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ANALYSIS OF QUANTITATIVE CHARACTERISTICS OF EMISSIONS OF "GREENHOUSE AND THERMAL" GASES DEPENDING ON THE TYPE OF FUEL

АНАЛІЗ КІЛЬКІСНИХ ХАРАКТЕРИСТИК ВИКИДІВ «ПАРНИКОВИХ ТА ТЕРМІЧНИХ» ГАЗІВ В ЗАЛЕЖНОСТІ ВІД ВИДУ ПАЛИВА

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Abstract. *The main goal of this article is to conduct a calculated study of the emission level of nitrogen and carbon oxides when burning different fuels at different power plants. Such installations are: boiler units with a circulating fluidized and fixed bed, as well as boiler installations with liquid and solid slag removal. Installations for burning anthracite coal with the aim of reducing the level of nitrogen oxide emissions are considered: boiler units with a circulating fluidized and fixed bed, as well as boiler installations with liquid slag removal and with solid slag removal. A comparative analysis of the emission level of nitrogen oxides during the burning of anthracite slag using different technological methods was carried out. The results of combustion of various types of fuel and the quantitative characteristics of carbon oxide emissions were analyzed. When burning any fuel, we get quite high values of carbon oxides, but we also observe that when burning coal, we get quite high values of carbon oxides, while burning wood and natural gas leads to the lowest values of carbon oxide emissions. It was established that the most optimal installation from the point of view of environmental friendliness is a circulating fluidized bed, the worst is an installation with liquid slag removal during flaring.*

Key words: *burning, fuel, emission level, nitrogen oxides, carbon oxides.*

Environmental pollution in fairly developed countries of the world is one of the most important and most urgent issues of our time, and it actually requires a lot of attention from both the community and state bodies, in particular, a lot of attention is paid to studying the environmental impact of energy production. Energy consumption is closely related to all types of human activity, such as: heating houses, cooking, moving vehicles, agricultural production, etc. But in Ukraine, compared to other countries, the situation is completely different. While all the countries of the world are trying to reduce the number of thermal power plants, Ukraine, on the contrary, is increasing the purchase of coal for thermal power plants. Combustion of solid and liquid fuel is accompanied by the release of sulfur, carbon dioxide and carbon monoxide gases, as well as nitrogen oxides, dust, soot and other polluting and dangerous substances [1].

Today, emissions from thermal power plants in Ukraine exceed the established standards of the European Union by 5-30 times and are the main air pollutants in the country. Therefore, providing favorable living conditions for the residents of the cities of our country is the main urgent problem that requires a clear analysis of the impact of harmful emissions of thermal power plants on the environment and the adoption of ways to solve this environmental problem

Worldwide, more than 80% of thermal and electrical energy is obtained by burning organic fossil fuels and converting its chemical energy into electrical and thermal energy. About 80% of all types of pollution of the biosphere are caused by energy processes. Due to the intensive use of the planet's non-renewable fuel and energy resources, their reserves have significantly decreased. In the structure of fossil organic fuels, the specific weight of oil is almost 45%, natural gas - 18%, coal - 37%. As a result of the combustion of C_nH_m hydrocarbons, n molecules of CO_2 carbon dioxide and m/2 molecules of H_2O water vapor are formed per one molecule of the fuel component. The named components belong to the so-called greenhouse gases, an increase in the concentration of which determines a change in the thermal equilibrium condition on the Earth's surface. In addition, in places with a large concentration of gross water vapor emissions, there may be negative consequences associated with a local change in the microclimate. In addition to the products of complete combustion of CO_2 and H_2O, nitrogen N_2 and an excess amount of oxygen O_2, flue gases may contain products of incomplete combustion in the form of carbon monoxide CO, commonly called carbon monoxide, hydrogen H_2 and unburned hydrocarbons $C_xH_yO_z$. Dissociation reactions also occur among the intermediate reactions in the combustion zone. For example, the oxygen dissociation reaction as a result of which two oxygen atoms are formed from one molecule.

$$O_2 \rightarrow 2O, \quad (1)$$

Oxygen atoms O are characterized by increased chemical activity and, having collided with the usually neutral nitrogen molecule N_2 at high temperatures, contribute to the reaction of the formation of the so-called thermal nitrogen oxide

$$NON_2 + O \rightarrow NO + N. \quad (2)$$

As a result of reaction (2), an active nitrogen atom N will be formed, which reacts with oxygen to form additional nitrogen oxide and chemically active atomic oxygen:

$$O_2 + N \rightarrow NO + O. \quad (3)$$

An appropriate amount of nitrogen oxides will be formed in the combustion products, the concentration of which depends on many factors and primarily on the temperature level in the combustion zone. Therefore, such nitrogen oxides are called thermal. The theory of their formation was first developed by Y. B. Zeldovych.

Analysis of recent research and publications. Different scientists deal with the problem of "greenhouse and thermal gases", such as nitrogen oxides and carbon oxides. Y. S. Mysak studied the combustion of fuel in pulverized coal boilers while maintaining the reliability of equipment operation, improving environmental indicators and reducing harmful emissions into the environment of thermal power plants [2]. L.O. Kesova developed and implemented a high-pressure dust supply system for TPP-210A boilers of the Trypil TPP [3], which contributes to the reduction of nitrogen oxides. Kotler, V.R. in the study "Nitrogen oxides in boiler flue gases" [4] described in detail the processes of nitrogen oxide formation in flue gases.

Highlighting previously unsolved parts of the overall problem. Scientists around the world are trying to reduce the amount of emissions into the environment, this can be done in many ways. One of these ways is the choice of technological process of combustion. A lot of research has been conducted on this topic, but in the literature there is no data on the comparative analysis of the amount of emissions of "greenhouse gases" by the type of fuel.

The purpose of the article. The main goal of this article is to conduct a calculated study of the emission level of nitrogen and carbon oxides when burning different fuels at different power plants. Such installations are: boiler units with a circulating fluidized and fixed bed, as well as boiler installations with liquid and solid slag removal.

Presenting main material. Let's consider the above settings in more detail. A fluidized bed is a two- or three-phase system, which is created by bringing the particles of the solid phase to a suspended state by dynamically affecting them with an upward flow of liquid or gas (air). In furnaces with a fluidized bed, the lifting force of the gas-air flow balances the weight of the particles, due to which fluidization occurs - intensive heat and mass exchange along the height and cross-section of the layer. In the upper layer space, the live cross-sectional area is larger, and, therefore, the gas velocity is lower (up to 1.0–2.5 m/s), and most of the particles removed from the layer fall back into the layer. Due to the fact that the combustible particles, the proportion of which is small in the layer, are surrounded by inert gases, they do not overheat, and the average temperature of the layer does not exceed 950°C. Under these conditions, the generation of nitrogen oxides is low. The relatively low specific rate of burning of carbon and its concentration in the layer are compensated by the relatively large mass and height of the layer (up to 1.0–1.2 m), and deep burning of most particles is achieved due to a sufficiently long time of their stay in the furnace. The fluidized bed is undemanding to fuel quality: it burns coal and carbon-containing waste with an ash content of up to 70% and a relatively low ash content of up to 60% [5].

A firebox with a fixed bed is a type of fuel burning that originates from the development of fire by ancient people in the form of bonfires. In furnaces with a fixed layer, the fuel lying freely on the grates is blown from below by air. The presence of fines in the fuel, on the contrary, is critical: it not only increases the loss of unburned carbon with carry-out, but, more importantly, prevents the free passage of the oxidizer through the bed. Due to this, zones of oxidizing leakage occur in the layer and, as a result, zones of uneven combustion - cooling (which causes local underburning and emissions of CO with flue gases), as well as zones of overheating (result - accelerated destruction of the lattice) [6].

There are different types of furnaces with liquid slag removal. The operating conditions of a semi-open single-chamber furnace with liquid slag removal are much more favorable. Here, the melting zone and the cooling zone are largely separated. In the combustion chamber, the screen pipes are studded and covered with a refractory coating. The fuel burning process is almost completely completed in this chamber, and its volume is relatively limited, due to which the intensity of heat generation here is 0.5-0.8 MW/m3, and the temperature is 1700-1800 °C. 20-40% of fuel ash is caught in the chamber, which is removed in a liquid state through the fly. In the upper part of the furnace, there are open screen surfaces that provide cooling of the gas and exhaust.

In a two-chamber furnace with liquid slag removal, the fuel combustion chamber with liquid slag and the cooling chamber are separated by slag separator grates, which are made of thin studded screen pipes with a refractory coating. The main amount of molten slag is caught in the combustion chamber. The additionally captured slag flows to the bottom of the furnace, from where it enters the water bath for granulation through the fly. Up to 70% of all ash is captured in a two-chamber furnace [7].

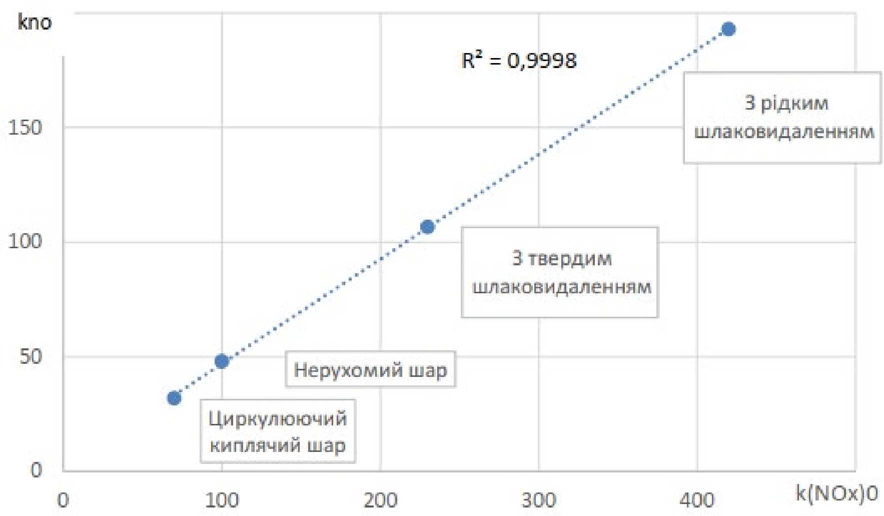
To determine the most effective technological method of burning anthracite slag, among those considered above, it is necessary to calculate the level of nitrogen oxide emissions. Calculations were performed according to [8]. According to the calculations, the following data were obtained, which are listed in Table 1.

Figure 1 shows the dependence of the emission of nitrogen oxides during coal combustion in a circulating fluidized bed, with liquid and solid slag removal during flare combustion and in a fixed bed. It can be seen from the graph that the most optimal setting from the point of view of environmental friendliness is a circulating fluidized bed, the worst is a setting with liquid slag removal during flaring.

Table 1. - Emission rate of nitrogen oxides when using different technological methods of burning anthracite wood.

Installation for incineration of AS	Emission rate of nitrogen oxides, /Gcal
With a circulating fluidized bed	32
With a stationary layer	49
With liquid slag removal	190
With solid slag removal	105

Source: author's development



Source: author's development

Figure 1. The dependence of the emission of nitrogen oxides.

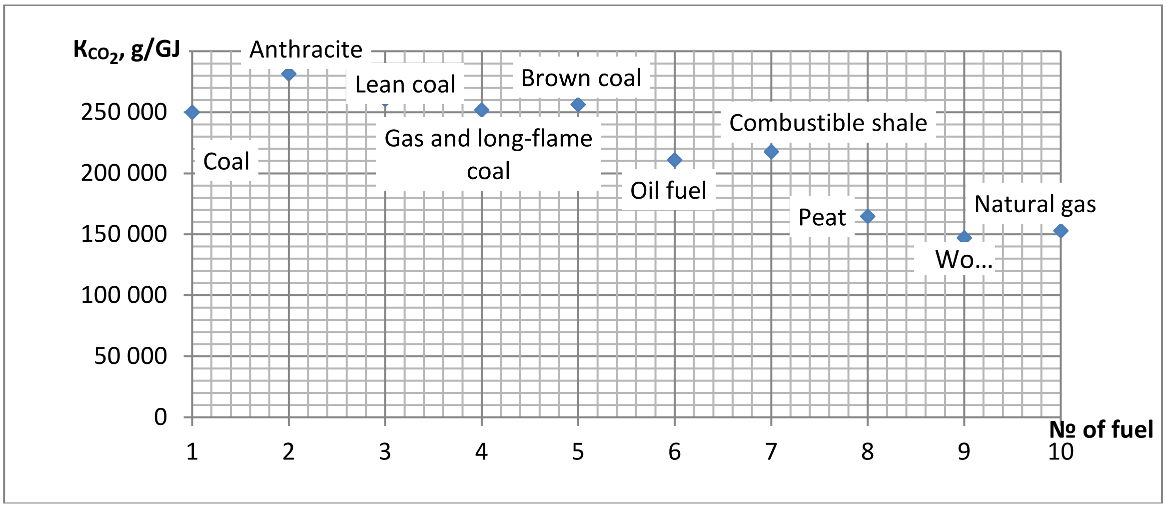
As for carbon oxides, according to [8], the following study was conducted on the dependence of carbon oxide emissions on the type of fuel. The resulting calculations are listed in Table 2.

Table 2. - Indicator of emission of carbon oxides when burning different types of fuel.

№ of fuel	Fuel	Value, g/GJ
1	Coal	250 000
2	Anthracite	281 600
3	Lean coal	260 500
4	Gas and long-flame coal	251 800
5	Brown coal	256 300
6	Oil fuel	211 000
7	Combustible shale	217 650
8	Peat	164 700
9	Wood	147 060
10	Natural gas	153 000

Source: author's development

According to the calculations, a graphical dependence was constructed, which is shown in Figure *2*.



Source: author's development

Figure 2. A graphical dependence according to the calculations.

It can be seen from the graphical dependence that when burning any fuel we get quite high values of carbon oxides, but we also observe that when burning coal, we get quite high values of carbon oxides, instead burning wood and natural gas leads to the lowest values of oxide emissions carbon

Conclusions and proposals. The following installations for burning anthracite coal with the aim of reducing the level of nitrogen oxide emissions were considered: boiler units with a circulating fluidized and fixed bed, as well as boiler installations with liquid slag removal and with solid slag removal. A comparative analysis of the emission level of nitrogen oxides during the burning of anthracite slag using different technological methods was carried out.

The results of combustion of various types of fuel and the quantitative characteristics of carbon oxide emissions were analyzed. When burning any fuel, we get quite high values of carbon oxides, but we also observe that when burning coal, we get quite high values of carbon oxides, while burning wood and natural gas leads to the lowest values of carbon oxide emissions.

It was established that the most optimal installation from the point of view of environmental friendliness is a circulating fluidized bed, the worst is an installation with liquid slag removal during flaring.

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