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Welcome to the 80th Conference on Glass Problems (GPC), an essential forum for the exchange of ideas and a reliable meeting place for the glass manufacturing industry. We have designed the GPC to provide maximum value in support of your professional goals.

The leading trade association bridging glass segments, the Glass Manufacturing Industry Council (GMIC), in partnership with Alfred University, the leading American glass teaching and research institution, co-organize the conference, with programming direction provided by an active industry advisory board.

GPC technical sessions address manufacturing issues, citing real world data from manufacturers and solutions providers. Additional value-rich resources are available, such as our two short courses on Refractories and on Fundamentals of Batch and Furnace Operations. The GMIC organized technical symposium, Sustainability in Glass Manufacturing, is presented as a full day session, which allows us to offer a deep dive into the topic. The GPC is a technical conference, and the proceedings manuscripts are made available to attendees and for publication.

Nearly as valuable as what is learned in our technical sessions is, what is perhaps the best opportunity for glass manufacturing industry networking and exhibiting in North America, where leading solutions providers come together with all segments of glass manufacturers at our social events, booth exhibits, hospitality salons and booths.

We are grateful for the sponsors who support the conference, for the time and effort of the conference organizers, and for you, the glass manufacturing industry professionals for which this conference is dedicated. We trust you will find the 80th Conference on Glass Problems a valuable and rewarding experience.
WHO IS GMIC
The Glass Manufacturing Industry Council (GMIC) is a trade association founded and funded by the glass industry to create opportunities to advance competitiveness and profitability across all manufacturing segments. GMIC includes among its members, representatives of container, fiber, flat, and specialty glass companies, as well as leading suppliers to the industry, research institutes, and industry experts. GMIC provides beneficial services to companies, including enhancing companies’ business development and technical development, providing technical education, coordinating technical initiatives, providing industry intelligence, workforce development, and promoting the usage and image of glass products.

If you are a glass industry manufacturer, supplier, or research organization, and you are not presently a member, we encourage you to join GMIC now, as an effective means to further your strategic goals in the industry. Contact GMIC’s Executive Director, Bob Lipetz, for full information.

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GMIC MISSION
Facilitate, organize, and promote the interests economic growth and sustainability of the glass industry through education and cooperation in the areas of technology and the environment.

ALFRED UNIVERSITY
The Kazuo Inamori School of Engineering at Alfred University (AU) is a leader in glass and ceramic education. Established in 1900 as the New York State School of Clayworking, the School has a long-standing history of providing industry a workforce well-educated in the manufacturing of glass and ceramic materials. Today, the School offers BS and MS degrees in five disciplines: Biomaterials Engineering, Ceramic Engineering, Glass Engineering Science, General Materials Science and Engineering, and Mechanical Engineering as well as doctoral degrees in the materials disciplines.

The School also serves industry by advancing the forefront of ceramics and glass research. In addition to maintaining an active portfolio of federally funded research, the faculty routinely collaborate with industry or projects ranging from fundamental research through product/process development. Interactions with industry are conducted through the Center for Advanced Ceramic Technology (CACT) and the Center for High Temperature Characterization (CHTC). The CACT facilitates collaboration between industry and academia with the goal of creating economic impact for the CACT’s industrial partners. The CHTC is a user facility that provides researchers unparalleled access to equipment designed for characterizing materials in situ at high temperatures.

More information about the Inamori School of Engineering: http://engineering.alfred.edu

Alastair Cormack, Professor Ceramic Engineering, Inamori School of Engineering, Alfred University

S.K. Sundaram, Inamori Professor of Materials Science and Engineering, Alfred University

SAVE THE DATE
The 81st Conference on Glass Problems October 26–29, 2020 | Columbus, Ohio
The Exhibit and Technical Sessions will take place at the Greater Columbus Convention Center. The Hospitality Suites will be located across the street at the Hilton Columbus Downtown.

PUBLICATION OF THE 80TH GPC PROCEEDINGS
Following the 80th Conference on Glass Problems, attendees will be emailed instructions with a link on how to download the 80th GPC proceedings.

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PROGRAM SCHEDULE

SUNDAY, OCTOBER 27, 2019
6 p.m.  GPC ADVISORY BOARD DINNER

MONDAY, OCTOBER 28, 2019
12 – 4:30 p.m.  STUDENT PLANT TOUR – OWENS CORNING NEWARK

SHORT COURSES
Columbus Hilton Downtown Hotel

FUNDAMENTALS OF BATCH AND FURNACE OPERATIONS
Monday, October 28, 2019  | Noon – 5 p.m.
Instructor: C. Philip Ross, President, Glass Industry Consulting International (GICI)
The course is an introduction to the principles of commercial glass production employed in Batch & Furnace operations by US Glass producers. Raw Materials, Glass Technology & Properties, Melting Furnaces, and Environmental Issues will all be touched upon. Suggested attendees could be vendors or newer individuals to glass manufacturing seeking an introduction to the issues faced in glass production.

REFRACTORIES
Monday, October 28, 2019  | Noon – 5 p.m.
Instructor: Michel Gaubil, PhD, Director of Refractory Solutions Engineering, SEFPRO
This training session will focused on process and product (both fused cast and sintered) for soda lime glass furnace (containers and flat glass). After presenting the main process characteristics, we will describe product family, properties and their application inside glass furnace. We will also discuss the challenges for regenerators refractory material in term of thermal performances and corrosion.
The training session will be divided in 3 parts:
– Fused cast process and product for soda lime application
– Sintered process and product for soda lime application
– Refractory solution for glass furnace regenerators

TUESDAY, OCTOBER 29, 2019
8 – 8:45 a.m.  EXHIBITING
8:45 – 9 a.m.  OPENING REMARKS: PLENARY SESSION
– Bob Lipetz, MBA, Conference Director, Glass Manufacturing Industry Council
– S. K. Sundaram, PhD, Program Director, Alfred University

9 – 10:30 a.m.  TECHNICAL SESSION: PLENARY
Session Chairs: Bob Lipetz, MBA, Conference Director, Glass Manufacturing Industry Council and S. K. Sundaram, PhD, Program Director, Alfred University
9 — 9:30 a.m.  Chandra Mangalagiri, Vice President Global Engineering, Libbey, Inc. – Glass Industry Today: Challenges & Opportunities
9:30 — 10:30 a.m.  Ludovic Valette, Vice-President, Global R&D, Owens-Illinois – The Need for Innovation in the Glass Container Industry
10:30 – 11 a.m.  BREAK & EXHIBITING
11 – 12:30 p.m.  TECHNICAL SESSION: PLENARY
Session Chairs: Bob Lipetz, MBA, Conference Director, Glass Manufacturing Industry Council and S. K. Sundaram, PhD, Program Director, Alfred University
11 – 11:30 a.m.  Hisashi Kobayashi, PhD, Senior Corporate Fellow, Praxair, Inc. – Future of Oxy-Fuel Glass Melting: Oxygen Production, Energy Efficiency, Emissions and CO₂ Neutral Glass Melting
11:30 a.m. – 12 p.m.  Ashtosh Ganjoo, Research Associate, Vitro Architectural Glass – Glass and Coated Glass for Solar Energy
12 – 12:30 p.m.  Nisha Sheth, PhD, Research Engineer, Vitro Architectural Glass – The Peculiar Wear Behavior of Soda Lime Silicate Glass and Its Implications
12:30 – 2 p.m.  LUNCH
12:30 – 2 p.m.  EXHIBITING
2 – 4:30 p.m.  TECHNICAL SESSION: MELTING AND COMBUSTION
Session Chairs: Uyi Iyoha, PhD, Associate Director Business Development, Praxair, Inc.; Jan Schep, Global Furnace Design Discipline Leader, Owens-Illinois, Inc.; and Justin Wang, Senior Process Engineer, Guardian Industries
2 – 2:30 p.m.  Jim Uhlík, Vice President of Technical Services, Toledo Engineering Company, Inc. – A Glass Problem Solved
2:30 – 3 p.m.  Marc Bernard, General Manager & Owner, Bernard Bonnefond and Alain Dupuy, Manager Bernard Bonnefond US Subsidiary – Electric Power Adjustment in Glass Furnaces with VariVolt Transformer
3 – 3:30 p.m.  Michael Gallagher, PhD, Sr. Principal Research Engineer, Air Products & Chemicals, Inc. – Synchronized Oxy-fuel Boost Burners for Zero-Port Performance Optimization in Float Glass Melting Furnaces
3:30 – 4 p.m. Wolf Kuhn, PhD, Senior Process Development Expert, Fives Stein Limited by Fives in Glass – Electric Boosting in Hybrid Furnaces (Practical Application and Limitations of Higher Levels of Electric Heat Input)

4 – 4:30 p.m. Erik Muijsenberg, H. P. H., Vice President, Glass Service, Inc. – Carbon Reduction with Super Boosting and Advanced Energy Management

4:30 – 5:30 p.m. EXHIBITING

5:30 – 7:30 p.m. FREE TIME

7:30 – 11 p.m. HOSPITALITY SUITES

WEDNESDAY, OCTOBER 30, 2019

8 – 9 a.m. EXHIBITING

9 – 10:30 a.m. TECHNICAL SESSION: BATCH, ENVIRONMENTAL, AND MODELING

Session Chairs: Phil Tucker, Principal Materials Engineer, Johns Manville and Chris Tournour, Senior Glass Process Engineer, Corning Inc.

9 – 9:30 a.m. Roger Barnum, Director, Jenike & Johanson, Inc. – Designing Furnace Feed Systems That Work

9:30 – 10 a.m. Jonathan Blevins, CFD Engineer, TECO – Case Study – CFD Solves Float Furnace Bottom Hotspot Problem

10 – 10:30 a.m. Ruediger Margraf, Managing Director, LUEHR FILTER GmbH – Bag Filter & Catalyst (SCR) - Does this Fit Together?

10:30 – 11 a.m. Brian J. Naveken, Furnace Design Engineer, TECO – Cullet – Another Step Towards Glass Sustainability

11 – 11:30 a.m. EXHIBITING

11:30 a.m. – 12:30 p.m. TECHNICAL SESSION: REFRACATORIES

Session Chairs: Larry McCloskey, Consultant, Anchor Hocking and Eric Dirlam, Director of Furnaces, Ardagh Group


Noon – 12:30 p.m. Rolf Weigand, PhD, Executive Director, Ancororo GmbH – Optimizations and Energy Savings Especially in Container Glass Production by Using a Refractory Coating

12:30 – 2 p.m. LUNCH

12:30 – 2 p.m. EXHIBITING

THURSDAY, OCTOBER 31, 2019

8 a.m. – 4 p.m. GMIC SYMPOSIUM Sustainability in Glass Manufacturing

IN MEMORY OF MARK POWYS
DESCRIPTION: Sustainability has many definitions, typically with at least three main aspects, Environmental, Economic, and Social/Cultural. This symposium will concentrate on sustainable glass manufacturing, defining “sustainable” as: Available Batch Materials, Energy, Affordable Business Economics, Compatible with Process, and Safe for the environment, for manufacturing, and for the use of the products.

SESSIONS: The Sustainability in Glass Manufacturing symposium will have four sessions, Environment, Energy, Technology, and Process.


OBJECTIVES: The participants should come away from the symposium with knowledge of the current state of glass manufacturing technology and both the ongoing and anticipated developmental efforts to improve the sustainability of glass manufacturing.

SYMPOSIUM DIRECTOR: Bob Lipetz, MBA - Executive Director, Glass Manufacturing Industry Council


PROGRAM COMMITTEE
- Sutapa Bhaduri, Technology Strategist and Sustainability Global Leader, O-I
- Scott Cooper, Glass and Materials Science Group Leader – R&D, O-I
- Rod Gravley, Technology Director, CCS Systems – Tri-Mer Corporation
- Aaron Huber, Senior Manager, Furnace Research Group, Process Technology – Johns Manville
- Patrick Jackson, Director, Global Energy Management – Corning, Incorporated
- Mikael Le Guern, Business Development Manager, Schneider-Electric
- Erik Muijsenberg, Vice President – Glass Service, Inc.
- Glenn Neff, Vice President – Glass Service USA
- Nassreen Olang, R&D Leader, Corporate Product Stewardship Leader – Owens Corning
- C. Philip Ross, President - Glass Industry Consulting International
- Adam Tomaino, Senior Engineer/Refractory Materials and Float Glass Production – Vitro Architectural Glass
- Jeff Yigdall, Chief Technology Officer – Green City Glass

SYMPOSIUM SCHEDULE:
8 – 8:15 a.m.  WELCOME – Bob Lipetz, Glass Manufacturing Industry Council and Brian J. Naveken, TECO

8:15 – 9:45 a.m.  SESSION I – ENVIRONMENTAL
8:15 – 8:40 a.m.  Emissions Considerations & Technologies Overview – C. Phil Ross, Program Chair
8:40 – 8:45 a.m.  Q&A
8:45 – 9:10 a.m.  Towards CO2 Neutral Glass – Production - Andries Habraken, Project Manager - Celsian
9:10 – 9:15 a.m.  Q&A
9:15 – 9:40 a.m.  Science Based Targets – John Sottong, Senior Associate - World Resources Institute
9:40 – 9:45 a.m.  Q&A
9:45 – 10:15 a.m.  BREAK

10:15 – 11:40 a.m.  SESSION II – ENERGY
10:15 – 10:40 a.m.  Waste Heat Extraction, Risks and Rewards – Aléssandro Monteforte – Tri-Mer Corporation
10:40 – 10:45 a.m.  Q&A
10:45 – 11:10 a.m.  Extracted Heat Utilization, Rewards – Gary Snedaker, Renewable and Conventional Power Generation Solutions – Powerthermix and Rod Gravley, Technology Director, Tri-Mer Corporation
11:10 – 11:15 a.m.  Q&A
11:15 – 11:40 a.m.  Energy Reduction Success Stories from Other Industries – Bruce Bremer, President, Bremer Energy Consulting Services

11:40 a.m. – 12:40 p.m.  LUNCH

GMIC PLANT TOUR GRANTS
GMIC is now accepting applications from higher education institutions for GMIC’s new grant program supporting student tours of glass manufacturing facilities. Deadline to apply for 2020 grants is November 4. Information at gmic.org/grants/.
12:40 – 3:10 p.m.  
**SESSION III – TECHNOLOGY**  
Adam Tomaino, Program Chair  

12:40 – 1:05 p.m.  
*Economic and Sustainability Considerations of All Electric and Hybrid Glass Melters* – Erik Muijsenberg, Glass Service, Inc.  

1:05 – 1:10 p.m.  
Q&A  

1:10 – 1:35 p.m.  
*All Electric Melting* – Rene Meuleman, Global Glass Industry Technical Lead - Schneider Electric  

1:35 – 1:40 p.m.  
Q&A  

1:40 – 2:05 p.m  
*Future of Hybrid Melting Furnaces including Economics* – Edward Ferreira, Furnace Design Engineer, TECO  

2:05 – 2:10 p.m.  
Q&A  

2:10 – 2:35 p.m.  
*All Electric Forehearts and Channels* – Brian Baker, Director Furnace Engineering, Knauf Insulation and Mark Paeplow, President – KTG Systems, Inc.  

2:35 – 2:40 p.m.  
Q&A  

2:40 – 3:10 p.m.  
BREAK  

3:10 – 4:40 p.m.  
**SESSION IV – PROCESS**  
Jeff Yigdall, Program Chair  

3:10 – 3:35 p.m.  
*Process Discipline – Aligning Production and Sustainability Goals* – Jeff Yigdall, Chief Technology Officer – Green City Glass  

3:35 – 3:40 p.m.  
Q&A  

3:40 – 4:05 p.m.  
*Four Major Levers for Contribution of Glass Industry Decarbonization* – Luc Jarry, Global Market Director, Air Liquide and Chris McCrea, Vice President Materials and Power Market – Airgas, an Air Liquide Company  

4:05 – 4:10 p.m.  
Q&A  

4:10 – 4:35 p.m.  
*Low Carbon Fuels* – Shrikar Chakarvarti, Associate Director, Business Development & Industrial Applications, R&D – Praxair, Inc.  

4:40 – 4:50 p.m.  
**CONCLUDING REMARKS**  
Brian J. Naveken, Furnace Design Engineer, TECO  

4:50 p.m.  
**SYMPOSIUM ENDS**
THE GLASS MANUFACTURING INDUSTRY COUNCIL
GLASS MANUFACTURING INDUSTRY REPORT


Comprehensive Data – Emissions Regulations Summary - Recycling
NEW! Expert Segment Analysis – NEW! Plant Lists & Contacts Spreadsheets

INDUSTRY DATA

Contained in the report are vital metrics broken out by glass manufacturing segments; float, fiber, container, and specialty glass, detailed as historical trends, industry predictions, graphs, tables, and analysis.

– Production volumes
– Revenue volumes
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– Competitive industries comparative analysis
– Operational data – COGS, margin, payroll, capital, etc.
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**Monday, October 28 | 5 – 11 p.m.**  
**Tuesday, October 29 | 7:30 – 11 p.m.**
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Phone: +0114 2634455
www.sgt.org

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Designing Furnace Feed Systems That Work

Furnace feed systems include several important components, including delivery equipment from the batch house, a day or surge bin, a feeder controlling bin discharge and a furnace charger (which may be combined or separate items), as well as optional processing units such as a wetting screw. These systems typically rely on gravity flow of the mixed batch material and given their proximity to the furnace ambient temperatures can cause hard build up in any areas that are stagnant. In addition, stagnant areas tend to accumulate one or more batch ingredients preferentially due to segregation, which can give rise to variations over time as the material is recovered. As a result of these aspects, the flow performance of the system is of considerable interest. Physical properties of the mixed batch, including cohesive strength and wall friction, characterize flow behaviors, and hence should be used as a basis for design. Hopper features such as shape, angles, outlet size, materials of construction and surface finish can be specified to achieve the desired outcome. Mass flow is when flow occurs along the hopper walls and is the preferred discharge pattern for these applications since it greatly reduces the potential for a range of problems. Wear resistant materials can be utilized in the construction of the equipment to prolong its life. Geometric and operational details of the feeder downstream of the bin can have a strong influence on its flow behavior, and hence need to be factored into the overall design. This paper will describe the design process in detail, including the typical links between lab test results and feature determination. Examples will be provided, showing problematic and successful arrangements in comparison.

Mark Bennett, Glass Sector Lead, AMETEK Land | Neil Simpson, Consultant, Simpson Combustion & Energy Ltd | S. Fiona Turner, Physics Section Manager, AMETEK Land | John Naughton, Technical Director, Allied Glass Containers Ltd.

Not Just A Pretty Picture – In-Furnace Thermal Imaging

The development of AMETEK Land’s in-furnace thermal imaging borescope, NIR-B Glass, has taken the glass industry from manual single temperature measurements at minimum 20-minute intervals to 325,000 continuous automatic temperature measurements. Initially developed as a fixed continuously operating thermal imager on a furnace, it is now being installed temporarily in peep sites and used for furnace thermal surveys. By installing the NIR-B Glass in existing peep sites it is possible to look at most of the internal furnace superstructure. An instantaneous thermal image during a non-firing reversal is sufficient to identify several problems with the refractory which may not be obvious by optical inspection alone. In soda lime applications the ability to identify areas of silica refractory temperature below 1388°C shows where NaOH can condense. A refractory temperature below 1000°C would suggest a hole! By using the NIR-B Glass small ratholes have been identified as part of thermal survey prior to being visible. Whilst the preceding is a focus on furnace asset protection there are clear additional benefits from an NIR-B Glass thermal survey for plant and personnel safety, staff training, validation of CFD models and general troubleshooting for quality and/or combustion.

Roger Barnum, Director, Jenike & Johanson, Inc. | Scott Clement, Senior Project Engineer, Jenike & Johanson, Inc.

Electric Power Adjustment in Glass Furnaces with Varivolt Transformers

Use of electric power increases in glass melting. There are several technologies available to adjust electric power delivery in glass melters: off-load or on-load transformers, SCR (Silicon Carbide Rectifiers) or IVR (Induction voltage regulators) and VARIVOLT. BERNARD BONNEFOND founded in 1925 in France is the only manufacturer of VARIVOLT in the world. Since 1968, more than 1700 VARIVOLT have been delivered, and more than 1300 are used in glass industry. Every year BERNARD BONNEFOND manufactures between 70 and 90 VARIVOLT, of which 80% are sold to glass producers and glass engineering companies.

As an electromechanical device based on transformer technology the VARIVOLT main advantages are: stepless variation of delivered power through stepless control of the secondary voltage, high efficiency, high power factor and long lifetime. The limitations of these advantages however is a slower power adjustment time which may not be adequate on some special applications requesting very frequent power adjustments or/and very short reaction time.

This is the reason why BERNARD BONNEFOND developed some new options to allow for more frequent power variations and drastically reduce the reaction time of the VARIVOLT through:

- Frequency drive on motor
- Addition of Variable Reactor on the secondary side

Frequency drive allows using full speed of the variation when the voltage is far from the set point and low speed when approaching. This solution can easily be implemented on existing or new installations. Variable reactor, designed for 5 to 10% of the maximum voltage, installed in series with the VARIVOLT allows making a Vernier regulation around the set point without consequences on the VARIVOLT itself. The advantages of the VARIVOLT remain. The number of changes on the VARIVOLT is not impacted. The power or current regulation is immediate. This variable reactor can be added on existing system and can be by-passed easily.

CONCLUSIONS:

Although VARIVOLT power adjustment is suited for all type of glasses processed in the glass industry (E glass, Composite fibers, container glass etc...) BERNARD BONNEFOND can propose technical solutions to improve power adjustment frequency and reaction time on existing or new VARIVOLT UNITS on.

Marc Bernard, General Manager, Bernard Bonnefond | Alain Dupuy, General Manager, Variable Voltage | Mehdi Zmirli, Research & Development, Bernard Bonnefond
**Application of Advanced Sensors in the Glass Industry**

The availability of advanced sensors, next to thermocouples, in industrial glass melting furnaces is a prerequisite for further automation in the glass manufacturing industry. These advanced sensors should provide real time, quantitative information about the quality of the glass melt, the position and thickness of the batch and foam layers, the key parameters of the combustion process, the energy flows in the furnace and the status/integrity of the furnace lining (refractories and insulation). In this presentation a survey will be given of available measuring techniques, like in-line chemical analysis of raw materials, redox sensors of the glass melt, laser sensors for combustion gases and batch monitoring cameras. Next, the needs for the development of new, reliable sensors will be discussed.

Jonathan Blevins, CFD Engineer, TECO | Andries Habraken, Team Leader Process Optimization, CelSian

**CFD Solves Float Furnace Bottom Hotspot Problem**

During the latter stages of one of Cardinal’s furnace campaigns, two areas of significant bottom wear were being managed by water sprays. The true extent of the problem was discovered at shutdown inspection. At the two given locations, the paving had eroded, and the glass had penetrated into the flux. TECO was commissioned to look into the driving force for the high wear and to find a solution. CFD was used for the study. The numerical model showed that the combination of the glass flows, and glass depth resulted in higher bottom refractory temperatures that accelerated wear, confirming what was seen. Parametric studies on cooler design as a short-term solution and refiner glass depth as a long-term solution were carried out. Bottom temperatures, glass velocities and glass quality indices were used to evaluate the results. The best cooler design was immediately implemented. The deeper refiner design was implemented at future rebuilds.

Lieve de Cock, (Ir.), Team lead Furnace Support, CelSian Glass & Solar B.V. | Anne-Jans Faber, PhD, Senior Scientist, CelSian Glass & Solar B.V.

**Glass and Coated Glass for Solar Energy**

We discuss the role of glass and coated glass in the area of solar power generation in this presentation. The evolution of the use of glass in the solar energy generation and the role of glass composition and how it enabled increased solar energy transmission, a critical factor for the use of glass in solar energy requirements, will be discussed. Anti-reflective (AR) surface treatments and resulting enhancements of solar energy transmission through the glass substrate which directly impacts the solar cell efficiency will also be discussed. The importance of transparent conductive coatings (TCO) and the advantages of highly resistive transparent (HRT) layers for thin-film photovoltaics will be given. Coated glasses as mirrors for concentrated solar power applications is also summarized along with discussions of various fundamental and manufacturing challenges for glass and coatings on glass for solar applications.


**Synchronized Oxy-fuel Boost Burners for Zero-Port Performance Optimization in Float Glass Melting Furnaces**

Zero-port oxy-fuel boost burners have become widely accepted in float glass melting furnaces as a valuable means for increasing glass production and/or improving efficiency. However, boost burner effectiveness is often limited by flame interaction with the highly turbulent air-fuel flames. Moreover, both the strength and direction of these oxy-flames versus air-fuel flame interactions are dramatically shifted following each regenerator reversal cycle. The result of these effects can include overheating of the charge wall and “snubbing” of the flame, causing concentrated heat release close to the breast wall and/or flame lofting toward the crown. By understanding the nature of these interactions, Air Products researchers have developed an advanced burner technology that is capable of automatically adjusting flame properties (particularly length, luminosity and momentum) with each regenerator reversal to avoid negative effects, while maximizing oxy-fuel performance benefits. This development combines Air Products Process Intelligence technology with the recently commercialized Cleanfire® HRx™ burner. Both the methodology and beneficial results of field implementation of synchronized oxy-fuel boost burners are presented in this paper.

Ashtosh Ganjoo, Research Associate, Vitro Architectural Glass | J.W. McCamy, Senior Scientist, Vitro Architectural Glass | Adam Polcyn, Vice President Research and Development, Vitro Architectural Glass | Zhixun Ma, Scientist, Vitro Architectural Glass | Paul Medwick, Scientist, Vitro Architectural Glass
Stability Assessment of New High Strength, High Temperature Thermocouple

Platinum-rhodium Type R and S thermocouples are extensively used as temperature sensors for measurement and control of glass manufacturing process. However, they are prone to failure at high temperatures and fail in service because of two main reasons: excessive grain growth in the platinum limb at high temperatures (causing wire breakage) and temperature drift (deviation of emf generated over time because of deposition of rhodium oxide on the platinum limb) out of accepted industry tolerances.

Finding a solution to the problem is challenging because of the contradictory requirements of strength and narrow permissible emf range: emf is extremely sensitive to any dopants or alloying elements that can be used to improve strength at high temperatures. Johnson Matthey has developed a new thermocouple wire (platinum limb) called ‘HTXTM’ by doping platinum with a small quantity of zirconium which is oxidized during processing to electrically neutral zirconia. Zirconia improves the high temperature strength of platinum wire by restricting the grain growth but does not significantly affect the emf.

The result is a wire which has the potential to last many times longer at high temperatures (>1200 °C) than standard platinum wire, whilst still achieving Class 1 tolerance (i.e. ± 1 °C at 1000 °C). It also improves the thermoelectric drift characteristics of the thermocouple by counteracting any reduction in emf due to rhodium contamination by an increase in emf as any remaining zirconium is converted to zirconia. This new development could be revolutionary as it will significantly reduce changeover costs and could lead to improved designs with built-in thermocouples.

The presentation will describe both the scientific principles and manufacturing process as well as the assessment of the long-term strength and thermoelectric stability (drift) of the product and the potential benefits of these properties for use in the glass industry. High resolution measurements of thermoelectric homogeneity throughout the life of the product will also be discussed in comparison to Type S and R standards and so will be of practical relevance to process designers and maintenance engineers aiming to improve process control and changeover costs.

Les Hutton, Technical Specialist, Johnson Matthey | Ritesh Rawal, PhD, Technical Manager, Johnson Matthey | Declan Tucker, Research Scientist, National Physical Laboratory | Jonathan Pearce, PhD, Principal Research Scientist, National Physical Laboratory

Hisashi (Sho) Kobayashi, PhD, Corporate Fellow, Praxair, Inc | Julien Pedel, Development Specialist II, Praxair, Inc | Gaurav Kulkami, Development Specialist, Combustion R&D, Praxair, Inc.


Over 300 commercial glass melting furnaces have been successfully converted to oxy-fuel firing worldwide since 1991 when the first full oxy-fuel conversion of a large container glass furnace took place. The main benefits for oxy-fuel conversion are fuel reduction, glass quality improvement, emissions reduction (CO2, NOx, SOx, particulates), and productivity improvements. Significant changes in the melting and fining behaviors were observed under oxy-fuel firing. Most furnaces required some batch modifications to optimize the glass fining chemistry. Although accelerated silica crown refractor corrosion was experienced in early conversions, improved burner and furnace designs have reduced alkali volatilization and proper crown temperature control enabled use of silica crown for full furnace campaign. The differences between and oxygen and air firing on heat transfer, glass fining and redox chemistry, alkali volatilization and refractory corrosion mechanisms have been well understood through extensive laboratory studies and mathematical modeling conducted over the last 30 years. Today most of high quality specialty glass products such as LCD display glass and fiber glass are melted in oxy-fuel fired glass furnaces. However, despite the demonstrated benefits of oxy-fuel use in glass furnaces and significant penetration of oxy-fuel in the specialty glass furnaces, only about 60 container and float glass furnaces have been converted to oxy-fuel firing, while most of large soda-lime glass furnaces are still fired with air using large regenerators to recover waste heat in the flue gas. This is primarily due to the additional cost of using oxygen.

Recent advances in oxygen production and oxy-fuel technology aim to make oxy-fuel glass melting a more cost-effective solution for making glass. For example, the efficiency of air separation technology has improved and the power consumption to produce oxygen has decreased significantly. Advanced waste heat recovery technologies for oxy-fuel fired furnaces have also been developed recently to reduce the fuel and oxygen requirement for oxy-fuel furnaces, reducing operating expense. Furthermore, with the need to reduce CO2 emissions oxy-hydrogen combustion is considered a leading option for glass melting of future. This paper reviews the evolution and advances in the oxy-fuel glass melting technology, and the future of oxy-fuel combustion for CO2 neutral glass melting.

**Electric Boosting and Hybrid Furnaces (Practical Application of Higher Levels of Electric Heat Input)**

There is growing interest in furnace designs able to operate with a wide range of electric boosting input. Such 'hybrid' solutions offer prospects of freedom to vary the ratio of energy input between gas and electric, allowing adaptation to suit changing energy costs both in the short-time and longer-term over the furnace campaign. This presentation examines challenges that arise naturally when designing such furnaces. We examine the implications of running with low combustion inputs and how this impacts the heat flux distribution, convection currents, and melting processes within a horizontal melting tank. We consider also potential problems relating to managing low waste gas volume and operating at low and variable crown temperatures. We propose that some of the factors discussed will, depending on production and glass type, impose limits to the achievable electrical heat input and the possible reduction of combustion input. We will propose that design compromises based on either the classical U flame or unit-melter design may not always be the best solution in terms of cost of ownership, and we will present alternative design concepts that address the identified issues giving a real prospect of true flexibility.

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Chandra Mangalagiri, Vice President Global Engineering, Libbey, Inc.

**Abstract not submitted by presenter**

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Ruediger Margraf, Managing Partner, Luehr | Daniel Gross, Sales Manager - Air Pollution Control

**Filter Fabric Filter & Catalyst (SCR) - Does this fit together?**

Bag filter and catalyst (SCR) – does this fit together? Operators of glass tanks in the USA as well as in Europe come more and more face to face with stricter requirements concerning air pollution control. Beside intensified emission limit values for particulate matter, including PM10 and PM2.5, heavy metals and acid crude gas components such as HF, HCl and SOx, this increasingly concerns as well the requirement of NOx reduction. To meet this challenge, a new process was developed on the market in Europe, dealing with a combination of bag filter and SCR. In comparison with other competing technologies, the combination of bag filter with SCR shows advantageous features: • extremely high efficiency regarding the separation of heavy metals and particulate matter; • a re-heating of gas downstream of filter for achieving the optimum catalyst temperature in the range of 540 F is realized without additional energy input by means of reliable heat recycling around filter; • by comparison low investment- and operating costs; • free selection of additive powder quality - Ca(OH)2, NaHCO3 or Trona. This allows in many cases the re-circulation of product separated in the filter into the mixture, landflling is not required; • avoidance of particle deposits inside of catalyst and poisoning of surface due to high-efficient separation of all compounds in the bag filter; • individual adjustment of catalyst volume to the requirements of application. The lecture presents the overall process concept as well as design features of equipment. The advantages of process are underlined by means of operational examples / references.

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Erik Muijsenberg, H.P.H, Vice President, Glass Service USA | Glenn Neff, Vice President | Glass Service USA

**Carbon Reduction with Super Boosting and Advanced Energy Management**

The share and use of electric melting are today steadily growing again. This is not new, as some decennia's ago it already was quite popular. The first furnace that used electric current was built in 1905 following Sauvageon's design was melting glass for window glass production. Since that time many different designs were tried. In more recent decennia's electric melting became less popular due to low price and wide availability of fossil fuels. Just in recent years with the fear of Global Warming and plans for CO2 reduction the interest in full or partial (Hybrid) electric melting is getting more attention again. The generation of electricity by alternative energy sources is of course a great help here as it brings costs of Electricity finally down and will be CO2 free. In Europe the average generation of electricity is already in range of 38% by renewable resources such as wind, solar hydro and bio. The question for the future is not if we will have more electric energy usage for glass melting, but if the future will be All Electric Melting (AEM) or hybrid that means a balance between using more Bio fuels some amount of fossil fuels and large amount of electric melting step by step to reduce our CO2 footprint. The paper will show some examples of the past & present and some ideas for the future strongly supported with mathematical modeling of new furnace designs and the use of advanced furnace control.

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Brian J. Naveken, Furnace Design Engineer, TECO | Christopher J. Hoyle, Sr. VP, Technical Director, TECO | Kevin L. Fulkerson, VP of Technology, TECO

**Cullet - Another Step Towards Glass Sustainability**

As the pressure to improve energy efficiency and reduce greenhouse gas emissions rises, the use of cullet, especially post-consumer cullet, will become more prevalent. Cullet can replace traditional raw materials in the batch recipe bringing both opportunities and challenges to the glass manufacturer. The formation of glass from traditional raw material is a complex physical and chemical process; glass furnaces are truly chemical reactors. Successfully increasing cullet use requires an understanding of these processes and the effective changes. This paper will explore the effects of increased cullet use and attempt to qualify and quantify the aspects of increased cullet usage.
Paulus Schreuders, CEO, XPAR Vision B.V.

**A New World of Glass Making!**

The container glass industry can do 25% better, resulting in glass becoming more competitive and sustainable. Lighter and stronger containers produced with (almost) zero defects at higher speed with minimum human dependency will be the result.

The paper is about development and application of hot end sensors and robotics. A path forward for a new world of glass making will be proposed; integration of data, creating smart intelligence, closed loop automation and use of robotics are building blocks of the glass forming process in the next decade.

The paper includes arguments for this path forward as well as a step by step approach for any container glass producer to be successful.

With regards to the use of robotics swabbing will be addressed specifically. Swabbing the molds has a great negative impact on the glass quality, is labor intensive and a cause for many defects and section blocks. It will be outlined that with a new lubricant and the use of a special robot the traditional swabbing will be changed removing all negative aspects of mold swabbing.

Besides many advantages the immediate significant economic importance in preform lubrication is that lubrication intervals can be extended by a factor of 5-10 (from one time per 20 minutes to one time per 3 hours), allowing the robot to execute other functions as well.

Interestingly application of this new method of lubrication makes the effect of sensors including closed loop automation and the use of robotics even bigger.

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Nisha Sheth, PhD, Research Engineer, Vitro Architectural Glass

**The Peculiar Wear Behavior of Soda Lime Silicate Glass and Its Implications**

The low usable strength of silicate glass is a major limitation for many glass products. Manufacturers often perform chemical or thermal strengthening treatments to increase the fracture strength of their glasses. Such treatments, however, also influence the resistance of the glass to wear, scratches, and other shear-induced damage. Previous works using ball-on-flat tribometer showed peculiar wear behavior of silicate glasses as a function of humidity. While in dry conditions, harder material typically abrade softer materials resulting in material loss, at high humidity conditions, adhesion of the wear debris from the glass substrate to the counter surfaces was observed. At these high-humidity conditions, glass composition and surface conditions were also found to dramatically influence the wear depth and the adhesion of the debris from the glass surface to the counter-surface.

In this work, the effects of glass composition, surface treatments, strengthening treatments, and counter-surface materials on the wear resistance of glasses is discussed. A surface-sensitive characterization protocol (x-ray photoelectron spectroscopy, IR spectroscopy, sum frequency generation) was used to probe changes in in the surface structure of the glass, incorporation of hydrous species into the glass structure, and the hydrogen bonding interactions of the adsorbed water layer. The effects of surface and strengthening treatments on the crack initiation, crack propagation, fracture, hardness, of glasses were also investigated. Finally, this work attempts to discuss several hypotheses as to what governs wear resistance for silicate glasses.

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Jim Uhl, Vice President of Technical Services, Toledo Engineering Company (TECO)

**A Glass Problem Solved**

This paper will discuss the resolution of a glass melting problem that caused months of lost production at a float glass plant. Significant reduction in pack yield was experienced for several months due to a degradation of quality from an intermittent melting problem. After efforts by the plant, then outside consultants, were made to find and resolve the problem, TECO was asked to quickly respond as an added resource to find the solution. This point of this paper will be to illustrate the various tools available used to troubleshoot the problem, and how, in this age of Factory 4.0, there remains the need to ‘place hands upon the sick’ to heal them (well, it...).

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Ludovic Vallette, Vice President, Global R&D, Owens-Illinois

**The Need for Innovation in the Glass Container Industry**

The food and beverage packaging industry are evolving rapidly and there is a noticeable renewed interest for glass packaging. After years of decline, 2016 was an inflection point. The glass packaging industry is growing again, at the same pace or even faster than other packaging materials in certain market segments or geographies such as Western Europe. Key influencers are getting more vocal to force the entire value chain to evolve – from consumers to brand owners to retailers to government, NGOs, and media. They shape clear market trends such as sustainability and the heightened awareness of environmentally friendly packaging; health and wellness and the preservation of taste and integrity of food and beverage; and premiumization and the new perception of value redefined through customization and differentiation.

The convergence of these forces combined with the fast pace of the market evolution requires the industry to reimagine glassmaking and the traditional glass packaging offering. We must enable ambidextrous innovation, e.g. developing an adequate balance between incremental improvement and radical innovation. Historically, the glass packaging industry has been effective in the field of continuous improvement, aiming at improving the structural context, being focused on issues with strong operational relevance, and exploiting well-known concepts and methodologies. This is a common characteristic for mature markets or technologies. Greater productivity efficiency, better process control, and incremental cost improvement are major opportunities for continuous improvement. However, it is important for the glass packaging industry to also invest in R&D and innovation that have a strong strategic importance. The exploration of breakthrough ideas and disruptive technologies requires a different culture and talents with complementary skills. Such an organization must embrace flexibility and drive for change while being generally more autonomous and comfortable with the experimental approach.

Several examples will be presented to illustrate the need for innovation in the glass industry and to propose potentially disruptive options.

- The push from consumers and governments for sustainable packaging solutions. This market driver should be addressed at two
different levels: (i) demonstrate that glass containers are the preferred choice for cradle-to-grave waste management, including the development and use of high-quality, cost-effective sources of cullet; and (ii) develop and improve furnace design with high energy efficiency and low emissions such as oxy-fuel combustion technology or hybrid electricity boosting.

- The emergence of digital solutions. Recent progress in direct-to-glass digital printing will lead to agile technologies that could address the need for late stage differentiation in craft markets and/or that could strengthen glass competitiveness by delivering affordable customization for mass segments.

- Reinventing glass containers production to address current operational constraints. When compared to alternative substrates such as PET or aluminum, the glass packaging industry is typically characterized by its high capital intensity, low scalability, slow speed-to-market for new capacity, and limited production flexibility. The development of more standardized and modular assets with greater operational flexibility would enable glass to be better positioned for growth and expansion.

Pierrick Vespa, Ing / R&D SEFPRO, Saint-Gobain SEFPRO | Michel Gaubil, Dr-Ing / Director Refractory Solutions

New Tuckstone Refractory Solution for Long Life Glass Furnace Superstructure

Tuckstones are the first superstructure parts in glass furnaces: the whole superstructure stability relies partly on their performances. A block rupture at an early stage of the furnace lifetime can be a critical issue (superstructure destabilization, tank block corrosion increase etc.) and generally requires high maintenance costs induced by hot repair processes.

Stresses undergone by these parts during glass furnace operation will be assessed thanks to experimental measurements, post-mortem analyses and endoscopic observations. With a numerical simulation study of stress field evolution support, we will discuss design a new refractory solution for tuckstone system including suitable materials, innovative fused-cast block shapes, and a specific insulating board associated. Some evidence of new solution advantages will be eventually presented in particular through some ongoing industrial tests.

With this new improved bilayer composite solution for tuckstone application, SEFPRO can provide more stable superstructures but also slow down corrosion rate of metal lines thanks to better and longer-lasting protection from radiative thermal transfer and from corrosive rundown.

Rolf Weigand, Dr.-Ing., Anocorro GmbH | Heiko Heßenkemper, Prof. Dr.-Ing., Anocorro GmbH

Optimizations and Energy Savings Especially in Container Glass Production by Using a Refractory Coating

The glass production is a very energy intensive process. Worldwide over 135 million tons of different glass articles are produced every year. Around 50% of these tonnages are defined by container glass production. In the past a lot of strategic decisions were taken - e.g. increasing the cullet content in the glass batch - to lower the energy consumption of the container glass furnace. A problem of container glass production is the nucleation and crystallization at the orifice ring which results in production downtimes combined with increasing production costs. To understand these processes a lot of tests were done in laboratory to clarify the mechanism of nucleation and crystallization which is defined by the interaction of glass melt and refractory. So, a surface treatment technology was developed to slow down the corrosion by glass melt. These coating can used on any porous refractory type to reduce the interaction with glass melt extremely. During the laboratory tests only, homogeneous nucleation was detected by using the surface treatment technology on the refractory before glass contact. Industrial tests on different components show the same results which opens the door for a batch modification to a higher CaO content. These batch modification results in a lot of savings (e.g. raw materials and energy) and was realized in different glass plants in Europe in the past. The presentation will give an overview about the mechanism of nucleation and crystallization, the prevention by treating the refractory and the advantages for the container glass industry in combination with some results of trials on a container glass furnace. At the end of the presentation the effect of a dark coating for the silica grown concerning energy savings will be discussed and combined with some pictures of industrial application. Calculating all the technological advantages savings of up to one million dollars can be realized per year and container glass furnace, which will make the container glass production more profitable.
NIR-B GLASS

The Near Infrared Borescope (NIR-B) Glass is a short wavelength infrared borescope designed to produce high definition, live radiometric images that accurately measure temperatures inside of a glass melt furnace.

A significant improvement over traditional manual methods of furnace monitoring, NIR-B Glass continuously measures temperatures across a high-resolution image—giving real-time monitoring that ensures high product quality, helps detect furnace structural damage, and improves melt tank efficiency.

PROVEN APPLICATIONS OVER A 70 YEAR HISTORY IN THE GLASS INDUSTRY

- HIGH TEMPERATURE MEASUREMENT ACCURACY
  Enables optimum process control through enhanced thermal imaging

- SHORT WAVELENGTH SENSOR
  Low sensitivity to emissivity changes

- DEDICATED SOFTWARE
  Data points, areas of interest, automated alarms and long term data trending and system inter-connectivity (DCS, OPC)

- 24 HOUR, 7 DAY MONITORING
  Shutterless operation guarantees accurate, reliable data with no blind

- REAL TIME THERMAL DATA COMBINED WITH HIGH RESOLUTION VISUAL IMAGE
  Allows true real time batch control, flame optimisation and the opportunity to improve energy efficiency without degrading refractory lifetime

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To make glass better, put us in the mix.

Improving combustion can enable you to increase glass production, reduce fuel consumption, enhance glass quality, and reduce emissions, such as NO\textsubscript{x}, SO\textsubscript{x}, CO\textsubscript{2}, and particulates. Let Air Products’ in-house modeling and melting experts help you get there.

For more than 70 years, we’ve delivered safe oxygen solutions, from our very first oxygen enrichment applications to our continuously evolving portfolio of low-emissions Cleanfire\textsuperscript{®} oxy-fuel burners. You can count on Air Products for reliable gas supply and to help optimize your production—just like we have done for hundreds of furnaces all over the world.

Contact us to put the skills and experience of our global team to work for you. Optimal melting takes one key ingredient: Us.

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