Air Pollution Engineering Manual

Second Edition

AIR & WASTE MANAGEMENT
ASSOCIATION
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the greater potential for abrasion associated with the internal bag cages.

The major advantage of the pulse type of collectors is that they operate at relatively higher filter velocities than the reverse-gas collector (typically 4 fpm, compared with 2 fpm for the reverse-air collectors), thus resulting in a substantially smaller collector. Ironically, the higher velocity tends to reduce bag life, increase outlet emissions, and increase pressure drop. Although these problems can be minimized by the choice of filter material and design changes, there is a cost for these factors that must be considered in evaluating design tradeoffs.

Electrostatic precipitators have been used in only a few large utility applications and, in one case, where units were already in existence. The primary disadvantage of the ESP is the decreased sorbent utilization that occurs when the fly ash and reaction products, collected on the plates of the precipitator, are removed from the gas stream. Several units have been installed, including Grand River Dam Authority (575 MW), Pacific Power and Light—Wyodak 1 (300 MW), and Basin Electric's Laramie River Plant (570 MW). The specific collector area (SCA) of the existing ESPs, which have spray dryers upstream, are 685 and 700 $\text{ft}^2/10^3$ acfm for the Grand River Dam Authority and Wyodak, respectively, based on the actual cubic feet per minute at the outlet of the spray dryers.

Nitrogen Oxides Control

The methods for controlling nitrogen oxides can be divided into (1) combustion control methods, in which operating conditions for combustion are modified to reduce the formation of NO_x; and (2) postcombustion control methods, in which NO_x is removed from the gas stream after formation.

The underlying concepts of the combustion control methods are as follows:

1. To reduce peak temperatures in the combustion zone by operating the primary flame zone under fuel-rich conditions, cooling the flame at a high rate, and decreasing the adiabatic flame temperature by dilution
2. To reduce the gas residence time in the high-temperature zone
3. To operate on an off-stoichiometric ratio by using a rich fuel–air ratio in the primary flame zone and lower overall excess air conditions

The actual method of combustion control used depends on the type of boiler, especially the method of firing the fuel. For example, in the case of pulverized-coal-fired boilers (which accounted for 70% of all utility NO_x emissions in the United States in 1989), low-NO_x burners (LNB) and overfire air (OFA) have been successfully applied to tangentially and wall-fired units, whereas reburning is the only currently available option for cyclone boilers.

The uncontrolled NO_x emissions from tangentially fired and wall-fired units at full load are estimated to range from 0.4 to 1.1 and from 0.5 to 1.4 lb/MBtu, respectively. In the United States, Europe, and Japan, most utilities incorporate LNB systems with OFA for NO_x control through combustion modifications. The LNB combustion scheme is shown in Figure 23. After the initial combustion zone, a pyrolitic zone is formed in which the liberation of volatile nitrogenous species takes place. In the next stage, a fuel-rich combustion zone is formed to limit the formation of NO_x. This region is followed by a burnout zone in which completion of combustion is allowed to take place.

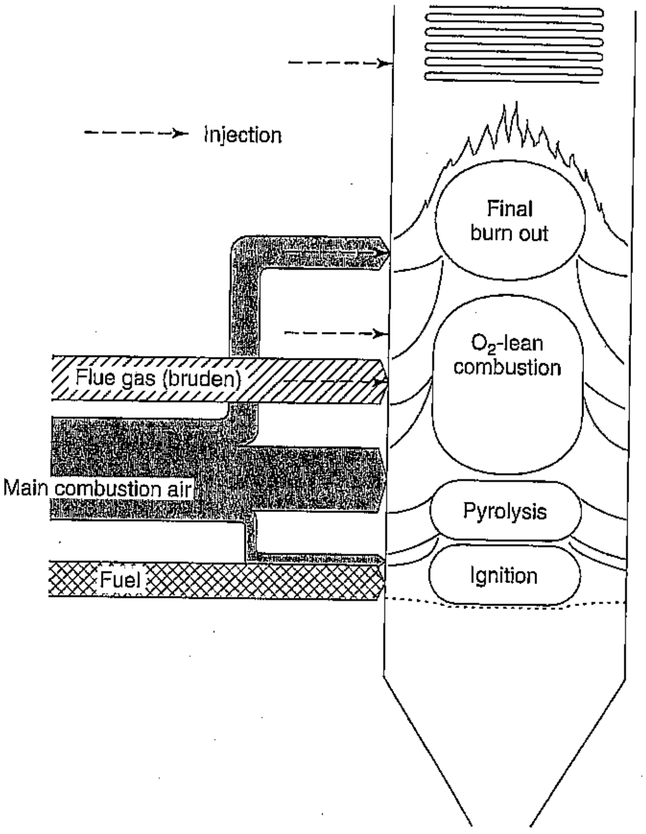

Figure 23. Low NO_x-Combustion (scheme) (from Ref. 27).

The actual design of the LNBs differs substantially between the two boilers. Figure 24 shows the schematic of an LNB for a wall fired unit; Figure 25 compares the configurations of a conventional burner and an LNB for a tangentially fired unit.

One of the major findings during recent retrofit LNB demonstrations was the importance of OFA in NO_x reduction. In fact, OFA could be used as a standalone modification in some cases to meet the emission standards. Results have indicated that up to 30% NO_x reduction can be achieved by conventional OFA systems that stage 10–20% of the combustion air. Advanced OFA systems, staging 20–30% of the combustion

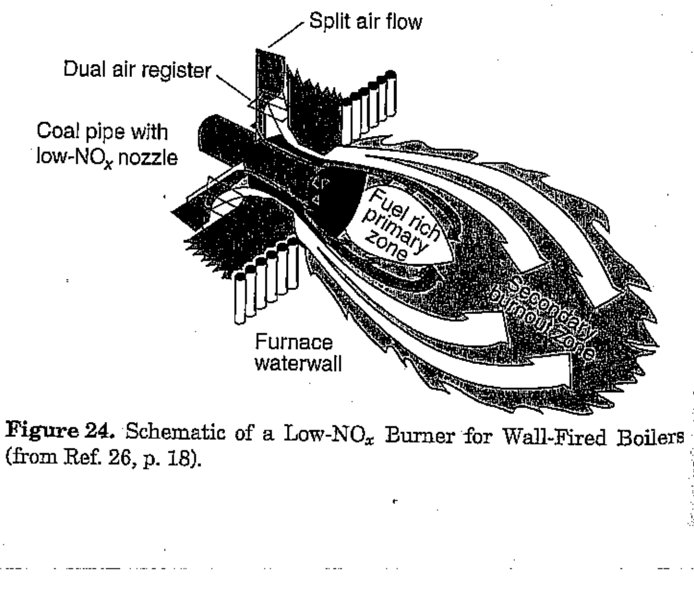

Figure 24. Schematic of a Low-NO_x Burner for Wall-Fired Boilers (from Ref. 26, p. 18).

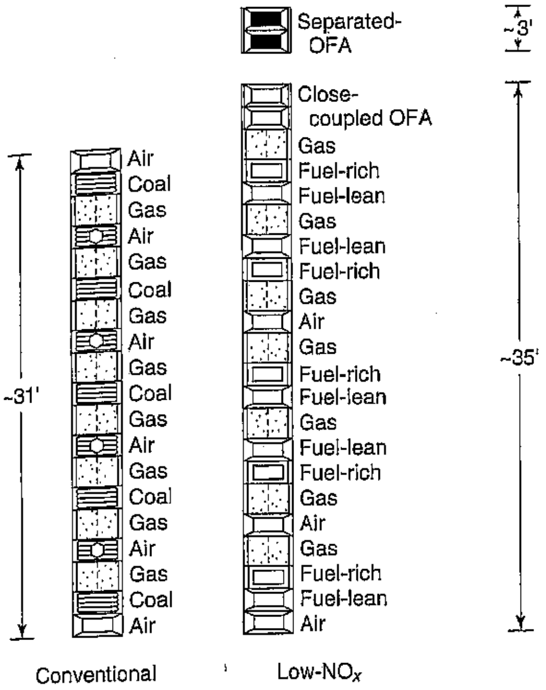

Figure 25. Comparison of Conventional and PM Burner Configurations (from Ref. 28, p. 2–77).

air, have a potential of higher reductions in NO$_x$. Figure 26 shows the dependence of NO$_x$ emissions on the percentage of combustion air staged in the OFA nozzles, and Figure 27 shows a furnace view of an OFA nozzle in a 400-MW wall-fired boiler.

Reductions in NO$_x$ of up to 50% have been demonstrated in LNB systems incorporating OFA. Capital costs for conventional and advanced OFA alone were estimated to be $5 per kilowatt and $10 per kilowatt in 1991. For LNB with OFA, the capital costs were estimated to range between $15 and $25 per kilowatt in the same period. Operating costs in all cases are expected to be low, but have not been estimated.

As of 1989, there were 105 operating cyclone-fired utility boilers with a capacity of 26,000 MW (approximately 14% of the pre-NSPS coal-fired generating capacity). However, these units contributed to approximately 21% of the total NO$_x$ emissions, largely because of their high operating temperatures, which are conducive to NO$_x$ formation. Uncontrolled NO$_x$ emissions from cyclone-fired boilers, shown in Figure 5, normally range between 660 and 1400 ppm.

The typical configuration of the cyclone furnaces prevents the successful application of standard LNB technology. The cyclone furnace consists of a cyclone burner connected to a horizontally water-cooled cylindrical chamber, as shown in Figure 28. Fuel (crushed coal) and air are introduced into the chamber by the cyclone burner. The large coal particles are forced onto the molten slag layer formed on the chamber wall by the cyclonic effect of the injection. Combustion of these large particles takes place in this slag layer. The finer particles are held in suspension by the gas stream and are burned in the primary combustion zone within the cylindrical chamber. The flue gases and the remaining ash leave the cyclone and enter the main furnace, which is a separate part of the boiler. Since the combustion occurs outside the main furnace, modification of the furnace, such as with LNBs, is not suitable for these applications. Other conventional NO$_x$

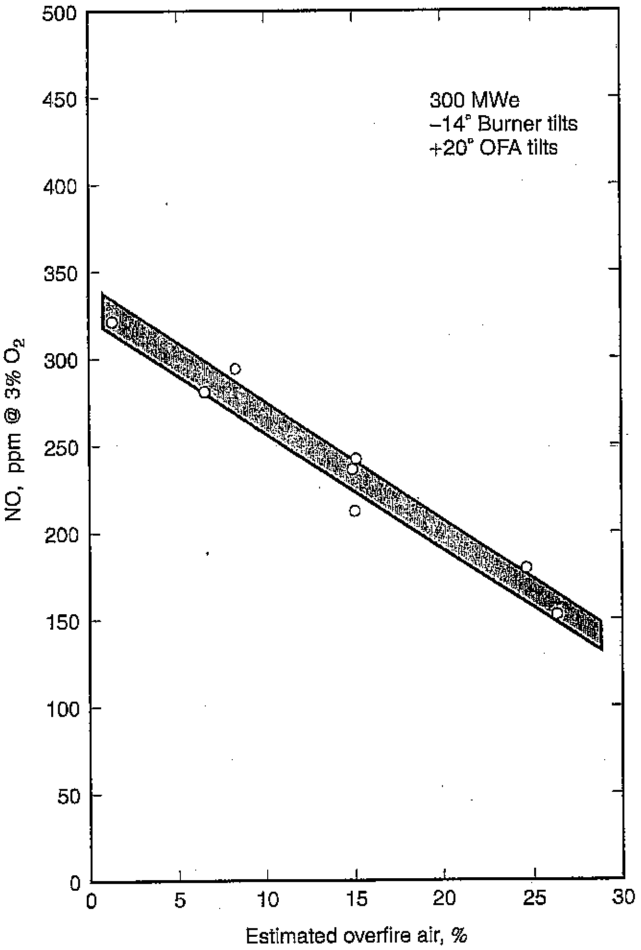

Figure 26. NO$_x$ Dependence on Overfire Air Flow (from Ref. 28, p. 2–82).

Figure 27. Furnace View of Separated OFA Nozzles (Offset) (from Ref. 28); A. Separated Overfire Air Nozzles; B. Top of Close Coupled Overfire Air Nozzles.