THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2021

# IDENTIFICATION OF SECONDARY ENERGY RESOURCE FROM COMBUSTION GASES FOR COMBUSTION AIR PREHEATING - CASE STUDY

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## ABSTRACT

*This article analysed the opportunity to implement the recovery of secondary energy resources in an industrial enterprise for the production of special building materials.*
*The inventory of secondary energy resources and the establishment of their characteristics and energy potential is an important step in the energy balance sheet.*
*The use of secondary energy resources, and in this case of flue gas, is one of the most effective ways to increase the use of energy consumed in industrial processes of this type.*
*In this paper, the internal recovery solution of the secondary energy resource identified in the flue gas is analysed for the regenerative preheating of the combustion air.*

KEYWORDS: secondary energy resources, combustion gas, combustion air, recovery, energy efficiency

## 1. INTRODUCTION

The applied recovery solution is an internal recovery of secondary thermal energy resources (burning gases). Internal recovery technology is characterized by the framing in the technological flow of the heat recovery, with the implications arising from this:
-the flue gas production regime is the same as the consumption regime;
-the main effect of energy and fuel economy is quantified at the technological aggregate;
-energy and fuel economy are also quantified under environmental aspects, both directly: reduction of emissions and indirectly: reduction of the degree of depletion of non-renewable natural reserves;
- the implemented recovery solution does not require additional expenses in view of its incorporation into the technological flow;
-energy and ecological effects can also be quantified from an economic point of view by reducing qualitative and quantitative ecotaxes (under the existence of a legislative basis).

In the case analysed the main features of the process are:
-preparedness of raw materials (drying sand, crushing, mixing, homogenization and storage);
melting and conditioning in the melting furnace;
- shaping materials;
- heat treatment of annealing;
-finishing, sorting, packaging.

The manufacture of special materials for construction is an energy-intensive process and the choice of energy sources, heating techniques and heat recovery methods are extremely important for the process to have high energy and economic performance. In general, the energy required to melt the component materials may constitute more than 75% of the total energy required to manufacture the finished product.

## 2. THEORETICAL ASPECTS OF ENERGY EFFICIENCY OF RECOVERY

The energy efficiency of the regenerative preheating of the combustion air results from the fact that this saves an amount of energy in the form of fuel greater than the sensitive heat introduced with the air in technology aggregate.

The energy efficiency of this recovery solution increases with the level of combustion air preheating. The main factors that influence fuel saving are [1]:

-the thermal level of the flue gas;

-type and temperature of fuel used;

-the technological process being the same, the exhaust temperature of the flue gas in the working room remains the same, being directly dependent on the process operating temperature.

Table 1 presents the thermal balance equations related to the working room before and after applying the recovery solution, as well as the expressions of the terms that fall into the balance sheet equations [3].

The meanings of the notations used in table 1 are:

**$Q_{mt}$** - heat input with technological products[kW];

**$Q_p$** - heat content of finished technological products [kW];

Table 1. Thermal balance equations related to the work chamber before and after application of the recovery solution

| Working conditions | Balance equation | Heat introduced with fuel | Heat contained in the flue-gases | Heat introduced with the combustion air |
|---|---|---|---|---|
| | kW | kW | kW | kW |
| Cold air operation | $Q_{c1}+Q_{a1}+Q_{mt}=Q_p+Q_r+Q_{g1}$ | $Q_{c1}=B_1(H_i+i_B)$ | $Q_{g1}=B_1[v_{g0}+(\lambda_1-1)v_{a0}]i_g$ | $Q_{a1}=B_1\ \lambda_1 v_{a0} i_{ae}$ |
| Functioning with preheated air | $Q_{c2}+Q_{PA}+Q_{mt}=Q_p+Q_r+Q_{g2}$ | $Q_{c2}=B_2(H_i+i_B)$ | $Q_{g2}=B_2[v_{g0}+(\lambda_2-1)v_{ao}]i_g$ | $Q_{pa}=B_2\ \lambda_2 v_{a0} i_{ai}$ |

The additional fuel consumption due to the additional power of the air and flue gas fans caused by the presence of the air preheater has a small share in the net fuel economy (5-10%). This is dependent on the flue gas route from the production site of these secondary energy resources to the recuperator (path length), the size of the recuperator, as well as the air and flue gas speed [2].

In order to highlight the energy efficiency of the recovery solution, the energy balance of the technological installation work chamber is taken before and after the application of combustion air preheating.

Establishing the balance sheet equation before and after applying the recovery solution is based on the following assumptions:

-in both situations, the amount of heat useful to the process in the working room is the same, the, because the process and technology are identical;

-the radiation heat losses of the working room to the environment are the same, because the constructive and technical characteristics of the working room are the same;

**$Q_r$** - heat lost from the working chamber by radiation[kW];

**$Q_{c1}$,$Q_{c2}$** - heat introduced with fuel before and after preheating the combustion air[kW];

**$Q_{a1}$, $Q_{PA}$** - heat introduced with combustion air before and after preheating[kW];

**$Q_{g1}$, $Q_{g2}$** - the heat output from the flue gas working chamber, before and after preheating of the combustion air[kW];

**$B_1$,$B_2$** - fuel consumption of the technology unit before and after preheating the combustion air[kg fuel/s] or [m3N/s];

**$\lambda_1$, $\lambda_2$**- coefficients of excess air for combustion;

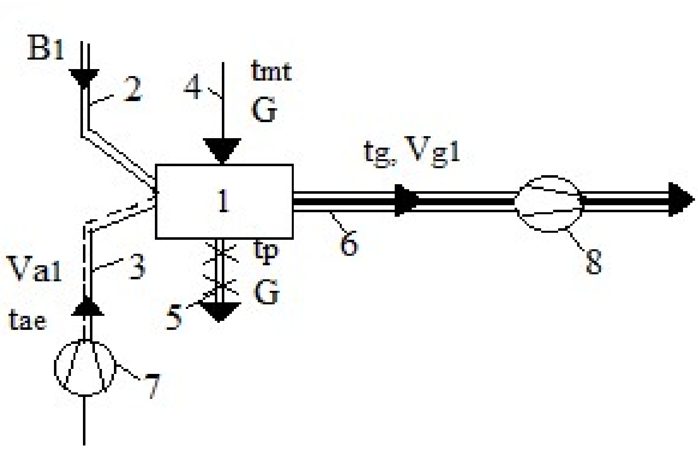
**$\Delta\lambda$** - false air ingress due to the assembly of the recuperating installation;

iae, iai - the enthalpy of the cold burning air and preheated air [ kJ/m3N ];

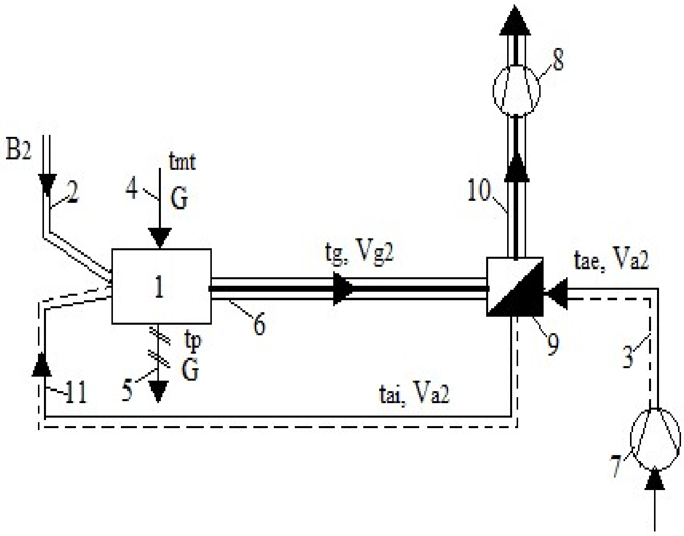
**$i_B$** - fuel enthalpy (at temperature tc) [kJ/m3N ];

**ig** – enthalpy of flue gases (at temperature tg) [kJ/m3N ];

**$v_{ao}$, $v_{go}$** - theoretical volume of combustion air, respectively flue gas[m3N¬/m3N].




(A)




**(B)**

**Figure 1.** Flue gas sensitive heat recovery principle scheme for preheating furnace combustion air: A – without preheating of combustion air; B – with preheating of combustion air

Figure 1 shows the main scheme of the recovery of the heat contained in the flue-gases for the purpose of preheating the combustion air entering the furnace (B) working chamber. The furnace is originally built without regenerative air preheater (A) [4].

1 – furnace working chamber;

2 – fuel (natural gas);

3,11 – cold burning air, preheated respectively;

4,5 – technological products at the entrance and exit of the working room;

6,10 – hot and cold combustion gases;

7,8 – air fan, flue gases fan respectively;

9 – air preheater;

B1, B2 – the fuel flow consumed before and after preheating the combustion air;

G – the mass of technological products;

Va1, Va2 - volume of cold air, respectively preheated;

Vg1, Vg2- volume of flue gas before and after preheating of the combustion air;

tae, tai – temperature of cold air, preheated respectively;

tg1, tg2, tgev – flue gas temperature at the exit of the working room before recovery, after recovery, respectively upon discharge into the environment;

tmt – temperature of technological materials at the entrance to the working room;

tp – temperature of finished products.

## 3. THEORETICAL ASPECTS REGARDING THE ENERGY EFFICIENCY OF THE AIR PREHEATER IMPLEMENTATION

The main criteria on which the energy efficiency of possible recovery solutions will be assessed are:

-fuel equivalent of saved energy (fuel economy);

-total degree of recovery;

Taking into account fuel consumption before and after application of the recovery solution, fuel savings and recovery can be calculated. Table 2 presents the general calculation expressions of the main energy analysis.

In this table, $\Delta B_{supl}$ it is the equivalent in fuel of the additional energy consumption for the annexed installations necessary for recovery.

The annual value of the gross fuel economy achieved following recovery is:

$$\Delta B_{an} = \Delta B*3600*\tau \ [m^3_N \text{ fuel/year}],$$

In which $\tau$ is the annual duration of use of preheating, in hours/year.

## 4. CONCLUSIONS

Economic efficiency of recovery secondary energy resources. it is established by balancing the value of the energy saving (in fuel equivalent) thus achieved with the surplus of investments and annual expenses for the realization of the recovery facilities and of the annexes.

Table 2. Energy indicators

| Gross fuel economy – absolute value | Net fuel economy – absolute value | Gross fuel economy – relative value | Net fuel economy – relative value | Recovery level |
|---|---|---|---|---|
| [kg fuel/s or $m^3_N$/s] | [kg fuel/s or $m^3_N$/s] | % | % | - |
| $\Delta B^* = B_1 - B_2$ | $\Delta B = \Delta B^* - B_{spl}$ | $\Delta b^* = (B_1 - B_2) / B_1$ | $\Delta b = (\Delta B^* - \Delta B_{spl}) / B_1$ | $\delta_{PA} = Q_{PA} / Q_{g2}$ |

In the recovery of secondary energy resources, the expenses are determined directly by the realization of the recovery facilities, as well as indirectly through the expenses occasioned by the realization of the entire recovery solution (additional auxiliary facilities), the transport and distribution of energy contained in the secondary energy resources., as well as the expenses related to the additional energy consumption required for some recuperating installations [5].

Taking all this into account, the decision on the recovery of secondary energy resources and of the effective recovery solution is always taken only on the basis of technical and economic calculations.

The economic reflection of the reduction of energy consumption, at the level of enterprises or industrial platforms, takes place by reducing the production expenses related to them, which ultimately leads to a reduction in the cost price of technological products.

In general, the economic efficiency of the recovery of secondary energy resources is established compared to the solution „without recovery". When analysing several recovery solutions, the optimal solution is determined by comparative analysis of each with the solution without recovery. That which leads to the maximum value of the economic effect - determined on the basis of a certain criterion - is considered to be optimal.

Within this analyse, the economic efficiency of flue gas recovery for flue air preheating was assessed on the basis of the criterion of the term of return on investment .

Recovery time is the period of time (calculated from the moment the investment is put into operation) in which the value invested is recovered on account of the annual profits. A solution that ensures a faster recovery of investment expenses is preferable.

Algorithm of calculation for the effective investment is:

Ief = IPA+IVG+IVA [€], where:
IPA = investments in air preheater;
IVA = investments in air fan;
IVG = gas fan investments.

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