Primary burner zone: Coal is fired at a rate corresponding to 75 to 90 percent of the total heat input. NO_x created in this zone is slightly lower than normal operation due to the lower heat release and the reduced excess air level.

- Reburn zone: Reburn fuel (micronized coal) is injected above the main burners through wall ports. The reburn fuel consumes the available oxygen and produces hydrocarbon fragments (CH, CH_2 etc.) which react with NO_x from the lower furnace and reduce it to elemental nitrogen, N_2. Optimum NO_x reduction performance is typically achieved when the reburn zone is operated at about 90% of stoichiometric ratio, which is slightly fuel rich (reducing). NO_x reduction can be adjusted by varying the reburn fuel injection rate, typically over the range of 10-25% of total boiler heat input. To minimize the reburn fuel required to achieve fuel rich conditions in the reburn zone, EER's design utilized injectors rather than burners, which would have introduced additional air. In addition, flue gas was recirculated (FGR) to carry the micronized fuel into the boiler. This also contributed to the fuel rich conditions in the reburn zone.

- Burnout (exit) zone: The oxygen required to burn out the combustibles from the reburn zone is provided by injecting air through overfire air ports positioned above the reburn zone. These ports are similar to conventional overfire air ports except that they are positioned higher in the furnace so as to maximize the residence time for NO_x reduction occurring in the reburn zone OFA is typically 20 percent of the total air flow. OFA flow rate and injection parameters are optimized to minimize CO emissions and unburned carbon in fly ash.

Several derived benefits can be realized with coal reburning. From an economic standpoint, coal reburning is less expensive to install and costs less to operate than selective catalytic reduction. With micronized coal as the reburn fuel, the utilization of the fuel is enhanced. This results in reduced carbon in ash, when compared to conventional coal reburning. These benefits outweigh the additional power requirements associated with operation of the micronizers and (FGR).

Kodak Test Program

The overall goal to reduce NO_x emissions to .60 lbs/MMBTU or below was achieved during the parametric test program. Several equipment problems have hampered the testing progress and will need to be resolved to make this a more reliable NO_x control program.

The testing to date has included the diagnostic testing which includes the parametric testing of the boiler. The purpose of the parametric testing is to define the relationships that exist between the controlling parameters (micronized coal flow rate, coal fineness, FGR flow rate, overfire air flow rate, coal flow biasing and soot blowing frequency) and the boiler outputs (stack emissions, carbon in ash, electrical power etc.). These relationships are used to approximate the boiler set points required for optimum reburning performance. The approach utilizes a formalized matrix consisting of a series of preplanned tests that vary one parameter at a time. It should be noted that the matrix functions as a guide only and modifications to the test direction may be required as events dictate.

The 1997 test program was divided into three periods rather than one continuous test due to problems encountered with both the boiler and reburn equipment. During the test program, process parameters such as cyclone stoichiometric ratio, reburn zone stoichiometric ratio, micronized coal flow and boiler load were varied. System performance data was collected to determine conditions which were optimum for NO_x control. The data from the tests was also used to establish optimum operational settings for the long-term test used to evaluate the long term impacts of the coal reburning system on both NO_x emissions and boiler performance. Concurrent with obtaining parametric test data, system start up test data were also acquired to provide input information for placing the reburn system in automatic control.

The first series of tests occurred during February 1997, while the system was in the startup mode. During this series of tests, boiler and operational problems occurred and included leakages from the transport gas fan due to incompatible gasket material, high mill vibration and inaccurate coal flow measurements. During this test NO_x emissions were reduced to the target .60 lb/MMBTU from the baseline level of approximately 1.25 lb/MMBTU, CO was maintained below 100 ppm at all times and loss on ignition was 21 to 24 percent at baseline and approximately 50 percent during reburning. The boiler efficiency decreased by 1.5 percent, which was within the project limit of 2 percent decrease or less. Opacity was in the range of 17 percent at the .60 lb/MMBTU NO_x emission level.

The second series of tests occurred in the month of May 1997 following the replacement of the transport gas fan gaskets, recalibration of the feedwater and steam flow meters; balancing of the micromills to reduce vibration, and adjustments to the coal flow indicators. The target NO_x level of .60 lbs/MMBTU was achieved at micronized coal input levels of approximately 15 percent or greater. Loss on ignition increased from an average baseline level of 40 percent to approximately 60 percent at 20 percent micronized coal heat input. The 6 minute opacity average increased substantially at high micronized coal inputs but stayed below the 20 percent limit during most of the tests, except on a few occasions where baseline opacity prior to coal reburning was already higher than the typical baseline level of 5 percent. The steam temperature was maintained above the plant's preferred lower limit of 875 F at micronized coal inputs up to 20%.

The third series of tests occurred in the month of November 1997 after the swirler on the coal injectors had been removed and replaced with a view port and both the east and west mills had been realigned to reduce vibration. The target NO_x levels during these tests achieved .60 lbs /MMBTU at micronized coal inputs of approximately 20 percent or greater with acceptable opacity and steam temperature. Opacity was 10 to 12 percent during most reburning tests, a slight increase form a typical baseline level of 5 percent. The steam temperature stayed above the plant's lower limit of 875° F. Loss on ignition averaged approximately 45 percent, a 5 percent increase from the baseline level of 40 percent.

Kodak MCR Assessment

The Kodak MCR project has been successful in reducing NO_x emissions by 50 percent. Figure 2 presents the relationship between NO_x emissions and reburn coal heat input for each of the three test series. The data shown on the plots represent cyclone stoichiometric ratios in between 1.05 to 1.15. In each test series, the plots demonstrate that the project NO_x target of .60 lbs/MMBtu was achieved with as low as 17% reburn fuel heat input. Based on an average baseline level of 1.45 lb/MMBtu, the .60 lbs/MMBtu emissions level represents a 59% reduction. NO_x emissions dropped immediately upon introduction of the reburn fuel and continued to decrease as more reburn fuel was added to the boiler. The best NO_x emissions reduction for a limited period of time occurred during the second test series at a low SR_1 level and at a reburn fuel heat input of 20%. The NO_x emissions reduction level at that point was .40 lbs/MMBTU.

Figure 3 presents the same data, plotted against reburning zone stoichiometry (SR_2). The plots show that the SR_2 decreased as more micronized coal was introduced into the furnace. The NO_x target of .60 lbs/MMBTU was achieved when SR_2 reached approximately 0.9, with cyclone stoichiometry (SR_1) maintained a 1.05 to 1.15. It was predicted that the SR_2 level required to achieve the project NO_x target of .60 lbs/MMBtu would be between 0.85 and 0.90. The data show that the prediction was verified.

Figure 4 presents the relationship between loss-on-ignition (LOI) and reburn fuel heat input. The baseline during the second series of tests was 35 to 45 percent while the baseline during the third series of tests was about 25 to 35 percent. Note that the LOI level showed high variability. The higher the baseline LOI during the second test series may have been due to lower excess air levels in the cyclone. The set point O_2 was approximately 2.8 percent during these tests as compared to 3.3 percent during the third series of tests.

The plots show that LOI increased with increasing reburn fuel heat input. The increase was due to the shorter residence times of the coal in the furnace. At 20 percent reburn fuel heat input, LOI increased by approximately 5 to 10 percent from baseline during the third series of tests. This test series is considered to be more representative of coal reburning impacts on LOI. The high LOI levels during the second series of tests were due to reburn fuel maldistribution caused by slag build up on some of the coal injectors.

However, several obstacles have prevented a complete and accurate assessment of the system. Some of the problems experienced during the testing included the following:

- <u>Fuel feed</u> - the fuel feed to the micromill is frequently interrupted due to pluggage within the coal handling system. Coal fineness and moisture have been a problem. Since coal feed is determined by the rpm of the screw conveyor an interruption or reductions in fuel flow can not be determined readily. A rebuilt rotary feeder and air canon have been added to the system to reduce future pluggage.

- <u>Micromills</u> - vibration and blade wear have been chronic problems and have also resulted in interruptions to the reburn system. This system has been overhauled and will be run continuously to determine reliability and maintenance costs.

- <u>Coal flow</u> - since coal has flow through each injector cannot be determined, biasing for flow has not been accomplished. Flow balancing will be accomplished by calculation.

- <u>Oxygen Accuracy</u> - additional oxygen probes were installed from 2 probes to 6 probes.

These areas are presently being addressed in order to fully assess the system under a continuous uninterrupted operation. This information will allow full assessment of the capabilities of the system and the costs associated with the maintenance and operation of MCR on a cyclone boiler. Long term testing is scheduled to begin by mid May and end by the end of July 1998.

Milliken Test Program

As part of the Milliken Clean Coal Technology Demonstration Project Unit 1 was retrofitted with new Low NO_x Concentric Firing System (LNCFS-3) with both close coupled and separated overfire air ports to achieve up to 40% of the NO_x reduction. The burners developed by ABB C-E utilize both air staging and early devolatilization of the coal to control the combustion NO_x formation. The close coupled and separated overfire air systems have a total of five elevations of overfire air ports to allow for operational flexibility. The combined overfire air capabilities approach 40% of the total combustion air. The coal nozzles were initially designed to retain flame front by creating recirculation zones at the burner tip. These coal nozzles were later redesigned for higher sulfur coal applications by increasing the burner outlet velocity and allowing for more air cooling around the fuel compartment. A set of offset air nozzles are part of the windbox design to deliver "cushion air" between the fireball and the waterwalls in order to minimize the fireside corrosion due to a reducing environment.

Although the new equipment offers a great degree of operational flexibility, the new burner systems are more sensitive to coal quality variation than the original equipment. Higher volatility coals (>36%) can cause close ignition and coking on the burner tips. The increased sensitivity can be explained by the air staging effect which reduces the secondary air velocity to maintain the flame front distance. The operators have developed awareness of such impact and are able to respond to the coal change before problems occur.

Since Milliken Unit 1 can produce coal fineness approaching the "micronized " level, a coal reburn can be simulated on the existing LNCFS-3 burners by biasing mill loading and air dampers. This simulated reburn condition can determine if NO_x reductions can be realized for future use during ozone season and whether a full conversion to micronized coal reburn system would be cost effective. A test program was initiated to quantify the ability to reduce NO_x emissions using the simulated reburn system at Milliken.

The bulk of the testing at Milliken occurred from March 10, 1997 to April 2, 1997 with some additional testing in December, 1997. ABB-CE provided the necessary manpower, test equipment and laboratory services for ultimate coal analysis. DB Riley provided laboratory services for ASTM mill fineness analysis. Consolidation Coal Co. (Consol) provided analytical data reduction support.

In cooperating with NYSEG, ABB-CE developed a test matrix consisting of 32 separate tests based on the following progression:

- 1) What is the maximum consistently achievable NO_x emission reduction based on deep staging of the combustion ?

- 2) What is the maximum consistently achievable NO_x emission reduction based on maximum coal micronization with the top elevation mill, in addition to combustion staging ?

- 3) What is the maximum consistently achievable NO_x emission reduction based on combined top mill micronization, deep staging and next to top mill removed from service, creating a separation between the main flame and the reburn flame (true reburn configuration) ?

The primary objective during the testing was to determine the minimum NO_x level attainable while maintaining marketable fly ash. Marketable fly ash is defined as having less than 4.5 % loss on ignition. Various parametric tests were run and the resulting NO_x, LOI, O_2 values were recorded during each test.

The test data collected during the test periods have defined the impact of various settings on NO_x emissions. The following graphs capture the impact of these settings on NO_x emissions in lbs/MMBtu and the percent of carbon found in the fly ash.

The following conclusions were derived:

- 1) <u>Effect of SOFA Tilt, (Fig. 5):</u> Varying the tilt from 0 to 150 degrees, had practically no effect on NO_x emissions, but increased the LOI from 2.8% to 5.1%, a net increase of 82%.

- 2) <u>Effect of Reburn Fuel Fineness (Fig. 6):</u> Changing the upper mill classifier speed from 95 RPM to 115 RPM effects the coal fineness as well as the production rate of the mill.

  For example, in the top mill, the fineness as a function of dynamic classifier speed is shown in the table below:

  CLASSIFIER FINENESS % Passing Mesh

RPM	-50 (297µ)	-100 (210µ)	-200 (74µ)	-325 (44µ)
115	100%	99.9%	95.1%	73.1%
105	100%	99.9%	90.6%	69.9%
95	99.9%	99.5%	85.2%	61.4%

  Fig. 6 demonstrates that increasing mill fineness does not affect NO_x emissions, even at various excess O_2 levels (as measured at the economizer). However mill fineness does have a significant effect on the amount of carbon found in the flyash. The finer grinds reduce significantly the % LOI in flyash, from 6.6% to 3.8%, a better than 42% improvement.

- 3) <u>Effect of Reburn Fuel Flow (Fig. 7):</u> Changing the reburn fuel flow of the micronizing mill (top mill) from 15% to 25% of total fuel flow has had a small impact on the NO_x emissions reduction but a large impact on the LOI in the fly ash. The NO_x emissions were reduced from 0.32 to 0.27 Lbs / MM Btu an actual reduction of about 15%, while LOI increases from 4% to 5.5%, an actual increase of more than 35%, rendering this ash unsuitable for commercial sales.

- 4) <u>Effect of Primary Air Flow (Fig.8):</u> Changing the primary air flow as a percentage of total air from 55% to 65%, had little effect on the NO_x emissions as well as the LOI. NO_x emission within the above range of air flow changed from 0.27 to 0.32 Lbs / MM Btu, which was an actual change of about 15% while the LOI varied from 4.2% to 3.8%, a variation of less than 10%.

- 5) <u>Effect of Excess Air (Fig. 9):</u> This is the single most significant parameter that affects both the NO_x emissions and the LOI. As evidenced in Fig. 9, and in the case of the top mill adjusted for regular grind (80% thru 200 mesh) an increase in measured O_2 at the economizer inlet from 2.5% to 3.75%, yields an increase in NO_x emissions from 0.36 to 0.43 Lbs / MM Btu, or about a 20% increase. When the top mill is adjusted for fine grind (micronizing), the NO_x emissions are only marginally better.

Fig. 9 shows the dramatic impact of excess air on LOI. When the economizer O_2 is varied from 2.5% to 3.5%, the LOI, in the case of the top mill adjusted for regular grind, will drop from 6.2% to 3.8%, a reduction of almost 40%. When the same measurements are made while the top mill is micronizing, the reduction in LOI is less significant, from 4.6% to 3.8%, or less than 20%.

- 6) Effect of mill pattern (Fig. 10): When mills are numbered from 1 to 4 on this unit, with #1 mill being the top mill, then removing mill #2 will give a gross approximation of a reburn configuration by creating a gap between the main flame (mill 3 & 4) and the reburn zone (mill 1). In addition, mill 1 is set for micronizing. As can be seen on Fig.10, at a given load (120 MW), NO_x emissions increase with the number of mills in service. For the same conditions, LOI decreases while increasing the number of mills in service, this is primarily due to the load on each mill being smaller which results in a higher average fineness.

These results were deduced from the 1997 test program. During the 1998 test program the most successful tests from 1997 matrix will be selected in addition to new tests designed to research better settings likely to yield higher NO_x reduction. In addition, 3 of the 4 mills on the unit will have major overhauls, the burners at the uppermost elevation will be fitted with burner tips redesigned to better cope with the flame attachment problems experienced.

We expect that the 1998 testing period will take place in the July-August time frame and that the collected data will be reduced in time for the issuance of a final report by November-December 1998.

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2. B.A. Folsom, NOx Control Using Micronized Coal Reburning, American Boiler Manufacturer's Association, Rochester, New York, September 1997

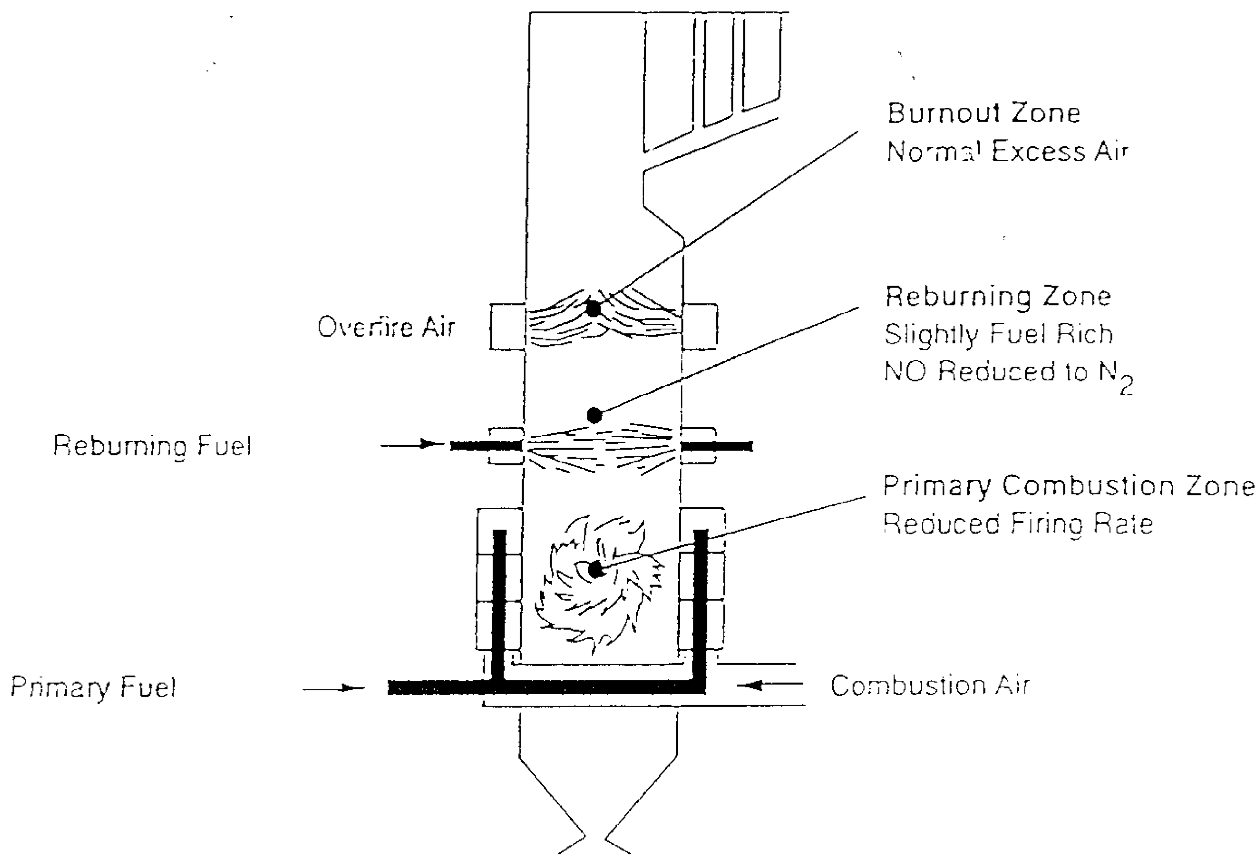

Figure 1. Application of a coal reburn to a utility boiler.

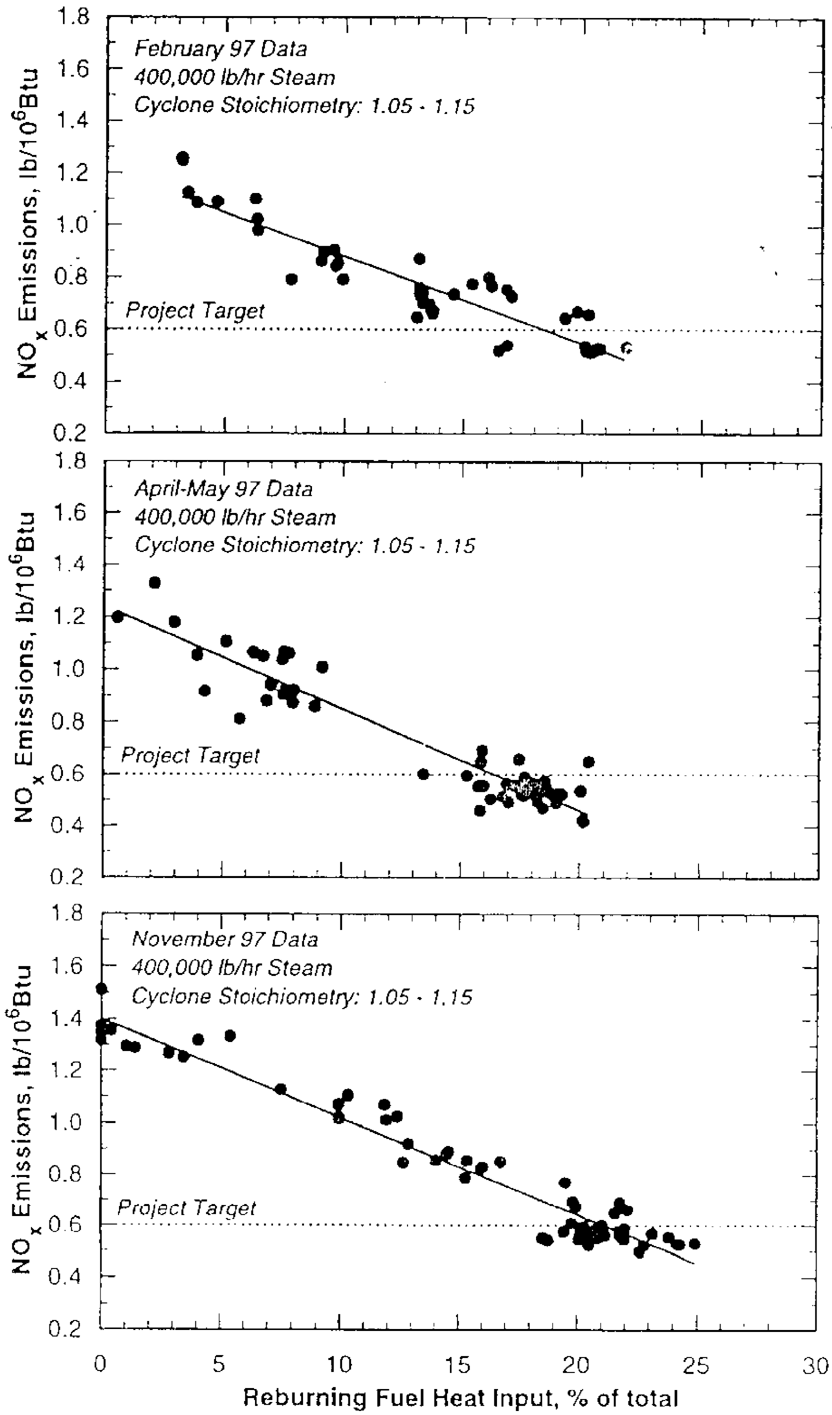

Figure 2. Impacts of reburn fuel on No_x emissions

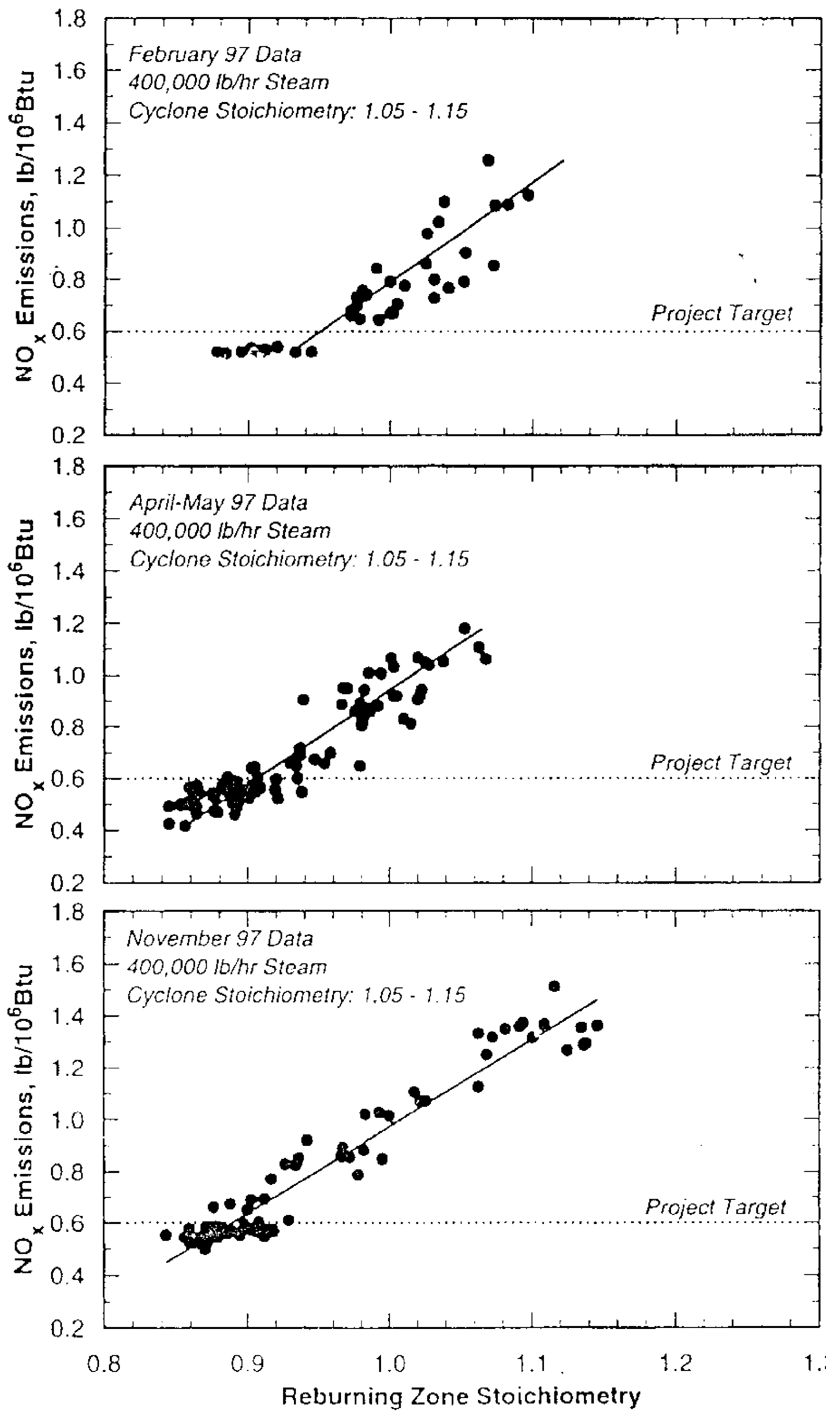

Figure 3 Impacts of reburning zone stoichiometry in NO_X emissions

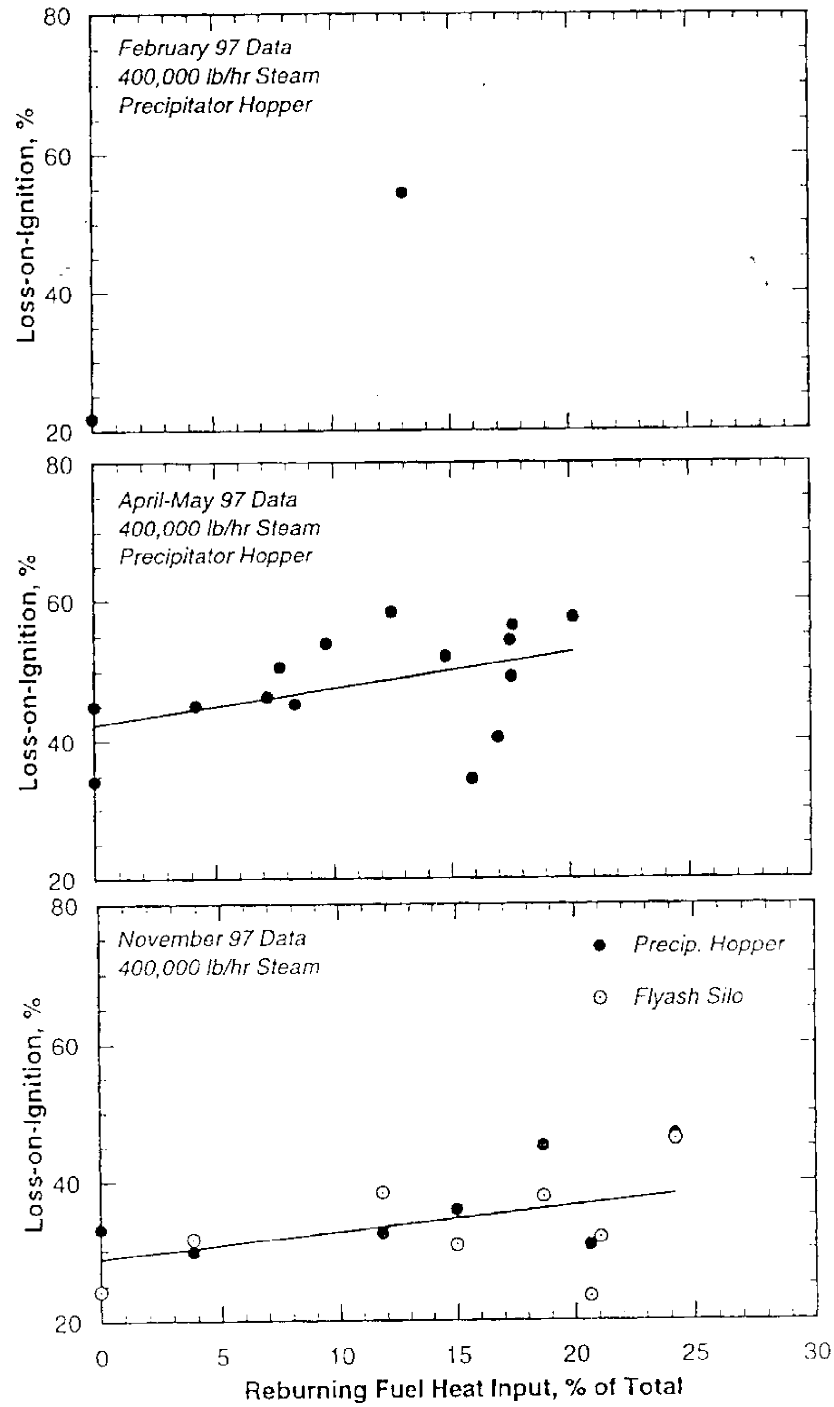

Figure 4. Impacts of reburning fuel on loss-on-ignition.

Figure 5 - Effect of SOFA Tilt

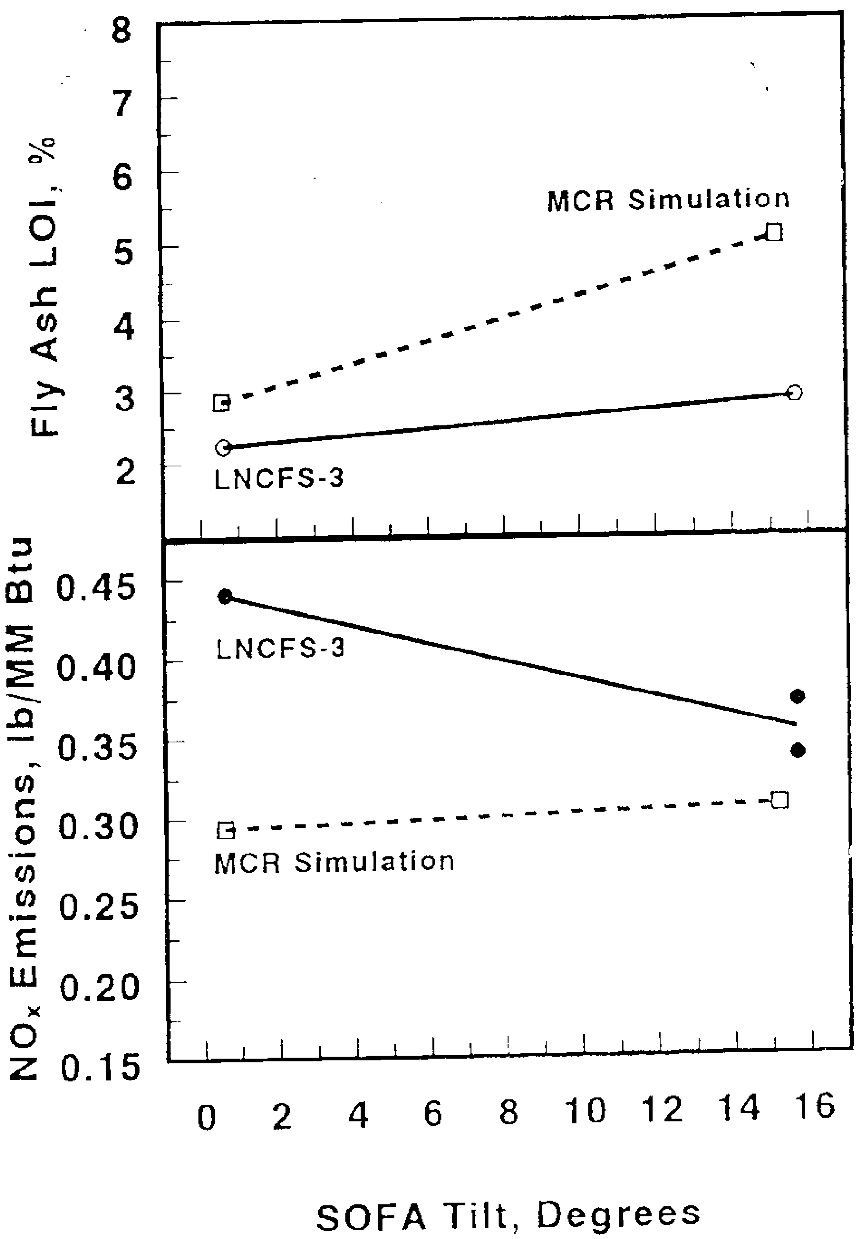

Figure 6 - Effect of Reburn Fuel Fineness

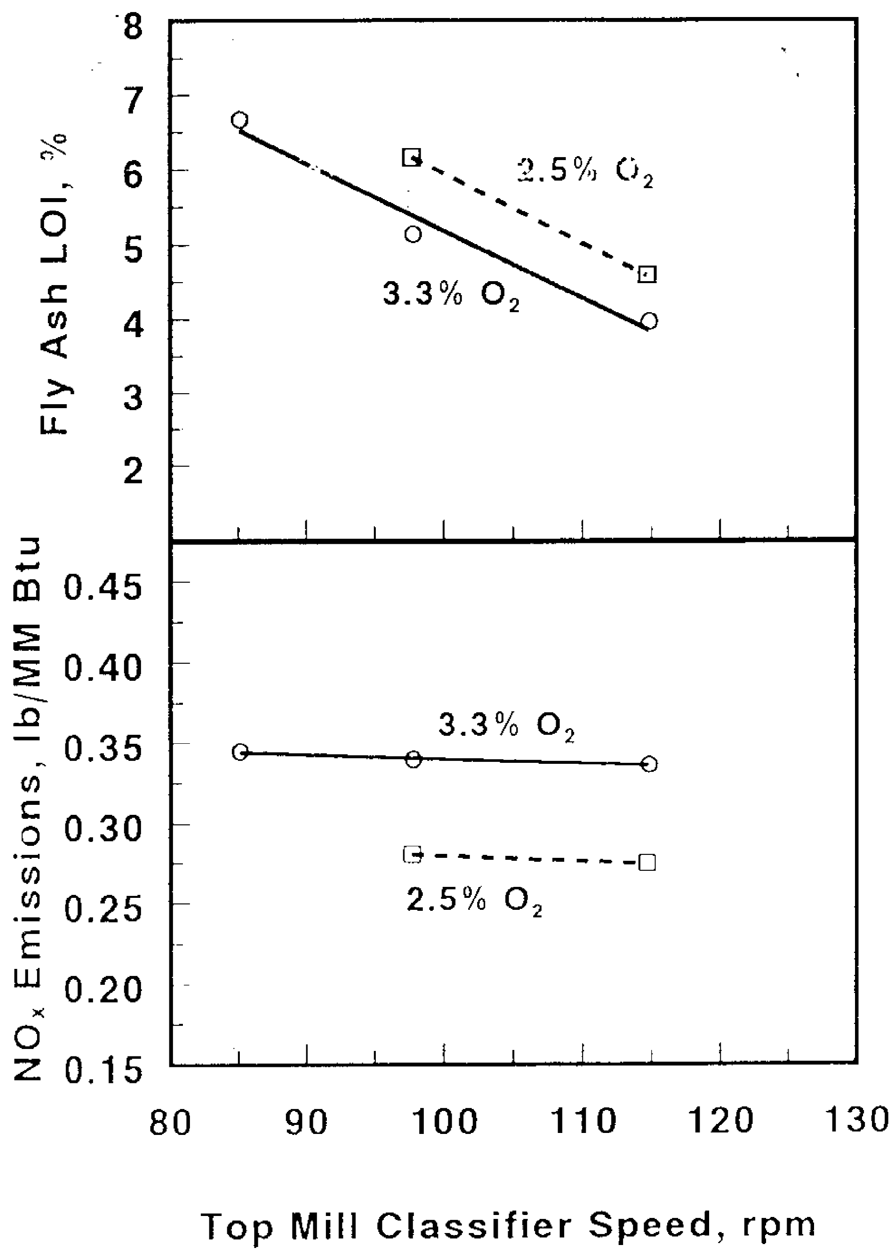

Figure 7 - Effect of Reburn Fuel Flow

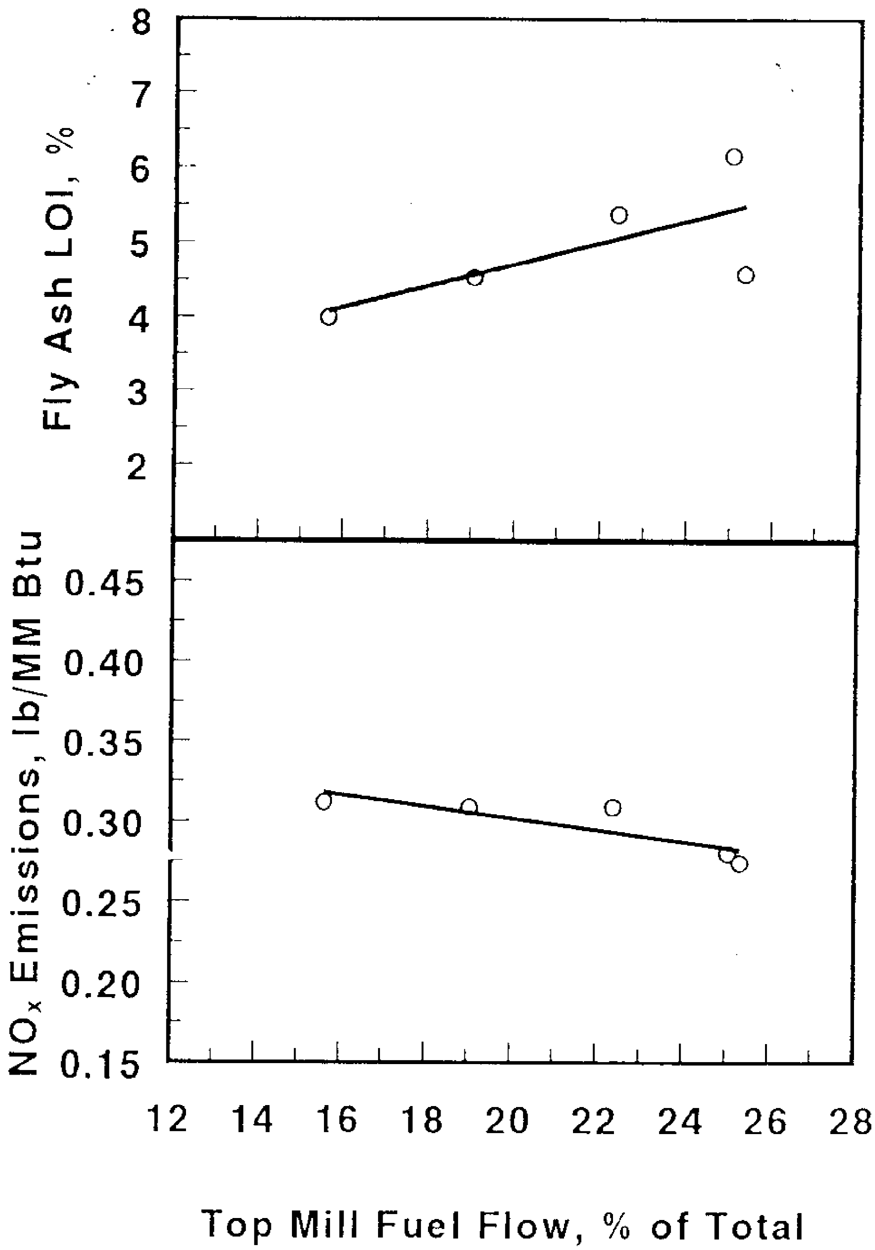

Figure 8 - Effect of Primary Air Flow

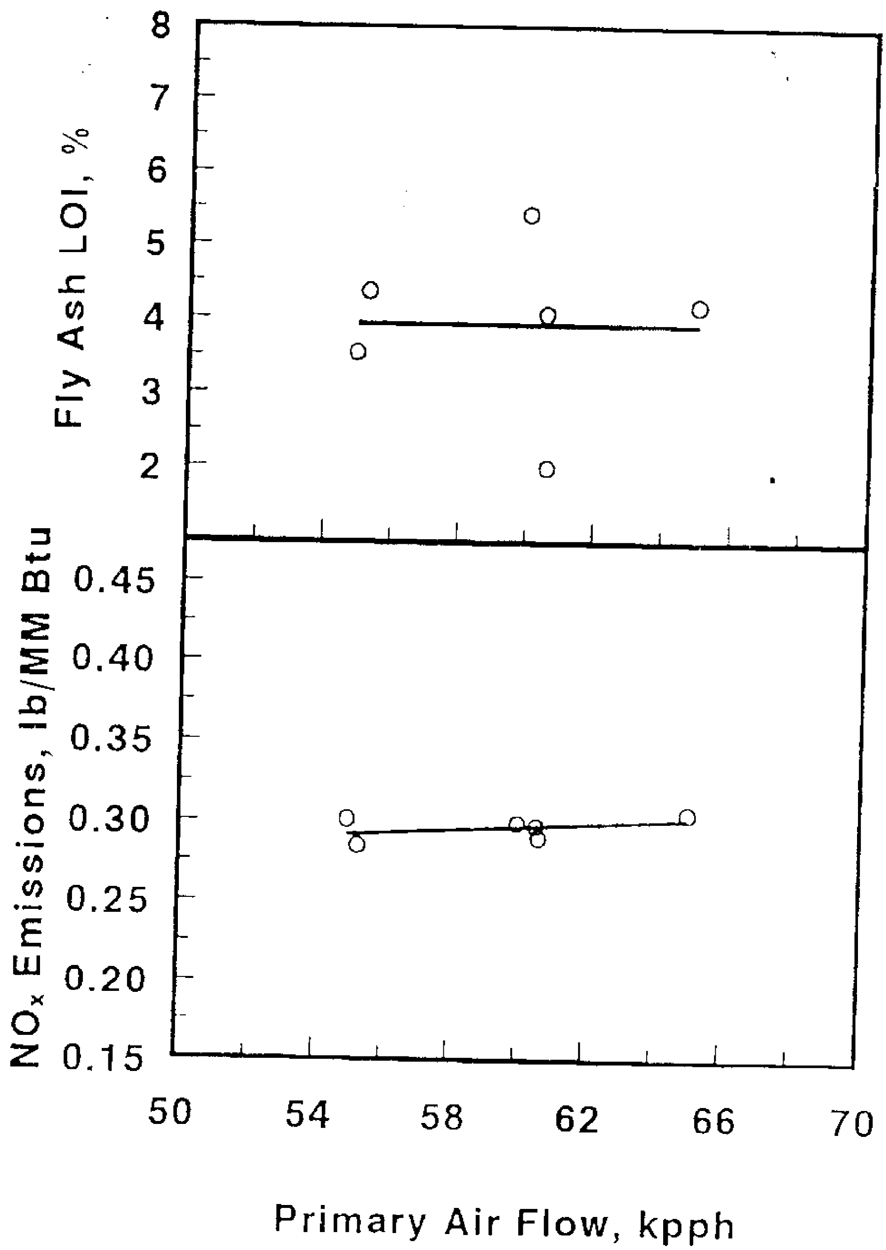

Figure 9 - Effect of Excess Air

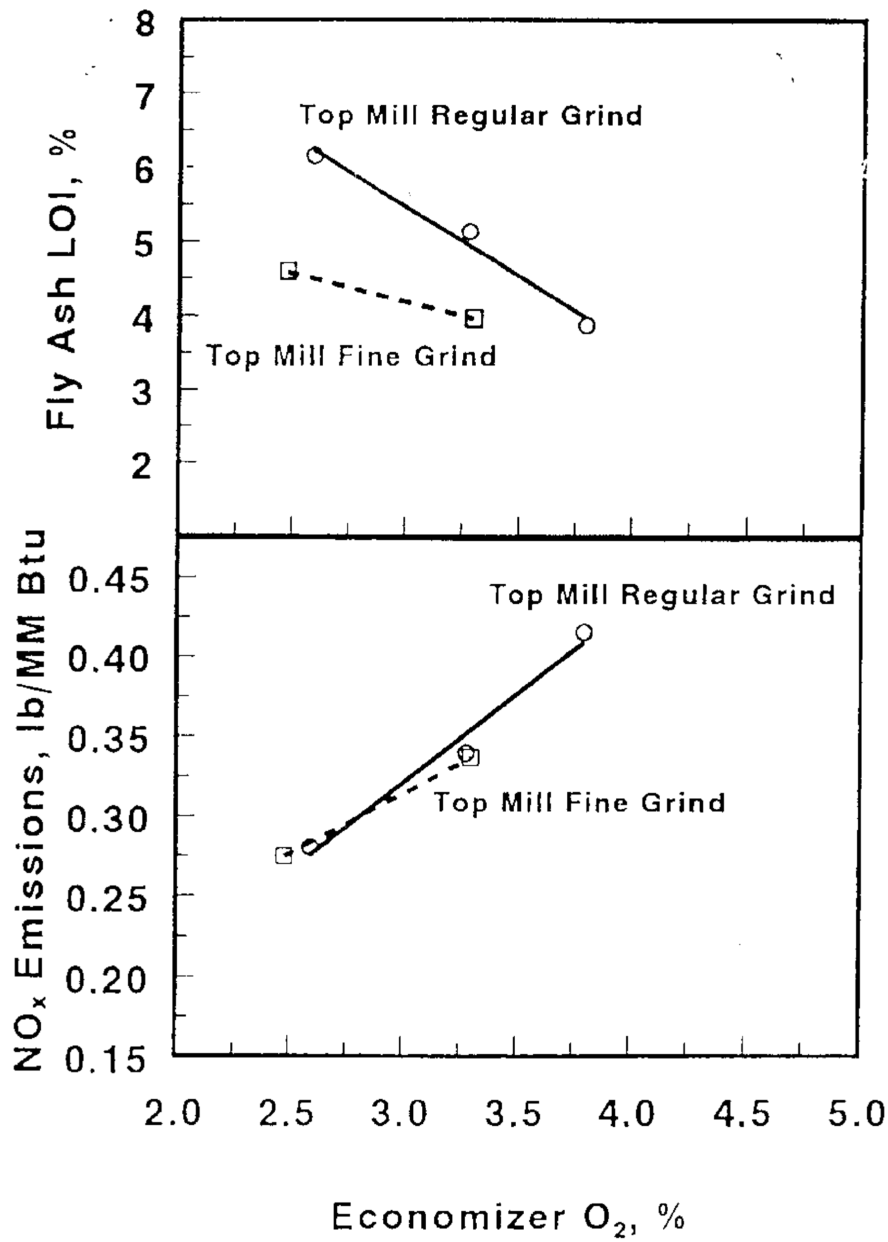

Figure 10 - Effect of Mill Pattern