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ANALYSIS OF THE PERFORMANCE COEFFICIENT OF THE ENERGETICAL RECOVERY OF THE DOMESTIC WASTE

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ABSTRACT

The paper critically analyses the way of defining the coefficient of performance of the systems used for the recovery of the energy of the domestic waste in cogeneration plants. The R1 criterion of performance of the European Waste Framework Directive (2008/98/EC) is taken as a basis for the discussion.

The philosophy of establishing the form of the coefficient of performance depending on the definition of the system "Product" and "Fuel" is discussed.

It is pointed out the fact that the performance criterion R1 is established on an energetic basis that makes it insensitive to climacteric changes.

To take into account the interaction of the system with the environment in which it operates, the paper aims at defining a coefficient of performance based on the exergy concept that would make evidence of both the quantity and quality of the processed energies.

KEYWORDS: energetic recovery, municipal waste, coefficient of performance

1. Introduction

The correct estimation of the coefficient of performance of a system or piece of equipment is of a capital importance that makes possible to point out, for the given system, the possibilities of improvement of its operating mode and construction.

When one considers that a system operates better than it really does, opportunities of improvement are lost. On the contrary, when a system is considered weaker than in reality, one will focus his attention on trying to improve its characteristics – efforts made in vain because the system was operating well.

What one expects from a system, called the system Product, represents its net output that another system or subsystem is interested to buy [1].

From an economic point of view, the Product represents the result of an activity that is sold by a subsystem and purchased by other subsystems.

The Fuel represents the net resource that a system consumes to accomplish the final product.

The efficiency of any subsystem or system as a whole is given by the ratio between Product and Fuel.

The correct estimation of the generic Fuel and product of each operating zone is the key action for a proper evaluation of the local and finally global efficiency of the system, pointing out possibilities for the improvement of the system operating and design [2].

2. The R1 criterion for assessing the efficiency of the energy recovery of the municipal solid waste

The package of good practice of the European Community regarding the municipal solid waste management, part of the Waste Framework Directive (2008/98/EC), introduces the R1 criterion depending on which any system of waste processing could be rated as an energy recovery system or as an incineration facility [3].

The relation for calculating the Coefficient of Performance of a municipal solid waste energy recovery system wants to account not only for the system efficiency taken on its own, but also for the way the energy recovered is used.

The R1 criterion is:

$$R1 = \frac{E_p - (E_f + Ei)}{0.97(E_{mw} + E_f)} \geq \text{ Limit} \qquad (1)$$

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where the Limit from which a system for processing the municipal waste could be considered an energetic recovery system is for the existing installations and for the systems starting the operation after adopting the Waste Framework Directive (2008/98/EC).

The terms in equation (1) have the following significance:

- energy produced annually as electricity or heat [GJ/y];
- annual consumption of energy with the conventional combustible necessary for producing process steam [GJ/y];
- it represents complementary energy different from an energy that does not contribute to the producing of process steam;
- the annual energy contained in the processed waste, calculated based on the Low Heating Value (LHV) [GJ/y].

3. Discussions on defining the Coefficient of Performance of a system for the energy recovery of the municipal solid waste

To understand the significance of the terms in Eq. (1) the Product and the borders of the system should be stated. Dealing with an energetic analysis, the observer is situated out of the system borders and accounts only for the energetic interactions by mass and energy transfer between the system and its surroundings.

The installation for the energetic recovery of the municipal waste produces process steam, electrical energy and heat, making use of a steam turbine system.

Figure 1 shows the schematic of the energy balance of the combined system made of the incinerator and the steam turbine for the energy recovery from the municipal solid waste.

The energy balance equation for the combined system becomes:

$$E_f + E_{mw} + E_f^{com} + E_{com} + E_{el}^i = \\ = E_{el} + E_Q + E_{st} + E_L \quad (2)$$

To point out the product of the system, the terms of Eq. (1) could be grouped in the following way:

$$E_p = (E_{el} - E_{el}^i) + E_Q + E_{st} = \\ = E_{el}^u + E_Q + E_{st} \quad (3)$$

$$E_i = E_{com} + E_f^{com} \quad (4)$$

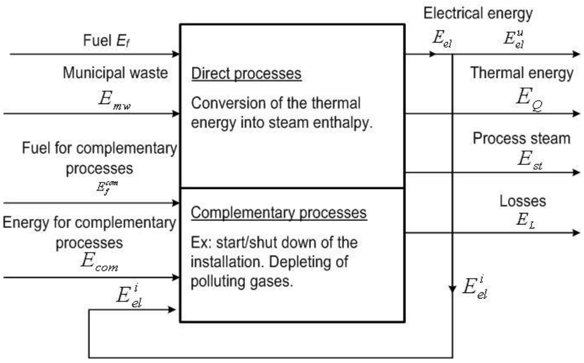

Fig. 1. *Schematic of the energy balance for the combined system, incinerator and steam turbine, for the energetic recovery of the municipal solid waste*

Accounting for equations (3) and (4), the energy balance equation (2) becomes:

$$E_f + E_{mw} + E_i = E_p + E_L \quad (5)$$

where Ep is the product of the system offered to external systems interested to buy it and E_L represents the losses with the energy thrown away into the environment for which, obviously, no money is earned.

The coefficient of performance of the system may be stated depending on the definition of the installation Product and Fuel.

If one wants to point out the net energy obtained by each product from the municipal waste, then Equation (5) becomes:

$$E_{mw} = (E_p - (E_f + E_i)) + E_L \quad (6)$$

where

$$E_{mw} = F_1 \quad (7)$$

and

$$E_p - (E_f + E_i) = P_1 \quad (8)$$

For this case, the coefficient of performance is:

$$COP_1 = \frac{P_1}{F_1} = \frac{E_p - (E_f + E_i)}{E_{mw}} = 1 - \frac{E_L}{E_{mw}} \quad (9)$$

By replacing Eq. (4) in Eq. (5), it gives:

$$E_f + E_{mw} + E_{com} + E_f^{com} = E_p + E_L \quad (10)$$

If one considers as Fuel the sum between the energy of the municipal waste (E_{mw}) then the energy of the conventional fuel is used in the auxiliary burners to maintain the prescribed temperature in the reactor (E_f).

$$F_2 = E_f + E_{mw} \tag{11}$$

Then by the identification of Eq. (10) with the equation (12) of the energy balance written with economic sense

$$F = P + L \tag{12}$$

the Product becomes:

$$P_2 = E_p - (E_{com} + E_f^{com}) = E_p - E_i \tag{13}$$

and as a consequence:

$$COP_2 = \frac{P_2}{F_2} = \frac{E_p - (E_{com} + E_f^{com})}{E_f + E_{mw}} = \\ = \frac{E_p - E_i}{E_f + E_{mw}} = 1 - \frac{E_L}{E_f + E_{mw}} \tag{14}$$

A last approach could be to consider as Fuel the entire energy utilized with direct or complementary effect for achieving the goal of the installation, namely to obtain electrical or thermal energy, or process steam.

$$F_3 = E_f + E_{mw} + E_i \tag{15}$$

as a consequence:

$$P_3 = E_p \tag{16}$$

and

$$COP_3 = \frac{P_3}{F_3} = \frac{E_p}{E_f + E_{mw} + E_i} = \\ 1 - \frac{E_L}{E_f + E_{mw} + E_i} \tag{17}$$

Observing that the energy loss due to its transfer into the environment is the same for all the approaches, it results that:

$$COP_1 \langle COP_2 \langle COP_3 \tag{18}$$

The second definition of the COP (COP2) is the closest to the definition given by the R1 criterion.

It must be pointed out that the R1 criterion as a coefficient of performance based on only the energetic balance cannot account for the internal losses or for the changes in the intensive parameters of the environment.

A better approach must use the exergy concept to account for both the quality and quantity of each kind of energy [4].

4. Conclusions

The coefficient of performance of any energetic system is the ratio between the Product of the installation and resources consumed with this aim, resources generically called Fuel.

The value of the coefficient of performance depends on the way one considers which part plays the role of the Product and Fuel in the system.

The proper estimation of the Fuel and Product opens the way to a more rapid procedure of optimization.

Criterion R1 of assessing the coefficient of performance of a system for the energetic recovery of the municipal waste represents just one point of view defined in the Waste Framework Directive (2008/98/EC) of the European Community.

The R1 criterion as a coefficient of performance is based only on the energetic balance and thatis why it cannot account for the internal losses or for the changes in the intensive parameters of the environment.

Correction must be added to the R1 criterion to account for the changes in the temperature of the environment.

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