A "TOTAL COMBUSTION SYSTEMS APPROACH" PROVES SUCCESSFUL FOR NOx CONTROL FOR TWO STEAM GENERATORS

by

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ABSTRACT

Emission reductions mandated by the Clean Air Act of 1990 will require a total combustion system approach to meet the new emission levels and maintain design steam generator performance.

Recent retrofit on a 35 year old 125 MW pulverized coal unit established a NO_x reduction of 50% using only Riley CCV burners. This reduction was possible by integrating the low NO_x burner design with an upgrade to the pulverization system. The system not only reduced NO_N, but reduced LOl, improved unit controllability, decreased opacity and improved unit heat rate.

The second example of integrating the total NO_x reduction system is on a 400,000 lb/hr industrial unit. Initially designed in 1982 to meet a NO_x of .45 lb/10^6 Btu, this unit utilized state of the art air staging system and low NO_S Riley TSV burners. When this combustion system design was recently tested the results were impressive. NO_x was 0.3 lb/10^6 Btu, on either of two bituminous coals, LOI was 3% and CO was below 25 ppm. Unit controllability and reliability remained excellent throughout the load range.

This type of performance can only be achieved utilizing a total combustion system approach.

INTRODUCTION

Recent amendments to the Clean Air Act have instigated a great deal of activity by utilities and large industrial users to lower NO_S emissions in power boilers. Original equipment manufacturers are thus implementing or developing new combustion technologies to meet the much more stringent NO_x emission requirements of the 1990's. In general, new boiler installations will be required to limit NO_x emissions to 0.3 lb/10^6 Btu. Existing boilers will be reuired to reduce their emissions to 0.5 lb/10" Btu when burning pulverized coal in a wall fired and 0.45 lb/10^6 Btu in a tangential fired application.

Riley Stoker involvement with developing low NO_x combustion systems has spanned the last 20 years. Work in the early 70's led to the establishment of our understanding of NO formation and reduction. Implementation of our first low NO_x system began in the 1970's with the Riley turbo furnace and directional flame burners. The 1980's saw the development of the Controlled Combustion Venturi (CCV) burners for wall fired units. During this time the Tertiary Staged Venturi (TSV) burner was developed to meet even lower NO_x emissions.

From these years of experience Riley has learned that it takes a total systematic approach to design low NO_x systems for new units or retrofits to comply with the more stringent requirements of the new Clean Air Act.

Combustion systems are designed to meet the thermal requirements of the steam generator. As such, they are auxiliary equipment to the final process of producing steam. If the cornbustion design or burner modifications result in poor boiler performance and operating difficulties, then that particular design is unacceptable.

It will take the knowledge and experience of suppliers that understand fuel processing, burner design, and furnace performance to effectively supply combustion systems that meet the required NO_x and other emission rates while at the same time maintain or improve overall unit performance.

This paper will discuss two applications of the integrated system approach to low NO_x emission combustion technology.

First is PSI Energy, Wabash Unit #5, a wall fired unit rated at 125 MW. The second is a 400,000 lb/hr industrial unit originally designed in 1982 to meet a NO_x value of .45 lb/10^6 Btu and recently tested to demonstrate further NO_x reduction capabilities.

DESCRIPTION OF THE LOW NO_x COMBUSTION SYSTEMS

A. PSI Energy's Wabash Unit #5 is a Riley Stoker pulverized coal fired steam generator with a rated capacity of 805,000 pounds of steam per hour, at a design pressure of 2075 psig and a final steam temperature of 1000°F superheat and 1000°F reheat with an operating throttle pressure of 1850 psig. Pulverized coal is supplied by three single ended ball tube mills feeding 12 burners. At this steam flow rate, the unit produces 125 megawatts of electrical power. (Ref. Figure 1.) This unit was commissioned in 1955 and has been successfully operated over the last 35 years.

During meetings with PSI, a mutually agreed upon set of goals was established.

- Improve wet coal grinding capacity, thus increasing boiler load
- Increase classifier exit temperature
- Improve burner mechanical reliability
- Reduce NO_x emissions
- Reduce unburned carbon

The consensus between PSI and Riley was that an engineered system approach was required to solving the existing problems on Unit #5. With poor fineness and low pulverized coal temperature it was clear that combustion and emission problems could not be resolved by burner replacement alone. It was necessary for the entire pulverizer system to be upgraded.

To address PSI's environmental concerns, Riley Engineering was convinced that combustion and emission problems could be solved by installing Riley Controlled Combustion Venturi (CCV-^{TM}) low NO_x coal burners with Model 90 registers. The new burners would address issues of mechanical reliability with the new register, and lowering NO_x emissions with Riley's patented CCV^{TM} coal nozzles.

During the initial review meeting it was quite evident a major factor in limiting reliability and capacity was wet coal. Focusing on wet coal, Riley's Engineering evaluated several alternatives and determined that increasing the wet coal handling capacity of the ball tube mill system would involve the following component changes or modifications. (Ref. Figure 2 & 3.)

1. Replace the original 503 duplex/feeder crushers with Riley 504 Model 80 shrouded crusher dryers. The 504 Model 80 is specifically designed to handle high moisture coals.

2. Replace the original bar type classifier and reinjection system with a Riley Model 80 centrifugal classifier and gravity return system.

3. Replace the existing two way riffle distributors with new riffles. The new riffles offers a uniform pulverized coal flow split from the exhauster discharge to each burner.

4. Install a primary air bypass system between the mill inlet and classifier. Adding the bypass increases the drying capacity of the system.

The burner operation at PSI Wabash #5 was less than optimal, and the problems in the coal milling system further aggravated the situation.

The status of the burner system was that pulverized coal/primary air mixture temperature was seldom above 110°F, flyash carbon loss ranged from 5-20% with a norm of 10-12%, NO_x emissions were not a current problem, but a future concern. Mechanically, the burner registers were difficult to operate, and flame appearance was poor. Windbox pressure was low, (≤ 1.0" H_2O) which lead to poor secondary air distribution and inefficient combustion.

Riley proposed a size 4A CCV^{TM} Burner with Model 90 register (Ref. Figure 4). The Model 90 register features separate swirl and air flow control. Burner swirl is controlled by an externally mounted register drive assembly. A moveable air shroud over the register blades controls the burner air flow, and each burner has Pitot tubes for measuring air flow. The register and secondary air barrel are connected by an expansion joint to allow for relative movement caused by varying boiler and windbox expansion rates. Control of secondary air flow to each burner is done by moving the shroud. Air flow measurement to each burner is read by a pitot and transducer that feeds the air flow signal back to the control system. By moving the shroud, air flow is balanced to each burner to match the coal flow from the mills. The shrouds are also used to maintain windbox pressure (set point 3") to assure efficient combustion throughout the load range by promoting good secondary air distribution.

The unique shroud design gives the capability of measuring the airflow to each burner in a common windbox thus assuring excellent secondary air distribution. Secondary air distribution is achieved throughout the load range by maintaining windbox to furnace pressure differential, and biasing individual burner shroud positions for burner pitot readings and mill load.

B. An advanced low NO_x combustion system was subsequently integrated into the design of a 400,000 pounds steam per hour industrial boiler. Figure 5 shows a front and side elevation view of the boiler #4 installation. Six (6) TSV burners rated at 85 x 10^6 Btu/hr are mounted on the furnace sidewalls with overfire air (OFA) above and underfire air (UFA) below each burner. Three (3) Riley Atrita pulverizers are used to process and convey pulverized coal to the burners. The unit produces superheated steam at 750°F and 630 psig operating pressure.

The advanced combustion system, developed by Riley Stoker in the early 1980's, focused not only on the low NO_x TSV burner design but integrating this burner with a unique furnace design that incorporates advanced air staging. The Riley Turbo-Furnace has been used for many years as an efficient way of burning a wide variety of coals and other fossil fuels because of its inherently longer retention time than more conventional wall fired installations (3).

The advanced air staging system integrated with the low NO_x TSV burner is shown in Figure 6. The TSV burner, shown in the right of the figure, is a circular shaped swirl stabilized burner. Pulverized coal is introduced into the furnace through a centrally located venturi shaped coal nozzle (Patent Numbers 4,479,442 and 4,517,904). The purpose of the venturi is to concentrate the coal air mixture and form a fuel rich combustion zone discharging from the center of the coal nozzle. As the rich mixture passes over the coal spreader, the blades divide the coal stream into four (4) distinct streams which enter the furnace in a gradual helical pattern. The intent is to produce more distributed, controlled and gradual mixing of the coal and air for reduced NO_x emissions.

Surrounding the primary air and coal mixture is swirling secondary air imparted by an air register for flame stability and combustion control. Tertiary air is introduced through outboard tertiary air ports surrounding the burner proper. Directional vanes within these ports can be used to direct the tertiary air into or away from the primary combustion zone as desired. The burner zone is designed to operate with only 60-75% of total combustion air.

The remainder of the air, required to complete the combustion process and to provide additional staging for NO_x control, is added through furnace staging ports located above and below the burners. Staged combustion combined with low NO_x burners has been proven to be a very effective technology for controlling NO_x emissions.

FIELD RESULTS

Results of PSI Wabash Unit #5 Firing System Upgrade

		Before	After	Comments
1.	Load	65 to 105 MW	95 MW	Exhauster Limited, 105 MW Was Only Possible on Dry Coal.
2.	Flyash Carbon Loss	5 to 20%	3%	Reduce Carbon Loss by an Average of 300%
3.	Mill Discharge Temp (Ave.)	107°F	137°F	Reduced Coal Line Surging and Sticking with 18% Moisture Coal
4.	NO_x	.8 to .9 lb/10^6 Btu	.4 to .5 lb/10^6 Btu	Represents a 50% Reduction in NO_x with Burners Only
5.	Pulverized Coal Fineness	<98% thru 50 Mesh <70% thru 200 Mesh	99.8% thru 50 Mesh 84% thru 200 Mesh	Classifiers are in the Wide Open Position. This is to Reduce System Pressure Drop. Fineness has not been Optimized.
6.	Windbox Pressure	≤ 1" H_2O	Controlled 3" H_2O	Stabilized Unit Operation
7.	Unit Operability	Poor	Good	Customer Pleased with Results. Unit Maintains Load During Wet Coal Conditions Without a Load Reduction.

Results of TSV Burner Testing

Testing began by measuring the same NO_x emission level that the unit was operating at six (6) years ago following boiler start up (0.45 lbs/10^6 Btu). Numerous tests were subsequently conducted to quantify emissions and carbon burnout efficiencies for various operating conditions and for two (2) different coals. Figure 3 shows the fuel analysis for the Oklahoma and Wyoming bituminous coals tested.

Figure 7 shows the effect of air staging on NO_x emissions at full load. Both the UFA and OFA ports were open with more staging air being introduced through the upper OFA ports. The NO_x emissions decreased from a high of 0.5 lbs/10^6 Btu to a low of 0.3 lbs/10^6 Btu for both coals. The NO_x emissions were higher for the Oklahoma coal as compared to the Wyoming coal at similar burner zone stoichiometries. This was due to the higher fuel nitrogen content for the Oklahoma coal. Lowest burner zone stoichiometries corresponding to the lowest NO_x emissions recorded were 0.86 and 0.925 for the Oklahoma and

Wyoming coals respectively. This level of air staging is still considered to be "conventional" as compared to "advanced" when stoichiometries approach 0.7.

CO emissions and carbon burnout were excellent throughout the range of burner stoichiometries tested. Figure 8 shows the impact of air staging on carbon burnout and CO emissions. Flyash % LOI results averaged < 4% while CO emissions remained < 15 ppm for both coals. Coal fineness produced by the three (3) Atrita pulverizers was a standard grind of 98% passing 50 mesh and 85% passing 200 mesh. Since the CO and LOI curves tend to increase slightly with decreasing NO_x emissions or burner zone stoichiometry it would appear that in order to achieve the same degree of excellent carbon burnout during extremely low NO_x operation (< 0.3 lb/10^6 Btu) on eastern bituminous coals with relatively high % fixed carbon/% volatile matter ratios, finer coal grind will most likely be required. A product fineness of > 99% passing 50 mesh and > 85% passing 200 mesh would be recommended.

As anticipated, rotating the directional air vanes in the tertiary air ports so that the tertiary air was directed into the primary combustion zone increased NO_x emissions by approximately 60 ppm from the levels produced with the directional vanes pointing away. Decreasing unit load from 100% to 75% MCR reduced NO_x emissions by approximately 25-50 ppm.

Overall boiler performance in regard to steam temperature, boiler efficiency, unit controllability and reliability were not adversely affected during the low NO_x operation.

CONCLUSIONS

These two units exemplify Riley's systematic approach of integrating 20 years of low NO_x technology into boiler design. It shows that when facing the need to reduce NO_x emission on existing or new units a total system approach is necessary. System design must take into account:

- Furnace Sizing
- Coal Properties
- Operational History
- Emission Levels Required
- System Flexibility
- Pulverizer Performance
- Coal Fineness
- Guarantees
- Future Emission Requirements

The examples discussed offered a range of low NO_x alternatives. They range from low NO_x burners capable of meeting .5 lb/10^6 Btu NO_x level to a system that provides advanced burner design with an air staging system of overfire air, and underfire air that can produce .3 lb/10^6 Btu NO_x on bituminous coal.

In order to meet and guarantee today's low NO_x emissions requirements, it takes an integrated systematic approach to design a system that is capable of low emissions and acceptable boiler performance.

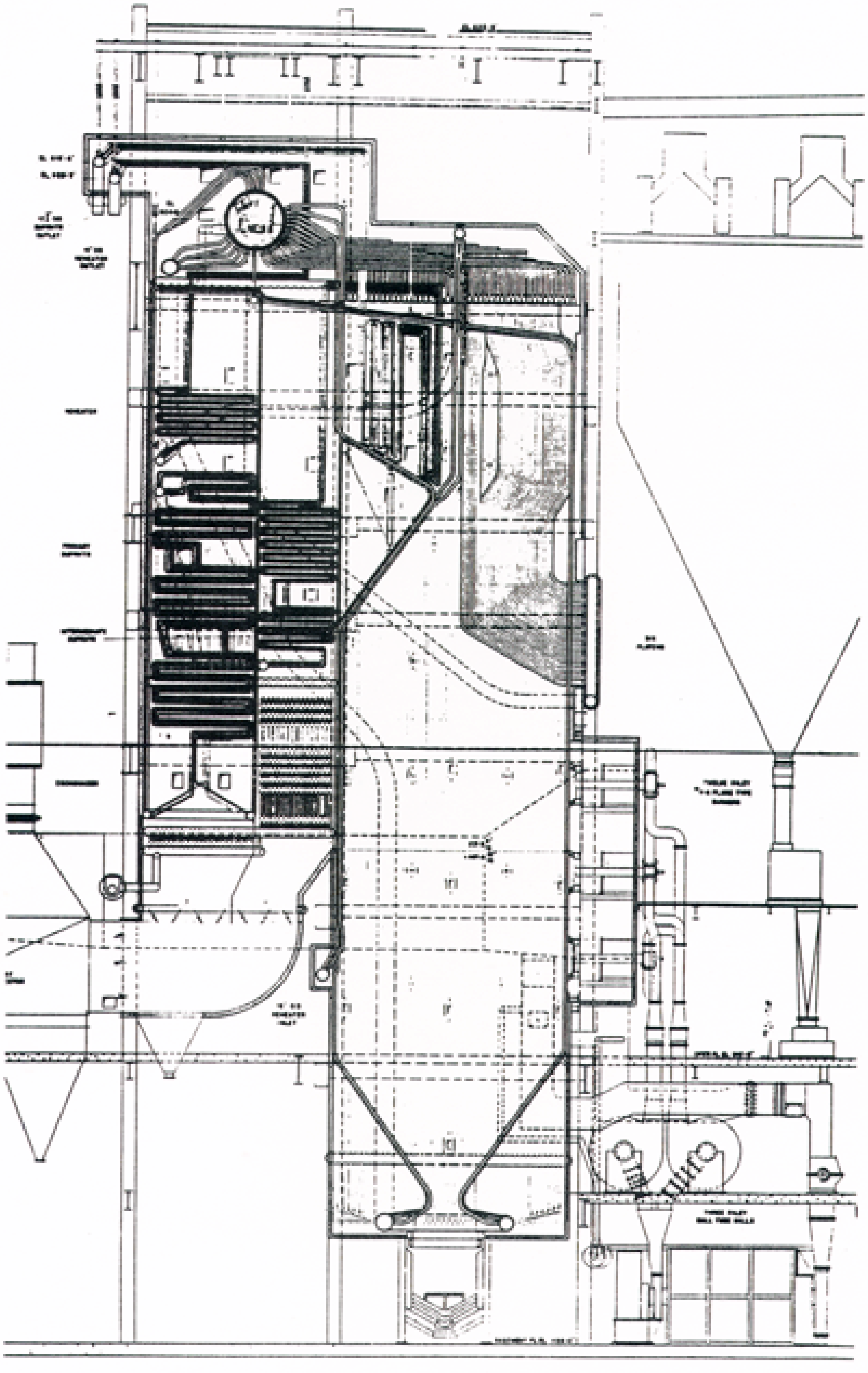


Figure 1. Wabash River Station

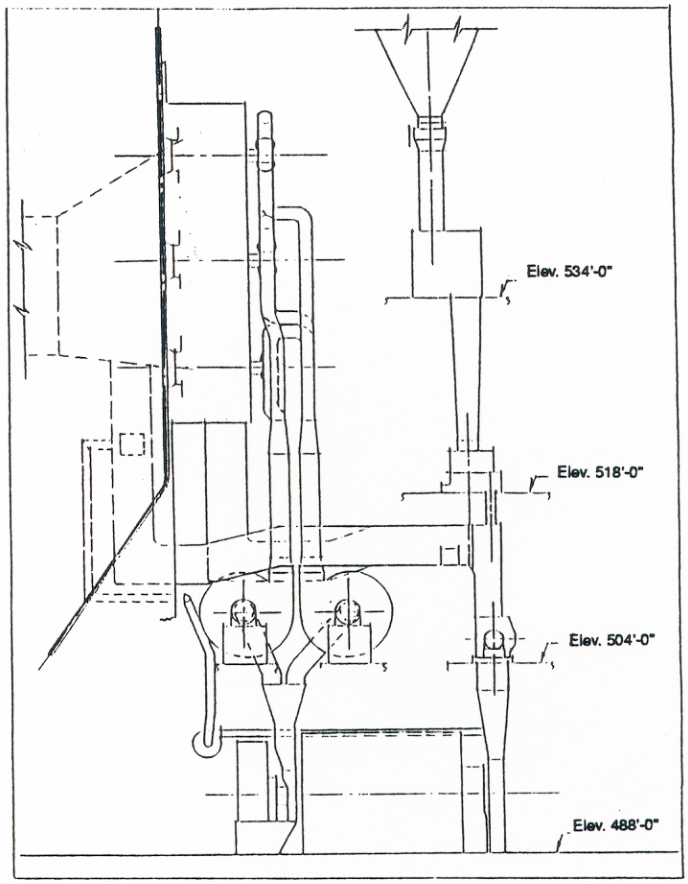


Figure 2 Original Fuel Burning System

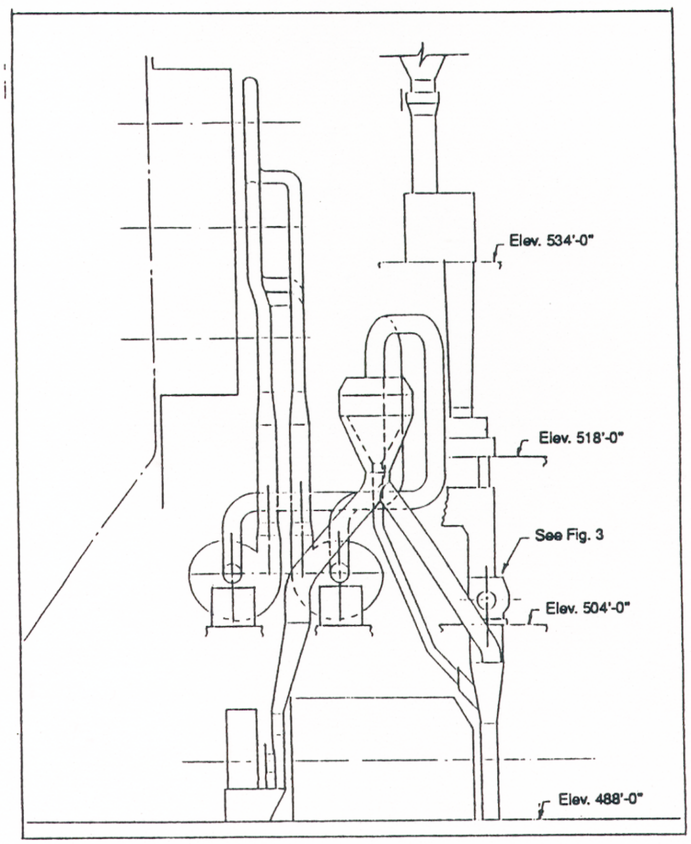


Figure 3 Up-Graded Fuel Burning System

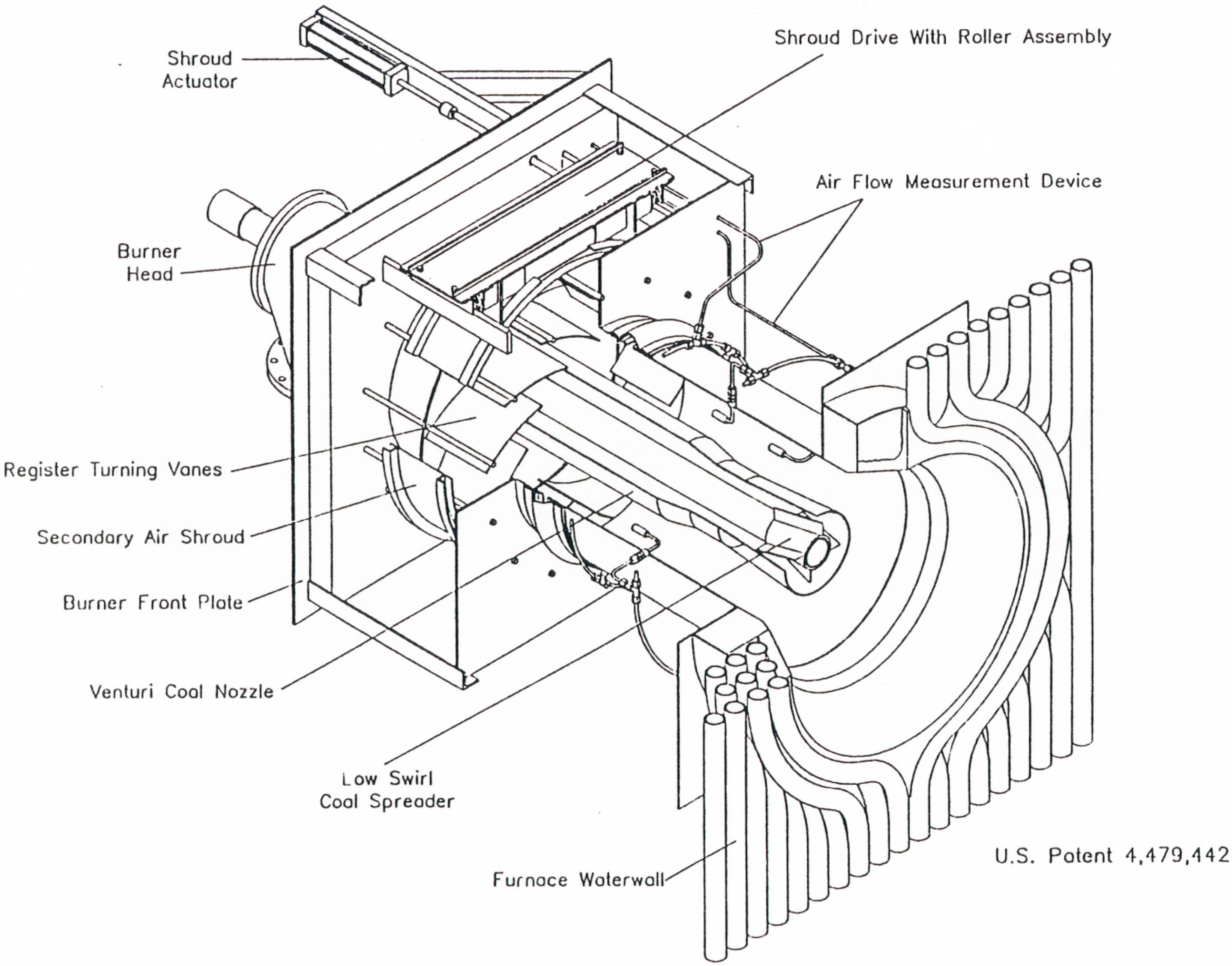


Figure 4 Riley Controlled Combustion Venturi (CCV) Burner for Wall Fired Boilers

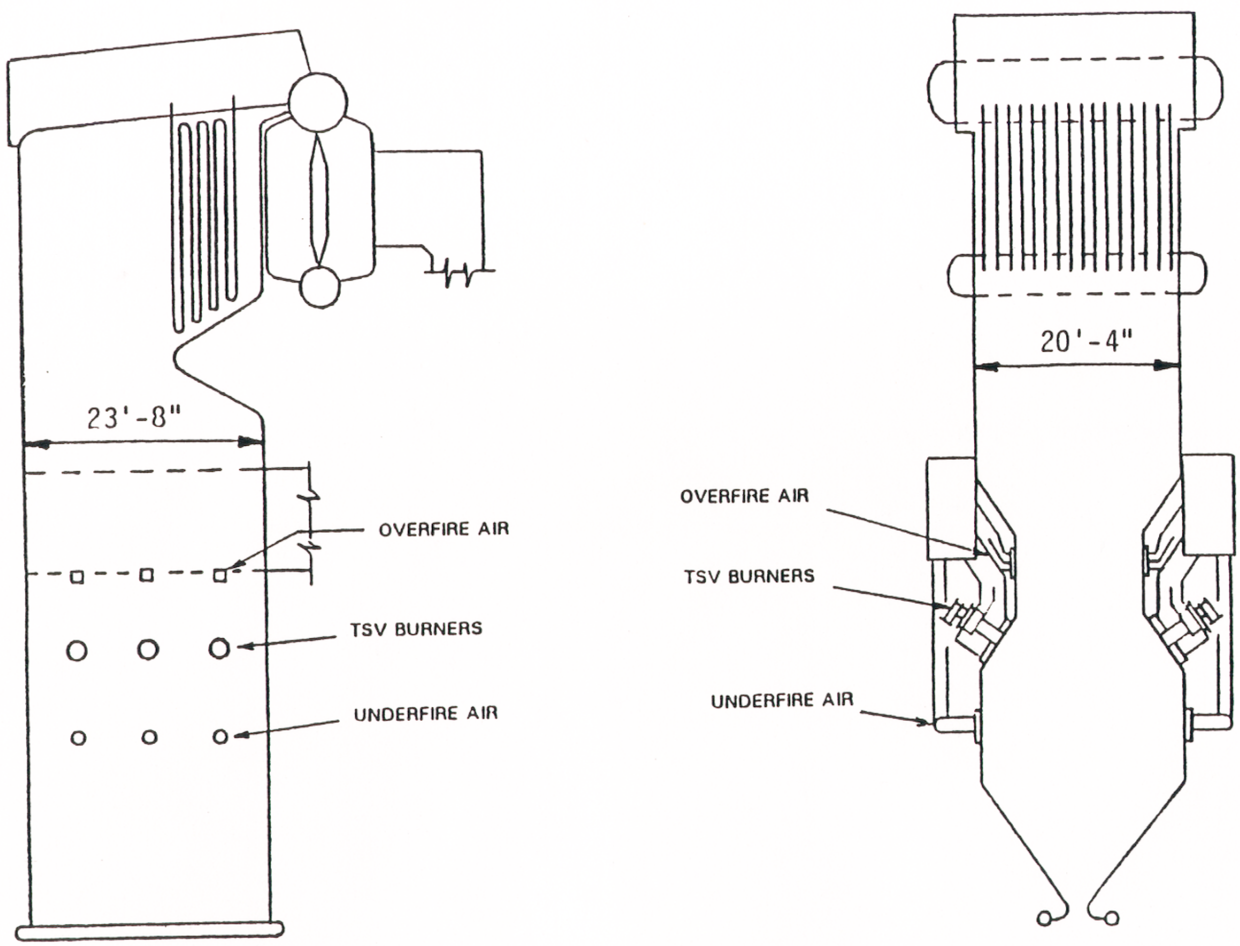
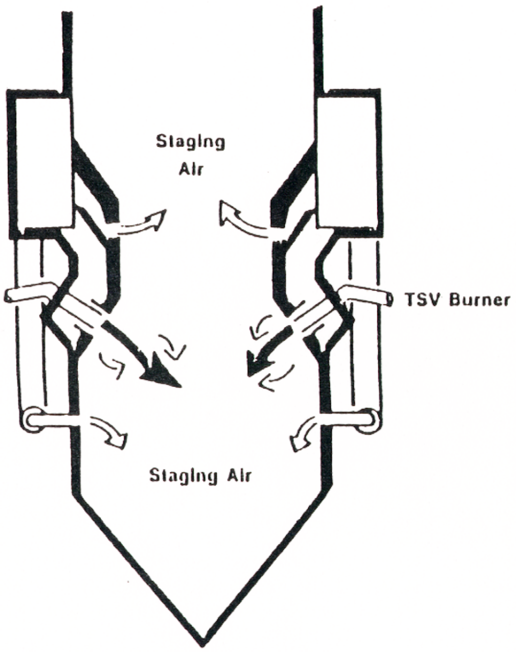
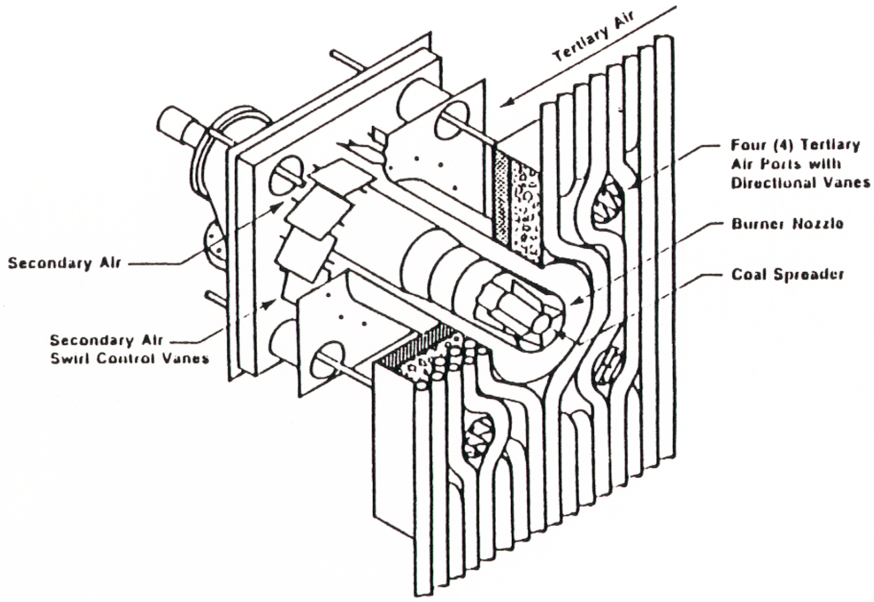


Figure 5. 400,000 lb/hr Unit



Advanced TURBO Furnace Staging System



TSV Burner

Figure 6. Riley Low NO_x TSV Burner and Turbo Furnace Staging System

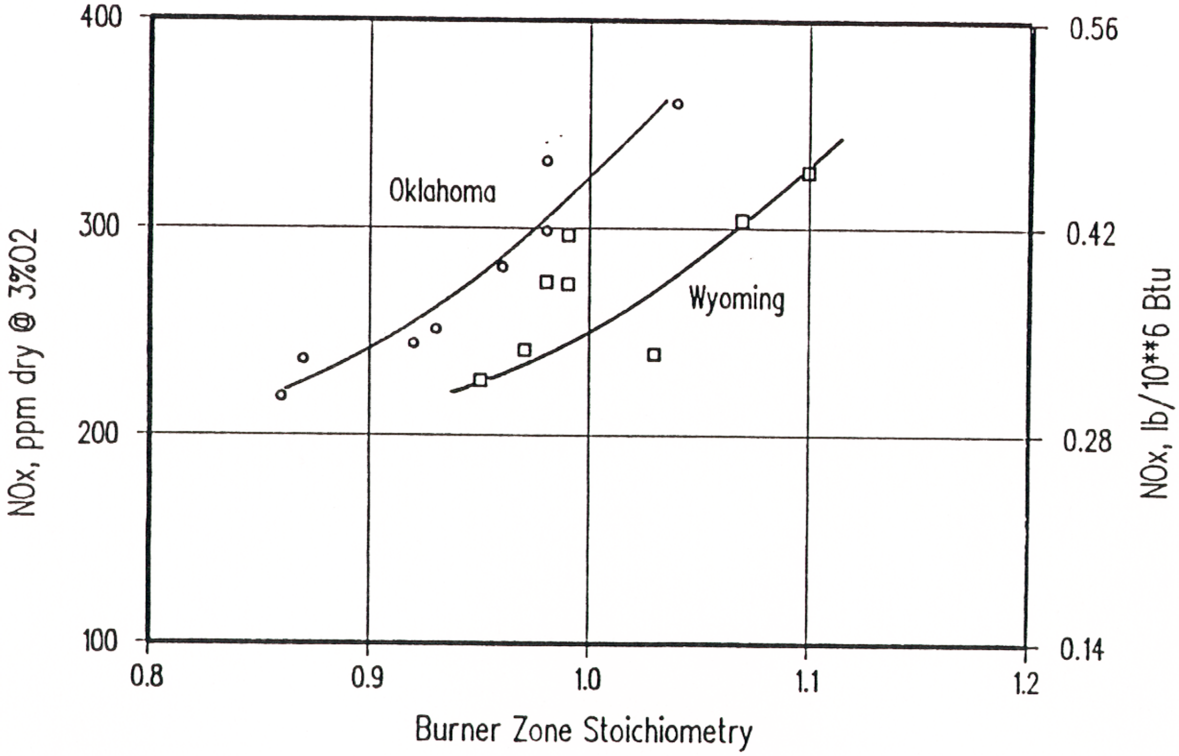


Figure 7. The Effect of Air Staging on NO_x Emissions

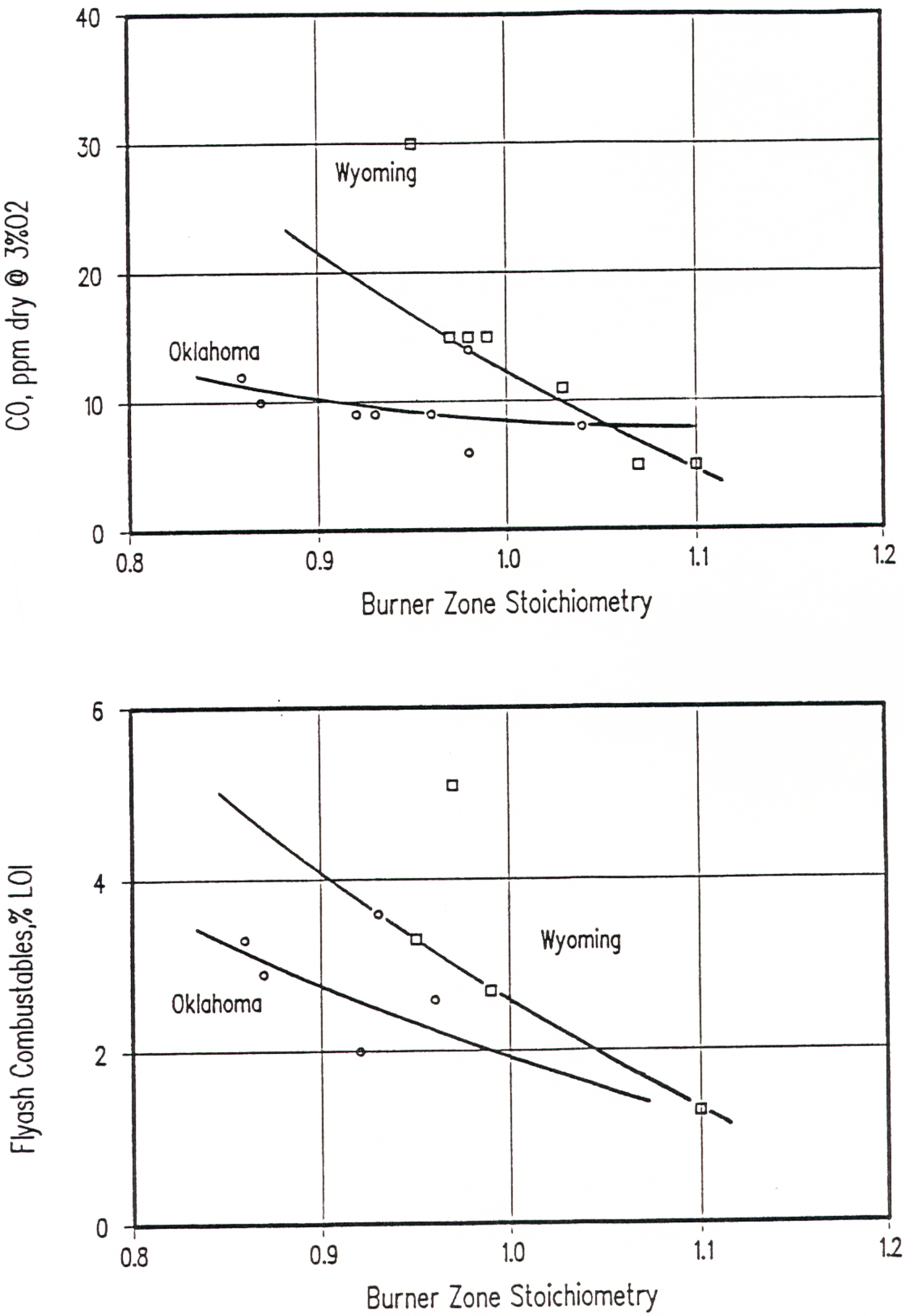


Figure 8. The Effect of Air Staging on CO Emissions and Carbon Burnout