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

1.5.5.1. Complex operational effectiveness of gas- and oil-fired furnaces with the vertical direct-flow swirling flame

A.M. Arkhipov, MPEI (TU); A.A. Vagner, OJSC "RAO UES of Russia"; N.I. Solovyev, OJSC CKB "Energoremont"; V.V. Abramov, OJSC "Zapadno-Sibirskaya TPP"

A layout scheme of burners for combustion of oil and gas in direct-flow swirling flame (DFSF) with vertical axis of rotation of flue gases [5] was initially introduced in 1978 at BKZ-160-100GM boiler at Efremovskaya TPP of Tulenergo. It is shown in Fig. 1.67. This combustion scheme was already used at all five reconstructed BKZ-160-100GM boilers, installed at Efremovskaya TPP and at two boilers of the same type at Voronezhskaya SDPP. Then this scheme was widely introduced at boilers of several types at TPPs of Ministry of Energy.

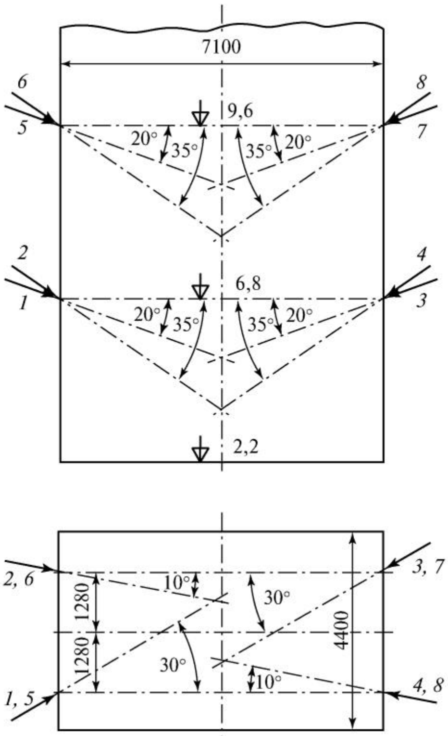

Fig. 1.67. Layout scheme of mazut and gas burners at boiler BKZ-160-100GM

According to modeling studies and observations of the flame body in axile zone of the reconstructed BKZ-160-100GM boiler furnace there is a drop swirling flow of flue gases arranged. Lifting movement of the burning down flame occurs from the furnace bottom along the screens by a spiral trajectory, as well as in the zone of movement of fresh combustion jets that come from axisymmetric burners. Forced addition and in-flow of gases that have incomplete combustion products are arranged into the face (in relation to the oncoming flow) and back parts of a perimeter of fresh combustion jets. Some air mass (5...10 %) is removed from their sides by the oncoming gas flow.

Thus, an average excess air in fresh flames of the burners comprises 0,9...0,95 of its value in the jet core, at that oxygen concentration is additionally reduced by inside gas recirculation. According to data of the studies [6], the concentration can reach 30...50 % of a mass of fresh combustion jets, depending on angle of slope, burners location and jet efflux speeds. A degree of inside gas recirculation increases if the second burners (with even count) along the tangential gas flow have a big slope down in comparison with the initial gas flow (Fig. 1.67.). At that high-temperature core of the flame body disperses throughout the height of the furnace.

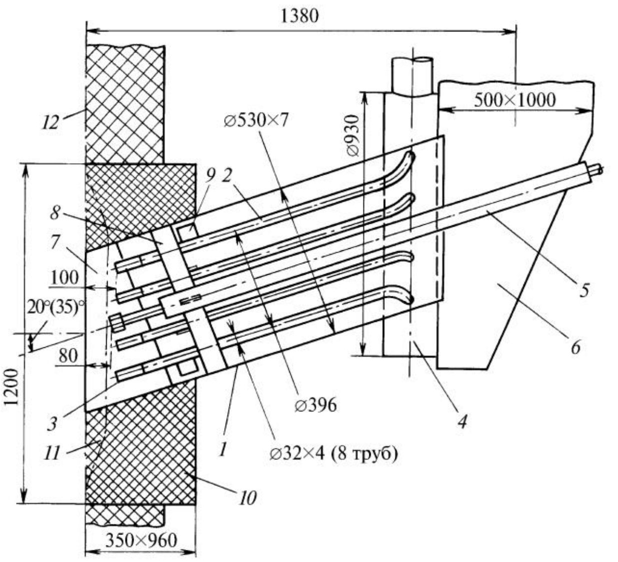

Fig. 1.68. A recommended reconstruction option of the direct-flow gas and oil burner for BKZ-160-100GM boiler:

1 — body; *2* — gas tubes; *3* — gas distributing heads (made from heatprof steel); *4* — gas collector; *5* — spraying nozzle tube; *6* — air pocket; *7* — body outlet (made from heatprof steel); *8* — cross for spraying nozzle tube fixing; *9* — knee piece for gas tube fixing; *10* — duct of breast (welded through joint plates to furnace tubes); *11* — inner tubes of furnace tube arrangement; *12* — axis of a screen (inspection hole, gas flame igniter and flame sensor are not shown); 8 труб – 8 tubes.

The recommended option of gas and oil burner reconstruction for BKZ-160-100GM boilers of Efremovskaya TPP is shown in Fig. 1.68. Gas distributing heads made from heatproof steal have the deaden end face and eight side holes of 8 mm in diameter, placed in two rows (in increments of 90^{o} in each row) chequerwise. In process of oil combustion at this plant, oil mechanical spaying nozzles of "Ilmarine" plant were used before and after the reconstruction. While using other oil spraying nozzles with a spray angle (at stand) of 90^{0} and higher, spaying nozzle tube has to be moved up in relation to burner axis by 50...70 mm. It is necessary to avoid a contact between the sprayed oil and the bottom of the burner breast.

Operational data and results of studies, obtained at BKZ-160-100 GM boilers of Efremovskaya TPP prior and after the reconstruction, are shown in Tab. 1.32 [6, 7]. The manufactured boilers were equipped with 12 face swirling burners, located in three stages. In connection with obtaining the complex indices of effective work of the reconstructed BKZ-160-100GM boilers, the burner installation diagram shown in Fig. 1.67 (without principal differences), was used during reconstruction of BKZ-210-140F boiler at Gorkovskaya SDPP, Orskaya and other TPPs, TP-230 and TP-170 boilers at Pervomayskaya and Yaroslavskaya TPPs, as well as BKZ-75-39GM boilers at other TPPs. By that, BKZ-210-140F at Gorkovskaya SDPP and TP-230 at Pervomayskaya TPP were additionally equipped with two flow nozzles of the secondary blow. They were installed at the upper level of burners in a central part of front and back walls and were directed tangentially at a slight slope down. Open flow area of nozzles corresponded to 15...20% of the supplied air. Moreover, BKZ-210-140F boilers of Gorkovskaya SDPP were equipped with a gas recirculating scheme with their dumping through the direct flow nozzle, installed at the uncooled bed and directed vertically along the furnace axis. Recalculating gases were injected to increase a temperature of the overheated steam, especially, during oil combustion.

The levels of specific NO_x emissions at the reconstructed BKZ-160-100GM and BKZ-210-140F boilers are shown in Tab. 1.33 (here and further in terms of $\alpha = 1,4$).

Data presented in Tab. 1.33 show that at boilers with aerodynamics of vertical DFSF during the staged gas and oil combustion, the actual levels of specific NO_x emissions are much less than the standard ones (125 and 250 mg/m^3, accordingly). Thus, the arranged excess air doesn't exceed 1,0 in case of the primary excess air reduction to 0,57 (in process of gas combustion). It shows an intensive and timely reagent mixing and high effectiveness of the staged gas combustion process.

Data from Tab. 1.32 show the dependability of operation of the furnace screens and convectional heating surfaces during oil combustion in vertical direct-flow swirling flame. In addition, several BKZ-75-39GM boilers (for example, boilers installed at TPP of Kuybyshevsky NPZ), transferred to oil combustion technology, were remarked as BKZ-100 [9].

Table 1.32. **Results of reconstruction of BKZ-160-100GM boiler at Efremovskaya TPP**

Indices	Before reconstruction	After reconstruction
Longtime available boiler steam capacity in process of oil combustion, t/h	140	160
Maximum temperature of the flame body, °C	1580	1500
Maximum dropping heat flow, kW/m^2	530	420
Thermal damage of water-wall tubes (in average at one boiler annually)	1...2	—
Temperature of the dew point of gases when D_{nom} is in stoichiometric regime, °C	153	120
Concentration of SO_3 in combustion products, %, measured:		
in stoichiometric regime	0,006	0.006
in process of the staged fuel combustion with oil cutoff at two burners	—	0,002
A character of ash deposits at the convection heating surfaces	sticky	loose
Operational resource of cold stuffing of the regenerative air heater, years	3...3,5	5...6
Critical excess air in process of oil/gas combustion:		
in stoichiometric regime	1,0/0,91	0,93/0,89
at the staged combustion	—	0,96/0,91
Concentration of H_2S in a wall area of screens at the staged oil combustion, %	—	Less than 0,001
Concentration of benzapyrene in flue gases before the regenerative air heater at the staged oil combustion (D = 140 t/h), mcg/100 m^3	—	2...3
Power consumption for dragging and blow, kW·h/t (steam)	4,7	
Gross efficiency at a maximum boiler load at stoichiometric oil/gas combustion, %	92,2/92,5	92,5/93,0

Table 1.33. **Specific NOx emissions from the reconstructed BKZ-160-100GM and BKZ-210-140F boilers**

Boiler, TPP, regime	Fuel, number of burners in operation	Load, t/h	Arranged air excess	Primary air excess	Concentration NO_x, mg/m^3
	Oil, 6	122	0.97	0.73	137
BKZ-160-100GM, Efremovskaya TPP	Gas, 6	112	0.97	0.73	85
BKZ-210-140F, Orskaya TPP	Gas, 6	210	0.89	0.67	108
BKZ-210-140F, Gorkovskaya SDPP, open nozzles,	Oil, 8	210	0.98	0.8	196
gas recycling	Gas, 6	210	0.98	0.59	90
TP-230, Pervomayskaya TPP, regime					
closed nozzles	Gas, 6	230	1.0	0.7	110
open nozzles	Gas, 6	230	1.0	0.57	65