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Technical Paper

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ABSTRACT

Babcock and Wilcox continues to expand its NOx control experience and technology along several fronts. The Dual Register Burner/Compartmented Windbox system is successfully performing on 35,200 megawatts of capacity in a wide range of coal/boiler applications. In addition, there are several new low NOx systems described in this paper. The Enhanced Ignition Dual Register Burner and the Hitachi-NR burners offer improvements for difficult-to-burn fuels and for further NOx reduction, respectively. In-Furnace NOx Reduction utilizes reburning technology to achieve extremely low NOx emissions for gas, oil, or PC and can be applied in new or retrofit situations. Also, the Low NOx Cell is being developed for direct retrofit for the unique cell burner design. Circulating fluidized beds with low NOx emissions are being sold for a variety of applications. Finally, Furnace Sorbent Injection combined with low NOx burners is providing a means of simultaneous NOx/SO_2 reduction for PC units.

INTRODUCTION

The U.S. utility market remains in a period of low growth and the timing of an upturn is uncertain. Meanwhile, life extension programs and reliability/availability improvements are being implemented at existing plants to forestall expenses of new units. Other alternatives to new, large PC-fired plants are cogeneration units and fluidized beds.

New regulations are expected to eventually mandate lower NOx emissions on existing units (acid rain legislation) and new units. The Environmental Protection Agency is reviewing New Source Performance Standards and may establish stricter federal standards for NOx emissions. Because of these issues, boiler manufacturers are developing technologies and equipment for reducing NOx emissions for new and retrofit applications.

This paper provides an overview of Babcock and Wilcox's contribution to the industry's need for low NOx combustion systems.

NEW UTILITY APPLICATIONS

The Dual Register Burner/Compartmented Windbox

The Dual Register Burner (DRB)/Compartmented Windbox system (Figures 1 and 2) continues as the mainstay of B&W's PC low NOx systems. Since its introduction in 1971 (1), this system has successfully met all applicable NOx emission limitations. These limitations have ranged from 0.7 to 0.45 lb NO/MBtu while actual emissions have ranged from 0.7 to 0.2 lb NO/MBtu. An additional 27 units representing 15,200 megawatts have been commissioned in the United States since the previous symposium (Dallas 1982). This brings the total U.S. operating experience to 61 units and 35,200 megawatts. Significant to this experience is the range of conditions now represented in the data base. The smallest of the units (65 MW) is single wall-fired with three pulverizers and six burners. The largest units (1300 MW series) have 14 MPS pulverizers and are opposed-fired with 98 burners. The coal used in these units ranges from low volatile, high ash bituminous, to low-grade Texas lignite (Table 1). These full-scale results are factored into computer-optimized empirical correlations which can more accurately predict emission performance. This will result in more precisely-designed furnace/combustion systems.

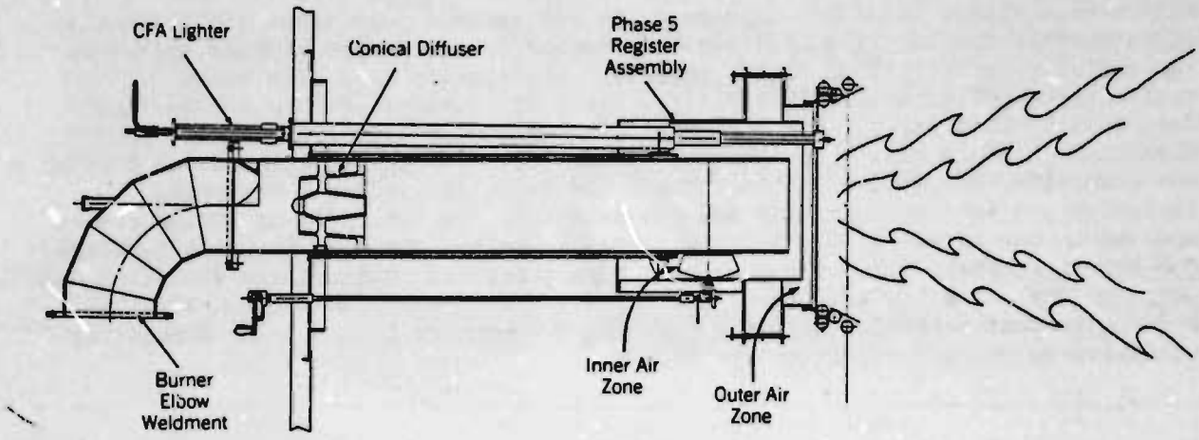


Figure 1. Phase 5 DRB

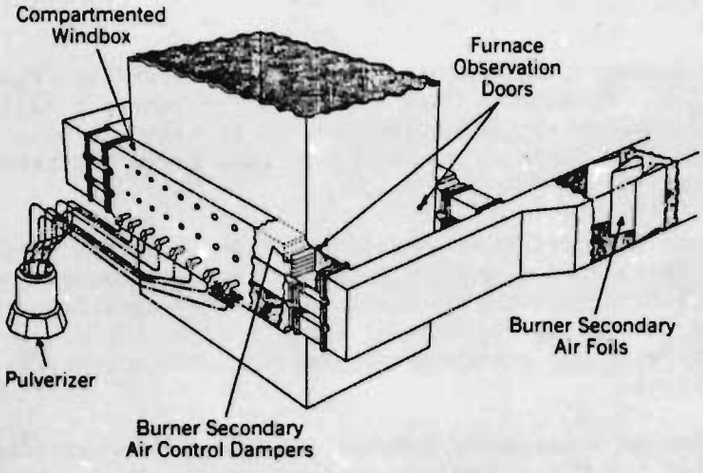


Figure 2. Pulverizer-Burner System

Table 1

COALS USED WITH DUAL REGISTER BURNERS

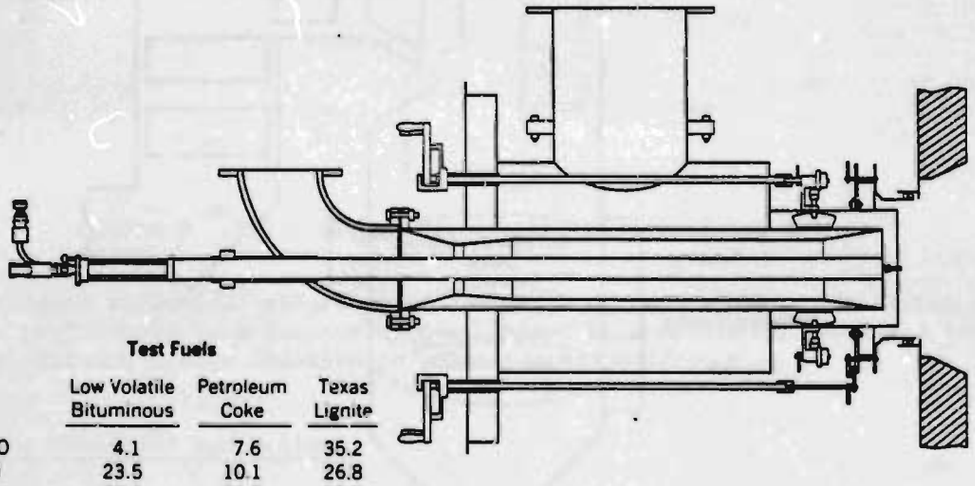
Fuel	Bituminous	Lignite	Bituminous	Subbituminous
Moisture	15.0	34.7	9.9	30.0
Volatile Matter	19.4	25.7	34.7	31.1
Fixed Carbon	30.6	20.7	40.0	33.6
Ash	35.0	18.9	15.4	5.3
Btu/lb	7150	5740	10850	8200

Enhanced Ignition - Dual Register Burner

Advancements to the above system are being driven by market requirements for higher standards of combustion performance with an even wider range of fuels. As a result, B&W has developed the Enhanced Ignition - Dual Register Burner (Figure 3) for low NOx performance with difficult-to-burn fuels (2). The international market, in particular, has coals which challenge the capability of low NOx burners to ignite, burn, and satisfy emissions. The Enhanced Ignition - Dual Register Burner (EI-DRB) accomplishes this by reduced burner nozzle velocity coupled with a dual register redesigned for increased swirl/recirculation. The EI-DRB has successfully burned petroleum coke and the other fuels listed in Figure 3 in a conventional, wall-fired, industrial furnace. The Texas lignite was successfully burned in a cool furnace with 90°F secondary air, without auxiliary fuel, after a five minute light-off period. NOx performance generally satisfied federal NSPS.

In-Furnace NOx Reduction

Lower NOx emission requirements are being encountered in some situations and are an eventuality for U.S. federal standards. Babcock and Wilcox recently licensed



Test Fuels

	Low Volatile Bituminous	Petroleum Coke	Texas Lignite
H_2O	4.1	7.6	35.2
VM	23.5	10.1	26.8
FC	62.6	81.7	26.3
Ash	9.8	0.6	11.7
Btu/lb	13,420	14,090	6,520

- Low nozzle velocity
- Increased swirl capability

Figure 3. Enhanced Ignition DRB

In-Furnace NOx Reduction (IFNR), a reburning technology, developed by Babcock-Hitachi K.K. and Tokyo Electric Power Company (3)(4). This technology has been applied commercially to oil- and gas-fired utility boilers in Japan. NOx emissions with IFNR are extremely low: 15 to 40 ppm on natural gas; 40 to 60 ppm on fuel oil; and 50 to 100 ppm on coal. The arrangement of the combustion system, depicted in Figure 4, is critical to performance. The main burners, of low NOx design, operate below 1.0 stoichiometry to minimize NOx emissions. The planetary burners operate at a much lower stoichiometry and generate hydrocarbon radicals that reduce NO generated in the lower furnace. Overfire air (OFA) ports are located above the planetary burners such that sufficient residence time is provided for the NOx reduction reactions. The adjustable OFA ports are designed to achieve rapid thorough mixing of the remaining theoretical air plus excess air to complete char reactions. The components are situated in compartmented windboxes to accurately control stoichiometry by zone. The IFNR system requires sufficient furnace height to provide the necessary residence times for the combustion zones.

Hitachi-NR Burner

Commercial application of IFNR in the U.S. may not be necessary for some time, although some utilities will be studying this prospect, in depth, together with B&W. However, the burner designs used in the IFNR system do have immediate application.

The Hitachi-NR burner (Figure 5) is the subject of a separate paper at this symposium. This modified DRB has demonstrated NOx reductions of over 50 percent on pulverized coal relative to the standard DRB and is in commercial use now in Japan on several boilers. The patented design acts to produce a pronounced, high-intensity, fuel-rich zone during the coal devolatilization. The tertiary air from the outer air zone then mixes and completes combustion in a flame no longer than that of a standard DRB. This burner will be tested in a major B&W program to

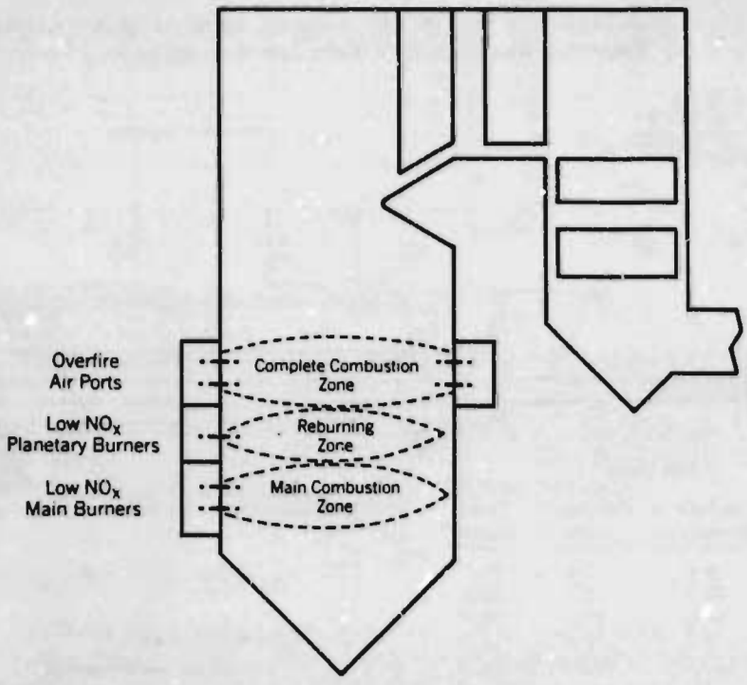


Figure 4. INFR System Arrangement

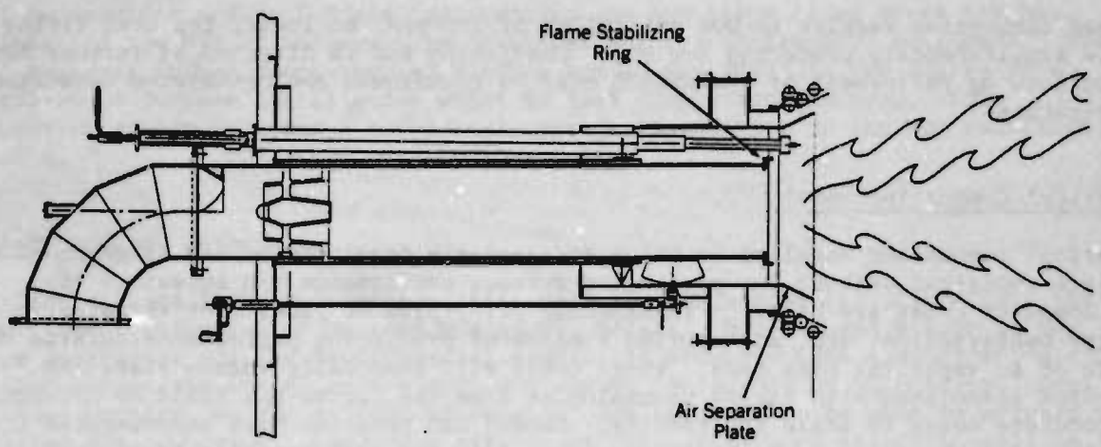


Figure 5. Hitachi-NR Burner

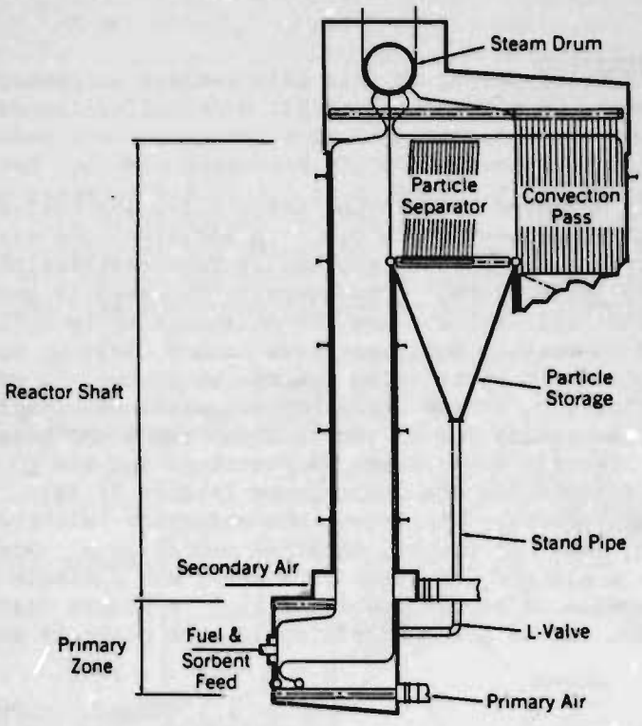


Figure 6. B&W/Studsvik Circulating Fluidized Bed Boiler

further enhance mechanical and functional aspects of the burner. The burner offers lower NOx performance in a furnace of given size, or conversely, permits a more economical furnace design relative to other burner designs.

Circulating Fluidized Bed Boilers

Circulating Fluidized Bed (CFB) boilers (Figure 6) are being utilized with a diversity of fuels for electric power generation and industrial purposes. B&W has joined with Studsvik Energiteknik of Sweden to offer a patented CFB boiler design. The CFB's combination of low combustion temperatures, typically 1450-1600°F, and

staged combustion results in NOx emisssions of 150 ppm, or lower, for coal firing while simultaneously producing low SO_2. Continuing R&D is directed at further NOx reductions by refinement of combustion staging techniques and optimizing combustion temperatures.

Numerical Combustion Model

Numerical combustion modeling is being aggressively developed by B&W as the tool to replace empirical methods for predicting furnace performance and emissions (5). The computer codes are based on fundamental principles of flow, heat transfer, energy conservation, etc. and provide a means of predicting performance outside the range of an empirical data base. These codes will eventually reduce risks and expenses associated with taking technologies from the lab to the field by providing an accurate means to scale the results. Recent R&D programs have demonstrated the ability of these codes to accurately predict flow and heat transfer in lab and utility furnaces. Incorporation of latest bench-scale information is now necessary to improve the predictions for species and emissions.

RETROFIT UTILITY APPLICATIONS

Low NOx Burners

Lower NOx emissions are mandated on existing gas-, oil-, and coal-fired utility boilers in non-compliance regions of the U.S. In addition, the east-central portions of the country are expected to eventually face restrictions on NOx emissions via acid rain legislation. Consequently, the need is growing for combustion equipment that will achieve low NOx emissions in retrofit applications. Some types of pre-NSPS combustion equipment have unique designs, which are not amenable to direct replacement by existing low NOx equipment. A prime example is the B&W cell burner, Figure 1, in use in 26,000 megawatts of capacity, primarily in the eastern U.S., and generating NOx at two to three times the present NSPS limit. These factors led the Electric Power Research Institute and B&W to cooperate in the development of a retrofitable low NOx cell burner (Figure 7) (6). Combustion tests at the 6 MBtu/hr scale produced a 65 percent NOx reduction relative to the standard cell burner, while achieving 0.2 percent unburned carbon loss. Scale-up combustion tests at 100 MBtu/hr are planned for later this year, and a single full-scale prototype is now in service at Dayton Power and Light's Stuart Station. A full-scale demonstration of the low NOx cell could take place as early as next year.

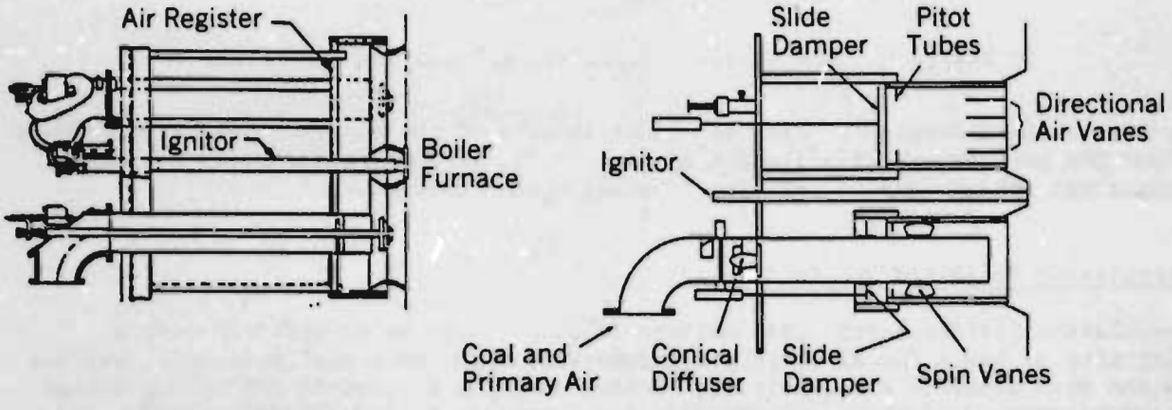


Figure 7. Existing 2 Nozzle Cell Burner and Low NOx 1 Cell

Coal conversions and/or furnace replacements are two other cases where B&W has implemented low NOx PC burners (Dual Register Burner) in pre-NSPS equipment. The Dual Register Burner/Compartmented Windbox system was added in the course of a spiral-wound furnace installation which is just completing start-up. This combustion system provided a mechanical upgrade in addition to the NOx reduction benefit.

Furnace Sorbent Injection

Coupling Furnace Sorbent Injection (FSI) to a low NOx burner retrofit offers the simultaneous reduction of SO_2 and NOx in the boiler. Babcock and Wilcox is the prime contractor for the Environmental Protection Agency's LIMB demonstration. Our project objectives are to reduce both NOx and SO_2 emissions by 50 percent. Dual Register Burners, or the Hitachi-NR version, are expected to be used to surpass the required NOx reduction. Long-term effects of furnace sorbent injection will be evaluated in the 12-month test program.

Cyclone Furnace

Cyclone furnace combustion systems will also be investigated for NOx/SO_2 reduction capabilities and compatibility with FSI technology for SO_2 removal. Cyclone furnaces fire crushed coal turbulently at high temperatures to enable wet tapping of slag. Coal-fired cyclones represent 23,000 megawatts of capacity and typically produce NOx in the range of 0.8 to 1.3 lb NO/MBtu. Field tests of two-stage operation have met with difficulties in slag tapping. However, reburning does offer potential as a means of NOx reduction. A consortium of utilities and EPRI are participating with B&W in FSI tests at the Alliance Research Center. B&W has successfully converted the 6 MBtu/hr Combustion and Fuel Preparation Facility

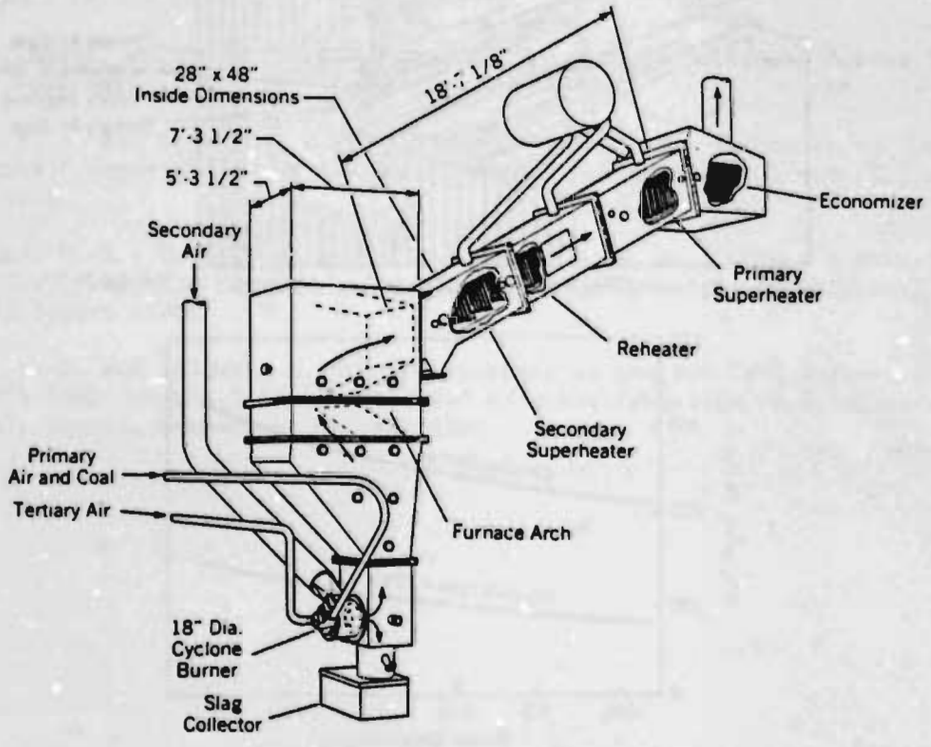


Figure 8. Combustion and Fuel Preparation Facility (CFPF)

(CFPF) to cyclone firing and a convection pass was added for these tests (Figure 8). The convection pass simulates temperatures and residence times encountered in coal-fired utility boilers and is equipped with deposition probes and sootblowers so that SO_2 reduction and deposition can be investigated.

Primary Gas - Dual Register Burner

Oil- or natural gas-fired units in non-compliance regions, or state or local legislation, may require further NOx reductions on existing boilers. The Primary Gas - Dual Register Burner (PG-DRB) can accomplish this by direct retrofit. The PG-DRB (Figure 9), developed by BHK and licensed by B&W, is an oil/gas-fired version of the dual register burner which includes a primary gas annulus surrounding the core pipe housing the oil atomizer. Recirculated flue gas is mixed with secondary air supplied to the windbox and serves to reduce oxygen availability and reduce peak flame temperatures to control NOx. The primary gas annulus is supplied directly with recirculated flue gas (no secondary air) which serves to blanket the base of the oil flame and further reduces oxygen availability as the oil devolatilizes. The PG-DRB reduces NOx by 50 percent relative to conventional burner designs in normal or staged combustion (Figure 10). NOx can further be reduced by adaptation of the IFNR system, although combustion system design and residence time requirements may require unit derating.

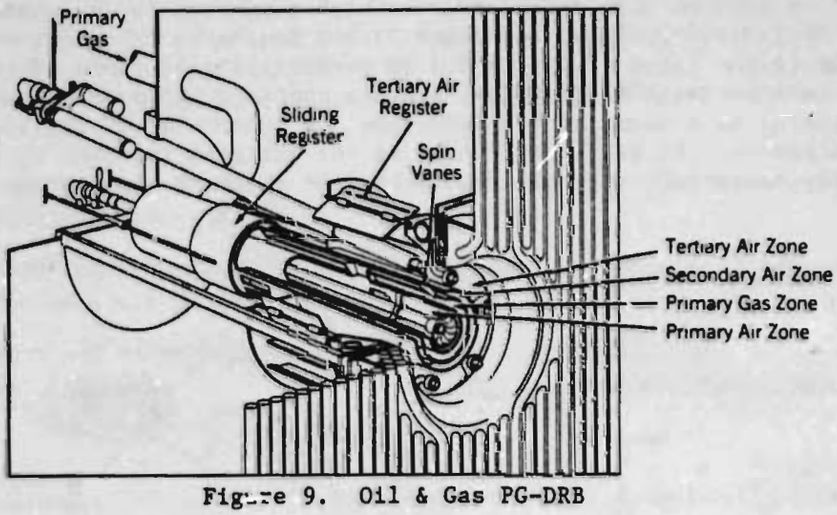


Figure 9. Oil & Gas PG-DRB

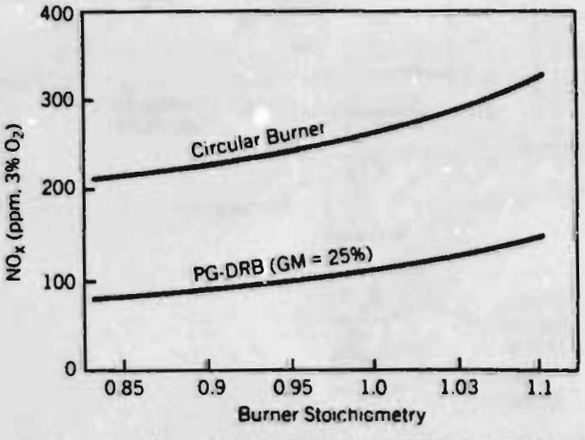


Figure 10. Oil-Fired Burner Comparison

CONCLUSION

Babcock and Wilcox has low NOx combustion equipment for new or retrofit application to PC-, oil-, or natural gas-fired utility boilers. The Dual Register Burner has achieved low NOx performance in extensive PC applications. The Enhanced Ignition DRB provides low NOx performance for difficult-to-burn coals. Other advancements in PC burner designs are the Hitachi-NR burner and the low NOx cell burner, both of which achieve significant NOx reductions without resorting to two-stage operation. The PG-DRB similarly reduces NOx for oil- or gas-fired units. In-Furnace NOx Reduction achieves extremely low NOx emissions but requires deep staging and increased furnace height. Selection of the appropriate low NOx system depends on NOx emission limits and site-specific factors in retrofit cases.

Circulating fluidized beds offer simultaneous NOx and SO_2 reductions for utility or cogeneration plants. Furnace Sorbent Injection similarly provides a means of SO_2 reduction in PC, and potentially cyclone-fired, utility boilers. Computer modeling is being applied to the combustion process to provide a means of predicting furnace and emissions performance, and for scaling from the lab to the field.

REFERENCES

1. Brackett, C. E. and Barsin, J. A., "The Dual Register Pulverized Coal Burner," paper presented to EPRI NOx Control Technology Seminar, San Francisco, February 1976.

2. Eckhart, C. F., "Enhanced Ignition Dual Register Coal Burner Tests," internal B&W report LR:82:7204-01:01, February 1985.

3. Okiura, Kunio, et.al, "Combustion Process for Reducing Nitrogen Oxides," U.S. Patent Application 06/175,823; August 1979.

4. LaRue, A. D. and Acree, M. A., "Advanced In-Furnace NOx Reduction to Control Emissions," paper presented to American Power Conference, Chicago, Illinois, April 1985.

5. Fiveland, W. A., Cornelius, D. K., and Oberjohn, W. J., "COMO - A Numerical Model for Predicting Furnace Performance in Axis-Symmetric Geometrics," ASME, HT-103, August 1984.

6. LaRue, A. D. and Rodgers, L. W., "Development of Low NOx Cell Burners for Retrofit Applications," paper presented to Joint Symposium on Stationary NOx Control, Boston, Massachusetts, May 1985.

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