HotOxyGlass

LIFE07 ENV/F/000179

http://www.oxyfuel-heatrecovery.com/

LAYMAN'S REPORT

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1. Introduction

1.1. Environmental challenge

Glass is a key element to many applications. In 2010, the world market for flat glass is estimated at around 48.5 millions of tonnes, and greater Europe (Russia included) has a market size of over 10 million tonnes (*Flat Glass Industry* report, 2010). The production of glass requires high levels of energy and entails the emission of pollutants. Nevertheless a lot of efforts were made over the last decades to reduce the energy needs. Indeed, the energy amount required to produce one tonne of flat glass was only 10% of the energy amounts required in the 1880's, when, between 60 and 70 giga-joules (GJ) were needed. In the 1960's, this level was brought down to 20 GJ, reached between 7 and 8 GJ in the 1990's, and in now around 6-7 GJ per tonne of flat glass. The theoretical minimum energy level required would be between 2 to 3 GJ, which is the energy necessary for the melting of glass raw materials.
Furthermore, glass production entails the emission of atmospheric pollutants, which mainly occurs during the melting of glass components:

- Combustion of natural gas or heavy oil and the decomposition of raw materials during the melting process produce CO2 (a major greenhouse gas).
- Fuel consumption (natural gas or heavy oil), high melting temperatures and in some case the decomposition of nitrogen and sulphur compounds in the furnace entail the emission of nitrous oxides (NOX) and sulphur oxides (SOX).
- The use of special coatings, the evaporation from molten glass and raw materials can cause the atmospheric emission of particles.

1.2. The HotOxyGlass project

The innovative concept of the HotOxyGlass furnace lies in the combination of:

1. The oxy-combustion technique: use of pure oxygen instead of air as oxidizer in the combustion process.
2. The pre-heating of reactants involved in the combustion (fuel and oxygen) to very high temperatures: 550C° for oxygen and 450°C for natural gas.

The first goal of the project was to reduce energy consumption in the flat glass production process. Energy consumption has constantly been challenged in industries, and this project proposes an innovative solution. The other goal of the project is to reduce pollutants emissions, especially NO_X and SO_X. The project thus contributes to limiting climate change.

1.3. Project Partners

AGC Glass Europe (coordinator):
Based in Brussels, AGC Glass Europe produces and processes flat glass for the construction industry (external glazing and indoor decorative glass), the automotive industry, solar applications and various specialist industries.
It is the European branch of AGC Glass, the world's leading producer of flat glass.
Its baseline "Glass Unlimited" reflects the possibilities offered by:

- glass as a material to meet a growing variety of needs (comfort, energy control, health & safety, aesthetics);
- innovation in products and processes, derived from sustained research in advanced glass technology;
- industrial facilities comprising more than 100 production, processing and distribution facilities throughout Europe, from Spain to Russia;
- a worldwide marketing network;
- the resources of its personnel motivated by operational excellence and innovation.

AGC Glass Europe currently employs some 13 500 people.
Sustainable development is an important part of AGC Glass Europe's Corporate Social Responsibility. The group has an Environmental Management System (EMS) to control and reduce its activities' environmental impact. A growing number of AGC Glass Europe plants have now achieved ISO 14001 certification. All factories in the raw glass division have acquired ISO 14001 certification by 2008. Furthermore the group plays a proactive role in developing new legislation. It is indeed at the forefront of innovation for implementing environment-friendly techniques for glass production. The HotOxyGlass project, which combines oxy-combustion and re-use of flue gases' heat, displays a good example of this philosophy.

Air Liquide (partner):
Air Liquide is the world leader in gases for industry, health and the environment, and is present in over 75 countries with 43,000 employees. Oxygen, nitrogen, hydrogen and rare gases have been at the core of Air Liquide's activities since its creation in 1902. Using these molecules, Air Liquide continuously reinvents its business, anticipating the needs of current and future markets. The Group innovates to enable progress, to achieve dynamic growth and a consistent performance. Air Liquide explores the best that air can offer to preserve life, staying true to its sustainable development approach.
Through its R&D program and acquired experience, Air Liquide is committed to constant innovation in combustion processes, meeting the dual aim of productivity and environmental protection. Today, this expertise allows our engineers to develop oxy-combustion processes that will enable CO_2 emissions to be efficiently captured as they are released from industrial units before being buried in the subsoil.
Air Liquide further engaged itself into responsibility objectives, as part of the Group strategy. This responsibility commitment is not new for Air Liquide and it goes hand in hand with the values the Group has previously expressed in its Principles of Action and in its Sustainable Development Policy. Innovating for tomorrow guarantees the

growth of the Company and its customers with more than 60 % of the R&D budget devoted to Sustainable development.

2. The HotOxyGlass Technology

2.1. Presentation of a flat glass furnace

In a flat glass furnace (figure 1), the raw materials are introduced in the melting area and brought to a temperature of 1 500°C. The molten glass is then refined and homogenised. Then, it is slowly cooled down to reach the proper temperature for its delivery to the float area (1 100°C).
The float area in the furnace consists in a bath of molten tin. In this area, there is a protective atmosphere containing a mixture of nitrogen and hydrogen, in order to prevent oxidation of tin. The molten glass flows onto the tin surface to form a floating ribbon with perfectly smooth glossy surface on both sides.
When the molten glass temperature decreases to approximately 600°C, it leaves the float area to enter the annealing lehr, where the glass is slowly cooled to handling temperature. The cooled glass ribbon is eventually conveyed to the cutting area.
Once it is started, a flat glass furnace will operate continuously and thus will have an average operation life of 15 years. This means that these furnaces have to be rebuilt approximately every 15 years. Most importantly a flat glass furnace cannot be significantly upgraded after its start. This implies a long term view when building a new furnace, in order to forecast future emissions and consumption standards.

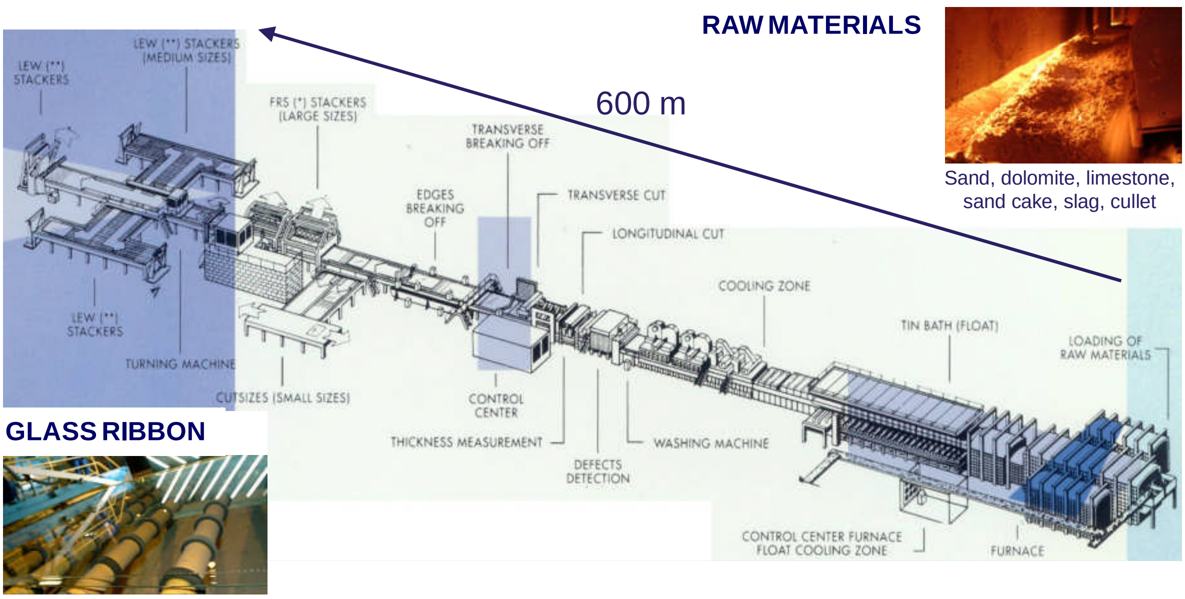

Figure 1: Presentation of a flat glass furnace

2.2. Pre-heating of air in a traditional furnace

In traditional air-combustion furnaces, various methods exist to re-use a part of the energy of flue gases generated by the combustion chamber of the furnace (average temperature of 1 550°C).
Figure 2 below displays the process in a traditional flat glass furnace:
There are two sets of regenerators, one at both side of the combustion chamber. The process operates following a shifting cycle. During 20 minutes, the air is introduced through the regenerator 1 into the combustion chamber. At the other end, hot flue gases exit the combustion chamber through the regenerator 2. In the process, they heat the regenerator 2. After 20 minutes, the process is reversed: the air is introduced through the regenerator 2, thus retrieving the accumulated heat (up to 1 250°C). So this process, by shifting the paths of air and flue gases every 20 minutes, allows a pre-heating of air before it is used in the combustion process.

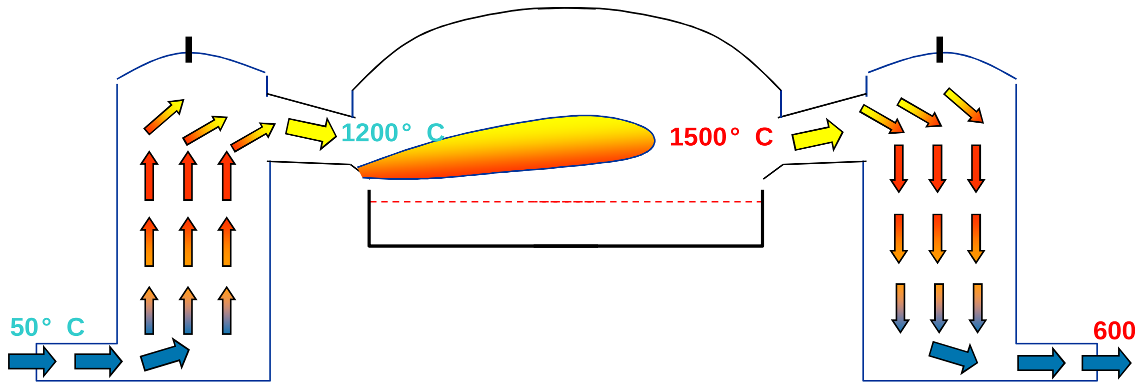

Figure 2: Heat recuperation in air-fired furnace

2.3. Technology of the HotOxyGlass furnace

The innovative concept of the HotOxyGlass furnace lies in the combination of the oxy-combustion technique (use of oxygen instead of air) and pre-heating of reactants (oxygen and natural gas) involved in the combustion.
Oxy-combustion is a well-proven technology that consists in using pure oxygen (from 92% to 100% purity) instead of air, avoiding thus to include the "un-necessary" nitrogen that penalizes the combustion yield. The associated oxy-burners generate flames (2 600°C) that produces more energy than air combustion flame (1 900°C), allowing to increase the furnace productivity. Contrary to air combustion (see §2.2) oxygen is never preheated: such technology does not exist and its development is a real challenge.
The technical concept demonstrated in HotOxyGlass project has been developed in such a way that the heat generated during the glass production process is re-used to pre-heat the oxidizer and the fuel.
In the HotOxyGlass furnace (figure 3 below), flue gases at a temperature of 1 450°C are directed towards a recuperator when they leave the furnace combustion chamber. In this device, atmospheric air is introduced, and there is a heat exchange with flue gases. At the exit of the recuperator, the atmospheric air is heated to 750°C.

Atmospheric air is merely used as a medium to convey heat. Then the hot air is directed towards heat exchangers designed to pre-heat reactants: oxygen is pre-heated at 550°C, natural gas at 450°C.

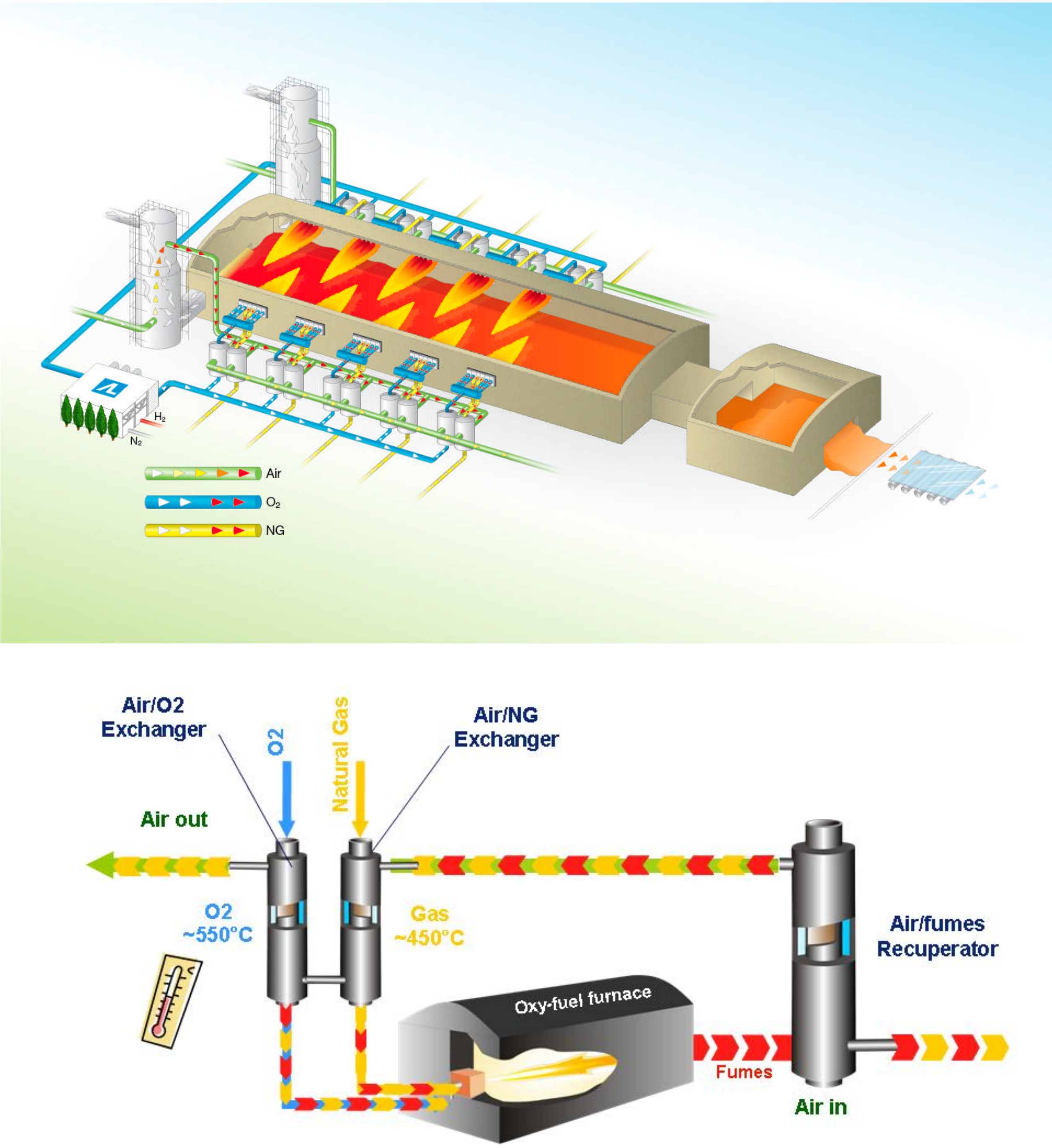

Figure 3: Technology of the HotOxyGlass furnace - (Upper view) Artistic design of the furnace (Lower view) Scheme of the concept

3. Results of the project

The LIFE+ project confirmed expected technical (burners, furnace, heat recovery equipment) and environmental results (energy, CO_2 NO_X, SO_X,): it demonstrated the correct performance of the hot oxy-combustion prototype furnace as well as validating its lower energy consumption and lower pollutants emission compared to a state-of-the-art furnace.

After testing and validation in the framework of the project, oxy-burners are operational in preheated oxy-combustion, and the prototype furnace is producing daily several hundreds of ton of quality flat glass. The consumption of the furnace has been reduced (-25% target reached) and its environmental impact has been optimized after 2 years of operation. Environmental results are summarized in the following table:

Environmental indicator	**Reduction measured (with margin) compared to a state of the art air-fired furnace**
Energy consumption	**- 25%** *(margin of 2%)*
CO_2 emissions	**- 15%*** *(margin of 3%)*
NO_X emissions	**- 83%** *(margin of 5%)*
SO_X emissions	**- 38%** *(mean value)*

** when taking into account the environmental cost of oxygen production*

This table summarizes the mean values obtained with the furnace operating in stabilized combustion. All the targets have been reached thanks to a combination of low NO_X separated jet oxy-burners and the heat recovery system.
Also qualitative parameters have been tracked. An adequate monitoring of the furnace has allowed:

- Tracking burner performances:
  - Burner flexibility: possibility to switch the fuel as a function of fuel costs (on a day to day basis)
  - Large burner power range: from -40% to +70% of nominal
  - Flame lengths: 4 to 7 meters in natural gas as a function of power
- Daily checking furnace behavior on Batch line, foaming, temperatures and Glass quality
- Measuring flue gases composition
- Validating the different elements constituting the heat recovery system (Air/fumes recuperator, Air/O_2 exchanger, Air/Natural gas exchanger).

For one year of functioning in standard conditions the HotOxyGlass furnace can reach the following reductions in terms of pollutant's emissions (compared to a similar state-of-the-art furnace):

- 15 325 tonnes of CO_2, equivalent to taking a total of around 3 400 cars out of circulation;
- 1 065 tonnes of NO_X;
- 170 tonnes of SO_X.

These results have been obtained thanks to the European Union's support; HotOxyGlass is today the less fuel consuming and the less pollutant among the 58 flat glass furnaces in Europe.

4. Transferability of project's results

This solution is very advantageous for the glass industry. Indeed the technical solution is both environmental and cost effective in the medium term.
The implementation of similar solutions will probably take place within AGC Glass Europe's group but the technology is available for other glass makers or industries requiring high levels of combustion. The use of oxygen and natural gas technology has been demonstrated for flat glass furnaces but can be implemented in any factory generating fumes and targeting at reducing its environmental footprint. Steel, iron, cement, boilers industries are all working for decreasing pollutants emissions and are good candidates for future implementation. In short-term, glass industry remains a privileged candidate for dissemination as it still represents a large sector in terms of furnace to be converted (for information: 58 Float tanks in Europe, 175 containers glass furnaces…).
A wider implementation of similar furnaces can easily be expected by the end of 2020. The impact on climate change will be important, taking into consideration the large size of the glass industry and market.

Partners involved in this project were truly committed to limiting the negative impact of their activities on the environment. In the glass industry, AGC Glass Europe already met the requirement of the European commission's "Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Glass Manufacturing Industry" (BREF 12.01, December 2001). Thanks to LIFE+ support, this project permitted to validate the possibility of going well beyond these requirements, and thus setting new environmental standards.

HotOxyGlass project's website:

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