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ENVIRONMENT PROTECTION

Studying the Removal of Nitrogen Oxides from Boiler Flue Gases in Firing Natural Gas

V. I. Kormilitsyn[a] and V. S. Ezhov[b]

[a] *Moscow Power Engineering Institute, Krasnokazarmennaya ul. 14, Moscow, 111250 Russia*
[b] *Southwestern State University, ul. 50 Let Oktyabrya 94, Kursk, 305040 Russia*

Abstract—Basic statements relating to the mechanism through which nitrogen oxides are oxidized and absorbed in the course of purifying flue gases using a new comprehensive method are presented together with versions used for implementing the purification process. The results obtained from tests of a pilot commercial installation are given, and its performance indicators are estimated.

Keywords: nitrogen oxides, flue gas cleaning, combustion, natural gas

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The problem of reducing the amount of nitrogen oxides emitted together with flue gases from thermal power installations is so important that a lot of methods and approaches for solving it have been emerged. Measures connected with the technology of operation (also called as primary environment protection) aimed at reducing the concentration of nitrogen oxides in flue gases have received wide acceptance [1–3]. However, despite their good effect in terms of reaching low concentrations of NO_x in flue gases (80–120 mg/m^3), the use of primary measures in cities and industrial centers—areas characterized by high background concentrations of polluting substances—sometimes does not exclude situations in which the maximum admissible concentrations of nitrogen oxides existing at the level of human respiratory organs are exceeded due to limitations imposed on the height of smoke stacks according to the requirements of air traffic, architectural landscape, and other considerations. Therefore, in order to comply with the norms regarding the purity of air basin specified by the relevant hygiene and sanitary regulations, additional (secondary) nature protection measures for reducing the concentrations of nitrogen oxides in flue gases to a deeper extent have to be used.

Feasibility study and environmental safety are the most important conditions determining the suitability of any secondary nature protection measure. The first condition assumes the use of cheap and accessible reagents, and availability of standard composite solutions for implementing the process and, accordingly, accessible and cheap standard equipment reliable and simple in operation, and the second condition implies the use of purification methods that exclude secondary pollution of the natural environment (the atmosphere, soil, and water basins) with components of the purification process and their regeneration.

The use of water as reagent and absorption as a method of purification carried out at temperatures below the dew point of steam contained in flue gases is considered. A fundamental factor hindering implementation of this method is that nitrogen oxide has poor solubility in water, because only higher nitrogen oxides are readily absorbed by water to produce nitric and nitrous acids. At the same time, it is exactly nitrogen oxide that is predominantly generated in firing natural gas, the content of which in the total amount of NO_x reaches 85–97%. Therefore, the process of absorbing nitrogen oxides (NO_x) in water should be preceded by oxidizing NO to NO_2. To do so, it was proposed to oxidize NO into NO_2 using ozone as oxidizer [4, 5], gas that in the case of its emergency release quickly transforms into molecular oxygen and poses no hazard to the atmosphere.

During the reaction of nitrogen oxide oxidized by air oxygen, the equilibrium shifts toward the right-hand side at low temperatures

$$2NO + O_2 = 2NO_2. \quad (1)$$

Therefore, if there is oxygen and if it remains in contact with water-insoluble nitrogen oxide for a sufficient period of time, the latter is additionally oxidized to water-soluble nitrogen dioxide.

In view of the technological conditions under which natural gas is fired in boiler furnaces, quite a long period of time is required for performing this reaction under usual conditions (a few hours). To speed up the reaction of additionally oxidizing NO to NO_2, it is proposed to decrease the temperature of flue gases containing NO_x.

The equilibrium constant of reaction (1) is given by

$$K_{eq} = \frac{p_{NO}^2 p_{O_2}}{p_{NO_2}^2}, \quad (2)$$