AP-42 Section 1.1
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Reference 33

GAS REBURN SYSTEM OPERATING EXPERIENCE ON A CYCLONE BOILER

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NOx CONTROLS FOR UTILITY BOILERS

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Cyclone-fired boilers make up approximately 9% of U.S. coal-fired generating capacity but emit about 14% of the NOx that utility boilers produce. Cyclone-fired boilers are not easily adapted to in-furnace NOx reduction technologies; for example low NOx burners cannot be installed on cyclone boilers.

Reburn Technology would appear to be one of the few technologies easily adaptable to cyclones for in-furnace NOx reduction. Reburn involves creating a second combustion, "reburn," zone downstream from the primary combustion zone in a boiler. Combustion gases from the primary combustion zone move to the reburn zone, where some staged fuel is injected, typically 15 to 20% of the total Btu input. This staged or reburn fuel creates a fuel-rich zone in which the NOx formed in the primary combustion zone is reduced and converted to molecular nitrogen and water vapor.

The Ohio Edison Niles Station Unit No. 1, is host to Reburn Technology full-scale demonstration $10.8 million project utilizing natural gas as the reburn fuel. The U.S. Environmental Protection agency (USEPA), the Gas Research Institute (GRI), the Electric Power research Institute (EPRI), the U.S. Department of Energy-Pittsburgh Energy Technology Center (USDOE-PETC), and the Ohio Coal Development Office (OCDO) have sponsored this project with ABB Combustion Engineering (ABB-CE) as the project manager. The Consolidated Natural Gas Company (CNG) specifically East Ohio Gas has financially shared in the program. Ohio Edison and East Ohio Gas are sharing a portion of the differential cost of natural gas from coal.

The Ohio Edison Niles No. 1 unit was placed in commercial operation in 1953. This pressurized furnace boiler has an electrical output of 108 MWe (net). It is a natural circulation, reheat type boiler with four (4) 9 ft. x 12 ft. cyclone burners on the front wall. Steam conditions are 1470/374 PSIG and 1000/1000 degree F.

The original reburn system design was installed during a four (4) week annual boiler outage during June 1990. This system consisted of five (5) Upper Fuel Injectors (UFI) and four (4) Additional-Air (AA) windboxes. Flue gas recirculation (FGR) was utilized as a transport media to allow for good reburn fuel mixing and penetration in the flue gas stream. Installation of ductwork, FGR fan, gas piping and valves, control system, air compressors and piping were completed as much as possible prior to the unit shutdown.

The unit was first operated with small quantities of natural gas injection on August 29, 1990. Full load automatic operation with 19% natural gas was achieved in September 21, 1990. The remainder of 1990 was used for parametric testing to examine NOx reduction and boiler performance at different boiler conditions (cyclone excess air, cyclones in service and boiler load), Reburn Zone conditions (natural gas flow, FGR flow, UFI tilt/yaw, UFI horizontal bias, and UFI tilt combinations) and Burnout Zone conditions (AA flow, yaw, tilt and bias).

Baseline NOx emissions averaged approximately 705 ppm at full load 108 MWe (net) and 630 ppm at 86 MWe (net) (80% boiler load). During parametric testing with 18% natural gas injection the NOx emissions were reduced to approximately 300 ppm or 58% reduction. FGR flow seemed to have little effect on results. A 0.5% reduction in boiler efficiency was calculated mainly due to increased flue gas moisture associated with combustion of natural gas.

An outage was scheduled for this unit in December 1990 to allow for initial measurement of boiler tube wall thickness readings which was part of the corrosion testing program. During this outage, it was found that the rear wall of the secondary furnace (Reburn Zone) had a very large build up of slag. This slag was removed and within two (2) weeks after start-up, the slag had again grown out on the rear wall. This condition was deemed unacceptable by Ohio Edison although it seemed to have little effect on the reburn system.

It was hypothesized that this heavy slag deposit was caused by the recirculated flue gas forming a cooler boundary layer along the back wall. This would have a tendency to freeze the normally molten, running slag which would then build up until it reached a new equilibrium point where the slag would again get hot enough to run down the wall instead of freezing.

A new reburn fuel (natural gas) injection system was designed by ABB-CE and was eventually installed during a normal annual boiler outage in the Fall of 1991. This consisted of removing the FGR windboxes for the UFI's and installing water cooled natural gas injectors. Natural gas is injected and distributed solely by the gas nozzles. This system has eliminated the excess slag build-up.

Long term testing is currently in progress. Preliminary results show an average of 46% to 48% NOx reduction over all boiler loads with this configuration; NOx reduction at full load has met the project target of 50% NOx reduction. The slight drop in NOx reduction with the modified reburn system is being addressed by ABB-CE at this time. It is believed that elimination of FGR has caused the natural gas to be slightly less effective in forming the desired hydrocarbon species for NOx reduction. In this regard another very promising modification is that of water injection into the natural gas stream as it is being injected into the boiler. Preliminary testing has indicated increased NOx reduction efficiencies. A water injection system is being installed the week of July 6th with testing to be carried out during the month of July.

Operation of the system has been fairly simple for the plant operators. The automated control system and the interface with main boiler controls allows for almost an invisible system of the operator. The Reburn System operation does put more heat into the superheat and reheat section which has increased attemperator flow rates by about 1 to 5%. Preliminary corrosion data does not indicate increased corrosion activity. However, in early June, a secondary superheater tube failed due to coal ash corrosion; this will be investigated during the August 1992 outage. Tube failures due to corrosion had occurred in that region prior to installation of the reburn system; it is presently unclear as to whether or not tube wastage was affected by the reburn system.

A skin casing leak in the reburn zone at the UFI level caused some concern in April 1992. At this time, a flame was observed about four (4) feet long on the outside corner of the boiler which extinguished itself when the natural gas was turned off. Since gases in the reburn zone are fuel rich, by design, it is possible that combustible gases could be emitted if a casing leak occurred; depending on the location of the leak and the flammability limits of the particular gases a flame may or may not be supported. Extensive gas monitoring was carried out, the casing leak was pinpointed and repaired and there has been no reoccurrence of the problem. However ABB-CE fully recognizes the significance of the potential for gas leaks form the reburn zone of a pressurized boiler and is working on solutions for same.

During long term testing the reburn system has operated and closely achieved the target of 50% NOx reduction at full boiler load. Natural gas as the reburn fuel is a simple and relatively easy retrofit to an existing boiler. The operating cost of a reburn system (NOx reduction) is almost solely dependent on the differential cost between natural gas and coal. Natural gas in the Ohio region is about twice the cost of coal; final selection of the most economical NOx reduction technique will necessarily be based on the dollars per ton of NOx removed.

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Ohio Edison Reburn Program

Host Site: **Ohio Edison's Niles Unit No. 1**
Niles Ohio;
108 M.W. Cyclone-Fired Boiler

Project Sponsors:

- **U.S. Environmental Protection Agency and The Department of Energy**
- **Gas Research Institute**
- **Electric Power Research Institute**
- **Ohio Coal Development Office**
- **Ohio Edison**
- **E. Ohio Gas**

Prime Contractor:

ABB Combustion Engineering

Reburning

NO_x Reduction Due to Staging the Fuel and Creating a Fuel Rich Zone

- By Direct Reduction of NO_x from the Primary Combustor:
  - $CH_4 \rightarrow CH \rightarrow HCN \rightarrow NH + NO \rightarrow N_2$
- Replacing Nitrogen Bearing Fuel with a Non-Nitrogen Bearing Fuel:
  - Natural Gas
- Decreasing Thermal NO_x:
  - Primary Combustor Operated at Lower Load

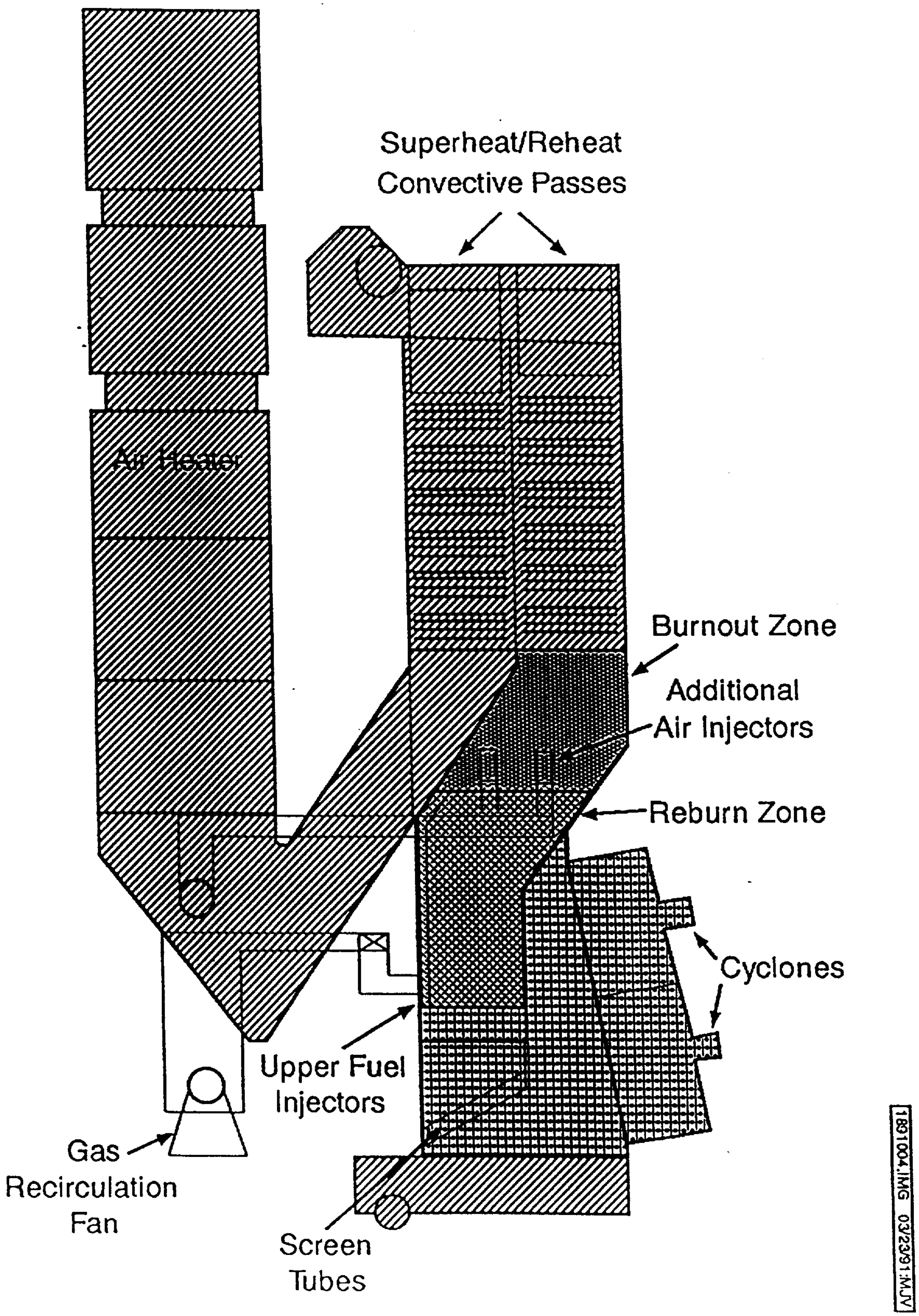
Reburn System Description

- Composed of Equipment / Material Familiar to Utilities
- Key Components for Reburn Zone
  - Flue Gas Recirculation Fan
  - Ductwork / Dampers
  - Natural Gas Pipeline / Valves
  - Upper Fuel Injectors

Reburn System Description

- Key Components for Burnout Zone
  - Ductwork / Dampers
  - Additional Air Injectors
- Control System
  - Allen Bradley Programmable Controller
  - Required Pressure, Temperature, Flow Sensors
- Requires Relatively Small Space and Short Outage

Schematic of Reburn Process



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Coal Analysis - As Received Basis

Proximate Analysis	Average	Maximum Value	Minimum Value
% Moisture	7.8	9.3	6.6
% Volatile Matter	32.2	33.7	31.1
% Fixed Carbon	47.3	49.3	45.3
% Ash	12.6	13.6	11.4
Total	100.0		
HHV Btu/lb	11576	11870	11277
Ultimate Analysis			
% Hydrogen	4.4	4.5	4.3
% Carbon	63.4	65.3	61.8
% Sulfur	3.3	4.1	3.0
% Nitrogen	1.4	1.5	1.3
% Oxygen	7.1	8.4	5.5

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Parametric Test Program

- Baseline Test Variables
  - Cyclone Excess Air
  - Cyclones in Service
  - Boiler Load

- Reburn Test Variables
  - Reburn Zone
    - Natural Gas Flow
    - Flue Gas Recirculation Flow / Compartment Bias
    - UFI Tilt / Yaw
    - UFI Horizontal Bias
  - Burnout Zone
    - Air Flow
    - AA Tilt / Yaw
    - AA and UFI Tilt Combinations

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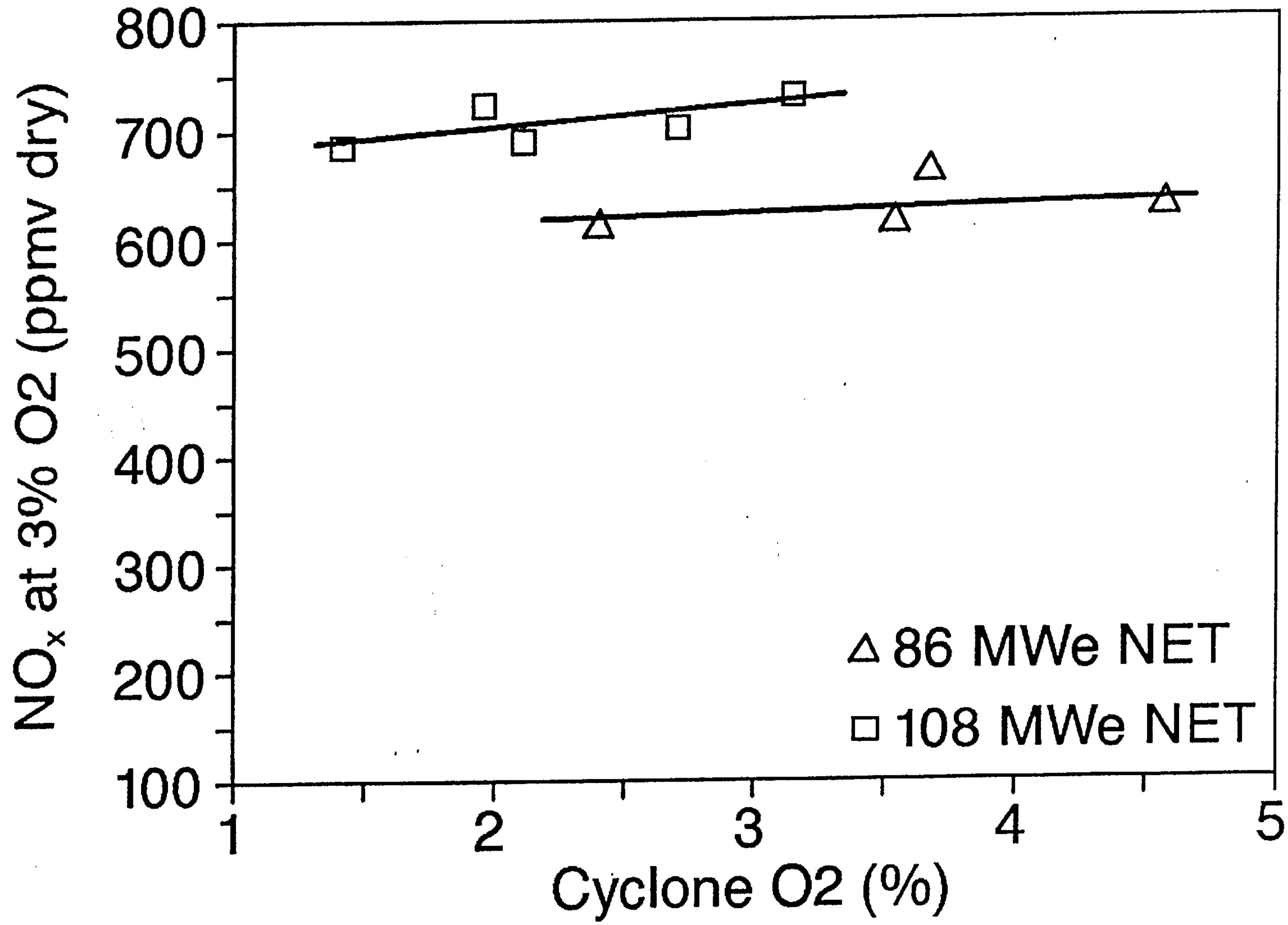
Baseline NO_x Versus Cyclone O2



NO_x Versus Percent Flue Gas Recirculation (FGR)

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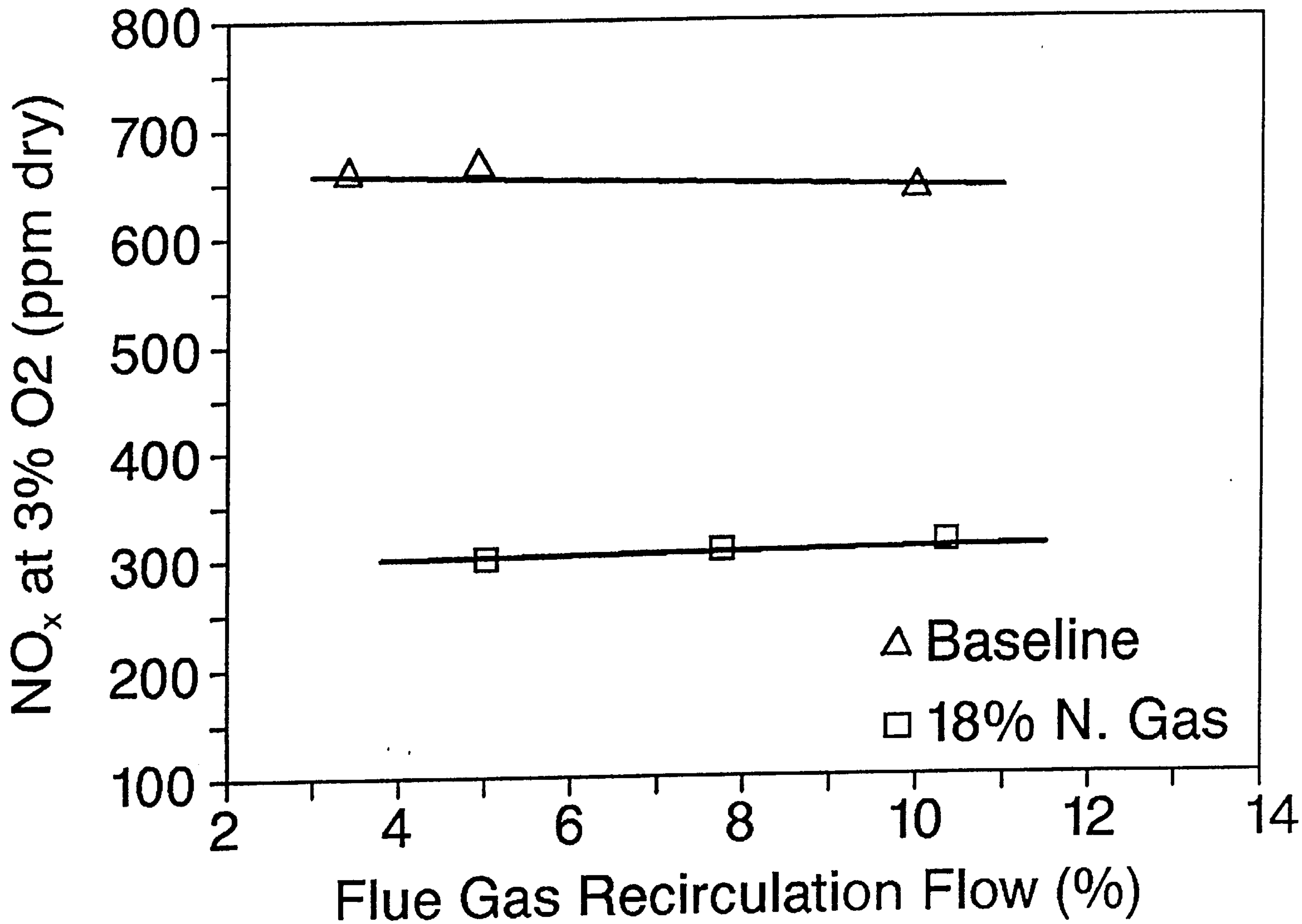
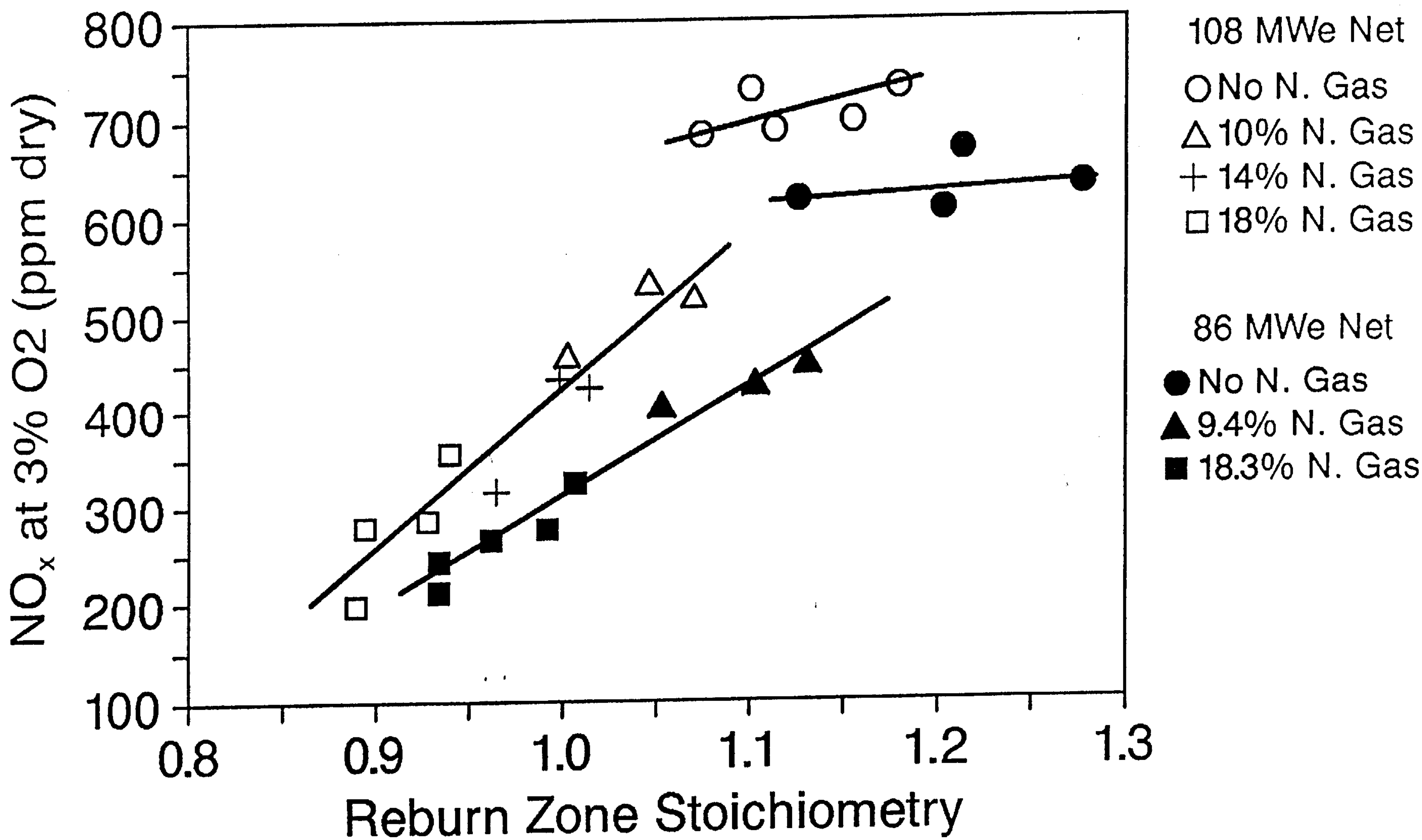


NO_x Versus Reburn Zone Stoichiometry at Various Gas Flow Rates



O2 and CO Versus Boiler Exit Duct Sample Location

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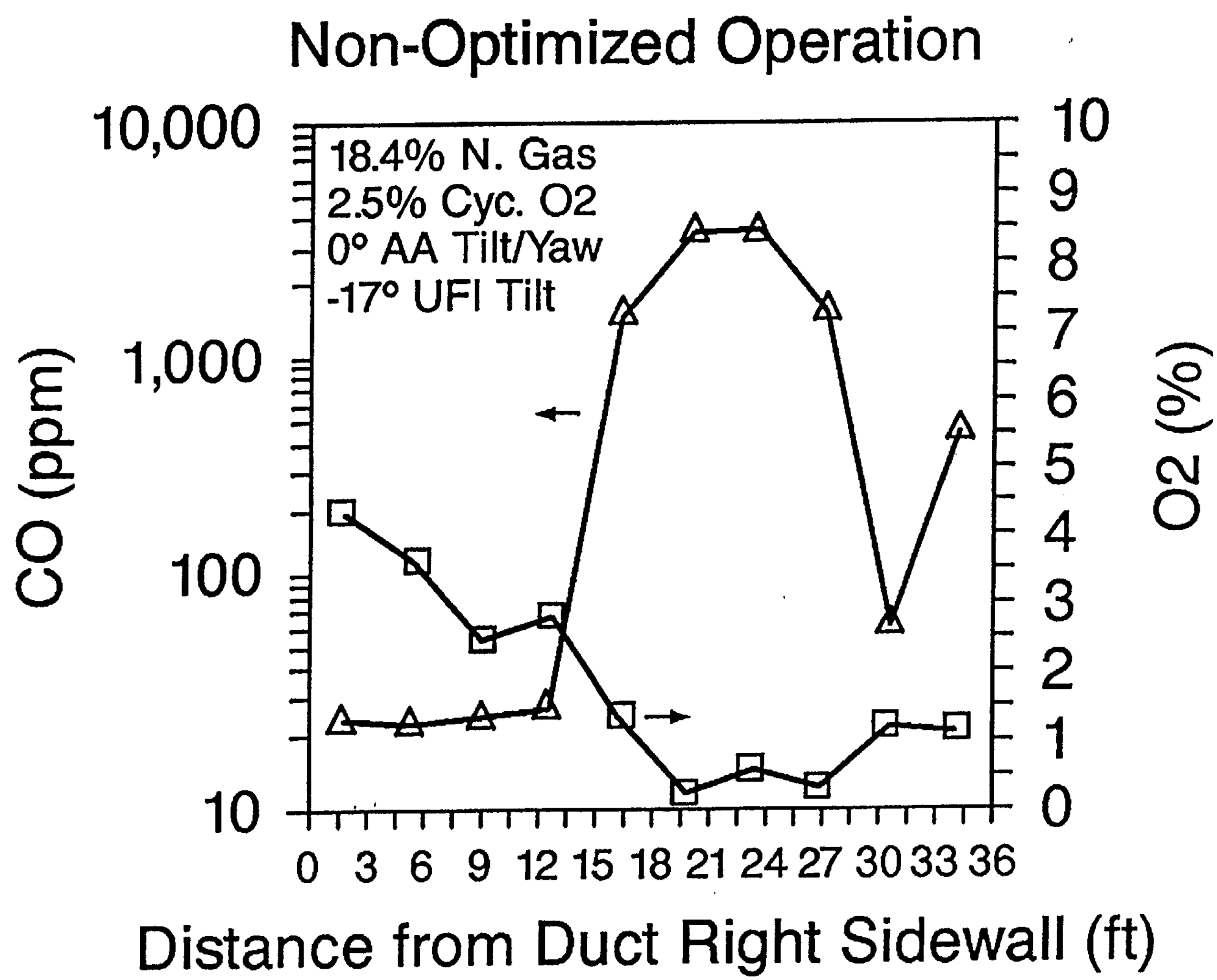

O2 and CO Versus Boiler Exit Duct Sample Location

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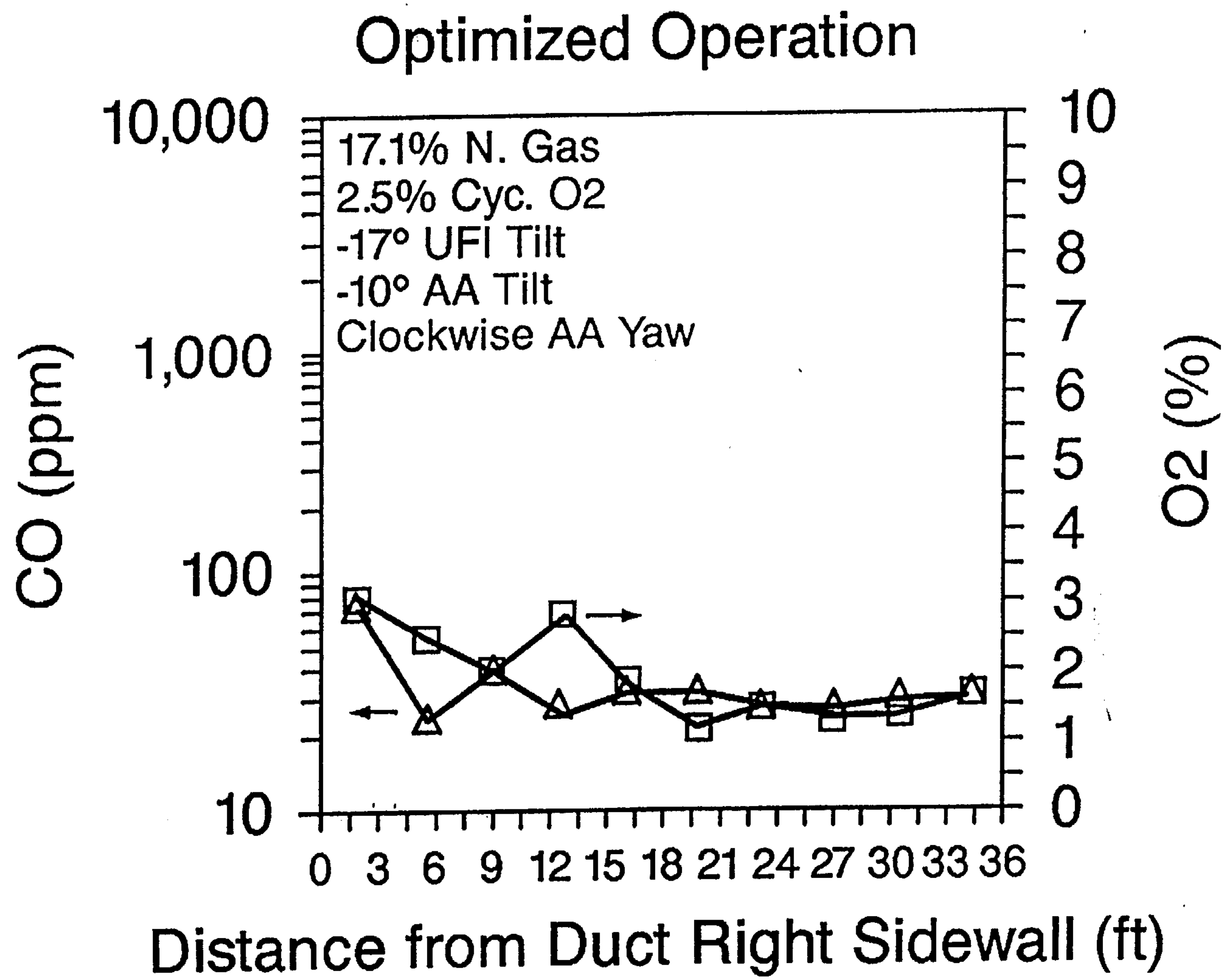

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Boiler Thermal Performance

- Changes Due to Reburning Caused By
  - Decreased Cyclone Load
  - Natural Gas Injected Into Secondary Furnace
  - Flue Gas Recirculation Injected with Natural Gas

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Boiler Performance Data (108 NWe)

	Baseline	Reburn
Fuel Type (%)		
Coal	100.0	82.8
Natural Gas	0.0	17.2
Excess Air (%)	15.0	14.2
Flue Gas Recirculation (%)	1.3	4.5
Flows (lb/hr)		
Main Steam	845,200	843,700
S.H. Attemp. Spray	10,260 (1.2%)	37,760 (4.5%)
R.H. Attemp. Spray	0	2,320

Boiler Performance Data (108 NWe)

	Baseline	Reburn
Temperatures (°F)		
Primary S.H. Outlet	736	758
Secondary S.H. Outlet	997	1,000
R.H. Outlet	988	1,000
Heat Absorption (10^6 Btu/hr-ft^2)		
Convective Sections	408.4	431.2
Waterwalls	590.3	563.0

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Boiler Efficiency

	Baseline	Reburn
Coal (%)	100.00	82.80
Natural Gas (%)	0.00	17.20
Heat Losses (%)		
Dry Gas Loss	2.70	2.66
Moisture from Fuel Loss	4.35	5.34
Ash Pit Loss	0.54	0.44
Carbon Loss	1.39	1.15
Remaining Losses	0.31	0.31
Total Losses %	9.29	9.90
Efficiency %	90.71	90.10

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Conclusions

- NO_x Reductions Ranged from 30 to 70%
- NO_x Reductions in 50 to 60% Range Possible with Acceptable Boiler Performance and CO Emissions
- Waterwall Heat Absorption Decreased by About 5%, Convective Pass Heat Absorption Increased by About 5% with Reburning

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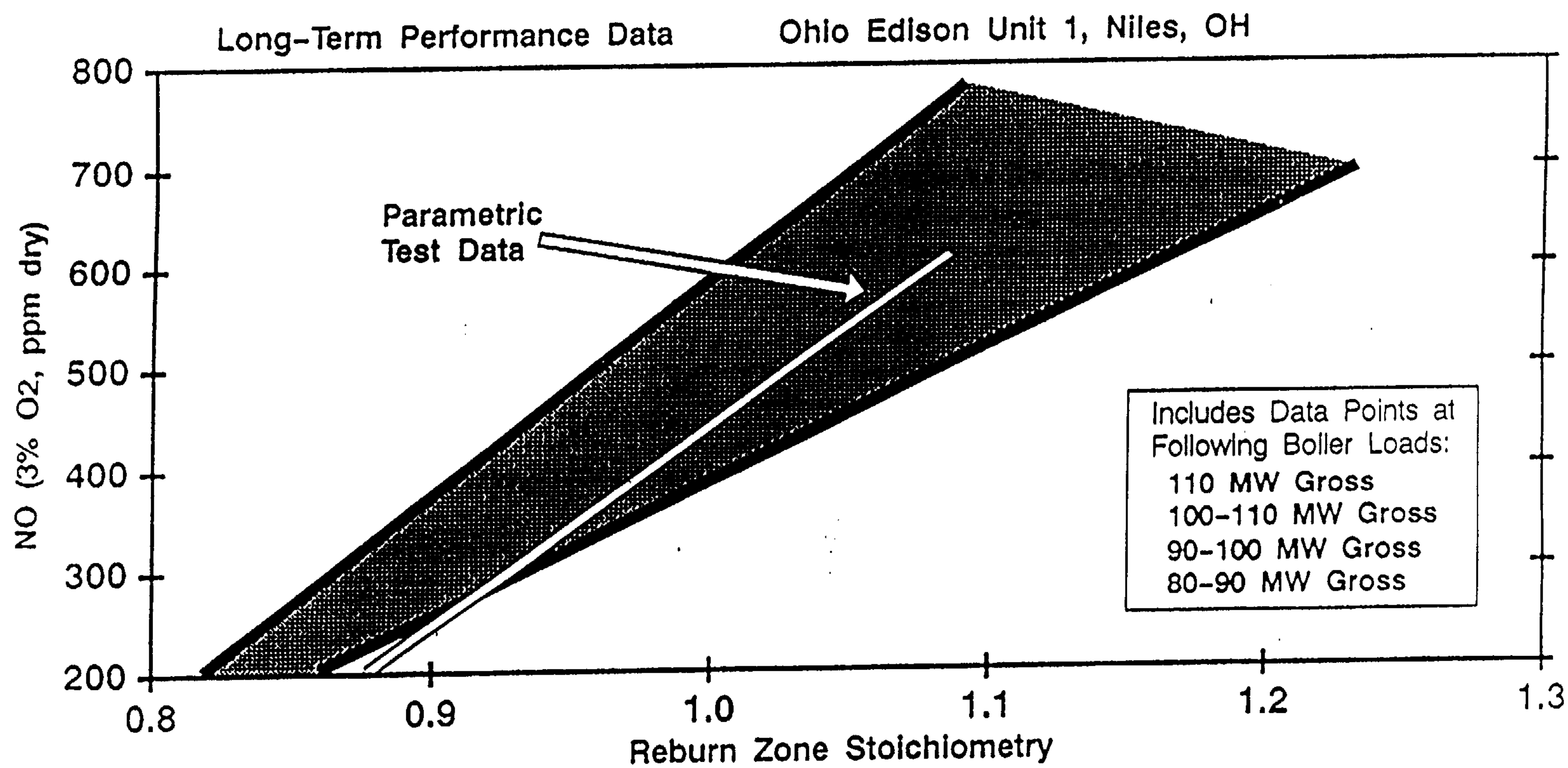
Conclusions

- Boiler Efficiency Decreased by About 0.6% with Reburning
- ESP Collection Decreased Slightly with Reburning; Outlet Dust Loadings Are Well Under Regulated Limit; No Optimization of Ammonia Injection
- Thicker Ash Deposits have Formed on Back Wall of Secondary Furnace Since Installation of Reburn System

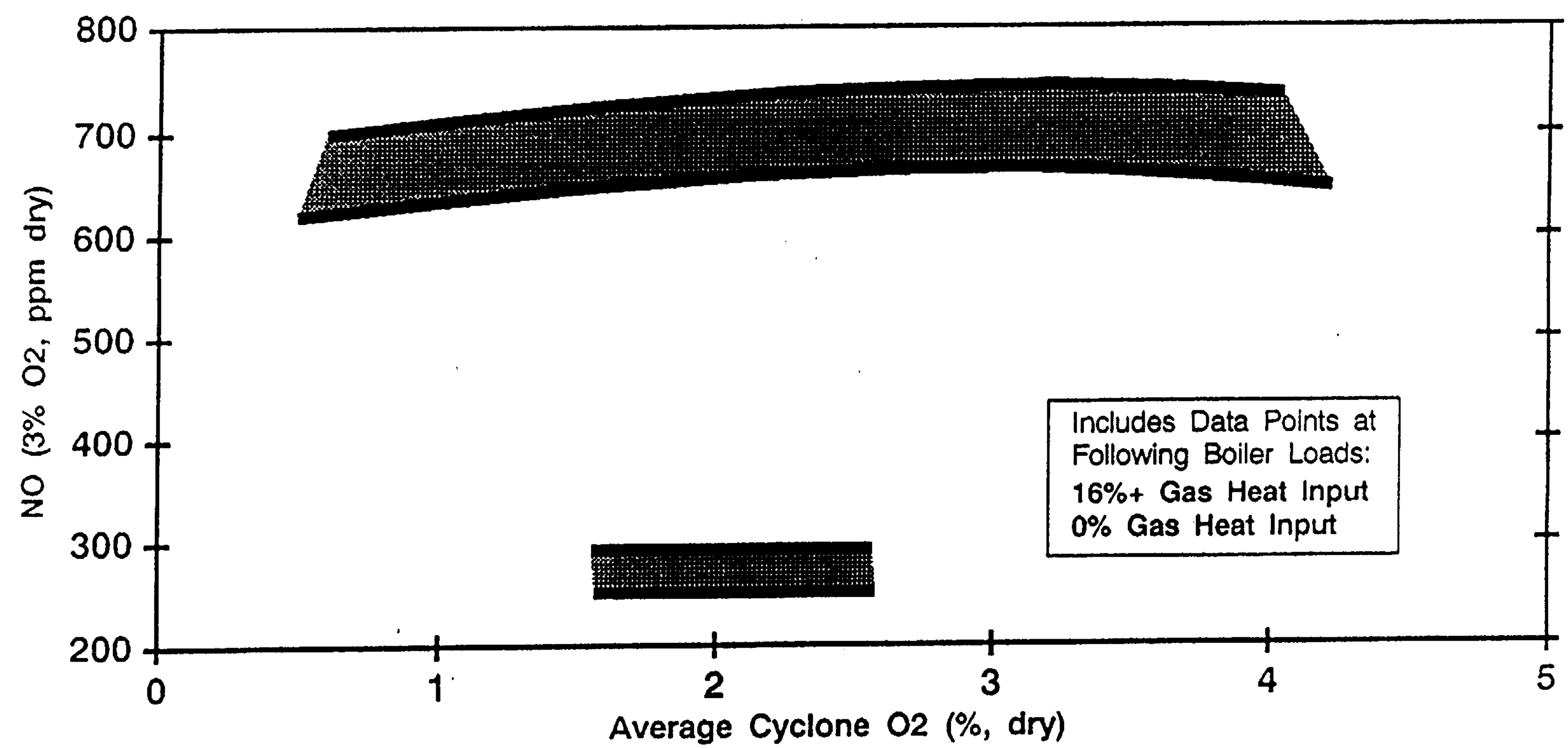
Advantages of Modified Reburn System

- Lower Capital Cost of Reburn System
- Less Space Required Because of Elimination of Gas Recirculation Fan and Associated Ductwork
- Shorter Outage Required to Install Reburn System
- Elimination of a Relatively High Maintenance Component, i.e., the Gas Recirculation Fan
- Because of Combination of Lower Cost and Ease of Installation the Modified Reburn System Could Now be Considered for Pulverized Coal Fired Boilers
- Less Shifting of Heat Absorption from Radiant to Convection Sections

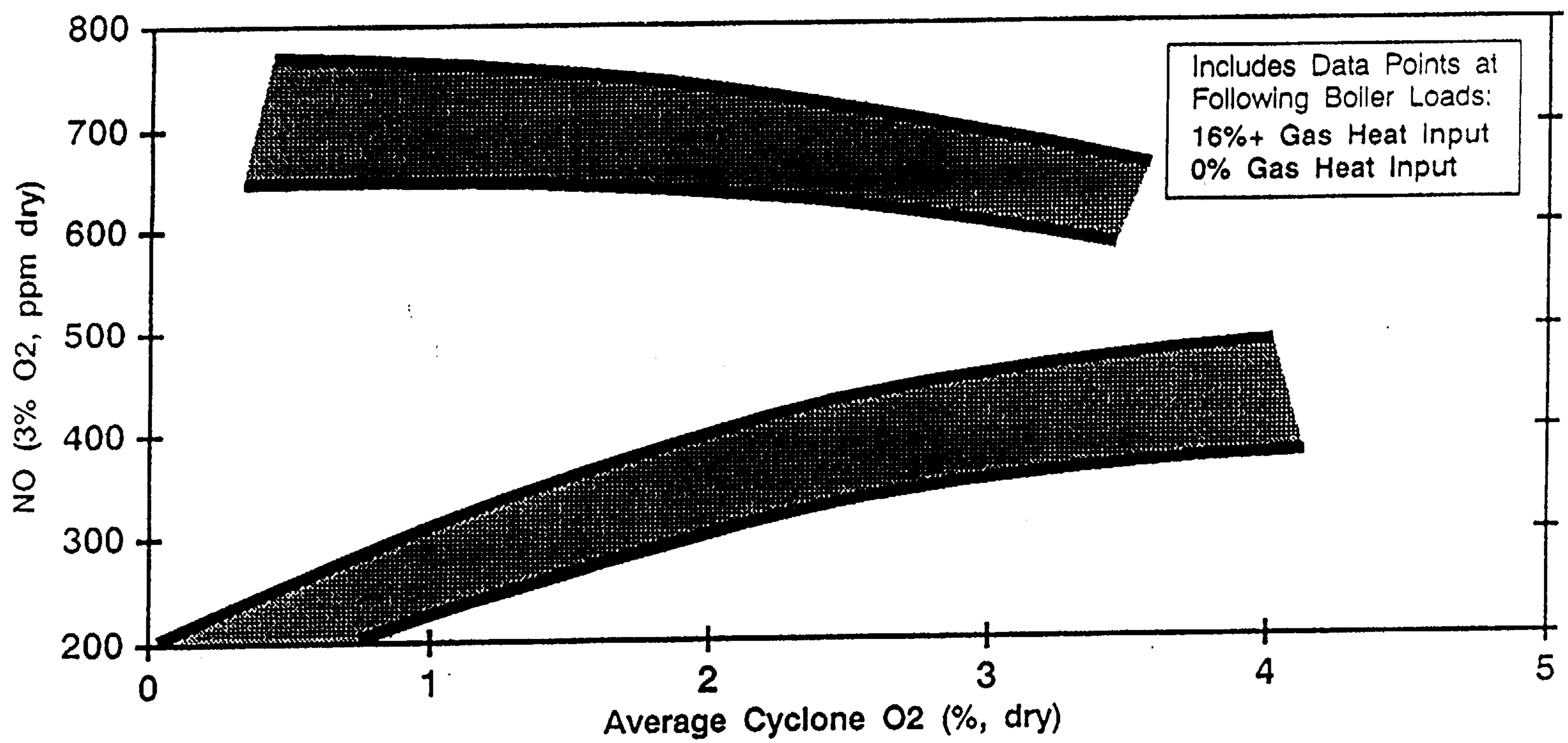
Variation of NO with Reburn Zone Stoichiometry
March 2–April 29, 1992 – (Preliminary)



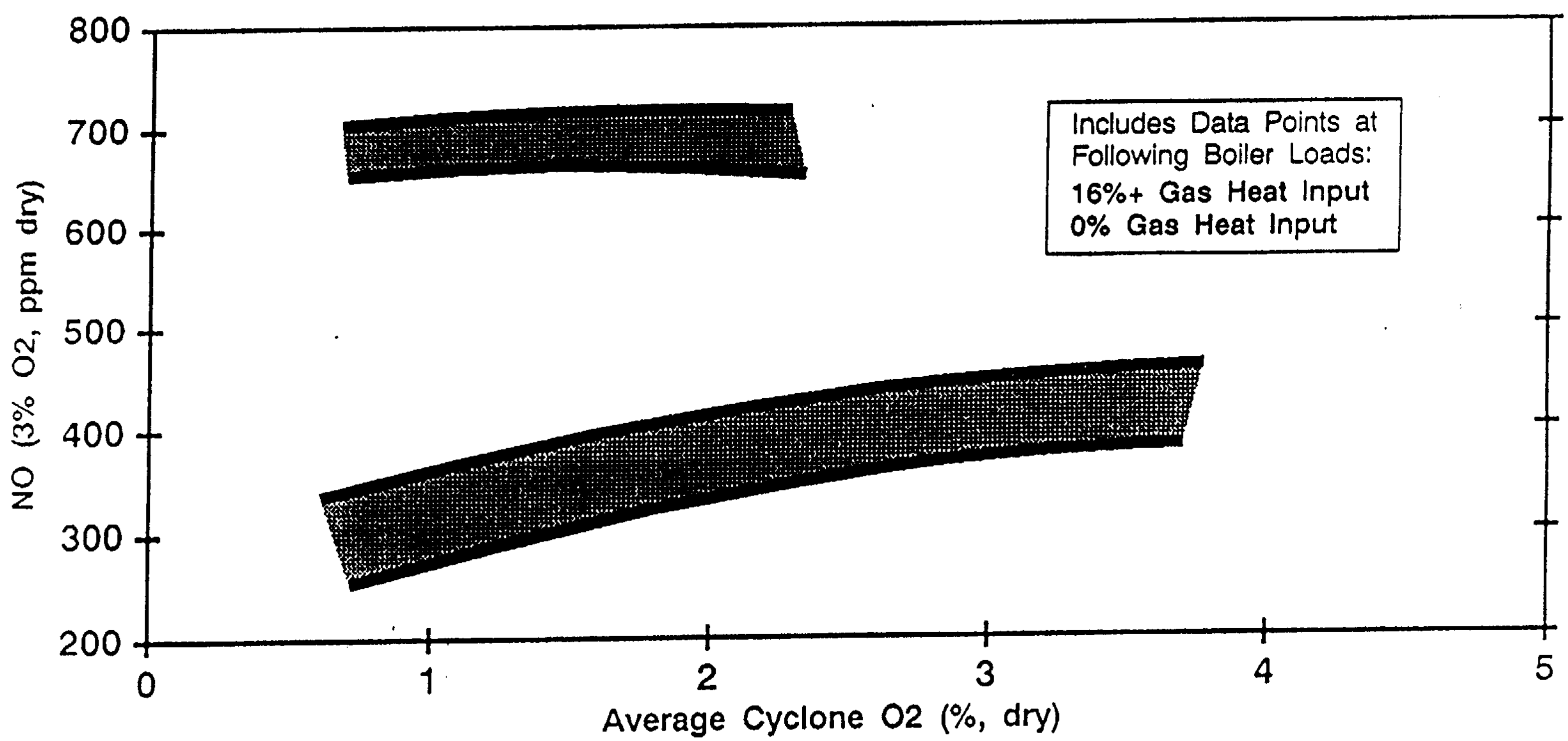
NO at 80-90 MW
Variation with % Gas Heat Input and Cyclone O2
March 2-April 24, 1992 - (Preliminary)



NO at 100-110 MW
Variation with % Gas Heat Input and Cyclone O2
March 2-April 24, 1992 - (Preliminary)



NO at 110+ MW
Variation with % Gas Heat Input and Cyclone O2
March 2–April 24, 1992 – (Preliminary)



Ohio Edison Reburn Program
Chronological Overview to Date

- Achieved 50–60 Percent NO_x Reduction During Parametric Testing of Original Reburn System with Acceptable Boiler Thermal Performance
- Noticed Thicker Buildup of Ash Deposits on Back Wall of Reburn Zone
- Determined That Recirculated Flue Gas Was Primary Cause of Thicker Ash Deposits
- Conducted Proof-of-Concept Tests Where Natural Gas Injected into Reburn Zone Without Recirculated Flue Gas — Results Positive

Ohio Edison Reburn Program
Chronological Overview to Date (Cont.)

- Modified Reburn System to Eliminate Need for Recirculated Flue Gas
- Noted That NO_x Reduction with Modified Reburn System Slightly Lower (5%) Than with Original Reburn System
- Attributed Slightly Lower NO_x Reduction with Modified System to Cracking/Soot Formation from Natural Gas When Flue Gas Eliminated
- Proof-of-Concept Test Showed That Water Injection with Natural Gas Significantly Improved NO_x Reduction (Potential for Further 15% Reduction)

Ohio Edison Reburn Program
Chronological Overview to Date (Cont.)

- Long-Term Operation of Present System Showing NO_x Reductions of About 50% at Full Boiler Loads

- Current Plans Are to Modify Reburn Fuel Injectors to Accommodate Water Injection by End of June '92 and Conduct Long-Term Testing During July '92 with Water Injection