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Waste heat energy recovery from an electrostatic painting line

Recuperarea energiei termice reziduale de la o linie de vopsire în câmp electrostatic

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Abstract. *The paper presents a case study regarding the feasibility of implementing a waste heat recovery system from combustion gases emitted by an electrostatic painting line. Our proposed recovery system aims to bring two main benefits: from an economical point of view, we want to decrease the costs of gas consumption for heating domestic hot water; from a climate and air pollution standpoint, we aim to considerably reduce the amount of combustion gases dumped into the environment, thereby diminishing the greenhouse effect.*

Key words: waste heat recovery, combustion gas, domestic water heating

1. Introduction

The 2413/2023 European Directive established the objective of climate neutrality in the Union by 2050 and an intermediate target of a reduction of net greenhouse gas emissions by at least 55 % compared to 1990 levels by 2030.[1] Nowadays, a lot of industrial waste heat is generated daily in different industrial processes without being put in practical use, causing two main disadvantages: rising concern regarding global warming (by producing greenhouse gas emissions) and wasting energy that could be harnessed rather than dumped into the environment. Therefore, we propose to study how the energy potential from the waste gases emitted into the atmosphere from the components of the electrostatic field painting line can be exploited for energy purposes

[1] Directive (EU) 2023/2413 of the European Parliament and of the Council,18 October 2023

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using heat exchangers on the hot exhaust circuit. The recuperated heat will be used for heating cold water, in order to have an adequate supply for the factory`s showers.
Our feasibility study concerns the assembly of painting booths of a local company, situated in the city of Timisoara. S.C. AMBASADOR PLUS S.R.L. is a Romanian, privately owned company, established in 1994, whose main activity is the production and marketing under the brand "ELTIM" of a wide range of heating systems. These include different types of boilers, furnaces, heat exchangers, heat recovery systems and hydrophores, that are being produced since 1957.[2] Since 2021, the company is using an electrostatic painting line, composed of: degreasing cabin, washing booth, drying booth, powder spraying booth, polymerization oven and distiller.

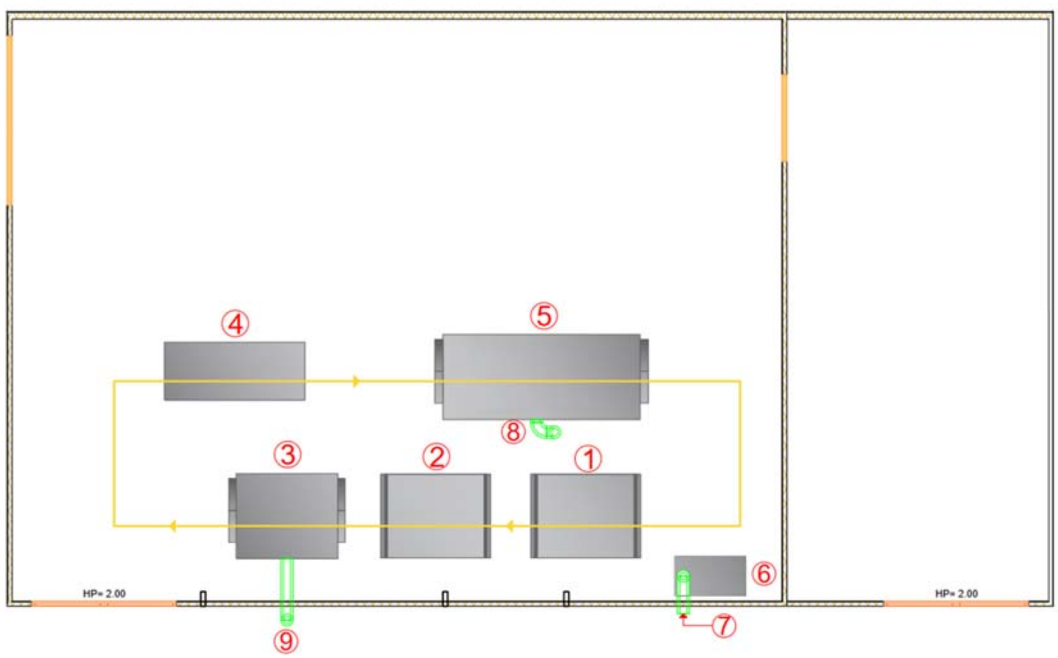


Fig.1. Position of the equipment in the painting hall
1-degreasing cabin; 2-washing booth; 3-drying booth; 4-powder spraying booth; 5-polymerization oven; 6-distiller; 7-chimney for evacuating combustion gases from the distiller; 8- chimney for evacuating combustion gases from the polymerization oven; 9- chimney for evacuating combustion gases from the drying booth, D=150

The technological units of the painting line are working simultaneously, in the following order: The painting process starts in the degreasing cabin (1), where the components are degreased from oils and greases. Further on, they are transported on the conveyor belt (yellow), located above the technological units, to the washing booth (2). After that, the pre-treated components are dried in the drying booth (3) before being painted. Inside the booth the operating temperature is 150 degrees Celsius and the

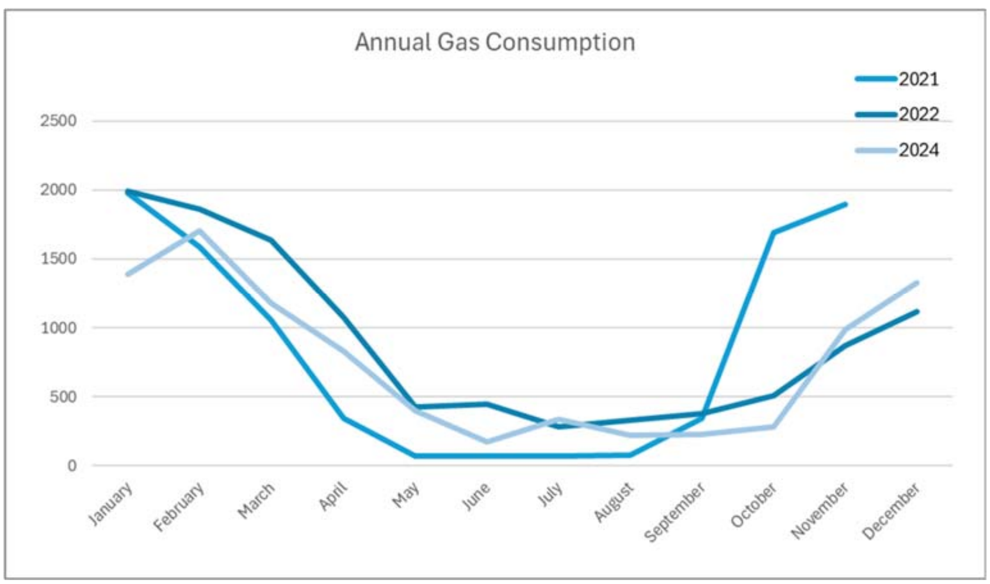
[2] https://www.eltim.ro/info/25/Eltim---cazane-de-baie-cazane-de-incalzire-centrala-boilere-electrice-boilere-termice.html

intense air movement required for drying is provided by 2 circulating fans. After drying, the components are transported to the powder spraying booth (4) and further to the polymerization oven (5), where the painted objects are dried at a temperature of 190°C. The distiller (7) has the role of ensuring evaporation of wastewater generated during the process, condensation and reuse of vapours during heating and selection of the generated sludge.

In the first phase, we aim to recover the heat from the combustion gases present in the chimneys of the drying booth and distiller. Both the drying booth and the distiller are equipped with chimneys with a diameter of 150 mm for evacuating the hot combustion gases formed as a result of the processes carried out in the equipment.

For designing and dimensioning our heat recovery solution we determined the heat recovery potential, starting with an energy audit. Since the factory has only one general gas metre, with no individual metres for the painting equipment, we had to analyse the company's gas bills and interpret the values, bearing in mind that the gas is used for the painting line, central heating and also for warm water, thus the gas consumption increases significantly in the colder months. With this in mind, we estimated an average warm season consumption of 300 m^3 /month (From May to October).

Fig. 2. The annual gas consumption of the company



According to the technical files of the products, the burners' maximum flow rate is 4.5 m^3 /h. By analysing and filtering the information, we have reached the following estimation: Out of the average summer consumption, 50 m^3 are used for heating the water and the rest is used by the 3 painting equipments (84 m^3/ equipment is used to assure the painting process).

2.The proposed heat recovery system

For the first phase of the recovery system, we plan to put the heat exchangers on the 2 machines that have the exhaust chimney (1) on the same wall: the drying booth and the distiller. To assure safe and uninterrupted exploitation of the machines, we decided on 3 in series heat exchangers (3), controlled with valves (2), with the following functional scenarios:

1. Normal heat recovery

   In this scenario, the valve status is the following:
   - V1.1, V1.3, V2.1 and V2.3 are open
   - V1.2, V2.2, V3.1 and V3.2 are closed

Each chimney has its own tubular heat exchanger for improved thermal energy recovery. Valves V3.1 and V3.2 are meant to separate the two exhaust chimneys, so that they do not influence each other's flow. The water from the accumulation tank (5) is being circulated through the exchangers, entering at the top cold and exiting at the bottom warm, returning to the hot water accumulation tank.

2. Overheating protection / Malfunctioning mode

This mode assures continuity and safe operation of the painting line. In case of overheating or malfunctions detected at one of the heat exchangers, the appropriate valves will isolate the malfunctioning heat exchanger(s). For example, if the water in the first heat exchanger were to overheat, valve V1.3 would close and valve V3.1 would open, ensuring the continuation of energy recovery. If the water accumulated in the tank reaches the set maximum temperature, then valves V1.1 and V2.1 will close and valves V1.2 and V2.2 will open.

3. Service mode

This mode can isolate the individual heat exchangers for maintenance purposes or by-pass completely the recovery system, by opening and closing the right combination valves.

The recovery of thermal energy starts with circulating the cold water from the accumulation tank (5) with the help of a circulation pump (4). The cold water enters at the top part of each heat exchanger and exits at the bottom, with an increased temperature. We chose a heat exchanger with countercurrent flow for improved energy transfer between the 2 fluids. The hot water resulted after the recovery process will be stored in an accumulation tank, at a high temperature (70-75°C). From here it will be used as the primary agent in one of the coils of a 2coil boiler for domestic hot water. The other coil, placed at the upper end of the boiler, will be reserved for a backup system, such as a gas water heater (CT).

With the described waste heat recovery system we aim to design the heat exchangers so that we can value around 50% of the useful energy of the exhaust gases. Preliminary calculations have shown that the 2 painting equipments can assure the necessary heat for the showers that take place daily in the factory. By also recovering the waste heat from the polymerization oven we can help reduce the load on the central heating system in the cold months.

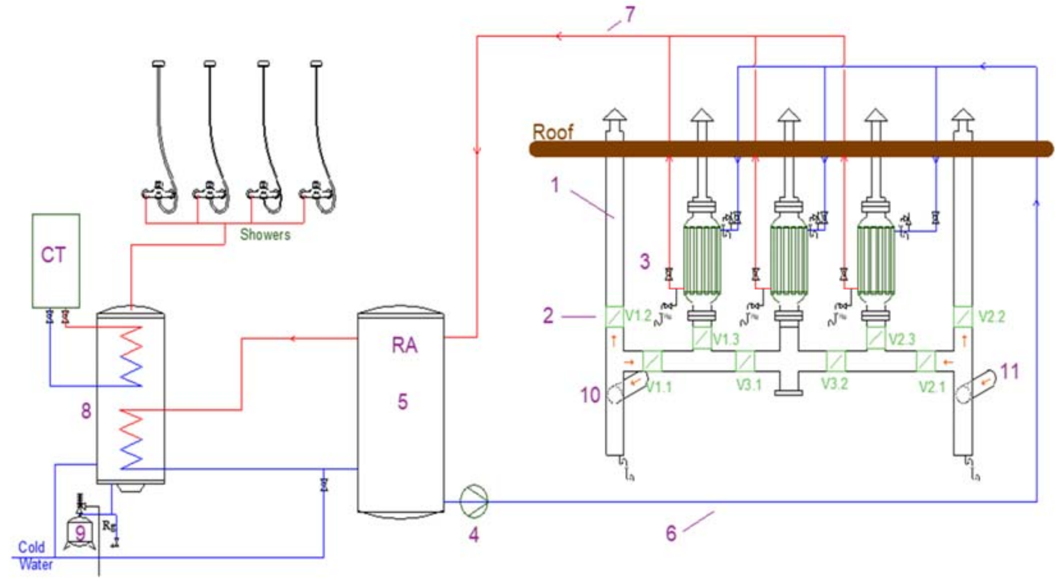


Fig 3. The functional scheme of the proposed heat recovery system
1-exhaust chimney, 2-control valves, 3-heat exchanger, 4-water pump, 5-thermal energy accumulation tank, 6-cold water, 7-hot water, 8-2 coil boiler, 9-expansion tank, 10-polymerization oven exhaust pipe, 11-distiller exhaust pipe, CT- gas water heater

3. Cost-benefit analysis

At the end of each workday, around 10 workers in the factory take showers. Estimating a consumption of 35 litres/person of warm water, we can deduce a 400 litres per day consumption (including warm water use during the day for activities like hand washing).

To prepare the hot water needed for the showers the factory uses 18.4 kW per day from burning natural gas. Bearing in mind this consumption and the efficiency of the gas water heater, the annual energy consumption for heating water is 4700 kW; this equals, at the beginning of 2024, when the gas prices are still being capped by the government, to about 4150 RON (835 EUR).

In Table 1 there are presented the results of investment calculation for our proposed heat recovery system, resulting in a total cost of 8000 Euros.

Taking into consideration the approximate value of the investment and the yearly savings made by the system we can observe that the company will recover its investment after less than 10 years. Furthermore, the company will reduce its carbon footprint by just consuming less natural gas.

Table 1

Calculation of the investment

Product	Qty	Unit	Price/Unit [EUR]	Total [EUR]
Flue gas valve 150mm	9	pcs	12	108
Heat recovery system (only cost of materials)	3	pcs	70	210
Accumulation Tank 2mc	1	pcs	300	300

Calculation of the investment

Water pumps	2	pcs	150	300
2 Coil Boiler (only cost of materials)	1	pcs	260	260
Water circulation pipes	35	m	8	280
Flue gas channel	8	m	70	560
Expansion Tank (only cost of materials)	1	pcs	30	30
Drain valve	4	pcs	6	24
Isolating valve	11	pcs	6	66
Safety valve	9	pcs	10	90
T Section with access panel	1	pcs	65	65
Condensate drain trap	2	pcs	40	80
Technical room 8m^2 (modular container)	1	pcs	1500	1500
Energy Meter	2	pcs	55	110
Thermal Energy Meter	2	pcs	155	310
Electrical Installation	[-]	[-]	1100	1100
Pipe Insulation	35	m	6	210
Connections to the water supply network	[-]	[-]	500	500
Automation system	[-]	[-]	600	600
Engineering Cost	[-]	[-]	500	500
Total cost				7203
TOTAL (including unpredictable costs)				8000

4.Conclusions

The paper shows how to increase the energy efficiency of a company by using the waste energy potential of the facility. The paper presents both the conceptual solution for the implementation of the waste energy recovery installation and its use to cover the domestic hot water needs as well as the synthetic way to carry out a cost-benefit analysis to help the beneficiary in making a decision to promote the investment. The implementation of the work will contribute to the reduction of CO2 emissions into the atmosphere and implicitly to the EU objective of reducing greenhouse gas emissions by 55% by 2030.

References

[1] ***, Directive (EU) 2023/2413 of the European Parliament and of the Council,18 October 2023.

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[3] I. Ionel, C. Ungureanu, D. Bisorca, “Termoenergetica si mediul”-Editie revizuită, Editura Politehnica Timisoara, 2006.