

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

1.5.5.2. Improvement of dependability, economical and ecological effectiveness of gas- and oil-fired boilers of PTVM type

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Complex effectiveness of boilers with the aerodynamic direct-flow swirling flame (DFSF) at high two-sided location of direct-flow burners and their sharp slope down is presented in item 1.5.5.1. Similar principles of burner location were used in technology of oil and gas combustion in boilers of PTVM type [10, 11].

A scheme of location of direct-flow burners at PTVM-50 boiler at Klaypedskaya SDPP reconstructed in 1982, is shown in Fig.1.69. Thanks to such location of the burners, two vertical swirls, rotating to and fro, are formed in the furnace. There are 12 burners, installed at PTVM-50 boiler in three stages (four in each stage) in order to adjust thermal load throughout the furnace. Burners of the first, second and third stages are inclined down at angles of 15, 25 and 45° accordingly, which lowers a possibility to carry-over upward a part of the fresh combustion jet mass by a gas flow. It is very important for the burners, located in the upper stage.

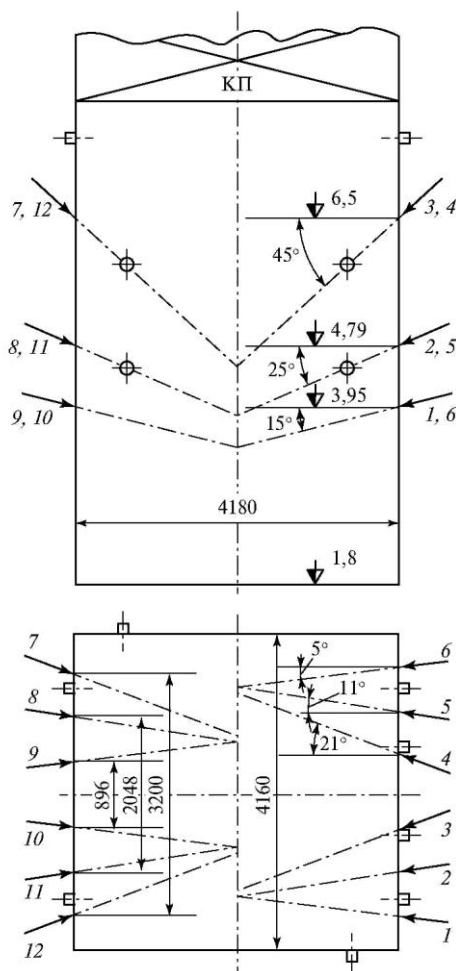


Fig. 1.69. Layout diagram of oil and gas burners at PTVM-50 boiler

A nature of motion of the burner jet of the upper stage #7, fixed in isothermal model, is shown in Fig. 1.70. It is seen

from Fig. 1.70 *b* that the jet of the burner #7 goes down to a level of the first and second burner stages and partially to the bottom. A discharge of the tail volumes of jets upwards as it's shown in Fig.1.70 *a*, happens along the spiral ellipsoidal trajectory. At that, tail volumes of jets are turbulized and partially ejected by fresh burner jets, located at the opposite wall, creating inner recirculation of combustion products, including unburnt products. Therefore, flame body observations at the reconstructed boiler when 12 oil burners are in operation ($Q = 50 \text{ Gcal/h}$) showed that there are no dense flame tails before the convection packets (CP).

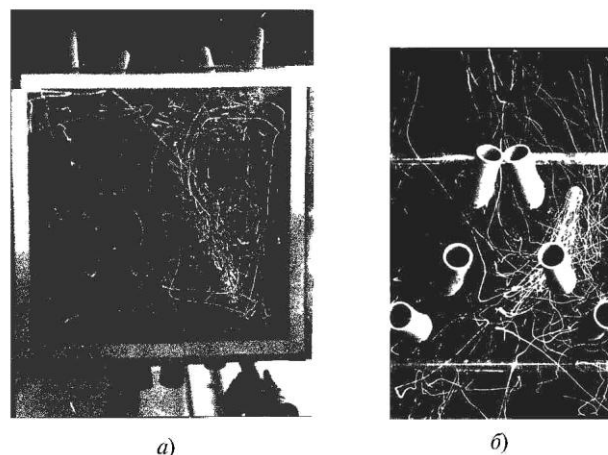


Fig. 1.70. A character of burner jet #7:
a — view through the transparent bed; *b* — view through the transparent front wall with burners # 1—6 (Fig. 1.69)

Empirical relations between the thermal capacity of the reconstructed PTVM-50 boiler and SO_3 concentration, dew point temperature $t_{d.p.}$ in flue gases and heat streams q_{fal} , falling on screens, are shown in Fig. 1.71. At the boiler with clean tubes (after bead-blasting cleaning of convective surfaces) $t_{d.p.}$ is about 55...60°C in the whole load range. At that, SO_3 concentration changes practically from zero ($Q = 25 \text{ MW}$) to $0,3 \cdot 10^{-3} \%$ ($Q = 62 \text{ MW}$). It shall be noted that during the tests at the reconstructed PTVM-50 boiler at Klaypedskaya SDPP the unmoistened sulfur oil was burnt ($W^p = 0, S^p = 2...2,5 \%$).

At pollution of tubes of convective surfaces (CSs) with ash deposits (when measurements were taken before the bead-blasting cleaning of CSs), the dew point temperature $t_{d.p.}$ increased to 115°C, and SO_3 concentration raised to $0,8 \cdot 10^{-3} \%$. Studies showed that in case there is a hole in the furnace (that is equal to oil moistening), the dew point temperature and SO_3 concentration increased to 130°C and $1,4 \cdot 10^{-3} \%$, accordingly.

Indices of the falling heat flows were quite moderate. At the middle stage burner level, they comprised about 320 (line 1 in Fig. 1.71), before CSs — 205 kW/m^2 (line 2) when $Q = 64 \text{ MW}$. It could be explained by distribution of the flame

body throughout the height of the furnace. Moreover, inner recirculation of combustion products into the fresh furnace jets occurs. At that, combustion products are cooled as before injection into the fresh furnace jets, they gave a part of their heat to bottom screens and furnace walls.

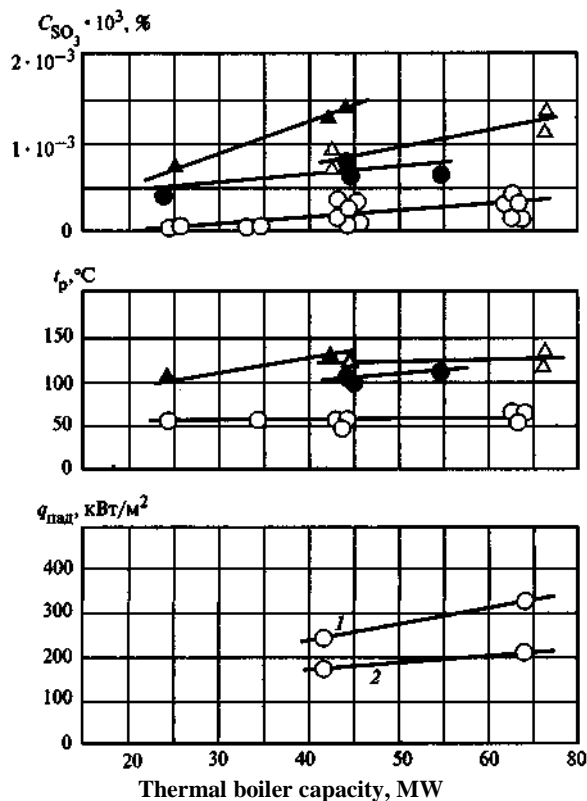


Fig. 1.71. Relations between sulfur oxide concentration, the dew point temperature, heat flows, falling on screens, and heat capacity of PTVM-50 boiler.

$$t_p = t_{d.p.}; q_{\text{пад}} = q_{\text{фал}}, \text{кВт/м}^2$$

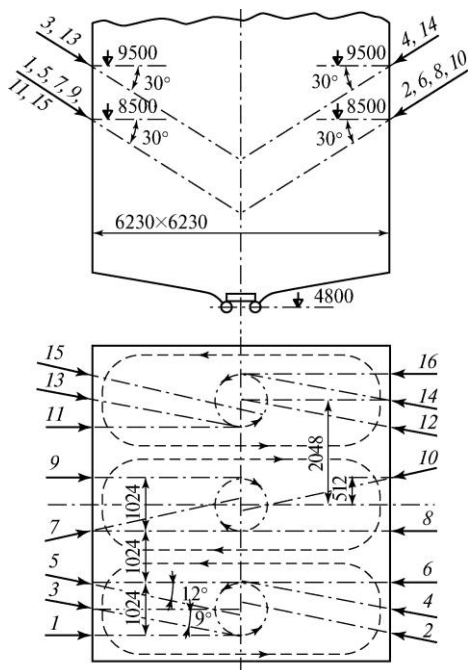


Fig. 1.72. Layout scheme of oil and gas burners at PTVM-100 boiler at Kaynasskaya TPP

A layout scheme of 16 direct-flow burners was introduced in 1985 at PTVM-100 boiler at Klauanasskaya TPP. At that, in the furnace three-vortex aerodynamics of the flame

body was arranged. PTVM-100 boiler of Klaypedskaya district boiler-house was reconstructed, using five-vortex aerodynamics of the flame body. For better use of the furnace bottom volume and application of the inclined downwards direct-flow burners (principal configuration of which is shown in Fig. 1. 74) at PTVM-100 boilers the furnace bottom was straighten and a mark of its lower collectors was decreased by 1 m.

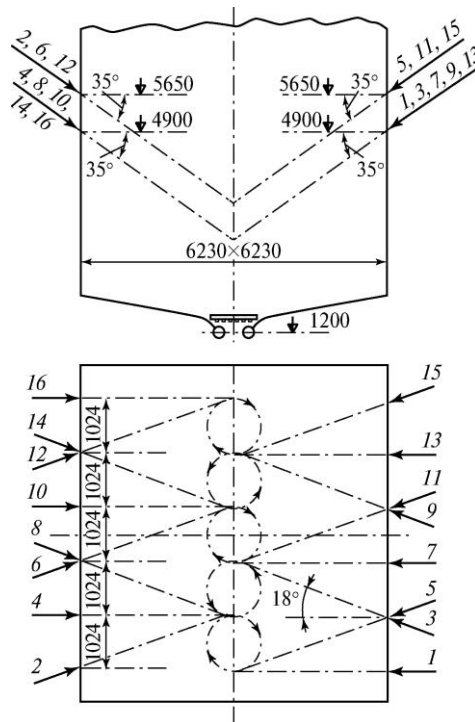


Fig. 1.73. Layout scheme of oil and gas burners at PTVM-100 boiler at Klaynedskaya district boiler-house

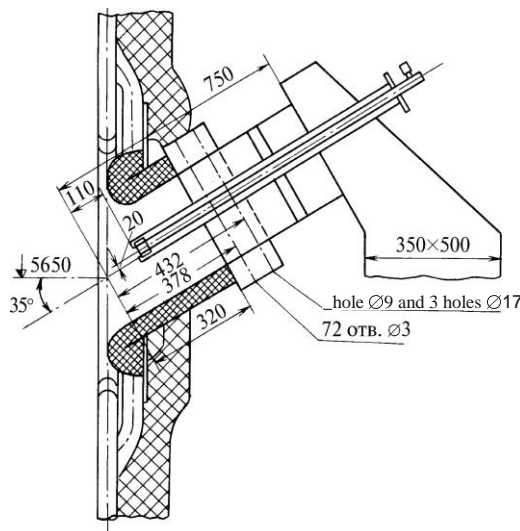


Fig. 1.74. Direct flow oil and gas burner of PTVM-100 boiler at Klaynedskaya district boiler-house

Modeling aerodynamic studies of furnaces of PTVM-1000 boilers showed that a presence of eddy zones, especially in the furnace, where the burners are installed in accordance with Fig. 1.73, is insignificant. However, burning down flames of the burners of one wall safely enter the area of fresh furnace jets of the opposite wall. It guarantees turbulization of the burning down flame and intensifies the inner recirculation of combustion products into fresh jets. As a result, flame trajectories are long enough which is very important in conditions of low located furnaces. Hence, oil com-

bustion products before CSs are almost transparent (no unburnt carbon), including the case when 16 burners are in operation.

Comparative data of PTVM-50 and PTVM-100 boilers before and after the reconstruction are presented in Tab. 1.34. As a result of reconstruction, these boilers were switched to oil and gas combustion in DFSF.

One of the most important results of PTVM boiler reconstruction is an increase in its longtime available thermal capacity in process of oil combustion up to nominal and sharp decrease in the flue gas temperature. This was possible because ash deposits in CS tubes became loose instead of sticky. It predetermined an efficiency of regular application of dry cleaning methods (at PTVM-50 boiler— bead-blasting cleaning, at PTVM-100 boiler— gas-impulse cleaning).

At the majority of PTVM boilers in the central part of Russia natural gas is the only fuel which lowers heat supply dependability. Positive experience, obtained during reconstruction of PTVM-50 and PTVM-100 boilers with their transfer to oil and gas combustion in DFSF can be used at the mentioned boilers in order to guarantee reliable combustion of gas and oil, as a reserve fuel. To ensure the better dependability of operation of bottom screen tubes at the recon-

structed PTVM-100 boilers, two-current system of water flow is preferred.

As it could be seen from Tab. 1.34, specific NO_x emissions from the reconstructed PTVM boilers in process of oil combustion meet the standard level (less than 250 mg/m³). At the same time, at gas combustion they exceed the standard level (more than 125 mg/m³). In process of gas combustion, a perspective decision can be usage of all the burners of the upper stage or a part of them as air nozzles. In this case other burners are additionally loaded by gas and its combustion will occur in a mode with the staged combustion elements.

Here, it should be noted that in 1986 and 1987 under the project of OJSC “CKB Energoremont” two KVGM-180 boilers at TPP-25 of the OJSC Mosenergo were reconstructed. These boilers were equipped with 12 direct-flow burners, installed in three stages and inclined down greatly. The reconstructed boiler tests showed that using four upper burners as air nozzles led to specific NO_x emission decrease from 185 mg/m³ (12 burner in operation) to 40 mg/m³ when gas recirculation system wasn't applied [13]. Results of reconstruction of the specified boilers are presented in more details in item 1.5.5.8.

Table 1.34. Results achieved at the reconstructed PTVM-50 and PTVM-100 boilers in comparison with typical boilers

Index	Typical boiler	Boiler with DFSF
Longtime available boiler steam capacity during oil combustion, Gcal/h		
PTVM-50 boiler of Klaypedskaya SDPP	37	50
PTVM-100 boiler of Klaypedskaya district boiler-house	75	100
SO ₃ concentration of flue gases at PTVM-100 boiler of Kaynasskaya TPP at polluted CS tubes ($Q = 60$ Gcal/h), %	$1,7 \cdot 10^{-3}$	$0,9 \cdot 10^{-3}$
A character of ash deposits at CS tubes	sticky	dry
Reduced to $t_w = 70$ °C temperature of flue gases during oil combustion, °C:		
at PTVM-50 boiler of Klaypedskaya SDPP	300	230
at PTVM-100 boiler of Klaypedskaya district boiler-house	250	215
NO _x concentration in flue gases at the rated capacity and oil/gas combustion, mg/m ³		
at PTVM-50 boiler of Klaypedskaya SDPP	—	200/140
at PTVM-100 boiler of Klaypedskaya district boiler-house	—	210/155

Note. During the tests at PTVM-100 boilers, oil with the average characteristics was burnt: $W^w = 2$ %, $S^w = 1,8$ %