Advanced oxygen burner for the glass industry[1)]

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1. Introduction

The adoption of the oxy-combustion technology by the glass industry has grown rapidly over the last years due to the following benefits brought by oxy-fuel technology: reduced pollutant emissions, reduced fuel consumption, reduction of electric boosting, batch savings, improved glass quality, improved furnace stability and reduced capital cost.

But as the technology evolved, the glass industry demands that the above benefits be taken to a much higher degree. This could only be achieved through improvements and new developments in burner technology. It is important to note that close attention must be paid to the burner selection and the flame behavior, which plays a significant role in determining refractory wear (and therefore furnace life) and productivity.

2. Introducing ALGLASS FC™

Several years ago, AIR LIQUIDE introduced a range of burners specifically designed for the glass industry named ALGLASS™. Since that time, more than a hundred of these burners have been installed worldwide for different types of applications: container, E-glass, float glass, LCD, insulation fiberglass, TV, crystal, technical glasses, etc., either fired with natural gas or with fuel oil or both. Many of them have been in trouble-free operation for years, so that their reliability is now demonstrated.

Based on this experience, AIR LIQUIDE has developed the new ALGLASS FC™ burner (FC stands for "Full Coverage") to address medium to large-size glass tanks with a wide, radiant and low-NO_x flame.

ALGLASS FC™ incorporates the same general features as the other burners of this series:

- Low O_2 pressure requirements (optimization for operation with O_2 produced by COMPACT VSA™),
- non water-cooled,
- bi-fuel, with possibility of a quick switch from one fuel to the other,
- low maintenance frequency.

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3. Characteristics of the new burner

A wide, radiant and low-NO_x flame was achieved through a unique burner block design, with an innovative, optimized oxygen/fuel injection strategy. This optimization was facilitated by the use of modeling and advanced metrology tools, available in the AIR LIQUIDE research centers such as:

a) CARS (Coherent Anti-Stokes Raman Scattering) and suction pyrometry are used for temperature measurements. CARS is a sophisticated method based on the use of laser beams. It offers a non-intrusive method that can provide data in the hottest parts of a flame, and is consequently suitable for oxy-combustion characterization. The counterpart of these very significant advantages is the need for skilled operators.

b) FTIR (Fourier Transform Infra-Red spectroscopy) and a variety of special cameras (visible, UV, IR), for characterization of the radiative properties of the flame. FTIR is a method for recording the flame-radiative emission spectrum within a very short period of time. It is therefore a necessary complement to devices such as radiometers or calorimetric loops for the complete and accurate evaluation of the heat transfer properties of a flame. UV visualization is related with the emission from the OH radical. In practice, the UV emission is emitted where the flame temperature is the highest, i.e., where NO_x production is the strongest; in other words, it visualizes the zones with the highest NO_x production. Therefore, UV visualization is a convenient way to optimize a flame, the goal being to reduce high-temperature zones within the flame.

c) MIE scattering is another laser-based method. Particulates are injected into the flow of either natural gas or oxygen, and crossed by a laser sheet thereby allowing the visualization of that flow by imaging the 90° scattered light. It is a powerful tool for the analysis of the mixing processes for a given burner configuration.

d) Sampling and analysis of the chemical species in the flames, resulting in a mapping of the atmosphere in the furnace.

Finally, the above measurements are used for calibrating the combustion coefficients used in computer simulations models.

Although these sophisticated tools are necessary for accelerating the laboratory development, they represent

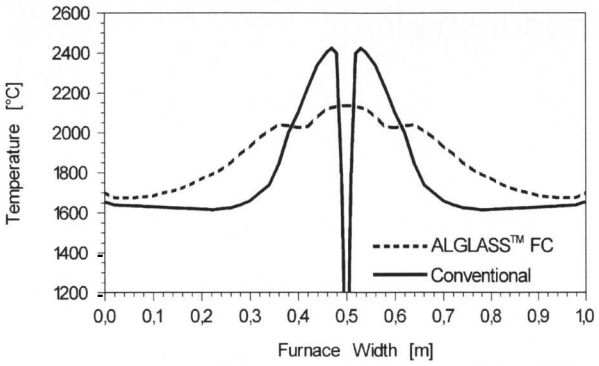

Figure 1. Temperature distribution across the flames of the conventional pipe-in-pipe burner and the ALGLASS FC™ burner.

just one aspect of burner development. Other key features are the installation in industrial glass tanks, the customer's feedback, and the improvements resulting from it with respect to flame behavior, efficiency, maintenance, etc. This iterative process is very significant for a successful burner development.

The wide flame of the new burner indeed exhibits advantages for melting glass:

- no hot spot on glass surface, due to more uniform bath coverage and reduced flame temperature (figure 1). This helps to avoid local overheating and consequently can reduce scum formation;
- reduction of the number of burners used.

Still, when designing a wide flame, two difficulties may arise:

- The flame has to be wide but yet long; typically a burner of the type 1 MW ALGLASS FC™ produces a 1.2 m wide flame with a length of 4 m.
- The flame must radiate as uniformly as possible throughout its length; spectra recorded at 1/4, 1/2, and 3/4 of the flame length, as well as visual inspection, show that it radiates homogeneously.

As mentioned above, all burners of this series are bifuel. As far as it is known, ALGLASS FC™ is the only oxy-oil burner with a "wide" flame successfully demonstrated in a commercial glass tank. It is well known that fuel consumption is lower with oxy-firing than with air-fuel combustion. Indeed, the main reason is the elimination of the energy required for nitrogen heating in the case of air combustion (even when air preheating is utilized). Nevertheless, this cannot explain the totality of the fuel savings experienced in the field. Other factors have to be stated:

- Due to the higher concentration of emissive molecules (CO_2 and H_2O) and the reduced speed of the gas, oxygen flames tend to release their available energy much quicker than air flames, and consequently flue gas leaves the furnace with a lower temperature, i.e., more energy is transmitted to the glass.
- Oxygen flames naturally tend to emit at shorter wavelengths than air flames, and radiation at short wavelengths (visible and near infrared) has a much better penetration into the glass melt.

These effects are natural features of oxygen flames. Still, they can be enhanced by a proper adjustment of the burner parameters. And then the flames, highly emissive, tend to transmit a maximum of the available energy before reaching the exit port. Moreover, a large portion of this energy can go deeply into the glass bath, preventing the creation of hot spots at its surface.

The flames produced by the new burners are luminous (figure 2) due to a design that promotes soot formation. A visual observation as well as sophisticated spectroscopic studies provide evidence of that. An additional benefit is that operators can see the flame.

The concept used for the design of ALGLASS FC™ basically leads to a decrease of the flame peak temperature. This is confirmed by computer simulation and temperature measurements, for both the natural gas and the fuel-oil version; depending on the operating conditions, ALGLASS FC™ produces a flame with a temperature which is 300 to 400 K lower than that of a conventional pipe-in-pipe burner. This is confirmed by the fact that the UV emission of this burner is very weak (as explained above, the strength of the OH radical emission in the ultraviolet is a strong indication of the flame temperature).

It is now well-accepted that NO_x production under the conditions of an oxy-gas flame occurs mainly through the so-called Zeldovitch mechanism, which is very sensitive to the temperature, consequently, a reduction of the flame temperature results in a decrease of NO_x production. The measurements in the laboratory furnace show that in the case of firing with natural gas the NO_x produced by ALGLASS FC™ is about 1/5 that of an optimized pipe-in-pipe low-momentum burner. In the case of fuel oil, atomized by air, NO_x emissions are also decreased by a factor of 5.

The configuration of ALGLASS FC™ is to a certain extent similar to that of an air burner (figure 3). Moreover, although the exact tailoring of the burner was not straightforward and resulted from a sophisticated parametric study, the described burner has a limited number of injectors, without any tiny holes or stringent tolerance. As a result, the maintenance frequency, as already mentioned, is very low.

Due to the simplicity of the design, inspection and maintenance is quick and easy and requires no tools. The tests performed at critical operating conditions in industrial furnaces show that the oxy-gas version can withstand without any damage a breakdown of an hour (which means no cooling at all), and can then be relit on without any cleaning.

The burner design provides a flame that is detached from the block, thus, avoiding any hot spot on it. More-

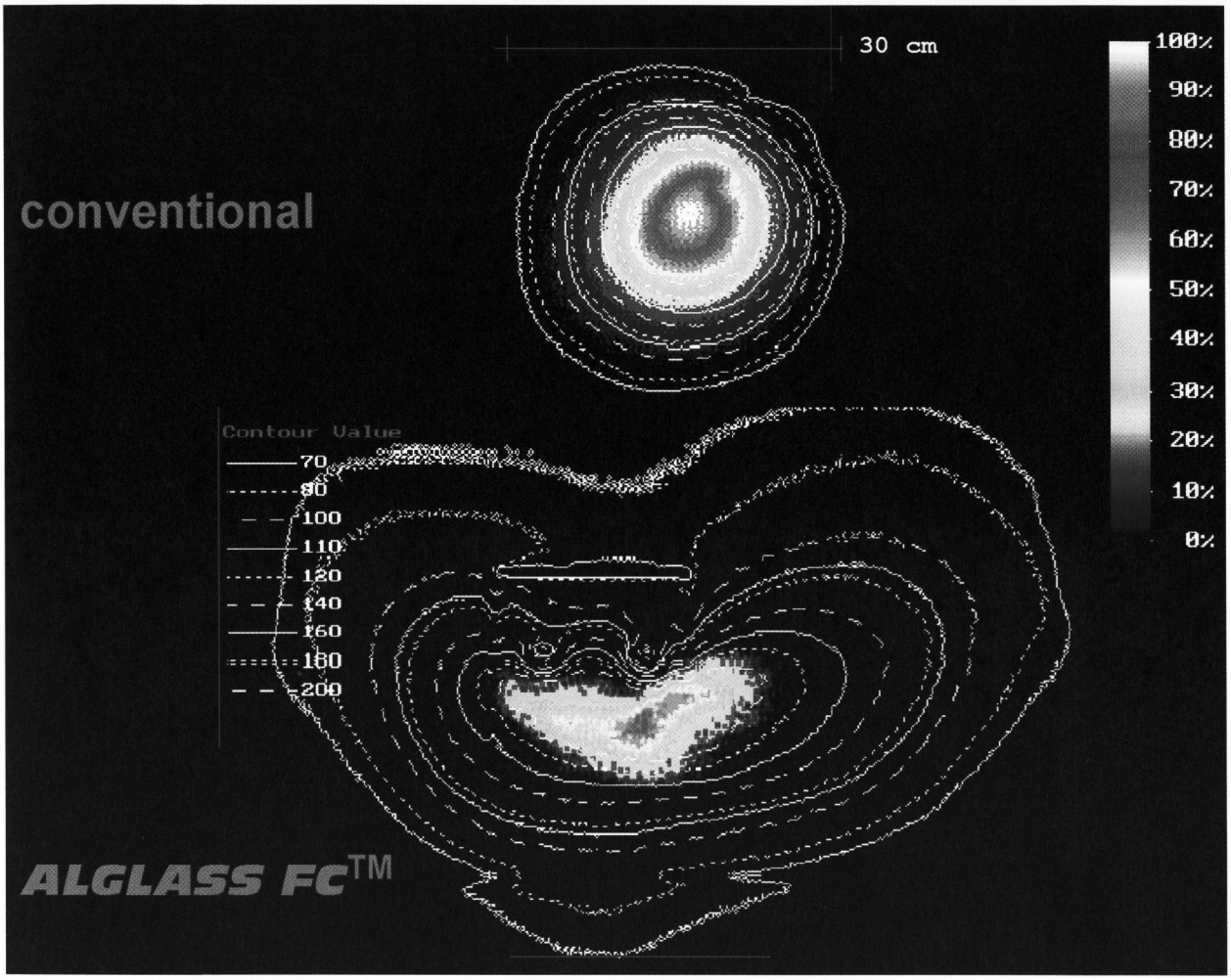

Figure 2. Relative OH radical concentration in the flames of the conventional and the ALGLASS FC™ burners. High concentration indicates high temperature and increased NO_x production. The contour value indicates the luminosity of the flame and thus its visibility.

over, the configuration prevents flame lofting, thus, keeping natural gas far from the crown. This results in a burner operation intrinsically safe with regard to refractory wear. Concerning refractory wear, it must be pointed out that, because the flame momentum is very low, the flame wide and its temperature low, alkali volatilization is decreased with respect to that of a conventional burner. This is not only good for crown lifetime, but also tends to reduce particulate emissions.

4. Industrial tests

The new burner was tested by glassmakers on different industrial furnaces (borosilicate and soda–lime–silica glass). In particular, both the natural gas and the fuel-oil version were installed in a 400 t/d container glass tank. From these tests, the selected flame geometry (width, length, homogeneity, luminosity) was confirmed as well as breastwall (near the burners) and crown temperature decrease. The reliability and maintenance requirements were also evaluated.

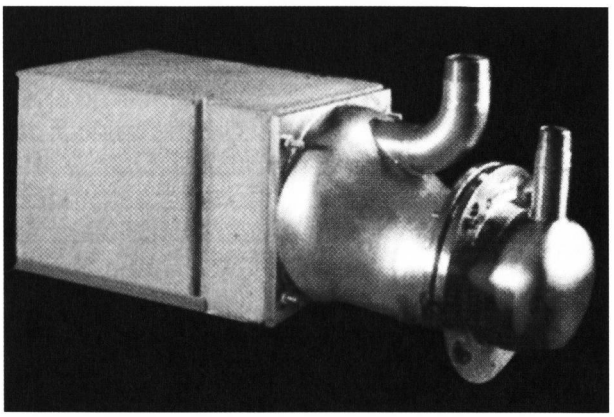

Figure 3. ALGLASS FC™ burner with burner block.

5. Conclusion

The flame characterization and the industrial tests demonstrated that AIR LIQUIDE's combustion technology with ALGLASS FC™ offers to the glass industry:

a) productivity improvements through combustion efficiency (more energy to the bath, due to a wide and radiant flame),

b) low pollutant emissions with strong NO_x reduction and lower particulate emission,

c) preservation of furnace lifetime through a decrease of alkali volatilization.

All of these benefits are achieved without any additional complexity of the burner design.

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