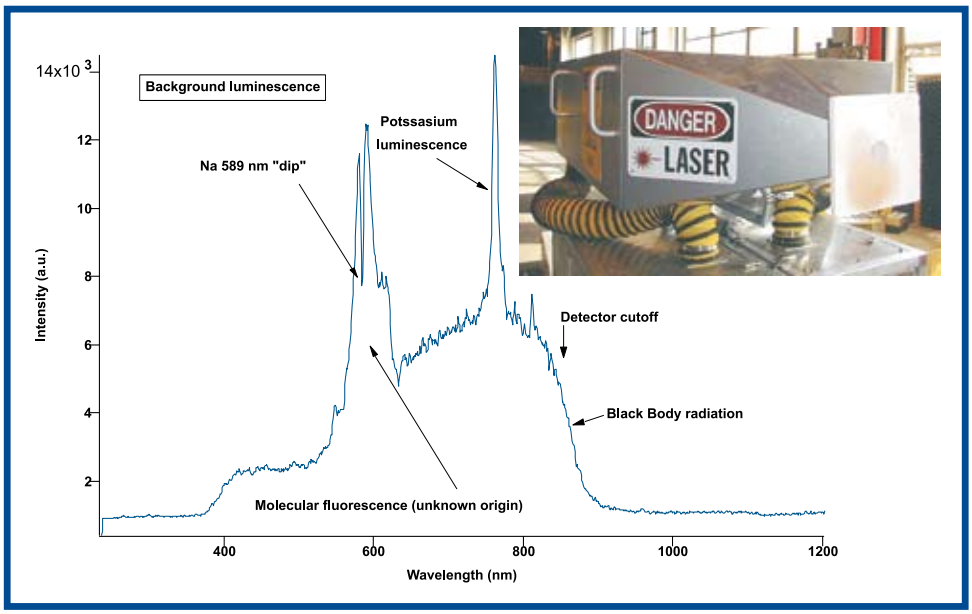
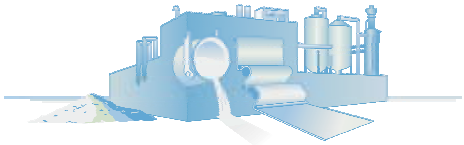
Diagnostics and Modeling of High-Temperature Corrosion of Superstructure Refractories in Oxyfuel Glass Furnaces

Extended Superstructure Refractory Life Will Enhance Oxyfuel Firing Process

Oxyfuel firing is rapidly becoming an energy-efficient and environmentally sound alternative to air combustion in the glass industry. However, because of higher temperatures and production of alkali vapors, refractories corrode significantly faster in oxyfuel furnaces; furnace crown life can be shortened by a factor of two to three. The project partners will determine corrosion factors and develop mathematical models that can predict corrosion rates, identify operating conditions that minimize corrosion, and define the attributes of improved refractories for oxyfuel firing. The researchers will also seek to develop optical techniques for monitoring gas-phase alkali concentrations in the melter headspace. Improving the oxyfuel process by extending furnace life will increase the cost-effectiveness of the process and make conversion more appealing to the glass industry.



Luminescence background looking directly into a glass furnace through a peephole (5 second exposure) along with the diagnostic tool utilized



Benefits for Our Industry and Our Nation

- Reduced production costs, since less corrosive refractories will lower the frequency of furnace rebuilds
- Reduced emissions through increased industry conversion to a more cost-effective oxyfuel process. Oxyfuel conversion can reduce NOx emissions from a typical float glass plant from over 320 kg/hr to approximately 40 kg/hr
- Improved energy efficiency and product quality by reducing defects—defects resulting from corrosion byproducts dripping onto the glass surface currently cause a 2 percent reduction in yield, and total energy loss for the entire U.S. glass industry due to defects is approximately 6 x 10^{12} Btu/yr

Applications in Our Nation's Industry

The mathematical models created can be used by process designers, material engineers, and manufacturers in all segments of the glass industry not only to optimize the oxyfuel process in existing furnaces and retrofits but also to design new ones.

Project Description

Goal: Characterize silica refractory corrosion processes in oxyfuel furnaces and use those characterizations to develop models that predict corrosion rates and define attributes of improved refractories. Increasing refractory life will further enhance the oxyfuel process.

During the experimental and diagnostic development phase of the project, the researchers will investigate the factors that contribute to the corrosion rates, particularly gas-alkali species (e.g., sodium hydroxide, potassium hydroxide), which are the most damaging compounds that attack the refractory. High concentrations of water vapor also produce increased amounts of damaging alkali. These higher concentrations of both alkali compounds and water vapor occur in oxyfuel furnaces as a result of the elimination of nitrogen from the input gases.

Once the corrosion data is gathered, mathematical models and on-line diagnostics will be developed that use the data to identify furnace conditions and/or refractory compositions that lower corrosion rates.

Progress and Milestones

- Experimental characterization of the corrosion process was completed.
- Thermodynamic property data relevant to silica and alumina corrosion was compiled and is available online at http://www.ca.sandia.gov/HiTempThermo
- Factors contributing to and controlling refractory corrosion were thoroughly analyzed
- Developed and converted corrosion model to a subroutine for incorporation in largescale furnace codes
- The subroutine was provided to Air Liquide and will be transferred to Argonne National Laboratory for use in their furnace code
- A laser-induced fragmentation fluorescence (LIFF) measurement tool was developed and used in two field tests at glass plants
- Detailed modeling discussion was published as a review article in *Glass Science and Technology;(*Robert H. Nilson, Stewart K. Griffiths, Nancy Yang, Peter M. Walsh, Mark D. Allendorf Benjamin Bugeat, Ovidiu Marin, K. E. Spear, and G. A. Pecoraro, "Analytical Models for High-Temperature Corrosion of Silica Refractories in Glass-Melting Furnaces," review article published in Glass Sci. Technol., 76 (2003), 136.)
- Results of the LIFF diagnostic testing was published in Glass Science and Technology (S. F. Rice, M. D. Allendorf "Detection of NaOH vapor in glass furnaces using excimer laser photofragmantation spectroscopy," Glass Sci. Technol. 78 (2005), 45.)
- A patent was issued for the LIFF diagnostic tool (Rice; Steven F. and Allendorf; Mark D. (Fremont, CA) "Apparatus for measuring the concentration of a species at a distance," U.S. Patent 7,027,150, issued April 11, 2006.)
- The project concluded in 2003.

Project Partners

Air Liquide
Countryside, IL

Air Products and Chemicals, Inc.
Allentown, PA

BOC Gases
Murray Hill, NJ

PPG Industries
Pittsburgh, PA

Praxair, Inc.
Tarrytown, NY

Sandia National Laboratories
Livermore, CA

Visteon Glass Systems
Dearborn, MI

For additional information, please contact

Elliott Levine
Industrial Technologies Program
Phone: (202) 586-1476
E-mail: elliott.levine@ee.doe.gov

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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