

AIR PROTECTION FROM POWER INDUSTRY EMISSIONS

1.5. Technologies of organic fuel combustion at TPPs with the lowered level of harmful emissions into atmosphere

1.5.5. Efficient reduction of nitrogen oxide emissions in the boiler furnaces by means of aerodynamic optimization of the staged fuel combustion

1.5.5.5. An efficiency of three-staged coal combustion in the U-shaped flame at BKZ-210-140FD(F) boilers of OJSC "Zapadno-Sibirskaya TPP"

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Before reconstruction BKZ-210-140FD boilers of OJSC "Zapadno-Sibirskaya TPP" were equipped with six dust, gas and oil burners of a snail-type, set by three at the side walls of the furnace under triangle scheme with its vertex down. By that, two top burners were installed at a mark of 10,7 m, and the lower burner – at a mark of 9.8 m.

Coal dust was directly fed from coal-pulverization systems through the annular channel. Buffer (and starting) fuel - coke oven gas was injected into the furnace through the annular channel of smaller diameter. Along the axis of burners, the nozzles, spraying oil, were installed. Oil is a reserve and an emergency fuel. The main buffer fuel - blast furnace gas and much of air fed into the furnace through four five-slot burners of blast furnace gas, set at a level of 10,5 m at the furnace front wall.

A main disadvantage of the technology consisted in supply into the furnace of different types of fuel and air in mutually perpendicular planes at a relatively low furnace. At combustion of intermediate products and oxidized kuznetsky coal, ignition was unstable, especially in regimes with a low proportion of buffer coke oven gas (there were cases of flame extinction even at medium boiler loads - 170 ... 180 t/h. The flame was drawn into the horizontal flue, slagging of steam superheater occurred and there was the uncontrolled rise in temperature of the metal pipe above its normal values. Combustibles in ash in case of large proportions of blast furnace gas combustion were often up to 25 ... 30%. The boilers were in operation at high specific emissions of nitrogen oxides (800 ... 850 mg/m³ compared to a standard value of 470 mg/m³).

The situation improved much after reconstruction of these boilers (during 1995 - 2001) with application of a technology of three-staged combustion of these fuels in the U-shaped direct-flow vortex flame [18 - 21]. The technology is as follows. Eight direct-flow burners, being rectangular nozzles of the coal dust mixture were installed at a level of 16,35 m at the furnace front wall. They were installed with a slope down to 60 ... 65° and placed in pairs over the burner of blast furnace gas. At a level of 14,5 m at the back wall coaxially with burners, rectangular nozzles of tertiary blast directed horizontally were placed. Two tubes of coke oven gas of 0,76 mm in diameter and the nozzle tube were placed under the body of each burner and slightly inclined to the center line of the vertical projection (Fig. 1.79 a).

At the boiler #5 (BKZ-210-140F) instead of missing burners of furnace gas, secondary air nozzles were installed in the same vertical planes with burners and nozzles with a uniform horizontal step. A level of their location was 9,75 m and the axes were inclined upwards to 10° (Fig. 1.80).

Coal-fired jet, flowing into the furnace at a speed of 27 ... 35 m/s at $\alpha_1 = 0,25 \dots 0,3$, dependably lights at a distance of 0,3 ... 0,4 m, even without coke oven gas lighting and at de-

crease in volatiles in coal. This is facilitated by the increased (with oblique cut) initial perimeter of ejection, elimination of jet ballasting by secondary air as well as velocity direction of the fresh jet towards the upstream flow of the burning down flame.

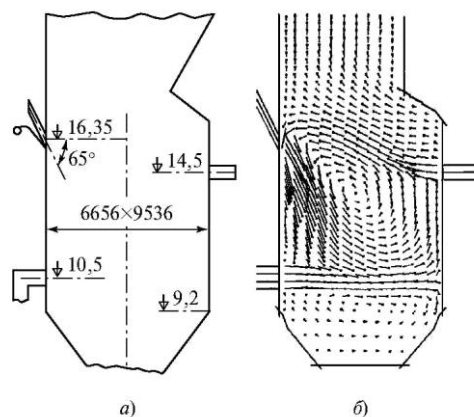


Fig. 1.79. Arrangement of burners and nozzles at BKZ-210-140FD boiler and the estimated velocity field in the vertical plane of the furnace: a - layout, b - velocity field

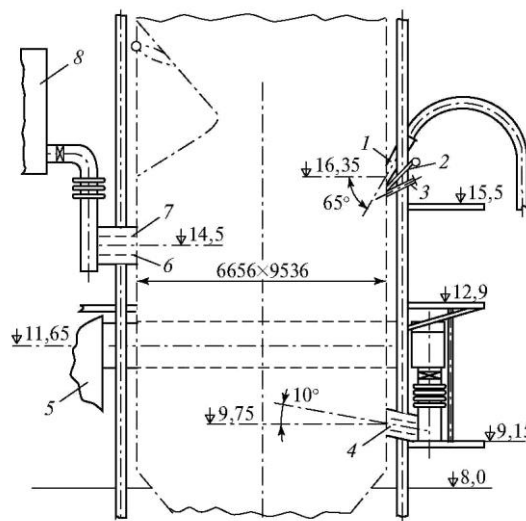


Fig. 1.80. Layout of burners, nozzles and supply air ducts at BKZ-210-140F boiler:

1 - pulverized coal burner, 2 - coke oven gas supply, 3 - nozzle pipe; 4 - secondary air nozzle, 5 - vertical hot air duct, 6 - lower section of tertiary air nozzle, 7 - upper section of tertiary air nozzle, 8 - outlet collector of air heater

At a distance of 5 ... 6 m (before meeting with the secondary air, entering the furnace from the furnace gas burners, the ignited dust moves with a slope down under conditions of a sharp shortage of oxygen. At the specified path there is a decrease in fuel NO_x formation due to decomposition of compounds of fuel nitrogen by products of incomplete burn-

ing with formation of molecular nitrogen.

Secondary air flow at $\alpha_2 = 0,55 \dots 0,6$ (or its mixture with the blast furnace gas) is mixed into a burning flame, moves with it to the back screen of the furnace, and then upwards, creating a cushion that prevents from falling out of the unburnt coal dust into the boiler throat, as well as from erosion and heat impact of the flame on the back screen. A lifting branch of the flame, interacting with tertiary blast jets and deflected by them to the over-burning furnace zone, afterburns due to tertiary air use.

Part of tail volume of tertiary air jet (mixed with furnace gases) is ejected by a fresh burner jet and enters together with it the furnace bottom. This could be clearly seen from Fig. 1.79 δ illustrating the estimated velocity field in the vertical plane passing through the pulverized coal burner, blast furnace gas burner and tertiary air nozzle.

Reliable ignition of coal dust and extended trajectory of the flame in case of three-staged air supply to the furnace contribute in levelling the flame temperature throughout its height, as well as in the flame turbulence and timely dust afterburning. As an example, Fig. 1.81 illustrates the results of the flame pyrometry at the boiler #5 at a load of 212 t/h, coke oven gas consumption of 2000 m³/h, two coal-pulverization systems in operation and $\alpha''_{ssh} = 1,275$ [22]. One can see that the recorded temperatures are almost the same throughout the furnace height. In the area of manholes located in the boiler throat at a level of 7,6 m, they were 1200 ... 1230°C, and at a level of 19,6 m (in front of screens), they made 1220 ... 1240°C. One can see that in the level range of 10,7 ... 14,2 m the flame temperature near the back wall was by 60 ... 70°C higher than near the front, which corresponds to the aerodynamics of the U-shaped flame in the second stage of combustion.

In the process of commissioning the boiler #5, tertiary blast jets were directed to interburner space of the front furnace wall due to installing one-way rail canopies in the upper and lower sections of nozzles at different side walls [23].

As a result, removal of the unburnt dust from peripheral layers of burner jets by tails of tertiary blast jets has been eliminated. In addition, doubling the number of fresh jets of tertiary blast resulted in more reliable cross section overlapping near the back wall of the furnace, where the burning down flame goes up, i.e. mixing of reagents has become more intense.

Fig. 1.82 shows the experimental relationship between α''_{ssh} and the key performance indicators of the reconstructed boiler #5 at a load of 175 ... 214 t/h and the heat percentage of coke oven gas of 2 ... 3%.

It can be seen that at the operational $\alpha''_{ssh} = 1,25 \dots 1,3$ specific emissions of nitrogen oxides were 360 ... 370 mg/m³ (instead of 900 ... 1000 mg/m³ before reconstruction), unburnt carbon decreased from 2,2 to 0,95%, and gross boiler efficiency increased by 1,0 ... 1,5% and made 91,7%.

During boiler testing before and after reconstruction, coal quality was about the same with the following average characteristics:

$Q_1^w = 4983$ kcal/kg; $W^w = 6,9$ %; $A^w = 26$ %; $V^c = 42,8$ %; $N^c = 2,5$ %. Fineness of coal dust grinding after the boiler reconstruction was recommended to be about $R_{90} = 11$ %.

At the reconstructed BKZ-210-140FD boilers at combustion of coal and coke oven gas, the unburnt carbon was about 2%, and specific emissions of nitrogen oxides made 380 ... 400 mg/m³.

The minimum permissible load at the reconstructed boilers ## 1-5 (under condition of a stable combustion without

flame lighting) was about 140 t/h vs 170 t/h before their reconstruction.

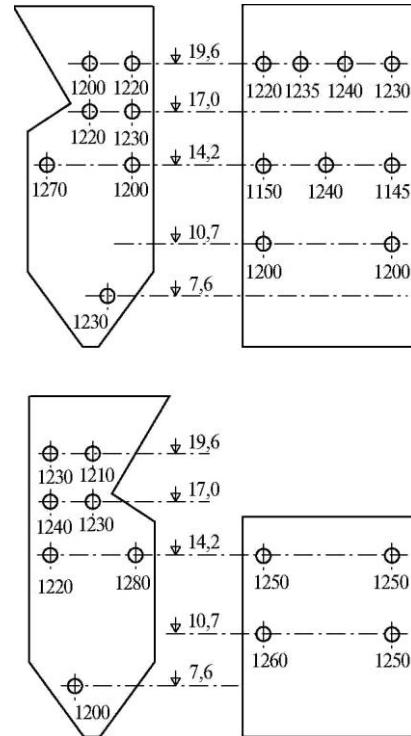


Fig. 1.81. Results of pyrometric measurements of the flame temperature at the reconstructed BKZ-210-140F boiler

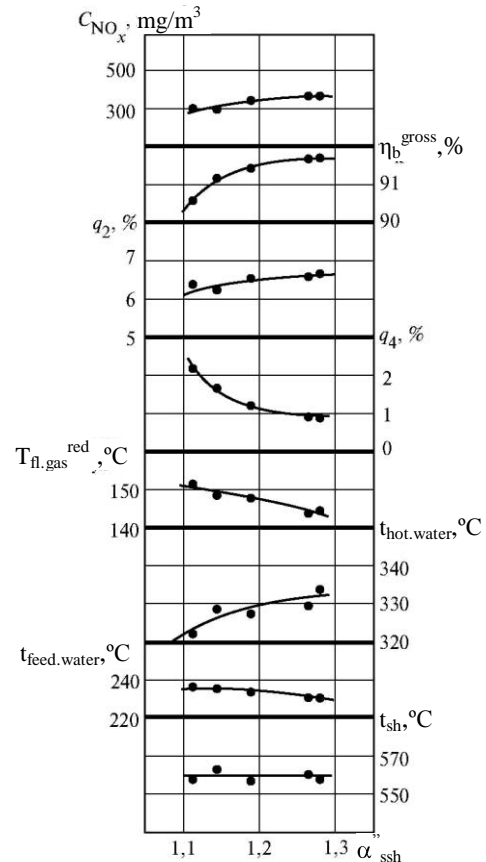


Fig. 1.82. Relationship between the key performance of the reconstructed BKZ-210-140F boiler and excess air after the steam superheater

Delayed combustion and slagging of steam superheaters stopped; in this connection a temperature of metal below the acceptable standards was provided.

Model studies have shown (Fig. 1.83, *a-z*) that an increase in the angle of burner inclination (in this case to 70°), adoption of higher speed of hot air flow (especially, of tertiary air), as well as an increase in horizontal partitions between burners and nozzles result in more expressed vortex nature of motion of the primary, secondary and tertiary air jets. From Fig. 1.83, *a*, *б* and *з* one can see that a part of the burning down flame makes a second turn, moving along the

spiral into interjet space, where it contacts a part of the tertiary air, falling here, i.e. this technology has a significant internal gas recirculation and the elongated trajectory of the turbulized flame. These features of the furnace aerodynamics predetermined a complex efficiency of the three-staged combustion of kuznetsky coal in the U-shaped direct-flow vortex flame.

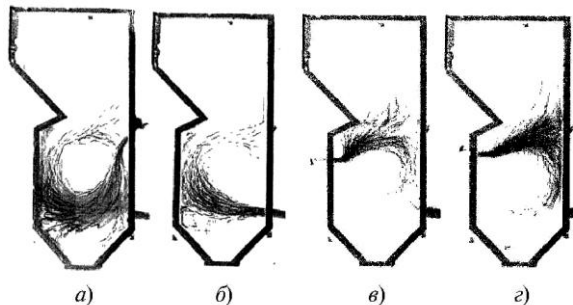


Fig. 1.83. A nature of aerodynamics in the optimum alternative of the model with the U-shaped flame at BKZ-210-140F boiler:

a - burner jets, *б* - secondary air jets, *в* and *з* - jets, flowing from the upper and lower sections of tertiary air nozzle