7.8 Improving combustion as a countermeasure to NOx

7.8.1 Introduction

Within the technology for the prevention of the discharge of nitrogen oxides, there are technologies for NOx suppression (low NOx combustion technology) and flue gas denitrification, and they are put to practical use at most combustion facilities. A low-NOx burner, a two-stage combustion method, an exhaust gas recirculation method and a denitration method within the furnace for large boilers are the means usually adopted to improve combustion as countermeasures for NOx.

7.8.2 History of combustion improvement as a countermeasure against NOx in Japan

NOx is harmful by itself in addition to being one of the materials that cause photochemical oxidants which tends to occur frequently in the years since the incident at Rissho high school in the summer of 1970. Various countermeasures have been adopted for the emission source such as combustion fixation equipment and automobiles.

The Environment Agency established an environmental quality standard for NO_2 (a value of 0.02 ppm or less per hour for a 24-hour average) in May 1973, but, in July 1978, it was again revised upward to the 0.04 to 0.06 ppm zone per hour on a daily average basis.

The Agency, in order to achieve this environmental quality standard, established a NOx emission standard for smoke and soot emitting facilities in August 1973 (the first regulation) and, after that, expanded the reinforcement in steps in December 1975 (the second regulation), June 1977 (the third regulation), August 1979 (the fourth regulation) and September 1983 (the fifth regulation).

Along with these regulations, the development of low NOx combustion technology was energetically carried forward in every direction. At first, the two-stage combustion method was typical for low NOx combustion technology, but, then, each maker developed a low NOx burner and, afterwards, an improved low NOx burner and an in-furnace denitrification method were developed and put to practical use.

Resulting from this, at present, it was possible to decrease the NOx concentration in exhaust gas by 60-70% through improved combustion for boilers, to 200 ppm for coal combustion, 100 ppm for heavy oil combustion and to about 50 ppm for gas combustion. Expenses for reduction is about 1/10 those of flue gas denitration [1].

7.8.3 Low NOx combustion technology in Japan

(1) The generation of NOx in the combustion process

As for nitrogen oxides which are generated during combustion, some is NO_2, but most is NO. NO is oxidized in the atmosphere and becomes NO_2. NO and NO_2 are together called NOx, but, NOx is classified into, thermal NOx which is generated from N_2 and O_2 in reaction in high temperature conditions in the combustion air, and fuel NOx which is generated from oxidization of N during in fuel combustion of fuel.

More thermal NOx is produced when ① the combustion temperature is higher, ② higher oxygen concentration in the combustion zone, and ③ combusted gas stays longer in high temperature area. Also, the more concentrated the oxygen, the more fuel NOx will be produced.

(2) Low NOx combustion technology

To decrease the discharge quantity of NOx at combustion in industrial equipment, NOx generation should be restrained according to the opposite principle mentioned above for the generating mechanism or flue gas denitrification should be conducted to remove the produced NOx from exhaust gas. Fig.7.8.1 illustrates the case of applied NOx restraint technology and flue gas denitrification technology for boilers in the generation of electricity.

To decrease the quantity of NOx emissions, combustion should implement countermeasures for NOx reduction first. Besides the implementation of a low air fuel ratio, or preventing air from invading the furnace, it is very important not to raise the temperature in the furnace, the furnace's load or the preheated air temperature higher than needed, considering the heating process and the entire balance of the equipment.

NOx countermeasures by improved combustion include the following.

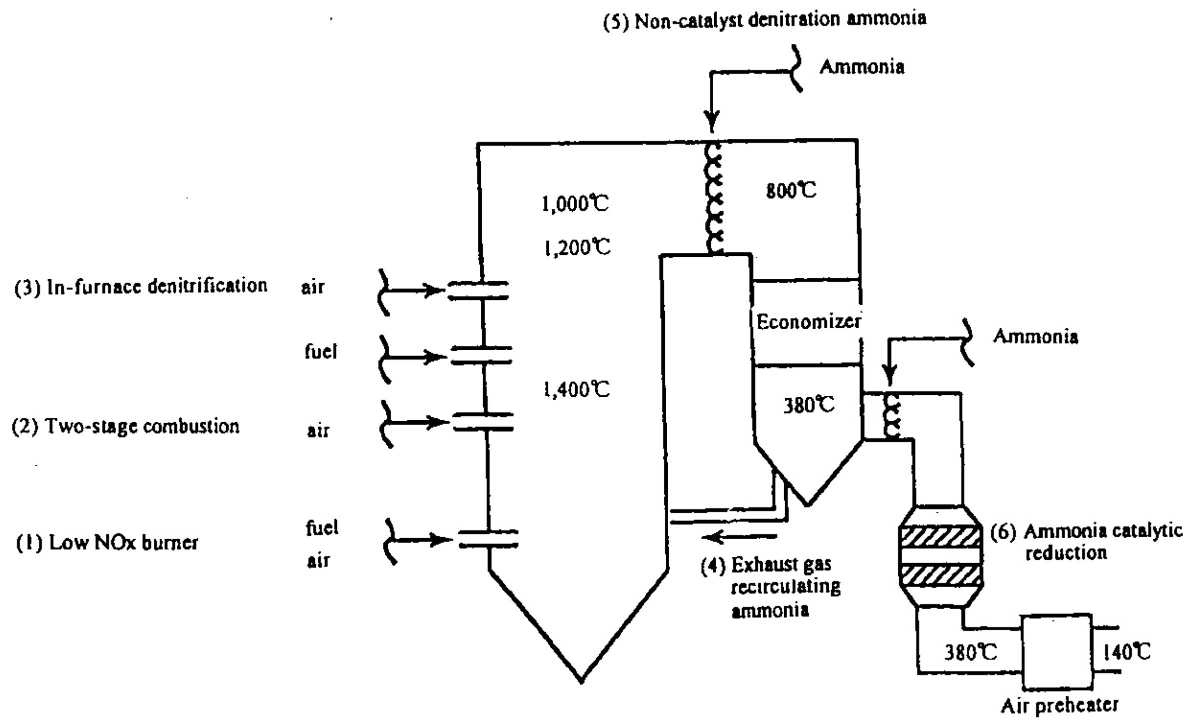

Fig.7.8.1 NOx reduction technology for boilers for power generation

① The use of the low NOx burner

Because the cost of the equipment to use a low NOx burner is comparatively low, and the reduction of NOx is effective, it is the mainstream NOx countermeasure at present. Methods to reduce NOx have been developed through decreased oxygen concentration, a lower flame temperature, and a shorter period of residence time gas in a high temperature area. One or a combination of these methods are incorporated into various types of businesses such as (a) a rapid combustion-type, (b) a divided flame-type, (c) auto-recirculation-type, or (d) a step-by-step combustion-type to reduce NOx. A step-by-step combustion type of burner is most popular because it is especially effective against both thermal NOx and fuel NOx, and there is a considerable reduction in the NOx ratio.

② The two-stage combustion method

Air for combustion is supplied in two stage, where, in the first stage, the supply of the air amount is limited to 80-90% of the theoretical amount of air, and, in the second stage, the shortage is supplemented with perfect combustion in the total system. By forming a deoxidization area in the first stage, the generation of NOx is restrained by the decline of the flame's temperature and the drop in the oxygen concentration. This method has been adopted for almost all large-sized boilers.

③ In-furnace denitrification method

This method is used to deoxidize NOx with hydrocarbon fuel by bypassing part of the main fuel and uses it as a fuel for denitrification and the denitrification reaction is completed entirely within the furnace. A reburning system and the three-stage system belong to this method. A reduction in NOx of 40% to 50% is possible, and, if used in conjunction with other improved combustion methods, an 80% reduction can be reached. However, Since this method requires a high (long) furnace, its application to existing furnaces is difficult in many cases [1].

④ Exhaust gas recirculating

This method mixes part of the exhaust gas in the air to be burned as shown in Fig.7.8.1 and, through combustion, NOx reduction is attempted by decreasing the flame temperature. The exhaust gas recirculating rate, restricted by the limit of stable combustion, is generally 10-20%.

(3) Recent trends in low NOx combustion technology

With the increase of pulverized coal-combustion boilers since the oil shock, many makers have energetically carried forward with development of a low NOx burner to burn pulverized coal. The PM burner divides the pulverized coal through a distributor into the pulverized coal flow of high concentration and low concentration to supply and forms a fuel surplus flame and a thin flame in the furnace. Exhaust gas is introduced in the top and bottom of the fuel surplus flame to delay the diffusion mixing, forming a strong deoxidization flame in the first combustion area of the burner in an attempt to keep production of NOx low. The burner itself reduces NOx to 200 ppm. In a combination of two-step combustion, reduction as low as 100 ppm is reported to have been achieved.

Looking at the advanced MACT method and the expanded deoxidization method (INPACT method) for denitration in the furnace, there is much residence time, between the burner and the over-fire air port (AOP). In the middle, there is an inter-stage air port (IAP) for two-stage combustion to produce namely multiple combustion stages to reduce the amount of NOx.

To counter NOx, the fuel direct injection (FDI) burner system was developed for the furnace which performs a high temperature preheated combustion. FDI is a method that combusts fuel and air in the furnace, directly injecting them separately at high speed and with certain intervals into the furnace, which has a high temperature exceeding the fuel's auto ignition temperature. Because the gas in the furnace is sufficiently mixed (the exhaust gas recirculating effect) by each jet stream, and the flow into the furnace of the fuel and air to be burned is nearly parallel, a rapid mixing does not occur (slow combustion effect). The two effects from this are that the occurrence of a peak temperature in the flame is suppressed and the amount of NOx discharged is reduced to the 1/10 level.

7.8.4 Indicated problems

As compared with the flue gas denitrification method, the NOx countermeasures with the improved combustion method has an inferior NOx reduction percentage, but the cost is 1/10 that of the flue gas denitrification method. Even in the case of employing the flue gas denitrification method, the cost is favorable as it reduces the amount of ammonia, if, at first, the flue gas is processed after the decrease in NOx from improved combustion. Also, depending on the combustion equipment, sometimes there is no space to install flue gas denitrification equipment.

With the rise of the acid rain problem, as for the flue gas processing by developing countries, countermeasures against SOx have become the focus at present, but the discharge of NOx will become a big problem. Improved combustion as a countermeasure against NOx should be immediately put to practical use in developing countries and a method with little energy loss occurring is especially needed.