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Increase of efficiency of heat sources work due to application of condensation economizers on an example of a boiler PTVM-180

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Abstract. In this article, a method is considered to increase the efficiency of boiler room operation with PTVM-180 boilers by the use of a flue gas flue in a condensing economizer. The efficiency evaluation of the utilization of the heat exchanger in accordance with the operating mode of the boiler house was evaluated, and the technical and economic parameters of the project were assessed, depending on the unplanned changes in such key factors as capital costs, operating time, operating mode.

The economy of fuel burned in boiler units is an urgent task when solving the problem of reducing the cost of produced heat energy.
At present, one of the ways to increase the efficiency of boiler houses is the use of deep utilization of the heat of flue gases using condensing economizers.
As an object for the introduction of condensation technology, the boiler house of Kazan is being considered. On the boiler-house are installed water-heating boilers of the type PTVM-180 in the amount of 2 pcs. In the summer period the boiler-house does not work.
The main indicators of the boiler house are presented in Table. 1.

Table 1 Main indicators of boiler plant operation.

Indicator	Output, Gcal		Operating time, h		Average load, Gcal / h		Excess air, α		Number of combustion air for α> 1, nm^3/h		Gas consumption, nm^3/h		
	ВК-1	ВК-2	ВК-1	ВК-2	ВК-1	ВК-2	ВК-1	ВК-2	ВК-1	ВК-2	ВК-1	ВК-2	General
January	94 085	79 542	728	740	129,24	107,49	1,24	1,14	154 007	119 701	12 420	10 500	22 920
February	90 772	71 188	672	672	135,08	105,93	1,23	1,14	144 753	105 216	11 769	9 230	20 998
March	80 920	60 969	744	744	108,76	81,95	1,27	1,18	130 756	91 536	10 296	7 757	18 053
April	65 133	60 490	704	720	92,52	84,01	1,28	1,17	103 902	88 203	8 117	7 538	15 656

Indicator	Output, Gcal		Operating time, h		Average load, Gcal / h		Excess air, α		Number of combustion air for α> 1, nm^3/h		Gas consumption, nm^3/h		
	BK-1	BK-2	BK-1	BK-2	BK-1	BK-2	BK-1	BK-2	BK-1	BK-2	BK-1	BK-2	General
May	-	14 671	-	106	-	138,41	-	1,13	-	18 995	-	1 681	1 681
Jun	-	-	-	-	-	-	-	-	-	-	-	-	-
Jul	-	-	-	-	-	-	-	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
Sept	-	21 133	-	263	-	80,35	-	1,19	-	180 92,8	-	15 204	15 204
Octr	43 446	76 591	443	745	98,07	102,81	1,18	1,16	79 408	137 616	6 730	11 863	18 593
Nov	70 093	76 294	720	720	97,35	105,96	1,18	1,16	105 052	112 408	8 903	9 690	18 593
Dec	79 631	87 320	744	744	107,03	117,37	1,18	1,15	119 567	127 779	10 133	11 111	21 244

The installation of condensing economizers on boilers allows to solve such tasks as deep cooling of exhaust gases, thereby reducing thermal pollution of the environment, and also to increase fuel efficiency. The utilized heat energy can be used to heat raw water, preheat the return network water before entering the hot water boiler.

In the condensation economizer, the combustion products are deeply cooled to a temperature at which the maximum possible part of the water vapor contained in the gases can be condensed and the latent heat of condensation can be used. In addition, deep cooling of gases allows fuller use of their physical heat [1].

The heat exchanger is installed behind the smoke exhausters of the PTVM-180 boilers through new flues, some gases (about 25%) are taken from the common flue, pass through the heat exchanger, cool and return to the common flue.

Smoke gases after the heat exchanger have a temperature of 50°C and, when mixed with the main stream, are heated, thereby preventing the condensation of water vapor in the common flue. The heat exchanger and part of the flue after it are made of stainless steel to prevent low-temperature corrosion.

The newly installed equipment will create additional aerodynamic resistance. The increase in resistance in the heat exchanger is partially compensated by the decrease in the volume of flue gases after the heat exchanger, which occurs due to a decrease in their temperature, condensation and removal of a part of the water vapor, which will eliminate the need to replace the operating smoke exhausters.

The condensate formed in the body of the utilizer is desalted water. The presence of weakly basic carbonic acid in the condensate (CO_2 binding with water) gives pH- 3.5. Condensate is removed from the body of the utilizer by gravity into a special tank through the body of the heat exchanger, equipped with a hydraulic seal. Further from the tank through the calciner the condensate pump is fed to the chemical water treatment.

The value of "dewpoint" of combustion products depends on the amount of excess air, which can be determined from the graph shown in Fig. 1.

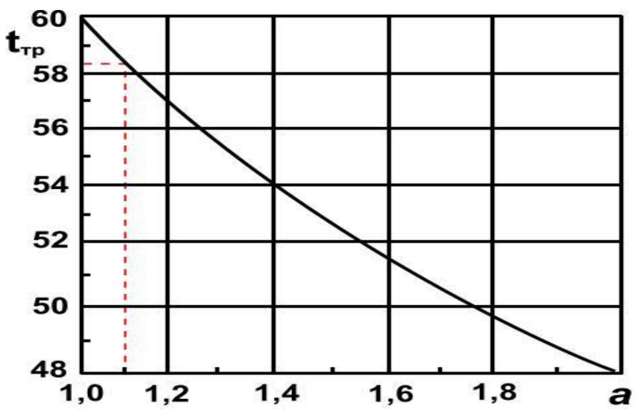

Fig.1 Dependence of the "dew point" of natural gas combustion products on the excess air factor

The amount of moisture condensing during the cooling of flue gases also depends on the value of the excess air factor and can be determined from the graph shown in Fig. 2.

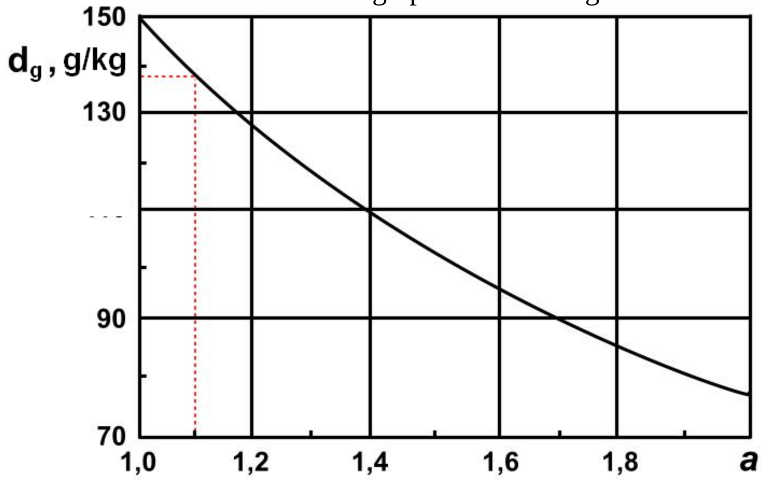

Fig. 2. Dependence of the moisture content of products of complete combustion of natural gas on the excess air factor (weighted average for gas fields in Russia and CIS countries)

The amount of heat that is utilized in the condensation economizer is the sum of the physical heat of the flue gases and the latent heat of condensation of the water vapor.
The amount of heat can be determined from equation (1).

$$0{,}9 \cdot \Sigma Q_{ke} = (G_{dg} \cdot c_p \cdot (t_{dg1} - t_{dg2}) + (G_{vp} \cdot r_{vp})/4{,}186, \text{ Gcal/h} \quad (1)$$

Where G_{dg} – flue gas consumption, nm^3/h; c_p – averaged heat capacity of flue gases, kJ/kg•°C; t_{dg1} – flue gas temperature at the condenser economizer inlet, °C; t_{dg2} – flue gas temperature at the outlet of the condensing economizer, °C; G_{vp} – the amount of condensing water vapor in the economizer, kg / h; r_{vp} – latent heat of condensation of water vapor, kJ/kg; 0,9 – efficiency of condensing economizer; 4,186 – the conversion factor from kJ to kcal.
It is proposed to use a condensation economizer to preheat make-up water [3].
The make-up temperature is assumed at 40 ° C in connection with the technological requirements of HVO. The heating temperature of the feed in the heat exchanger is regulated by the flow rate of the flue gases.
The amount of condensate formed during the operation of the utilizer for the period October-April is determined by the expression (2):

$$G_k = G_{vp} \cdot \sum \tau \quad (2)$$

The amount of thermal energy contained in the resulting condensate formed when the part of the boiler gas is cooled is determined by the formula (3):

$$Q_k^{p/m} = ((t_g - t_{v1}) \cdot G_{vp} \cdot /1000) \cdot \tau \quad (3)$$

The results of the calculation are given in Table. 3.
The consumption of flue gases is determined by formula (4):

$$G_{dg} = B \cdot K_1 + K_2 \cdot Q_i + (-1) \cdot (k_3 + K_4 \cdot Q_i) \cdot (273 + t_p)/273 \quad (4)$$

where B – second consumption of natural fuel, kg/s (nm^3/s); K_1, K_2, K_3, K_4 – numerical coefficients selected for each type of fuel by the least squares method; K_1 – -0,739 for natural gas; K_2 – 0,278 for natural gas; K_3 – 0,0864 for natural gas; K_4 – 0,267 for natural gas; Q_i – lower heat of combustion of fuel MJ / nm^3; α - coefficient of excess air; t_p – flue gas temperature.
The amount of moisture formed during condensation is determined by formula (5) and nomogram (Fig. 2).

$$G_{vp} = \frac{d_{vp}}{1000} \cdot \rho_{dg} \cdot G_{dg}\text{, kg/h} \quad (5)$$

where d_{vp} – moisture content of flue gases (determined from the nomogram of Fig. 2), g / kg;
ρ_{dg} – averaged density of flue gases (in the temperature range 50-145 ° C), kg / m^3;

It is intended to use a condensing economizer to preheat the return network water before feeding it to the hot water boiler.
The temperature of the return network water at the outlet of the condensing economizer is determined by formula (6).

$$t_{2в} = t_{1в} + \frac{\sum Q_e}{(G_в \cdot c_в \cdot 1000)/1000000} \quad (6)$$

where $t_{1в}$ – return water temperature at the condenser economizer inlet, °C; $G_в$ – return water flow rate, t / h; $c_в$ – heat capacity of water, kcal / kg ·°C; 1000 – density of water, kg / m^3;1000 000 – transfer to Gcal.
The amount of heat received in the economizer is determined by the equation (7):

$$Q_т = \frac{G_в \cdot c_в \cdot (t_{2в} - t_{1в}) \cdot \tau}{1000}\text{, Gcal} \quad (7)$$

where τ - operating time of the boiler within a month, hour.
Further, an increase in the production of thermal energy is determined, the values of which are given in Table. 2.

Table 2. The results of calculating the amount of thermal energy that is utilized in the condensation economizer [2].

Period	Water temperature at the heat recovery, ^0C	The water temperature at the output of the heat recovery boiler, ° C	Amount of heat, Gcal	Increase in output,%
October	50	40	295,65	0,29

Period	Water temperature at the heat recovery, ^{0}C	The water temperature at the output of the heat recovery boiler, ° C	Amount of heat, Gcal	Increase in output,%
November	48,41	40	1 066,69	0,74
December	50,81	40	1 169,47	0,65
January	48,57	40	1 175,58	1,33
February	44,34	40	1 102,59	0,84
March	39,8	40	1 181,69	0,9
April	40,63	40	892,89	1,14
Total			6884,55	0,84 (average.)

Table 3. The results of calculating the thermal energy of the condensate formed in the utilizer.

Period	Amount of heat, Gcal
October	27,30
November	90,68
December	97,73
January	98,95
February	92,73
March	95,45
April	72,94
Total	575,78

To assess the natural draft of the chimney in the conditions of reducing the temperature of the flue gases, an aerodynamic calculation of the chimney was performed, taking into account the work of the condensing heat exchanger. Calculations showed that with the introduction of heat recovery, the natural draft of the existing chimney will have a reserve of 7.29 mm.vod.st.

Conclusion

As a result of the conducted studies, the introduction of a condensing heat recovery unit for flue gas at the boiler house with PTVM-180 boilers will reduce the cost of heating raw water, as well as reduce the amount of feed-through due to the beneficial use of condensate formed during deep cooling of a part of the flue gases. A simple payback period for the introduction of a condensing economizer will be 5.76 years with a capital expenditure of 17,849,724 rubles. The economic effect will amount to 3,096,651 rubles.

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