Determining the Environmental and Thermal Characteristics of Coke Oven Batteries


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Abstract—A method is proposed for assessing the environmental and thermal characteristics of coke oven batteries and is tested for coke oven batteries 1 and 5 at OAO Zaporozhmkoks. On the basis of data for the environmental and thermal value of the coke oven batteries, their operation is analyzed, and recommendations for compliance with pollutant-emission standards are outlined.

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The main goal of coke oven battery management is to organize the production of the required quantity of blast-furnace coke of specified quality. However, this must be accomplished in a socially acceptable manner: without excessive heat consumption in coking or excessive environmental emissions of pollutants [1–4]. Measures for compliance with standards regarding the stack emissions of coke oven batteries must be developed, in accordance with Order 108 of the Ukrainian Environmental Ministry. One approach here is regulation of coke oven battery heating.

The production of coke and gas is accompanied by heat consumption and copious atmospheric emissions of pollutants. Accordingly, it is necessary to reduce heat consumption in coking, to comply with emissions standards, and to develop indices quantifying the environmental and thermal characteristics of coke oven batteries, as a function of their design, the state of the furnace-chamber walls and the heating system, the operating conditions, the thermal efficiency of the batteries, and the consumption and quality of the heating gas employed [5].

The growing requirements on fuel efficiency and air quality call for systematization, generalization, and supplementation of the existing methods for testing and assessing the level of coke oven battery operation, as well as the thermal and environmental characteristics of the coke oven batteries [6].

Similar issues were addressed in 1992 for boiler systems, by the Ukrainian Gas Institute, with the collaboration of the Environmental Ministry and the State Gas Administration. A uniform approach to the testing of boiler systems and the formulation of accounting documentation was outlined in the resulting methodological handbook [7–9].

Atmospheric protection from pollutants in fuel combustion entails reducing the volume of pollutants released into the air and reducing the energy consumption in industrial production [4].

In developing recommendations for determining the thermal and environmental characteristics of coke oven batteries, we take account of the methodological handbook already mentioned [7–9]; methodological recommendations (developed by the Coal-Chemistry Institute) regarding the development of an inventory of pollutant releases into the atmosphere at coke plants [10]; and European experience with standards limiting pollutant content in coke oven battery waste gases (adopted in the 1990s) [2, 4, 5].

The pollutant emissions depend on the operational conditions of the coke oven batteries, the state of the heating system, the quality of the heating gas, the coal blend quality, and the level of maintenance (removal of all deposits within the oven chamber; sealing of surface cracks and damage; maintenance of unclogged gas passages; maintenance of appropriate pressure in the gas collector, etc.).

In the combustion of coke-oven gas in the heating system, the following pollutants are formed and released to the atmosphere with the waste gases: nitrogen oxides (NO and NO₂); sulfur dioxide (SO₂); carbon
Nitrogen oxides are regarded as major environmental pollutants. Depending on the combustion zones of the flame in which they are formed, they are classified as thermal gases, fuel gases, or fast gases. The NO formed in the heating channels is sent through the stack to the atmosphere. In the coke oven batteries, there is practically no conversion of NO to NO\(_2\). After leaving the stack, most of the NO is oxidized to NO\(_2\). The formation of nitrogen oxides in gas combustion may be reduced by thermal methods (such as selecting a rational air excess; recirculation in the combustion zone; or combustion in stages) based on reducing the maximum temperature in the combustion zone. This minimizes the formation of thermal NO; the total yield of nitrogen oxides then consists only of the fast and fuel gases [2, 3, 12].

Coke-oven gas includes hydrogen sulfide H\(_2\)S, which burns in an oxidative atmosphere to form mainly sulfur dioxide and water.

Given that the quantity of sulfur oxides depends only on the hydrogen-sulfide content in the heating gas and does not depend on the combustion conditions, we recommend sampling of the SO\(_2\) content in the waste gases be disregarded in determining the thermal and environmental characteristics of coke oven batteries.

The gross pollutant emissions from coke oven battery stacks may be determined both on the basis of experimental data and by calculation from the flow rate and composition of the gas used in coke oven battery heating [10, 13].

The pollutant concentration in the waste gases is due to the following factors:
- the temperature in the heating channels;
- the air excess;
- the gas consumption in battery heating and its content of hydrogen sulfide, ammonia, cyanides, and unsaturated hydrocarbons;
- the leakage of coke-oven gas into the heating system.

To assess the influence of these factors on the pollutants emissions with the waste gases, we need to determine their concentration in the combustion products, in different coke oven battery operating conditions.

The actual emission rate (g/s, t/yr) at the coke oven battery stacks is established on the basis of measurements. The plant’s pollutant emissions must not exceed the limiting permissible values established by state standards. The plant’s level of emissions is determined on making an inventory of pollutant emissions.

For coke oven batteries, environmental and thermal tests are conducted with the following goals:
- determination of the thermal and environmental characteristics of the coke oven batteries;
- compilation of an inventory of pollutant emissions with the waste gases;
- establishment of optimal conditions of coke oven battery operation (in the light of the technological conditions and the minimum possible heat losses with the waste gases) and determination of the pollutant emissions consistent with the corresponding standards.

Gas analyzers are recommended for determination of the pollutant content in the waste gases. Such analyzers permit rapid (real-time) and accurate determination of the following parameters: the O\(_2\), CO, CO\(_2\), NO, NO\(_2\), and SO\(_2\) concentrations in the waste gases; the temperature of the waste gases; the ambient temperature; the pressure; and the flow rate.

The tests must be conducted using equipment included in the State Register of Measuring Instruments, with a certificate of metrological attestation (by the State Committee on Standardization, Metrology, and Certification) and also a verification certificate. Depending on the system design, the temperature conditions, and the measuring instruments, we recommend sampling of the waste gases from coke oven batteries in the flues at the sides of the battery, in the common flue, or in the stack, in view of the requirements of State Standards GOST 17.2.4.06 and 17.2.4.07 and standard KND 211.2.3.063–98 and the methodological recommendations noted earlier regarding the compiling of an inventory of pollutant emissions at coke plants [10].

For the specific heating-system design—the exchange of gas flows in the heating channels (switching)—combustion-product samples must be taken over at least one switching cycle with gas combustion in each of the different heat channels—in other words, over two successive switching cycles. The result is the mean of a series of data for samples corresponding to switching cycles in each case.

The environmental and thermal tests of coke oven batteries include assessment of the actual state of the heating system, with the determination of the following parameters:
- the leakage of coke-oven gas into the heating system;
- the temperature and composition of the waste gases;
- the air excess;
- the thermal efficiency of the ovens;
- the pollutant content in the waste gases.

On the basis of the results, a program of adjustment and environmental and thermal testing is formulated. The tests program may be refined on the basis of snapshots of coke oven battery operation. Since the basic factors determining the thermal and environmental characteristics of the coke oven battery are the temperature conditions and the combustion conditions of the heating gas, the environmental and thermal tests are...