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

1.5.5.7. Results of the first phase of TP-87 slag-tap boiler adjustment at three-staged air supply into the flame of direct-flow burners

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TP-87 boiler of OJSC "Zapadno-Sibirskaya TPP" was reconstructed in 2005 under development of Boiler Plants and Ecology in Power Engineering Department of the Moscow Power Engineering Institute – MPEI TU and according to the project of OJSC "CKB Energoremont". A layout diagram of burners and nozzles, as well as of the feeding air lines in the longitudinal furnace section is shown in Fig. 1.85.

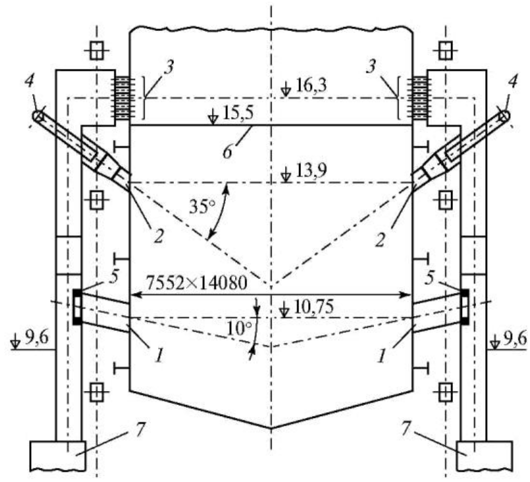

Fig. 1.85. Layout of burners, nozzles and supply air ducts at the slag-tap boiler TP-87: 1 – pulverized coal/oil burner ∅ 720 × 7 mm (12 pcs); 2 - combined nozzle ∅ 377 × 6 mm (12 pcs); 3 - unit of eight tubes ∅ 133 × 6 mm, within the tertiary air nozzles (12 pcs); 4 – discharge dust line ∅ 325 × 6 mm (12 pcs); 5 – bounding puck ∅ 470 mm (12 pcs); 6 - screen lining level; 7 - existing hot air collector (2 pcs)

Due to rotation at an angle of 8,5° relative to a normal, twelve direct-flow burners form in the horizontal projection of the furnace a system of high-speed jets, providing a stable position of the flame in its center [25]. A slope of the burners down at an angle of 10° provides a reliable washing of the bottom (Fig. 1.86) and rapid burnout of the separated dust on the film of liquid slag. The calculated values of excess air and primary air velocity were 0,52 and 23,4 m/s.

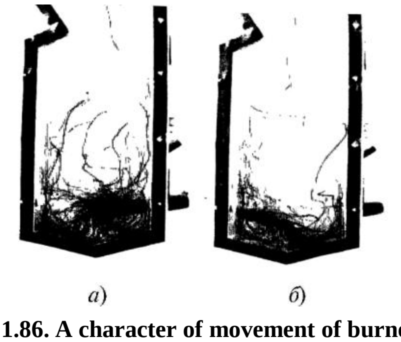

Fig. 1.86. A character of movement of burner jets: *a* - burners № 4, *б* - burners № 9

Twelve combined nozzles of 365 mm in diameter are designed to supply the discharge agent from coal-pulverization systems and secondary air to the furnace. They have a significant downward slope (35°) for the flame turbulence and reliable burning-out of fine dust. In the horizontal projection of the furnace, they form a system of high-speed jets due to their rotation at an angle of 8,5° relative to a normal, but in the opposite to burners direction. The estimated excess air at the combined nozzle outlet (in case of two coal-pulverization systems in operation) made 0,4. As model studies showed, these arrangement features of the combined nozzles provide good mixing of jets with the primary flame (Fig. 1.87) and partially compensate the asymmetrical aerodynamics of burner jets.

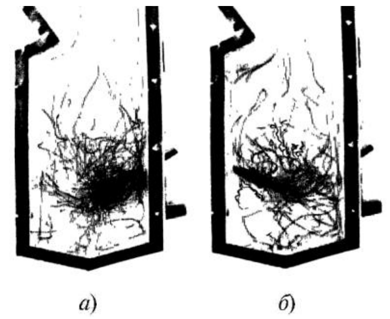

Fig. 1.87. A character of movement of jets from the combined nozzles: *a* - burners № 4, *б* - burners № 9

Tertiary air nozzles (12 pcs) are installed in vertical planes of location of burners and combined nozzles and are directed horizontally. Each nozzle represents a unit of eight tubes ∅ 133×6 mm, directed in the horizontal projection of the furnace at an angle of 8,5° to the normal in all directions. The nozzle design provides a stable motion of jets. In addition, the total initial perimeter of ejection of all the jets, flowing from one nozzle, is 2,84 times greater than this parameter for a circular jet, flowing from the nozzle of an equivalent cross section, and 2,37 times greater than that of a rectangular jet, flowing from the equivalent nozzle, in which wall dimensions are in the ratio of 2:1. The calculated values of excess air and tertiary air velocity were 0,26 and 50 m/s. A nature of jet motion is shown in Fig. 1.88, from which it could be concluded that in the central furnace zone there's an intensive process of mixing the reagents.

Design of the pulverized coal and oil burner is shown in Fig. 1.89. Coal dust is fed into the furnace under technology of high-concentration dust (HCD). HCD is pulverized with application of compressed air sprayer (p = 40 ... 45 kPa), which leaks out at a rate of about 190 m/s from 12 holes of 4 mm in diameter, staggered at the conical end surface of the spray nozzle. Spraying angle is 120°. At the inlet to the burner body of ∅720×7 mm a bounding puck of ∅ 470 mm is set.

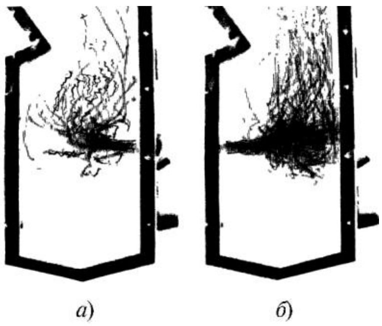

Fig. 1.88. A character of movement of tertiary air jets:
а - burners № 4, *б* - burners № 9

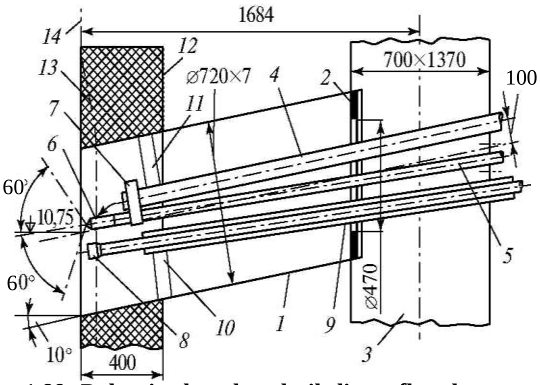

Fig. 1.89. Pulverized coal and oil direct-flow burner of TP-87 boiler: 1 - body, 2 - bounding puck, 3 - air box; 4 – HCD pipe ∅89×6 mm, 5 - compressed air pipe ∅ 42x5 mm; 6 - jet spray nozzle, 7 - clamp, 8 - head of steam and mechanical nozzle, 9 - spray pipe, 10 - plate mounting the nozzle tubes, 11 - plate mounting the HDC pipe, 12 – embrasure box (welded by overlays to screen tubes) 13 - screen tubes, separated into the embrasure; 14 – axis of screen tubes

Trials of the reconstructed boiler, conducted in October – November, 2005 showed good results [26] relating to reliable evacuation of liquid slag, a level of specific emissions of nitrogen oxides and flue gas temperature, as well as unburnt carbon. As can be seen from graphs presented in Fig. 1.90 at the operational excess air after steam superheater (α''_{ssh} = 1.25), specific emissions of nitrogen oxides were approximately 560 mg/m^3 (instead of 1150 ... 1200 mg/m^3 before reconstruction compared to a standard value of 570 mg/m^3). Unburnt carbon was not higher than 0,55%, which roughly corresponds to the same operational parameter of the unreconstructed boilers TP-87 in the stoichiometric combustion mode. Reduced flue gas temperature was 134°C, that is by 5 ... 7°C lower than at the mentioned boilers. Indicators, given in Fig. 1.90, were slightly dependent on the boiler load and excess air after steam superheater in the range of α''_{ssh} = 1,1 ... 1,32. In most experiments at the increased load, the gross boiler efficiency was about 92%. In a process of testing, the characteristics of coal burnt were as follows: Q^w = 4378 ... 5847 kcal/kg, W^w = 8,75 ... 17,03%, A^w = 11,7 ... 20,66%, V^c = 40,8 ... 42,4%, N^c = 2,4 ... 2,5%. Fineness of coal dust grinding met the normative values: R_{90} = 14 ... 15%.

However, after the boiler reconstruction, increase in the off-nominal gas temperature after steam superheater was fixed, occurred with a greater intensity than at the unreconstructed TP-87 boilers, furnaces of which are equipped with constrictions and operate in the stoichiometric combustion mode. Analysis showed that this was due to contamination of the furnace screens above the studded zone, as well as due to superheater slagging. These negative processes are connected with the insufficient height of the flame afterburning zone under conditions of the staged combustion and the fact that at the boiler # 9, as well as at other boilers of "Zapadno-Sibirskaya TPP" means of operational cleaning of screens and superheater are not applied, therefore since December 2005 till June 2006 the reconstructed boiler operated with a load of less than 300 t/h, and bounding pucks before the burners were demounted to reduce the proportion of tertiary air.

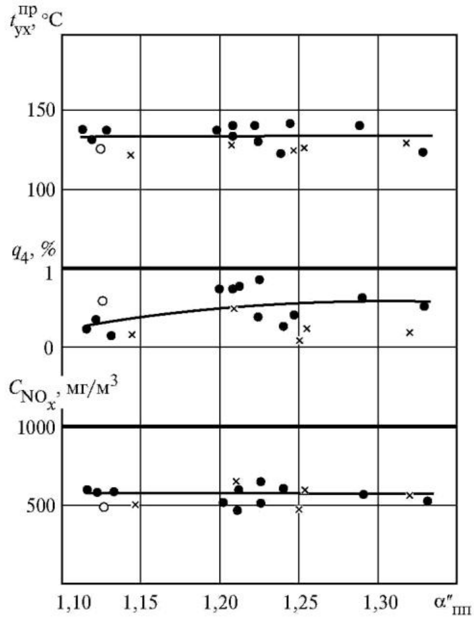

Fig. 1.90. Dependence of the reduced flue gas temperature, unburnt carbon and specific emissions of nitrogen oxides on excess air after steam superheater at the reconstructed TA-87 boiler: • - two mills in operation; x – one mill in operation; o - two mills out of operation; $t_{ух}^{пр}=t_{fg}^{red}$; $\alpha_{пп}''=\alpha''_{ssh}$; мг/м^3=mg/m^3

In summer and autumn of 2006, the boiler #9 was shut down before conducting the second stage of reconstruction, the main purpose of which was to raise the height of the afterburning flame zone by reducing a bottom level and decrease in levels of setting the burners and nozzles by 2,5 m Zone-to-zone calculations showed that in this case the gas temperature at the level of aerodynamic bulge is reduced by 80 ... 90°C and makes about 1160°C. Thus, it becomes less than the ash softening temperature for coal of GROK grade (about 1200°C).

A decision on complete revitalization of facilities for steam blowing of screens in the middle and upper sections of the furnace, was made. In addition, an effective system of gas and impulse cleaning of the screen bottom and the first along the gas flow pipes of convective superheater was developed.

For timely mixing of the burning down flame with tertiary blast and its reliable pressing from the front and back screens, there were provided the following: a slope of tertiary air nozzles at an angle of 30° down and greater (to 45°) rotation angle of pipe ∅133x6 mm relative to the normal in the horizontal projection of the furnace. It was considered to be expedient to divide the air supply ducts into burners and tertiary blast nozzles and provide the possibility of regulation of air flow by these or other regime means.