P a r t 1

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

1.1. Nitrogen oxide emission reduction

1.1.2. Technological methods of nitrogen oxides reduction in boilers at combustion of different types of organic fuel

1.1.2.2. Modernization of the furnace process

1.1.2.2.5. Three-staged combustion

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One of the most effective methods, providing a partial reduction of the already formed NO_x to N_2, is a three-staged combustion method, called in the U.S. and Western Europe as a reburning process. An essence of the method is that into the primary burners (working with the optimum excess air in terms of efficiency) only 75 ... 85% of all fuel is supplied. The remaining 15 ... 25% is fed into the intermediate zone of the flame (above the primary burners) with a great lack of air. This results in formation of the reducing zone, in which due to hydrocarbons and nitrogen-containing components (eg, amines) NOx is reduced.

Above the reducing zone of the furnace tertiary air is fed for reburning of incomplete combustion products, coming up from the reducing zone. Thus, there are formed three zones in the furnace with different working conditions (Fig. 1.18).

For creating the reducing zone, one can use the same fuel as for the primary burners, but preference should be given to the gaseous fuel, which contains no fixed nitrogen and, moreover, does not create difficulties when burned. At coal combustion, for the reducing burners fine dust is preferable to be used to ensure reburning of coke particles on a way from the reducing zone to the outlet of flue gases into the zone of a screen superheater.

Efficiency of the method of three-staged combustion depends on several factors, most important of which are:

1) degree of a lack of oxidant in the reducing zone of the oxidizer (preferably α_{II} = 0,85 ... 0,95);

2) residence time of combustion products in the reducing zone (preferably to ensure the estimated time τ_{II}> 400 ms);

3) temperature in the reducing zone should be high (preferably not lower than 1200°C);

4) intensity of ignition of the additional fuel and mixing of its combustion products with flue gases from the main combustion zone;

5) the excess air in the main combustion zone (it should be minimal in view of providing the admissible unburnt carbon q_4);

6) residence time and intensity τ_{III} of mixing of tertiary air jets with combustion products from the reducing zone (τ_{III} should be more than 600 ms).

Three-staged combustion method can be implemented both at creation of new boilers, and at modernization of the existing ones. In the last case, preference should be given to the option - coal/gas (for primary and secondary burners, respectively). But excessively high prices for natural gas (in Europe and the U.S. they are 4 times higher than the cost of coal per 1 kcal) prevent from the widespread introduction of this option abroad. Nevertheless, boilers, transferred to three-staged combustion, operate in the U.S., Japan, Britain and Italy. In the territory of the former USSR, this method was introduced for the first time in Europe at slag-tap boiler (unit № 4 of 300 MW capacity at Ladyzhenskaya SDPP), as well as at several smaller boilers, using the simplified scheme and applying the upper burners to create a reducing zone [12] In Table. 1.6 basic information on the proven technological methods for NOx reduction is provided.

Table 1.6. **Efficiency estimation at application of technological methods of nitrogen oxide reduction in boiler furnaces at combustion of different types of organic fuel**

Method	Efficiency, %	Recommended fuel	Application limit	Notes
Regime and commissioning activities				
Low excess air (LEA)	10...20	Gas, minor coal	CO formation and a growth of loss on ignition in ash and slag	Efficiency of the method depends on the boiler condition before introduction of the method
Biased Burner Firing (BBF)	20... 50	The same	The same	Preferably for the boilers with two or more numbers of burner stages
Simplified two-staged combustion (BOOS)	20...40	»	Increase in the temperature of the pipes of screen or conventional superheater	Capacity reserve of the burners under operation is needed
Modernization of the furnace process				
Low-NOx burners (LNB)	30...50	All types of fuel	Stability of the flame and complete fuel combustion	For staged air or fuel supply at the horizontal section of the flame, the certain distance to the opposite screen is required

Flue gas recirculation (FGR)	20**...** 60	A great figure **—** for gas, the less **—** for high-reaction coals Not for ASh, T and SS coals	Stability of the flame, at drum boilers —a growth of the superheating temperature	Supply of recirculation gases through the burners, at coal combustion — through the coal-pulverized system (together with the primary air)
Two-staged combustion (OFA)	20**...** 50	All types of fuel	Increase in loss on ignition, corrosion of the low reaction section	At sulfur-containing fuel combustion, especially in supercritical boilers, a danger of high-temperature corrosion of the furnace screens occurs
Concentric combustion (CTF)	20**...** 50	Brown and black coal with high volatiles content	CO formation and a growth of loss on ignition	At reconstruction of the tangential furnaces, replacement of burners could be enough. Together with it, slagging and corrosion of the furnace screens are less
Three-staged combustion (reburning process)	30**...** 60	All types of fuel (for ASh and T coals 10…15 % of gas on heat is required)	The same	More effect is achieved in case of using gas for creation of the reducing zone (10…15 % on heat)