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A Solution to Reduce Pollutant Emissions by Recovering the Flue Gases Waste Heat

From the point of view of the energy efficiency improvement and environmental protection, the recovery of waste heat from thermal systems is a necessity. The heat recovered through an economizer is a viable solution in order to achieve energy savings. For this reason, the article deals with a solution for recovering a quantity of thermal energy exhausted into the atmosphere through the dyeing/drying booths (DDB) burners stove pipes at an economic agent. The study illustrates the importance of recovering heat from flue gases in order to reduce pollutant emissions.

Keywords*: economizer, waste heat, recovery, efficiency, emissions, flue gas*

1. Introduction

In the context of policies regarding the efficient use of energy, the European Union (EU) has committed to develop a sustainable, competitive, secure and decarbonized energetic system [1]. Thus, besides the measures taken to increase the share of consumed renewable energies, clear measures are also needed to reduce energy consumption by adopting solutions to recover waste energy solutions that contributes to the greenhouse gas emissions reduction. For the existing real estate fleet in the EU, ensuring a high level of energetic efficiency and low carbon emissions, Member States must draw up guidelines and establish clear measures not only for new buildings but also for the existing ones. From this point of view, the plant systems optimization and upgrading should be an important step in the buildings rehabilitation in all sectors.

Despite the current efforts to optimize/upgrade and improve the plant equipment efficiency, a significant amount of energy is still discharged into the environment through the flue gases, especially in the industrial sector. For this reason, specialists in the thermal field, approached and researched through comparative studies (analytical and experimental) various solutions for using the flue gases energy. By conducting these studies it was sought to improve the heat transfer by increasing the heat exchange surface of the heat exchanger or by increasing the heat transfer coefficient of the flue gas flow. To improve the heat transfer there are many techniques that can be classified as active, passive or combined. For these techniques, specialists anticipated the effects of using the proposed solutions on energy savings and, implicitly, on reducing production costs due to heat recovery [4], [8]. In the study of fluids in motion, current research drew attention to the difficulty of determining the fluid flows real temperature, which affects readings while measuring parameters without knowing their deviation [9].

On the other hand, although various heat transfer devices have been developed and studied lately and can be used to convert and recover heat in many industrial and domestic applications, these solutions are still not widely implemented. For this reason, besides the areas with recoverable energy potential detection and waste energy recovery solutions implementation, it is particularly important to inform the consumer about this potential and the importance of recovering and reducing the energy consumption.

2. Flue gases, a source of air pollution

The composition and diversity of pollution sources indicate the danger to which both the environment and humanity are subjected. Important quantities of polluting substances such as oxides and sulfur dioxides, nitrogen oxides, phosphorus, chlorine, fluorine, hydrocarbons, heavy metal compounds, carbon monoxide and carbon dioxide emitted from combustion plants in various sectors of activity, especially in the industrial and household sectors, contributes, within alarming limits, to environmental degradation.

At European Union level, flue gases from heat and power generation processes are responsible for the discharge of large amounts of CO_2 into the atmosphere. Even if these environmentally harmful chemicals have long been brought to the attention of environmentalists and there are standards limiting the maximum admissible concentrations of pollutants released into the atmosphere, yet their effects on the environment are now more and more worrying.

Regarding pollutant emissions discharged through the combustion plants stove pipes, calculation stove pipe heights is considered to ensure the spread of noxes so that at the ground level concentration falls within the maximum allowed by the standards in force. However, the spreading of the pollutants amounts annually discharged through the stove pipes and the cumulative effect of several sources can cause immissions to be exceeded at different heights and even on the ground. In these situations, the pollutant effects increase over time generating harmful effects. The magnitude and danger to humans and the environment is due to high noxes concentrations and poor dispersion in air. On the other hand, the large amount of waste heat released in the last years in the environment through the flue gases of plants and technological endowments has contributed greatly to the environment pollution. For this reason, more attention was paid to the possibility of using residual heat due to its potential, reducing fuel consumption and reducing environmental problems.

Given the complexity of technological processes in the industrial sector, various solutions have been developed and implemented to recover heat lost from different types of equipment and technological endowments. The recovered energy is mainly used for space and water heating.

Regarding the advantageous exploitation of flue gases with average temperatures up to 100°C, it is important that the average difference between the temperatures of the agents entering and exiting the economizer. The average temperature difference significantly influences the economizer energetic and exergetic yields, as well as the overall energy saving. Calculation of the flue gases temperature and enthalpy can be made by: considering the theoretical combustion of the fuel in the air presence at a temperature of 0°C and a coefficient of excess air equal to 1; defining a flue gases calorimetric temperature influenced by fuel characteristics, combustion nature and temperature, and excess air (oxygen) coefficient; calculations of the flue gases calorimetric temperature influenced by fuel and combustion characteristics and certain thermotechnical indicators [10]. As a series of losses occur during the combustion process, in fact the temperature of the flue gases is lower than the calorific value [10].

3. The impact of flue gases from DDB on the environment through waste heat recovery

Flue gases can be considered as waste, considering that they are exhausted into the atmosphere. In addition to classical treatment and recycling of various types of waste, flue gases, especially those from the industrial sector, are recovered by using various methods. Regardless of the recovery method, the recovered energy can be considered as a renewable resource that can be capitalized. With a view to energy efficiency improvement at large energy consumers from the industrial sector, the article addresses the issue of using the waste energy capitalization in the form of heat.

In the case DDB used by an economic agent for the dyeing and drying metallic products or fiberglass reinforced resins, the possibility of recovering energy from the flue gases from natural gas combustion in DDB burners was analyzed. In order to choose the optimal option for recovering the energy lost through the flue gases, an air-to-air heat exchanger, intercalated on the exhaust gas circuit (Fig. 1) [11] was installed.

Figure 1. The flue gas waste heat recovery plant

Analyzes made on flue gases from natural gas combustion have shown that carbon dioxide and carbon monoxide contribute to climate heating and nitrogen oxides are the origin of acid rain, it is important that their concentrations to be as low as possible. For this reason, in parallel with monitoring the inlet and outlet temperatures of the economizer, in order to determine the its efficiency [Report] it is also necessary to monitor the pollutant emissions with concentration emission from flue gases devices.

The Testo 350S gas analyzer was used to measure the flue gas emissions. Therefore, measurements of NO_x in mg/Nm^3, CO in mg/Nm^3, CO_2 in % and O_2 in % concentrations, both before and after the economizer, have been carried out for the flue gases.

As a rule, for these emissions monitorization it is necessary to relate them to the basic volumetric concentrations of oxygen in the smoke (OB).

Table 1. Pollutant emission values at the stove pipe

Measured parameter	Flue gas temperature [°C]	
	84	120
CO_2 [%]	3,23	4,91
CO [mg/m^3]	4,11	5
NO_x [mg/m^3]	17	24
NO [mg/m^3]	16	23
O_2 [%]	13,2	12,34
Environmental temperature [°C]	28,8	28,8
Excess air coefficient	1,78	2,42
Yield [%]	93,8	92,2

As a result of the measurements, it was found that after the economizer installation the pollutant emissions concentrations were lower due to the hot flue gases cooling that occur during their passing through the economizer.

5. Conclusions

In order to reduce energy consumption, not only techniques for improving heat transfer and the optimal use of energy sources are very important but also the recovery of waste energy in various forms. The recovery of this energy through the exhaust of flue gases can be an advantage for the economic agent savings point of view.

As a result of the analyzes carried out for capitalization of the waste energy at the industrial consumer, after the optimal solution has been set with regard to the recoverable energy potential and the possibility of economizer location in situ, measurements at the DDB have provided important information. On the other hand, measurements of the pollutant emissions concentrations have highlighted that heat recovered from hot flue gases contributes to the reduction of the negative effects on the environment by their concentration reduction.

In conclusion, the visible impacts of climate change force all energy consumers, especially industrial consumers, to improve their plants, systems and technological endowments and to apply measures in order to recover fractions of waste energy in various forms.

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