72nd Conference on Glass Problems

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Charles H. Drummond, III
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Edited by
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72nd Conference on Glass Problems

Foreword

The conference was sponsored by the Department of Materials Science and Engineering at The Ohio State University.

The director of the conference was Charles H. Drummond, III, Associate Professor, Department of Materials Science and Engineering, The Ohio State University.

The themes and chairs of the four half-day sessions were as follows:

Glass Melting
Martin H. Goller, Corning Incorporated, Corning, NY, Glenn Neff, Glass Service, Stuart, FL, and Tom Dankert, O-I, Perrysburg, OH

Refractories
Matthew Wheeler, RHI Monofrax, Batavia, OH, and Jack Miles, H. C. Starck, Coldwater, MI

Process Control, Safety and Emissions
Larry McCloskey, Toledo Engineering, Toledo, OH, and Phillip J. Tucker, Johns Manville, Denver, CO

Recycling and Batch Wetting
Warren F. Curtis, PPG Industries, Pittsburgh, PA, and Elmer Sperry, Libbey Glass, Toledo, OH

Preface

In the tradition of previous conferences, started in 1934 at the University of Illinois, the papers presented at the 72nd Annual Conference on Glass Problems have been collected and published as the 2011 edition of The Collected Papers.

The manuscripts are reproduced as furnished by the authors, but were reviewed prior to presentation by the respective session chairs. Their assistance is greatly appreciated. C. H. Drummond did minor editing with further editing by the American Ceramic Society. The Ohio State University is not responsible for the statements and opinions expressed in this publication.

This is my final year as Director of the Annual Conference on Glass Problems. I became Director in 1976 and have served as Director for all Conferences at The Ohio State University since that time. I would like to express my sincere appreciation to all the many authors who have made presentations over these years. Without the assistance of the various Advisory Board members the meeting would not be the success that it has been. Their hard work for which they volunteered their time and devotion to have a high quality program has been invaluable.

CHARLES H. DRUMMOND, III
Cocoa Beach, FL
December 2011

Acknowledgments

It is a pleasure to acknowledge the assistance and advice provided by the members of Program Advisory Committee in reviewing the presentations and the planning of the program:

Warren F. Curtis–*PPG Industries*
Tom Dankert–*O-I*
Martin H. Goller–*Corning Incorporated*
Larry McCloskey–*Toledo Engineering*
Jack Miles–*H. C. Starck*
Glenn Neff–*Glass Service*
Elmer Sperry–*Libbey Glass*
Phillip J. Tucker–*Johns Manville*
Matthew Wheeler–*RHI Monofrax*

Contents

Glass Melting

OPTIMIZATION OF BURNERS IN OXYGEN-GAS FIRED GLASS FURNACE

Marco van Kersbergen[1], Ruud Beerkens[1], Wladimir Sarmiento-Darkin[2], Hisashi Kobayashi[2],

[1)] TNO Glass Group, Eindhoven, NL

[2)] PRAXAIR Inc. Tonawanda and Danbury, New York, USA

ABSTRACT

The energy efficiency performance, production stability and emissions of oxygen-fired glass furnaces are influenced by the type of burner, burner nozzle sizes, burner positions, burner settings, oxygen-gas ratios and the fuel distribution among all the burners. These parameters have been optimized for a 300 tpd (metric tons per day glass pull) oxygen-gas fired container glass furnace in order to improve the heat flux into the glass and to improve convective flows in the glass melting tank. An objective of these adaptations was a reduction of foam formation and decrease of evaporation from the melt. Energy consumption and emission of NOx and dust were measured before, during and after the modifications in these combustion parameters. Glass quality parameters such as seed count and glass color were monitored daily and were kept in very tight ranges. The paper describes the combination of burner optimization measures that have been applied and the results concerning energy consumption reductions, emission changes and stabilizing glass quality.

INTRODUCTION

Energy efficiency is a key parameter in the operation of a glass furnace and a main contributor for reducing melting costs. Optimization in energy consumption is always desired and sought. Unfortunately, almost any optimization brings additional capital expenditures that in many cases are difficult or impossible to justify on fuel savings alone. Ideal case would be to optimize furnace performance by adjusting operational variables of existing equipment. By utilizing the tools at hand, benefits can be achieved with minimum added costs. The following sections present the results obtained from a rigorous optimization process carried out, in an European industrial container glass furnace, to improve energy consumption without incurring in major capital expenditures.

OBJECTIVES

The following general objectives were established for the project.

- Decrease foaming and improve heat transfer to melt;
- Increase energy efficiency of glass furnace;
- Stabilize glass quality: fining, color stability, redox stability;
- Keep low emissions (NOx) and low alkali evaporation from melt;
- Optimize burner settings
    - Increase nozzle size (lower gas velocities);
    - Optimize oxygen-natural gas ratio per burner;
    - Change burner orientation;
    - Optimize fuel (natural gas) distribution among burners;

FURNACE DESCRIPTION

The glass furnace used during these tests produces green container glass, typically with about 65%- 85 % cullet in the batch (i.e., 65 to 85 % of glass produced from recycled cullet). The typical pull is about 300 to 320 metric tons molten glass per day. This furnace underwent a major cold repair in the summer of 2010. Figure 1 shows a schematic view of the flame coverage in the furnace when fired with ten burners. The numbers indicate the burner locations in the sidewalls.

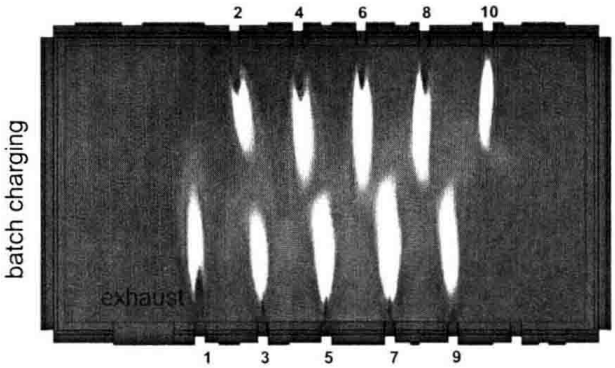

Figure 1. Test Furnace showing flame coverage and burner location

The furnace has eleven Praxair's DOC-JL burners[1] installed. During the tests burner 11 was taken out of operation. These burners are capable of generating a fuel rich luminous flame while keeping very low NOx emissions. Some of the most relevant characteristics of the burners are listed below.

- Deep staging to produce a rich, luminous, "low NOx" flame;
- Oxygen staging to control:
  - Flame shape, length;
  - flame stability;
  - Atmosphere stratification (above melt surface).
- Multi-fuel burner;
- Alkali volatilization control;
- Produce a "targeted" flame.

Figure 2 shows front and rear view of the burner. The furnace also uses Praxair's Tall Crown Furnace design that minimizes silica crown corrosion caused by alkali vapors[2]. This technology combined with optimized burner design and positioning was shown to provide excellent service life performance for silica based crowns.

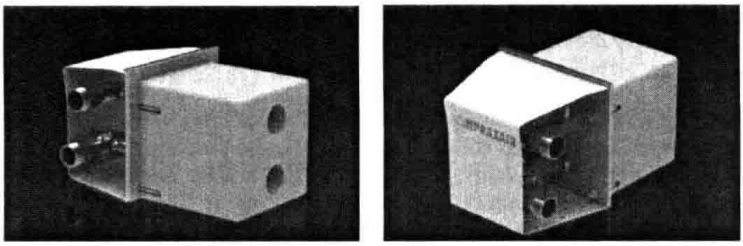

Figure 2. Praxair's DOC-JL burners. In the picture, upper port is NG+O_2, while lower port is O_2

BASELINE OPERATION

For the baseline operation eleven DOC-JL burners were used. As shown in Figure 2 the DOC-JL burners consist of two injection ports; the upper port for natural gas and first stage oxygen injection at a controlled ratio (under-stoichiometric), comprising the burner port itself.

The lower port is only for oxygen gas injection to inject the second stage oxygen to achieve oxidized conditions in the combustion atmosphere near the glass melt surface. For the baseline operation all burners were mounted in the standard configuration, i.e., the secondary oxygen injection port positioned below the natural gas/oxygen port for all burners. During January 12-17, 2011, the following parameters were measured for the baseline operation.

- CO_2, NOx and SO_2 concentration in the exhaust, just after the furnace
- O_2 concentration in this exhaust
- Total sodium and potassium vapor pressures in the exhaust and on several locations in the combustion space just above the melt/foam
- Temperatures in exhaust as measured by suction probe thermocouple
- Photographic record to observe foam layer close to bubbling system

Operational variables modifications

TNO, Praxair and the European container glass company performed several modifications to the oxy-fuel burner settings between January and June 2011. Main modifications are summarized below.

- Burners 3 to 10: O_2 injection port placed above NG/O_2 port, i.e., the burners were flipped over vertically to produce CO rich atmosphere near the glass melt surface. Inverting the burners would expose the foam layer, floating on the glass melt in the hot spot area, to a CO rich atmosphere. Increasing CO concentration in foam's close proximity has been demonstrated to deactivate the surfactants that stabilize foam structure[3].
- Stoichiometric ratio adjusted and fuel input distribution optimized. Oxygen excess was decreased and fuel input distribution changed for burners 3 to 9 to optimize energy consumption by steeper crown temperature profiles to create better flow patterns in the melting tank.
- Burner nozzles were replaced to reduce gas injection velocities by 30% for natural gas and 25% for oxygen. (Higher injection velocities were used in the original installation to try to minimize NOx emissions.)

- Burners 1 and 2 were left operating with the oxygen injection at the lower port to keep an oxidizing atmosphere above batch blanket (to avoid the early decomposition of sulfate fining agent).
- Burner 11 was shut down.

These changes were made with the following technical considerations. First, it appeared rather difficult to apply a low oxygen excess on all burners and still achieving complete combustion and low CO levels in the exhaust gas flow plus good glass quality. Therefore, the two burners closest to the flue port were set on higher oxygen excess to compensate for the total oxygen supply in the furnace. Second, oxidizing conditions above the batch are important for sulphate retention and batch redox as well as to prevent high SO_2 emissions.

Adjustments in the operational conditions were made in six steps, named A, B, C, D, E and F. In this paper details concerning each step are not fully explained and only the results after the last phase (F) will be compared with those from the baseline operation. The following figure shows the changes performed in the fuel distribution of the furnace.

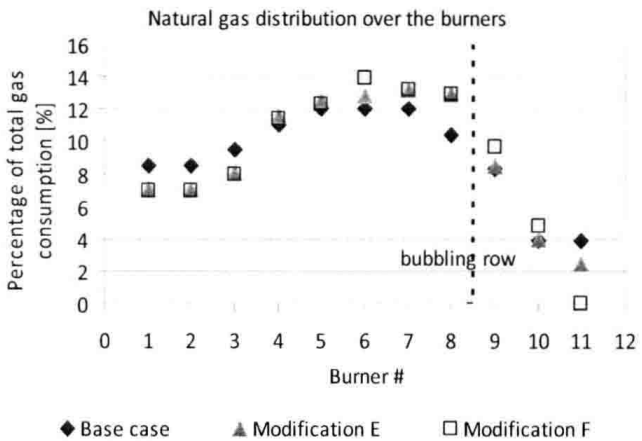

Figure 3. Fuel distribution in each burner

As can be seen in Figure 3, the fuel distribution was changed to favor a higher energy delivery in the hot spot zone of the furnace (creating a more distinct hotspot). Last burner (B11) was shut down to compensate for the additional temperature given to the glass in the hot spot. Figure 4 shows oxygen fuel ratio optimization during the test. Changes performed also contributed to stabilize furnace operation (such as crown temperatures), as shown in Figures 5 and 6.

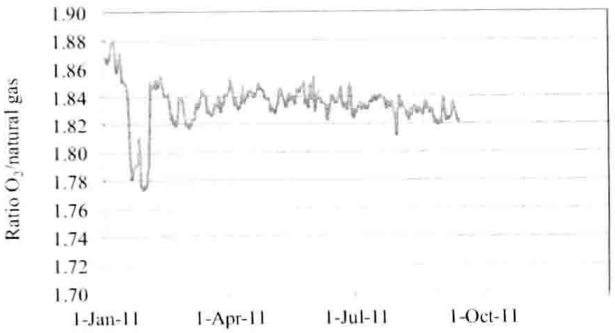

Figure 4. Total Oxygen/Natural Gas ratio for combustion process during the test

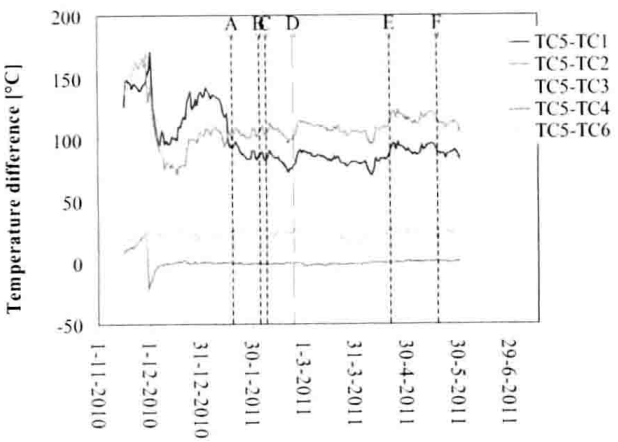

Figure 5. Crown temperature difference relative to the hot spot (T5)

Figure 5 shows crown temperatures at different crown thermocouple locations with respect the hot spot (TC5). Magnitude of the difference as well as the variations experienced over time decreased after modification A. Similar behavior is described in Figure 6.