The efficiency of gas combustion in TGM-84B boilers with a different number of burners

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Abstract. The efficiency of fuel combustion in energy boilers of thermal power plants largely depends on the layout of the burners in the combustion furnace, on their number and unit capacity. An important condition for the cost-efficiency of the selected combustion mode is the absence of a torch projecting from the combustion products onto the screen surfaces of the heating of the furnace. To prevent the formation of large quantities of harmful emissions of nitrogen oxides into the atmosphere, the necessary requirement for fuel combustion is to reduce the local values of the torch temperature in the volume of the furnace. In addition, the intensity of the radiation of the torch from the furnace into the horizontal gas duct on the pipe surface of the heating of the superheater should not exceed the permissible values for the thermal resistance of the metal pipes. With a frontal arrangement, the use of burners with a low unit thermal power with an increase in their number allows to reduce the length of the torch and prevent the torch from projecting onto the rear screen. However, this reduces the coefficient of efficiency of the boiler, as it increases the loss of heat with flue gases due to an increase in their temperature.
Keywords. Boiler, combustion, gas, furnace, burner, twisting of air, torch, temperature, radiation, combustion products, coefficient of efficiency, emissions, nitrogen oxides.

1. Introduction

The choice of unit power and the number of gas-oil burners in the design of energy steam boilers for thermal power plants depends on many of its design features and operating conditions [1-6]. The main ones are the size of the furnace and its cross-sectional area, the location of the superheater elements, and the design of the lowering gas duct. As a rule, steam power boilers have balanced traction and are operated at small and large steam loads. In this regard, duringoperation at low loads, part of the burners is turned off or transferred to the mode of operation with low fuel consumption. The efficiency of fuel combustion depends on the method of controlling the combustion mode for a given number of working burners. For the experimental research of the efficiency of fuel combustion, three TGM-84 boilers with a nominal capacity of 420 t/h and the number of burners equal to 6.8 and 18 were selected. During studying the efficiency of burning natural gas from Urengoy field with lower heat of com-

bustion LHV=34257 kJ/m³. The efficiency of fuel combustion is characterized by the coefficient of efficiency of the boiler. Another important indicator is the concentration of nitrogen oxides in the products of combustion. These indicators depend on the intensity of the torch radiation and the load of the boiler. Therefore, the planned volume of experiments included measurements of the intensity of torch radiation while measuring the concentration of nitrogen oxides at different loads.

2. Materials and Methods

The layout schemes of the burners on the investigated TGM-84B boilers of Nizhnekamsk TPP-1 and Ufa TPP-4 are shown in Figure 1.
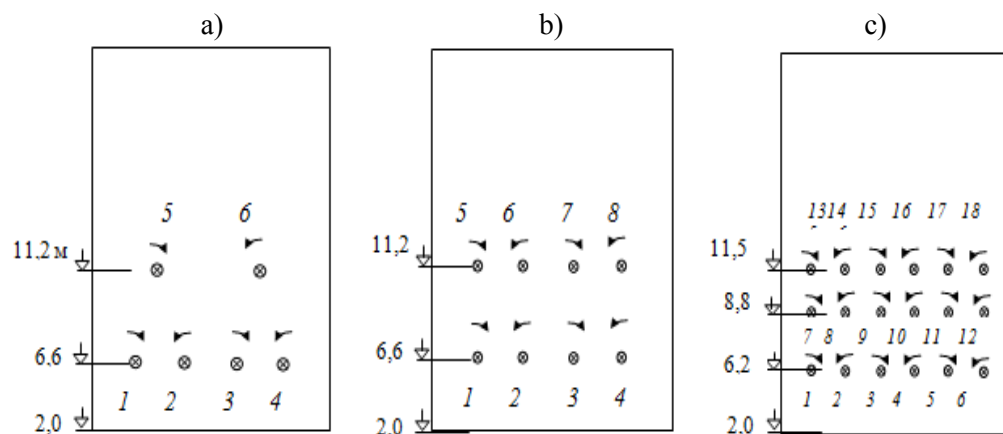

Figure 1. The layout schemes of the numbers and directions of twisting of air revolutions for the burners on the investigated TGM-84B boilers: a) TGM-84B boiler of Nizhnekamsk TPP-1 (station No. 6) with the number of burners equal to 6; b) TGM-84B boiler of Ufa TPP-4 (station No. 14) with the number of burners equal to 8; c) TGM-84B boiler of Nizhnekamsk TPP-1 (station No. 1) with the number of burners equal to 18.

The productivity of TGM-84B boiler is 420 t/h at a superheated steam pressure of 14 MPa and temperature of 560°C. The burners of Taganrog boiler plant construction are located on the front wall of the furnaces of TGM-84B boilers at elevations ranging from 6.2 m to 11.5 m.

The furnaces have a two-light screen that divides the furnace volume in height into two half-furnaces. The sizes of the furnaces are: width 16 m, depth 7.5 m, height 24 m. For TGM-84B boilers of Nizhnekamsk TPP-1 the unit capacity of each of the six burners is 50 MW, each of the 18 burners is 17 MW, for TGM-84B boiler of Ufa TPP - 4 - 38 MW. The burners have a central gas distribution through a coaxial conical nozzle 1 with three rows of gas supply holes of various diameters (Figure 2).
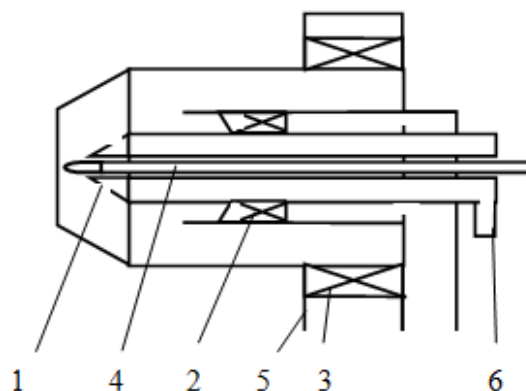

Figure 2. Diagram of a two-flow vortex burner for TGM-84B boilers: 1 - conical gas nozzle, 2 - blades of an axial internal air twisting, 3 - blades of a peripheral tangential air twisting, 4 - nozzle, 5 - air supply duct, 6 - gas supply.

The air twisting in the burners is rotated by axial blade 2 and tangential peripheral 3 air swirlers, which are the main ones. During burning gas,the nozzle 4 is removed from the burner and placed on a rack for intermediate storage.

Measurements of the parameters of Urengoy gas combustion process were carried out in the operational sections of the boilers in the cut of the water economizer and in the balance sections after the smoke exhaust. The test procedure is given in [7-11]. Coefficient of efficiency of boilers was determined by the reverse balance. During the tests, the indications of standard station instruments were used.

A radiometer with a calibration of RK-15 through the hatches on the walls of the furnaces measured the intensity of the radiation of the torch from the furnace volume at various loads. The concentration of nitrogen oxides NO_x in the combustion products in the operating section was measured using the DAG-500 gas analyzer. The error in determining the coefficient of efficiency was ±70.71%. Figure 3 shows the measurement scheme of the operating parameters of the operation of the TGM-84B boilers during experiments.
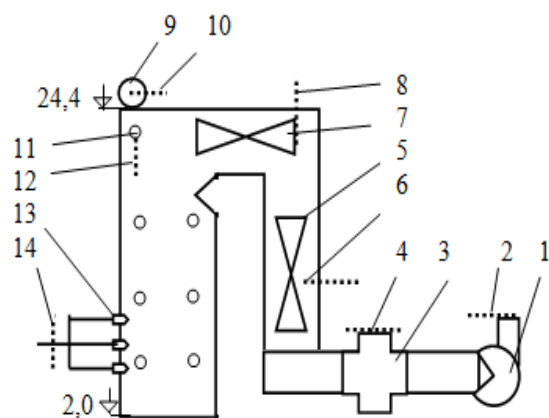

Figure 3. The measurements scheme of the operating parameters of the operation of TGM-84B boilers during the experiments: 1 - smoke exhaust, 2 - balance section, 3 - regenerative air heater, 4 - air parameters after the regenerative air heater, 5 - economizer, 6 - operating section, 7 - superheater, 8 - parameters of superheated steam, 9 - cylinder, 10 - parameters of the steam-water mixture in the boiler cylinder, 11 - inspection hatches, 12 - measurement of the temperature and intensity of the torch radiation, 13 - burners, 14 - measurement of the parameters of air and fuel supplied to the combustion.

3. The received results and their discussion

Tables 1-3 show experimental data on the operation parameters of TGM-84B boilers (station No. 6 and No. 1) with the number of burners 6 and 18 for Nizhnekamsk TPP-1 and for Ufa TPP-4 (station No. 14) with the number of burners 8 for various steam loads.

Table 1. The operation parameters of TGM-84B boiler (station No. 6) of Nizhnekamsk TPP-1 with the number of burners equal to 6.

Parameter	Load, t/h				
	210	260	320	380	420
Number of operational burners, pc.	6	6	6	6	6
Gas pressure in front of the burners, kg/cm^2	0.11	0.12	0.17	0.24	0.28
Air pressure in front of the burners, kg/cm^2	50	80	125	180	225
Coefficient of sir excess	1.09	1.07	1.06	1,05	1.05
Temperature of flue gases,°C	105	113	123	131	136
Heat losses with flue gases, %	4.55	4.58	4.75	5	5.21
Heat losses in the environment, %	0.8	0.65	0,5	0,44	0.4
Boiler gross coefficient of efficiency, %	94.65	94.77	94.75	94.56	94.39
NO_xcontent in flue gasesreduced to air excess 1.4, mg/m^3	105	125	150	175	190

The air temperature in front of the regenerative air heaters was 30°C, the temperature of the feed-water was 230°C.

Table 2. The operation parameters of TGM-84B boiler (station No. 1) of Nizhnekamsk TPP-1 with the number of burners equal to 18.

Parameter	Load, t/h			
	240	300	360	420
Number of operational burners, pc.	10	12	16	18
Gas pressure in front of the burners, kg/cm^2	0.32	0.34	0.36	0.41
Air pressure in front of the burners, kg/cm^2	60	75	100	125
Coefficient of sir excess	1.07	1.07	1.06	1.05
Temperature of flue gases, °C	138	143	148	154
Heat losses with flue gases, %	7	7.05	6.9	6.85
Heat losses in the environment, %	0.7	0.56	0.47	0.4
Boiler gross coefficient of efficiency, %	92.3	92.39	92.63	92.75
NO$_x$ content in flue gases reduced to air excess 1,4, mg/m^3	190	240	290	345

Table 3. The operation parameters of TGM-84B boiler (station No. 14) of Ufa CHPP-4 with the number of burners equal to 8

Parameter	Load, t/h					
	220	260	300	340	380	420
Number of operational burners, pc.	8	8	8	8	8	8
Gas pressure in front of the burners, kg/cm^2	0.15	0.21	0.27	0.36	0.43	0.52
Air pressure in front of the burners, kg/cm^2	35	45	65	85	110	145
Coefficient of sir excess	1.05	1.047	1.045	1.042	1.04	1.04
Temperature of flue gases, °C	132	134	137	141	145	149
Heat losses with flue gases, %	5.58	5.63	5.76	5.93	6.09	6.27
Heat losses in the environment, %	0.76	0,65	0.56	0.49	0.44	0.4
Boiler gross coefficient of efficiency, %	93.06	93.72	93.68	93.58	93.47	93.38
NO$_x$ content in flue gases reduced to air excess 1,4, mg/m^3	165	175	182	189	197	205

As can be seen from the table. 1-3, the highest coefficient of efficiency at all loads has TGM-84B boiler (station No. 6) with six burners at Nizhnekamsk TPP-1. The lowest values of the coefficient of efficiency has TGM-84B boiler (station No. 1) with the number of burners 18. The decrease in the co-efficient of efficiency with an increase in the number of burners is associated with an increase in the temperature of the flue gases. The concentration of NO$_x$ in flue gases increases with an increase in the number of burners. During the experiments it was found that a change in the temperature of the feed-water by ±10°C leads to a change in the temperature of the flue gases by ±2.5°C, and a change in the temperature of the cold air by ±10°C leads to a change in the temperature of the flue gases by ±5°C.

As can be seen from figure 4, with an increase in the number of burners n, a decrease in the intensi-ty of the torch radiation q$_f$ near the rear screen of the furnace occurs due to a decrease in the length of the torch. However, in this case, the radiation intensity and the temperature of the central area of the torch increase. This leads to an increase in the formation of thermal nitrogen oxides NO$_x$ with an in-crease in the number of burners. The data of this research are consistent with the experimental results [11] obtained by burning gas for TGM-84B boiler with the number of burners n=4.

Results of a pilot study on influence of number of torches on regime indicators at joint combustion of gas and fuel oil (tab. 4-6) are received during the work of coppers at air temperature in front of re-generative air heaters 70°C and at a temperature of feed water of 230°C. Heating of air in front of re-

generative airheaters to 70°C at combustion of fuel oil is carried out in order that will increase temperature of products of combustion at the exit from a fire chamber in front of boiler superheaters.
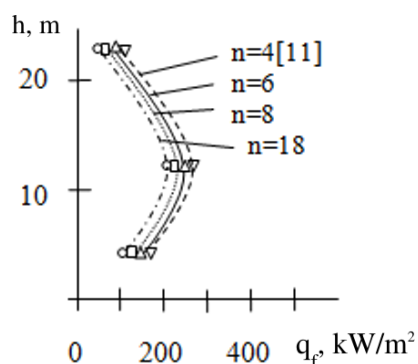

Figure 4. Dependence of torch radiation intensity q_f on the height of the furnace h for the furnaces of TGM-84B boilers with different number of burners n at a load of 320 t/h for burning gas with a heat combustion of 34257 kJ/m³ as measured through the side hatches of the right wall at the rear screen in comparison with the research data [11].

Table 4. The operation parameters of TGM-84B boiler (station No. 6) of Nizhnekamsk TPP-1 with the number of burners equal to 6 for combined combustion of gas and fuel oil.

Parameter	Load, t/h			
	210	270	350	420
Gas burner numbers		5, 6		
Fuel oil burner numbers		1, 2, 3, 4		
Gas pressure in front of the burners, kg/cm²	0.10	0.11	0.18	0.28
Fuel oil pressure in front of the burners, kg/cm²	10	14.5	17.5	25
Air pressure in front of the burners, kg/cm²	75	105	170	245
Gas flow rate per boiler, nm³/h×10³	6.5	7.2	9	11.5
Fuel oil consumption per boiler, t/h	9.5	11	15.5	18.8
Coefficient of sir excess	1.13	1.12	1.09	1.08
Temperature of flue gases, °C	136	141	148	153
Heat losses with flue gases, %	6.4	6.51	6.65	6,72
Boiler gross coefficient of efficiency, %	92.8	92.85	92.87	92.88
NOₓ content in flue gases reduced to air excess 1,4, mg/m³	148	183	225	283

Table 5. The operation parameters of TGM-84B boiler (station No. 1) of Nizhnekamsk TPP-1 with the number of burners equal to 18 for combined combustion of gas and fuel oil.

Parameter	Load, t/h		
	300	360	420
Gas burner numbers		8,11,13-18	
Fuel oil burner numbers	2-5, 7, 12		1-7,12
Gas pressure in front of the burners, kg/cm²	0.18	0.24	0.4
Fuel oil pressure in front of the burners, kg/cm²	28.5	31	35
Air pressure in front of the burners, kg/cm²	65	80	120
Gas flow rate per boiler, nm³/h×10³	12	15	18.5
Fuel oil consumption per boiler, t/h	7.2	12	13
Coefficient of sir excess	1.06	1.06	1.06
Temperature of flue gases, °C	137	143	156
Heat losses with flue gases, %	6.56	6.88	7.59
Boiler gross coefficient of efficiency, %	92.80	92.65	92.01
NOₓ content in flue gases reduced to air excess 1,4, mg/m³	178	210	298

Table 6. The operation parameters of TGM-84B boiler (station No. 14) of Ufa CHPP-4 with the number of burners equal to 8 for combined combustion of gas and fuel oil.

Parameter	Load, t/h		
	260	340	420
Gas burner numbers		5-8	
Fuel oil burner numbers		1-4	
Gas pressure in front of the burners, kg/cm^2	0.21	0.36	0.52
Fuel oil pressure in front of the burners, kg/cm^2	12	17	23
Air pressure in front of the burners, kg/cm^2	70	110	160
Gas flow rate per boiler, $nm^3/h \times 10^3$	1.065	1.058	1.048
Fuel oil consumption per boiler, t/h	150	160	166
Coefficient of sir excess	6.50	6.80	6.94
Temperature of flue gases, °C	92.82	92.75	92.66
Heat losses with flue gases, %	280	320	360
Boiler gross coefficient of efficiency, %	0.21	0.36	0.52
NO_x content in flue gases reduced to air excess 1,4, mg/m^3	12	17	23

As can be seen from tables 4-6, when gas and fuel oil are combusted together, the efficiency decreases with increasing number of burners at all boiler loads.

4. Conclusions

1. An increase in the number of gas-oil burners in TGM-84B boilers from 6 to 18 leads to a decrease in the coefficient of efficiency due to an increase in heat losses with flue gases

2. Due to the decrease in the torch length with an increase in the number of burners, the radiation intensity and temperature in the central area of the torch increase, that leads to an increase in the formation of thermal nitrogen oxides.

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