P a r t 1

AIR POOL PROTECTION FROM EMISSIONS OF THE POWER INDUSTRY

1.1. Reducing nitrogen oxides emissions

1.1.1. Formation and и standards of nitrogen oxides emissions

1.1.1.1. The formation mechanism and standards of nitrogen oxides emissions

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Nitrogen oxides NO_x ($NO + NO_2$) are produced by combustion of all types of organic fuels in the boilers of TPPs. Nitrogen and air nitrogen components of the organic fuel mass are sources of nitrogen oxides.

Thermal NO_x (mechanism of Zeldovich) and fast NOx (mechanism of Fenimore) are formed from air nitrogen. Fuel NOx are formed from fuel (coal, oil) associated with organic nitrogen mass.

The formation rate of thermal NO_x depends on the oxygen concentration in degree 0,5 and on the temperature – exponentially [1]. Given the high activation energy of the formation reaction of thermal NO_x, shall be interpreted, that the formation of thermal NO_x are significant only at a certain temperature range – the so-called temperature step ΔT [2]. For hydrocarbon fuels ΔT = 50…70 °C, so the frequent confirmation that the amount of NO_x formed depends on three factors (excess air, temperature and residence time) are not quite accurate: residence time should not be as an independent factor. Importantly, thermal NO_x are formed at the maximum temperature, i.e. in the flame zone, where the basic fuel mass has burned already.

Fast nitrogen oxides are formed in the flame front and mainly depend on the stoichiometric ratio at the site of their formation. Therefore, a significant number of fast NO_x are formed only by burning gas with excess air ratio is somewhat less than one in the combustion zone.

Fuel nitrogen oxides are not formed during combustion of natural gas (with rate exception it does not contain bound nitrogen), but the quantity of fuel NO_x is very high during oil combustion and especially all types of solid fuels (peat, slate stone, brown and black coals), and in some cases is amount to 100 % of the total NO_x emission [3].

Main quantity of electricity generation due to the power plants in the Russian Federation. Their share was 65,7 % in total electric power generation in 2002, and it increased to 66,5 % in 2005. Combustion of more fossil fuels (even taking into account the fact that 2/3 of the fuel necessary for natural gas) leads to atmospheric pollution with toxic substances, primarily nitrogen oxides. In the Table 1.1 provides information on the dynamic of pollutants by enterprises of RAO Unified Energy Systems of Russia [4]. Listed in the Table 1.1 data indicate that TPPs pollute the air with toxic nitrogen oxides along with companies in other sectors. As a result, occurs both regional (acid rains), and local (increase of NO_2 concentration in the air) influence on the environment. Proved, that higher concentration of nitrogen oxides in the lower atmosphere have harmful effect on the human health, flora and fauna.

All this leads to the need to improve the organic fuel combustion technologies to reduce NO_x emissions from the flue gases of steam generating units of TPPs (Table 1.2).

In addition to the existing many years GOST R 50831-54, Russia has been prepared (and soon to be approved) the technical standards for emissions, necessary for existing power plants (Table 1.3).

Table 1.1**. Dynamics of the pollutant emissions by enterprises of RAO "UES of Russia"**

Pollution agents	Years				
	2001	2002	2003	2004	2005
Pollutant emissions, thousands of tons per year	3002,2	2741,2	2617,8	2484,7	2664,4
Including nitrogen oxides NO_2, thousands of tons per year	762,2	710,8	712,5	672,8	705,4

Table 1.2. **NO_x emission standards for foreign and Russia energy boilers**

Fuel	Russia		European Community	
	GOST P 50831—95		Emission standards introduced in 2004	
	New installations		New installations (installations operated from 01.01.2002 to 27.01.200)	
	Thermal power, MW	Emission standard, mg/m^3	Thermal power, MW	Emission standard, mg/m^3
Gas	< 300 > 300	125 125	50...300 (50...500) > 300 (> 500)	150 (300) 100 (200)
Liquid	< 300 > 300	250 250	50...100 (50...500) 100...300 > 300 (> 500)	400 (450) 200 200 (400)
Solid	Brown coal при dry bottom / slag-tap boilers			
	< 300	300/300	50...100 (50...500)	400 (600)
	> 300	300 (-)	100...300	200
	Black coal при dry bottom / slag-tap boilers			
	< 300	470/640		
	> 300	350/570	> 300 (> 500)	200 (500)

Table 1.3. **Russian technical standards of NO_x emissions, g/MJ (mg/m^3 at 6 % O_2)**

Fuel	Installations developed from 01.01.1997 to 31.12.2000, steam capacity	
	less 420 tons/h	more 420 tons/h
Black coals at dry bottom with reduced nitrogen content N_{pr}, % kg/MJ:		
$N_{pr} < 0,04$	0,17 (470)	0,2 (550)
$N_{pr} > 0,04$	0,21 (570)	0,21 (570)
Black coals at slag-tap boilers	0,23 (640)	0,25 (700)
Anthracite Culm at slag-tap boilers	—	0,29 (800)

Brown coals at dry bottom with reduced nitrogen content N_{pr}, % kg/MJ: $N_{pr} < 0,05$ $N_{pr} > 0,05$	 0,12 (320) 0,13 (350)	0,14 (370) 0,17 (450)
Oil	0,086 (250)	0,086 (250)
Natural gas	0,043 (125)	0,043 (125)