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# EMISSIONS OF CARBON DIOXIDE WHEN BURNING DIFFERENT TYPES OF FUEL AND CONSTRUCTION OF NOMOGRAMS FOR CALCULATION OF NITROGEN OXIDES

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***Abstract.*** *Carbon oxides as well as nitrogen oxides can have a negative impact on the environment and human health. They are one of the main factors of air pollution and can cause respiratory diseases and other health problems. Various methods can be used to reduce carbon oxide emissions from fuel combustion, such as using cleaner fuels, increasing combustion efficiency, and implementing emission control technologies. One of the most important methods of combating nitrogen oxides is the control of emissions of nitrogen oxides into the atmosphere. This can be achieved by installing effective exhaust gas treatment systems on vehicles, industrial plants home heating systems.*

***Key words:*** *burning, natural gas, solid fuel, oil fuel, nitrogen oxides, emission index, carbon oxidation.*

**Introduction**. The main sources of harmful emissions into the atmosphere also include thermal power plants and industrial and heating boiler houses. Energy carriers at these facilities are organic fuel, which is divided into solid, liquid, and gaseous. During the burning of various types of coal, fuel oil, and natural gas, a large number of pollutants enter the atmosphere, which have a negative impact on the environment and atmosphere.

Carbon oxides are one of the most common gases produced during fuel combustion in various power plants. Nitrogen oxides are among the most toxic and harmful emissions. Therefore, the study is devoted to the calculation of carbon dioxide emission indicators and nitrogen oxide emission indicators for different types of fuel and different brands.

**Main text.** The results of the research can be used to develop more effective methods of controlling gas emissions into the atmosphere and reducing their negative impact on the environment and human health.

Combustion is one of the main processes that occur in nature and is used by humans to obtain energy. During discharge, substances usually combine with air oxygen, forming oxides. When hydrocarbons and carbon fuels are burned, hydrogen and carbon form water and carbon dioxide, respectively.

In the work, carbon oxide emission indicators were calculated for different types of fuel and different brands [2].

Carbon dioxide emission index $k_{CO_2}$, g/GJ, during combustion of organic fuel is determined by the formula

$$k_{CO_2} = \frac{44}{12} \cdot \frac{C^r}{100} \cdot \frac{10^6}{Q_i^r} \varepsilon_C = 3{,}67 k_C \varepsilon_C , \qquad (1)$$

where $C^r$ –mass content of carbon in fuel per working mass, %;

$Q_i^r$ –lower working heat of fuel combustion, MJ/kg;

$\varepsilon_C$ –degree of carbon oxidation of the fuel;

$k_C$ –fuel carbon emission index, g/GJ.

The results of the calculations are summarized below and presented in graphs in Figures 1-2.

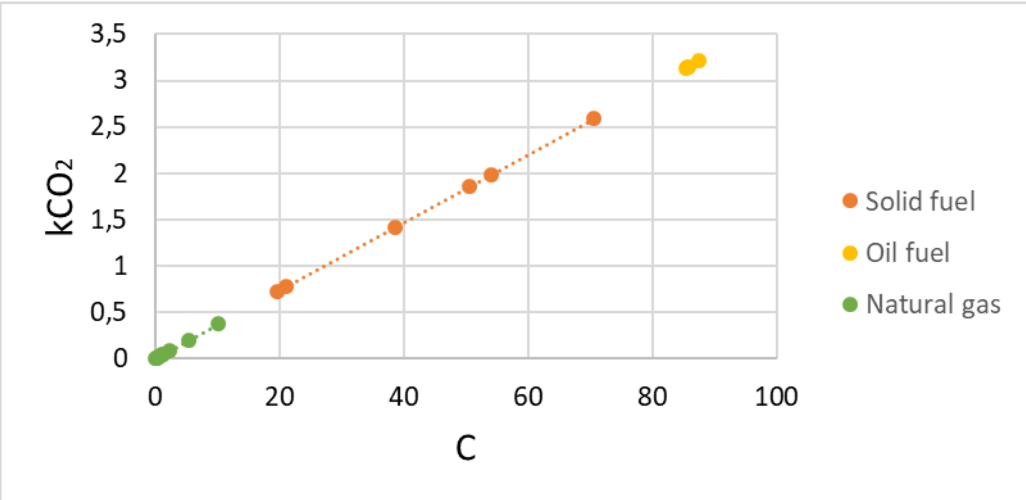


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**Figure 1 - Dependence of carbon dioxide emission indicators when burning different types of fuel.**

The degree of carbon oxidation of the fuel $\varepsilon_C$ in the power plant is calculated according to the formula

$$\varepsilon_C = 1 - \frac{A^r}{C^r}\left( a_{вин} \frac{\Gamma_{вин}}{100 - \Gamma_{вин}} + (1 - a_{вин}) \frac{\Gamma_{шл}}{100 - \Gamma_{шл}} \right), \qquad (2)$$

where $A^r$ – mass content of ash in fuel per working mass, %;

$C^r$ – mass content of carbon in fuel per working mass, %;

$a_{вин}$ – the fraction of ash that is removed in the form of fly ash;

$\Gamma_{вин}$ – mass content of combustible substances in the removal of solid particles, %;

$\Gamma_{шл}$ – mass content of combustible substances in slag, %.

The work also calculated nitrogen oxide emission indicators for different types of fuel and different brands.

The indicator of the emission of nitrogen oxides kNOx, g/GJ, taking into account emission reduction measures, is calculated [4]:

$$k_{NOx} = (k_{NOx})_0 f_н (1-\eta_I)(1-\eta_{II}\beta), \qquad (3)$$

where $(kNOx)_0$–indicator of the emission of nitrogen oxides without taking into account emission reduction measures, g/GJ; $f_n$ – degree of NOx emission reduction during low-load operation; $\eta_I$ – effectiveness of primary (regime-technological) emission reduction measures; $\eta_{II}$ – efficiency of secondary measures (nitrogen treatment plant); β – the coefficient of operation of the nitrogen treatment plant.

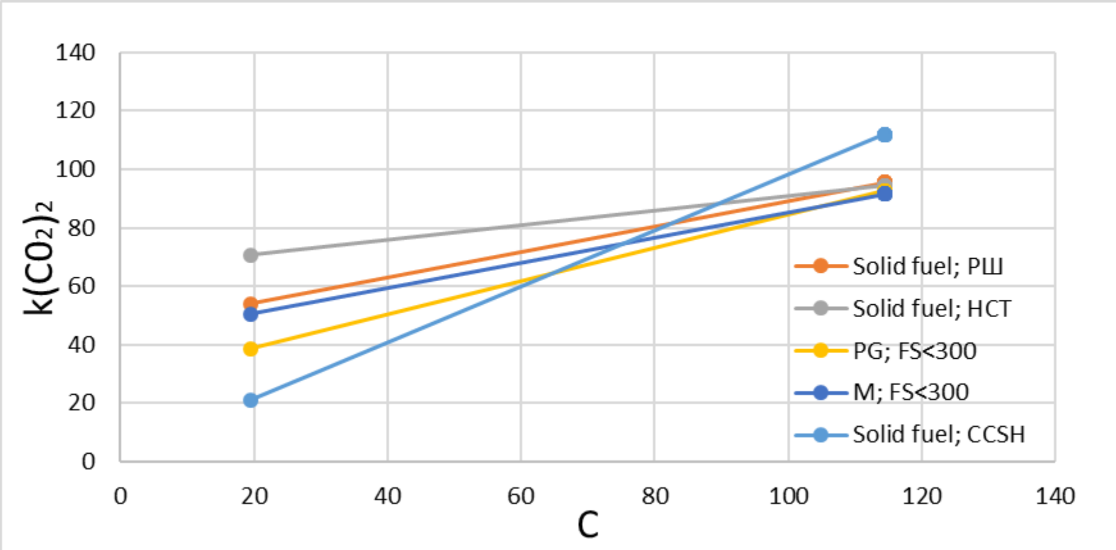


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**Figure 2 - The degree of dependence of the generalized emission indicators of carbon oxidation of the fuel $\varepsilon_C$ in a power plant.**

The results of the calculations are summarized below and presented in graphs in Figures 3-7.

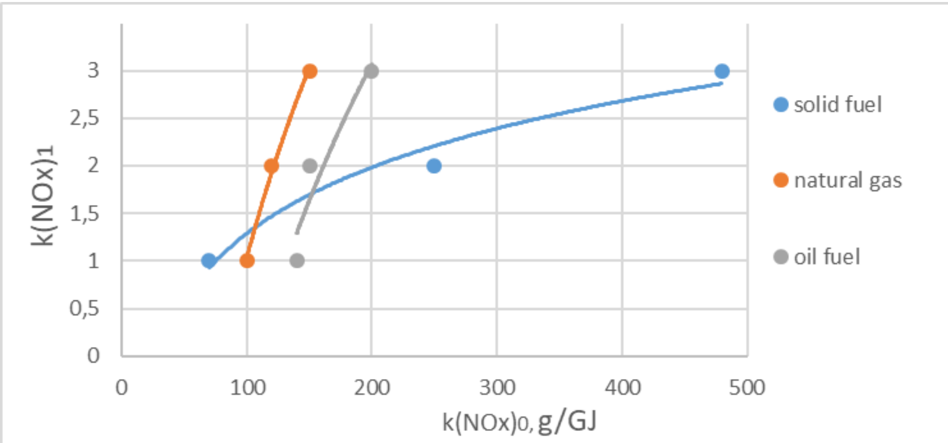


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**Figure 3 - Dependence of nitrogen oxide emission indicators when burning different types of fuel.**

Figure 3 shows the results of calculating the nitrogen oxides emission index relative to the nitrogen oxides emission index without taking into account primary measures, i.e. the formula took the form:

$$k_{NOx} = (k_{NOx})_0, \quad (4)$$

It should be noted that k(NOx)1 is a calculation step.

It can be seen from the graph that when fuel oil and natural gas are burned, the nitrogen oxide emission indicators are somewhat lower, so they are smaller and grow rapidly, in contrast to the indicator when burning solid fuel.

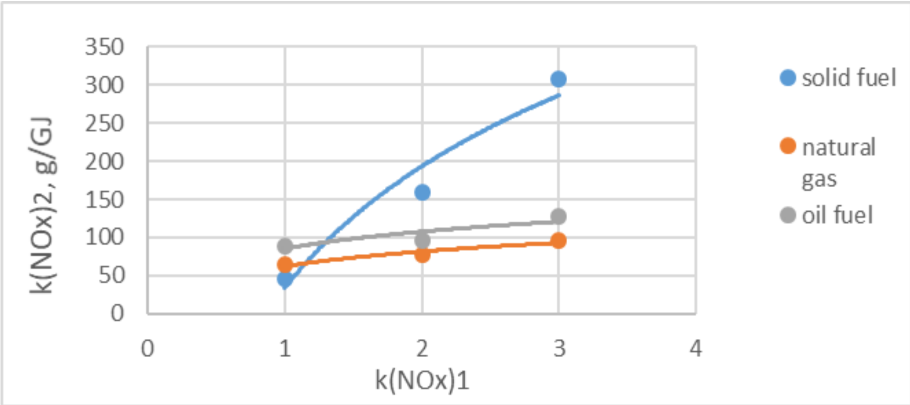


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**Figure 4 - Dependence of nitrogen oxide emission indicators taking into account the degree of reduction of NOx emission during operation at low load ($f_n$).**

Now the formula looks like this:

$$k_{NOx} = k_{(NOx)2} = (k_{NOx})_0 f_n, \quad (5)$$

where, in turn: $f_n = (\frac{Q_f}{Q_n})^z$

$Q_f$ - the actual input thermal power of the combustion plant, MW ($Q_f = 0,7\ Q_n$); $Q_n$ - the nominal input thermal power of the combustion plant, MW; z - an empirical coefficient that depends on the type of combustion plant, its power. For solid fuel z =1,15, and for fuel oil and natural gas – z =1,25).

From the graph, we can say that the indicators when burning natural gas and fuel oil are much lower and the difference between their maximum and minimum values is not large, so their graphs are more horizontal and straight.

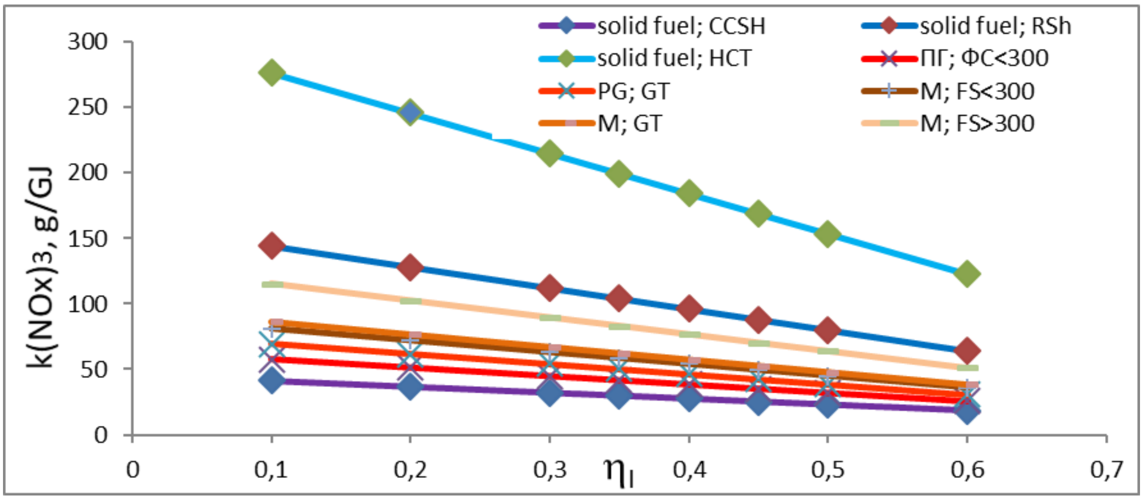


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**Figure 5 - Dependence of generalized indicators of nitrogen oxide emissions, taking into account the efficiency and the coefficient of operation of the NOx nitrogen treatment plant with different combustion technologies ($\eta_I$).**

Now the formula looks like this:

$$k_{NOx} = (k_{NOx})_3 = (k_{NOx})_0 f_n (1 - \eta_I), \quad (6)$$

It can be seen from the graph that the most optimal option for all technologies and types of fuel is the value $\eta_I$= 0,3-0,45, which corresponds to such type of primary measures as step air supply and tertiary air supply [3].

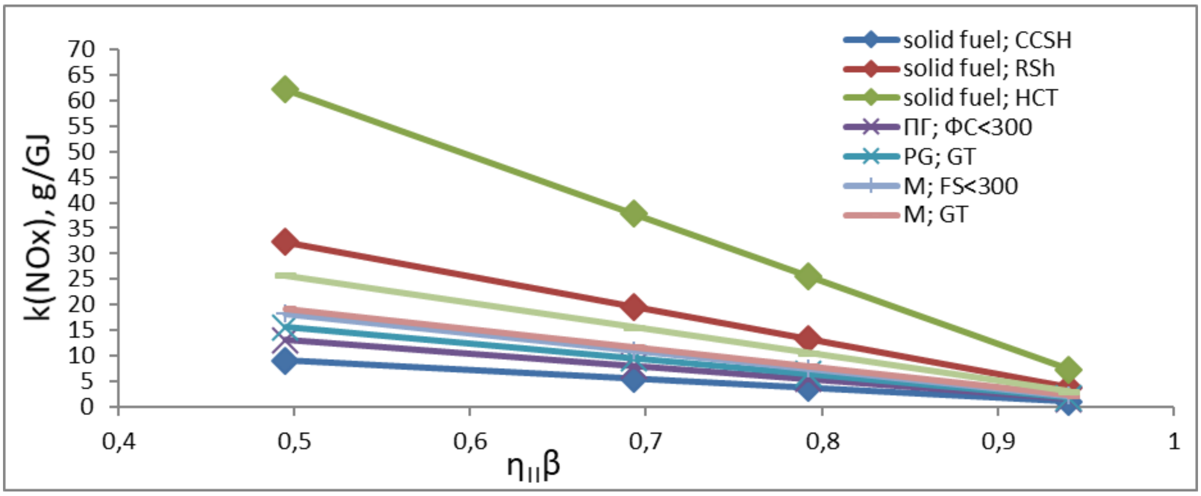


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**Figure 6 - Dependence of the minimum values of nitrogen oxide emission indicators taking into account the effectiveness of secondary measures$\eta_{II}$and the operation coefficient of the $NO_x$ nitrogen treatment plant at different combustion technologies ($\eta_{II}\beta$).**

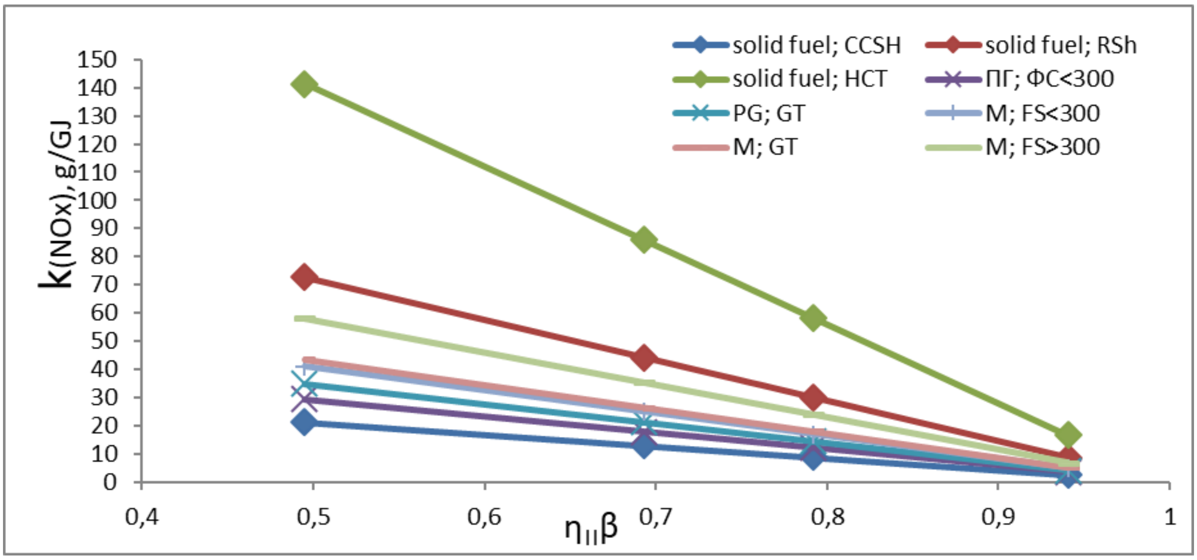


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**Figure 7 - Dependence of the maximum values of oxide emission indicators nitrogen, taking into account the effectiveness of secondary measures$\eta_{II}$and the coefficient of operation of the NOx nitrogen treatment plant at different combustion technologies ($\eta_{II}\beta$).**

Figures 6 and 7 show the results of the calculation of the generalized indicator of the emission of nitrogen oxides kNOx at the minimum and maximum values of the indicator (kNOx)3 in relation to the effectiveness of secondary measures$\eta_{II}$and the coefficient of operation of the NOx nitrogen purification plant. That is, the formula took the form:

$$k_{NOx} = (k_{NOx})_0 f_н (1-\eta_I)(1-\eta_{II}\beta), \quad (7)$$

It can be seen from the graphs that the highest indicator of nitrogen oxide emissions remained when solid fuel was burned using the technology of flare combustion with a thermal power of a boiler < 300 MW with a horizontal cyclone furnace for hard coal. The lowest and average indicators also remained for the same combustion technologies and types of fuel.

The optimal value of ηIIβ for all types of fuel is 0,8, that is, it is possible to choose such a technology for cleaning flue gases from NOx as selective catalytic reduction (SCR).

**Summary and conclusions**. Were received that the most effective in reducing nitrogen oxide and carbon dioxide emissions is a three-stage supply of air and fuel. Calculations showed that the use of a combination of "low-toxicity burners, staged air supply and tertiary air supply" helps to reduce the content of nitrogen oxides in exhaust gases. It is also advisable to use selective catalytic reduction (SCR).

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