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RELEVANCE OF USING HEAT FROM WASTE HEAT FROM BOILER AND FURNACE GASES TO PRODUCE HOT WATER AND STEAM

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Currently, the policy in the field of energy saving and energy efficiency is defined by such normative acts as the Law of the Republic of Kazakhstan "On Energy Saving and Energy Efficiency Improvement" (13 January 2012) and "On Amendments and Additions to Certain Legislative Acts of the Republic of Kazakhstan on Energy Saving and Energy Efficiency Improvement".

When designing boiler plants, one of the directions of energy saving and environmental protection is the application of the method of complex energy-technological utilisation of the heat of fuel combustion products.

By the present moment in the world a lot of researches on development of technology of utilisation of low-potential heat of flue gases of boiler plants have been carried out and the works of a number of domestic and foreign specialists are devoted to the questions of effective utilisation of heat of flue gases.

The essence of the method lies in the maximum utilisation of the heat of fuel combustion products, which can be considered as a quality heat carrier in complex staged plants of different temperature levels, namely: high-, medium- and low-temperature.

At the same time, the fuel combustion products discharged from high-temperature units sequentially pass-through other heat-using units operating at lower temperatures, in which not only the physical heat of gases (up to 8 %), but also the heat of condensation of water vapour contained in them (about 10 %) is used by reducing their temperature below the dew point temperature. The introduction of such technologies allows to significantly (by 10-15 %) increase the efficiency of utilisation of the thermal potential of fuel and ensure its saving.

As a result, in addition to increasing the energy efficiency of the plants, the temperature of combustion products emitted into the atmosphere is reduced and, thus, the environmental situation in the area where the boiler houses are located is improved by reducing the "thermal" pollution of the air basin and the number of harmful emissions of nitrogen oxides and carbon dioxide into the environment.

The utilisation of physical heat by waste gases is determined by their quantity, composition, heat capacity and temperature. The highest temperature of waste gases of oxygen converters (1600-1800 °C), the lowest - the temperature of waste gases of blast furnace air heaters (250-400 °C) [1]. The use of waste gas heat is organised in different ways. At regenerative or closed-circuit cooling, the heat of waste gases is used to directly increase the efficiency of the technological process (heating of regenerators or recuperators, charge or technological product, etc.). If not all of the waste gas heat is used as a result of regenerative cooling, utilisation boilers are used. The physical heat of waste gases is also used to generate electricity in integrated gas turbine plants. Blast furnace gas grate dust, iron oxides in open-hearth furnace gases and oxygen converters gases are captured at gas cleaning plants and returned to the technological process as a recycled product.

Loss of heat with flue gases occupies the main place among the heat losses of the boiler and amounts to 5-12 % of the produced heat. In addition to this, the condensation heat of water vapour, which is formed during fuel combustion, can be used. The amount of heat released during condensation of water vapour depends on the type of fuel and ranges from 3.8% for liquid fuels and up to 11.2% for gaseous fuels (methane) and is determined as the difference between the highest and lowest heat of combustion of fuel (Table 1) [2].

Table 1 - Higher and lower heating values for different fuels

Тип топлива	PCS (Ккал)	PCI (Ккал)	Разница (%)
Солярка	10,6 /кг	10,21 /кг	3,82
Керосин	10,7 /кг	10,29 /кг	3,98
Печное топливо	10,2 /кг	9,76 /кг	4,51
Метан	9,53 /л	8,57 /л	11,2
Пропан	23,85 /л	21,6 /л	10,42
Бутан	30,50 /л	28,3 /л	7,77

It turns out that the escaping gases contain both apparent heat and latent heat. And the latter can reach a value exceeding in some cases the apparent heat. Apparent heat is the heat at which a change in the amount of heat supplied to a body causes a change in its temperature. Latent heat is the heat of vapour formation (condensation), which does not change the temperature of the body, but serves to change the aggregate state of the body. This statement is illustrated by a graph (Fig. 1, where enthalpy (amount of heat supplied) is plotted on the abscissa axis and temperature is plotted on the ordinate axis). The largest difference between the highest and lowest heat of combustion, as can be seen from Table 1, is for methane, so natural gas (up to 99% methane) gives the highest profitability.

In the A-B section of the graph, water is heated from a temperature of 0 °C to a temperature of 100 °C. At the same time, all the heat supplied to the water is used to increase its temperature.

The plot B-C shows the process of water boiling. In this case, all the heat supplied to the water is used to convert it into vapour, and the temperature remains constant at 100 °C.

The C-D section of the graph shows that all the water has turned into steam (boiled off), after which the heat is used to raise the temperature of the steam.

If water vapour is cooled, under certain conditions it will condense (change from gaseous to liquid) and additional heat will be released (latent heat of vaporisation/condensation).

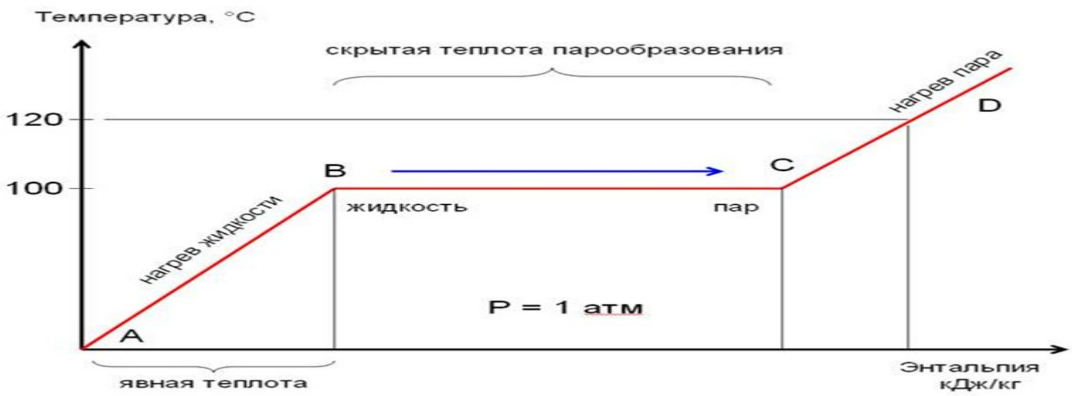

Figure 1 - Dependence of enthalpy change for water

Thus, the introduction of the described technology allows to solve a number of problems, it is the maximum full and useful use of flue gas heat (as well as the latent heat of condensation of water vapour), reducing the volume of NOx and SOx emissions into the atmosphere, improving the environmental situation, the elimination of the smoke flare, reducing fuel costs.

In the S.Seifullin Kazakh Agro Technical Research University for bachelors EP 6B07101 "Heat and power engineering", 6B07107 "Heat and gas supply, ventilation and ecoengineering in agriculture" in the discipline "Energy saving and energy efficiency in heat power engineering and heat technology" in the formative learning outcomes of the discipline is prescribed to possess knowledge of environmental laws in complex engineering activities for the production and distribution of energy, where it is necessary to use: new effective energy and resource-saving technologies at energy enterprises, renewable energy sources and renewable energy sources. In this regard, in the list of laboratory and practical exercises for successful mastering of the course "Energy saving in heat power engineering and heat technology" in the name of the module "Secondary and non-traditional energy sources" in the subtopic "Use of heat from waste boiler and furnace gases to produce hot water and steam" is set "Calculation of the amount of heat (kJ/s), given by waste boiler and furnace gases to the utiliser", where the aim of the lesson is to master general theoretical information and practical solutions of problems on the use of heat from waste boiler and furnace gases to produce hot water and steam.

An important source for additional heat production is waste boiler and furnace gases. The waste boiler and furnace gases are used in water heat recovery units (economisers) and HRSGs to produce hot water and steam.

The amount of heat (kJ/sec) given by the waste boiler and furnace gases to the utiliser is found by the formula:

$$Q_T = V_{Г.ср.} \cdot c^{/}_{Г.ср.} \cdot \left(\theta - \theta^{/}\right), \qquad (1)$$

where $V_{Г.ср.}$ - is the average flow rate of flue gases during their cooling in the utiliser from θ to $\theta^{/}$, m ^{3}/ sec;

$c^{/}_{Г.ср.}$ - average volumetric heat capacity of gases, kJ/(m^3 K);

$\theta^{/}$ - gas temperature at the utiliser outlet,^{0} C.

The flow rate (m^3/sec) of flue gases from the boiler room is determined according to the formula:

$$V_Г = n \cdot B_p \cdot \left[V_Г^0 + (\alpha_y - 1) \cdot V^0\right] \cdot \left[\frac{(\theta + 273)}{273}\right], \qquad (2)$$

where n - is the number of boiler units;

B_p - design fuel flow rate, kg/sec;

$V_Г^0$ - theoretical volume of gases, m^3/kg (m^3 /m^3);

α_y - excess air ratio behind the utiliser;

V^0 - theoretically required air volume, m^3 /kg (m^3 /m^3);

θ - gas temperature at the utiliser inlet,^{0} C.

The amount of generated heat (kJ/sec) in the utiliser due to the heat of flue gases is determined by the formula:

$$Q_T^{/} = B_p \cdot (J_Г - J_Г^{/}) \cdot \beta \cdot (1 - \zeta), \qquad (3)$$

where $J_Г$ - is the enthalpy of gases at the furnace outlet, kJ/kg (kJ/m^3);

$J_Г^{/}$ - enthalpy of gases at the utiliser outlet, kJ/kg (kJ/m3);

β - a coefficient that takes into account the mismatch between the mode and number of operating hours of the utiliser and the unit - source of secondary energy resources;

ζ - coefficient of heat losses of the utiliser to the environment.

The coefficient of utilisation of secondary energy resources (SER) is determined by the formula:

$$\delta = \frac{Q_{ВЭР}}{Q_T^{/}} \qquad (4)$$

As the costs of fuel extraction and energy production increase, there is a growing need to utilise them more fully when they are converted into combustible gases, heated air heat and water. Although utilisation of secondary energy resources is often associated with additional capital investment and an increase in the number of operating personnel, the experience of advanced enterprises confirms that the use of secondary energy resources is economically very profitable.

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