P a r t 1

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

1.1. Nitrogen oxide emission reduction

1.1.3. Flue gas cleaning from nitrogen oxides

1.1.3.2 Selective Non-Catalytic Reduction (SNCR)

Kotler V.R., Open JSC "VTI"

The second method of cleaning flue gases from NO_x, widely spread in the global energy sector and tested in Russia (TP-87 boilers at Tolyatti CHPP) is also a selective (i.e., using ammonia or urea), but non-catalytic reduction of NO to molecular nitrogen. The reduction process takes place without a catalyst in the temperature range, which depends on the reagent use. This approximate range is from 850 to 1100°C.

The main reaction of nitrogen oxide reduction is the following

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O.$$

Reaching the lower limit temperature range, the reaction rate is significantly reduced, and when reaching the upper limit, the adverse reaction of ammonia oxidation becomes dominant:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

To apply SNCR method, the following is required, firstly, building a facility for receiving, storing, cooling and evaporating the reagent and, secondly, mounting in the boiler a proper installation of SNCR for the reagent injection and its subsequent interaction with nitrogen oxides to have a molecular nitrogen and water vapor (Fig. 1.21).

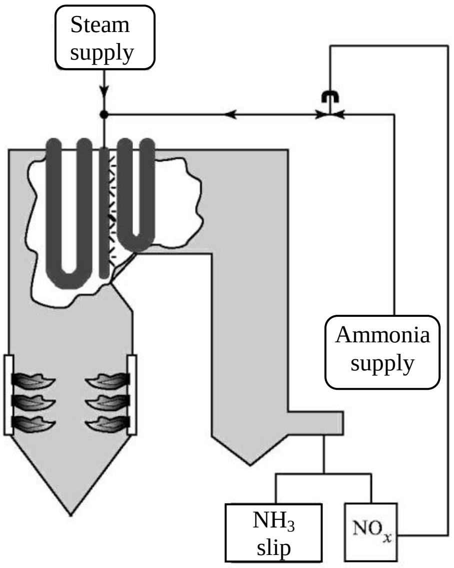

Fig. 1.21. SNCR process arrangement

The difficulty of this method implementation is that in any selected by developers cross section of flue gas path, there is a temperature range. At an average temperature of gases, which are even in the centre of the temperature range, there are areas, where the gas temperature is beyond the boundaries of this range.

If to consider, in addition, variable load of the boiler, as well as unevenness of NO concentration in the cross section of the flue gas duct, it becomes clear how difficult it is to maintain an optimal balance of NH_3/NO in the selected cross section of the duct.

To avoid difficulties associated with changes in boiler load, some developers have tried to implement a scheme of SNCR with two or even three places of ammonia water injection (Fig. 1.22). This scheme didn't only increase the amount of reconstruction work, but also complicated the operation, since all the devices for NH_3 injection needed to be cooled. To intensify mixing of the reagent with the flue gases, developers must not only optimize the aerodynamics of jets, injected into the flue gases, but also to select the optimal size of ammonia water drops. Too small droplets will evaporate quickly even at a higher temperature, and too large ones will evaporate more slowly and react at lower temperatures, that could increase the ammonia slip.

In addition to water, compressed air or steam may serve as reagent carriers. In some cases, the reagent can be fed into the furnace together with a tertiary air or recycling gases, i.e. it's a combination of SNCR method with one of the technological methods of NO_x emission reduction.

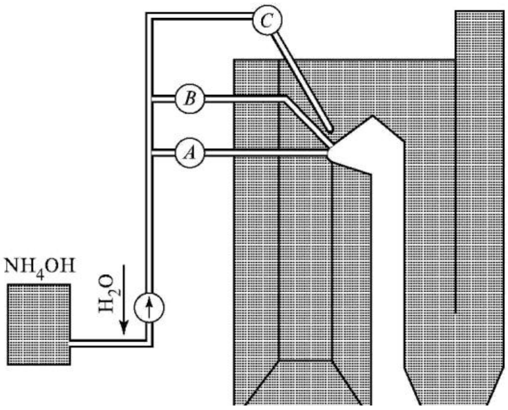

Fig. 1.22. Various methods of ammonia injection into the flue gas flow: A, B, C - points of ammonia water injection

A choice of the reagent is also playing a big role. As mentioned earlier, urea is easier to transport and store than ammonia. But it turns out, if urea is fed into the furnace, then a large amount of nitrous oxides - N_2O is formed, which, in contrast to NO_x, are greenhouse gases and are also destroying the ozone layer in the atmosphere. In addition, use of urea increases a risk of corrosion.

As in the case of SCR, the efficiency of SNCR largely depends on the uniformity of distribution of ammonia or ammonia water through the cross section of flue gas duct. An important role is also played by the temperature: using ammonia or caustic ammonia, the temperature of 870°C is considered to be an optimal one (in the range of 850 ... 1000°C), and using urea - 1000°C (800 ... 1100°C). The residence time in the temperature window should be between 200 to 500 ms [20].

It is clear that to improve the process efficiency it is desirable to increase the molar ratio of NH_3/NOx, but it's necessary to remember that it raises the ammonia slip, which leads to pollution of the convective heating surfaces. The optimal molar ratio of NH_3/NOx at operation of SNCR is 1.5 ... 2.5.

SNCR method is usually used in addition to the already implemented primary methods, since its effectiveness is not too high. Preference is given to the boilers that operate at constant load, combusting fuel with constant characteristics. Variable loads and changes in fuel quality don't allow to achieve good performance when using SNCR.

The cost of implementing SNCR installation depends on a size of the boiler and its features. According to rough estimates for the coal-fired boiler with thermal capacity of 250 MW, operating 4000 hours per year, reduction of 1 ton of NO_x emissions costs about 2,500 euros [20]. According to other reports [22], at introduction of SNCR method at the boiler with capacity factor of 75% with a payback period of 10 years and $DeNO_X$ efficiency of 20 to 60%, reduction of 1 ton of NO_2 costs about 5500 UK pounds (i.e. about 10 thousand U.S. $). These costs take into account, in particular, conversion of the collected ash from the end product to wastes that require space for their storage.

Table 1.7 contains the basic information about the methods of cleaning of flue gases from nitrogen oxides tested in domestic and world practice.

Table 1.7. **Evaluation of methods for cleaning the flue gases from nitrogen oxides**

Method	Efficiency, %	Recommended fuel	Limits of applicability	Notes
Selective Catalytic Reduction (SCR)	80**...** 95	All fuels	Ammonia slip, no space for the installation at the operating boilers, high construction and operation costs	Possible alternatives ("high-dust", "low-dust" and "tail-end"), which differ in terms of capital and operation costs. A plant for storage of ammonia or urea is required
Selective Non-Catalytic Reduction, (SNCR)	20**...** 50	The same	Ammonia slip, time of residence in the zone of temperature range, increase in the own needs	A process of NO reduction is possible only in the temperature range of 850 ... 1050°C, so fluctuation of the boiler load reduces the process efficiency and increases the ammonia slip. A plant for reception and storage of ammonia or urea is required.