Semi-industrial experimental studies of perspective technology for reducing harmful emissions produced by coal-fired thermal power plants

E A Boiko¹, A V Strashnikov¹ and P V Shishmarev¹
¹Siberian Federal University, Krasnoyarsk, Russia

E-mail: eboiko@sfu-kras.ru

Abstract. The results of experimental studies of preliminary thermal processing of pulverized solid fuel under conditions of a semi-industrial installation for the preparation and combustion of coal with a productivity of up to 150 kg/h are presented. The studies were conducted over a wide range of pre-processing temperatures from 300 to 900 °C, air excess from 0.2 to 0.9%, and the residence time of the carbon particles in the installation from 0.6 to 2.5 sec. The effect of preliminary thermal processing regimes on the reduction of nitrogen oxide emissions during the combustion of heat treatment products is shown experimentally. At a heat treatment temperature of 650-800 °C, emissions of nitrogen oxides are reduced by 2-3 times compared to burning of the initial fuel. An interpretation of the mechanism of the effect of preliminary thermal processing of coal on the reduction of nitrogen oxide emissions is proposed.

1. Introduction

The increase in the production of electrical and thermal energy on solid organic fuels is associated with large ecological stresses on the environment and, first of all, on the atmosphere. The need to ensure regulatory requirements for the protection of the environment from emissions of harmful substances will require the implementation of projects of fuel-consuming devices that meet the established standard indicators for emissions of solid and gaseous substances to the environment required for environmentally friendly boiler units (\( \mu_{\text{ash}} = 50 \text{ mg/m}^3 \); \( \text{NO}_x = 200 \text{ mg/m}^3 \); \( \text{SO}_2 = 400 \text{ mg/m}^3 \)). Provision of requirements for protecting the environment from emissions of TPPs according to specialists only in the next five years will require additional capital investments in the amount of up to 28 billion rubles. In this connection, the problem of developing environmentally friendly technologies for the preparation and combustion of solid organic fuels becomes topical.

One of the most promising and economically viable approaches to reduce emissions of harmful substances in thermal power plants is the use of preliminary thermal processing of the fuel before combustion. However, the simplicity of providing such performance indicators for boiler units as efficiency and reliability of operation requires experimental studies and confirmation of an increase in their environmental safety in conjunction with the regime and design characteristics of the device for thermal preparation of coal [1].

2. Methods and data

2.1. The mechanism of behavior of nitrogen-containing fuel components during its thermal processing and combustion.

The basis for the elaboration of all technical solutions related to the reduction of nitrogen oxide emissions to the atmosphere with gaseous combustion products of solid organic fuel is the knowledge of the mechanism of behavior of nitrogen-containing fuel components during its preparation and combustion in a furnace chamber of a boiler unit. The most detailed model for the formation of nitrogen
oxides in the combustion of coal dust corresponds to the Mitchell-Tarbell kinetic scheme [2]. According to this scheme, the process of the kinetic mechanism for the formation of nitrogen oxides is as follows. During the thermal decomposition of the pulverized-coal particle and the release of volatile vapor-gas components, part of the bound nitrogen of the fuel (nitrogen, which is part of the components of volatile substances \(N_\text{vol}\), constituting up to 70-80% of the total amount of nitrogen \(N\) contained in the initial fuel) practically instantaneously passes into the gas phase in the form of cyanides (HCN). The residual nitrogen of the non-volatile residue (\(N_\text{coke}\) approx. 20-30% of the total nitrogen of the fuel), evenly distributed throughout the coke-base particle, is oxidized directly to the nitrogen monoxide (NO) at a rate proportional to the burning rate of the non-volatile residue. Cyanides formed during the release of volatile substances are further converted to amines (for example, \(NH_3\) – a typical representative of the amine \(NH\) group), which, reacting with both oxygen (\(O_2\)) of air and with nitrogen monoxide (NO), can promote the formation of nitrogen oxides and the reduction of molecular nitrogen \(N_2\) from \(NO\). In addition, reactions of “reverse” cyanide formation (HCN) as a result of the interaction of hydrocarbons (eg, methane \(CH_4\)) with a heterogeneous NO absorption reaction on the free carbon of coke are important reactions in terms of conversion of nitrogen oxides. The scheme also takes into account the “thermal” mechanism of NO production according to Ya.B. Zeldovich as a result of the \(O_2\) dissociation reaction at a high process temperature.

Thus, environmentally friendly technological processes of preparation and combustion of coal in the pulverized state should provide:

1. Elimination of the formation of thermal nitrogen oxides due to the realization of relatively low temperature of gases in the combustion chamber (<1300 °C).

2. Output of nitrogen with volatile gas-vapor components in conditions of lack of oxygen during the preparation of coal dust before burning.

3. The process of burning coal dust and products of thermal processing of fuel at low values of the excess air factor.

4. Recovery in the combustion process of nitrogen oxides from \(NO\) [3, 4].

The most effective way to reduce such harmful gaseous emissions as nitrogen oxides (up to 200 mg/m³) with the energy use of solid organic fuels is the preliminary thermochemical treatment of coal dust with a heating temperature of 600-850 °C in conditions of a lack of oxygen. The atomic nitrogen released from volatile substances is supposed to bind into molecules of \(N_2\). Remaining nitrogen in nonvolatile products, at moderate temperatures in the furnace and the correct organization of the combustion process, do not form oxides, but are released as the coke residue burns out. However, the above assumptions require further experimental confirmation in the conditions of a semi-industrial installation [5].

2.2. Experimental setup

To carry out full-scale fire studies of the device for thermal preparation of solid fuel, an experimental stand of the Thermal Power Plants department of SibFU (Fig. 1) was used, which includes a pulverizing system with a ball drum mill, a boiler plant with a vertical combustion chamber of a cyclonic type and a horizontal convective gas flue, air supply and disposal devices gaseous combustion products. The dust preparation system with a performance of up to 300 kg/h makes it possible to obtain ready-made coal dust with the characteristic of fractional composition \(R_{90}= 10-60\%\) and humidity \(W_{\text{coal dust}}= 5-24\%\). The crushed fuel from the bunker (4) is fed into the ball drum mill with the aid of a tray raw coal feeder (5). High-temperature combustion products of diesel fuel (\(T= 400-450\) °C) from the source (1) are also delivered here. Dried, milled fuel from the mill enters the inertial-type separator (6). Large particles of fuel through the flasher system return in the mill for additional grinding, and the separated coal dust enters the three-section cloth bag filter (8), and from there to the intermediate bunker (7). Ventilation of the dust preparation system is carried out by a fan with a performance of 0.8 thousand m³/h.
Combustion of the initial and heat-treated coal dust is carried out in a combustion chamber (9) of a cyclone type with an incineration temperature from 1000 to 1600 °C and an excess of air from 1.05 to 1.5. The performance of the device for thermal preparation of coal is 40-150 kg/hr in the initial fuel. The cyclone combustion chamber has an internal diameter of 0.6 m and a height of 2.8 m. From inside, the combustion chamber is thermally insulated with chamotte chromium-magnesite brick. Outside, the furnace has a water-cooled shirt.

Primary air with coal dust and secondary air are fed tangentially through the splines located in the upper part of the combustion chamber. At an altitude of 1.2 m from the upper slots, the tertiary air intake is arranged. At the bottom of the chamber is a tap hole, through which the slag enters the slag receiver. In the lower part of the combustion chamber there is a side outlet window for flue gas discharge through the radiation cooling chamber into the convective horizontal flue, which is a rectangular channel.

In the flue there are air- and water-cooled heat exchangers for regulating the temperature of the outgoing gases and simulating the corridor and chess tube bundles of the convective heating surfaces of the boiler unit. Behind the horizontal section of the flue there is a five-way two-stage air heater (12) which provides primary air heating from 80 to 130 °C and secondary air – up to 250-300 °C.

The device for studying the process of thermal preparation of fuel (see Fig. 1) consists of a coal dust preheating chamber (13), a linear horizontal heat processing section and a bypass provided for burning the source fuel (RF patent No. 2088851). The device for thermal treatment of coal dust provides preheating of fuel from 300 to 900 °C with air excess $\alpha = 0.2-0.9$. The residence time of the carbon particles in the plant is from 2.5 to 0.6 s.

The design of the unit for preliminary thermal processing of solid pulverized fuel is shown in Fig. 2. The device for the thermal preparation of coal dust consists of two coaxial cylinders. The inner cylinder performs the function of the muffle, the outer one is the coal dust heater. The coal dust at the inlet to the preheater is divided into two parts, a smaller part of the fuel (approx. 1/6) is fed to the muffle to maintain
the temperature regime, and the remaining part (approx. 5/6) is sent to the annular space of the dust preheater. Heat processing of the main part of the fuel is carried out due to the heat released by the combustion of dust in the muffle. To regulate the temperature of coal dust heating, it is possible to change the fuel supply to the muffle. During the start-up of the unit, the device is heated by feeding diesel fuel into the muffle. Ignition of diesel fuel is carried out with the help of an electrostatic device. The body of the device for thermal processing with a diameter of 600 mm is made of steel 20 with an inner lining of refractory bricks, the diameter of the muffle is 273 mm. The lid of the body of the dust preheater is water-cooled.

Fig. 2. Installation for the thermal processing of pulverized solid fuel: 1 – water-cooled lid; 2 – a branch pipe of a supply of secondary air to muffles; 3 – a branch pipe of a feed of fuel in muffle; 4 – a branch pipe of fuel supply for thermal processing; 5 – refractory bricks; 6 – injector for supplying diesel fuel; 7 – electrostatic device; 8 – muffle; 9 – coal dust heater; 10 – rectilinear heat treatment section, dust and gas hatches; 11 – furnace burner; 12 – a cyclone furnace; 13 – control equipment board

To the output of the device a rectilinear horizontal experimental section with a length of 4000 mm and a diameter of 100 mm (stainless steel), imitating a real dust-and-gas duct is connected. To study the kinetics of drying processes and thermal destruction of coal dust along the length of the horizontal heat processing section, four dust-collecting hatches are made at a distance of 1000 mm from each other. The arrangement of the device for the thermal preparation of coal dust in the fire stand is made at a height of 3.5 m so that the fuel is supplied to the upper part of it and the exit window of the device is located 0.3 m above the slots of the fuel supply to the burner of the cyclone combustion chamber.

2.3. Method of processing results
To determine the influence of the ‘temperature-time’ regime of preliminary thermal processing on the intensity of the process of formation of nitrogen oxides, experimental studies were carried out according to two schemes. The first with the preliminary thermal processing of coal dust in the temperature range of the dust and gas mixture is from 300 to 900 °C and the processing time is from 2.5 to 0.6 s, the second is the burning of the initial fuel. In the process of studies, not only the processing temperatures of coal dust, but also the excess air, as well as the combustion temperature, varied. The control analysis of flue gases for the content of nitrogen oxides was performed by the DAG-500 gas analyzer.

3. Results
According to the results of experimental studies, it has been established that the influence of the coal dust processing temperature on NO production is negligible. Under the investigated conditions, the NO concentration in the gaseous products of thermal decomposition leaving the heat treatment device was small, at the level of 13-25 mg/m³.
With increasing processing temperature from 500 to 920 °C, the content of hydrogen cyanide in the thermolysis gas at the outlet from the device increased monotonically from 12 to 27 mg/m$^3$. As regards the ammonia content, there is a tendency to reducing its concentration in the gaseous products of the fuel destruction as the temperature of coal dust preheating increases. The part of fuel nitrogen converted to the $\text{HCN}$ compounds through the thermal processing is small and is less than 1% of the nitrogen contained in the initial fuel, but even so the concentration of nitrogenous compounds in the gas medium is several hundred times higher than the allowable average daily concentrations of these substances in air. Therefore, as one of the requirements for developing real schemes and designs for the thermochemical transformation of solid fuels before burning, it is necessary to comply with the condition of ensuring the operation of the device under vacuum with respect to the ambient air [6].

The dependence of the $\text{NO}_x$ content in the flue gases on the air excess ratio in the combustion chamber is shown in Fig. 3, a. As can be seen from the figure, the minimum reduced concentration of nitrogen oxides obtained by burning the heat-treated regular Berezovsky coal was 220 mg/Nm$^3$ with the air excess factor in the combustion chamber $\alpha_{\text{furn}} = 1.05$. With increasing of air excess ($\alpha_{\text{furn}}$), the concentration of nitrogen oxides ($C_{\text{NO}_x}$) increases. When using oxidized Berezovsky coal under the same regime conditions of preparation and combustion, the concentration of nitrogen oxides was observed at the level of 280-290 mg/Nm$^3$.

When burning the initial (not heat-treated) Berezovsky coal, the concentration of nitrogen oxides was at the level of 375-850 mg/Nm$^3$ with $\alpha_{\text{furn}} = 1.05\text{---}1.35$. The effect of the air excess ratio on the $\text{NO}_x$ production practically ceased from $\alpha_{\text{furn}} = 1.35$. A somewhat higher concentration of nitrogen oxides obtained by burning oxidized Berezovsky coals compared with regular one is due to a large content of nitrogen in the initial oxidized coal than in the regular one. Moreover, the average concentration of oxygen in the combustion chamber during the combustion of the thermally prepared fuel is steadily lower than when burning the raw coal at the same values of the air excess supplied to the plant, which indicates the high reactivity of nonvolatile products of thermochemical processing of pulverized fuel.

Fig. 3, b shows the dependence of the concentration of nitrogen oxides in the combustion products on the depth of preliminary thermal processing of regular and oxidized Berezovsky coal. The concentration of nitrogen oxides in the flue gases with an increase in the temperature of the preliminary thermal processing process is noticeably reduced. Thus, when combustion of pre-heated fuel at a temperature of 700 °C, the concentration of nitrogen oxides decreases by a factor of 2 compared to the use of the initial (not thermally treated) coal, regardless of the degree of its oxidation. The presented results show good agreement with the data of the studies published in [7], whose authors, unfortunately, do not give an explanation of the results obtained.
Fig. 3. Dependence of the reduced (to $\alpha=1.4$) $NO_x$ concentration in the flue gases at the outlet from the combustion chamber on the air excess ratio in the furnace (a), on the temperature of the preliminary thermal processing ($T_{\text{flame}} = 1200^\circ C$, $\alpha_{\text{tarr}}=1.24$, $\tau_p=0.8-1.2$ s) (b) (c): ● – refural Berezovsky coal; ○ – oxidized Berezovsky coal; 1 - initial coal; 2 - pre-treatment temperature of coal $T_{\text{tp}}=600^\circ C$; 3 - pre-treatment temperature of coal $T_{\text{tp}}=780-800^\circ C$; 4 - pre-treatment temperature of coal $T_{\text{tp}}=800^\circ C$.

It is known that when burning solid fuels in the furnaces of steam boilers, nitrogen oxides $NO_x$ are formed, representing the sum of monoxide $NO$, dioxide $NO_2$ and nitrogen hemioxide $N_2O$. The share of nitrogen hemioxide $N_2O$ in total emissions with flue gases is low. The major share of $NO_x$ is nitrogen monoxide $NO$, which consists of prompt $NO_{\text{pr}}$, fuel $NO_{\text{fuel}}$ and thermal nitrogen oxides $NO_{\text{therm}}$ [8].

4. Discussion

Thermal nitrogen oxides, according to Zeldovich, are formed at high temperatures due to oxidation of the molecular nitrogen of the fuel. At temperatures above $1480^\circ C$ there is a very sharp increase in the rate of occurrence of the reaction of formation of thermal nitrogen oxides, which in practice is confirmed by the combustion of coals in furnaces with liquid ash removal [7].

In our experiments on the burning of Berezovsky coal and its thermal coal on a semi-industrial installation, a noticeable increase in concentration is observed with an increase in the temperature in the combustion chamber above $1400^\circ C$ (see Fig. 3, c). This proves that, along with the formation of fuel nitrogen oxides, endothermic reactions of formation of thermal nitrogen oxides begin to have a significant effect on the concentration.

In experimental combustion of Berezovsky coals of different degree of oxidation and products of their thermal processing in the combustion chamber of the fire stand, which is an integral part of the semi-industrial installation (Fig. 2), the change in the value of the air excess ratio in the furnace ($\alpha_{\text{tarr}}$) was carried out by changing the secondary air flow into the combustion core. In this regard, the results of the experiments have well confirmed earlier studies on the increase in fuel $NO_x$ concentration with an increase of the air excess in the furnace, as confirmed by the data presented in Fig. 3, a.

In our opinion, nitrogen hemioxide $N_2O$ can play a significant role in reducing fuel and prompt nitrogen oxides in the organization of preliminary thermal preparation of fuel. As a result of a numerical experiment, it was established in [8] that the yield of $N_2O$ begins at the pre-flare stage of the flame in the region of low temperatures. Having reached the maximum values, the $N_2O$ concentration gradually decreases along the length of the flame. Further, decomposition of nitrogen hemioxide is being observed. The calculated value of $N_2O$ in the outgoing flue gases from the boiler unit is about 0.2 mg/Nm$^3$, which agrees well with the results of foreign experimental studies [9].

The authors of [8] note that a characteristic feature of $NO_x$ formation at the initial stage of combustion in the low-temperature range of the flame is an earlier yield of $N_2O$ in comparison with nitrogen monoxide $NO$. They assume that since the formation of prompt $NO$ nitrogen oxides, as well as $N_2O$, occurs at the initial portion of the flame, the yield of $N_2O$ occurs with the participation of the prompt ones formed in this zone. When burning solid fuels, nitrogen hemioxide is formed due to the following reactions:

$$N_2 + HO_2 \rightarrow N_2O + OH,$$  \hspace{1cm} (1)
The radical \( HO_2 \) appears in the flame much earlier than other intermediate radicals. Intermediates (\( NCO \), \( NH \)) are formed from nitrogen cyanide and ammonia, the release of which, as is known, occurs during the pyrolysis of coal particles prior to their ignition.

Prompt nitrogen oxides in reactions (2), (3) are formed in a very short period of time, like \( N_2O \) and \( HO \). Under the conditions of a furnace with air excess, the formation of prompt nitrogen oxides occurs due to the chemical interaction of molecular nitrogen of air and hydrocarbons with the formation of radicals \( HCN \), \( NH \), \( N \). The latter are oxidized by oxygen-containing radicals \( (O, OH) \) to \( NO \). The emission of prompt nitrogen oxides is described by the following chemical reactions:

\[
\begin{align*}
NCO + NO & \rightarrow N_2O + CO, \\
NH + NO & \rightarrow N_2O + H.
\end{align*}
\]

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\[
\begin{align*}
CH + N_2 & \rightarrow HCN + N, \\
CH_2 + N_2 & \rightarrow HCN + NH, \\
RN + RO & \rightarrow \ldots \rightarrow NO,
\end{align*}
\]

where RN is nitrogen-containing radicals \( (HCN, NH, N) \); RO – oxygen-containing radicals \( (O, OH) \).

The maximum yield of prompt \( NO \) is observed with air excess ratio \( \alpha_{\text{max}} = 0.65-0.8 \), depending on the combustion conditions and the composition of the fuel [10]. In this regard, to reduce the emission of prompt \( NO \), it is necessary to maintain the excess air factor in the nodes of thermal preparation much lower than \( \alpha_{\text{max}} \).

When the yield of radicals \( O, OH, H \) from the fuel particles begins, the reaction rate of the reactions (1-3) decreases substantially. Nitrogen hemioxide at a high pace is converted into molecular nitrogen by the reactions:

\[
\begin{align*}
N_2O + H & \rightarrow N_2 + OH, \\
N_2O + HO & \rightarrow N_2 + HO_2.
\end{align*}
\]

At the same time, oxidation reactions of the hemioxide take place with the formation of \( NO \):

\[
\begin{align*}
N_2O + O & \rightarrow NO + NO, \\
N_2O + H & \rightarrow NO + NH.
\end{align*}
\]

The rates of the reactions (9) and (10) are very small [3] in comparison with the conversion reactions (7) and (8). The authors of [8] believe that practically all the nitrogen hemioxide formed as a result of the reactions (1-3) will be converted to molecular nitrogen \( N_2 \). Further, they conclude that the more fuel nitrogen and prompt nitrogen monoxides in the initial pre-flare stage of combustion go to nitrogen hemioxide, the smaller will be the final concentration of nitrogen oxides \( NO_x \).

It should be noted that in spite of a thorough study of the role of nitrogen hemioxide in reducing the concentration of nitrogen oxides in flue gases, Roslyakov and his collaborators [8] only recommend to delay the ignition process of volatile and mixing of secondary air. They do not give recommendations on how to implement the results of a numerical experiment in the conditions of a real boiler unit and increase the residence time of fuel particles in the pre-ignition period. These questions are partly answered by the results of these studies. When thermal coals were obtained at a semi-industrial installation, the time for thermal preparation of coal particles was 0.6-1.5 s, which is an order of magnitude greater than the pre-ignition period during traditional flaring of fuels.

Thus, in the organization of thermal preparation of coals before their ignition an independent, rather long period of thermal decomposition of coal dust is formed. In the thermal processing unit, conditions will be provided for the transition of a significant portion of the parent nitrogen of the raw coal from the prompt \( NO \) oxides to the nitrogen hemioxide \( N_2O \). As a result, the concentration of \( NO_x \) in the flue gases leaving the boiler unit will be significantly reduced. This is well confirmed by the results of the studies presented in Fig. 3, a, b, c.

The process of formation of fuel oxides of nitrogen in the stage of production and combustion of volatile substances with some assumptions can be represented as follows. When coal particles are heated, volatile substances and resins are released. Most of the nitrogen is found in resins in the form of heterocyclic compounds, such as pyridine, pyrrole or amines. The resins undergo secondary pyrolysis.
with the formation of compounds $HCN$ and $NH_3$ [10]. According to studies [8], when pyrolysis of brown coal the most of the fuel nitrogen is released in the form of ammonia, in hard-coals, nitrogen is more prominent in the form of cyanides. Cyanide and ammonia in the oxidizing medium react with an $OH$ radical or atomic oxygen, forming a nitrogen monoxide according to the reactions:

$$NH + O \rightarrow NO + H,$$  \hspace{1cm} (11)  

$$NH + OH \rightarrow NO + H_2,$$ \hspace{1cm} (12)

In a reducing atmosphere $HCN$ and $NH_3$ react with $NO$, forming a stable $N_2$ molecule [10]. Roslyakov [11] believes that for a deeper binding of nitrogen oxides with nitrogen-containing substances (ammonia, urea, etc.), they should be supplied into the volume of the combustion chamber with an inert medium. He proposes to supply them in the combustion zone, either with water or with flue gases.

Thus, if the technology of preparation and combustion of Kansk-Achinsk coals includes the unit for the preliminary thermal processing of pulverized fuel, it will be possible to organically implement the recommendations of Roslyakov, namely the formation of a mixture of $HCN$ and $NH_3$ products with an inert medium consisting of water vapor and flue gases.

It was established in [12] that the share of conversion of fuel nitrogen during the combustion stage is 20% at a maximum combustion temperature of 1,450 °C, i.e., the bulk of nitrogen remains in the coke particles. Then the question arises, why the main yield of fuel oxides of nitrogen occurs when the volatile substances burn, and not the coke residue.

IFHIMS (now – The Institute of solid state chemistry and mechanochemistry of Siberian Branch of the Russian Academy of Sciences) staff under the leadership of Orenbach established for the first time that when burning coal in combustion chambers of boiler units, the reactions with oxygen take place not only on the external surface, but also in the volume of fuel particles. It is noted that the internal surface of the reacting pores can significantly exceed the outer surface of the coke particles. Intraporous combustion covers mainly large pores (> 1 μm), and due to this process, the combustion of a pulverized-coal flame sharply intensifies. It has been established by special experiments that the internal reactions in the combustion of pulverized coal particles in the oxygen medium are associated with the penetration of carbon dioxide particles, not the oxygen, into the interior, as previously thought. Carbon dioxide is formed in the volume around the carbon particle during oxidation of $CO$.

The hypothesis of such a mechanism for the diffusion combustion regime was previously expressed, however, there was no experimental confirmation. According to Orenbach, penetration of $CO_2$ into the interior of a burning fuel particle becomes possible because of the low reaction rate constant

$$NH + OH \rightarrow NO + H_2,$$ \hspace{1cm} (13)

The carried out researches show that at high temperatures inherent in traditional designs of combustion chambers of modern boiler units, the rate of reaction of carbon with oxygen is 15-20 times lower than that with $CO_2$. When the temperature in the combustion chamber decreases from 1600 °C to 1100 °C, the effect of internal combustion gradually decreases.

Analyzing all of the above, the reason for the insignificant release of fuel oxides of nitrogen from brown coal coke particles can be explained as follows. Under the condition of intraporous combustion due to the penetration of carbon dioxide into the coke particles, according to the reaction (13), a reducing medium in the pores will be formed. This, in our opinion, will be one of the main reasons for the sharp decrease in the yield of fuel oxides of nitrogen in the burning of coke residues of solid fuels with a large yield of volatile substances.

Thus, it is experimentally confirmed that the industrial introduction of the technology of burning solid organic fuels in thermal power plants using the technology of their preliminary thermal preparation will allow to reduce emissions of nitrogen oxides by at least 2-3 times.

5. Conclusion

1. A semi-industrial installation was designed and mounted to implement a fundamentally new technology for preliminary thermal processing of coal in the temperature range from 300 to 900 °C, based on the partial combustion of coal dust with air excess ratio of 0.1-0.6, with the residence time of
coal particles in the installation of 0,6-1,5 s and using the received heat for the organization of high-
temperature heat processing of the main dust stream with the subsequent burning of products of thermochemical transformation. The quantitative and qualitative relationship between the regimes of the preliminary thermal processing of Kansk-Achinsk coals with a combination of physicochemical reactions taking place in the preparation and combustion of pulverized fuel is established.

2. It has been experimentally established that combustion of products of thermal processing of Kansk-Achinsk coals reduces the concentration of nitrogen oxides in flue gases. With a constant combustion temperature and air excess in the combustion chamber, at a preliminary thermal processing temperature of 650 – 850 °C, the concentration of nitrogen oxides in flue gases is at least 2-3 times lower than in the case of using raw (without preliminary processing) fuels.

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