# FLUE GASES RECUPERATOR USING AN EJECTOR

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ABSTRACT

Scope of paper is to develop a specific flue gases heat recovery system which preheats the combustion air by mixing fresh air with flue gases. This procedure is suitable when the initial combustion process has large excess air, more than 2.0. The mixture of the flue gases and fresh air, (half and half by weight), will double the quantity of flue gases flow but with half of the initial stack temperature. That allows to split the flow in two, half will be exhausted at stack and half will be used as combustion air having enough oxygen for combustion. The result will be the same flue gases quantity evacuated to atmosphere but with half of initial temperature. In the same time the fresh air used for combustion will have a higher temperature instead the ambient initial temperature, thus using less energy.

## 1. SCOPE OF WORK

Heat recovery from exhaust flue gases with a temperature higher than 150°C is very economical, taking into account actual fuel prices. The recovery processes, as well as the required equipments differ based on application, the fuel used and the sulphur content of the fuel.

SC TURBOEXPERT srl designed systems of heat recovery, heat recovery equipments, which not only recover heat, but are solving specific problems that are found in existing plants. The advantages are:

- „competitive price”, rapid installation, maximum fiability;
- Small footprint for the equipment;
- Minimum maintenance; the installations do not require personnel for operation.

On our company site [3] all these advantages are detailed. In previous papers, [1], the recuperator with <Pseudo heat pipes> was described; this application was operating at the desired parameters. These types of recuperators are compact surface heat exchangers, but are not covering the whole spectrum of heat recovery. There are cases when the composition of the flue gases permits the use of a mixing type of recuperator. This kind of heat recovery was installed in a (....) in fall of 2012.

## 2.TECHNICAL AND SCIENTIFIC CONSIDERATIONS

In numerous industrial processes the flue gases have the parameters that permit that some of the gases (about half) to be rerouted as combustion air, after mixing with the same quantity with the ambient air.

In the analysis of the heat recovery solution using mixing, the flue gases will be called primary gases, and the gases resulting after the mixing with the ambient air will be called secondary gases.

### 2.1. The thermodynamic mixing process.

By mixing the primary flue gases with ambient air (same quantity as in the initial combustion process), the flue gases quantity will be double. The excess air in the primary gases will diminish by a unit, than in the case without mixing.

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If the initial excess air (without recovery) is $\lambda_0$=2,0, there is a possibility of heat recovery through mixing of fresh ambient air (same quantity as in the process without mixing) with primary flue gases by splitting secondary flue gases 50% ( gravimetric) for combustion and 50% to be exhausted at the stack.

During this process the temperature of the secondary gases will be half of the primary, and the combustion air will become preheated to the same temperature. This will produce saving in fuel consumption corresponding with the gradient of preheat.

*Note: The mixing of flue gases with the fresh air increases the combustion products and decreases the oxygen component. The process is represented mathematically as a harmonic geometric series with the limit:*

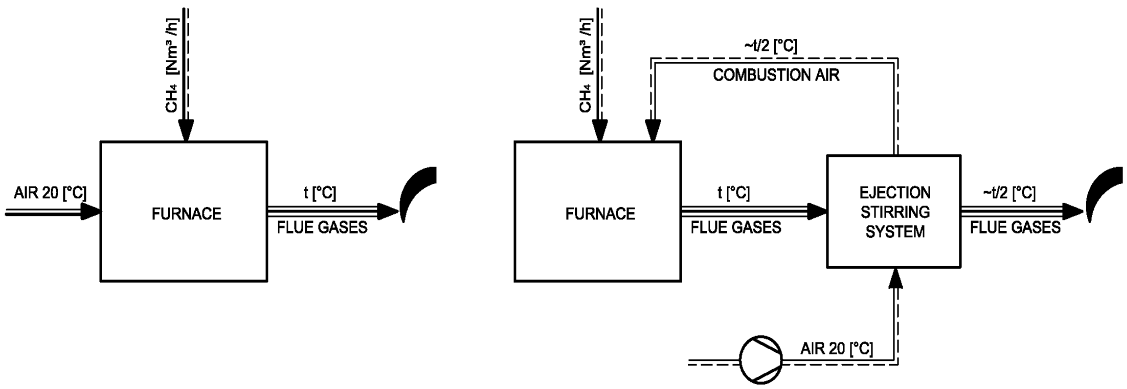
$$\boxed{\lambda=\lambda_0-1}$$

(1) *relationship of recovery through mixing, the lower limit is* $\lambda_0$>2, 0.

An accurate stoechiometric calculation of the combustion process in the existing configuration will deviate from the above formula, but the approximation is in the acceptable limits for the design of the heat recovery system.

Schematic representation of the solution is shown in Fig. 1

The mixing process and the rerouting of the flue gases in the recovery solution presented will increase the pressure losses. Although efforts were made to minimize the pressure losses an additional fan was required. The mixing process between the primary gases and the ambient air is more complicated to be implemented in an existing installation.




a) b)

Fig.1 Recovery by mixing: a) initial; b) by mixing (with an ejector)

### 2.2. Description of technical solution

The simplified thermal considerations outlined above are not sufficient for using the mixing heat recovery; the existing installation must allow for this recovery.

The main thermal problems are:

a) Lowering of oxygen used in the burner as primary air;

The combustion air (the secondary flue gases) has a higher temperature than the ambient temperature. The existing system must accommodate this increase in temperature. By increasing the temperature of combustion air, for the same volumetric flow the mass flow decreases and proportionally the oxygen content decreases. Also due to mixing the oxygen content is lower that the initial conditions. The burners will operate with an oxygen quantity reduced to about half, so the combustion air must be introduced around the flame; the existing geometrical configuration must allow this modification.

b) The influence of increase temperature of combustion air on the burners;

Sometimes combustion air with significant higher temperature is incompatible for some type of burners, such as burners with embedded ventilation systems which contain bearings

c) The available space for installing the mixing chamber with a minimal pressure loss.

The mixing of the flue gases (primary gases) with the ambient air is done by injecting one into another, but without a properly designed aerodynamic solution the lengths of the mixing duct will be at least 15÷20 times its transversal dimensions. Because the flows are in the order of tens or even thousands of $m^3/h$, the large cross sections will require extensive duct lengths; that may present a problem for the available space. If the mixing is done in a smaller volume the pressure losses become prohibitive. The separation/splitting of the secondary gases to combustion area and to the stack also require additional space and induce more pressure losses.

## 3.APPLICATION. RESULTS

Applying the above considerations TURBOEXPERT sol [3] has done a pilot installation of heat recovery using mixing with an ejector. The project beneficiary was in food processing industry, the project was used for a vegetable roasting oven as shown schematically in Fig.1b). Due to the seasonal character of the installation, the 4÷5 roasting ovens work non stop a number of months of the year, using a high quantity of natural gas. The fuel contribution to the product cost is very high.

During the initial measurements it was found that the thermal efficiency of the process was around 7÷10%; this was a strong incentive for finding a recovery solution. The roasting oven shown in Fig. 2 is located in a very restrained location in all directions.

The excess air was high $\lambda_0$=3,5 so the method of heat recovery by mixing was feasible.

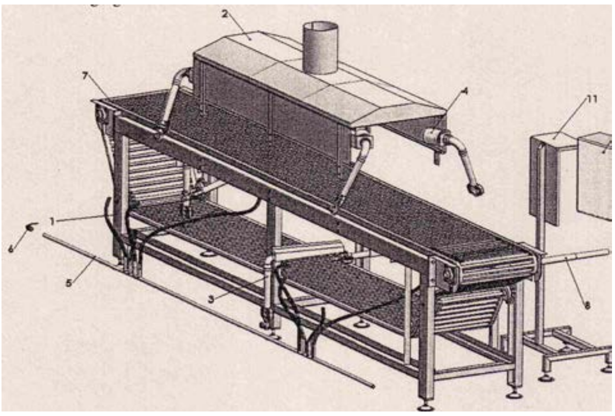


Fig 2. Roasting oven without recovery

Initial data:

- Fuel flow $CH_4$: 42$Nm^3/h$;
- Flue gases temperature <primary>: 620÷640°C;
- Efficiency: 7÷10%.

The mixing chamber design used a special system with an ejector; the primary fluid was ambient air and the induced one the flue gases <primary>.

The air is delivered by an additional fan (it uses a small amount of the recovered power 2÷3%).

In Fig. 3 shows the project and Fig. 4 shows a picture of the heat recovery installation.

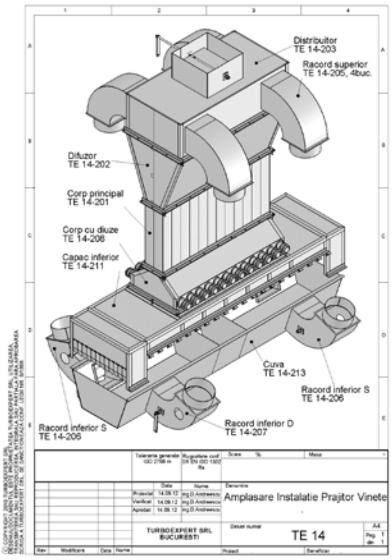



Fig. 3. Heat recovery system

Fig. 4. A picture of the heat recovery solution with the ejector

The operation of the system is as follows: the air brought in by the additional fan is delivered to the mixing chamber. The mixing chamber is on the top of the oven, in the location where the flue gases were delivered to the stack by natural draft.

In the mixing chamber, the primary flue gases are mixed with the combustion air by the ejector which mixes the jets coaxially. There natural compression in the diffuser after the ejector ensure the proper mixing as well as the increase in pressure in required for the flow. After the diffuser half of the secondary gases are exhausted to the stack and the remaining half in returned to the combustion area, some to the burners and some under the transporting grate.

In order to transport the gases to the lower transporting grate four descending ducts were installed, these also enclose the lower side of the transporter. Controlling dampers ensure a better control of air and gases.

The following results were obtained:

- Fuel consumption reduction by 30÷35%;
- Secondary gases temperature at the stack 310÷330°C, (about half of the initial temperature).
- Correct full combustion; visually the flame did not change the colour.
- The ejector operated as designed, producing the desired fluid circulation (a bit over designed).
- The pressure loss due to the additional fan uses about 2% from the recovered power.

## 4. Bibliography

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[3] www.turboexpert.ro