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Effect of LPG Emission on the Performance of Glass Bending Furnace

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ABSTRACT

The extant research design LPG give a good temperature distribution for a specific burner design of low consumption burners and relays to a method for bending the glass sheets, in which method the swirl burner LPG is used in a small furnace. Using LPG fuel gives more stability in the combustion process, the LPG is a gaseous fuel that helps to have easy control of the combustion rate and the temperature behavior inside the combustion zone by increasing and decreasing the mixing ratio with air. The heat flux from the flame moves in the front direction due to the momentum of the fuel mixture and the design of the burner rim, which keep the flow adhesive, such behavior leads to creating different temperature zone since the combustion process is a continuous process. The main result is that clean or low emission combustion of LPG fuel will increase the gained temperature and give a good temperature distribution for a specific burner design of low consumption burners and the clean combustion will reduce the unwanted deformation of soot on melting glass surface. Generally, high energy cost and the environmental pollution are the major issues in the glass industries which must be reduced through reduce the fuel consumption of the glass furnaces. For these reasons, this type of furnace can be used in other applications, not only in melting glass.

1. Introduction

Two essential parameters in the design of recent manufacturing furnaces are high thermal efficiency and low emissions. A better experimental understanding of behaviour in industrial glass melting furnaces is necessary to meet these two competing aims. Glass manufacturers include a transfer of heat requisite for the fusion glass to attain a low viscous melt [1]. Smelting in glass-made furnaces is done using several types of materials from which these furnaces are made, each of which is distinguished by its specific properties, capacity, type of metal produced from it, its quantity, and the nature of its use. Among the furnaces commonly used in foundries are: crucible furnace, dust furnace, electric furnaces, and others, as shown in this study. Glass melting furnaces are worked by fossil fuel energies or electricity, where the heat is mainly transported to the glass melt surface in the fossil fuel-fired furnace via radiation from the combustor. Glass production is ordered as one of the

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great scaled fields in energy consumption [2]. Generally, high energy cost and the environmental pollution are the major issues in the glass industries which must be reduced through reduce the fuel consumption of the glass furnaces. Although of the current progressions in used energy decrease, there is still a long way to attain the ultimate aims of glass manufacture which involves improving thermal efficiency, lessening environmental effects, and conserving glass quality [3]. Many researches have been carried out to enhance the thermal efficiency of glass melting furnaces. Some of these works have employed simulation methods to study the effect of different factors on energy consumption in glass furnaces [4-7]. Many researches utilize the innovative techniques to improve the thermal performance of glass furnace [8-10]. In addition, some works focus on applying new burners and heat recovery schemes for preheating burning air and raw materials to considering new geometries of combustion space and the optimum performance of glass furnace [11-18].

Heat transfer in the combustion chamber of the furnace as radiation is collected from three components: gaseous types radiation, soot radiation and radiation from the crown surface. Soot radiation aids to increase the furnace efficiency by improving the heat transfer between the crown and the glass surface that way reducing the overall temperature in the combustion chamber [19-20] have used an industrial, regenerative, gas-fired, float glass furnace and measured the crown incident radiant heat flux at different locations in the furnace during both firing and nonfiring periods. Additionally, the time-resolved data at all several locations through both reversal and firing manners of the regenerator cycle have been discussed. The measured data have been comparison with a three-dimensional numerical model of the combustion furnace.

Calculating and classification of gaseous emissions from furnaces is very important for many reasons which comprises; agreement of source emission to regulations and available set standards, evolving appropriate emission management and developing the strategies to reduce this emissions, ambient air quality estimate in the affected source regions and assesses the effect exposure of the human and the environment [21-25]. There are international efforts directed to usage of clean fuels for the furnaces and cooking to decrease air pollution, enhance air quality and protect human health. Increase in embracing of liquefied petroleum gas has resulted in development of different design of burner heads used in LPG glass furnaces in the industry and cook stoves. Laboratory analysis by Darweesh *et al.,* [26], Abbas & Mushin [27], Durox *et al.,* [28], Dhaher *et al.,* [29], Saleh *et al.,* [30], Santosa *et al.,* [31], and Abulqasim *et al.,* [32] were investigated on 16 conventional difference LPG burner heads to develop the emission inventories for LPG cook stoves and the study data used to calculate the effects of LPG cook stoves on air quality in the enclosed environment. The experimental study determined that selecting the right material of manufacture for burner is important for moderating air pollutants from combustion of LPG and enhance air quality greatly. They found that the burners made of cast iron and brass have emission indices which satisfactory standard limit by International Organization for Standardization and other regulations [33-40].

Because the strong demand has emerged to less fuel consumption while meeting stringent environmental regulation targets without compromising glass quality and productivity, this experimental work presents a design and building of melting glass furnace with a new method to reduce the fuel consumption and the emissions depending on utilization of used a hybrid burner (swirl and tangential) of Liquefied Petroleum Gas (LPG) to product of flat [41-46] and bent tempered glass.

2.Experimental Setup and Procedure

2.1 Selection of Burner

In recent decades, the technologies used in engineering fields have advanced where the swirl burner technology has been used. These swirls enhance the mixing rate of the fuel and air that used in the combustion procedure, which increases the energy produced and decreases emissions. The combustion procedure by this technology has a more stable range of blowoff and flashback levels, high levels of turbulent flame speed and low burning volumes by using these technique of flow [47-49].

To obtain a combustion system suitable to the nature of furnace work and more efficient and with low fuel consumption and maintenance costs and less gaseous emissions, there was an important development in the design and manufacture of swirler mixing burners. The tangential swirl burner has been employed due to the transverse entrance system has a better performance in creating a spiral at the core of the internal space of the burner [27], as shown in Figure 1. This burner consists of two lateral air consumptions with 1.4 cm in diameter for each side to make vortices inside the burner. Where the air is mixed with the liquefied petroleum gas (LPG) that supplied from the lowest of the swirl chamber of burner with a diameter of 0.6 cm. Thus, producing a homogeneous mixture of air and fuel which is prepared for combustion at the exit of burner. The two side of air intakes generate a complete combustion for the fuel mixture burned in that region due to the presence of a sufficient amount of oxygen, which means clean combustion. Since the flame doesn’t touch the burner, the low eddy burning is also extremely energy-effective due to the non-loss of the burner energy [27]. The compressed fresh air is supplied from a compressor which is consist of a pressure gauge and switch control. While the fuel is equipped from the LPG gas cylinder with regulator[50-52].

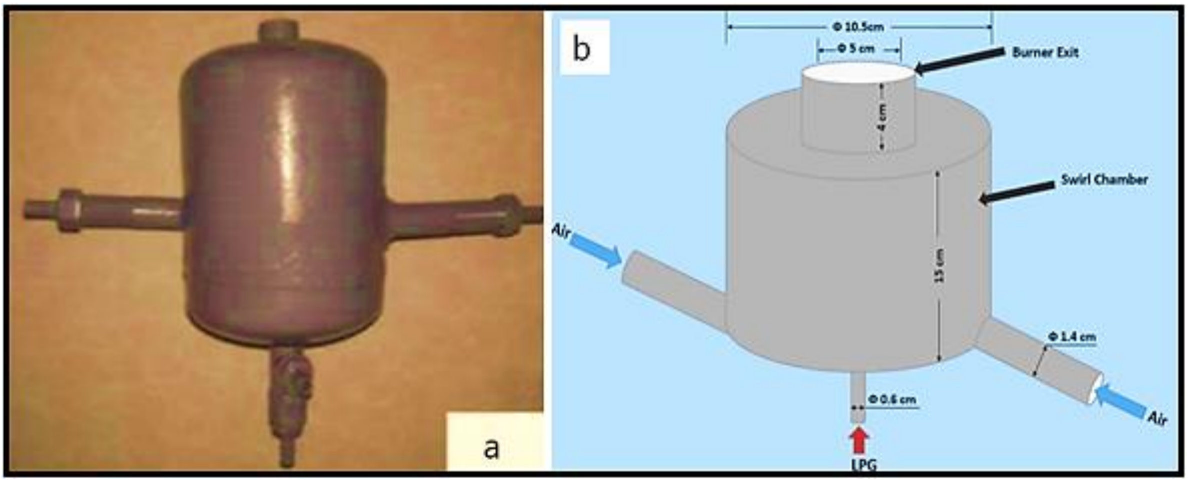


Fig. 1. (a) A tangential swirl burner (b) Geometry specifications of the tangential swirl burner

2.2 Geometry and Building of the Furnace

The furnace has been built from three successive layers for retaining the heat: refractory cement, refractory bricks, and an outer layer of iron. The inner layer of refractory cement with thickness 0.4 cm which is represent the inner walls for furnace space. The middle layer of refractory bricks is 10 cm thick which represent the main layer of the furnace. The outer layer of iron is 0.2 cm thick, covered with a black thermal paint. The furnace is 74 cm high, measured from the outside from the bottom to the maximum curved height of the crown, 81 cm wide and 100 cm long (L). The furnace is constructed with two exhausts for the exhaust of combustion waste, one on each side. It also contains two windows with heat-resistant glass, one for monitoring the burner flame and the other for monitoring the sample. The burner is located in front of the furnace, while the gate through which the sample is entered and taken out is located backwards, Figure 2. Three thermocouple plugs with datalogger (multi-channel temperature meter) have been used to measure the temperatures during the experiment. First plug is in front of the glass sheet sample at (x/L=0.28), second plug is in next to glass sheet at (x/L=0.675), and the third plug is behind it at (x/L=0.7) according to studies by Darweesh *et al.,* [26] and Abbas and Muhsin [27].

Fig. 2. Experimental setup

The firing from the burner is done in a precise manner to ensure that the entire glass melt is uniformly heated. The burner control valve is opened and LPG fuel is passed to maintain uniform inlet pressure of the gas to the burner head, the furnace is switched on and the spark is inserted into the combustion zone close to the burner head. A flame is formed, then the air valves are opened to increase the efficiency of fuel combustion and to obtain a clean combustion. The temperature of the furnace zone is measured from the beginning of the combustion process. A glass sheet sample is heated to a bending temperature by supporting it on a concave mold. The experimental procedure continues until the glass is melted and takes the shape of a mold. LPG combustion and compressed air are carried out at a variable mass for the burner to increase the temperature inside the furnace gradually with time. The experiment continued for 4 hours to melt the glass inside the furnace with a continuous increase in temperature to convert the glass from a flat shape to a curved one.

Micro emission analyzer model 500 (Enerac) as shown in Figure 3 has been used to for analysis of combustion exhaust emissions. Glass fusion should be clean burning with as few emissions as possible to avoid deformation of the glass and failure zones [53-54].

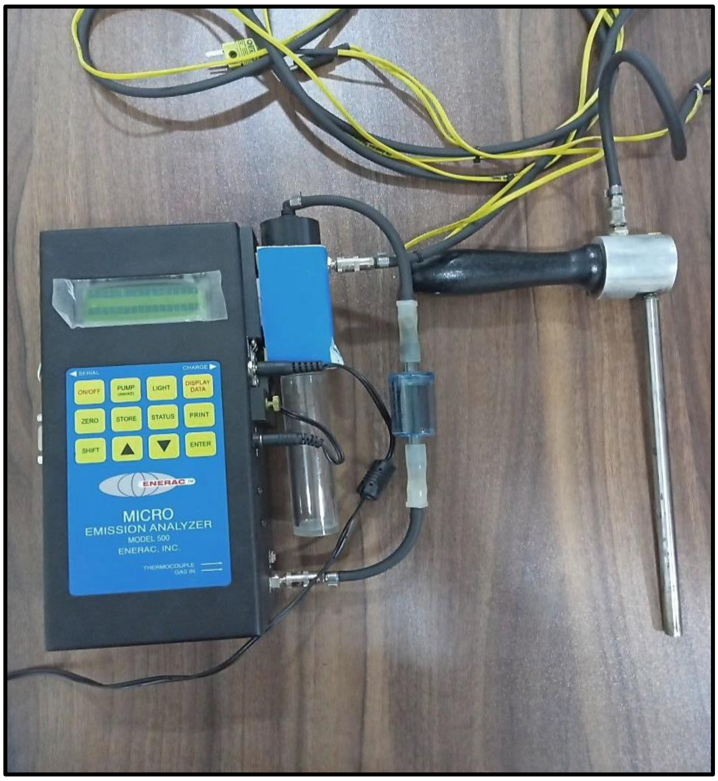
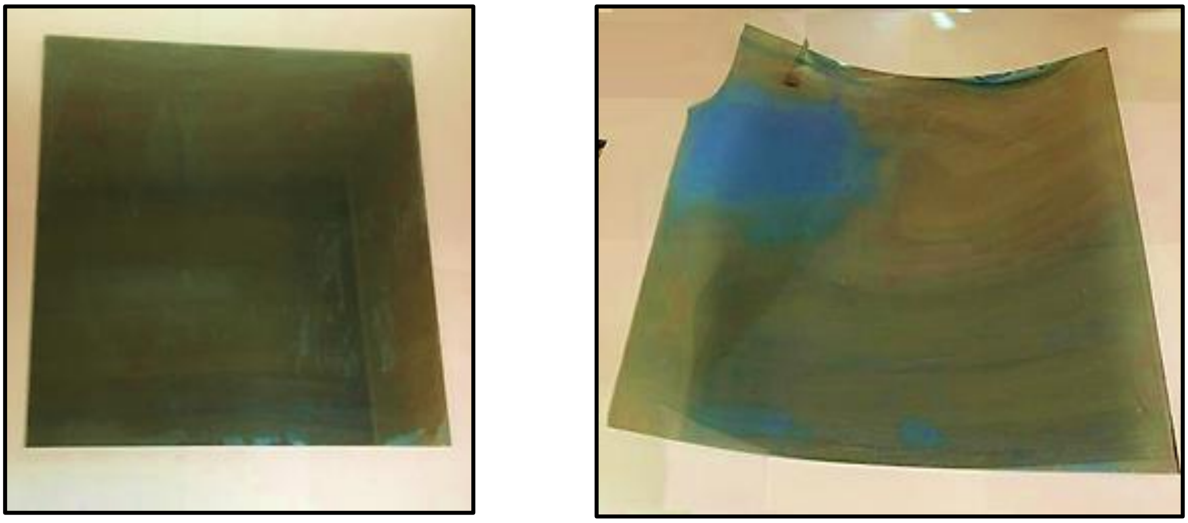


Fig. 3. Micro emission analyzer model 500 (Enerac)

When the glass sheet enters the furnace, it absorbs energy from the furnace chamber by radiation during the bending. Also, the heat transfer occurs by the conduction on the bottom glass surface where it is in contact with the mold. A flat glass sheet model with dimensions 37.5 cm width, 41 cm long and 3.5 mm thick as shown in Figure 4, is introduced to the furnace after 20 minutes from the beginning of the experiment. Bending the glass progress with time and increase temperature. The cooling process [46-49] is in the same furnace and it is also gradually with the time to avoid deformation in the glass model, where the burner is extinguished and left the furnace is closed until the temperature is reduced naturally within it [50-52].



(a) (b)

Fig. 4. Glass sheet model (a) Flat glass before entering the furnace (b) Bending glass after exiting the furnace

3. Results and Discussion

The temperature distribution during the experiments is plotted as shown in Figure 5. The temperature based on location with constant time intervals (10min) shows the combustion chamber behaviour. As the temperature rises in the glass industry is a very critical issue due to the sensitivity of the glass to sudden thermal deformation. The heat flux from the flame moves in the front direction due to the momentum of the fuel mixture and the design of the burner rim- which keep the flow adhesive- such behaviour leads to creating different temperature zone since the combustion process is a continuous process. The area behind and around the burner rim will be heated mainly through radiation and to a less degree by convection. Moving to the middle of the combustion zone the diffusion of the flame increase which increases the temperature at this point and the amount of heat received increases. The rest of the combustion zone will be heated by convection between the hot flue gases and the environment which explains the high temperature values in this area compared to the other parts of the furnace parts at the same time. In glass bending, the gradual temperature is the best scenario because the slow rising in piece temperature will prevent tiny cracks that could happen due to thermal shock if the temperature changes dramatically as shown in Figure 6. Using LPG fuel gives more stability in the combustion process the LPG is a gaseous fuel that helps to have easy control of the combustion rate and the temperature behaviour inside the combustion zone by increasing and decreasing the mixing ratio with air. Air in this process could be used as an oxidizer and a cooler for the burner and nearby area. The burnout of LPG will emit less combustion flue gases which concentrate the energy of the combustion on the furnace zone. However, the piece chosen for experiments has a low softening temperature of around 600 °C to reduce the operation time and fuel combustion. Figure 7 represents the micro emission analyser readings for furnace exhaust. Calculating and classification of gaseous emissions from furnaces is very important for many reasons which comprises; agreement of source emission to regulations and available set standards. The readings show a clean or low emission combustion of LPG fuel which will increase the gained temperature and give a good temperature distribution for a specific burner design of low consumption burners and the clean combustion will reduce the unwanted deformation of soot on melting glass surface [52-55].

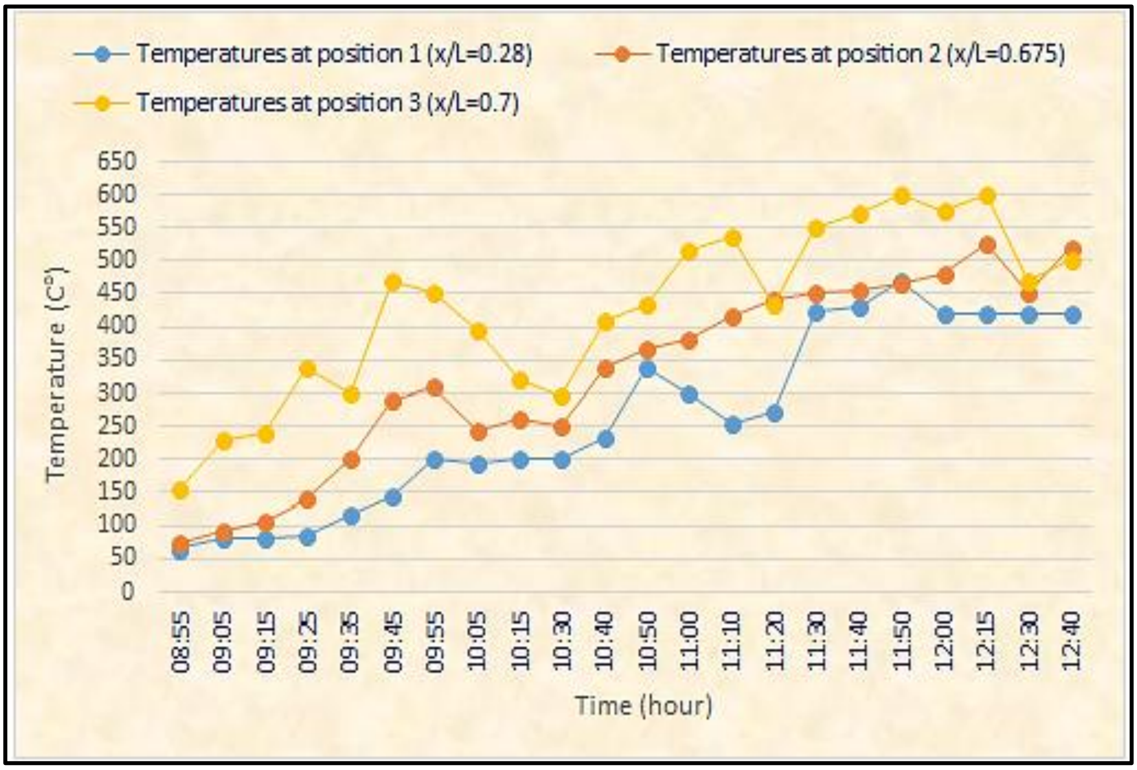


Fig. 5. Temperature distribution during the experiments

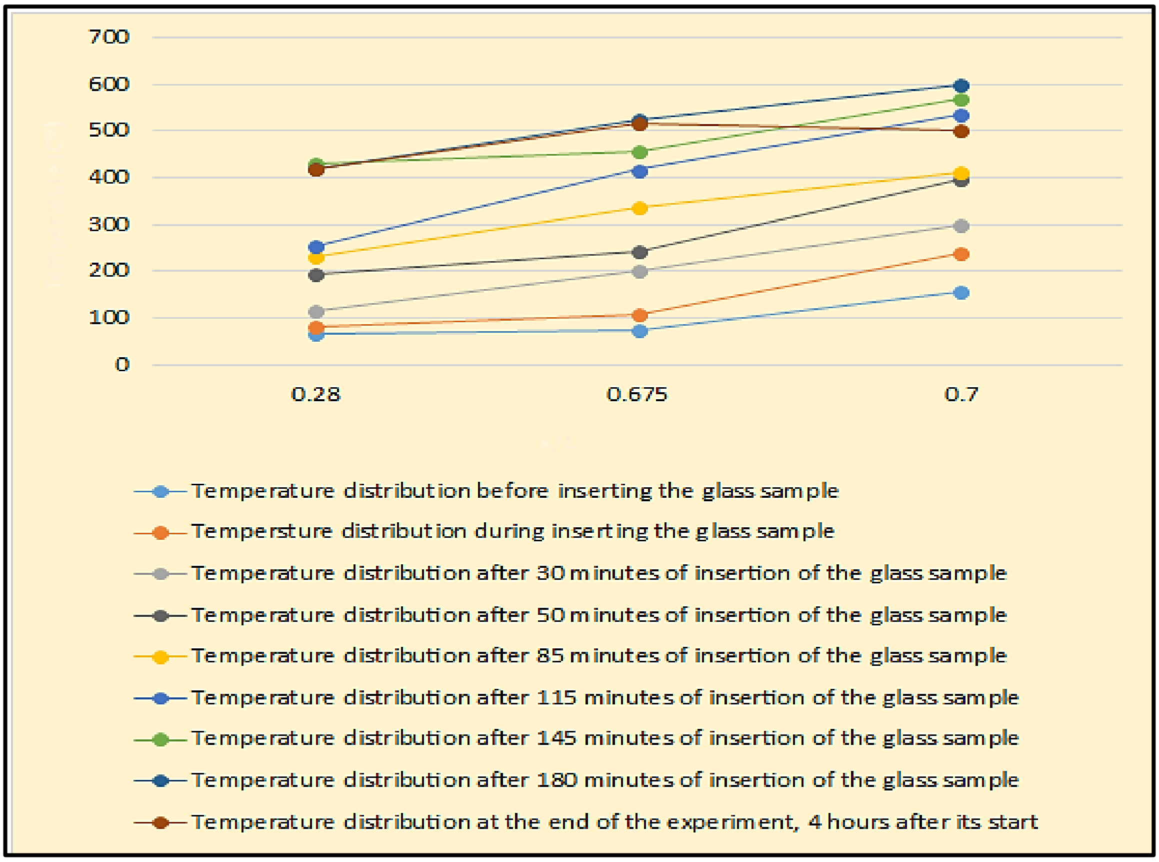
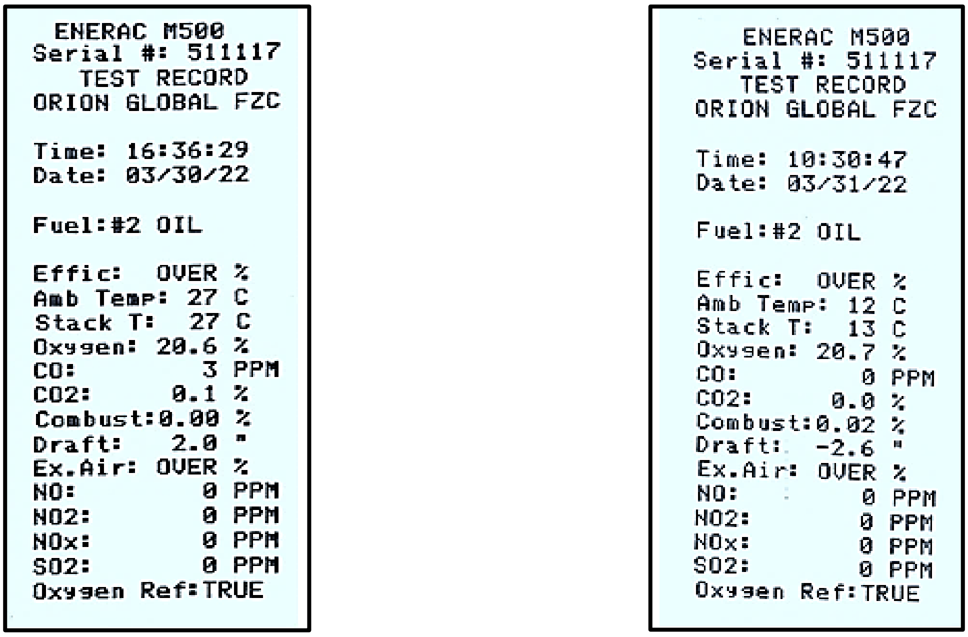


Fig. 6. Gradual temperature distribution along the furnace



(a) (b)

Fig. 7. Micro emission analyzer readings (a) Exhaust emissions from glass furnace (b) Outside natural air

4. Conclusion

The major object of the project was to investigate and document on the basis of reference plants the best available techniques of the glass industry in the field of environmental control. An LPG swirl burner is used in a small furnace to be used in melting glass. Using LPG fuel gives more stability in the combustion process, the LPG is a gaseous fuel that helps to have easy control of the combustion rate and the temperature behaviour inside the combustion zone by increasing and decreasing the mixing ratio with air. The heat flux from the flame moves in the front direction due to the momentum of the fuel mixture and the design of the burner rim- which keep the flow adhesive- such behaviour leads to creating different temperature zone since the combustion process is a continuous process. The main conclusion is that clean or low emission combustion of LPG fuel will increase the gained temperature and give a good temperature distribution for a specific burner design of low consumption burners and the clean combustion will reduce the unwanted deformation of soot on melting glass surface.

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