HOW DOES THE TECHNICAL EXPERTISE AND OPERATIONAL KNOWLEDGE SHARING GENERATES GREEN GROWTH FOR INDUSTRIES?[1]

ENERGY EFFICIENCY FOR INDUSTRIAL PROCESSES

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Abstract

In the recent years, many scientific and technical knowledge has been developed. The combination of this knowledge with the operational excellence generates significant gains in terms of quality, production and efficiency. In this paper are described energy efficiency projects for industrial process. The gains can be created at different levels : improve or change the component with clean technologies, control process level, by the recovery of renewed energy, by mixing the three previous points. The key success factors of an energy efficiency project are: rigorous expertise including the specific production and quality constraints, establishment of the decision matrix based on the criteria by the operational and the expert, implementation of the solutions, and performance verification. This article shows some results in the improvement of the energy efficiency processes. 32% of energy saving on heat treatment furnace (new combustion equipment and new heating curves) and 10% of reduction in specific fuel consumption by implementing a process model. When the maximum efficiency is reached at the process level, then waste heat is valorized as renewed energy source. Examples are shown where the heat from the fumes is transferred to another process or to generate electricity by Rankine cycles. Innovative solutions to recover heat from hot solid product are also shown. The methods (technological or business model) are applicable to all intensive process industries.

Keywords: Energy efficiency; Process optimization; Heat recovery.

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1 INTRODUCTION

This paper introduces approaches to carry out energy efficiency projects in intensive industries. Different case studies are shown, dealing either with process efficiency improvement and valorization of the waste heat. Boyer, Ferrand and Halkein[1] already have shown some examples about the valorization of energy in the industrial context.

The first case study shows how, by applying different solutions, a saving of 32% of gas consumption can be obtained. The furnace is a treat furnace for seamless tubes.

The second case demonstrates the performance of a new mathematical model such as the CMI RTOP® model for generating savings in re-heating furnaces. More than 8% of potential savings can be obtained by updating heating strategies and transient management.

The next case two studies deal with valorization of waste heat:

- Transfer energy from the fumes of a processing line furnace to another process with a expected 40 GWh per year of saving)
- Transform energy of the fumes of a re-heating furnace to generate power (14 GWh per year of electrical power).

An example of simple innovative approach is then described to capture the heat from hot solids by radiation to be transformed to heat cold air and then used to increase the furnace efficiency.

For each of the projects, we will explain some of the key success factors. One of the key is the collaborative work between an expert team (of technologies and thermal process knowledge) and an operational team. The first (in general external to the company) brings a broad view of what exists through different industries and the knowledge of best available technologies. The second team brings a knowledge of the industrial process and all the constraints. This collaborative work generates the most efficient solution based on an agreed criteria.

To close the subject about services for energy efficiency, a new business model is introduced. The services are not only linked to technological portfolio. Services to industries means also to bring a complete package solution with different financing options.

2 FROM ENERGY AUDIT TO PERFORMANCE TESTS

2.1 Context

The first example deals with a premium seamless tubes forging mill line. The heat treatment process includes autenization (>900°C) and tempering of steel tubes (between 550°C and 800°C). Two furnaces were dedicated to each process. In 2010, a project was launched to improve the performances of one of the furnace. Ferrand et al.[2] describes the results in their paper.

The goal was to improve the heat treatment quality (+/-5°C of heating uniformity) while reducing operating costs : only one furnace operating for all purposes, minimized natural gas consumption and NO_x emissions. CMI was chosen to implement this project from the initial audit to determine the optimal technical-economical choices, to the project implementation.

Main challenges were the high targets of performances, the necessity to integrate solutions in the existing frame of the furnace at lowest costs and the short stoppage constraints for erection.

2.2 Energy Audit

2.2.1 Methodology

The aim of the audit is to:

- Understand the current working conditions and performances of the furnace.
- Determine the best technical-economical choices to reach the performance targets

The expertise is a combination of experimental data analysis and numerical simulations. A simulation tool of the furnace is than set up validated by experiments. The expert use this tool to investigate potential solutions.

2.2.2 Thermal expertise

CMI uses two complementary tools for such problems :

- CFD (Computational Fluid Dynamic) tools to properly design furnace enclosure and integration of heating technologies (Figure 1).

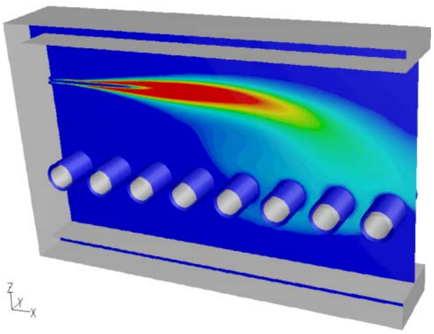

Figure 1. Help of simulation tools to secure the design.

Nodal network tools (Figure 2), for fast computing of thermal heat transfers and heat consumption. These tools are internally developed, and are basically based on an original combination of 1D, 2D or 3-Dimensional solvers, based on the nature of heat transfer mode (ex : 3D for radiation factors, 1D for conduction through the insulated walls).

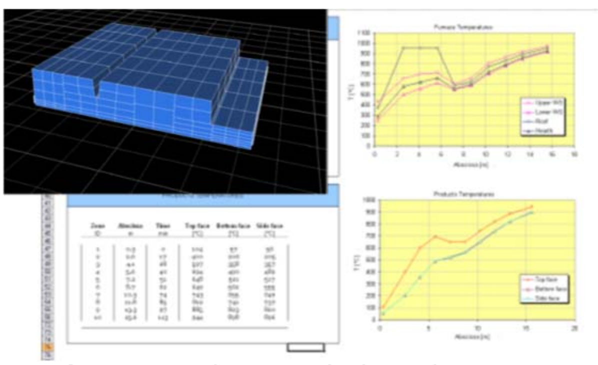

Figure 2. Nodal network simulation tool

Both approaches have been used to investigate potential technical solutions:

Different furnace profiles : number of zones, roof nozzles, separation screens, etc.
Different combinations of heating equipment solutions : centralized recuperator, regenerative burners, auto-recuperative burners, oxy-fuel burners, electric heaters
Different ways to minimize heat losses: hot charging/discharging rolls, choice of insulating parts.
Different process solutions: pulse firing vs proportional control, furnace pressure control devices, air/fuel ratio accurate control solutions.

2.2.3 Decision criteria and choices

Through the audit study, Operational team and expert team agreed on best technico-economical solutions, based on the following criteria:
Energy savings (Figure 3) and low NOx emissions.
Furnace flexibility, to ensure high quality for a large spectra of working conditions.
Maintenance costs.
Erection risks and feasibility.

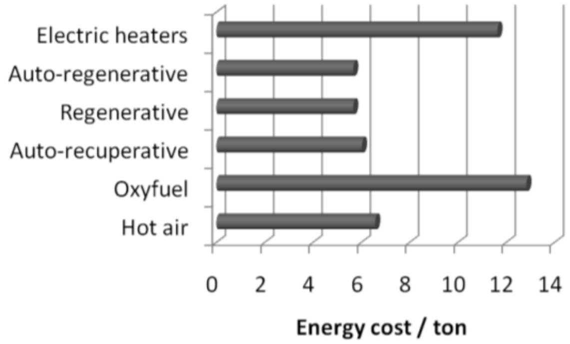

Figure 1. Energy costs of different solutions for this furnace configuration.

The basic design choices were the following:
15 control zones (8 zones previously).
72 Auto-recuperative burners + 5 hearth burners in the last zone to ensure uniformity.
ONOFFSoft Pulse firing, developed by CMI for optimal firing sequences.
Un-cooled mechanical parts with special new design and choice of alloys.

2.3 Project Implementation

The engineering was completely designed with Autodesk Inventor 3D (Figure 4) to study all interface problems and minimize the risk during site works.

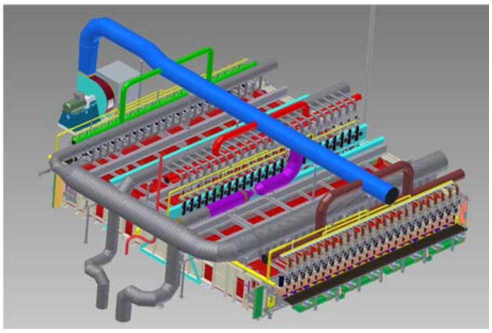

Figure 4. New piping distribution on the furnace.

Main key data of the erection phase are the following:

- 8 weeks, 350 workers, 46 external companies
- 3x8 shifts, 6 days a week.

High standards of safety (“top 5” procedures), no accident over the full period.

Figure 2. New heating equipment, operated with ONOFFSoft by CMI.

2.4 Performances

The furnace was qualified for production through measurement tests using tubes equipped with thermocouples. The uniformity proved to be excellent, both in austenizing mode and tempering mode. The thermal consumption was reduced by 32% (Figure 6). CEE (Energy Efficiency Certificates) were delivered by EDF in 2011.

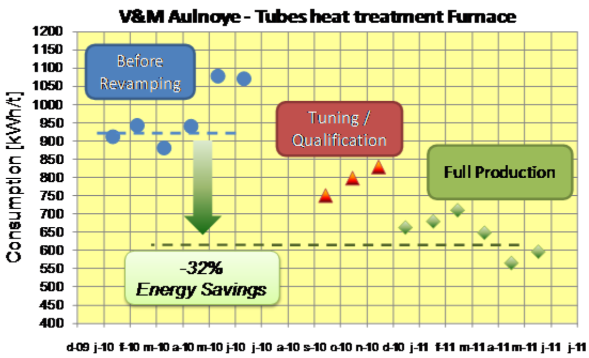

Figure 6. Measured energy saving.

This project has shown that a rigorous initial audit, knowledge of best available solution, dialogue between expert and operational team are key factor for the success of an energy saving project.

3 HOW A BETTER USE OF THE EQUIPMENT WITH PROCESS CONTROL SOLUTION CAN GENERATE SAVINGS?

3.1 Context

A lot of thermal industrial processes deal with high temperature cycles and transitory aspects. The transition could be due of different size or format of the products to treat or by different temperature profile (temperature target, soaking time etc) or by a mix of both.

With the help of numerical tools and expertise from the operational team, new heating strategies can be implemented as well new transient strategies depending on the type of situation and quality/operational constraints.

Again a key success factor is the dialogue between the expert team and the operational team to set up a hierarchy of constraints to be applied.

3.2 Gain of 10% in Consumption by Implementing a Mathematical Model

This case study deals with a bloom reheating furnace for high speed train railway products. On such products, constraints are severe in terms of metallurgical quality and then ,on decarburization and thermal homogeneity.

The first step is to understand the heating strategies, the quality constraints linked to the products and operational constraints linked to the furnace configuration. In a second step, new heating curves could be studied, as well improving product transient situations and stoppages. In this case, burners are used differently. It has been demonstrated that new heating strategies will decrease the consumption of the furnace.

In a third step the new strategies are then implemented in a mathematical model. The new mathematical model will manage the furnace. Mitais e Brochard(3) describes the main principles and the implementation of RTOP® level 2 for re-heating furnace.

The last step is the validation of the new strategies. Figure 7 show the specific consumption during the time before and after the modification. Around 10% of gain is demonstrated. The annual gain is estimated around 24GWh.

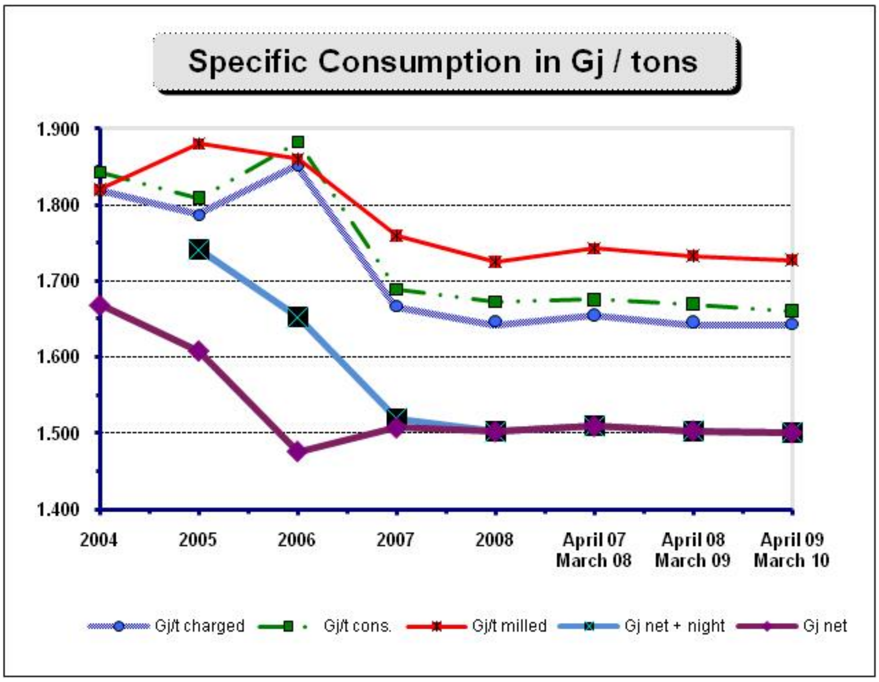

Figure 7. More than a 10% Gain on the Energy Consumption and *Repetitivity* of the heating performance with time.

4 HOW TO INCREASE ECONOMICAL PERFORMANCE WITH THE USE OF RENEWED ENERGY?

4.1 Holistic Approach

When the efficiency of process is sufficiently improved, some waste may still exist.

An holistic audit is then necessary to analyze the sources and the sinks (Figure 8) of energy at the industrial unit level, at the industrial plant level or at the industrial or urban area level. The means are recovery of energy, storage, transformation and distribution. After the audit phase a list of potential energy valorization projects is then establish including Capex, OPEX, Net Present Value analysis.

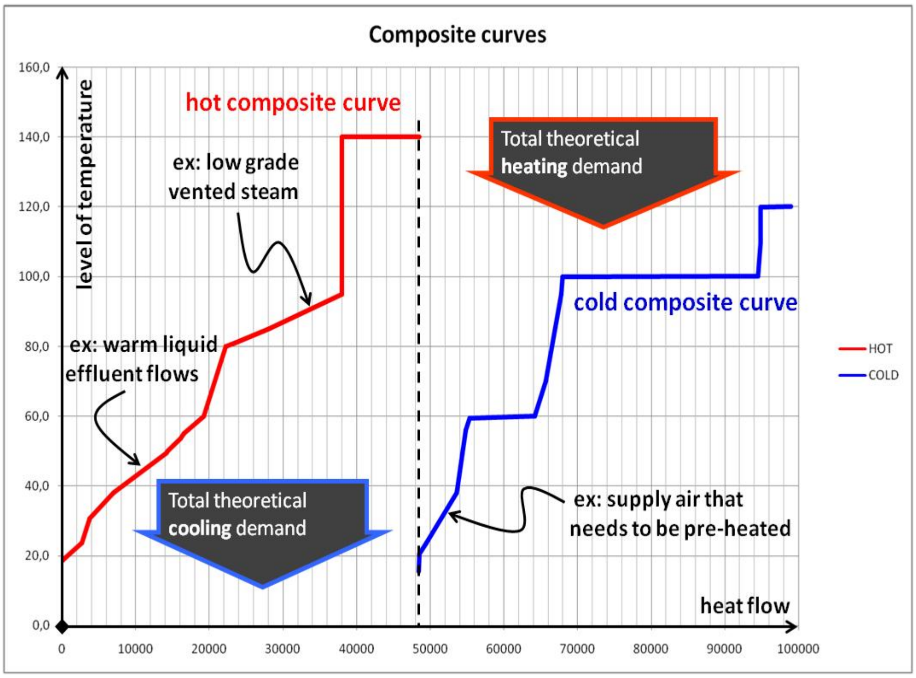

Figure 8. Process composite curves from the analysis of the sources and the sinks (Pinch Method Analysis)

Typically, the analysis is a mix of energy audit at the process level and an holistic audit at industrial plant level. Figure 9 shows a typical example of a Sankey diagram of an industrial furnace. The other part of the audit list the need of others process.

The heat contain in the fumes of processing line furnaces could be used by pickling section through a transfer with a steam circuit. Saving is mainly in this case the decrease of gas consumption of the plant steam production.

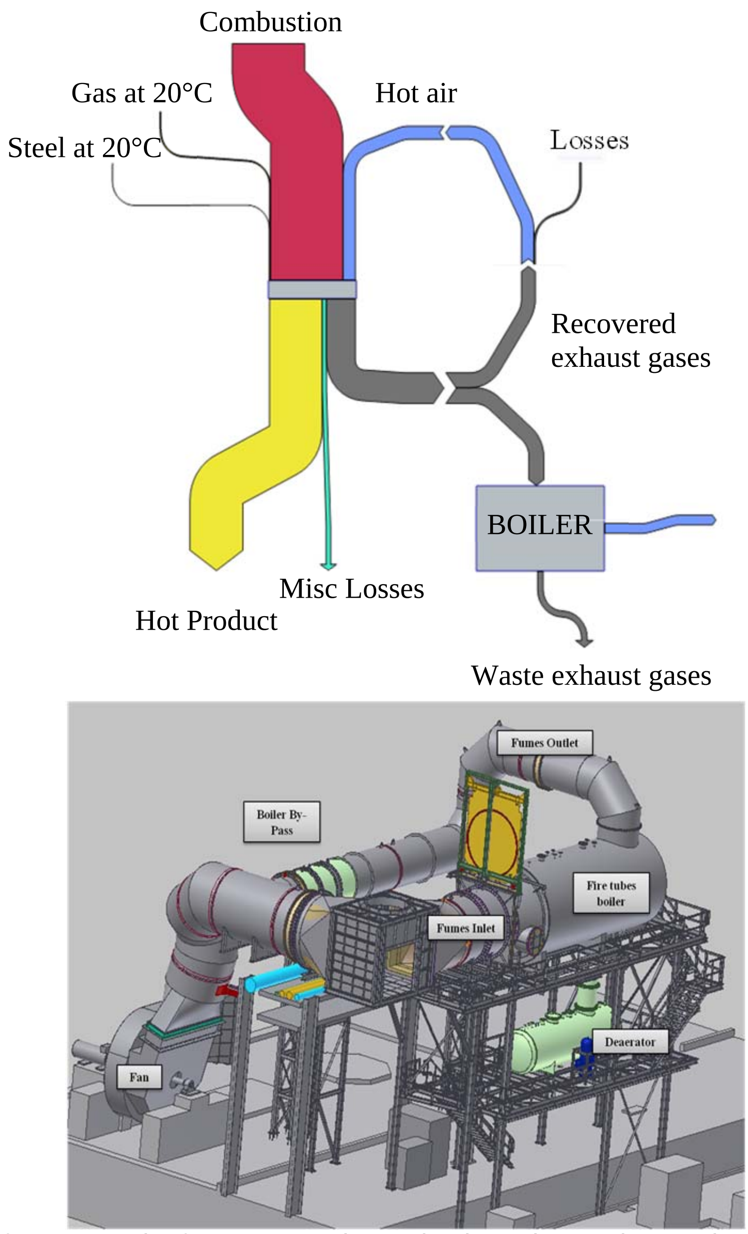

Figure 9. 11% of energy at the furnace entry is used to heat degreasing section via a steam network.

4.2 Waste to Power Approach

Another use of the waste heat is the power generation via steam turbine or via Organic Rankine Cycle (O.R.C). The source is then called renewed energy. Figure 10 show the principle of a waste heat recovery system of walking bean furnace in steel industry. The furnace generate electrical power from its fumes and from water cooling system of the beans. A steam turbine of 3MWelec is installed. It is estimated that 14GWh of power is generated per year. The global efficiency is then around 90%.

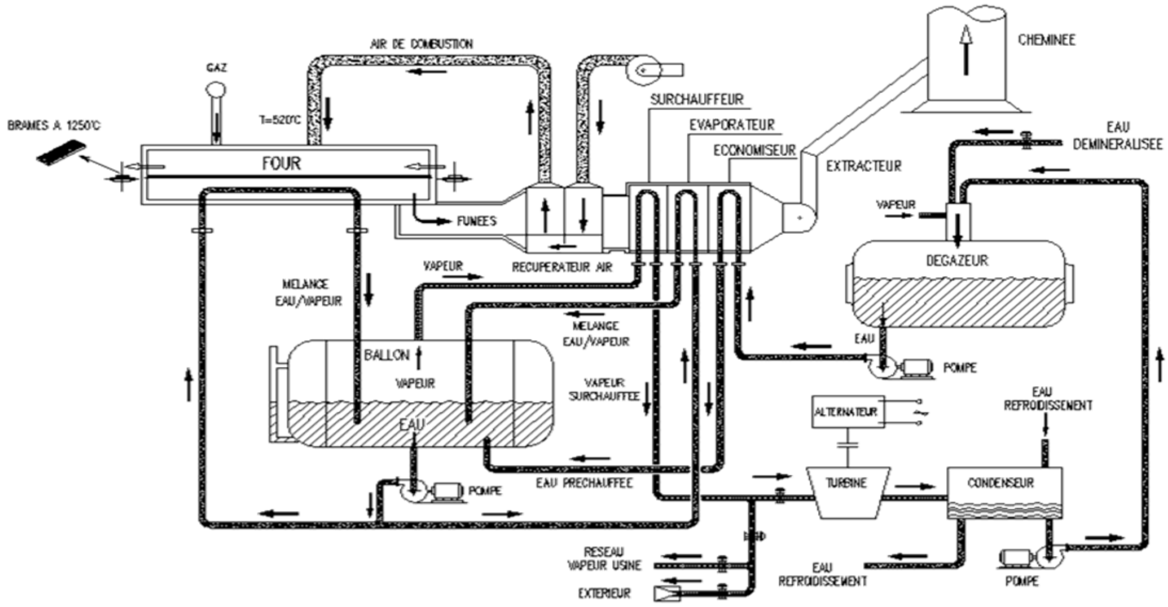

Figure 10. A 320t/h furnace generate 3MWelc power to be used on site.

4.3 Example of a Simple Way to Recover Heat from Hot Material: Thermosyphons Based Heat Recuperator

The potential saving via valorization of waste is not only from the fumes. It could be from the hot product himself. In many heat treatment process, pieces are cooled in open space. All the heat is then lost. Figure 11 show the principle of a new process of heat recovery from hot pieces. The heat is to transfer the heat via radiation to a thermosyphon device. Then energy is used to heat air. The hot air could be then used into the process himself or for building heating purpose.

Durand showed the potential of gain on a reference case : a billet heat treat furnace with short pay-back.

Table 1. Payback for a heat treat furnace[4]

Capacity	Furnace Efficiency	Pre-heat air temperature	Running time hot products	Natural gas cost	Gain
50t/h	70%	212°C	70% of 3800h	42€/MWh	118 700€/year

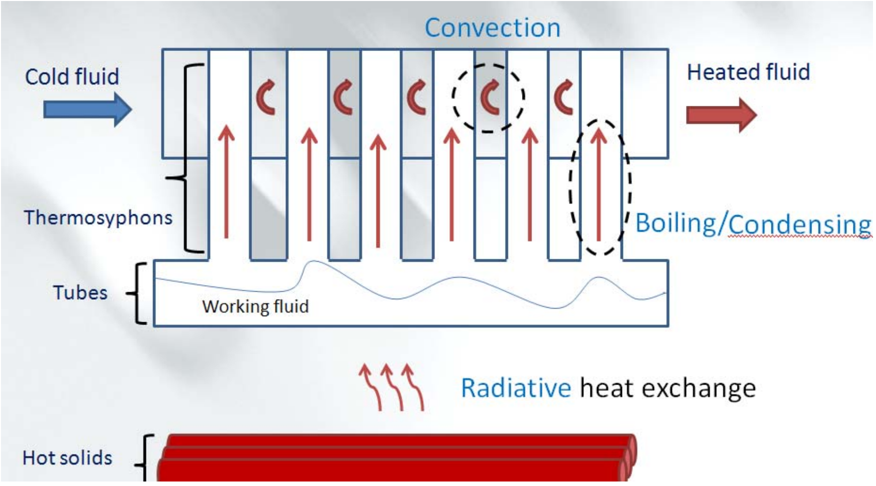

Figure 11. Example of pieces cooled in open air area. Radiation coupled with thermosyphon principle allow to transform energy lost from solids in a heating of cooled air.

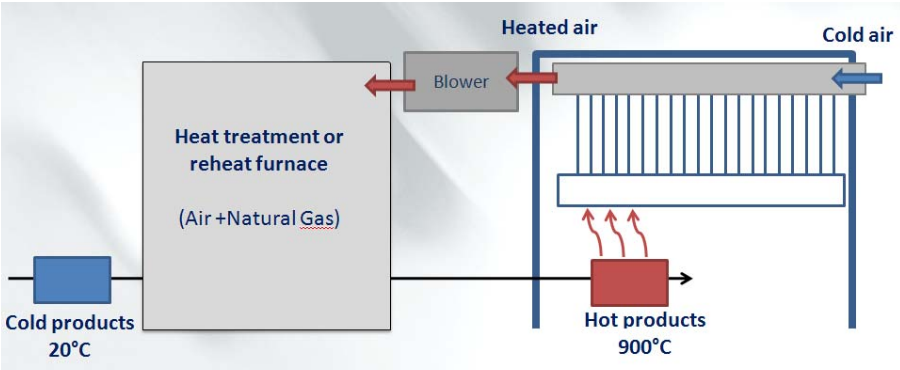

Figure 12. The system is used to save gas necessary to heat the piece by pre-heating combustion air.

4.4 Update of the Business Model

The new services in energy efficiency include financing services, especially for heat recovery projects. The principle is that service to efficiency companies propose a package to the industries with the adequate technological portfolio and the operational or financing scheme. Then human and financial resources from the industrial customer are used to develop their core business.

5 CONCLUSION ON BEST PRACTICES

Several case studies were presented in this paper showing great potentials on energy saving. Energy efficiency sources could be found at the component levels with clean technologies, at the industrial process level (design and control improvement) or at the plant level (holistic source and sinks approach with pinch method).

One of the key success factor is identified as the generative collaboration between expert team and operational team. A general methodology is duplicated project after project to assure the industrial success :

- Rigorous expertise including on site analysis, simulation of different solutions, common analysis with final users about the constraints (quality & operational),
- Create a decision matrix with agreed criteria between the expert team and the operational team,
- Implementation of the chosen solution
- Verification and monitoring of the performance,
- Benefit sharing between an investor and the industrial for some specific contract.

The industries cannot have all the resources (human, technological and financial) for energy efficiency projects. The capability of coupling both internal and external excellence via collaborative dialogue is then important.

The methods (technological or business model) are applicable to all intensive process industries.

REFERENCES

1 BOYER, M; FERRAND, L; HALKEIN, J-Y From energy user to energy supplier : a new business model for industrial furnace manufacturers and their customers ?. p301 *HEAT PROCESSING ISSUE* 4 2009.

2 FERRAND, L et al. From the energy audit to the final performance tests: success story of a furnace revamping JSI 2012, Paris.

3 MITAIS, JC; BROCHARD J-A; RTOP® : Level 2 Optimal Control of Reheating Furnaces Presentation at *CMI International Technical Meeting* dates January 2012

4 DURAND M; Industrial processes energy efficiency : Thermosyphons based heat recuperator Presentation at *CMI International Technical Meeting* dates January 2012