73rd Conference on Glass Problems

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S. K. Sundaram
Editor

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73rd Conference on Glass Problems

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Edited by
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73rd Conference on Glass Problems

Foreword

The 73rd Glass Problem Conference is organized by the Kazuo Inamori School of Engineering, Alfred University, Alfred, NY 14802 and The Glass Manufacturing Industry Council, Westerville, OH 43082. The Program Director was S. K. Sundaram, Inamori Professor of Materials Science and Engineering, Kazuo Inamori School of Engineering, Alfred University, Alfred, NY 14802. The Conference Director was Robert Weisenburger Lipetz, Executive Director, Glass Manufacturing Industry Council, Westerville, OH 43082. The themes and chairs of six half-day sessions were as follows:

Glass Melting
Glenn Neff, Glass Service, Stuart, FL and Martin Goller, Corning Incorporated, Corning, NY

Melting, Raw Materials, Batching, and Recycling
Phil Tucker, Johns Manville, Denver, CO and Robert Weisenburger Lipetz, GMIC, Westerville, OH

Coatings, Strengthening, and Other Topics
Jack Miles, H. C. Starck, Coldwater, MI and Martin Goller, Corning Incorporated, Corning, NY

Refractories
Matthew Wheeler, RHI US LTD, Batavia, OH and Thomas Dankert, Owens-Illinois, Perrysburg, OH

Warren Curtis, PPG Industries, Pittsburgh, PA and Elmer Sperry, Libbey Glass, Toledo, OH

Process Control and Modeling
Bruno Purnode, Owens Corning Composite Solutions, Granville, OH and Larry McCloskey, Toledo Engineering Company, Toledo, OH

Preface

A tradition of this series of Conference, started in 1934 at the University of Illinois, includes collection and publication of the papers presented in the Conference. The tradition continues! The papers presented at the 73rd Glass Problems Conference (GPC) have been collected and published as the 2012 edition of the collected papers.

The manuscripts included in this volume are reproduced as furnished by the presenting authors, but were reviewed prior to the presentation and submission by the respective session chairs. These chairs are also the members of the GPC Advisory Board. I appreciate all the assistance and support by the Board members. The American Ceramic Society and myself did minor editing of these papers. Neither Alfred University nor GMIC is responsible for the statements and opinions expressed in this volume.

As the incoming Program Director of the GPC, I am truly excited to be a part of this prestigious historic conference series and continue the tradition of publishing this collected papers that will be a chronological record of advancements in the areas of interest to glass industries. I would like to record my sincere appreciation of impressive service of Charles H. Drummond, III as the Director of this Conference from 1976 to 2011. I am thankful to all the presenters at the 73rd GPC and the authors of these papers. The 73rd GPC continues to grow stronger with the support of the audience. I am deeply indebted to the members of Advisory Board, who helped in every step of the way. Their volunteering sprit, generosity, professionalism, and commitment were critical to the high quality technical program at this Conference. I would like to specially thank the Conference Director, Mr. Robert Weisenburger Lipetz, Executive Director of GMIC for his unwavering support and strong leadership through the transition period. I look forward to working with the Advisory Board in the future.

S. K. Sundaram
Alfred, NY
December 2012

Acknowledgments

It is a great pleasure to acknowledge the dedicated service, advice, and team spirit of the members of the Glass Problems Conference Advisory Board in planning the entire Conference, inviting key speakers, reviewing technical presentations, chairing technical sessions, and reviewing manuscripts for this publication:

Kenneth Bratton—*Emhart Glass Research Inc. Hartford, CT*
Warren Curtis—*PPG Industries, Inc., Pittsburgh, PA*
Thomas Dankert—*Owens-Illinois, Inc., Perrysburg, OH*
Martin H. Goller—*Corning Incorporated, Corning, NY*
Robert Weisenburger Lipetz—*Glass Manufacturing Industry Council, Westerville, OH*
Larry McCloskey—*Toledo Engineering Co. Inc. (TECO), Toledo, OH*
Jack Miles—*H.C. Stark, Coldwater, MI*
Glenn Neff—*Glass Service USA, Inc., Stuart, FL*
Bruno A. Purnode—*Owens Corning Composite Solutions, Granville, OH*
Elmer Sperry—*Libbey Glass, Toledo, OH*
Phillip J. Tucker—*Johns Manville, Denver, CO*
Mathew Wheeler—*RHI US LTD, Batavia, OH*

Contents

COATINGS AND STRENGTHENING

REFRACTORIES

PROCESS CONTROL AND MODELING

Glass Melting

ENERGY RECOVERY FROM WASTE HEAT IN THE GLASS INDUSTRY AND THERMOCHEMICAL RECUPERATOR

Hans van Limpt and Ruud Beerkens
CelSian Glass and Solar
The Netherlands

ABSTRACT/SUMMARY

Energy is expensive and therefore most glass producers are looking for methods to optimize the energy efficiency of their glass melting furnaces. For glass furnaces good housekeeping in combination with energy recovery from waste heat may result in energy savings between 15 and 25%.

Large parts of the energy supplied to fossil-fuel fired glass furnaces are lost through the chimney. Even efficient regenerative or oxygen-fired furnaces typically show losses of 25-35 % of the total glass furnace energy input through the stack. Different types of flue gas heat recovery and other energy saving measures are analysed to show their energy efficiency improvement potential for industrial glass furnaces.

Different options to re-use the waste gas heat of glass furnaces are:

- Batch & Cullet Preheating;
- Drying and preheating of pelletized batch by flue gas heat contents;
- Application of a Thermo-Chemical Recuperator (TCR) to covert natural gas, water and waste heat into a high calorific preheated fuel: syngas or reformer gas;
- Steam and/or electricity generation by steam or organic vapours (ORC);
- Natural gas and/or oxygen preheating.

INTRODUCTION

Figure 1 shows a typical distribution of energy supplied to an air-fired regenerative float glass furnace and figure 2 shows a typical energy balance for a modern end-port fired regenerative container glass furnace. Note, the relatively large part of energy losses by the flue gases despite the application of effective regenerator systems for combustion air preheating. Today, batch & cullet preheating systems [1 -7] are applied in the container glass sector for a few (container) glass furnaces using more than 60 % cullet. Energy savings of 12 to 18 % are reported. A new generation of batch/cullet preheaters, that can operate with lower cullet fractions is in development.

Also indirect preheating of cullet only with steam is an alternative way to recover waste gas heat. Other methods shortly described in this paper are: steam generation using flue gas heat contents, batch pelletizing and pellet preheating, application of a so-called Thermo-Chemical Recuperator (TCR) and preheating of fuel (natural gas) and/or oxygen.

Preheating of pelletized batch is an alternative for glass furnace without cullet or relatively low cullet levels. On-site, glass forming raw material batch is pelletized, dried and preheated with heat of the flue gases and, preheated pellets are introduced into the furnace. Figures 1 and 2 show that waste gas (flue gas) heat / energy recovery is probably the most important potential for energy savings in glass melting.

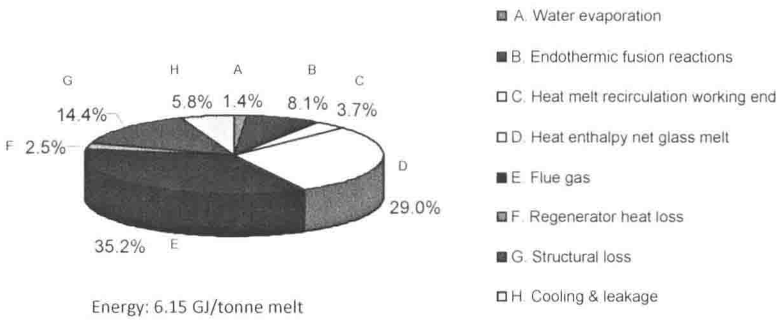

Figure 1 Energy distribution in modern regenerative float glass furnace without working end, including re-circulating melt (return flow from working-end).

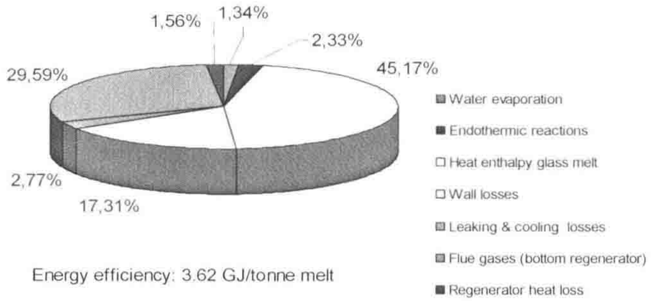

Figure 2 Energy balance of modern & energy efficient container glass furnace (end-port regenerative, natural gas - air fired, 84% cullet), no batch preheater.

In the average Dutch glass industry, the glass melting process consumes almost 60 % of the total (primary) energy input in the primary glass industry. But for some sectors, the melting process consumes even more than 60 %, such as in float glass production (about 85-90 %) and container glass production (60-65 %).

SYSTEMS FOR SECONDARY FLUE GAS HEAT RECOVERY

Typical temperatures of flue gases downstream regenerators of glass furnaces are in the range of 450-550 °C. For recuperative furnaces, flue gas temperatures may be above 800 °C or even 900 °C and for oxygen fired furnaces, flue gas temperatures before quenching or dilution may be as high as 1400-1450 °C. A high temperature is advantageous from a thermodynamic point of view, a high temperature difference between a medium that releases energy to a medium at lower temperature level will favour the quantity of energy/heat that can be transferred and the heat transfer rate.

However, at high temperatures, material constraints may limit some methods of heat transfer and flue gas temperatures need to be reduced before secondary heat recovery.

Kobayashi [8] reported about the development of a high temperature batch & cullet preheating system being in development especially for flue gases at very high inlet temperatures e.g. in combination with oxygen-fuel fired glass furnaces.

Production of steam

Production of steam, using flue gas heated boilers (waste heat boilers) and economizers. Today, systems able to handle flue gases of soda-lime-silica glass furnaces have been applied with success, using self-cleaning systems. One of these systems is based on a so-called fire-tube boiler (flue gases flow through pipes/tubes that are bundled in a large vessel filled with water under pressure), producing typically steam between 20-30 bar and 200-250 °C or higher, depending on the flue gas inlet temperature [9], and required steam pressure. Other systems are used as well even for flue gas inlet temperatures above 1200 °C. Such systems provide steam that can be used for several purposes:

a. Preheating cullet [9];
b. Wetting the raw material batch with high temperature humidity to avoid soda clogging below 35.4 °C;
c. Steam to drive turbines that may produce cooling air or pressurized air for the forming machines (e.g. IS machines);
d. Steam to drive turbines connected to an electricity generator, making own power;
e. Steam for heating of buildings;
f. Process steam for other process steps in a glass factory, e.g. preheating of fuel oil;
g. Steam for neighbouring companies, often the transport of heat (in form of steam) requires insulated ducts and investment costs may be high.

   Steam may also be supplied to municipalities. However, the supply of this heat/steam cannot be guaranteed in all cases for instance during flue gas system or glass furnace maintenance.

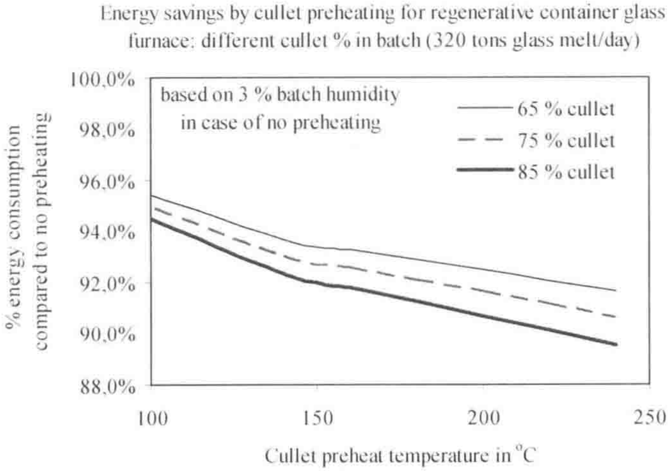

Figure 3 Energy savings for regenerative container glass furnace by cullet preheating at different temperature levels (heating medium: steam)

In most cases option 1 and sub-options a-g depend very strongly on economic and ROI (return on investment) considerations. Especially options 1c – 1d may face high investment costs and longer time periods for their Return On Investment, but at the end these methods may be cost-effective on the longer term. Electricity generated from steam can directly be used for oxygen generation or for electric boosting or be supplied to the electricity grid. Examples are shown in the German glass industry.

Self cleaning Steam boiler vessel

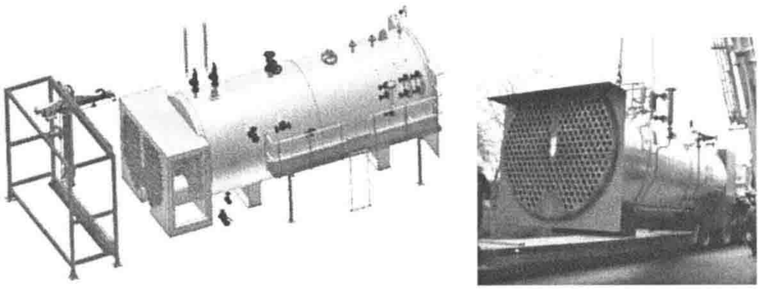

Figure 4 Waste heat boiler for steam generation using glass furnace flue gases as supplied by OPTIMUM [9].

The application of steam for cullet drying and preheating has been discussed in [9]. Steam can be applied to preheat cullet up to 200-220 °C. For furnaces using 75 % cullet in the batch energy savings of 8-10% seem possible for air-fired regenerative (see figure 3) and even ±10-12 % for oxygen fired furnaces (with additionally 10-12 % oxygen savings).
Although, the technology of steam production from flue gas heat from glass furnaces is a mature technique and fouling plus corrosion problems can be handled and minimized, demand for steam is not always present or steam distribution over longer distances may be too expensive. For flue gas temperatures of 500 °C, about 50-60 % of the sensible energy of the flue gases (reference temperature is 0 °C) can be converted in the energy contents of the steam. In case of 1000 °C flue gas temperature inlet, (oxygen-fired glass furnace situation), the steam generation can be more efficient, 70-80 % of the sensible heat can be recovered. Figure 4 shows a steam boiler, with tubes heated by flue gases flowing through these tubes. This combination of a special designed fire tube boiler with an in-line cleaning system has been successfully applied in multiple float and container glass plants.

Batch and cullet preheating

The preheating of batch with more than 50-60% cullet, is considered as a mature technology in the glass industry and exploited since the mid 1980-ties, especially in the container glass industry in Germany. In case of complete batch (including cullet) preheating, typically at temperatures of 250-325 °C, the energy savings on a fossil-fuel fired glass furnace are in the range between 12-18 % (or sometimes more in connection with increased melting capacity). Highest energy cost savings can be achieved by increasing the pull on a furnace when preheating batch without increasing fuel input or by keeping constant pull and fuel input but lowering electric boosting. Probably the pull can be increased by 18 to 20 % if batch and cullet would be preheated to 290 °C (reference: batch and cullet at room temperature with 3 % moisture).

Despite the high capital costs, pay-back times low 2-3 years are reported, of course strongly determined by energy prices. Today lifetimes up to 20 years are expected for batch-cullet preheating systems [1-5]. The batch preheat temperature is very important for the energy consumption of the glass furnace. In case of high batch humidity and for instance cullet with high water content, the preheat temperatures are limited due to the evaporation heat required to evaporate the water.
One of the most important aspects of concern is charging a completely dry preheated batch into a glass furnace. This, may lead to dusting in the doghouse area but can also increase batch carry-over into the flue gases. Special doghouse designs are in development to avoid dusting problems in the charging area and limit the dust release from the batch blanket when entering the melting furnace [10].
There are direct contact preheaters [1, 5] (direct contact between flue gas and batch/cullet) and in-direct preheaters [2, 3, 4] on the market. The direct contact preheaters offer the possibility to act as a scrubber device: raw materials in the batch absorb acid species (SO_2, SO_3, HF, HCl, SeO_2) from the flue gases. But direct preheaters often show high dust loads in the flue gases downstream the preheater system. This asks for a high efficient filtering (ESP or bag filter) system.