

## AIR POOL PROTECTION FROM EMISSIONS OF THE POWER INDUSTRY

## 1.1. Reducing nitrogen oxides emissions

## 1.1.2. Technological methods to reduce nitrogen oxide formation in the boilers during combustion of different types of organic fuel

## 1.1.2.2. Modernization of the furnace process

1.1.2.2.1. Low  $\text{NO}_x$ -emission burners

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Feature of these burners is the structural features, which regulate the intensity and sequence of mixing fuel with air flow. Using the ration of the velocity and twist inward and outward flows of secondary air, the authors of low-emission burners actually organize a stepped air inlet in the flame of separate burner, and in some cases even stepped fuel supply with the partial restoration of  $\text{NO}$  in each flame.

Virtually all boiler-building factories in Europe, Japan and the USA have spent design coal-fired swirl or straight-flow burners, which providing reducing of  $\text{NO}_x$  emissions on 30...50 % during combustion of gas and high-quality brands of black coals. Structural details of these burners are different, but they are all characterized by a common ideology. Low-emission burners must:

- inhibit the oxide-rich admixture of secondary air to ignite of air-fuel mixture in the inflamed root of flame;
- intensify heat and mass transfer between the air-fuel mixture and high temperature exhaust gases, which containing small amounts of oxygen;
- to ensure efficient combustion of fuel at the lowest possible quantity of primary air (for coal-fired burner);
- reduce the peak temperature in the flame core without affecting the stability of ignition and fuel combustion efficiency.

On oil-gas boilers suppression of  $\text{NO}_x$  is reached largely through recycling of exhaust gases, which fed in a certain way through the low-emission burners.

As a result, gas recycling not only reduce the maximum temperature in the flame core and reduce the current concentration of oxygen, but also localize zone by along the length of flame, enriched and depleted fuel – in fact on the horizontal section is provided by a two-stage combustion in the flame of each burner.

A good example of such a low-emission burner is a burner tube GTVich(III)-50 construction of TKZ-VTI, mounted on TPP-23 of the Open JSC “Mosenergo” during reconstruction of boiler TGMP-312C. At this boiler were installed 16 such burners in two tiers of burners instead of the four cyclones furnace extension (eight burners on the front and rear walls of the combustion chamber). The distance between the tiers of burners in the height of 3 m and above upper burners arranged nozzles of forced draught.

The design of burners (Fig. 1.11) provided the use of gas recirculation for staged combustion of fuel in the horizontal section of the flame. Scheme of gas-air ducts allow to feed through the nozzles of forced draught is not air, and gases recirculation during oil combustion in the boiler [10].

As seen in Fig. 1.11, natural gas is fed into the central part (through a cone nozzle) and in the middle part of the burner (on the gas-distributing tubes).

Air enters through the central and the two annual channels with internal and peripheral channel are separated by

channel-gas recirculation. Streams of the central air and gas recirculation move forward flow, and internal and peripheral flow of air to spin in an axial blending.

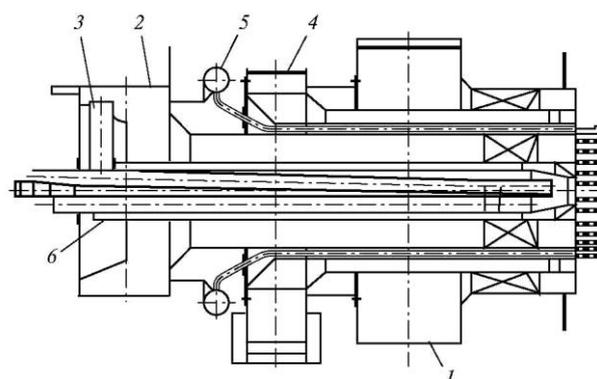


Fig. 1.11. Oil-gas burner TKZ—VTI:  
1, 2, 3 — air; 4 — gas recirculation; 5, 6 — natural gas

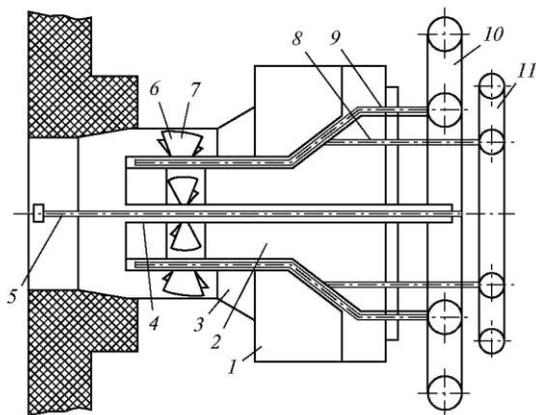
After reconstruction in conducting the parametric testes of the boiler was the dependence of the nitrogen oxide emissions from the basic regime parameters. It turned out that the proportion of air supplied through the upper nozzle,  $\beta = 32\%$  and a quantity of gas recirculation, which varies from 6 to 13 % by decreasing the boiler loading, the concentration of  $\text{NO}_x$ , even the loading close to nominal, does not exceed the allowable value ( $125 \text{ mg/m}^3$ ).

During oil combustion the nitrogen oxide emissions also were significantly lower, than in similar boilers with convectional swirl burners: the recycling of 6 % of exhaust gases and flow into the nozzle of forced draught 7...8% of the air concentration of  $\text{NO}_x$  was lower than  $220 \text{ mg/m}^3$  (expressed as  $\text{NO}_2$  at  $\text{O}_2 = 6\%$ ), which is lower than normal on the technical specifications ( $250 \text{ mg/m}^3$ ).

During tests of the reconstruction of the boiler were measured, confirming, that the step input of air, exhaust gas recirculation and reduction of excess air in the new burners do not create problems with emissions of the most dangerous gases. Measurements showed that the operating conditions benzopyrene content does not exceed  $0,063 \text{ mcg/m}^3$  at gas combustion and  $0,08 \text{ mcg/m}^3$  at oil combustion. The calculation of the maximum power of the benzopyrene emissions ( $M_{BP}$ , g/s) revealed that taking into account the dispersion of its contents in the surface layer of air does not exceed 0,05 MAC (maximum allowable concentration). This circumstance eliminated TPP-23 from the necessary of accounting and valuation of emissions of benzopyrene.

Another good solution to the problem of nitrogen oxide emissions by installing low low-emission oil-gas burner is boiler E-160-3.9-440, working for over 4 years at SPP-1 of the Open JSC “Mosenergo”. To solve the problem of nitrogen oxide emissions have developed a new low-emission burner VTI-ZiO (Fig. 1.12). The burner is made dual-stream

as on a fuel and on the air. A smaller part of the natural gas was fed through 10 gas-distribution tubes from small (lighting-up) gas collector. Through the other 20 tubes the rest of the gas supplied from a large gas collector. The air supplied through the central and peripheral channels of the burners, twisted blades of axial swirls. Gas recirculation were fed into the chamber in a mixture with air.



**Fig. 1.12. Oil-gas burner BTI—ZiO:**

1 — intake channel; 2 — central channel; 3 — peripheral channel; 4 — труба под форсунку; 5 — oil nozzle; 6 — центральный аксиальный завихритель; 7 — периферийный аксиальный завихритель; 8 — gas- I ступени; 9 — газораздающие трубы II ступени; 10 — газовая камера II ступени; 11 — газовая камера I ступени

Increasing the speed of natural gas and gas-air mixture at the exit of the burner, as well as the possibility of swirling off one of the gas reservoir and a gas-air channels provided a range of load control of the boiler from 100 to 30 % of the nominal without turning off the burner [11].

Parametric tests, which assess the dependence of the  $\text{NO}_x$  emission from the loading and excess air, have shown that the burner designed for natural gas combustion with recirculation of exhaust gases in an amount of 16 % provided the  $\text{NO}_x$  concentration is not above  $64 \text{ mg/m}^3$ . The maximum content of benzopyrene was obtained at minimum loading, and was  $0.039 \text{ mcg/m}^3$  (at  $\text{O}_2 = 6 \%$ ).

In the experiments, at the combustion of oil of type M100

new burner has confirmed the name “low-emission”: the concentration of  $\text{NO}_x$  at  $\alpha_d = 1,27$  was  $240 \text{ mg/m}^3$ , the content of smoke particle on the scale of Bacharach – 2, and the concentration of benzopyrene depending on the excess air was varied from 0.075 to  $0.105 \text{ mcg/m}^3$ .

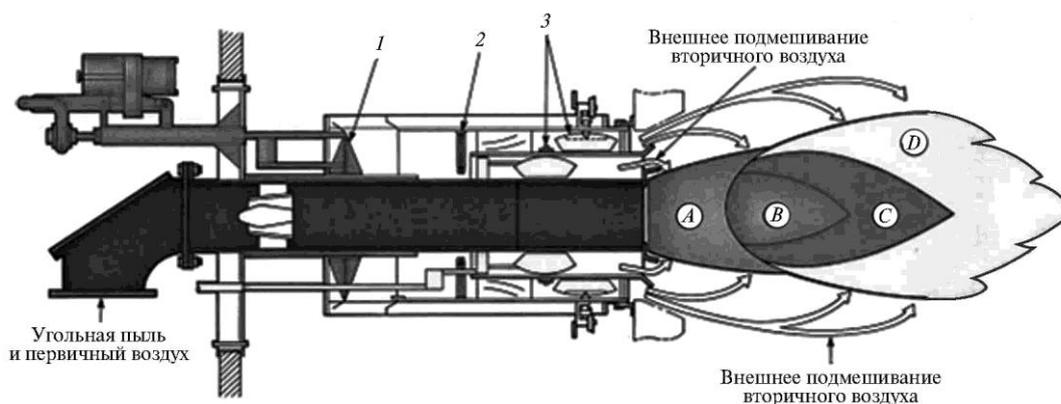
Calculation of the dispersion of the program “Ecolog” which made taking into account the height of the chimney and other parameters of SPP-1 showed that the content of benzopyrene in the air-ground interface does not exceed 0.005  $\text{MAC}_{\text{BP}}$  at combustion as natural gas, and as oil.

At solid fuel combustion design of the low-emission burners also can significantly reduce nitrogen oxide emissions. As noted earlier, almost all boiler-builds firms abroad have developed and successfully implement low-emission coal-fired burners. Enjoyed great fame of the two-register burners DRB-XCL™ (Fig. 1.13), developed by experts from Babcock & Wilcox McDermott company(USA, swirl burner (Fig. 1.14) by Mitsui — Babcock (UK) company and some other.

VTI staff together with designers from CCB “Energoremont” developed low-emission straight-flow burner for combustion of brown and black coals with high volatile-matter yield (grades G and D). This burner is characterized in that part of the secondary air deviates from the direction of the jet air-fuel mixture (fig. 1.15).

With this in boilers with tangential furnace organized “concentric” combustion, in which the center of the combustion chamber (cross section) the environment enriched with fuel, and on periphery is formed, closer to top of furnace screens, - enriched with air. Such an organization of furnace process reduces the risk of corrosion and crossing waterwall tubes, but most importantly, creates a staged combustion horizontally. In the central part of the furnace the fuel nitrogen is transformed into molecular nitrogen  $\text{N}_2$ , as a result of reduced emissions of nitrogen oxides.

The effectiveness of concentric combustion was confirmed in the 90<sup>th</sup> years after the introduction of burners on the boilers PK-24 of Irkutskaya TPP-10 and TP-85 of Irkutskaya TPP-9 [12/



**Fig. 1.13. Low-emission goal-fired burner by Babcock & Wilcox McDermott company:**

1 — slide air damper; 2 — measuring apparatus; 3 — regulate blade system; A — exit zone of flying; B — zone formation of reducing gases; C — decay zone of  $\text{NO}_x$ ; D — zone of chark post-combustion

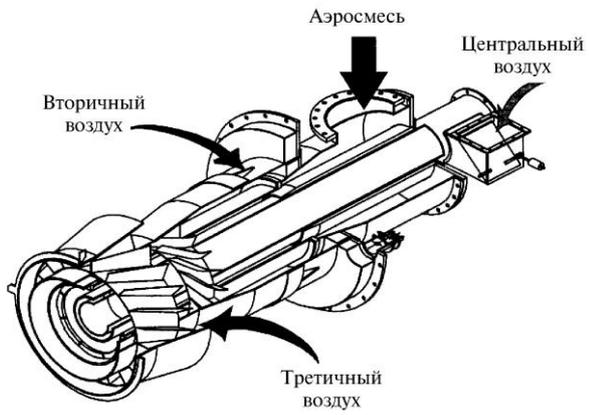


Fig. 1.14. Low-emission swirl burner by Mitsui — Babcock company

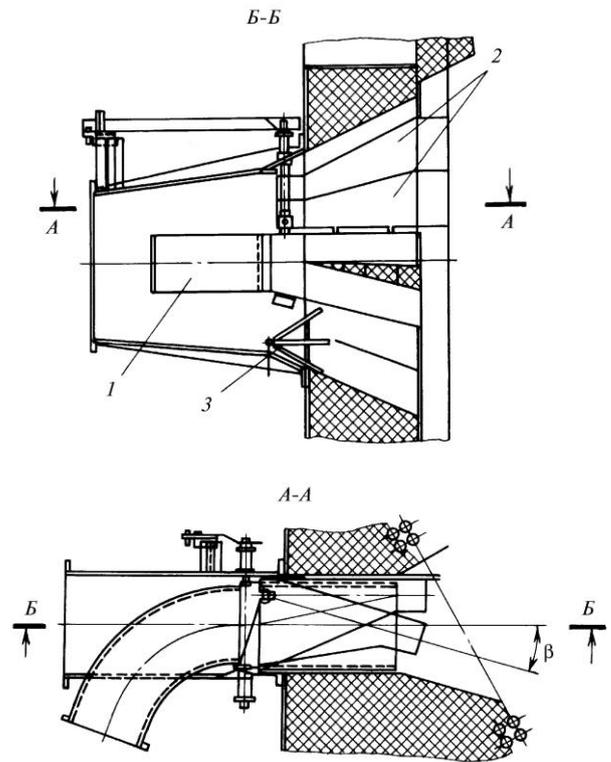


Fig. 1.15. Straight-flow coal-fired burner design by VTI-CCB “Energoremont” for the organization of concentric combustion:  
 1 — air-fuel mixture; 2 — upper rotating nozzle of secondary air (Over fire-air); 3 — butterfly damper for flow rate control of the secondary air