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Investigation of utilization technologies in existing heating units.

Khurramov B.S.

Junior scientific researcher Institute of energy problems of the Academy of Sciences of the Republic of Uzbekistan, 100074, Tashkent, Uzbekistan

ABSTRACT: The paper presents the results of a study of the temperature and humidity regime of a cylindrical reinforced concrete prefabricated chimney of a boiler house with various schemes of waste gas heat utilization. The types of utilization of the heat of combustion products were considered by using regenerative, mixing, combined devices operating with various methods of using the heat contained in the exhaust gases to identify the most effective method of deep heat utilization.

I. INTRODUCTION

Modern energy development is characterized by an increase in the cost of energy sources and all types of natural resources, as well as increasing difficulties in protecting the environment from the impact of various types of enterprises. Improving energy technologies, saving energy, saving fuel and other natural resources, and protecting the environment are priority areas for the development of fundamental energy research. The analysis of power plants shows that one of the ways to significantly reduce the level of gas consumption is the utilization of waste gas heat in condensing heat exchangers. In this case, a 1% decrease in fuel consumption in the installation is achieved by reducing the temperature of the flue gases by 15-20 ° C. In utilizers, together with the cooling of the combustion products, the content of nitrogen oxides in the flue gases decreases. However, the widespread use of surface-type utilizers is significantly limited by the lack of theoretical developments on heat and mass transfer under conditions of condensation of water vapor from combustion products. Cooling the flue gases in condensing heat exchangers below the dew point reduces the moisture content.

II. LITERATURE SURVEY

Increasing the efficiency of the boiler by reducing the temperature of the exhaust gases is relevant and effective. There are several main ways to dry flue gases: the first is the use of a heat pump in the technological scheme [1]; the second method is the use of a centrifugal dryer in the technological scheme [2,3]. An analysis of the literature sources of information, as well as operational experience, has shown that one of the ways to significantly increase the fuel utilization factor is deep cooling (below the dew point) of combustion products in condensing heat exchangers [4-7].

We prove the theoretical possibilities of reducing the temperature of the exhaust gases below the above values, which do not lead to the appearance of condensate on the walls of the exhaust stroke. To prevent condensation of water vapor in the flues and the chimney, the technological scheme suggests installing a condensation heat exchanger on the bypass of the chimney. Let's determine the theoretically necessary volume of air for burning 1 m^3 of natural gas [8].

The constant rise in energy prices in the short and long term makes us think about the modernization of existing units in order to increase efficiency (efficiency) and, consequently, reduce the consumption of gas and other energy resources. Today, the main sources of heat for residential buildings and structures are district boiler houses and thermal power plants operating on fossil fuels. Currently, the market situation is not the best due to the technical condition of the

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equipment and the high cost of natural gas and electricity. An important task is the development and implementation of low-cost and quick-return energy-saving technologies. In the production of thermal energy, as in any other production, you need to strive for the most efficient production. In boilers, one of the ways to reduce the cost of heat production is to increase the efficiency of the boiler. The efficiency of boilers operating on natural gas and fuel oil is 85–92% (calculated based on the net calorific value of fuel). In addition, due to wear and tear of equipment, boiler houses operate with low efficiency. As a result, the problem of increasing energy efficiency through the modernization of boiler equipment or energy saving measures becomes urgent. Boiler efficiency increase is one of the ways to reduce the cost of heat production [9].

Most enterprises generate high-temperature and low-temperature waste that can be used as secondary energy resources. These include combustion gases from various boilers and process furnaces. One of the most effective ways to increase efficiency, in addition to saving fuel and energy resources, is the use of heat from flue gases. Modernization of waste gas heat recovery methods will save the cost of fossil fuel, improve the environmental situation in the area, and reduce emissions into the environment in the form of nitrogen oxides and carbon dioxide. An important point in this problem is that the heat loss with flue gases is from 16 to 18% when calculated using the gross calorific value of the fuel. By using the heat of waste gases from heating units, significant fuel savings can be achieved. When using flue gases of various origins, a large amount of heat is emitted into the atmosphere, as well as thousands of tons of gaseous and solid pollutants. Heat loss with flue gases occupies the main place among the heat losses of the boiler, although it can be useful to use and increase the boiler efficiency up to 10%. Such an increase is quite realistic, since at flue gas temperatures, which are found both in domestic and in foreign-made boilers and are at the level of (140-200) C, heat losses with flue gases are (16 -18)% (when calculated by higher heat of combustion of fuel).
The solution to the specific problem of utilizing heat from flue gases depends on a number of factors, including the presence of pollutants (determined by the type of fuel burned and the object that is heated by flue gases), the presence of a consumer of heat or hot water directly. One of the ways to introduce a heat exchanger: a gas-liquid heat exchanger is installed at the flue section, which uses the heat of flue gases to heat the liquid heat carrier. The medium to be heated in the future can be either directly the final heat carrier, or an intermediate agent that transfers heat through an additional heat exchanger to another circuit [9].

A schematic diagram of the heat exchanger connection is shown in (Figure 1.1). Design the heat exchanger can be either a conventional surface heat exchanger in which the flue gases do not come into contact with each other, i. e. heat transfer from gases to liquids occurs through a dividing wall, or a contact heat exchanger, into which flue gases come into direct contact with water, which is sprayed by nozzles in their stream [9].

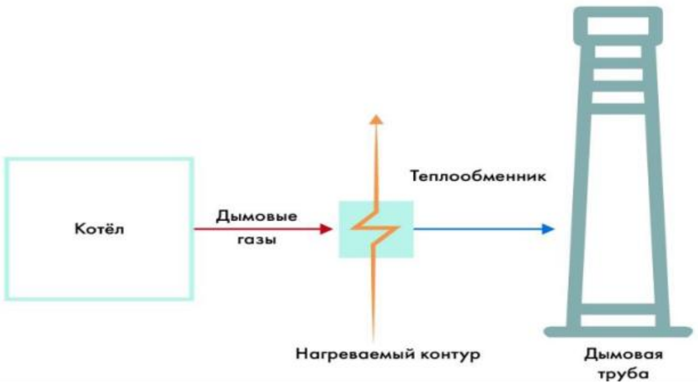

Figure 1.1 - schematic diagram of switching on the heat exchanger

Until recently, mainly contact heat exchangers were used for deep cooling of flue gases below the dew point. The use of contact heat exchangers provides a developed surface and a high intensity of heat transfer, which by an order of magnitude increases the heat transfer coefficient during convective heat transfer. Contact heat exchangers are quite

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simple, however, water heated by a contact method absorbs carbon dioxide and oxygen from combustion products and can acquire corrosive properties that do not have a beneficial effect on power equipment [8,9].

One way to overcome these difficulties is use of surface condensing heat exchangers for deep cooling of off-gases. Heat exchange surface condensing heat exchangers is the most advanced in comparison with classical economizers, as in contact heat exchangers a large area of the heat transfer surface is used for one cubic meter of device volume [10].
In boiler rooms as well as modular boiler rooms, the flue gas recovery system can use part of the flue gases for preheating the boiler feed water. In addition, the waste heat can be used to heat the combustion air using an air heater. In both cases, the corresponding reduction of the boiler's fuel demand. According to research data, with an increase in the temperature of the feed water through the heat exchanger or an increase in the temperature of the combustion air through the air heater in the boiler, significant fuel savings occur [10].

The efficiency of the boiler has a great influence on the heating system, which is associated with energy savings. Therefore, it is important to maximize heat transfer and minimize heat losses in the boiler. The heat losses from the boiler can be varied, such as heat losses with flue gases, radiation losses and blowdown losses, etc. In order to optimize the operation of the boiler plant, it is necessary to indicate where energy losses can occur. A significant amount of energy is lost through the exhaust flue gases, since all the heat generated by the burning fuel cannot be transferred to the boiler. Since the temperature of the flue gas discharged by the boiler usually ranges from 150 to 250 ° C, a part of the thermal energy is lost through it. Since most of the heat loss from the boiler occurs in the form of heat in the flue gas, the use of this heat can lead to significant energy savings. This indicates that there is a huge potential for saving boiler energy by minimizing its losses [11].

Boilers equipped with heat recovery units can have an overall efficiency that increases the boiler efficiency in some cases even up to 107%. The heat exchanger can increase the overall efficiency of the boiler house and extract the latent heat of condensation of water vapor, as well as increase the profitability of the heating system as a whole by reducing the temperature of the exhaust flue gases, which leads to an increase in efficiency from used waste heat. The temperature of the flue gases of the boiler can be reduced by installing a heat recovery unit; cooling of the combustion products also reduces the content of nitrogen oxides, which has a positive effect on the environment. The system can be used in modular boiler houses, thermal power plants of hospitals, schools, factories, office buildings and various commercial facilities [12].

Heat exchangers of contact and surface types can be used as a heat exchanger. Contact type heat exchangers are compact, low metal content and relatively low efficiency. Flue gases are cooled to 40 ° C, while 60-90% of the water vapor is condensate. The main disadvantage is the saturation of heated water with carbon dioxide, this water can cause corrosion, which limits its further use.

III. MATERIAL AND METHODS

First, it is necessary to determine the volumes and enthalpy of air and combustion products.
1.Determine the theoretical volume of air, m^3/m^3, required for complete combustion of fuel:

$$V_{в}^{o} = 0{,}0478 \cdot \left[0{,}5CO + 0{,}5H_2 + 0{,}5H_2S + \sum \left(m + \frac{n}{4} \right) C_m H_n - O_2 \right], \quad (1)$$

where m is the number of carbon atoms;
n is the number of hydrogen atoms.
We determine the enthalpy of the theoretical volume of combustion products for the entire selected temperature range, m^3 kJ:

$$I_{г}^{0} = V_{ro2}(c\nu)_{ro2} + V_{N2}^{o}(c\nu)_{N2} + V_{H2O}(c\nu)_{H2O}, \quad (2)$$

where cυ, $(c\upsilon)H_20$ are the enthalpy of 1 m3 of triatomic gases, the theoretical volume of nitrogen, the theoretical volume of water vapor, kJ/m^3; V_{RO2}, V^0_{N2}, V^0_{H2O} are the volumes of triatomic gases, the theoretical volume of nitrogen and water vapor, m^3/m^3.
We determine the enthalpy of excess air, m3 kJ:

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$$I^{в}_{изб} = (\alpha_y - 1) I^{o}_{в}, \tag{3}$$

The heat received by the heated medium into the heat exchanger according to the balance is equal to the sum of the heat received by each heat carrier in each stage, m^3 kJ: [12].

$$Q_б = \frac{\sum_{i=l}^{i=n} G_i c_i (t_i'' - t_i')}{B_p} \tag{4}$$

where Gi , ci , t'', t' are respectively the flow rate, heat capacity, input and output temperatures of the coolant.

3. Enthalpy of gases excluding H2O condensation

- at the input I' = 3655.42 kJ/m^3

- - at the dew point Tr= 1080 kJ/m^3

The heat given off by flue gases in the heat exchanger according to the balance is calculated as the sum of the heat of physical cooling of gases to the dew point and the latent heat of condensation of water vapor during further cooling of combustion products to the temperature at the outlet of the heat exchanger, kJ/m^3:

$$Q_б = g_n \cdot \phi \cdot (I' - I_p + \Delta I^{w}), \tag{5}$$

where φ is the coefficient of heat conservation, taking into account its losses to the environment, can be conditionally assumed to be the same as in the thermal calculation of the boiler unit;

I' and I_p are the enthalpy of combustion products without taking into account the latent heat of vaporization (according to the lowest heat of combustion) at the temperature of gases at the inlet to the utilizer and at the dew point, kJ/m3.

Currently, the situation has changed significantly, and deep cooling of flue gases has become economically feasible due to a sharp increase in fuel and heat prices and the emergence of more advanced designs of metal heat exchangers, in particular bimetallic heat exchangers. With all the attractiveness of using contact heat exchangers when utilizing the heat of flue gases from boilers, the main disadvantage of the installations - the absorption of carbon dioxide and oxygen by water from the combustion products and the acquisition of corrosive properties by it - hinders the widespread use of such heat exchangers. For normal operation of installations, it is necessary to carry out decarbonization, deaeration of water, which in some cases complicates the use of irrigation water. In this regard, attention is paid to the use of condensation heating surfaces. The heat exchange surface of condensation heating surfaces is much more developed in comparison with conventional economizers. Condensing heat exchangers have the same high efficiency as contact heat exchangers, but they are more metal-intensive structures. At the same time, the absence of direct contact between the combustion products and the heated water makes them preferable from the point of view of the quality of the heated water.

IV. INPUT DESIGN

In order to investigate the effectiveness of introducing exhaust gases into the thermal scheme of a boiler room with a heat exchanger, an experimental procedure was developed, which included the following steps:

1. Conducting trial tests on the functioning of individual elements when operating in the partial load mode of the exhaust gas heat exchanger to check the aerodynamic characteristics of the gas;
2. Conducting an experiment in different operating modes of a boiler room with weather control: when one boiler unit and two boiler units are operating.

Conducting trial tests confirmed the readiness of the experimental installation. With a stable increase in the volume of flue gases, the necessary throughput is provided through the flues and the heat exchanger. The pressure drop of flue gases does not affect the operation of boilers.

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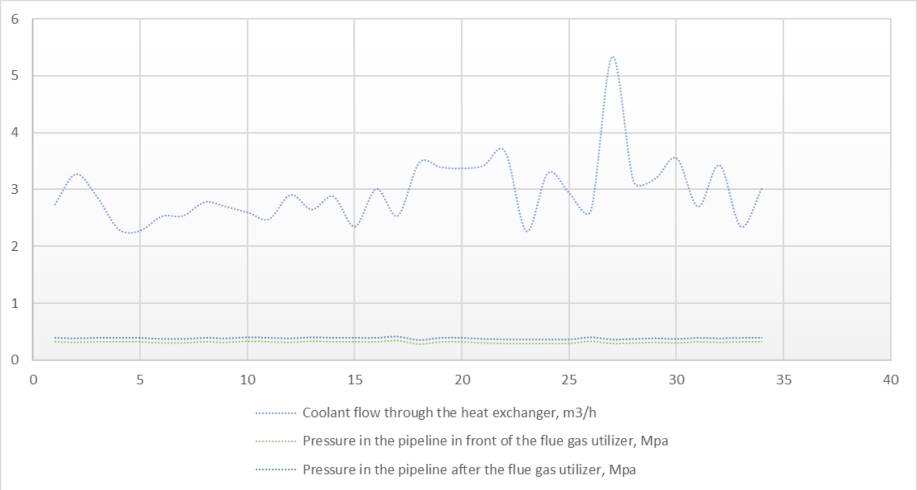

Figure 1 - Flow rate and pressure of the coolant in the flue gas heat exchanger

As follows from the graph Figure 1, the flow rate of the coolant through the exhaust gas heat exchanger on average during the experiment period is 2.99 m^3/h commensurate with the calculated flow rate. The pressure at the inlet and outlet is 0.33 and 0.27 Mpa, the pressure drop does not exceed the maximum permissible values for heat exchange equipment.

V. CONCLUSION

A review of the technical characteristics of boiler houses based on heat recovery units and an assessment of the energy resource of deep utilization of flue gas heat revealed their significant energy potential. As a result of the analysis of existing technologies for deep heat utilization of flue gases using the results of tests on experimental and laboratory samples of contact and surface heat exchangers, it was found that the greatest potential can be realized with deep cooling of exhaust gases. In this case, the heat exchanger must include two stages.

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