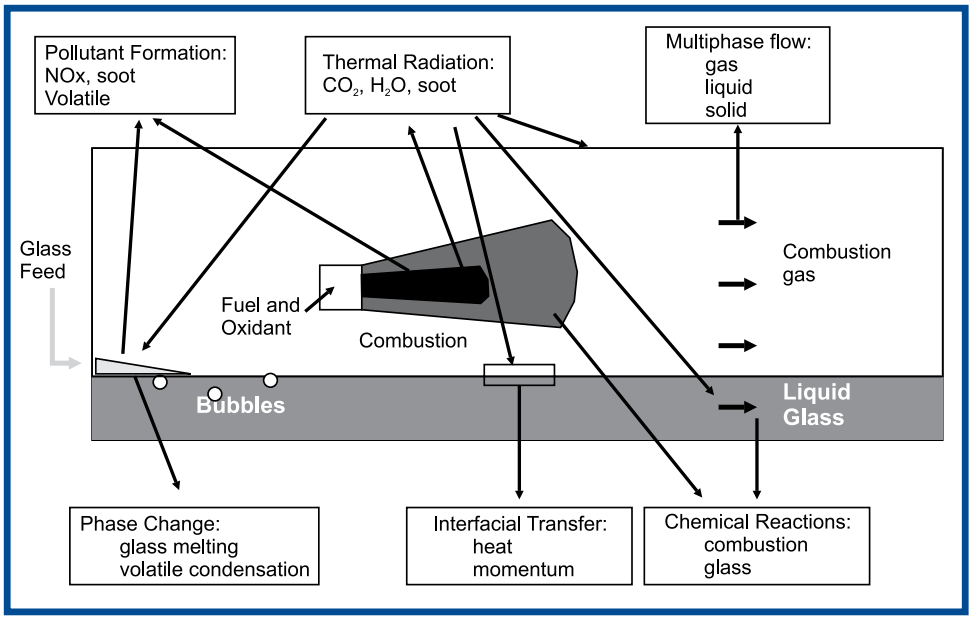
Development and Validation of a Coupled Combustion Space/Glass Bath Furnace Simulation

Glass furnace simulation model will improve energy use and efficiency while reducing emissions

Competitive and regulatory pressures are motivating glass manufacturers to seek new ways to improve productivity while reducing furnace energy use and emissions. The pursuit of these goals, however, often leads to conflicting requirements for the design and operation parameters of glass melting furnaces. To surmount these conflicting requirements, a robust, validated, computational model of glass melting furnaces is being developed. Although three-dimensional computer models of the individual components of the melting system do exist, they have not been coupled into an entire furnace model. One innovative feature of this proposed model is that the newly developed code will directly couple the combustion space with the glass batch/melt through a rigorous spectral radiation model that computes radiant transfer throughout the whole furnace volume, allowing for spectral radiation from combustion species such as H_2O and CO_2 and radiation to and from the crown and glass melt, thus producing a more accurate model of the entire system. This accurate modeling tool will lead to optimization of existing melter operation, which in turn will improve production efficiency and quality while reducing operating costs and emissions.



New model will couple and simulate all components of a glass melting furnace.

Benefits for Our Industry and Our Nation

- Optimization of melter operation and combustion process, yielding improved production efficiency and reduced costs and emissions
- A modeling capability that can aid in problem solving and facilitate more rapid design and introduction of new products
- Accessibility to modeling tools for manufacturers throughout the industry without the expense of maintaining in-house modeling capabilities

Applications in Our Nation's Industry

The project will offer the industry a validated, analytical tool that can be used to evaluate new furnace designs, evaluate furnace performance, develop optimal fuel-firing strategies, and devise methods to improve cost efficiency and environmental performance. Since the model is being developed collaboratively with industry partners that already employ modeling capabilities, the development and validation of this coupled model will result in immediate application.

Project Description

Goal: Develop, validate, and apply an innovative, three-dimensional, glass melting furnace simulation model that provides a more accurate representation of the entire melting process by coupling the combustion space with the glass batch and the glass bath.

Argonne National Laboratory developed the combustion space model; Purdue University assisted ANL in developing the glass bath model. The two models, together with a detailed glass batch model, have been synthesized into one code by ANL and validated against existing industrial furnace measurements as well as data from a measurement program conducted on an operating furnace. The simulation will be available to be used to optimize furnace performance with regard to energy use, emissions, and productivity.

Progress and Milestones

Project partners have completed the following:

- Constructed and validated a computational fluid dynamics (CFD) based combustion space model that incorporates a rigorous treatment of spectral radiation from combustion species such as H_2O, CO_2, and soot and radiation exchange between interior surfaces, most prominently, the crown.
- Developed a simulation of the glass melt based on one of Argonne's CFD codes, which has inherent multi-phase flow capabilities and directly incorporated models for glass batch heat transfer and melting.
- Conducted furnace data gathering campaigns at selected furnaces of industrial partners for model validation. Data collected included temperatures, velocities, species concentrations, and radiation heat flux. Used the furnace data to validate the sub-models contained in the combustion space and glass melt models.
- Activated the gaseous phase transport equations built into the glass melt model to model the effects of bubblers on the heat transport and flow in the melt.
- Made beta versions available to the program participants, and provided training and support. Used feedback from users of the beta versions to develop the latest version of the Glass Furnace Model (GFM 4).
- Implemented enhancements to improve marketability of GFM including: a greatly simplified user interface with automated file handling, a new hybrid radiation heat transfer algorithm that increases both the speed and fidelity of the computation, automated cycling between the combustion and melt computation that can reduce the time to complete a coupled simulation from two weeks to two days, depending on problem size, an automated soot model calibration procedure, a new progress monitoring program and data gathering capability to enable rapid identification of problems and show the level of convergence of the models, and many other enhancements to improve usability and accuracy of the GFM software.

Commercialization

A commercialization plan to transfer the model to the glass industry was implemented. Seventeen no-cost trial licenses for GFM 2 were provided to 12 companies and a university. Users from eight companies received training in the use of GFM. All trial licensees of GFM 2 were provided free technical support for one year. Based on experience with this first group of trial users, plans for GFM 3 were substantially modified, and GFM 4 was developed. GFM 4 will be released with a six month no cost trial license. A summary of GFM capabilities and licensing information will be available on Argonne's Software Shop web site. Other options for commercialization of GFM 4 are being pursued.

Project Partners

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Argonne, IL

Libbey Glass Co.
Toledo, OH

Mississippi State University
Mississippi State, MS

Osram Sylvania Inc.
Exeter, NH

Owens Corning
Granville, OH

Purdue University
West Lafayette, IN

Techneglas (now defunct)
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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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