The usage of waste heat recovery units with improved heat engineering rates: theory and experimental research

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Abstract. Use of recuperator in heat producing plants for utilization of natural gas combustion products allows to achieve the saving of gas fuel and also provides for environmental sanitation. Decrease of the volumes of natural gas combustion due to utilization of heat provides not only for reduction of harmful agents in the combustion products discharged into the atmosphere, but also creates conditions for increase of energy saving in heating processes of heat producing plants due to air overheating in the recuperator. Grapho-analytical method of determination of energy saving and reduction of discharges of combustion products into the atmosphere is represented in the article. Multifunctional diagram is developed, allowing to determine simultaneously savings from reduction of volumes of natural gas combusted and from reduction of amounts of harmful agents in the combustion products discharged into the atmosphere. Calculation of natural gas economy for heat producing plant taking into consideration certain capacity is carried out.

1. Introduction

Presently much attention is paid to economy of fuel and energy resources and, in particular, economy of natural gas used in various spheres of economics. At that the pressing problem is also reduction of pollution of air basin from discharge of combustion products containing a lot of carbon dioxide (CO_2).

2. Materials and Methods

2.1. Relevance, Scientific Importance

Solution of the problems of energy saving has been earlier reviewed in the article [1–2], where the dependence is given of the energy saving from the temperature of air heating supplied for natural gas combustion in the heat producing plant. As an example energy saving heat-exchange unit (radiation recuperator) is given. The unit is engineered for heat recovery of products of natural gas combustion for blast air heating. However, the issues of sanitation of air medium into which combustion products are discharged, have not been reviewed. At the same time upon solution of the issue of energy saving sanitation of the environment happens in the zones of use of heat producing plants [3–10].

Under the conditions of economical use of natural and energy resources, as well as their rather high price, a special meaning is given to joint solution of the issues of provision of ecological safety, energy efficiency and preservation of energy on basis of scientifically proven methodological approach to choosing of simulation of the system of reduction of negative impact of discharge of combustion products on the environment and management of parameters influencing ecological efficiency and energy saving [11–20].

2.2. Task Setting

As applied to the heating furnaces, the temperature of products of natural gas combustion is 1100...1200 °C. In the structure of the heat-exchange unit the intensification of heat exchange between products of natural gas combustion and heated air is provided. As the result, the usage of heat of exhaust products of natural gas combustion to heat the air used for burning is one of the most effective ways of efficiency increasing for industrial heating furnaces. Aim of the research is diversified solution of the combined issue of efficiency, energy saving and protection of environment in using natural gas in heat producing plants. For achievement of the set aim a theory of energy saving and reduction of combustion products discharged into the atmosphere is reviewed in the article. Solution of the theoretical task on utilization of heat of combustion products in heat producing plants is carried out by known thermophysical equations which are used for the new purpose with receipt of positive effects on energy saving and environmental protection.

2.3. Theoretical part

For calculation of the economy of use of natural gas we determine the volume of air necessary for heating in the recuperator, taking into consideration the air excess factor:

$$V_a = V_g \cdot V_t \cdot a, \ m^3/h \tag{1}$$

where V_g – is the volume of gas used in heat producing plant, m^3/h;

V_t – is theoretically necessary volume of air for combustion of natural gas in the heat producing plant, m^3/m^3;

a – is the air excess factor

With consideration to known values of energy saving expressed in per cent (%), we assume the following initial data: air heating 100 ^{0}C and 300 ^{0}C, temperature before recuperator 600 ^{0}C. To determine heat content we use the following formula of heat energy consumption:

$$Q_e = V_a \cdot C_{a.h.} \cdot t_a \tag{2}$$

where $C_{a.h.}$ is average mean specific heat of heated air kJ/(kg·^{0}C);

t_a is the temperature of air heating in the recuperator, ^{0}C

Energy saving expressed in m^3/h:

$$V_e = Q_e / Q_{l.h.} \tag{3}$$

where $Q_{l.h.}$ – is the lowest heat of combustion of natural gas 33.600 kJ/m^3

Further the volume of products of natural gas combustion should be determined in combustion $1m^3$ with consideration to air excess ratio. Since natural gas consists mainly of methane, reaction of the combustion process shall be assumed as per the following formula:

$$CH_4 + 2O_2 + 2 \cdot 3.76N_2 = CO_2 + 2H_2 + 7.52N_2 \tag{4}$$

where left part of the equation is gas and air mixture, and right part is the volume of combustion products $V_{p.c.}$ = 10.52 m^3/m^3 with a=1. Consequently, the aggregate saved volume of combustion products shall be calculated by the formula:

$$EV_{p.c.} = V_e \cdot V_{p.c.} \cdot a \tag{5}$$

Using initial data for the theoretic calculation we have obtained results of economy of natural gas and decrease of volumes of combustion products discharged into the atmosphere shown in the table 1.

Table 1. Main parameters and calculation data, determining economy of natural gas and reduction of volumes of combustion products discharged into the atmosphere

Initial data for calculation						Results of calculation			
V_g	t_a	V_t	$t_{e.g.}$	$C_{a.h.}$	L	V_a	Q_e	V_e	$V_{p.c.}$
1	2	3	4	5	6	7	8	9	10
500	100	9.52	600	1.47	1.2	5712	839664	24.99	315.5
500	300	9.52	600	1.67	1.2	5712	2861712	85.2	1075.6

For grapho-analytical multi-functional solution of the issue of the problem of energy saving and environmental protection, using the data of the table, a three-stage diagram has been developed for consecutive determination of the interconnection of the influence of energy saving and environmental protection when using natural gas in heat producing plant figure 1.

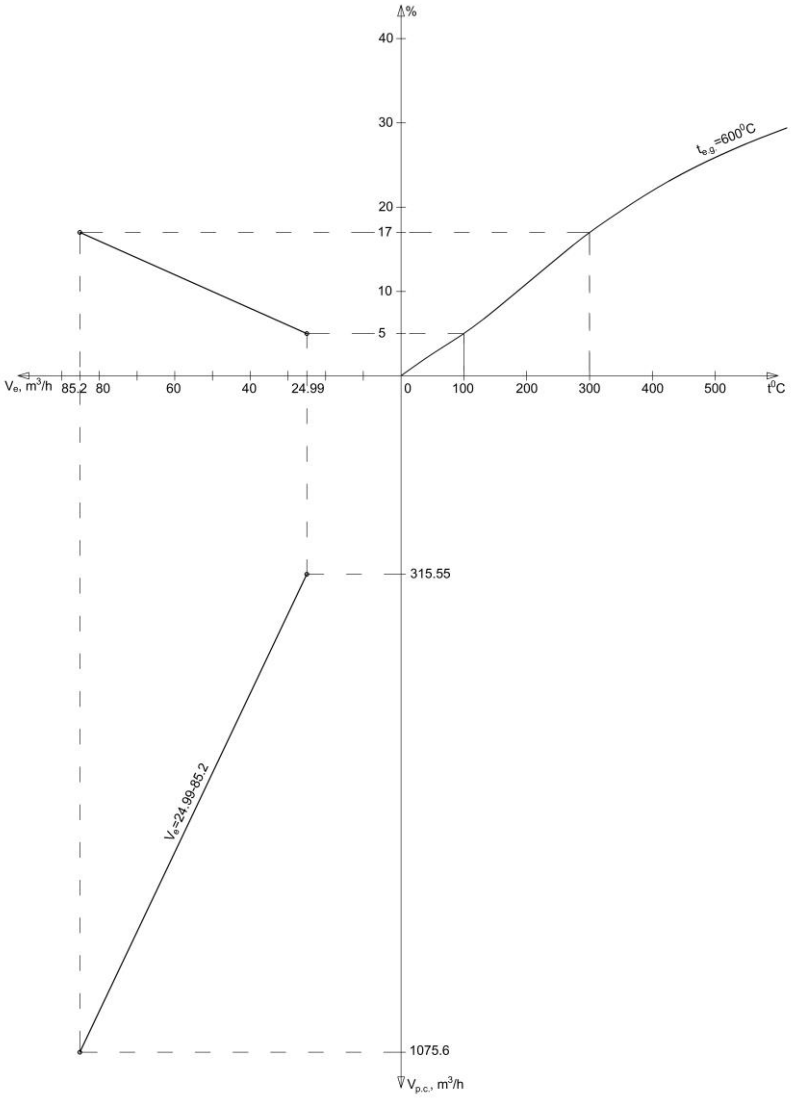

Figure 1. Grapho-analytical dependence of ecological state of environment from energy saving in using natural gas

The first stage of the diagram is used in earlier published article [1] for the temperature of discharged combustion products 600 ^{0}C and air heating in the recuperator 100 ^{0}C and 300 ^{0}C for heat producing plant with initial air consumption of gas 500 m^3/h.

In the second stage of the diagram calculated economy of natural gas is shown in dependence from the temperature of the discharged combustion products and temperatures of air heating.

In the third stage of the diagram a dependence is given of the reduction of volumes of combustion products discharged into the atmosphere from the energy saving of heat producing plant

3. Results

As the result of the research we have held the following tasks have been solved:

- interconnection of energy saving and reduction of harmful agents discharged into the atmosphere with combustion products of natural gas has been researched and calculated;
- influence of utilization of heat of combustion products on energy saving has been reviewed (economy of natural gas and reduction of discharge of harmful agents in the combustion products discharged into the atmosphere);
- dependence of the reduction of volumes of combustion products from the energy saving of heat producing plant has been researched.

4. Conclusions

The usage of waste heat recovery units with improved heat engineering rates for the better use of the heat recovery of products of natural gas combustion is suitable for heating furnaces and the process furnaces of the enterprise of mechanical-engineering, metallurgic, glass and other industry sectors. The scientific results obtained carried out on basis of methodological approach to choosing of simulation of the system of reduction of negative impact of discharge of combustion products on the environment and management of parameters influencing ecological efficiency, efficiency and energy saving shall allow management of the behavior of gaseous fuel under the conditions of increase of energy saving in heating processes of heat producing plants and, in the end, shall influence the reduction of environmental pollution.

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