Flue Gases Residual Heat Recovery - a good business - In 6 months Invested Money will be Pay Back

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Flue Gases Residual Heat Recovery - a good business - In 6 months Invested Money will be Pay Back: *Scope of paper is to show how economically efficient is flue gases residual heat recovery. The TURBOEXPERT srl Bucharest constructive solutions and experience prove it. We have to underline that counting the economically efficiency is mandatory to be aware that the total cost of investment could be up to twice than the cost of the Recover (heat exchanger) itself due to the auxiliary circuits, measuring devices, mounting, a.s.o.. The TURBOEXPERT heat recovery constructive solutions could be split in three directions, every having an own <zone> were is more suitable to use then others and so results the best economically efficiency. An economic efficiency means the period for <pay back> of money invested. Anyway, every solution presented is very effective.*

Key words: *Heat Recovery; Flue Gases; Economizer; Condenser; Boiler; Furnace.*

1. CONSTRUCTIVE SOLUTIONS

Heat recovery from exhaust flue gases with a temperature higher than 150°C is very economically efficient. The recovery processes, as well as the required equipments differ based on application, the fuel used and the sulphur content of the fuel, [2].

Heat from flue gases issued by boilers or furnaces can be recovered, through the installation of a heat exchanger, higher dew point temperature, named <ECONOMIZERS> and lower, with <CONDENSERS>.

We can reach a significant growth in increasing power efficiency, 5% to 10% for the boilers using <Economizers> and twice, CONDENSERS (but the investment increases also) and higher increase for furnaces, 20-40%. Very significant in heat recovery domain, is the difficulty to find <the consumer> of the heat, then the source. That fore, we take care about this issue also.

Efficient is to use recovered energie in the same process which issued it and for:

- Heating water (make-up water; boiler feeding water; buildings heating water, a.s.o.).
- Heating air (combusting air, conditioning air, a.s.o.).
- Drying processes.

SC TURBOEXPERT srl designed systems of heat recovery which ones heat recovery equipment [5] solving specific and very different problems that occurs. The advantages are:

- "Competitive price" – in 6 months investment will be "paid back", rapid installation, maximum fiability;
- Small footprint for the equipment and/or possibility to be installed in unsuitable spaces, as in many cases there is;
- Minimum maintenance; the installations do not require personnel for operation;

Systems of the flue gases heat recovery that does not affect exhaust pressure of the boiler / furnace.

1.1. Heat recovery system with heat pipes, HP,(thermo siphons)

The main equipment of a recovery system is the heat exchanger named economizer or condenser depending the decreasing of the flue gas temperature, up or down the condensing zone.

More than the <classical> solution is developing now the solution with <heat pipes>. And TURBOEXPERT srl is developing its own solution with <pseudo heat pipes>.

The advantages of heat pipes are (pseudo heat pipes being really cheaper):

a) Eliminating of possibility, because of damages, of entrance of one fluid in the space of other fluid;

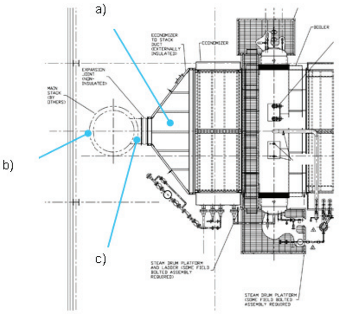
b) Variable geometry, versatile gauge that allows a location in very small and irregular spaces.

c) Almost total insensitivity at transient regimes, accepting any thermal shock.

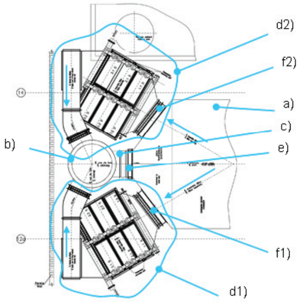
But these advantages are deeply contra balanced by a big price, technological and constructive difficulties and is very dangerous when the cooling agent is shut down or the design temperature is overpass. That fore, the effective domain of heat pipes is limited, only for a real special situation.

An application of flue gases heat recovery with HP (thermo siphons) Economizer was made by TURBOEXPERT srl for Q-POWER srl at ARCTIC PAPER, a paper manufacturing company in Poland. ARCTIC PAPER had previously installed two gas turbine installations (GTI), 10 MW for each, equipped with a recovery boiler. At stack, the flue gases had a temperature of ~200ºC. The location of HP Economizer had reduced with ~100ºC the flue gases temperature and the constructive solution had to take account of existing space in the building (Fig.1). The HP economizer, consists of two identical parts, symmetrically placed (see Fig. 2).

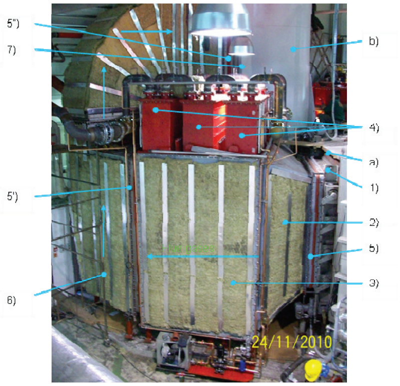
The recovery heat quantity is 5 MW. A DCS is controlling the entire installation.



a) Downstream area of horizontal recovery steam boiler
b) Stack
c) Connection boiler-stack with expansion joint



a) Existing recovery boiler
b) Existing stack
c) Existing connection
d1), d2) Additional route of flue gases
e) Main louver (closed / open)
f1), f2) Louvers of flue gases bypass through the HP economizer (open / closed)



a) Recovery boiler of Gas Turbine Installation
b) Stack
1) Upstream louver – entrance flue gases
2) Upstream chamber
3) HP economizer
4) Cooling water chambers of HP economizer
5), 5'), 5") Expansion joints
6) Downstream collection chamber of flue gas
7) Stack connection – exhaust flue gases to stack

Fig.3. General view 5MW Economiser

1.2. Heat recovery system with Pseudo Heat Pipes, PHP

To avoid the disadvantages of HP, Turboexpert srl developed a recovery system with pseudo heat pipes, PHP, being really cheaper and not danger at cooling agent shutting down or over temperature regimes, [1]. All another advantages of HP are preserved.

An application in a food factory industry succeeded and show some particularities issued by the the real operating conditions. The main problem is the intermittent boiler feeding water pump operating. This make unless to put the Economiser <on line> with the feeding water circuit which is working about 50% of period.

That fore was made a secondary circuit circulating continuously the feeding water from reserve water tank, Fig. 4.

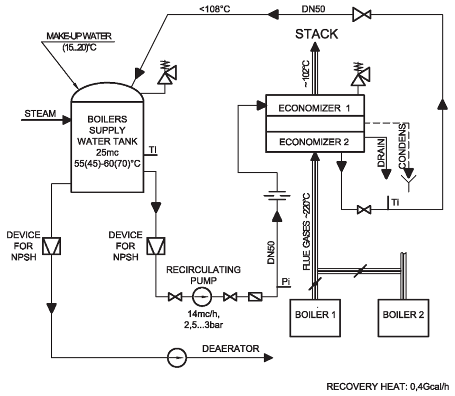


Fig. 4. Thermal schema for flue gases recovery heat for an industrial boiler

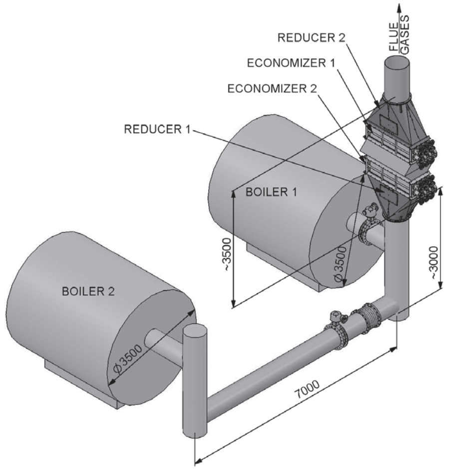


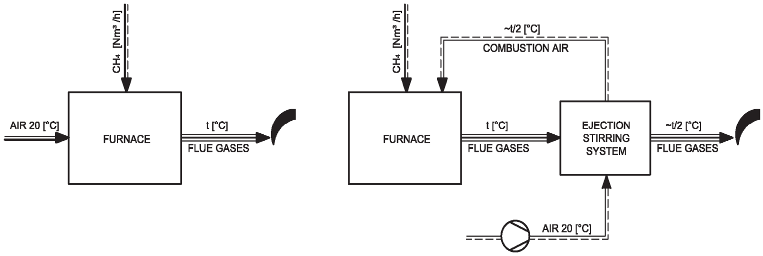
Fig. 5. General view of a Turboexpert stack Economizer

1.3. Flue gases heat recovery system with ejection

Another system was to develop a particular flue gases heat recovery system which preheats the combustion air, stirring the fresh air and exhausted gases. This procedure is suitable when the initial burning process is with a big air excess, more 2,5. So, the blend of the flue gases and fresh air, half and half by weight, will give a double quantity of gases flow but with half of the initial chimney temperature. That allows to split the current in two, half will be exhausted by chimney and half will be used like combustion air having enough oxygen for burning. As result will be the same flue gases quantity evacuated in atmosphere but with half of initial temperature. In the same time the <fresh air> for burning will have the same high temperature instead the ambient initial temperature, in this is consisting the heat recovery process.

The technical issue is that the stirring process of flue gases and fresh air means pressure losses and needs a big space and duct length for stirring process. In the existing installations as well in the new one the disposable space is not sufficient or will drive to a big amount of costs.

So, to have a good and economically solution TURBOEXPERT srl Bucharest developed a so called <Ejection stirring system> which using the initial air pressure, stirs the gases with a multiple ejection system which has a small dimension [3] and a sufficient output gases pressure to drive them half in atmosphere by chimney and half to the burners.



a) b)

Fig.6. Recovery by mixing: a) initial; b) by mixing (with an ejector)

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:

$$\lambda=\lambda_0-1$$

(1) *relationship of recovery through mixing, the lower limit is* λ_0>2, 0.

This system was recently applies for a vegetables baking machine which are a lot in the food industry and consumes a lot of methane gas. Installing this heat recovery ejection system gave important conclusions:

- the initial methane gas consumption was reduced with 30-35%;
- the burners worked very well with the <new> preheated, combustion air having already CO_2;
- The ejection stirring system is very constant having like an < itself control>.

2. CONSTRUCTIVE SOLUTIONS - COMPARISON

Heat recovery from exhaust flue gases with a temperature higher than 150°C is very economically efficient. The recovery processes, as well as the required equipments differ based on application, the fuel used and the sulphur content of the fuel, [2].

In the next table, taking in account the main factors technical and economic which are relevant for a recovery system, there is a comparison between the previous solutions.

Table 1. Comparison between the solutions

FACTOR	HEAT PIPE	PSEUDO HEAT PIPE	EJECTION STIRRING
Unequal thermal expansion, which is the main cause of the classic heat exchanger damages	Absolute insensible	Absolut insensible	Absolut insensible
The penetration of a fluid in space of the another fluid	Practically impossible	Practically impossible	No case
Flue gases maximum operating temperature, in economically conditions.	< 300°C	<500°C	<900°C
The operating position of the pipe	Only vertical one or close	Anyone, without restrictions	Anyone, without restrictions
Types of the fluids involved in the heat exchange	gas – liquid gas-gas liquid – liquid	Gas – liquid No (*) Liquid – liquid	Gas-Gas
Corrosion/erosion	Good	Excellent	Excellent
Air excess The unitary relative price	- 150% -175%	- 100%	>2,5 65% – 75%

Note (*) This heat recovery is possible for PHP with an intermediate fluid only

3. ECONOMIC EFFICIENCY

Making the answer shorter is important to show to the customer how long the period is that the invested money will be <pay back> with the Turboexpert srl heat recovery systems. A significantly example could be shown on the Fig.7.

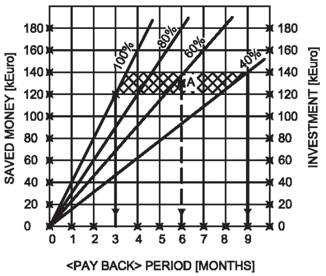


Fig.7. "Pay back" period

For "A":

- Economizer: 1Gcal/h with PHP
- $t_{1flue\ gases}$: 200°C
- t_{1water}: 55°C
- Price of fuel: 50€/1GcalCH_4

This is computed for a very common in practice situation: economizer for a boiler with 200°C flue gases output temperature; heating boiler feeding water with 55°C input temperature; recovery heat: 1,0 Gcal/h; fuel: CH4.

Very important is the real load of the boiler like steam flow and working period. That fore is necessary to count a <real working period coefficient> which is the ratio between the steam flow produced in a period (at least a month) and the maximum flow which could be produced at the rated regime and working continuously.

This coefficient is obviously far of 100% and usually is between 40%-60%. This is important because the working regimes a very variable is mandatory to design the recovery system at the rated parameters but this one, unfortunately, will sure work at a partial regime. Like the result the <investment cost> is for working at the rated regime but the efficiency is corresponding to the partial regime, means less.

In Fig.7 in the left vertical axis is the <saved money> depending of the <real working period coefficient> and related to 1,0 Gcal/h recovered heat. In the right vertical axis is the <Investment cost> including all the spend money, which could lies between an upper and a lower limit. The <pay back period> is when the <saved money> are equal with the<investment> and at the cross with line of <real working period coefficient>. For a real and usual operating condition result an average of 6 months for<pay back>.

4. CONCLUSION

These three constructive solutions cover almost any recovery heat issue.

The theoretically heat transfer computation of all this constructive solution is a good guide, [4], but only an <*in situ*> experiment on the real installation is util.

The economic efficiency of Turboexpert srl Bucharest constructive solution allows to recovery the investment in average 6 months for an Economizer of 1,0Gcal/h.

For another solution the period will change like the unitary price from Tabel1 shows and the values of recovered heat bigger or lower of 1,0Gcal/h will change the period also.

REFERENCES

[1] Andreescu, D., Cerchez, E., Schema termica pentru recuperarea caldurii gazelor arse la cazanele industriale, UPB, 2012.

[2] Popa, B. s.a., Recuperarea caldurii in industrie,Editura Tehnica, Bucuresti, 1971.

[3] Sokolov, E., Ia. Struinae apparata, GEI, Leningrad, 1960.

[4] Stefanescu, D., s.a., Transferul de caldura in tehnica, ET, Bucuresti, 1982.

[5] www.turboexpert.ro

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