AN OVERVIEW OF RILEY STOKER'S BURNER DEVELOPMENT EFFORTS FOR NO_X CONTROL

by

C. A. PENTERSON

Supervisor, Fuel Burning Product Development

RILEY STOKER CORPORATION

WORCESTER, MASSACHUSETTS

Presented to the

Committee on Power Generation

ASSOCIATION OF EDISON ILLUMINATING COMPANIES

San Francisco, California

APRIL 7, 1983

RST-23

RILEY STOKER

POST OFFICE BOX 547

WORCESTER, MASSACHUSETTS 01613

An Ashland Technology Company

AN OVERVIEW OF RILEY STOKER'S BURNER DEVELOPMENT EFFORTS FOR NO_X CONTROL

by

C. A. PENTERSON
Supervisor, Fuel Burning Product Development

RILEY STOKER CORPORATION
WORCESTER, MASSACHUSETTS

INTRODUCTION

In the 1970's, Riley Stoker Corporation manufactured two distinctive pulverized coal-fired boilers for the utility industry. These units were classified as wall-fired and TURBO® Furnace-fired boilers. The wall-fired boilers were equipped with swirl-stabilized, flare-type burners, while the TURBO Furnaces utilized axial-flow, directional flame burners.

While both boiler types were reliable steam generators, field testing did indicate the wall-fired boilers were producing NO_X emissions exceeding the 1971 Federal New Source Performance Standard of 300 ng/J or 512 PPM corrected to 3% O_2. At design operating conditions, NO_X typically averaged 800 PPM[1, 2]. However, by incorporating techniques such as differential burner firing, overfire air and flue gas recirculation, NO_X emission levels could be brought into compliance.

Conversely, the TURBO Furnace, with its long turbulent diffusion-type flames and characteristically long residence time, did produce inherently lower NO_X. Field testing indicated NO_X averaged somewhat below 500 PPM[3] at design conditions. Overfire air, underfire air and coal spreader redesign were techniques later used to further reduce this NO_X level.

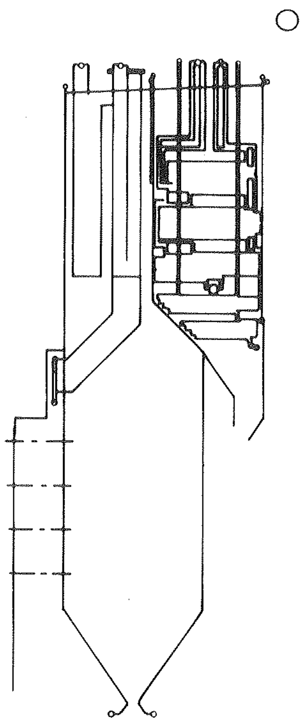
Figure 1 compares these furnace and burner designs and their respective NO_X emissions as a function of overall stoichiometry.

BURNER DEVELOPMENT

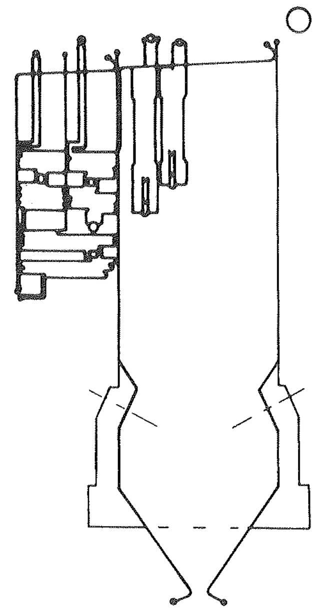
Wall-Fired Boilers

In early 1980, Riley Stoker initiated a program to reduce NO_X emissions from its pulverized coal, wall-fired steam generators. This development program was specifically directed at further NO_X reduction through burner redesign, independent of furnace geometry, porting and flue gas recirculation. The primary goal was to develop a low NO_X burner for existing as well as new wall-fired units.

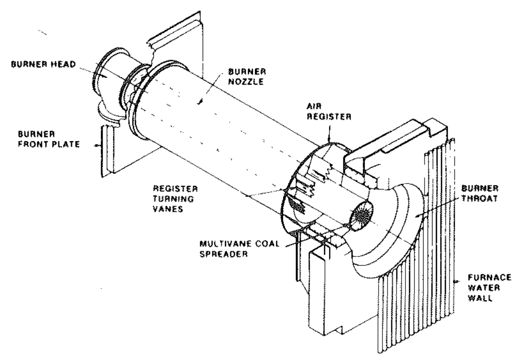
By the spring of 1981, Riley had completed extensive laboratory testing of the original flare-type burner



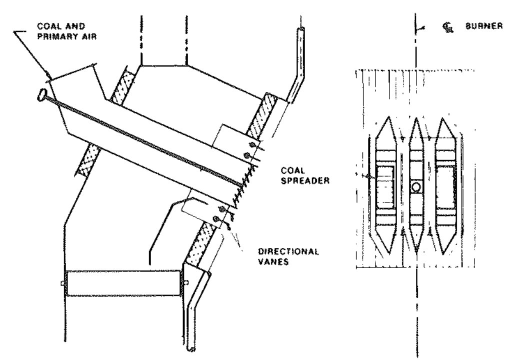
Wall-fired Boiler



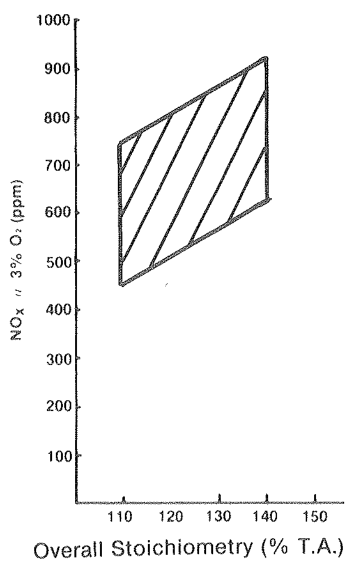
Dry Bottom TURBO Furnace



Flare-type Burner



Directional Flame Burner



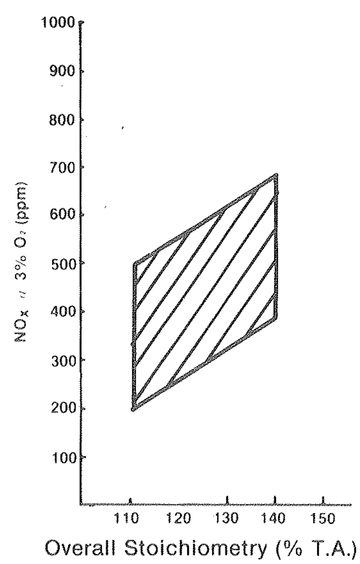


Figure 1 1970 NO_X Emissions

and several low NO_X burner configurations. The prototype burner testing was conducted in the Medium Tunnel Test Facility at Energy and Environmental Research Corporation in Irvine, California, from which the Riley Controlled Combustion Venturi (CCV) Burner was developed. This burner design, shown in Figure 2, consisted of the flare-type burner design modified with a venturi coal nozzle tip and a four-bladed conical coal spreader. As Figure 3 shows, NO_X emissions were reduced 50%[2] from the levels measured in the prototype flare burner. In addition, the flame shape changed from a short V-shape to a long tubular shape, indicative of the combustion characteristics necessary for low NO_X production. These flame shapes are compared in Figure 4.

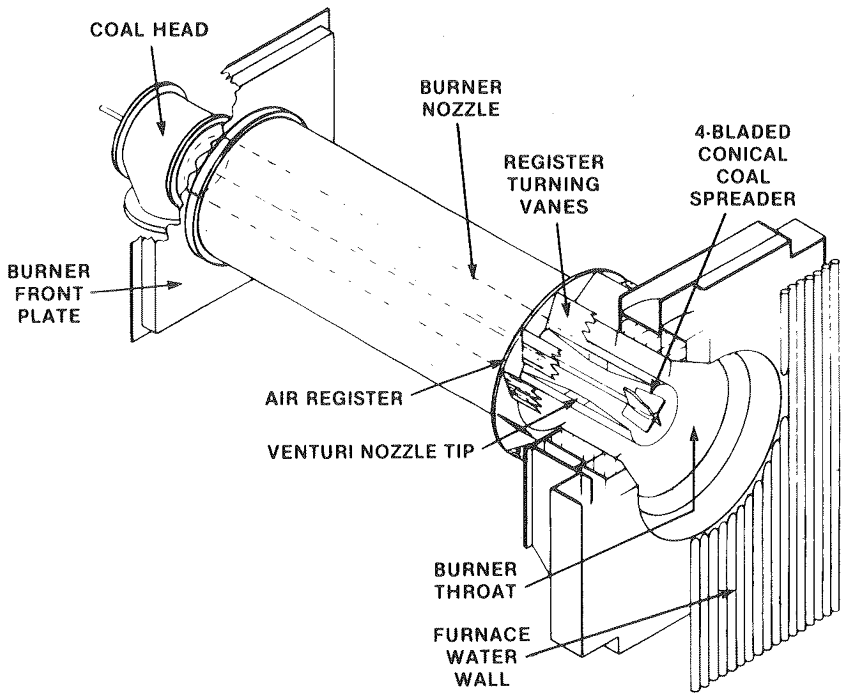


Figure 2 Controlled Combustion Venturi (CCV) Burner

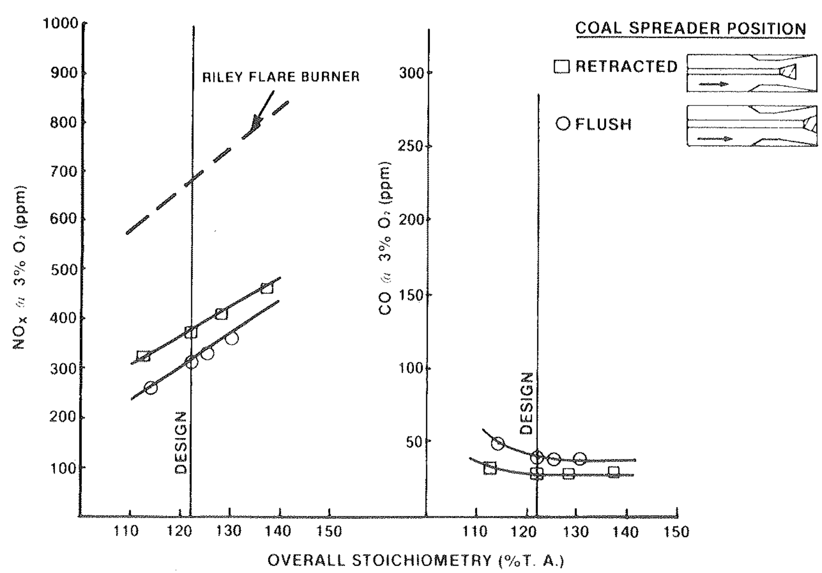


Figure 3 Laboratory Test Results - Controlled Combustion Venturi Burner

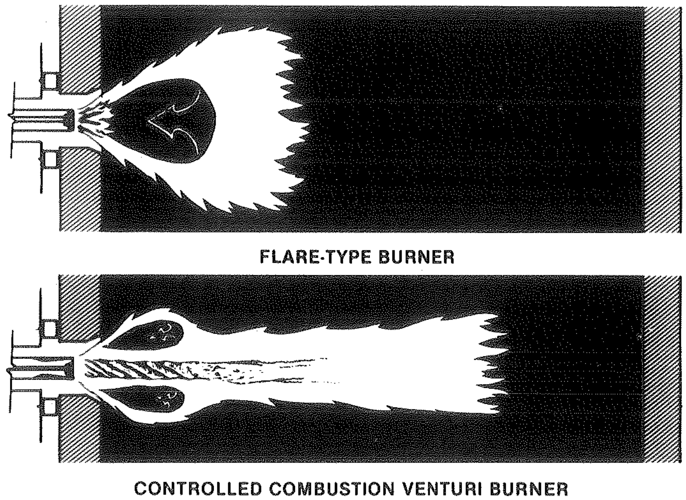


Figure 4 Typical Flame Shapes

Later that summer and fall, two wall-fired Riley boilers, equipped with original flare-type burners, were retrofitted with the new Riley CCV Burner. The first unit chosen, one which had been used previously to collect baseline test data, was at Central Illinois Light Company's (CILCO) Duck Creek Station, Unit #1. This unit, shown in Figure 5, is a 400 MW boiler with twenty-four burners mounted on the front wall.

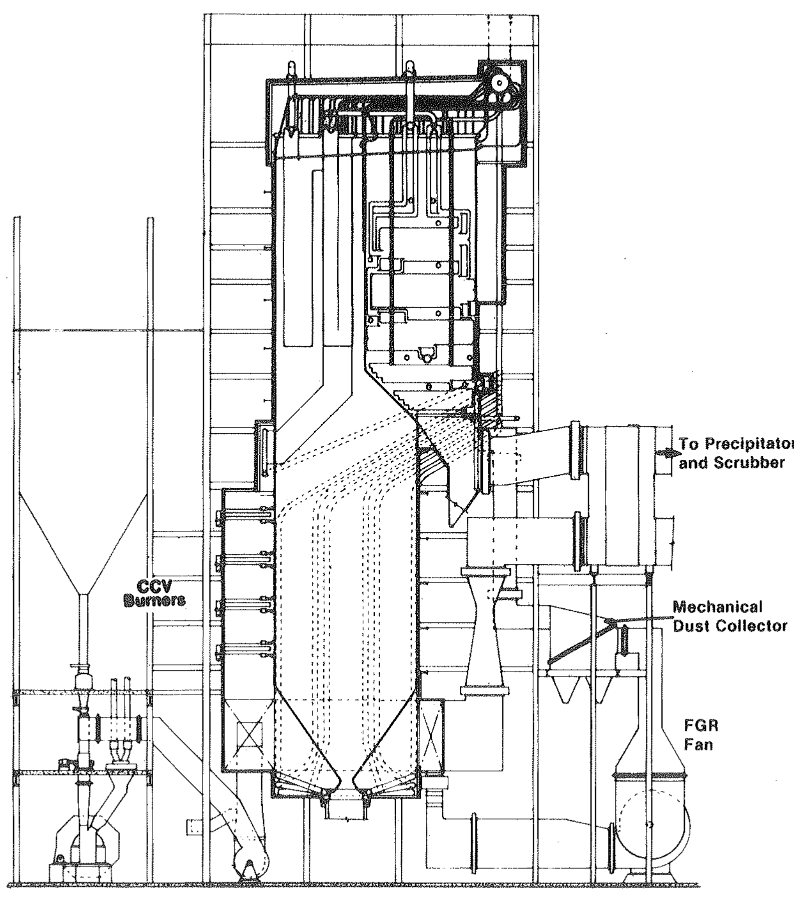


Figure 5 CILCO, Duck Creek Unit No. 1

Figure 6 compares the NO_X and CO emissions measured between the CCV and original flare-type burners. At design stoichiometry of 122%, we achieved a 55% reduction in NO_X with acceptable CO emissions. Superheat and reheat steam temperatures as well as overall boiler efficiency showed no significant changes.

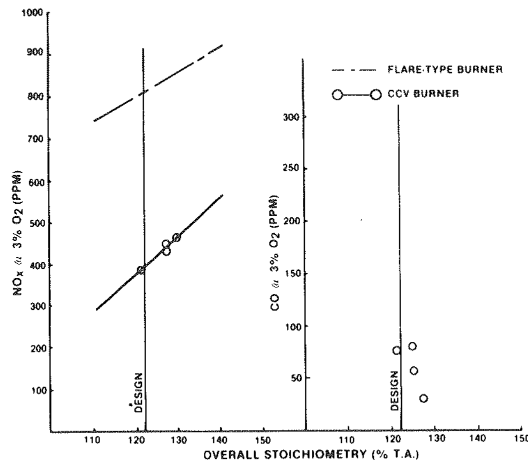


Figure 6 Field Test Results at CILCO, Duck Creek Unit No. 1

CCV Burners were also retrofitted at Carolina Power and Light Company's (CP&L) Roxboro Units 4A and 4B, a 700 MW twin boiler, single turbine installation shown in Figure 7. Twenty-four CCV Burners, mounted on the front and rear waterwalls of each unit, were installed to replace the original flare-type burner equipment.

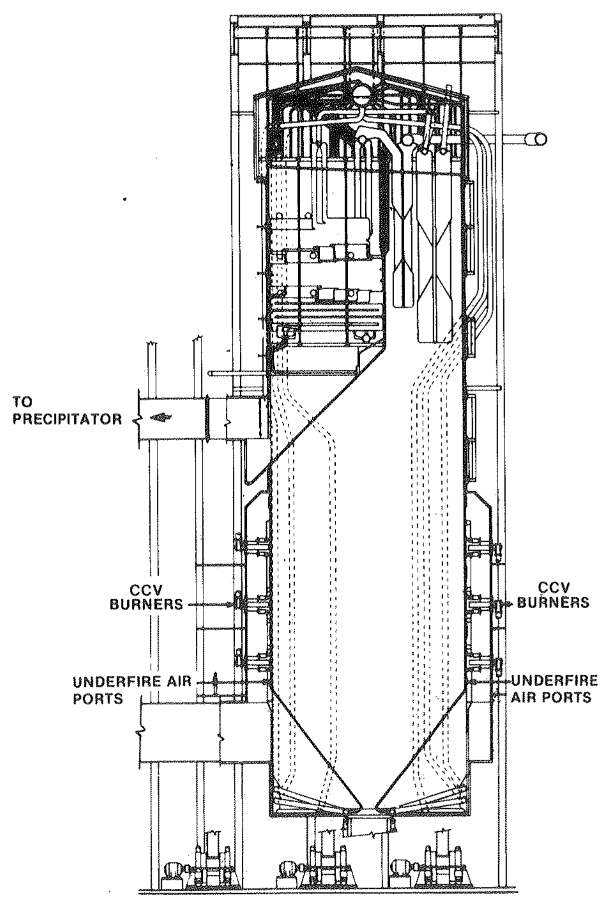


Figure 7 CP&L, Roxboro Units 4A and 4B

Subsequent field test results from both units showed a 56% reduction in NO_X, with acceptable unit performance. Figure 8 illustrates the NO_X and CO emissions recorded for both the CCV and original flare-type burners. Again, superheat and reheat steam temperatures along with overall boiler efficiency did not appreciably change.

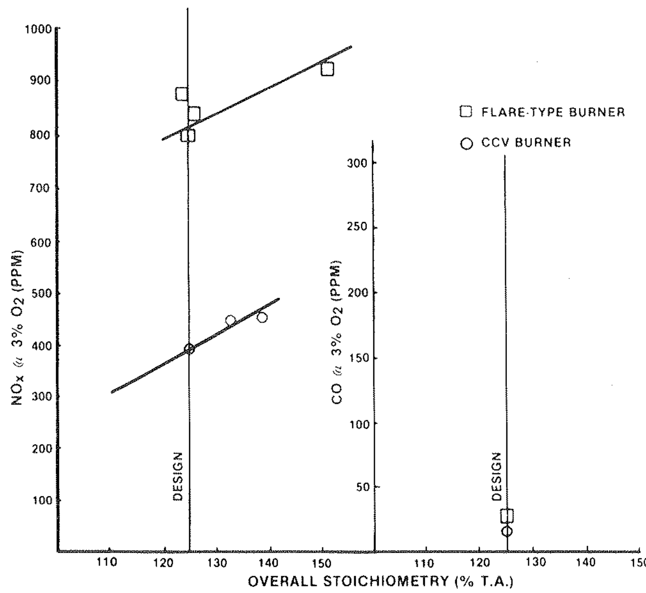


Figure 8 Field Test Results at CP&L Roxboro Units 4A and 4B

TURBO Furnace Boilers

Advanced burner designs are currently under study at Riley for application to the TURBO Furnace. The goal is to achieve NO_X emission levels of 90 ng/J or 150 PPM corrected to 3% O_2 with reliable boiler operation. Two advanced burner designs shown in Figure 9, which incorporate knowledge obtained from our

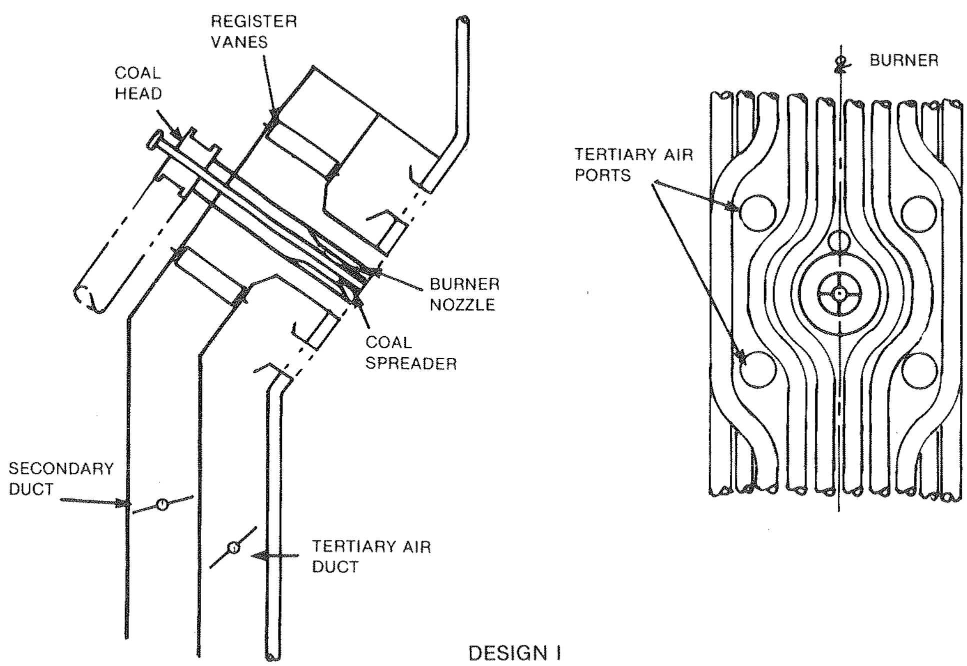
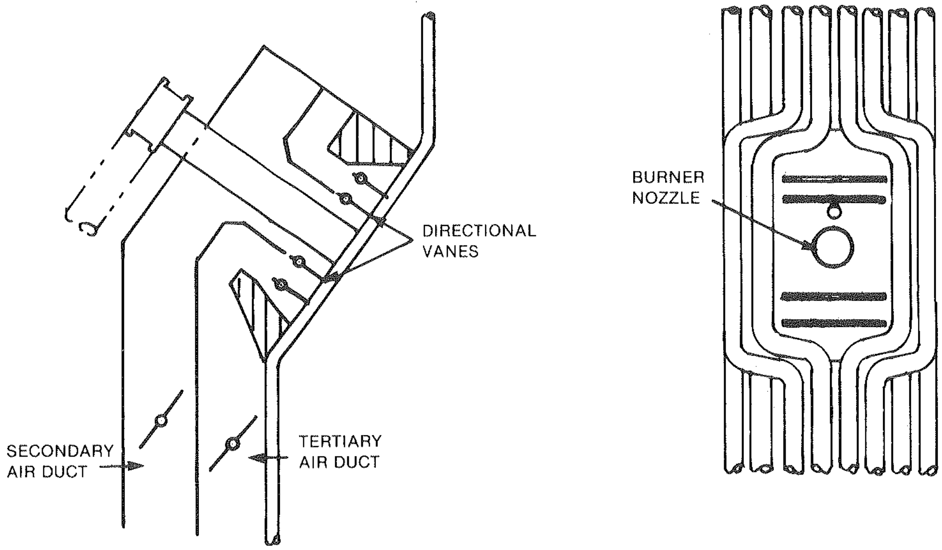


Figure 9 Advanced Burner Designs



DESIGN II

Figure 9 Advanced Burner Designs (Continued)

previous burner development work, are being tested at the newly completed Coal Burning Test Facility at the Riley Research Center in Worcester. Similar to the CCV Burner, advanced Design I is swirl-stabilized, whereas Design II uses the mixing of axial flow streams like the directional flame burner. Through aerodynamic modeling and combustion testing[4], we expect to meet this NO_X goal with acceptable overall burner performance.

Riley Research is seen in Figure 10 while Figure 11 shows a flow schematic of the combustion test furnace in which we are testing the two advanced burner designs at 30 MW thermal (100 MBTU/HR) pulverized coal capacity.

Preliminary test results on advanced burner Design I have already demonstrated that NO_X emission levels of 150 PPM can be achieved. Combustion testing of Design II is currently underway.

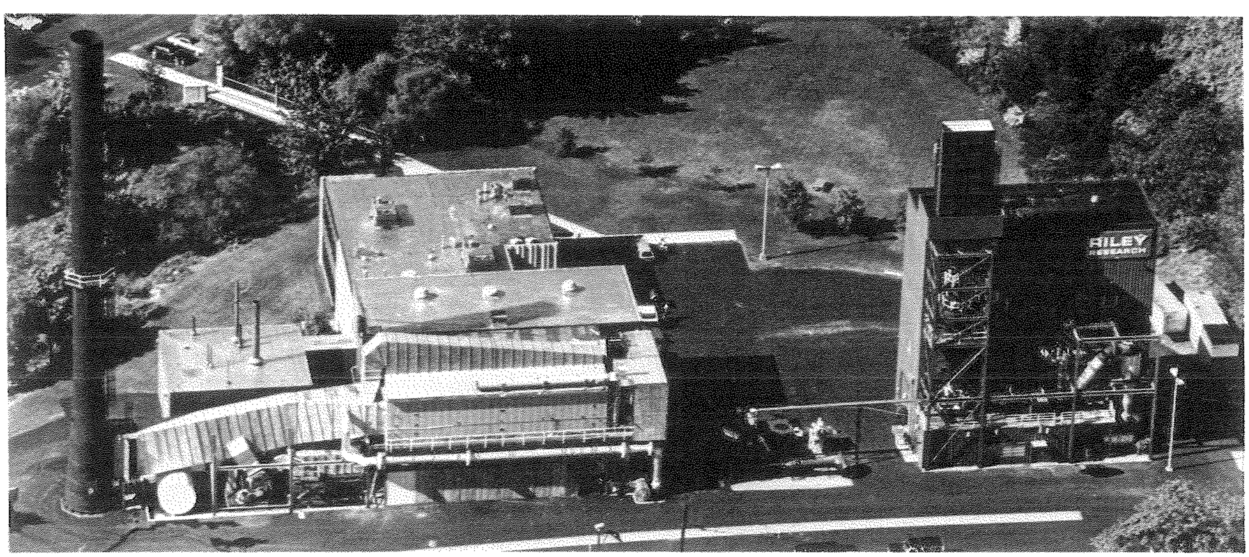


Figure 10 Riley Research Center

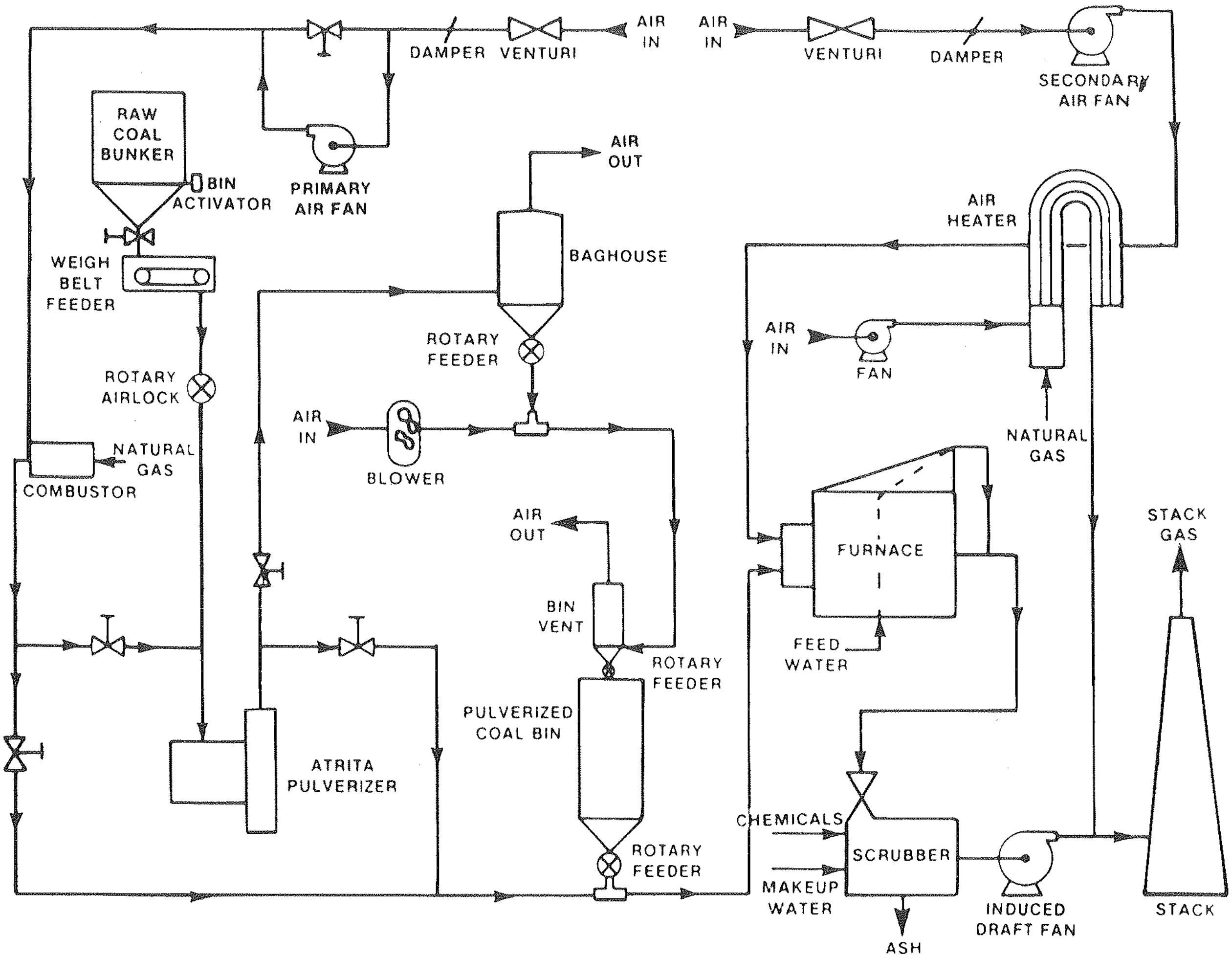


Figure 11 Coal Burning Test Facility Process Flow Diagram

FUTURE WORK

In addition to our current TURBO Furnace burner development effort, this year has also been allocated for conducting advanced fuel and air staging tests on the CCV burner. This pulverized coal testing will be performed at Riley Research under a retrofit low NO_X control development program sponsored by the Electric Power Research Institute[4]. The overall objective of this program is to develop an advanced retrofittable staged combustion system which will permit the operation of existing wall-fired boilers at NO_X emission rates of 75-220 PPM corrected to 3% O_2.

Riley Stoker is also currently engaged in an EPA program to test a 30 MW thermal (100 MBTU/HR) distributed mixing burner (DMB) in EPA's large watertube simulator located at Energy and Environmental Research Corporation, in Irvine, California[4]. The DMB design is similar to the Riley CCV burner with the exception of one additional air register and outboard tertiary air ports. Testing will include direct injection of sorbents for combined in-flame NO_X and SO_X control.

Riley has undertaken these development programs to offer the industry demonstrated fuel burning systems to meet our challenging environmental concerns. Through a combination of the Riley-funded work and the EPRI and EPA contracts mentioned earlier, conceptual ideas are being transformed into commercially available systems. The growing local and national interest in health and in acid rain issues will keep attention focused on lowering NO_X/SO_X emissions through controlled combustion techniques.

REFERENCES

1. Rawdon, A. H. and Johnson, S. A., "Application of NO_X Control Technology to Power Boilers," Proceedings of the American Power Conference, Vol. 35, pp. 828-837, May, 1973.
2. Penterson, C. A., "Development of an Economical Low NO_X Firing System for Coal-Fired Steam Generators," ASME Joint Power Conference, Paper No. 82-JPGC-Pwr-43, October, 1982.
3. Rawdon, A. H., Lisauskas, R. A. and Zone, F. J., "Design and Operation of Coal-Fired TURBO Furnaces for NO_X Control," presented at the Second EPRI NO_X Control Technology Seminar, Denver, CO, November, 1978.
4. Lisauskas, R. A. and Rawdon, A. H., "Status of NO_X Control for Riley Stoker Wall-Fired and TURBO Furnace Boilers," EPA/EPRI Joint Symposium on Stationary Combustion NO_X Control, Dallas, Texas, November, 1982.