Appendix 5.0-5

MICRONIZED COAL REBURN DEMONSTRATION PROJECT RETROFIT OF EASTMAN KODAK'S UNIT 15 FOR NO_x CONTROL ON A CYCLONE BOILER

Micronized Coal Reburn Demonstration Project
Retrofit of Eastman Kodak's Unit 15
For NOx Control on a Cyclone Boiler

Kodak Contract No. LH-68X-94207X
Babcock & Wilcox Unit RB-230

OPTIMIZATION STUDY RESULTS

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TABLE OF CONTENTS

Summary

Optimization of the Micronized Coal Reburning System retrofit to Eastman Kodak's #15 boiler is now complete. NOx emissions were reduced from 1.36 pounds per million btu to .60 pounds per million btu at full boiler load with a reburn heat input of 20%. The following document details the results of the optimization study. The fieldwork was performed by Babcock & Wilcox's Field Service and Results Engineering departments between April 13 and April 29, 1998. Tests were performed to evaluate pre and post reburn performance relative to NOx reduction, boiler efficiency and superheater performance. Various overfire air port settings were evaluated to deliver optimum combustion efficiency for the reburn system. The combustion stoichiometries in the cyclone, reburn and burn-out zones were optimized to produce the air and fuel flow data necessary to operate the system in automatic control. The study determined the operating load range of the reburn system while not adversely affecting boiler performance. The test data was used to identify the maximum NOx reduction capability of the system and create a NOx vs. boiler load profile. Finally, the combustion control system was configured to match the emission vs. load profile and the boiler was successfully put into automatic operation.

Introduction

This Micronized Coal Reburn Demonstration Project was initiated by the 1990 Clean Air Act Amendments (CAAA) as part of Kodak's State Compliance Plan with the New York State Department of Environmental Conservation. Under Title 1 of the CAAA, the New York State DEC published a regulation entitled "Reasonably Available Control Technology for Oxides of Nitrogen (NO_x RACT). This document is a revision to regulation 6 NYCRR Part 227 "Stationary Combustion Installations" and states 'Any owner or operator of an existing major stationary source of oxides of nitrogen in New York State must use RACT to control emissions of oxides of nitrogen'. The regulation covers many combustion system types and sizes, and a variety of fuels. With respect to coal fired cyclone boilers, the regulation may require operators to spend up to $3000 per ton of NOx removed to achieve an emission rate of .60 pounds per million btu's fired. Kodak Park operates four Babcock & Wilcox cyclone fired boilers that are subject to this regulation and they are Boilers 15, 41, 42 and 43. Compliance with this regulation is based on the use of combustion modifications that include but are not limited to, the use of low NO_x burners, overfire air systems, staged combustion, reburning, burners out of service, and flue gas recirculation. Kodak has chosen to implement Natural Gas Reburn on 43 Boiler (installation complete 1995), Coal Reburn on 15 Boiler (installation complete 1997) and Natural Gas Reburn on 42 and 41 Boilers (installation complete 1998).

The Micronized Coal Reburn project on 15 boiler is part of the DOE Clean Coal Technologies Program and was partially funded by the DOE and others. The engineering design was provided by a five party team consisting of Energy and Environmental Research (EER), Parsons Power, Fuller Mineral Processing, New York State Energy and

Gas (NYSEG) and Eastman Kodak. The system was constructed to achieve a 50% NOx reduction from a baseline NOx of 1.36 pounds per million btu at full boiler load. EER was responsible for the design and supply of the micronized coal injector equipment and overfire air system as well as expected boiler performance. Parsons Power provided Architectural, Mechanical and Structural Engineering for the balance of systems (coal feed and transport gas, coal piping & ductwork layout) as well as the Electrical, Instrumentation and Control System engineering. Fuller was responsible for the micronizer design and associated equipment. NYSEG acted as the project team administrator and DOE interface. Eastman Kodak is the project owner, execution administrator and host.

Reburn History

Presently, 105 cyclone equipped utility boilers exist in the United States producing over 26,000 Megawatts. Amidst growing environmental pressure to reduce NO_x, economic forces have many utilities attempting to extend the life of their cyclone units. Up until 1993, a commercially viable combustion technology to reduce NO_x on cyclones was not available. Previous attempts to significantly lower NO_x without adversely affecting cyclone performance and integrity had failed. In 1986, Babcock & Wilcox began to investigate alternative technologies for controlling NO_x formation associated with cyclone boilers. In 1989 a process called NO_x Reburning was demonstrated on Small Boiler Simulator at the Babcock & Wilcox Alliance Research Center facility. Reburning technology, using pulverized coal as the reburn fuel, was commercially demonstrated for the first time in 1993 at Wisconsin Power & Light's Nelson Dewey Station in Cassville, Wisconsin. This project was engineered by the Babcock & Wilcox Company and funded by the United States Department of Energy and eleven different utility companies. Since the Wisconsin Power & Light project, various manufacturers have implemented several Natural Gas Reburn retrofits. The addition of Micronized Coal Reburn on Kodak's number 15 boiler represents the second coal Reburn project in the U.S. and the first to utilize micronizers rather than traditional coal pulverizers.

Definition of Reburn Related Combustion Terms

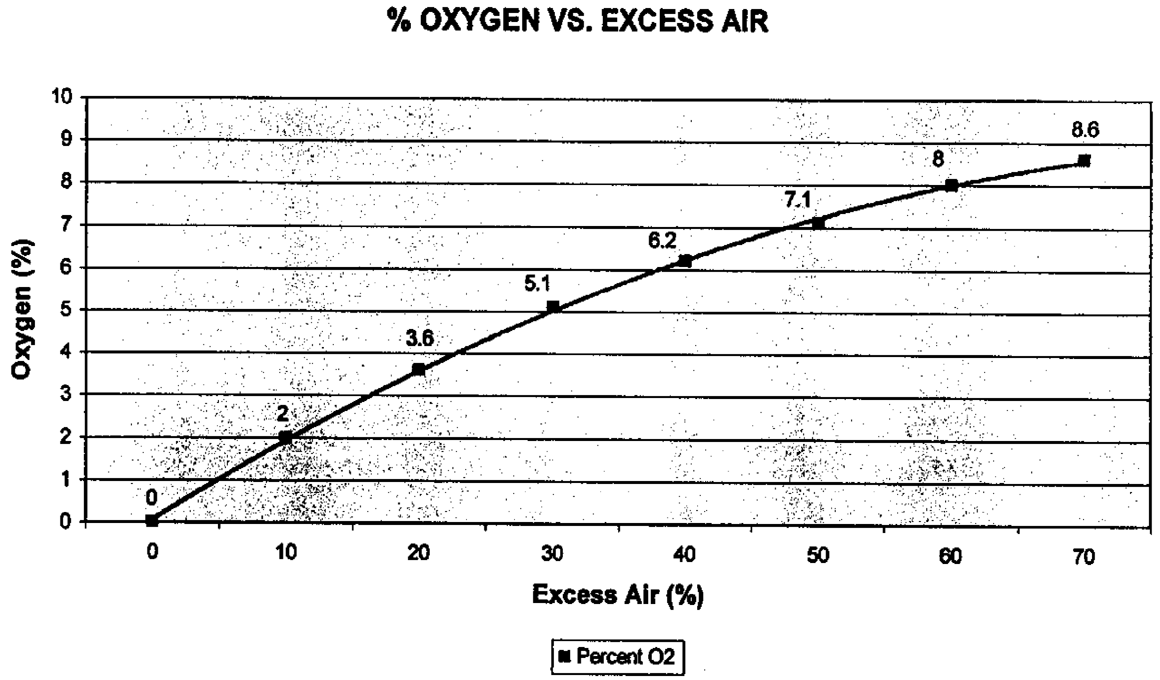
Understanding the reburn process requires a fluent understanding of general combustion terminology such as O_2, theoretical air, excess air, total air, stoichiometry, overfire air and residence time.

The definition of these terms is as follows:

O_2 -The amount of oxygen in a gas, measured in percent by volume. The O_2 in air is approximately 20.9%. The O_2 in flue gas is the O_2 in the combustion air that has not reacted with the combustibles in the fuel. Typical Cyclone boiler O_2 is 2.5 to 3.5%. O_2 and excess air are related but not the same.

Theoretical Air - The exact quantity (100%) of air required to provide the perfect amount of oxygen for combustion with no losses and no excess O_2 (i.e. the O_2 for a combustion process operating at theoretical air would be 0.0%, this is sometimes called theoretical O_2). The theoretical air required for one pound of fuel will vary with the fuel type because of the different percentages of each combustible element.

Excess Air - The air quantity delivered to the combustion system that is greater than that required for theoretical combustion. For example, 10% excess air is 10% more air than theoretically needed. Because ideal combustion cannot exist, some amount of excess air is always required. Excess air is not the same as O_2. The relationship between the percent O_2 and the percent excess air for bituminous coal combustion is illustrated below.



Total Air - The amount of theoretical air plus the excess air delivered to the combustion equipment. For instance, 10% excess air would represent 110% total air.

Stoichiometric - Another term for theoretical air.

Stoichiometry - A term for the ratio of the total air quantity delivered to a combustion system divided by the theoretical amount required. For example, a combustion process operating at theoretical air would have a stoichiometry of 1.0, (100/100) while a process operating at 110% total air (10% excess) would have a stoichiometry of (110/100) or 1.1. In the same fashion, if only 90% of the theoretical air is delivered to the combustion equipment then the stoichiometry is 90/100 or .9. When the stoichiometry falls below 1.0 the term **sub-stoichiometric** is often used.

Overfire Air - Air that is added above the main combustion zone to bring the total air quantity added to the system up to the amount required for complete combustion. Overfire air is normally part of a staged combustion process and is normally added through Overfire Air Ports sometimes referred to as NO_x ports.

Residence Time - The amount of time a chemical reaction has to occur within a given zone of the burner or furnace.

Reburn Technology Definition -

Reburning is a process by which NO_x compounds produced in the cyclone are decomposed to molecular nitrogen by the addition of a secondary fuel to the main furnace. This secondary fuel, called the reburn fuel, can be coal, oil or natural gas depending on unit configuration and design. 15 Boiler will utilize micronized coal as the Reburn fuel. Micronized coal is defined as 80% passing through a 325 standard mesh sieve (45 micron) while pulverized coal is defined as 70% passing through a 200 standard mesh sieve (75 micron).

The reburn process employs multiple combustion zones in the furnace defined as, the main combustion zone (cyclone), the reburn zone and the burnout zone. For coal reburn, the furnace is retrofitted with coal injectors or burners located as close to the cyclone re-entrant throat exit as slagging conditions will permit. Overfire air ports (OFA ports) are added above the reburn fuel to allow for the input of additional combustion air. The cyclones are operated at a stoichiometry of approximately 1.1 (10% excess air or 2% O_2) and are responsible for the majority of the boiler heat input (approximately 80% in this case). The remaining heat input is introduced through the reburn injectors. To minimize the amount of oxygen introduced in the reburn zone, the injectors utilize flue gas for the transport of coal from the micronizer to the boiler. The combustion gases from the reburn fuel mixes with the combustion products from the cyclones to obtain a furnace reburn zone stoichiometry of .85 to .95. In other words, the total air delivered to the boiler at this point is only 85 to 95% of that required for the theoretical combustion of the combined amount of cyclone coal and Reburn fuel. In this environment, the NO_x compounds are reduced to their elemental constituents in a series of reactions that result in the oxygen being consumed by the combustion process and the nitrogen being left behind as N_2. The balance of air required to combust the residual fuel rich mixture (10 to 20% excess air at the economizer) is added through the OFA ports. Like the reburn zone, the burnout zone requires sufficient time and turbulence to complete the combustion process and produce minimal CO. Figure 1 is a schematic of the Reburn Process illustrating the various zones and stoichiometries.

Natural gas was chosen as the reburn fuel for Kodak's #43 Boiler because the furnace was too short to permit the complete combustion of slower burning pulverized coal. In a relative comparison, the furnace volume of 15 Boiler is much larger than that of 43 Boiler and will provide more than twice the amount of residence time in the reburn zone. Even so, the

Reburning Process

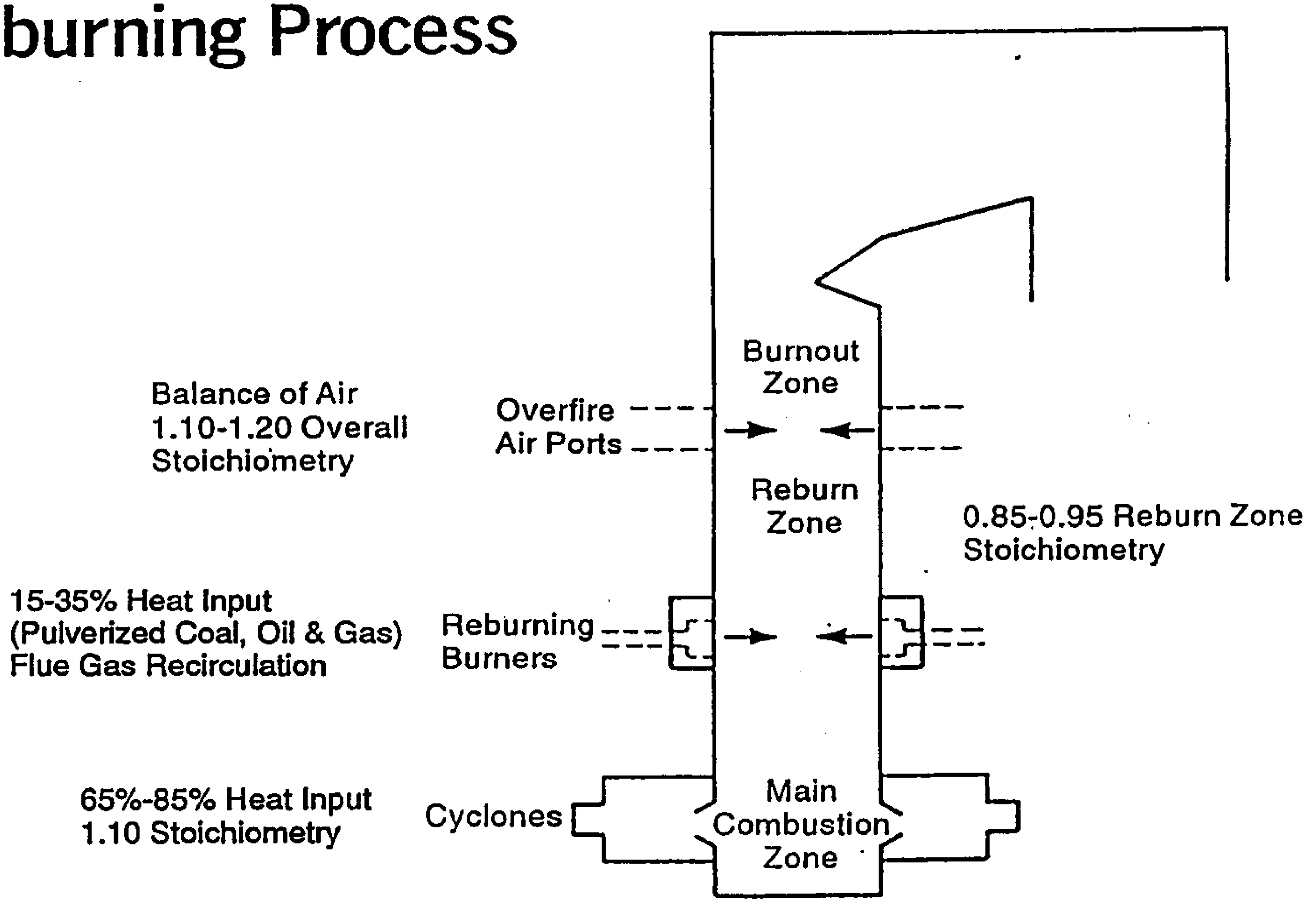


Figure 1

residence time in the burn-out zone is marginal and this will result in high unburned carbon losses. Micronized coal will be utilized in lieu of pulverized coal as the finer coal particles will reduce the burn-out time required and minimize the unburned carbon losses.

Boiler and Reburn System Description

Kodak's 15 Boiler (B&W's RB-230) was built in 1956 and is equipped with two 8 foot diameter cyclones. The boiler is designed to produce 1425 psi, 900°F steam at the superheater outlet from a steam flow of 300,000 pph up to a Maximum Continuous Rating (MCR) of 400,000 pph (cyclone turn down of 75%). The boiler has a 4-hour peak capacity of 440,000 pph at the same steaming conditions. The reburn system is designed to provide up to 30% of peak load heat input through two Fuller micromills and eight EER coal injectors. Each micromill is capable of 8000 pph coal flow (about 23% heat input at MCR). The reburn fuel is fed from the main bunker through two variable-speed screw feeders that feed the micromills. The eight coal injectors are located in the lower furnace just downstream of the slag screen (refer to the enclosed side sectional and arrangement drawings in Appendix "A"). Six injectors are located in the rear wall at el. 225'-6" and one in each side wall at el. 227'-2". Four overfire ports capable of providing 140,000 pph of combustion air are located in the front wall at elevation 247'-9". Micronized coal transport is provided by flue gas taken from the precipitator outlet. The transport flue gas is boosted to 90" static pressure and blown through the micromill and into the furnace. The normal flue gas temperature is 350°F + or -20°F. Steam coil flue gas heaters were meant to boost the transport gas temperature to 500°F as necessary however they were only designed for 1/2 of the gas side static pressure and are currently out of service. The cyclone coal feed system utilizes 1950's vintage B&W apron feeders (volumetric). The combustion control system was upgraded to a Westinghouse DCS (WDPF) during the reburn retrofit outage.

Startup Background

The first fire date was January of 1997 but extraordinary coal feed and transport gas system problems caused the system to operate less than 1000 total hours in the first year. Many of these problems have since been resolved, however continued improvements in functionality, maintainability and reliability of the hardware will be necessary for successful long-term operation. During the abbreviated amount of running time leading up to this study, the system showed promise of achieving the expected 50% NOx reduction although several serious operational concerns were identified. For example, control of the cyclone, reburn, and burnout zone stoichiometries was unsuccessful. Coal feed rates from both the cyclone and reburn feeders were not identified accurately enough to provide consistent operation. The boiler outlet O_2 measurement was not representative of the process and therefore not useful for control. Cyclone and furnace slag tapping was difficult and resulted in periodic metallic iron formation. Final superheater temperature decayed as much as 100°F below original design at reburn rates achieving the 50% NOx reduction. Baseline unburned carbon was uncontrollable ranging from 10 to 35% and increasing to 40 to 70% with reburn. Slagging of the coal injectors resulted in a furnace fuel and air imbalance that created potentially dangerous operating conditions.

The start-up work conducted prior to the optimization phase included various activities designed to resolve these operational issues. Extensive airflow calibration tests were completed to accurately identify all combustion air and leakage air entering the setting. Micronized coal transport gas balancing tests were conducted to insure balanced micronized coal input to the furnace. Micronizer tuning was performed to determine the optimum settings for producing satisfactory fineness while maintaining stable mill operation. Coal fineness results can be found in Appendix "B". A furnace observation door was added to monitor slagging conditions at the injectors. Cyclone coal flow and reburn coal flow calibration tests were performed to determine the volumetric feed rates and properties of the coal feeders. Finally, numerous test taps were added to the furnace to allow for the measurement of flue gas products to determine combustion performance.

Expected Performance and Test Goals

The complexity of having five different parties involved in the design of this system resulted in much confusion regarding the expected performance of this design. The combustion system designer, Energy and Environmental Research (EER), guarantees that their system will reduce NOx emissions from the pre-Reburn baseline of 1.36 pounds per million btu to .60 pounds per million btu at 400,000 pph steam flow while limiting the reduction in boiler efficiency to no more than 2%. EER also guarantees no slagging and fouling conditions that would impact boiler reliability and states there shall be no loss in superheater outlet temperature. Predicted performance was given only at full load and assumes 20% reburn heat input and 80% cyclone heat input to achieve .60#'sNOx/mmbtu. With the cyclone heat input reduced to 80%, the cyclones will be near their minimum load when reburning at full load (i.e. cyclones producing an equivalent steam flow of 320kpph, 80% of 400kpph). This operating condition implies that the boiler will not be able to turn down to lower loads while maintaining the .60 pounds per million btu emission rate. The micromill operating instructions call for a micronizer fuel ramp rate of 1000 pounds per 10-minute time interval. This response rate would not allow the boiler to follow plant loading. With these factors in mind and considering the boiler was not modified in any way to improve cyclone turn down, it appears the system was designed to operate in a static condition with the boiler at full load. Therefore it would follow that this design is incapable of complying with NOx RACT at any load other than MCR.

Currently, plant conditions ***do not*** allow for base loaded operation and therefore the reburn system must be commissioned to operate throughout the load range with the maximum NOx reduction possible while maintaining satisfactory boiler performance.

Test Outline

The following tests were designed to provide the information necessary to determine the operating boundaries of the system, optimize the NOx reduction process, and provide the control curves necessary to operate the system in automatic control through the DCS.

Test Series 1	Boiler Load (kpph)	Micron. Coal (%)	Micron. Coal Flow (kpph)	Test Description - Cyclone only tests to determine baseline NOx and unburned carbon loss. These tests will also establish the optimum cyclone stoichiometry at minimum cyclone load.
1A	400	0	0	Cyclone only test, steam flow at 400 kpph.
1B	370	0	0	Cyclone only test, steam flow at 370 kpph.
1C	340	0	0	Cyclone only test, steam flow at 340 kpph.
1D	315	0	0	Cyclone only test, steam flow at 315 kpph.

Test Series 2	Boiler Load (kpph)	Micron. Coal (%)	Micron. Coal Flow (kpph)	Test Description - Cyclone heat input held at absolute minimum while increasing reburn heat input. This test will determine boiler operating load range.
2A	340	7	2	Cyclones held at equivalent coal flow for 315 kpph steam flow. Reburn added at 2.0 kpph.
2B	355	11	3.5	Cyclones held at equivalent coal flow for 315 kpph steam flow. Reburn increased to 3.5 kpph.
2C	375	15	5	Cyclones held at equivalent coal flow for 315 kpph steam flow. Reburn increased to 5.0 kpph.
2D	400	20	7	Cyclones held at equivalent coal flow for 315 kpph steam flow. Reburn increased to 7.0 kpph.

Test Series 3	Boiler Load (kpph)	Micron. Coal (%)	Micron. Coal Flow (kpph)	Cyclone and reburn heat inputs fixed while making overfire air port adjustments. This test series will determine optimum overfire air port settings for NOx reduction and unburned carbon loss. Overfire air equivalent for 3.0% O_2 unless stated otherwise.
3A	400	20	7	Test 3A - core zone 100%.
3B	400	20	7	Test 3B - core and annulus open 100%.
3C	400	20	7	Test 3C - core closed and annulus open 100%, no spin.
3D	400	20	7	Test 3D - core closed and annulus open 100%, with spin.
3E	400	20	7	Test 3E - Best port set-up from previous tests but this test with high overfire airflow equivalent to 4.0% O_2.
3F	400	20	7	Test 3F - Best port set-up from previous tests but this test with overfire airflow equivalent to 2.0% O_2.

Test Series 4	Boiler Load (kpph)	Micron. Coal (%)	Micron. Coal Flow (kpph)	Test Description - Study of reburn heat input percentage versus baseline NOx when operating boiler at MCR (full steaming capacity of 400 kpph).
4A	400	6	2	Equivalent cyclone steaming rate = 376 kpph.
4B	400	11	4	Equivalent cyclone steaming rate = 356 kpph.
4C	400	17	6	Equivalent cyclone steaming rate = 332 kpph.
4D	415	23	8.3	Maximum reburn input for one mill. Equivalent cyclone steaming rate equals 320 kpph.

Test Series 5	Boiler Load (kpph)	Micron. Coal (%)	Micron. Coal Flow (kpph)	Test Description - Guarantee test with reburn and boiler at MCR (full steaming capacity of 400 kpph). Boiler must meet .60 pounds per million btu with no more than 2% efficiency loss and no effect on superheat temperature.
5A	400	TBD	TBD	Micronized coal flow To Be Determined (TBD) as necessary to meet guarantees.

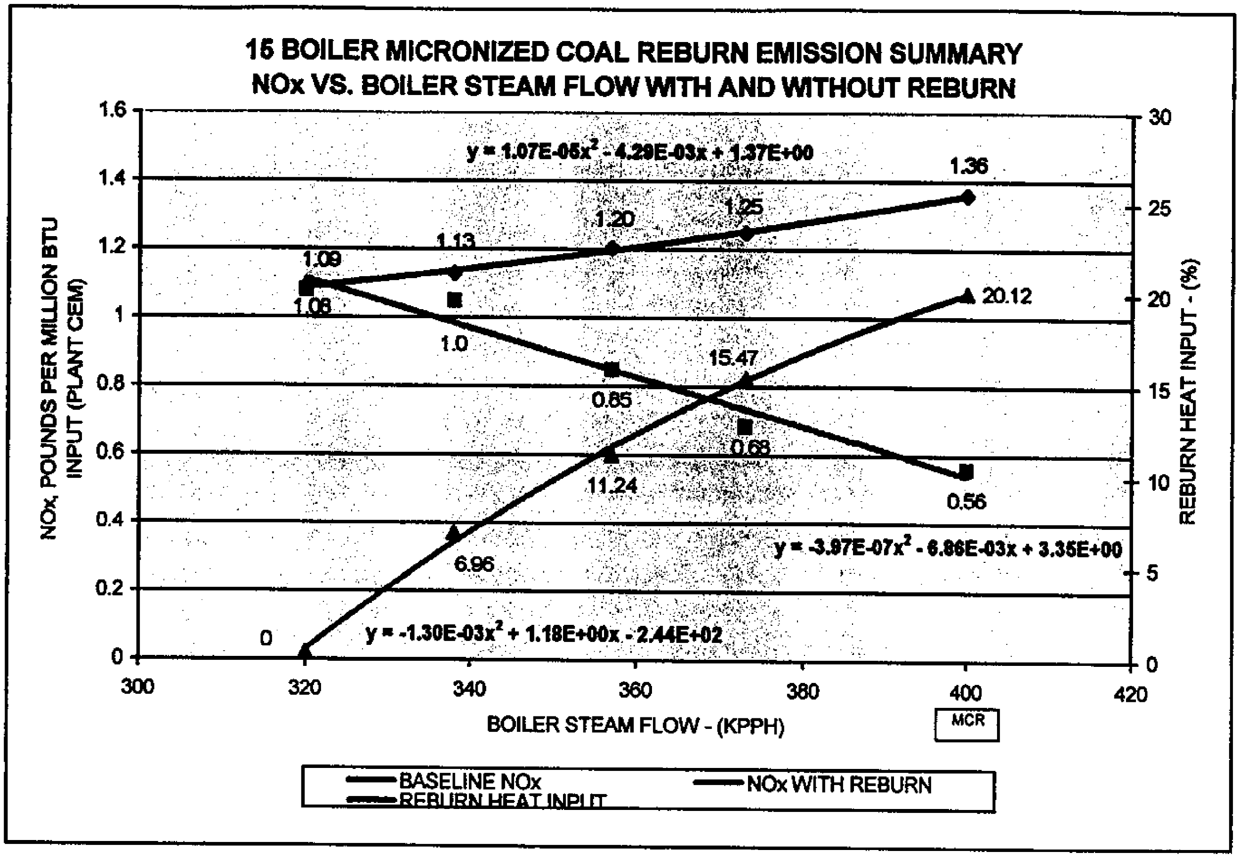
Testing Equipment and Methodology

To tune this system, B&W Results Engineering monitored the boiler flue gas for O_2, CO, NOx and temperature from an 18 point sampling grid installed at the boiler's economizer exit. Flyash samples were collected and analyzed for unburned carbon throughout the testing to determine the systems impact on boiler efficiency. To understand the effect of reburn on boiler performance, Results Engineering collected boiler performance data from the boiler's DCS (distributed control system) and fed it into B&W's Boiler Simulator Computer Models P140 and CUE (Combined Utilized Efficiency). The P140 program provides heat transfer performance to analyze the effect of reburn on performance variables such as furnace exit gas temperature, final superheat temperature and air heater exit temperature. This information was used to validate the readings from the plant's instrumentation. The on line boiler efficiency program (CUE) calculates boiler efficiency with and without reburn along with air and coal flows that are an order of magnitude more accurate than the field flow devices. This information along with a third computer program called TPM Reburn Calculations was used to calculate the cyclone, reburn and burnout zone stoichiometries that were critical to controlling this process. A spreadsheet of the raw performance data is included in Appendix "B".

NOx vs. Load

It was determined that NOx emissions could be maintained below .60 pounds per million btu when operating at full boiler load with a reburn heat input of 20% of the total heat input to the boiler. Figure 2 illustrates a comparison of NOx emissions with and without reburn. With a baseline NOx at full load of 1.36 pounds per million btu and a reburn NOx of .56 pounds per million btu, the addition of reburn represents a 59% NOx reduction from the baseline. As load is reduced however, the reburn NOx emission rate climbs gradually until it eventually meets the baseline NOx at 320 kpph steam flow.

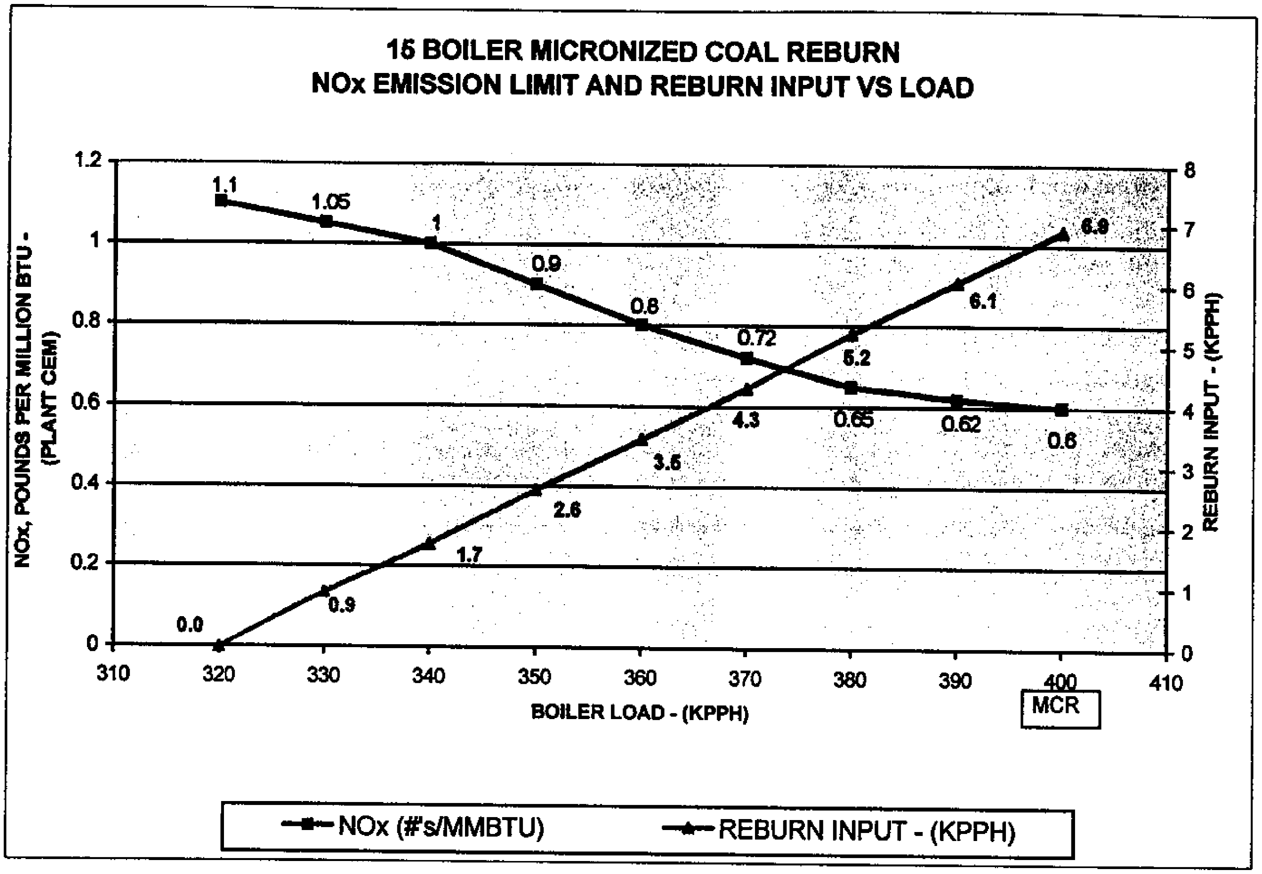
FIGURE 2.



Notice that the NOx emission rate increases as load decreases. For cyclone boilers, the heat generated from the cyclones must be great enough for the ash to remain in a molten state until it drains from the furnace into the slag tank. The amount of cyclone coal flow that is necessary to keep the slag molten, varies with furnace design, slag tap design and fuel characteristics. For 15 boiler, a cyclone coal flow equivalent to 80% of the full load coal flow is required to maintain slag tapping. Therefore the normal, no-reburn, minimum boiler load is 80% of 400 kpph or 320 kpph. Starting with this minimum cyclone condition, NOx begins to come down as reburn fuel is added; however the .60 pounds per million btu condition is not obtained until the unit is essentially up to full load.

A plot of NOx emissions from 320 to 400 kpph steam flows with a cyclone fuel input equivalent to 80% of full load and reburn making up the remaining input, is shown in Figure 3.

FIGURE 3.



This curve represents the lowest obtainable NOx levels that can be expected on a commercial basis. To operate the system in automatic, the DCS has been configured to add the amount of reburn fuel shown in the curve and alarm the operator anytime NOx is above the curve. Adjustments to the cyclone air and fuel flow, reburn input and boiler load will be used to maintain the emission level under the alarm point.

Boiler Efficiency

The reburn system has a negative impact on boiler thermal efficiency causing a 1.54% drop at full load. This decrease is a direct result of higher unburned carbon loss as the LOI[1] in the boiler flyash increased from 12.4% without reburn to 41.5% with reburn as shown in Figure 4.

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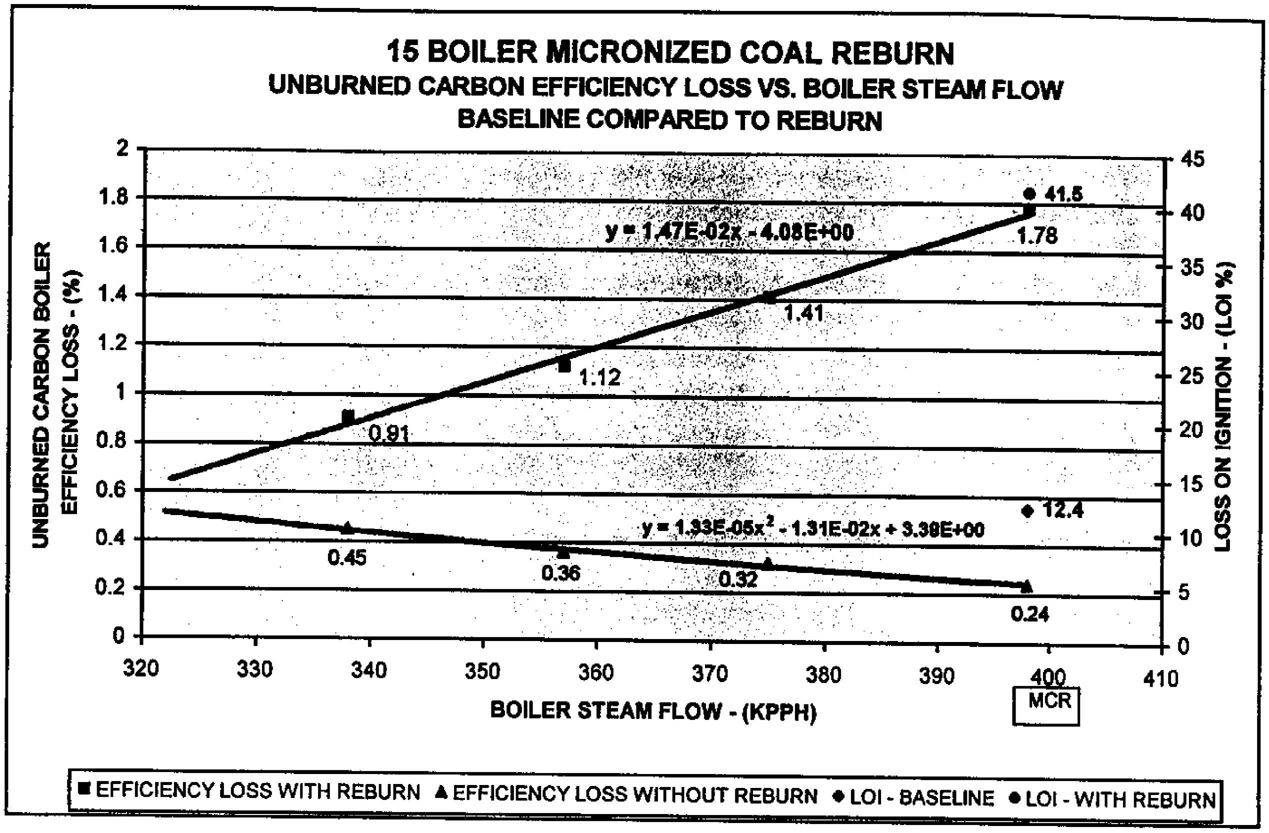
[1] Loss on ignition is defined as the percentage of weight lost after a dried ash sample is fired to 700° C. The entire weight loss is assumed to be elemental carbon for this study.

FIGURE 4.



The unburned carbon loss is calculated based on the assumption that 80% of the ash from the cyclones is tapped from the furnace as slag and 20% remains in the gas stream as flyash. The slag is assumed to have an LOI of 1.0% resulting in an unburned carbon efficiency loss of approximately .05%. The reburn fuel is assumed to produce 100% flyash. The equation to calculate the Unburned Carbon Loss is as follows:

[(% Cyclone coal input * % ash in coal * 20%) + (% reburn coal input * % ash in coal)] * [% LOI / (1- % LOI)] * Carbon btu's / Coal btu's * 100 + .05.

This equation can be reduced to -

Reburn Input % + [(1-Reburn Input %) * .20] * % ash * LOI / (1-LOI) * 1.0898 * 100 + .05.

Where;

Carbon = 14,500 btu/lb.
Federal coal = 13,305 btu/lb.
Ash in Federal coal = 6.2%.
%LOI / (1-%LOI) = adjusts the ash quantity to include the carbon in the ash.

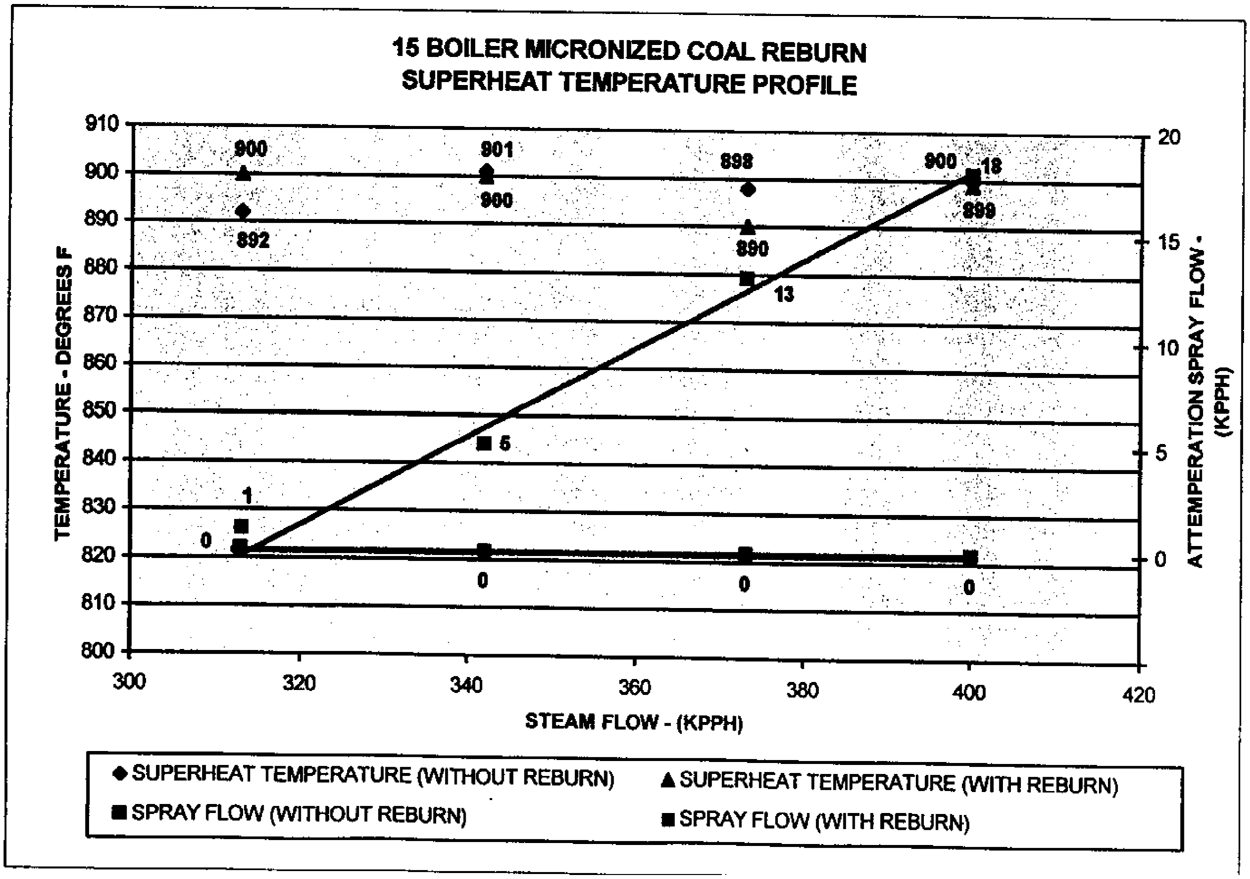
Assuming the boiler operates 8000 hours per year at a capacity factor of .95%, the loss in efficiency equates to an increase in annual fuel consumption of approximately $95,000 at current coal prices.

Test Series 3 was deigned to optimize the overfire air port settings and burnout zone stoichiometry. The ports are designed with inner and outer air zones with the option of spinning the air at the outer zone. Best results were achieved with the inner zone shut, the outer zone open 100% and the spin vanes out of service however the differences between were very small. Burnout Zone stoichiometries of 1.10, 1.125 and 1.15 produced negligible changes in unburned carbon performance. It is clear from this test series that the high level of unburned carbon is strictly a function of lack of residence time in the burnout zone. Since the overfire air ports are as low on the front wall as functionally possible, increasing the residence time would take major furnace modifications and does not appear economically feasible.

Superheat Performance

The boiler is designed to produce 1425psi, 900°F steam from a boiler load of 300 kpph to 400 kpph utilizing inter-stage attemperation for superheat temperature control. Figure 5 illustrates a comparison between pre and post reburn superheater performance.

FIGURE 5.



The final steam temperature with reburn in service remains within 10°F of the desired 900°F throughout the load range. It is interesting to note that the reburn system has a tempering affect on superheat as attemperation flow is practically eliminated. This is the result of a decrease in Furnace Exit Gas Temperature caused by moving the reburn portion of fuel out of the small refractory insulated cyclones and into the large and relatively cool, bare tube open furnace. Transport flue gas, overfire air and changes in flue gas constituents also play a role in changing the absorption profile. It is by coincidence however that the Flue Gas Temperature produced by the cyclones and reburn combined results in the desired 900°F superheat temperature throughout the load range and without attemperation flow.

Cyclone Fuel-Air Optimization

Prior to the installation of Reburn, this boiler was being operated with a single O_2 meter located on each side wall (2 total) just downstream of the economizer. Each meter was responsible for controlling the oxygen to its respective cyclone. This arrangement was successful in controlling the combustion process and produced flyash unburned carbon levels (Loss On Ignition - LOI) of 12 to 18% at full boiler load. Prior to the optimization testing and during "cyclone only" operation, the LOI became very erratic ranging from 12 to 40%. Observing the boiler operation revealed that the O_2 meters and trim controllers were not properly controlling the fuel air relationship to the cyclones. Over several hours the cyclone fuel was being biased significantly from side to side while airflow remained constant.

Considering the existing O_2 equipment was more than 25 years old and only provided one reading to control each cyclone, the project team felt a more modern multi-point system would be necessary to improve the cyclone fuel air control. The team decided to install a 6 point system that would cover the entire cross section of the economizer. The new arrangement would be almost identical to the one successfully controlling the 43 boiler Natural Gas Reburn process in Kodak's building 321. The furnace would be divided in half and the three meters on each half would be averaged to control the respective cyclone. Normally the decision to modify an O_2 system in this fashion would follow extensive field testing to insure that the location and quantity of probes was appropriate. Unfortunately, project time constraints forced a parallel path approach and the new O_2 system was designed and installed before the testing began.

The new system was not fully operational during the optimization testing and therefore O_2 trim was still controlled via the old 2 point system. The B&W flue gas sampling test grid was installed at the same elevation and within inches of the six new O_2 probes. The individual readings from each new probe were recorded for comparison to the corresponding grid point. The new probes and the B&W grid points matched exactly verifying that the new system was functioning properly.

During the baseline testing and without reburn in service, the 2-point oxygen trim system could not control the individual cyclone O_2 and poor unburned carbon performance resulted. The fuel and air to both cyclones was put in manual. The air was increased on one cyclone and all O_2 meters saw a relative gain including the 6 new probes. This test verifies that the flue gases are mixing sufficiently to effectively obscure the O_2 analyzers from seeing the process. Since this problem began after the reburn installation it is assumed that the flue gas transport and overfire air systems create flue gas turbulence and mixing that does not allow the O_2 meters to interpret the actual oxygen coming from their respective cyclones. Therefore, although the new probes metered the O_2 accurately, they did not improve the control systems ability to monitor the fuel air relationship in each cyclone.

To correct the fuel-air imbalance and produce satisfactory unburned carbon, it would be necessary to measure the O_2 directly after the cyclone and before the reburn injectors. The environment at this location is extremely harsh where the temperature is approximately 2800°F and the ash exists as slag. In 1985, Kodak purchased a 20-foot water-cooled High Velocity Thermocouple (HVT) probe that is used in the industry to measure furnace temperatures up to 3000°F. The temperature-sensing element was removed and the probe was modified to accommodate sampling flue gas. The probe was inserted through furnace doors just downstream of the furnace slag screen. All tests, with and without reburn were conducted with the O_2 balanced at this location. Unburned carbon became repeatable and returned to normal levels as illustrated in the baseline unburned carbon loss curve illustrated in figure 4. Measuring the O_2 at this location allowed for optimizing the cyclone fuel-air relationship throughout the load range, with and without reburn in service and without interference from setting leakage (seal air, overfire air and transport gas O_2).

Control System Philosophy

The reburn combustion control philosophy prior to the optimization testing called for the cyclones to run in parallel control, the reburn system to run in parallel control and the O_2 meters to trim the cyclone fuel. This control philosophy did not provide a safe operating environment and often resulted in poor cyclone performance. The reburn feed system pulls coal from the cyclone bunkers with variable speed screws. Both the inlet and outlet of the screw feeder are prone to coal pluggage in wet periods of the year. When a reburn fuel interruption occurred, boiler O_2 would increase and subsequently the trim controller would decrease the combustion air to the cyclones. Meanwhile, the cyclones were increasing their fuel input to make up for the lost reburn fuel. This same situation would occur continuously on a smaller scale through all fluctuations in reburn heat input. This philosophy resulted in the cyclones running fuel rich on a periodic basis which can lead to cyclone iron formation, possible boiler tube corrosion, poor slag tapping and potentially dangerous air fuel mixtures.

The control philosophy was modified in the following way. The data taken during the optimization testing along with the cyclone coal feeder and air flow meter calibrations was used to produce the optimum cyclone air-fuel curve. The excess air delivered to the cyclone for a given fuel input is displayed on an Excess Air controller. Excess air is calculated by multiplying the cyclone coal flow by 10 pounds of air, per pound of coal and then multiplying by the percent excess air. This number is adjusted downward by 4kpph per cyclone to account for infiltration (star seal air, conditioner seal air, observation ports and burner ports). The excess air controller allows the operator to run the cyclones in fixed parallel control from 0 to 20% excess air. Optimum cyclone excess air was found to be 8% throughout the operating range. The reburn master determines the amount of reburn fuel required for a specific steam load to produce the optimum NOx reduction for the system at that load.

The overfire air set point is developed in the DCS in the following manner. The total fuel to the furnace is summed together (cyclone plus reburn). The total theoretical airflow required to the furnace is calculated by multiplying total coal flow by 10 pounds of air per pound of coal. The cyclone airflow is subtracted off, along with 23kpph of infiltration air (this accounts for the seal air leakage to the furnace and the oxygen in the transport gas). The difference between the total theoretical air and the cyclone air is the theoretical air for reburn. The overfire air set point is the theoretical air for reburn adjusted for the proper boiler outlet O_2. The O_2 process variable is the combined average of all six new O_2 probes. The O_2 trim controller determines the required amount of overfire air to meet the furnace exit O_2 set point. In this fashion the air and fuel are treated as inputs to the furnace as a whole rather than two individual processes. If the reburn feeders have a fuel interruption the cyclones will operate unaffected and the O_2 trim controllers will trim overfire air down to the reburn fuel cross limit which is equivalent to theoretical air for the reburn feeder speed (with a 20,000pph minimum). At worst, the furnace will run a higher excess air than normal and NOx will climb. The operator will recognize this as an interruption in reburn fuel feed and address the problem.

As mentioned earlier, the reburn fuel ramp rate recommended by the designer (Fuller) was 1000 pounds fuel per ***ten*** minute interval. This response time would not be satisfactory for the boiler to be load following in automatic control. Field tests were conducted to identify a fuel ramp rate that would allow for satisfactory operation within the new alarm curve without jeopardizing the safety of the equipment or personnel. The ramp rate was increased while monitoring mill vibration, classifier delta-P and transport gas flows. The system acted completely normal at a fuel ramp rate of 1000 pounds per minute, which was responsive enough to meet the plant demands. A rate limiter was installed on the reburn master output that limits the reburn feeder output to the 1000 pounds/minute rate of change regardless of demand. When subject to wide instantaneous swings in load the cyclones will take the immediately load response and overshoot their final position until the reburn system catches up. This control scheme was tested with 80kpph load swings and produced textbook results.

Conclusion

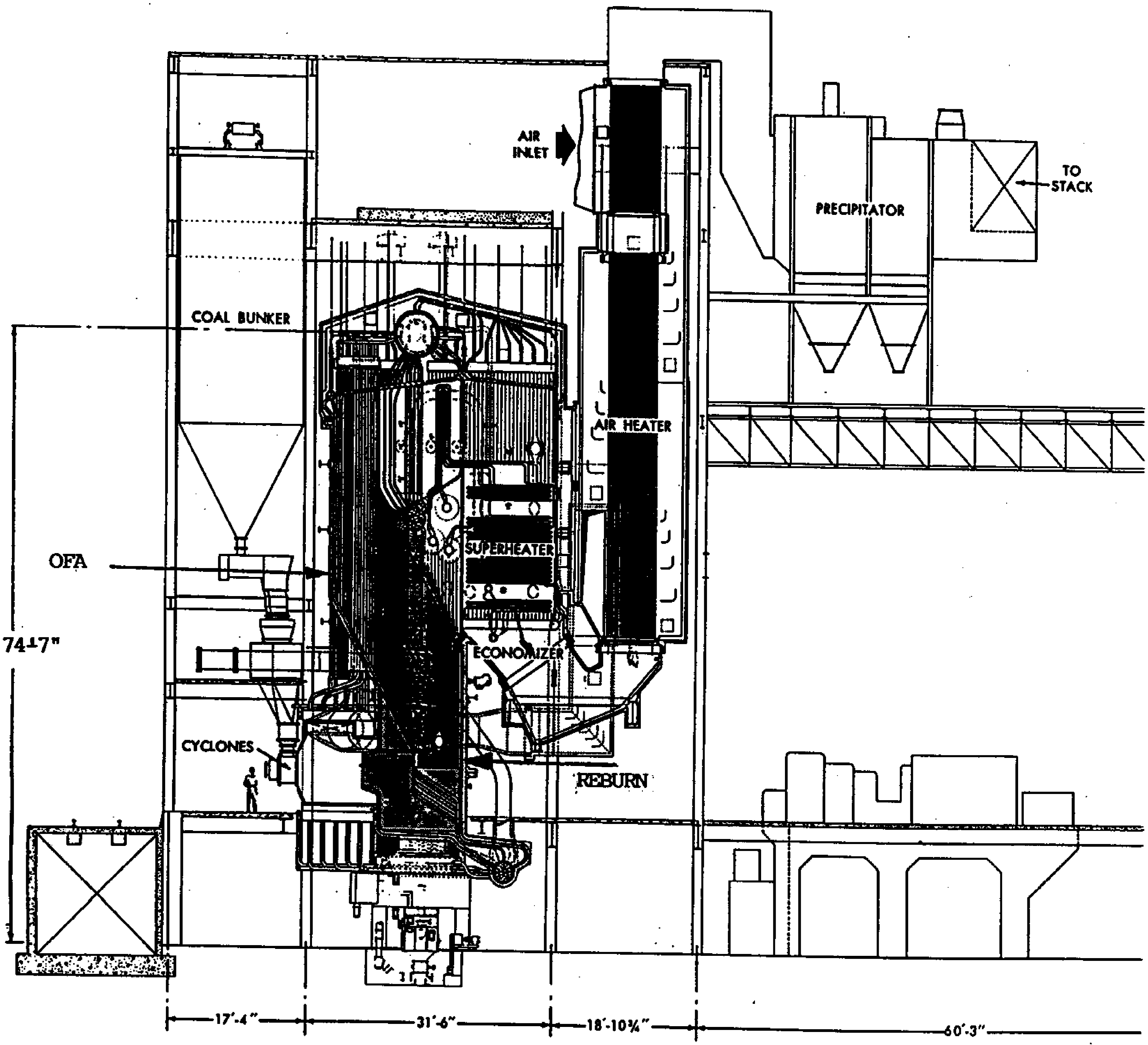
The Micronized Coal Reburning Demonstration Project on Eastman Kodak's 15 Boiler has achieved the guaranteed NOx emission reduction from a baseline of 1.36 pounds per million btu to .60 pounds per million btu with a reburn heat input of 20%. The guarantees that there will be no decrease in steam temperature, no adverse slagging and fouling, and less than 2% loss in boiler efficiency have also been met. The combustion control system has been tuned to run in fully automatic control on a NOx emission curve from 1.10 pounds per million btu to .60 pounds per million btu between steam loads of 320kpph and 400kpph. Attempts to operate at .60 pounds per million btu at loads less than MCR (400 kpph) were unsuccessful due to unsatisfactory furnace slag tapping. Therefore, the system is only compliant with NOx RACT at full load. An engineering study would be required to evaluate the feasibility of improving the cyclone turndown through furnace floor and slag system modifications and / or coal ash fluxing.

The addition of the reburn system results in an unburned carbon efficiency loss of 1.78% at full load with an LOI of 42%. The efficiency loss as compared to operation without reburn is approximately 1.54%. The higher heating value of the flyash is approximately 6000 btu's per pound as compared to coal at 13250 btu's per pound. The recovery of this lost heat may be possible through flyash re-injection where the precipitator flyash is returned to the cyclone by blending it with the coal stream. The success of flyash re-injection would depend heavily on the ability of the electrostatic precipitator to process the increase in flyash loading without producing adverse opacity. Flyash erosion and possible pluggage in the boiler convection pass are also concerns. 15 Boiler operated with flyash re-injection from 1956 through the early 1980's. An engineering study could evaluate the boiler and precipitator concerns as well as the requirements to restore the existing flyash re-injection equipment to working order.

cc: lastdance.doc

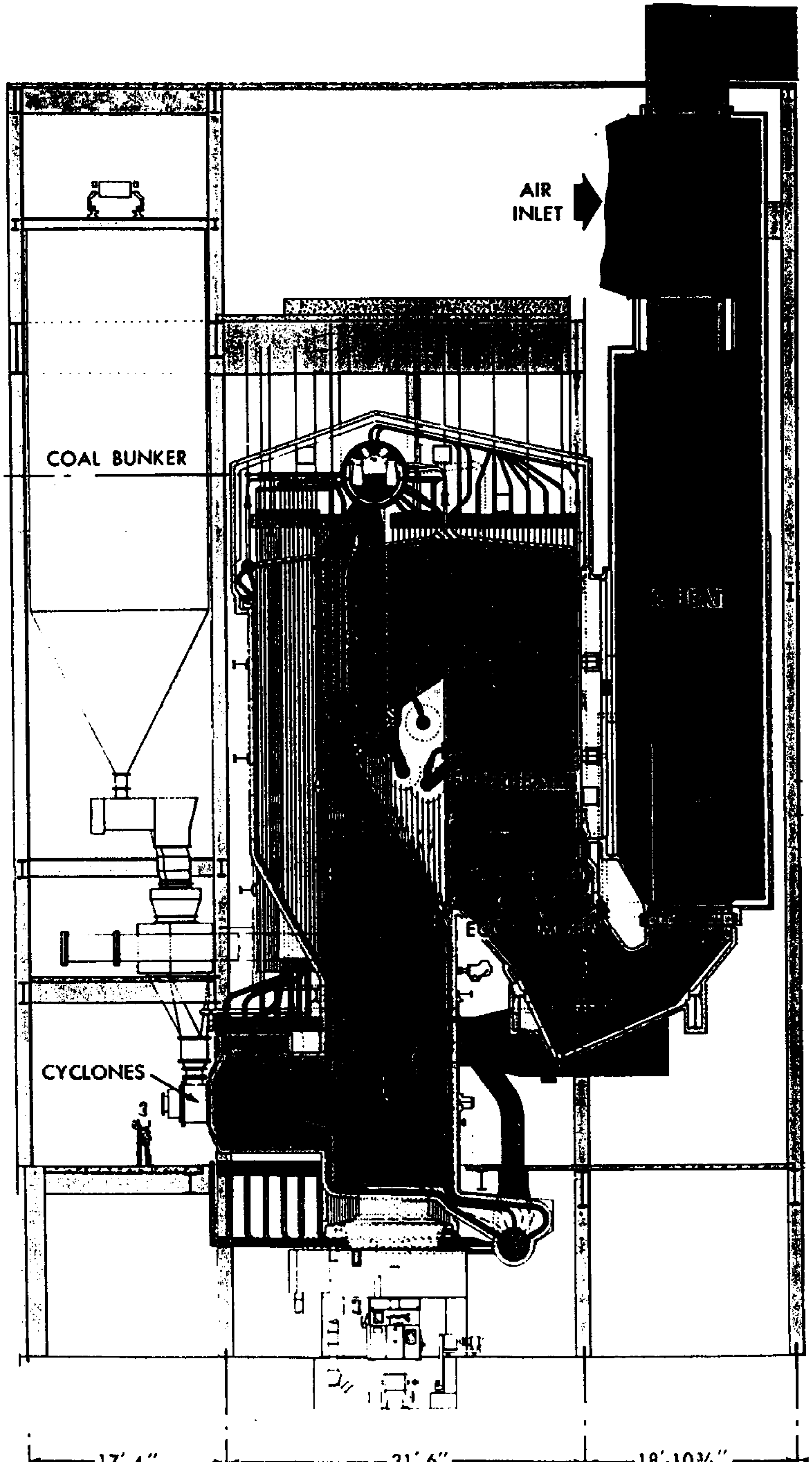
APPENDIX - A

1. Boiler Side Sectional Drawings
2. Coal Reburn Schematic from Wisconsin Power & Light
3. Project Elevation Drawings
4. Project Plan & Sectional Drawings



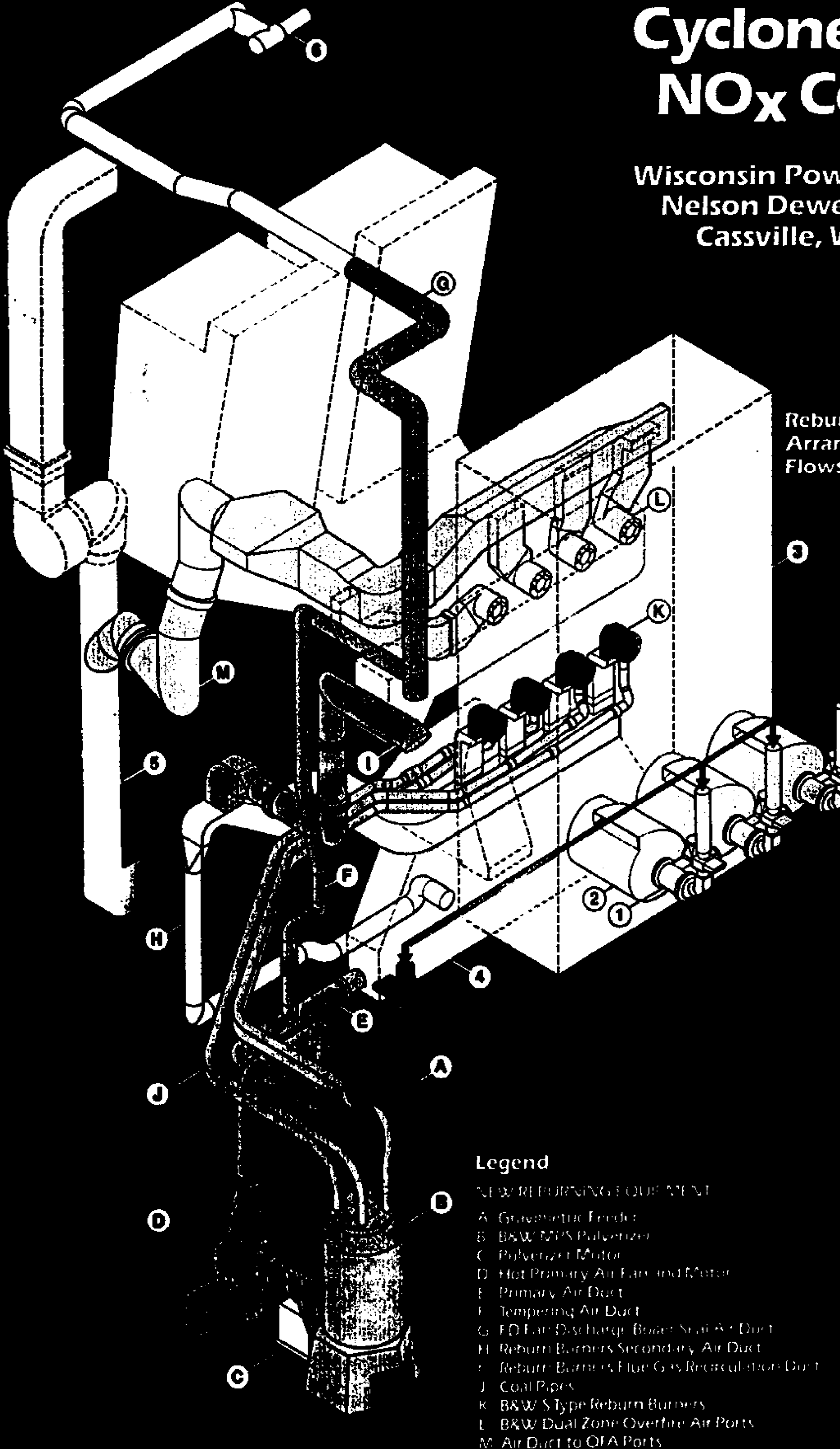
EASTMAN KODAK COMPANY
KODAK PARK WORKS
ROCHESTER, NEW YORK
B & W CONTRACT NO. RB-230

CY:RB-230-50

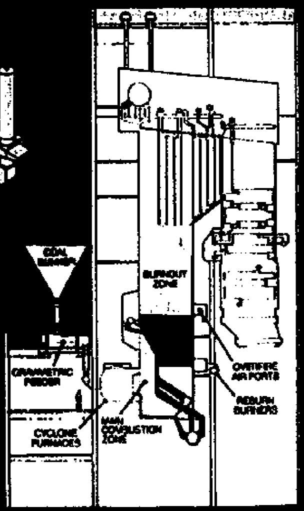

AIR INLET
COAL BUNKER
CYCLONES
17' 4"
21' 6"
18' 10¾"

Coal Reburning for Cyclone Boiler NO_x Control

Wisconsin Power & Light Co.
Nelson Dewey Unit No. 2
Cassville, Wisconsin



Reburn System General Arrangement with Process Flows Shown



Boiler Sectional Side View

Legend

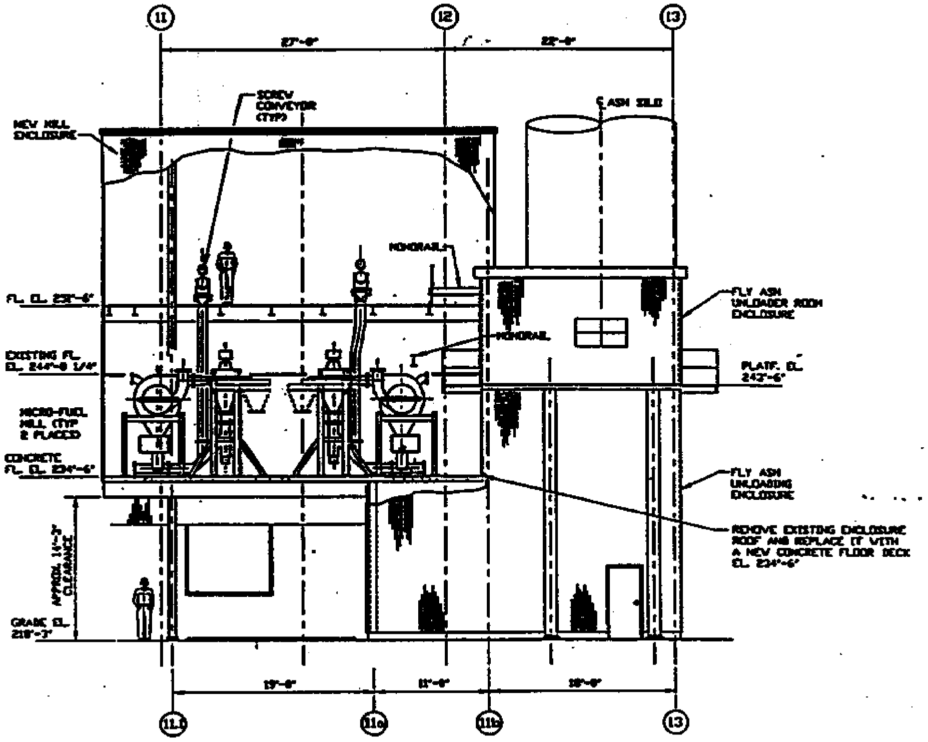
NEW REBURNING EQUIPMENT

A Gravimetric Feeder
B B&W MPS Pulverizer
C Pulverizer Motor
D Hot Primary Air Fan and Motor
E Primary Air Duct
F Tempering Air Duct
G FD Fan Discharge Boiler Seal Air Duct
H Reburn Burners Secondary Air Duct
I Reburn Burners Flue Gas Recirculation Duct
J Coal Pipes
K B&W S Type Reburn Burners
L B&W Dual Zone Overfire Air Ports
M Air Duct to OFA Ports

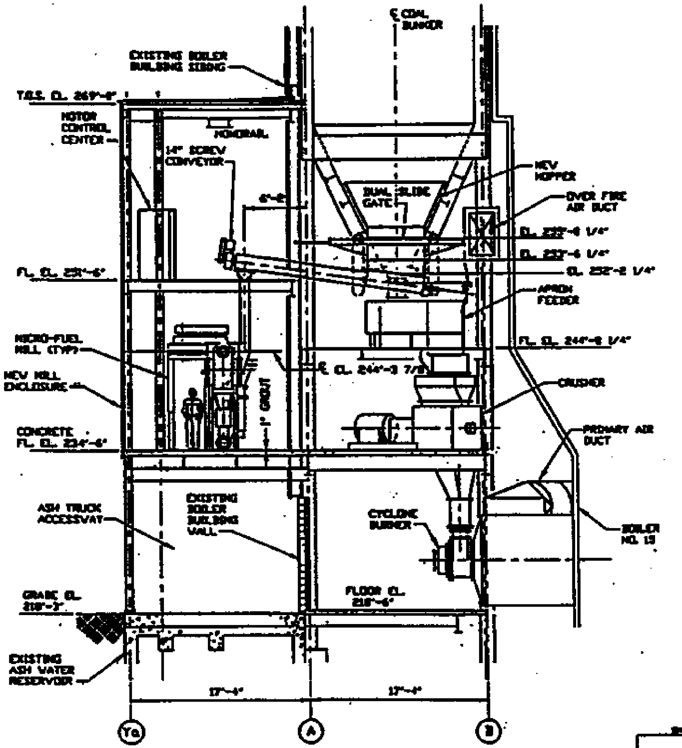
EXISTING EQUIPMENT

1 B&W Vortex Burners
2 B&W Cyclone Furnaces
3 Furnace Enclosure
4 Air Heater Outlet
5 Hot Air Recirculation Duct (AH Outlet to FD Fan Discharge)
6 FD Fan Discharge Duct

D03115-331-017



SECTION A-A



SECTION D-D

GILBERT/COMMONWEALTH, INC.

ACAD/

D

3/16"=1'-0"

EASTMAN KODAK COMPANY
KODAK PARK DIVISION

R.A.

4/17/96

L.CAHNEY

8/96

GENERAL ARRANGEMENT
MICRONIZER BLDG ADDITION
SECTION A-A & SECTION D-D

31

KPE

D03115-331-017

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G/C-DATE: 08/14/96 - 3:52 PM

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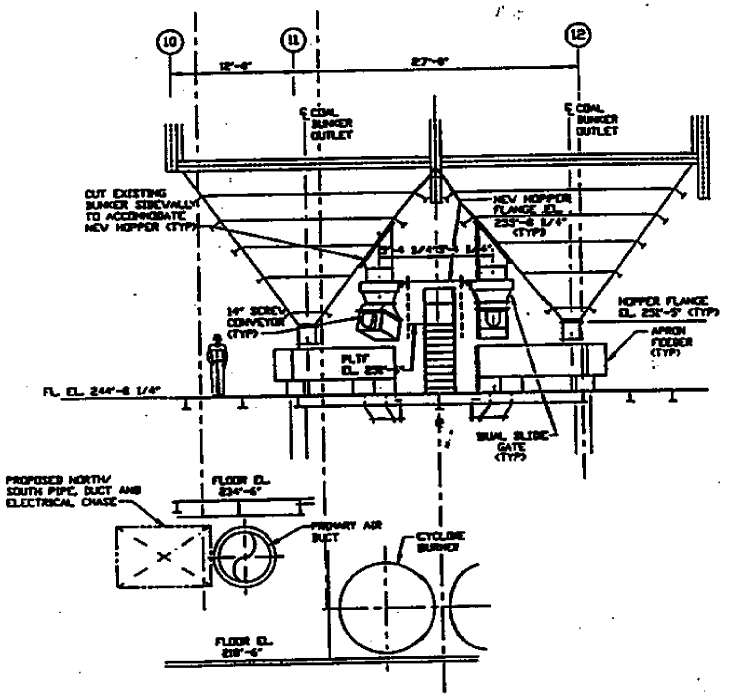
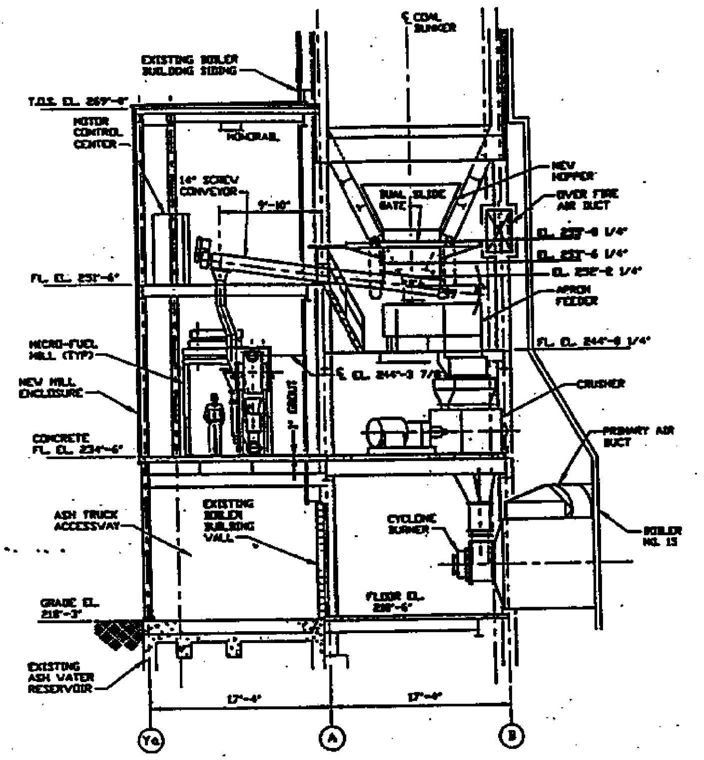


SECTION C-C



SECTION B-B

GILBERT/COMMONWEALTH INC.

ACAD/

D

3/16" = 1'-0"

EASTMAN KODAK COMPANY
KODAK PARK DIVISION

N.A.
4/17/96

_GENERAL ARRANGEMENT
MICRONIZER BLDG ADDITION
SECTION B-B & C-C

31

KPE

D03115-331-018

LEHANEY

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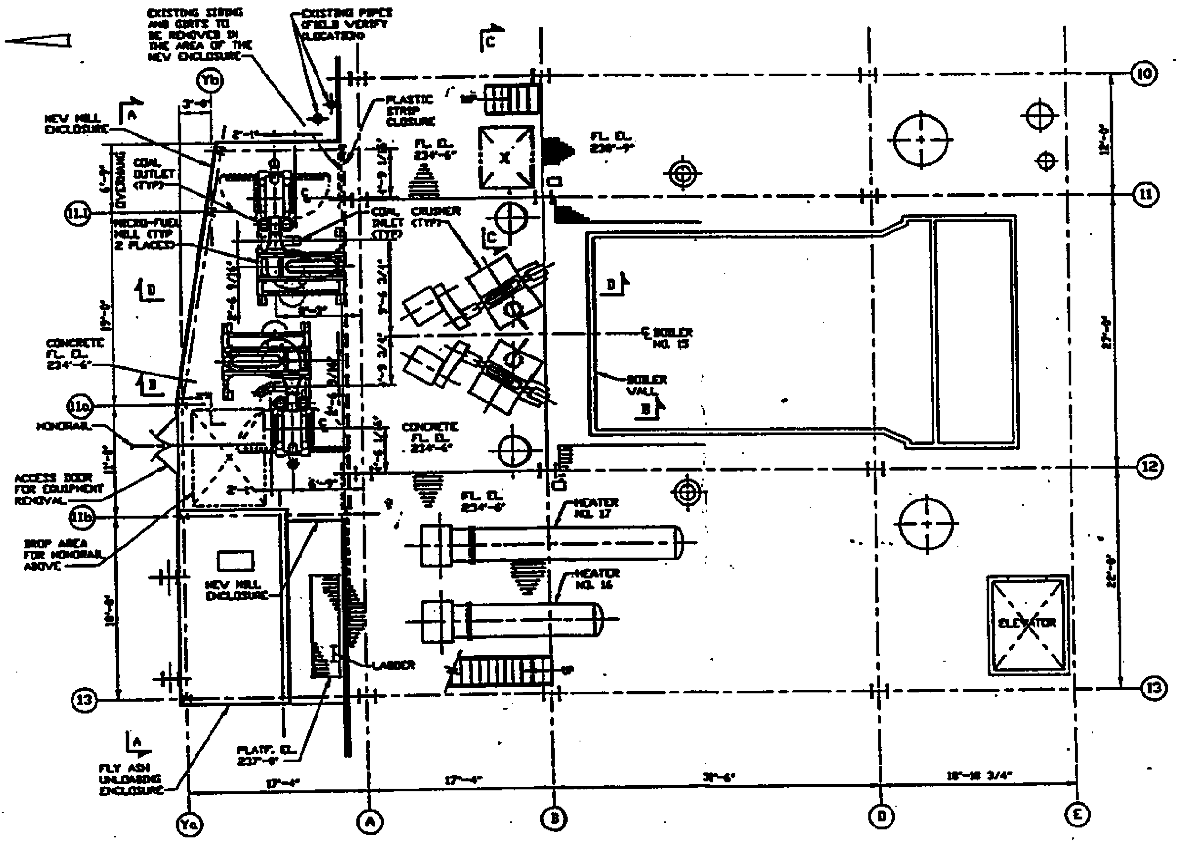

PLAN AT EL. 234'-6"

GILBERT/COMMONWEALTH, INC.

ACAD

D

3/16" = 1'-0"

EASTMAN KODAK COMPANY
KODAK PARK DIVISION

N.A.
4/17/96

GENERAL ARRANGEMENT
MICRONIZER BLDG ADDITION
FLOOR EL. 234'-6"

31

KPE

D03115-331-015

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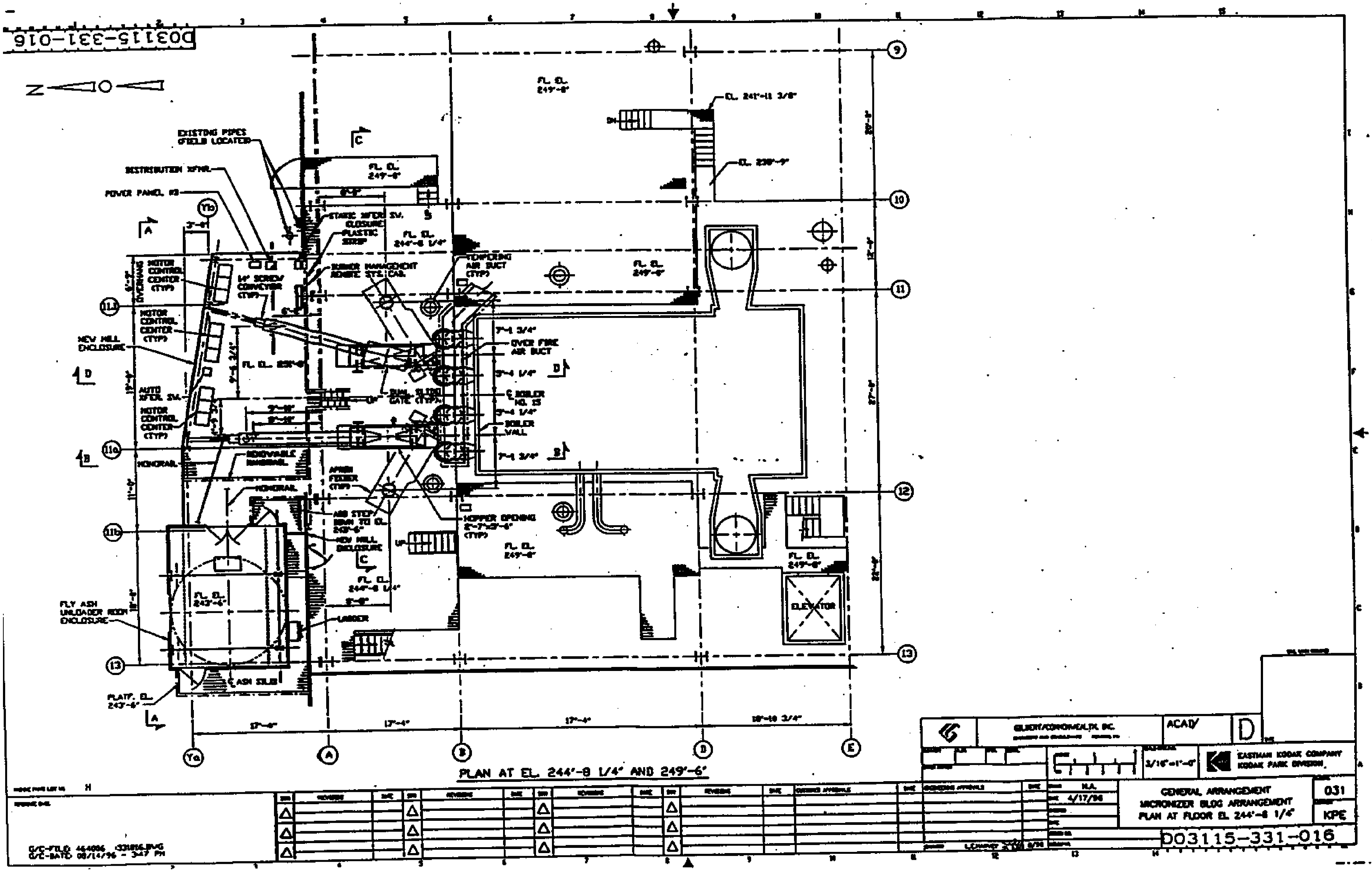
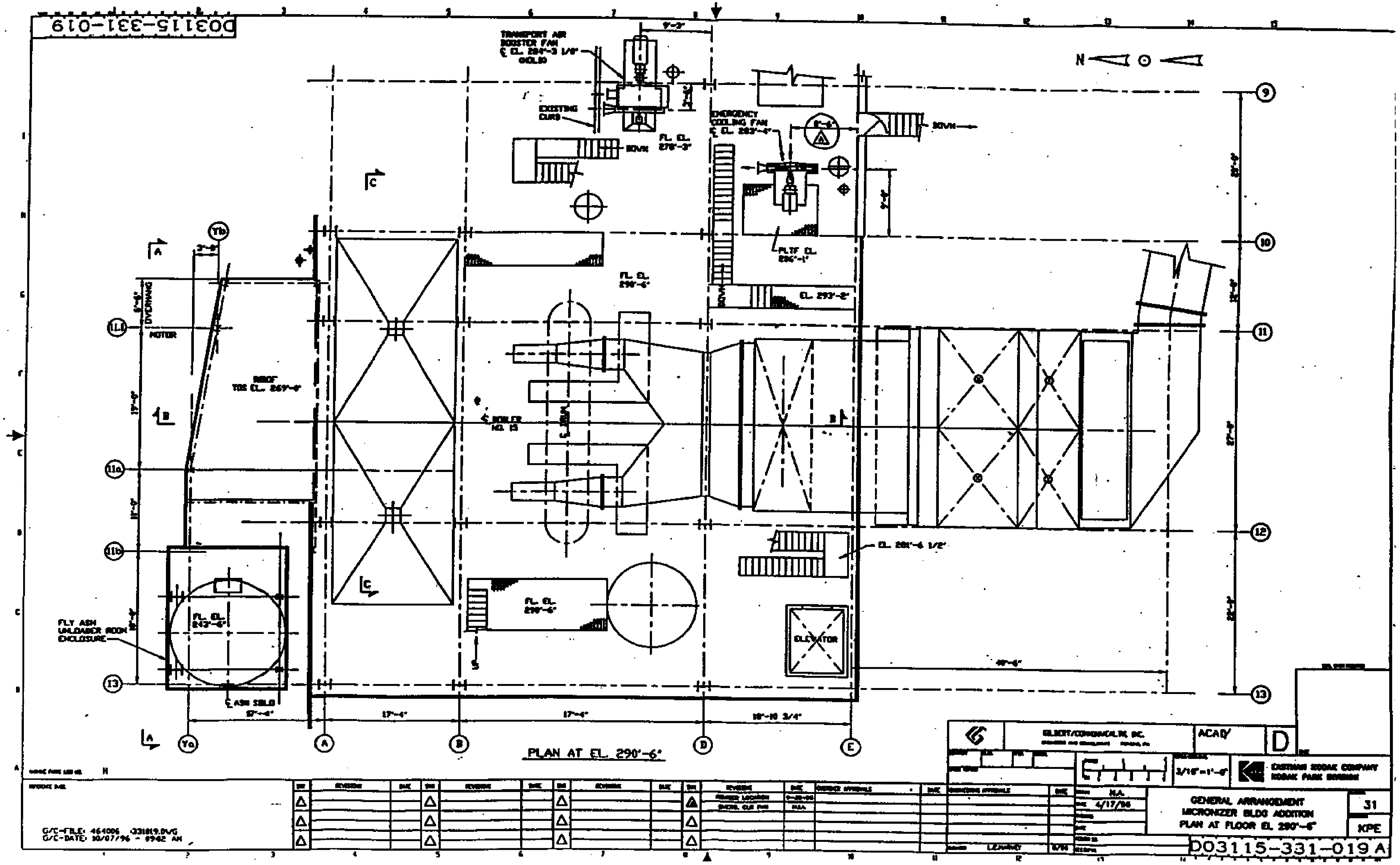

D03115-331-016
N
EXISTING PIPES (FIELD LOCATED)
DISTRIBUTION XFMR.
POWER PANEL #3
Yb
A
3'-0"
MOTOR CONTROL CENTER (TYP)
OVERHANG
14" SCREW CONVEYOR (TYP)
11.1
MOTOR CONTROL CENTER (TYP)
NEW MILL ENCLOSURE
D
FL. EL. 251'-0"
AUTO XFER. SW.
MOTOR CONTROL CENTER (TYP)
11a
B
MONORAIL
REMOVABLE HANDRAIL
MONORAIL
11b
FLY ASH UNLOADER ROOM ENCLOSURE
FL. EL. 243'-6"
13
ASH SILO
PLATF. EL. 243'-6"
A
Ya
C
FL. EL. 249'-6"
6'-0"
STATIC XFER SW.
CLOSURE
PLASTIC STRIP
FL. EL. 244'-8 1/4"
BURNER MANAGEMENT REMOTE STS. CAB.
DUAL SLIDE GATE (TYP)
UP
APRON FEEDER (TYP)
ASH STEPS DOWN TO EL. 243'-6"
NEW MILL ENCLOSURE
C
FL. EL. 244'-8 1/4"
LADDER
UP
TEMPERING AIR DUCT (TYP)
7'-1 3/4"
OVER FIRE AIR DUCT
3'-4 1/4"
D
℄ BOILER NO. 15
3'-4 1/4"
BOILER WALL
7'-1 3/4"
B
HOPPER OPENING 2'-7"x3'-6" (TYP)
FL. EL. 249'-6"
FL. EL. 249'-6"
FL. EL. 249'-6"
EL. 241'-11 3/8"
EL. 238'-9"
DN
FL. EL. 249'-6"
ELEVATOR
9
10
11
12
13
20'-0"
12'-0"
27'-0"
22'-0"
17'-0"
17'-4"
17'-4"
18'-10 3/4"
A
B
D
E
PLAN AT EL. 244'-8 1/4" AND 249'-6"
GILBERT/COMMONWEALTH, INC.
ACAD/
D
EASTMAN KODAK COMPANY
KODAK PARK DIVISION
3/16"=1'-0"
N.A.
4/17/96
GENERAL ARRANGEMENT
MICRONIZER BLDG ARRANGEMENT
PLAN AT FLOOR EL 244'-8 1/4"
031
KPE
D03115-331-016
H
G/C-FILE: 464096 (331016.DWG
G/C-DATE 08/14/96 - 3:47 PM



PLAN AT EL. 290'-6"

G/C-FILE: 464006 331019.DWG
G/C-DATE: 10/07/96 - 09:42 AM

GILBERT/COMMONWEALTH, INC.

ACAD

D

EASTMAN KODAK COMPANY
KODAK PARK DIVISION

3/16"=1'-0"

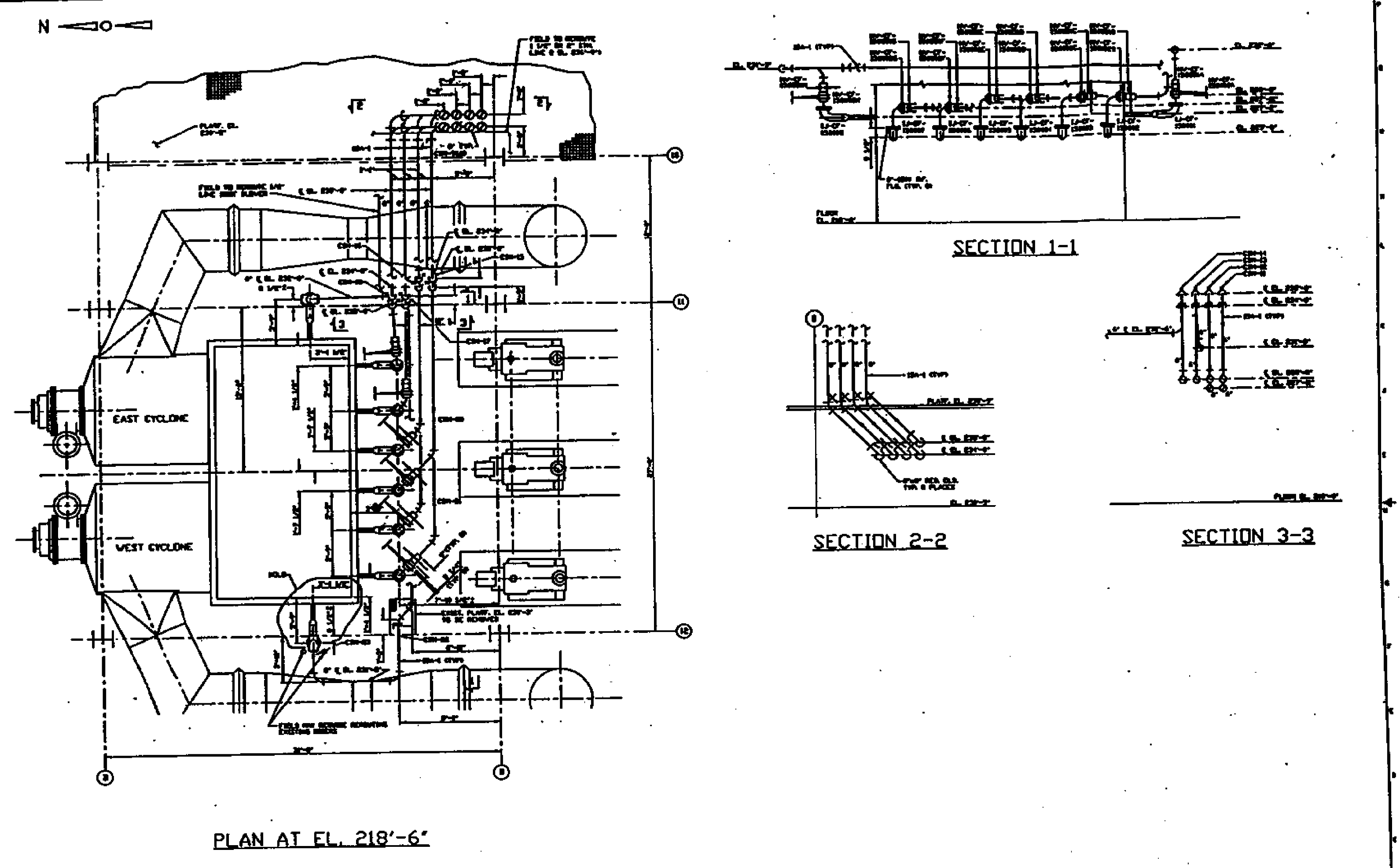
N.A.
4/17/96

GENERAL ARRANGEMENT
MICRONIZER BLDG ADDITION
PLAN AT FLOOR EL 290'-6"

31

KPE

D03115-331-019 A



PLAN AT EL. 218'-6"

ACAD/

D

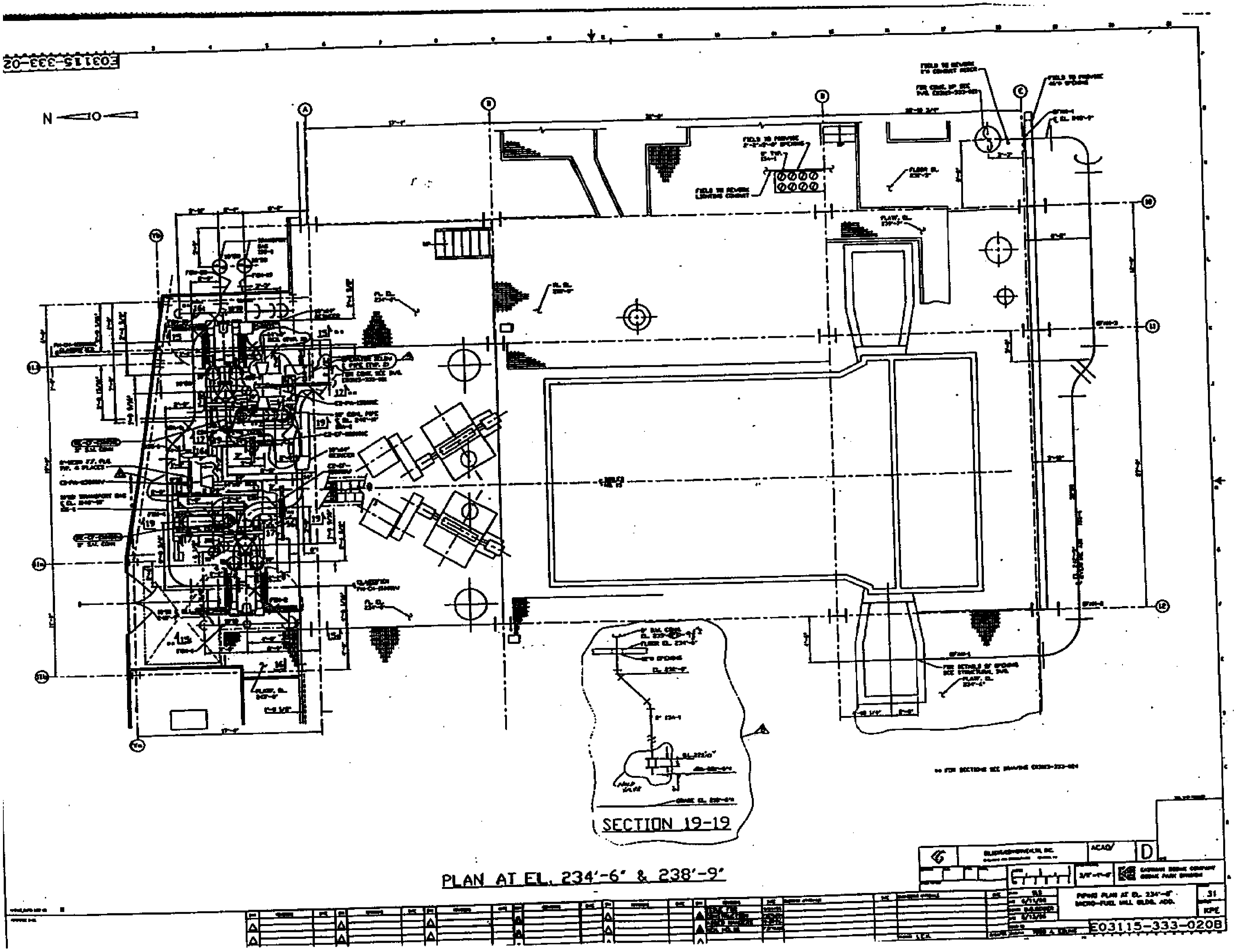
3/8" = 1'-0"

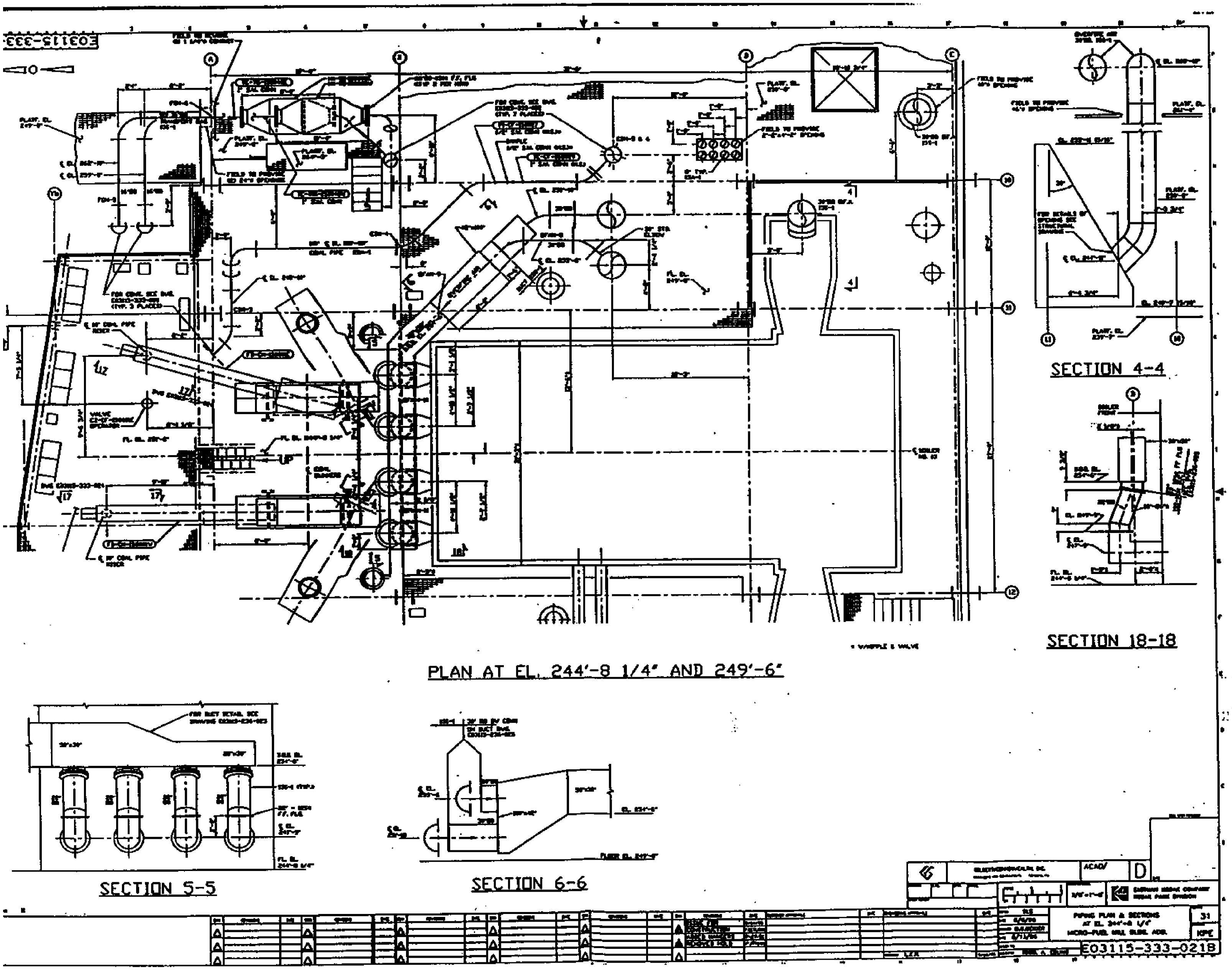
PIPING PLAN & SECTIONS
OPERATING FLR. EL. 218'-6"
MICRO-FUEL MILL BLDG. ADD.

8/13/94

31

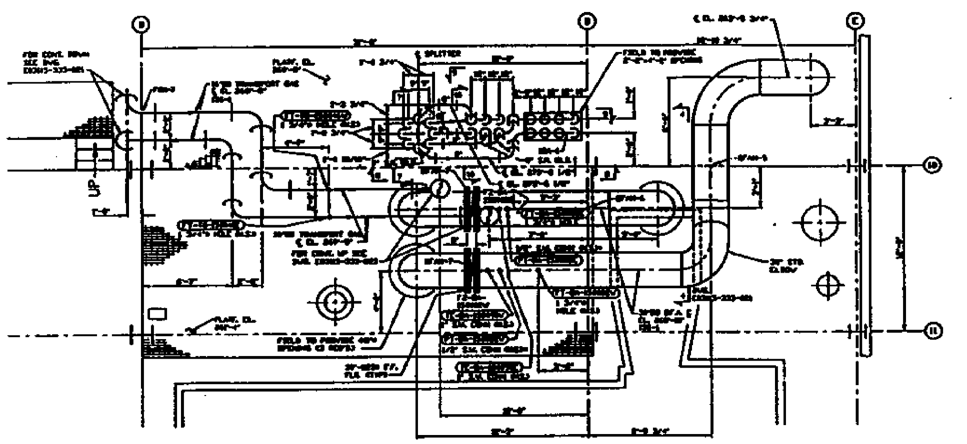
E03115-333-019B


PLAN AT EL. 234'-6" & 238'-9"

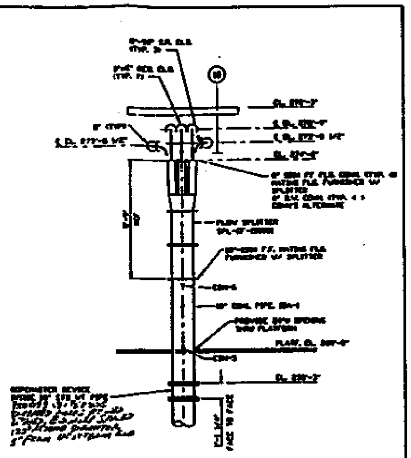

E03115-333
PLAN AT EL. 244'-8 1/4" AND 249'-6"
SECTION 4-4
SECTION 18-18
SECTION 5-5
SECTION 6-6
GILBERT/COMMONWEALTH, INC.
ACAD/
D
3/8" = 1'-0"
EASTMAN KODAK COMPANY
KODAK PARK DIVISION
PIPING PLAN & SECTIONS
AT EL. 244'-8 1/4"
MICRO-FUEL MILL BLDG. ADD.
31
KPE
E03115-333-021B

E03115-333-

N



PLAN AT EL. 261'-4"



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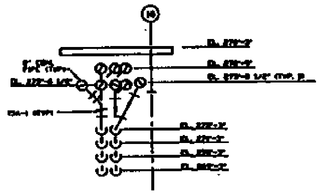

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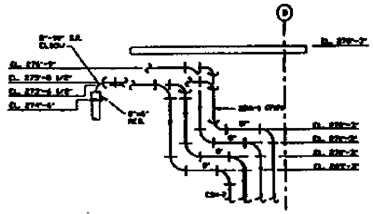
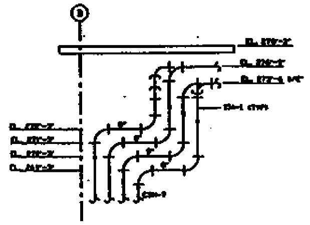


SECTION 8-8



SECTION 9-9

ACAD/

D

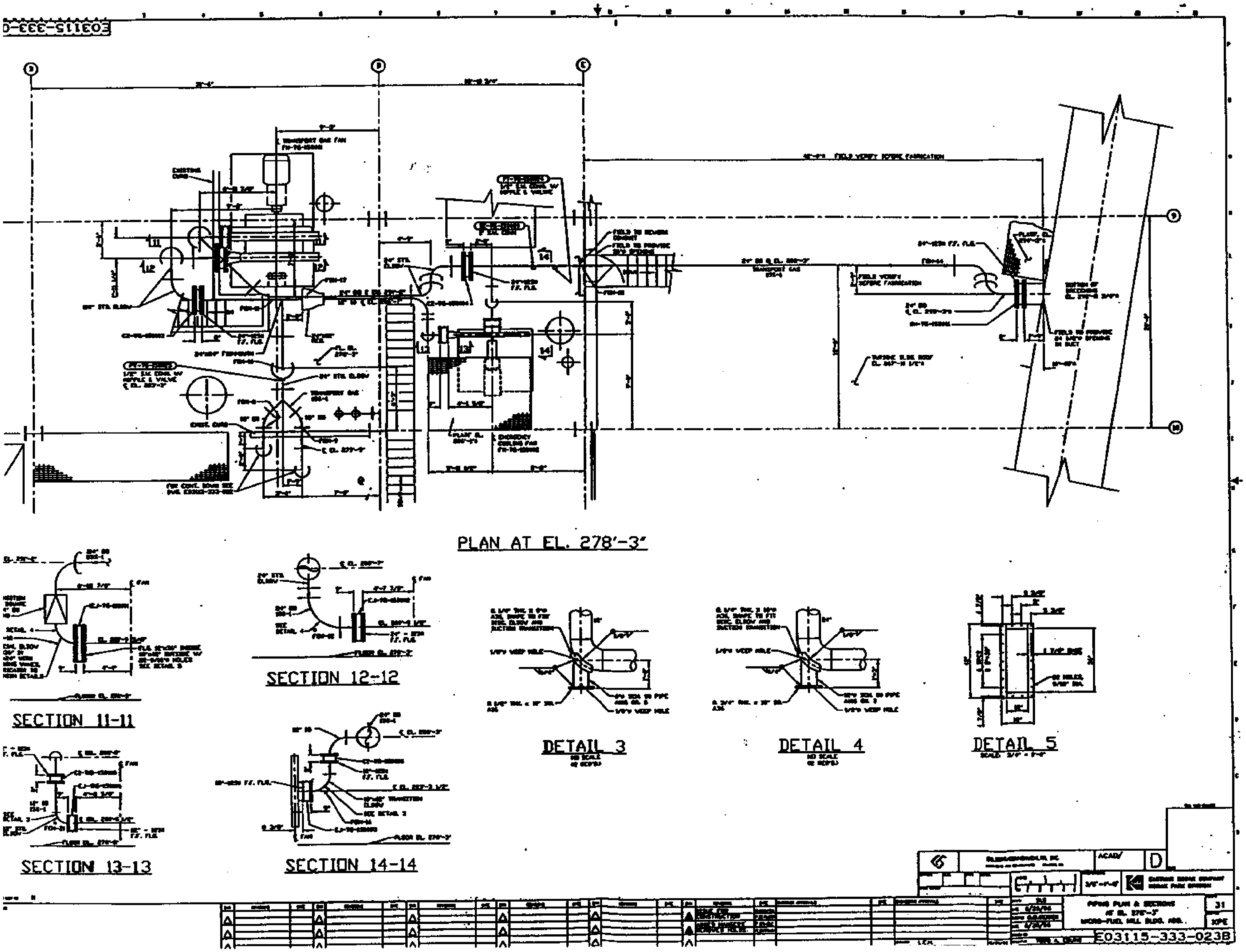
EASTMAN KODAK COMPANY
KODAK PARK DIVISION

PIPING PLAN & SECTIONS
AT EL. 261'-4"
MICRO-FUEL CELL BLDG. ADD.

31

KPC

E03115-333-022B

E03115-333-0
PLAN AT EL. 278'-3"
SECTION 11-11
SECTION 12-12
SECTION 13-13
SECTION 14-14
DETAIL 3
NO SCALE
DETAIL 4
NO SCALE
DETAIL 5
SCALE 3/4" = 1'-0"
ACAD/
D
3/8" = 1'-0"
EASTMAN KODAK COMPANY
KODAK PARK DIVISION
PIPING PLAN & SECTIONS
AT EL. 278'-3"
WOOD-FUEL MILL BLDG. ARR.
31
XPE
E03115-333-023B

APPENDIX - B

1. Optimization Test Data
2. Micronizer Fineness Data
3. Full Size Curves

TEST SERIES	DECRIPTION	BOILER LOAD KPPH	CYCLONE COAL FLOW EAST	CYCLONE COAL FLOW WEST	CYCLONE COAL FLOW TOTAL	CYCLONE COAL FLOW BY EFF.	CYCLONE COAL FLOW DELTA	TOTAL COAL FLOW BY EFF.	REBURN COAL FLOW FEEDER
1A	400KPPH, NO REBURN	400	17.58	16.95	34.53	35.23	-0.7	35.23	0
1B	370KPPH, NO REBURN	373	16.79	15.95	32.74	32.61	0.13	32.61	0
1C	340KPPH, NO REBURN	342	15.98	14.48	30.46	29.83	0.63	29.83	0
1D	315KPPH, NO REBURN	313	13.93	14.18	28.11	27.13	0.98	27.13	0
2D	400K, RB 7K, - SPIN VANES OUT	398	13.93	14.21	28.14	27.87	0.27	34.89	7.02
2C	5K REBURN, HOLD CYC INPUT	375	14.07	14.48	28.55	27.69	0.86	32.51	5.03
2B	3.5K REBURN, HOLD CYC INPUT	357	14.07	14.48	28.55	27.69	0.86	31.13	3.5
2A	2K REBURN, HOLD CYC INPUT	338	14.07	14.48	28.55	27.69	0.86	29.44	2.05
1D	315KPPH, NO REBURN	320	13.93	14.18	28.11	27.13	0.98	27.13	0
3A	400KPPH, RB 7K, .6 NOx -BASE	400	14.61	14.61	29.22	28.01	1.21	35.03	7.02
3E	400KPPH, RB 7K, .6 NOx - HIGH OFA	399	14.47	14.54	29.01	28.07	0.94	35.1	7.03
3B	400K, RB 7K, - IN & OUT OPEN	400	14.57	14.62	29.19	28.44	0.75	35.47	7.03
3B	400K, RB 7K, - IN & OUT OPEN	401	14.6	14.49	29.09	28.28	0.81	35.3	7.02
3B1	400K, RB 7K, - SPIN VANES IN	402	14.38	14.52	28.9	28.32	0.58	35.34	7.02
3D	400K, RB 7K, - CORE CLOSED	399	14.24	14.46	28.7	28.2	0.5	35.22	7.02
3C	400K, RB 7K, - SPIN VANES OUT	398	13.93	14.21	28.14	27.87	0.27	34.89	7.02
3C	400K, RB 7K, - SPIN OUT, BAL CYC O2'S	400	14.2	14.42	28.62	28.12	0.5	35.17	7.04
3C	400K, RB 7K, - SPIN OUT, BAL AIR MON.	400	14.2	14.59	28.79	28.2	0.59	35.25	7.04
3E	400K, RB 7K, - SPIN VANES OUT, HIGH OFA	399	14.2	14.17	28.37	28.21	0.16	35.25	7.04
3F	400K, RB 7K, - SPIN VANES OUT, LOW OFA	402	14.2	14.17	28.37	28.21	0.16	35.25	7.04
1A	400KPPH, NO REBURN	400	17.58	16.95	34.53	35.23	-0.7	35.23	0
4A	400KPPH, 2K REBURN	399	16.45	16.58	33.03	32.92	0.11	34.91	1.99
4B	400KPPH, 4K REBURN	398	15.41	15.61	31.02	30.88	0.14	34.9	4.03
4C	400KPPH, 6K REBURN	403	14.65	14.86	29.51	29.15	0.36	35.07	5.92
4D	415KPPH, 8K REBURN	414	14.17	14.43	28.6	28.12	0.48	36.49	8.37
5A	7K REBURN, HOLD CYC INPUT	398	14.07	14.48	28.55	27.69	0.86	34.6	7.03

TEST SERIES	DECRIPTION	CYCLONE COAL FLOW ADJUSTMENT	CYCLONE COAL FLOW ADJUSTED	REBURN COAL FLOW BY EFF.	REBURN INPUT BY EFF.	CARBON IN FLYASH HOPPER	UBC HOPPER	UBC LOSS EFFICIENCY HOPPER	BOILER EFFICIENCY %
1A	400KPPH, NO REBURN	-0.10	34.63	0.00	0.00	0.124	0.23	0.25	90.86
1B	370KPPH, NO REBURN	0.20	32.54	0.00	0.00	0.165	0.30	0.32	90.76
1C	340KPPH, NO REBURN	0.51	29.95	0.00	0.00	0.223	0.41	0.44	90.77
1D	315KPPH, NO REBURN	0.82	27.29	0.00	0.00	0.386	0.83	0.90	90.59
2D	400K, RB 7K, - SPIN VANES OUT	0.74	27.40	7.49	21.46	0.416	1.63	1.78	89.44
2C	5K REBURN, HOLD CYC INPUT	0.76	27.79	4.72	14.51	0.384	1.29	1.41	89.64
2B	3.5K REBURN, HOLD CYC INPUT	0.76	27.79	3.34	10.72	0.354	1.03	1.12	90.02
2A	2K REBURN, HOLD CYC INPUT	0.76	27.79	1.65	5.59	0.333	0.84	0.91	90.43
1D	315KPPH, NO REBURN	0.82	27.29	0.00	0.00	0.386	0.83	0.90	90.09
3A	400KPPH, RB 7K, .6 NOx-BASE	0.72	28.50	6.53	18.64	0.415	1.62	1.77	89.43
3E	400KPPH, RB 7K, .6 NOx - HIGH OFA	0.71	28.30	6.80	19.38	0.442	1.81	1.97	89.14
3B	400K, RB 7K, - IN & OUT OPEN	0.67	28.52	6.95	19.60	0.475	2.05	2.24	88.81
3B	400K, RB 7K, - IN & OUT OPEN	0.69	28.40	6.90	19.54	0.375	1.38	1.50	89.57
3B1	400K, RB 7K, - SPIN VANES IN	0.68	28.22	7.12	20.16	0.432	1.73	1.89	89.31
3D	400K, RB 7K, - CORE CLOSED	0.70	28.00	7.22	20.49	0.442	1.81	1.97	89.11
3C	400K, RB 7K, - SPIN VANES OUT	0.74	27.40	7.49	21.46	0.367	1.34	1.46	89.58
3C	400K, RB 7K, - SPIN OUT, BAL CYC O2'S	0.71	27.91	7.26	20.63	0.447	1.84	2.01	89.13
3C	400K, RB 7K, - SPIN OUT, BAL AIR MON.	0.70	28.09	7.16	20.31	0.437	1.77	1.93	89.17
3E	400K, RB 7K, - SPIN VANES OUT, HIGH OFA	0.70	27.67	7.58	21.50	0.428	1.71	1.86	89.06
3F	400K, RB 7K, - SPIN VANES OUT, LOW OFA	0.70	27.67	7.58	21.50	0.403	1.55	1.68	89.58
1A	400KPPH, NO REBURN	-0.10	34.63	0.00	0.00	0.124	0.23	0.25	90.86
4A	400KPPH, 2K REBURN	0.16	32.87	2.04	5.85	0.206	0.44	0.48	90.38
4B	400KPPH, 4K REBURN	0.39	30.63	4.27	12.25	0.281	0.75	0.82	90.07
4C	400KPPH, 6K REBURN	0.59	28.92	6.15	17.54	0.387	1.35	1.47	89.54
4D	415KPPH, 8K REBURN	0.71	27.89	8.60	23.56	0.419	1.75	1.91	89.09
5A	7K REBURN, HOLD CYC INPUT	0.76	27.79	6.81	19.67	0.379	1.41	1.54	89.52

TEST SERIES	DECRIPTION	TOTAL AIR FLOW	CYCLONE AIR FLOW	AVERAGE BOILER O2	AIR HEATER EXIT GAS T	SUPERHEAT TEMP	ATTEMP SPRAY FLOW	NOx BY CEM
1A	400KPPH, NO REBURN	411.00	387.00	3.25	341.00	900.00	18.00	1.38
1B	370KPPH, NO REBURN	381.00	357.00	3.35	346.00	898.00	13.00	1.23
1C	340KPPH, NO REBURN	343.00	320.00	3.10	340.00	901.00	5.00	1.16
1D	315KPPH, NO REBURN	318.00	294.00	3.60	344.00	892.00	0.00	1.06
2D	400K, RB 7K, - SPIN VANES OUT	415.00	302.00	3.85	346.00	899.00	0.00	0.56
2C	5K REBURN, HOLD CYC INPUT	377.00	302.00	3.35	347.00	890.00	0.00	0.68
2B	3.5K REBURN, HOLD CYC INPUT	357.00	303.00	3.12	347.00	900.00	0.00	0.84
2A	2K REBURN, HOLD CYC INPUT	344.00	300.00	3.50	349.00	900.00	1.00	1
1D	315KPPH, NO REBURN	318.00	294.00	3.60	345.00	892.00	0.00	1.08
3A	400KPPH, RB 7K, .6 NOx -BASE	408.00	312.00	3.55	339.00	893.00	0.00	0.57
3E	400KPPH, RB 7K, .6 NOx - HIGH OFA	417.00	305.00	3.80	341.00	895.00	0.00	0.54
3B	400K, RB 7K, - IN & OUT OPEN	420.00	307.00	3.90	343.00	901.00	1.00	0.55
3B	400K, RB 7K, - IN & OUT OPEN	412.00	300.00	3.50	342.00	901.00	2.00	0.52
3B1	400K, RB 7K, - SPIN VANES IN	416.00	303.00	3.75	339.00	896.00	0.00	0.52
3D	400K, RB 7K, - CORE CLOSED	416.00	302.00	3.75	345.00	900.00	2.00	0.55
3C	400K, RB 7K, - SPIN VANES OUT	415.00	302.00	3.85	346.00	899.00	0.00	0.56
3C	400K, RB 7K, - SPIN OUT, BAL CYC O2'S	413.00	300.00	3.70	341.00	893.00	0.00	0.57
3C	400K, RB 7K, - SPIN OUT, BAL AIR MON.	414.00	302.00	3.70	343.00	898.00	0.00	0.55
3E	400K, RB 7K, - SPIN VANES OUT, HIGH OFA	431.00	297.00	4.40	345.00	900.00	1.00	0.57
3F	400K, RB 7K, - SPIN VANES OUT, LOW OFA	392.00	304.00	2.70	348.00	900.00	0.00	0.54
1A	400KPPH, NO REBURN	411.00	387.00	3.25	341.00	900.00	18.00	1.38
4A	400KPPH, 2K REBURN	394.00	359.00	2.75	362.00	900.00	13.00	1.19
4B	400KPPH, 4K REBURN	392.00	336.00	2.70	362.00	902.00	4.00	0.87
4C	400KPPH, 6K REBURN	392.00	314.00	2.75	359.00	888.00	0.00	0.62
4D	415KPPH, 8K REBURN	405.00	304.00	2.65	359.00	901.00	1.00	0.5
5A	7K REBURN, HOLD CYC INPUT	395.00	301.00	3.25	348.00	886.00	0.00	0.51

MILL FINENESS DATA WORKSHEET

DATE	4/21/98
TIME	4:30
MILL	EAST
BOILER LOAD	400K
COAL FLOW K#/HR	
STRIPPING AIR NOTCH	
	SAMPLE#2

COMMENTS 15 BLR.

COAL TYPE MICRO COAL

SAMPLE WEIGHT 45

SAMPLE PLUS PAN WEIGHT 30MINUTES 417.7

5 MINUTES 418.1

MESH SIZE	COAL WEIGHT PLUS PAN	PAN WEIGHT	COAL WEIGHT	% PASSING
30	424.7	424.7	0	100.00
100	335.1	334.9	0.2	99.56
200	347.3	346.9	0.4	98.67
325	341.2	337.8	3.4	91.11
PAN	418.1	377.9	40.2	

MILL FINENESS DATA WORKSHEET

DATE	4/23/98
TIME	3:00
MILL	West
BOILER LOAD	
COAL FLOW K#/HR	
STRIPPING AIR NOTCH	

COMMENTS 15 BLR.

COAL TYPE MICRO COAL

SAMPLE WEIGHT 56

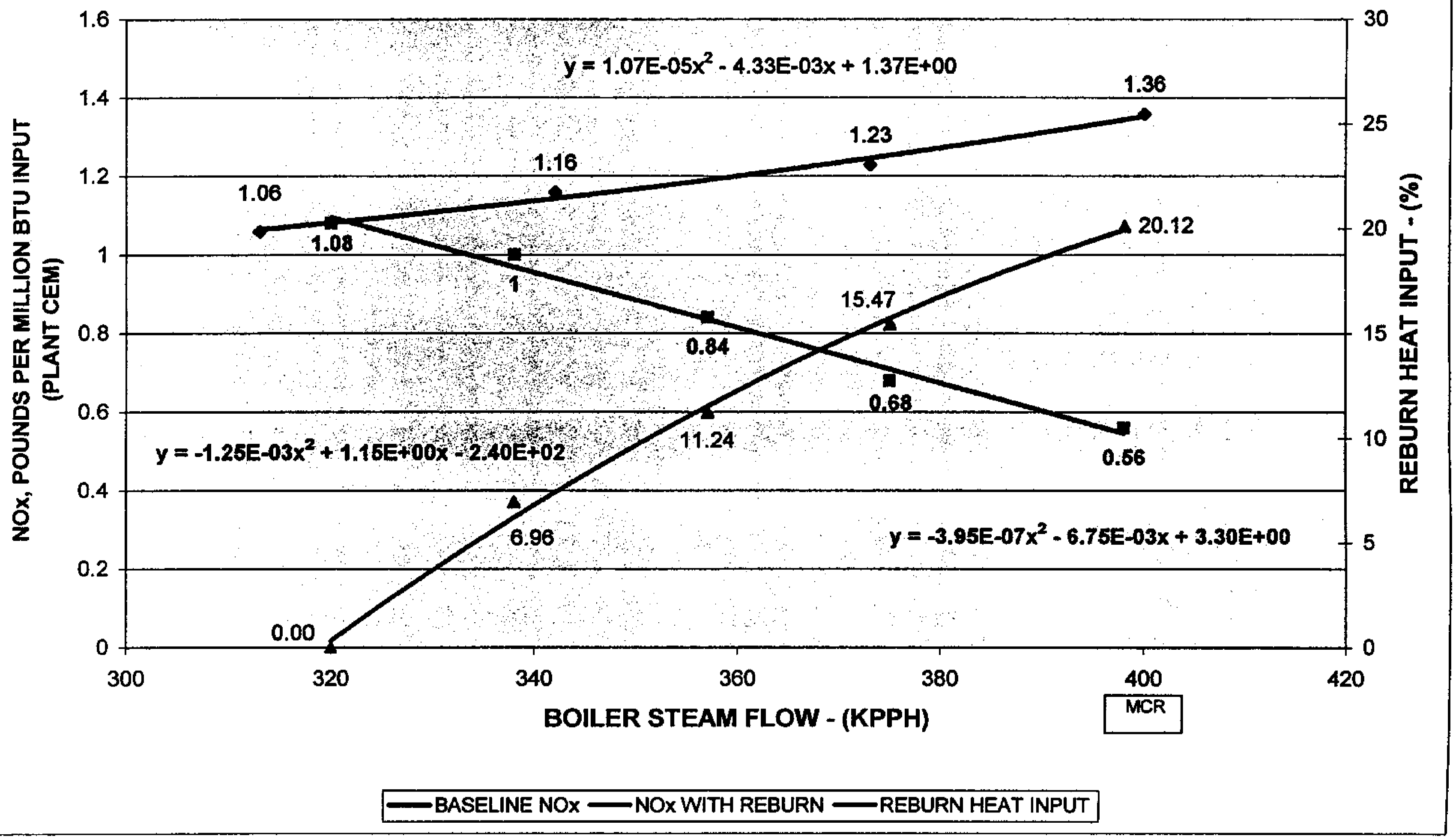
SAMPLE PLUS PAN WEIGHT 30MINUTES 427.6

5 MINUTES 428

MESH SIZE	COAL WEIGHT PLUS PAN	PAN WEIGHT	COAL WEIGHT	% PASSING
30	424.9	424.9	0	100.00
100	335	334.9	0.1	99.82
200	347.3	347	0.3	99.29
325	341.8	337.9	3.9	92.32
PAN	428	377.9	50.1	

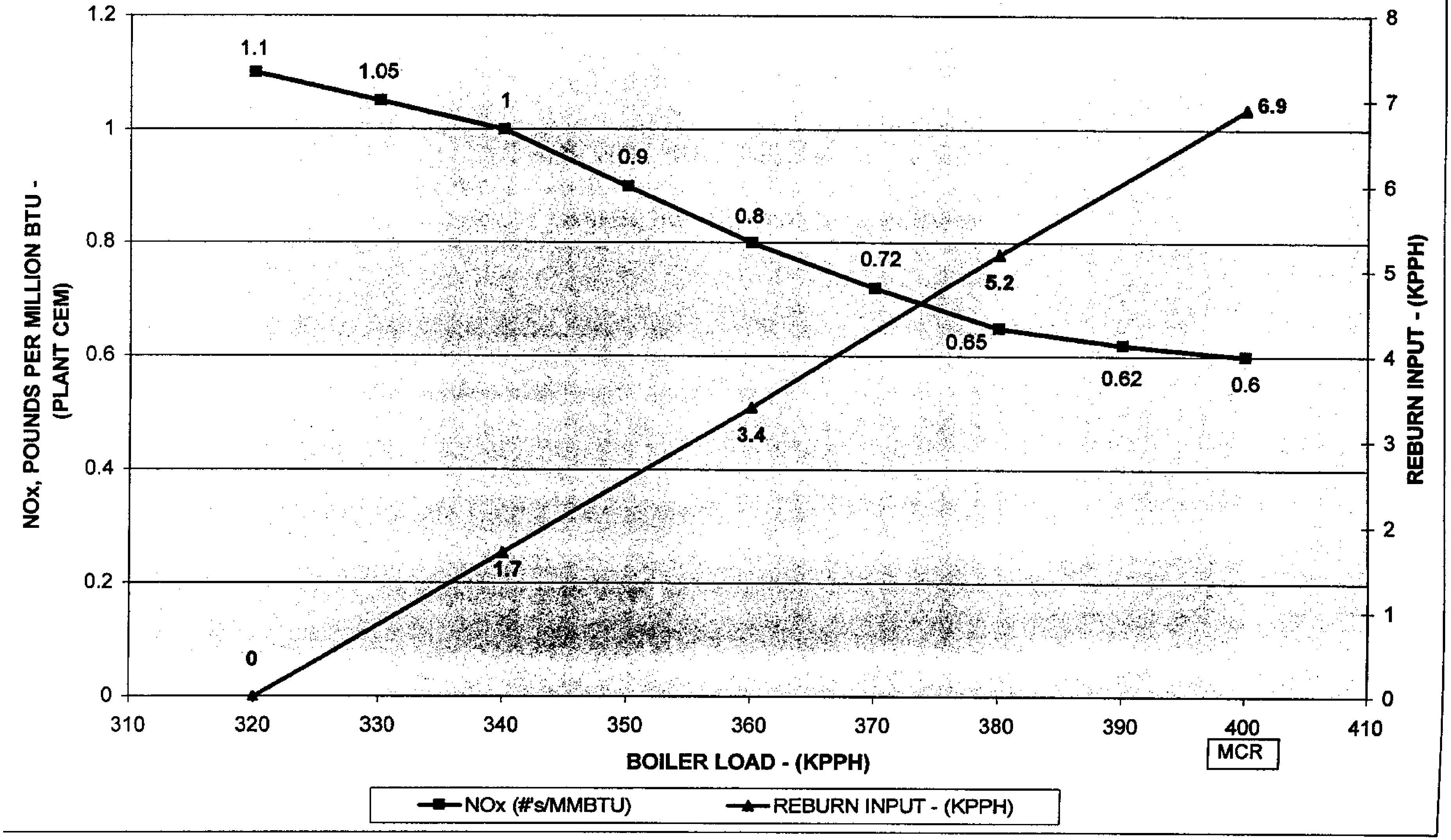
TOTAL 54.4

15 BOILER MICRONIZED COAL REBURN EMISSION SUMMARY
NOx VS. BOILER STEAM FLOW WITH AND WITHOUT REBURN



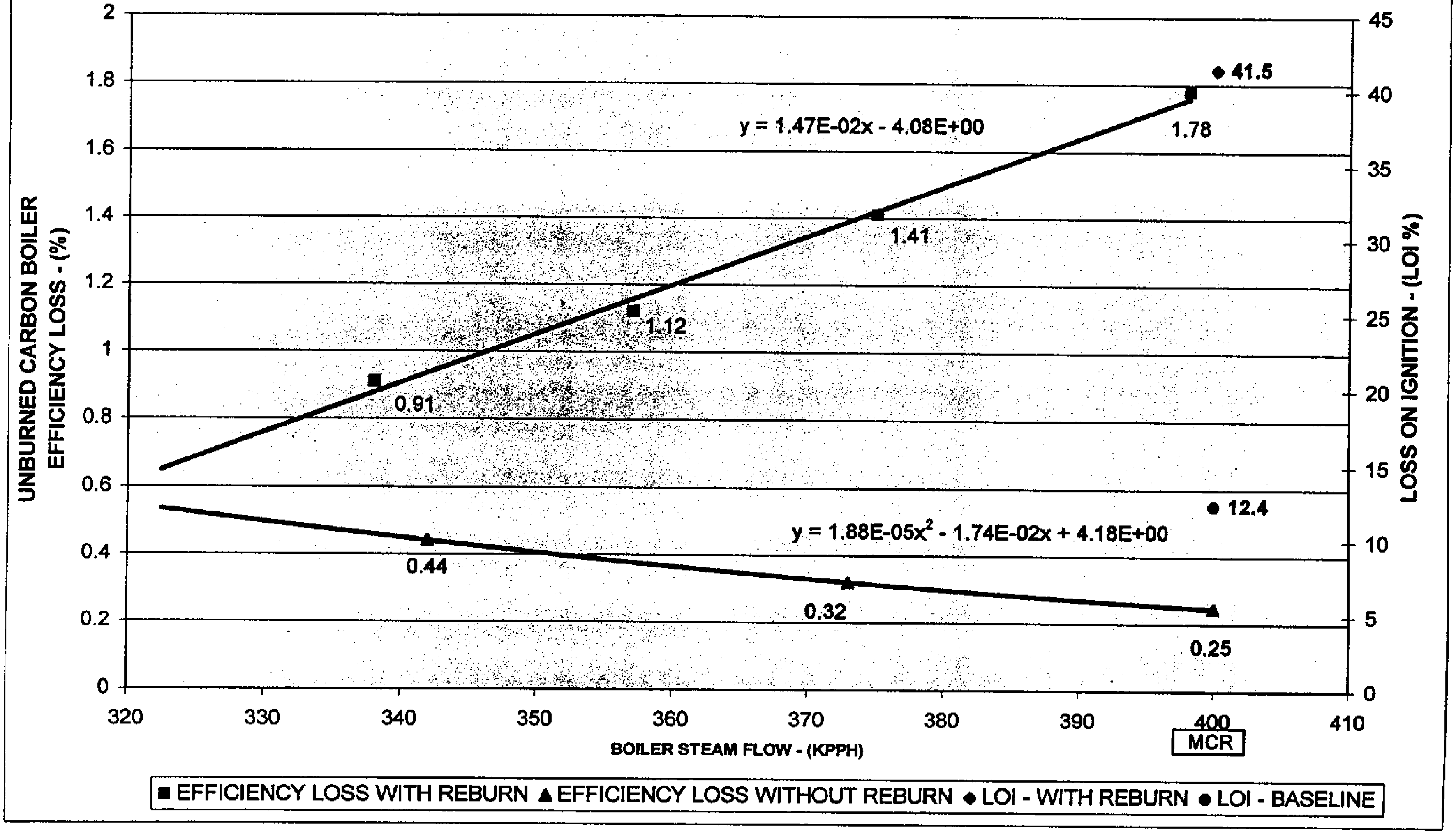
MCR = Maximum Continuous Rating (400 kpph)

15 BOILER MICRONIZED COAL REBURN
NOx EMISSION LIMIT AND REBURN INPUT VS LOAD

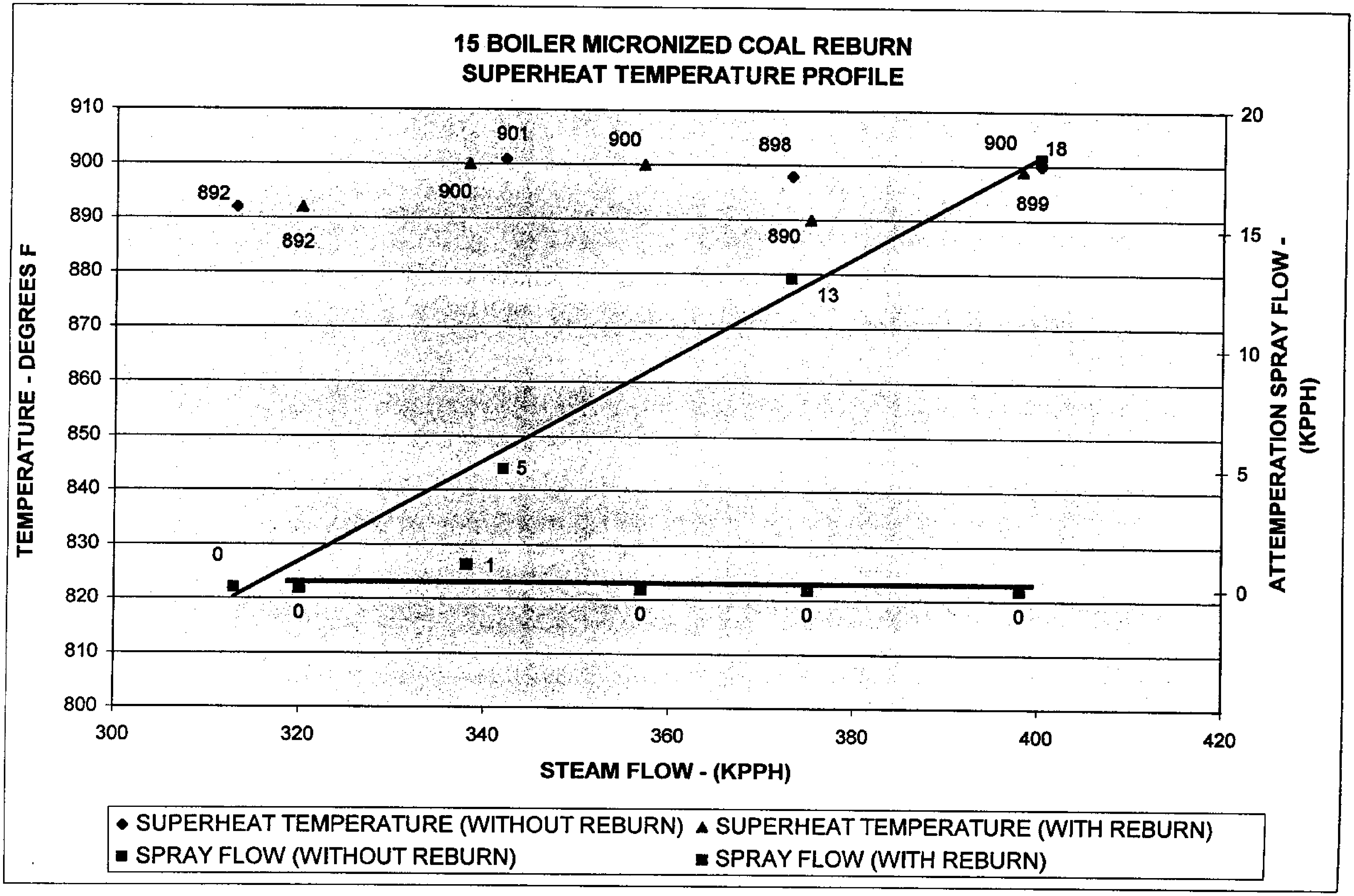


MCR = Maximum Continuous Rating (400 kpph)

15 BOILER MICRONIZED COAL REBURN
UNBURNED CARBON EFFICIENCY LOSS VS. BOILER STEAM FLOW
BASELINE COMPARED TO REBURN



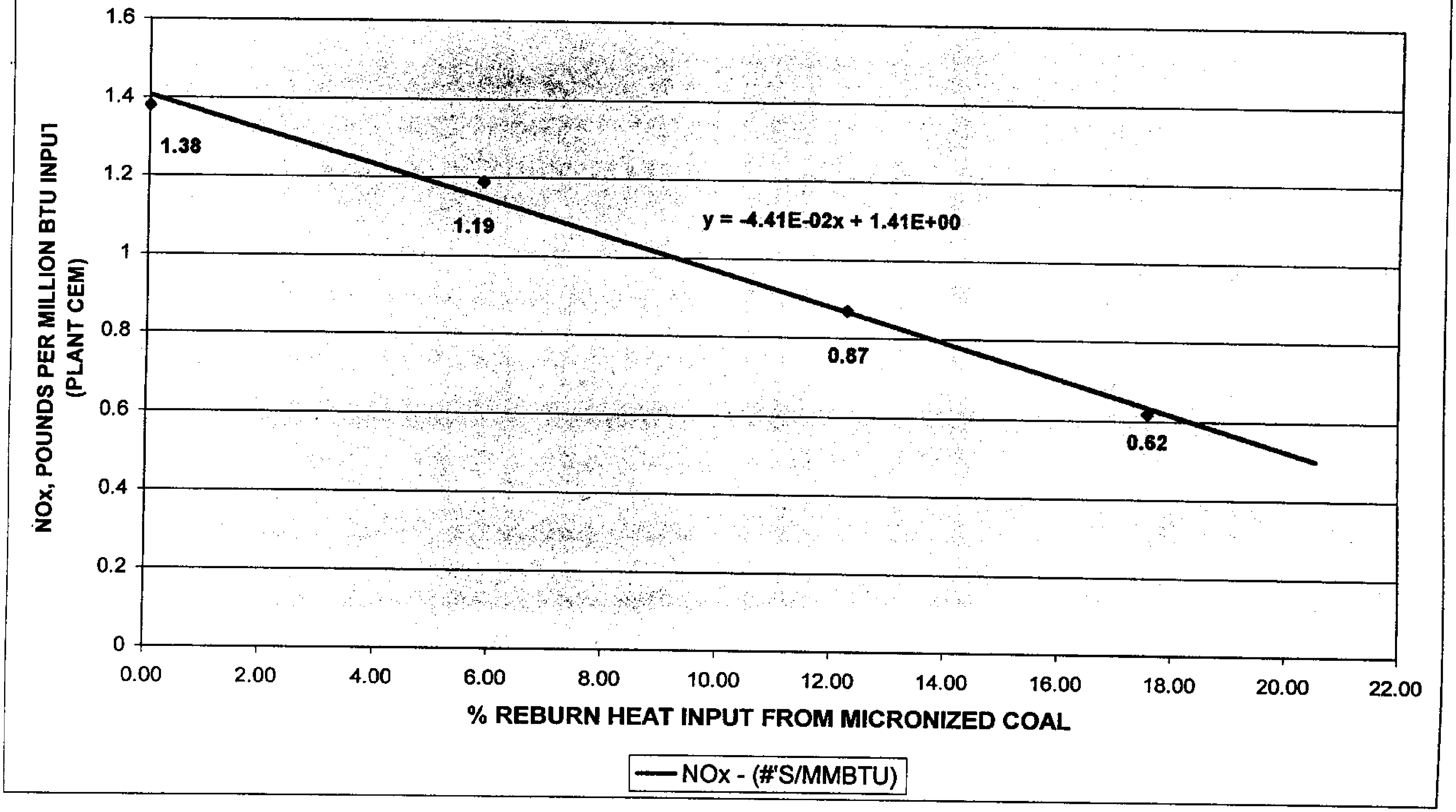
MCR = Maximum Continuous Rating (400kpph)



Note: Attemperation water is boiler feedwater at 235°F.

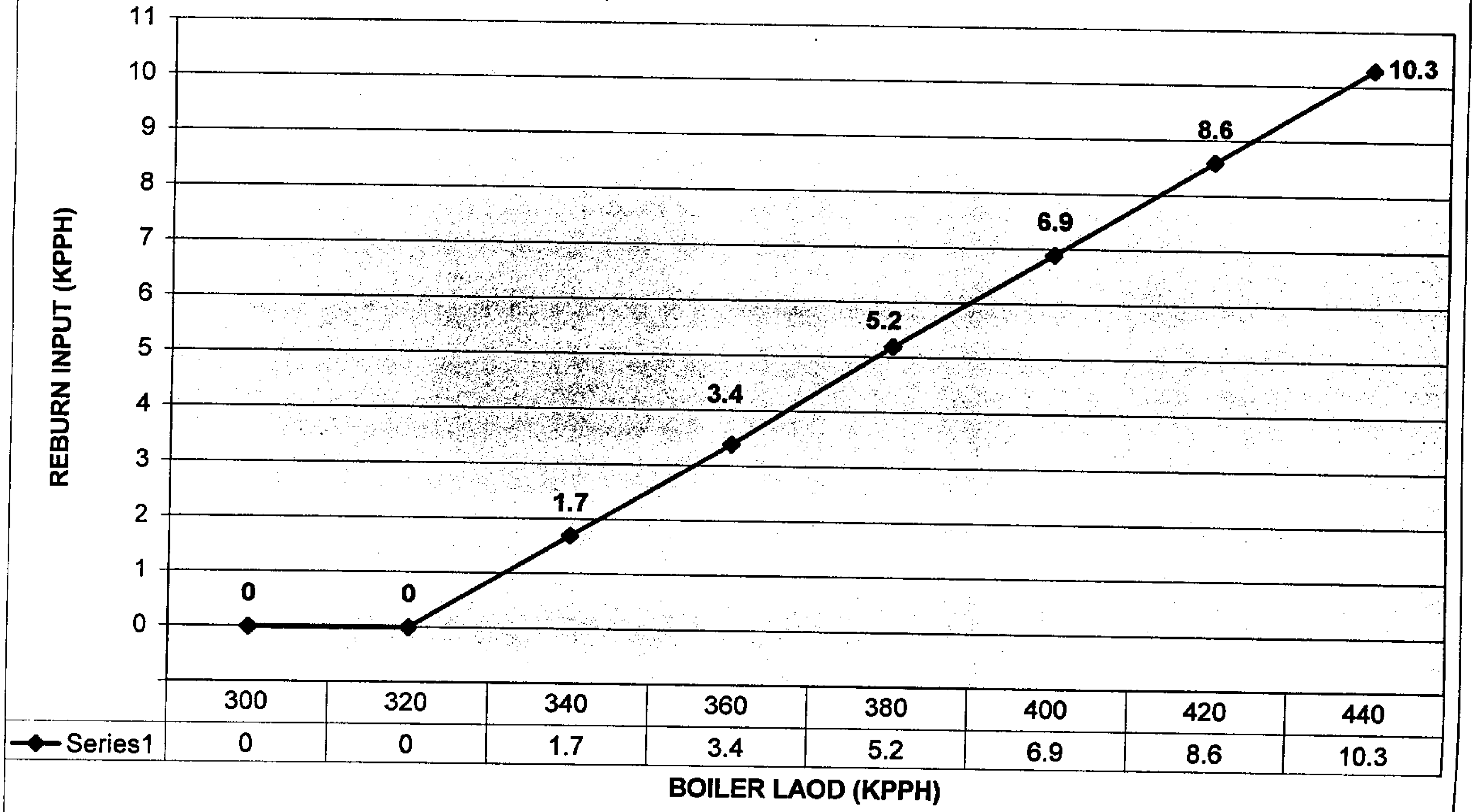
15 BOILER MICRONIZED COAL REBURN EMISSION SUMMARY

NOx VS. REBURN HEAT INPUT AT 400 KPPH STEAM FLOW



MCR = Maximum Continuous Rating (400 kpph)

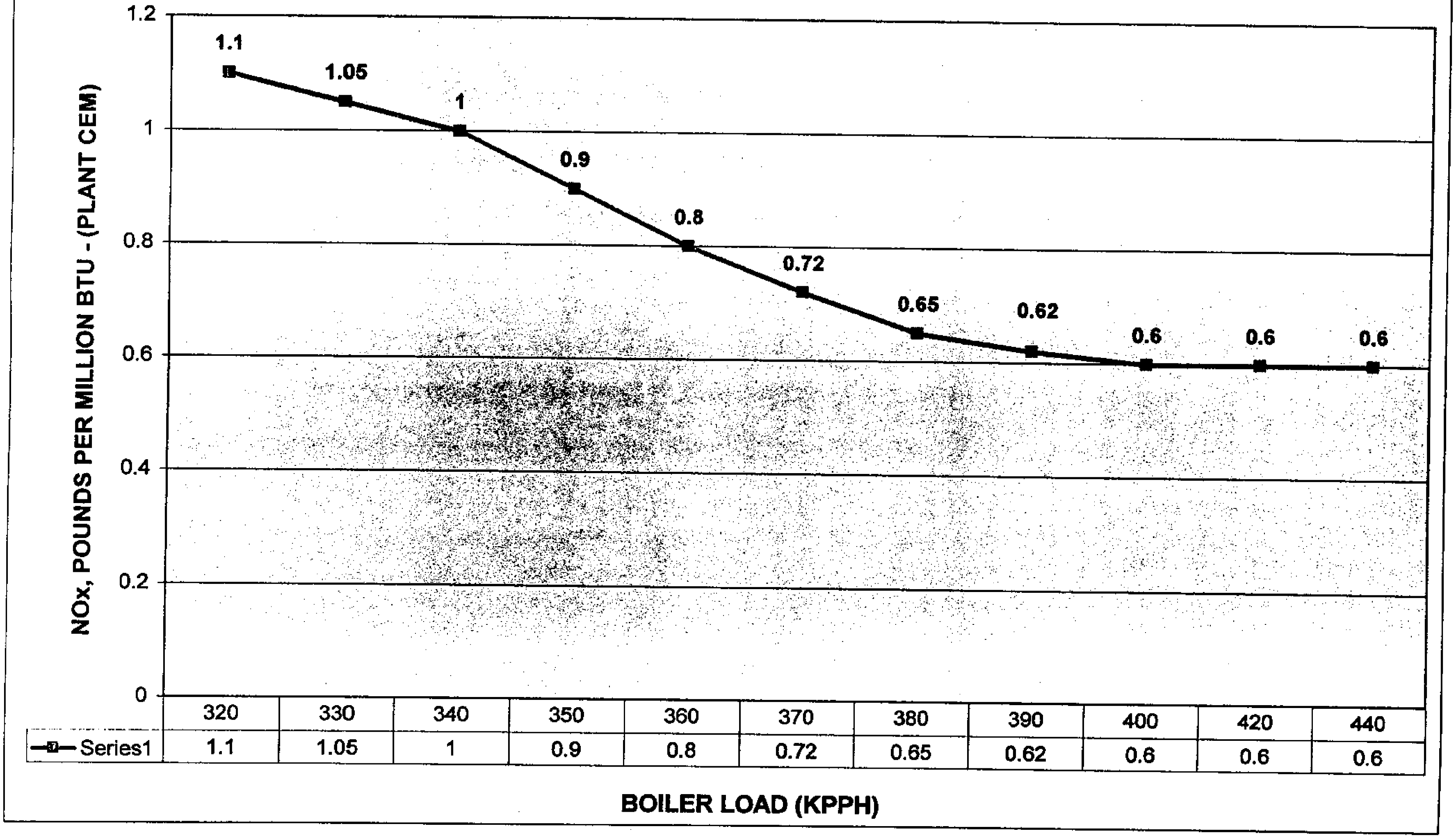
15 BOILER MICRONIZED COAL REBURN START-UP
REBURN INPUT (KPPH) VS. BOILER LOAD FOR AUTOMATIC CONTROL



	300	320	340	360	380	400	420	440
Series1	0	0	1.7	3.4	5.2	6.9	8.6	10.3

15 BOILER MICRONIZED COAL REBURN

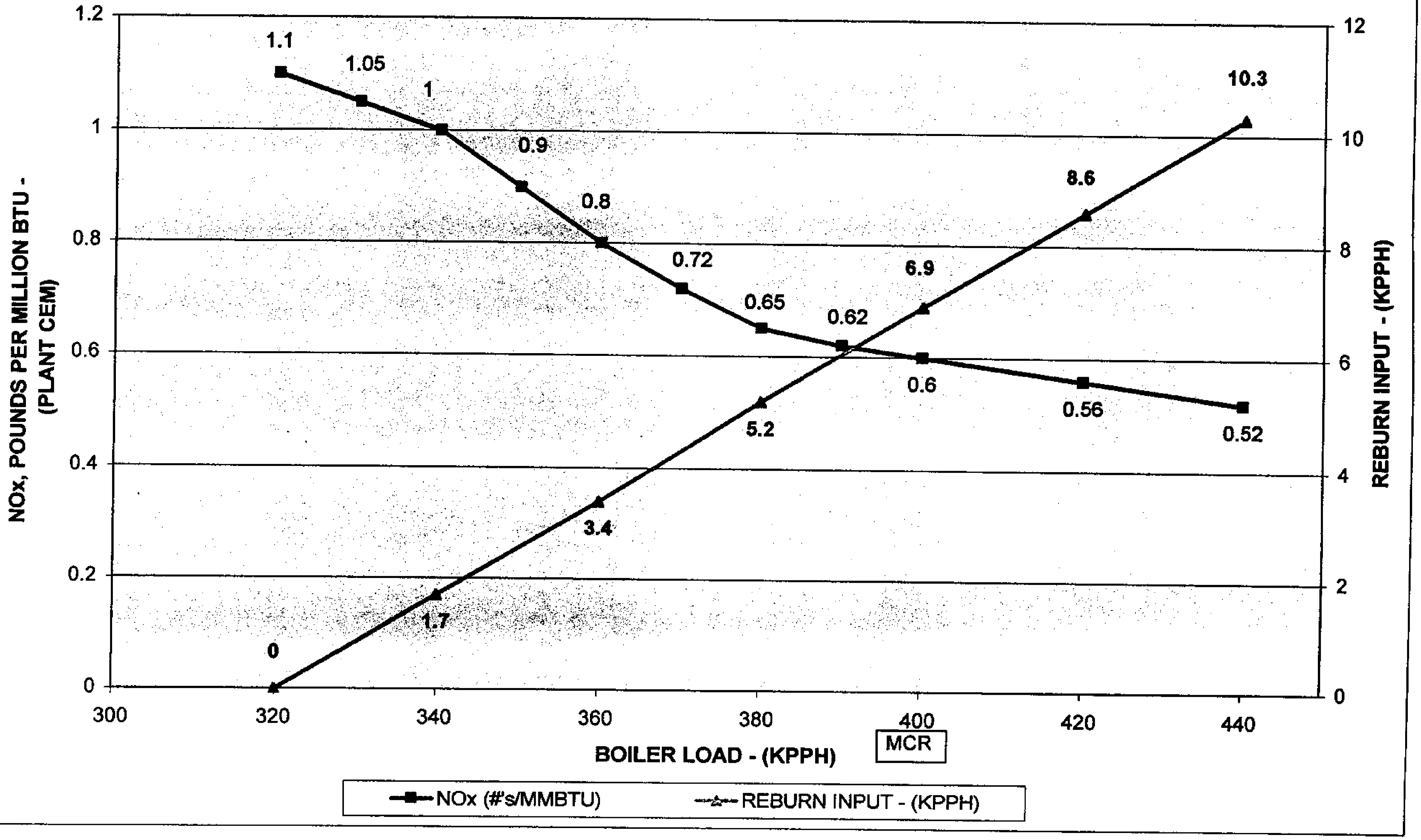
NOx EMISSION LIMIT VS. BOILER LOAD



	320	330	340	350	360	370	380	390	400	420	440
Series1	1.1	1.05	1	0.9	0.8	0.72	0.65	0.62	0.6	0.6	0.6

MCR = Maximum Continuous Rating (400 kpph)
4 - Hour Peak Rating = (440 kpph)

15 BOILER MICRONIZED COAL REBURN
NOx EMISSION LIMIT AND REBURN INPUT VS LOAD



MCR = Maximum Continuous Rating (400 kpph)