INTRODUCING GFM

A POWERFUL, VERSATILE CFD COMPUTER CODE FOR ANALYZING GLASS FURNACE PERFORMANCE

The Glass Furnace Model (GFM) code is now available on a no-fee, trial basis, for a limited time. GFM simulates the multiphase (solid, gas, liquid) reacting flows in both the combustion space and the glass melt and couples them through a new and novel rigorous spectral radiation model to create the overall furnace model.

The GFM can help you conduct cost-effective evaluations of the impact of changes in furnace operating and design parameters on combustion and glass-melting efficiency and, therefore, on overall furnace performance. The code has been validated with an extensive data base derived from *in-situ* measurements made in three different types of furnaces.

The GFM's user-friendly pre- and post-processor allows quick and easy construction of a furnace simulation and visualization of the results. During the free trial period, technical support will be provided.

The code was developed by the U.S. Department of Energy's Argonne National Laboratory (Argonne) in close collaboration with a consortium of five industry members: Techneglas, Inc.; Owens-Corning; Libbey, Inc.; Osram Sylvania, Inc.; and Visteon, Inc.

Purdue University and Mississippi State University's DIAL Laboratory were also collaborators.

The Glass Furnace Model: Meeting an Industry Need

Responding to competitive and regulatory pressures, glass manufacturers are seeking ways to improve productivity and product quality — and yet reduce furnace energy use and emissions.

The GFM (Glass Furnace Model) — a state-of-the-art CFD glass furnace simulation code that was developed at Argonne National Laboratory, with the assistance and guidance from a glass industry consortium — is a an advanced, powerful new tool industry can use to define and evaluate furnace design changes and operating strategies to:

- Reduce energy use per unit of production;
- Solve problems related to production and glass quality by defining optimal operating windows to reduce cullet generation and maximize throughput; and
- Make changes in furnace design and/or operation to reduce critical emissions, such as NO_x and particulates.

The glass industry has long recognized the value of using CFD models — like the GFM — as a tool to help design improvements in furnace design and operation[1].

GFM Is Easy to Use

The GFM is a PC-based code with an easy-to-use graphical interface that allows quick construction of a model of a glass furnace by using the preprocessor. In addition, the GFM has a robust post-processor that facilitates the display of the simulation results. Massively parallel computers are not needed to use the GFM; it was designed to run efficiently (i.e., in a day or two for the largest furnaces; in hours for smaller furnaces) on off-the-shelf PCs. All that's needed to learn how to use the code is an appropriate engineering and glass technology background.

GFM Advances the State of the Art

The GFM significantly advances the state of the art in glass furnace modeling by incorporating a number of innovations and advances, such as:

- Built-in burner models (e.g., tube-in-tube burners) that can be automatically included in the combustion space simulation,
- A computationally efficient spectral radiation model that maintains local and global energy balances,
- A multiphase (liquid, solid, gas) reacting flow melt model that calculates (not imposes) the batch-melting rate and the batch shape,
- A multiphase reacting flow model melt model that calculates bubble generation and transport throughout the entire melt volume, and
- The calculation of the foam distribution and thickness on the glass melt surface.

Figure 1 shows computed batch and bubble distributions.

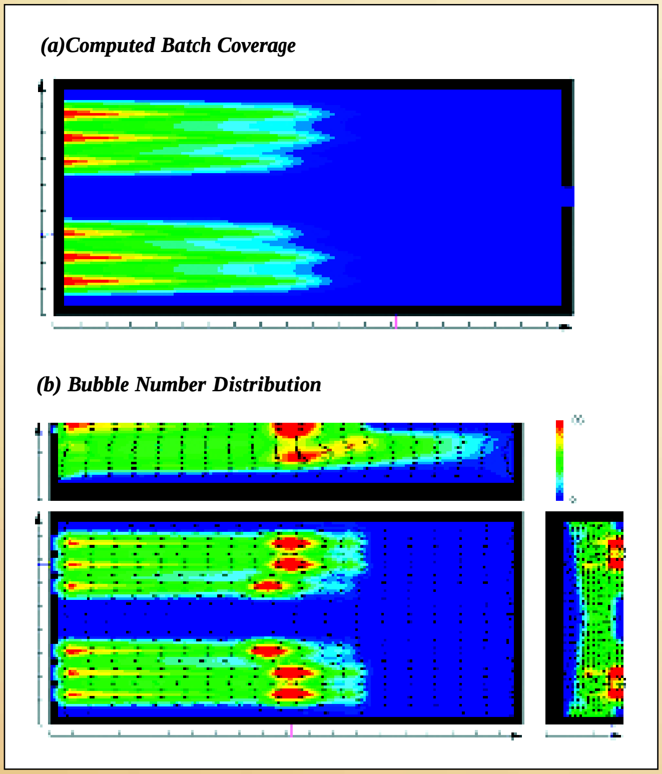

Figure 1: (a) Computed Batch and (b) Bubble Distributions

[1]Glass Technology Roadmap Workshop, Alexandria, Virginia, April 24–25, 1997.

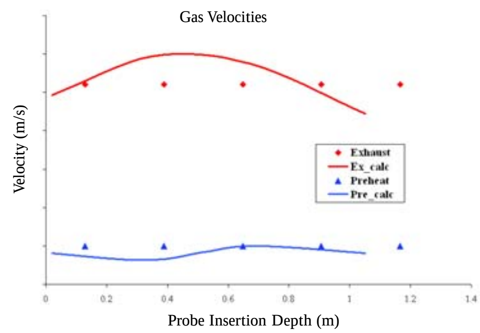

Figure 2: Gas Velocity Validation

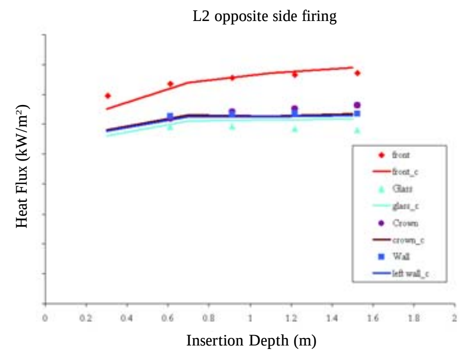

Figure 3: Gas Temperature Validation

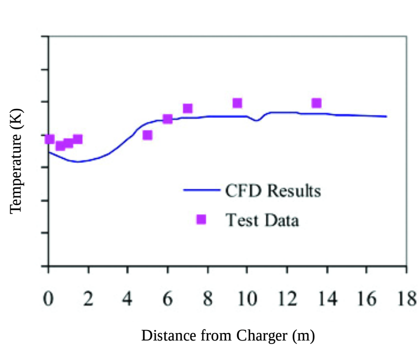

Figure 4: Glass Temperature Validation

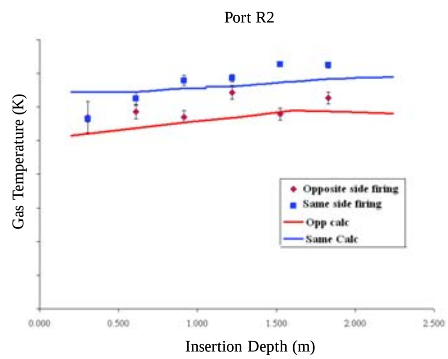

Figure 5: Radiation Heat Flux Validation

Validated and Ready to Use

The GFM code has been used to simulate a number of different types of glass furnaces. It has also been extensively validated against a comprehensive database acquired from *in-situ* measurements in three of the furnaces. Figures 2–5 show comparisons of computed and measured results from analyses of various furnace parameters. The good agreement shown in Figures 2–5 confirms the validity of the GFM code and its capabilities.

The industrial consortium members, with assistance from Argonne, used the GFM to conduct a number of parametric, sensitivity, and optimization studies on different types of furnaces.

Furnace types modeled:

- Cross-fired oxy-fuel furnace,
- Recuperative furnace,
- End-fired regenerative furnace, and
- Side-fired regenerative furnace.

Examples of parametric and optimization studies:

- Performance of staged burners versus tube-in-tube burners,
- Effect of an obstruction in the melt on glass melt flow field and glass quality,
- Impact of burner firing pattern on energy efficiency in an end-fired regenerative furnace,
- Effect of refiner depth on the performance of a side-fired regenerative furnace,
- Effect of nitrogen loading (open ports) on NO_x formation in a furnace,
- Effect of heat flux distribution on backflow in a submerged throat,
- Effect of gas released from batch/melt reactions on combustion space flow field,
- Effect of crown height on heat transfer to the melt,
- Effect of electric boost location on melt flow field, and
- Effect of batch particle size on melting and glass melt flow field.

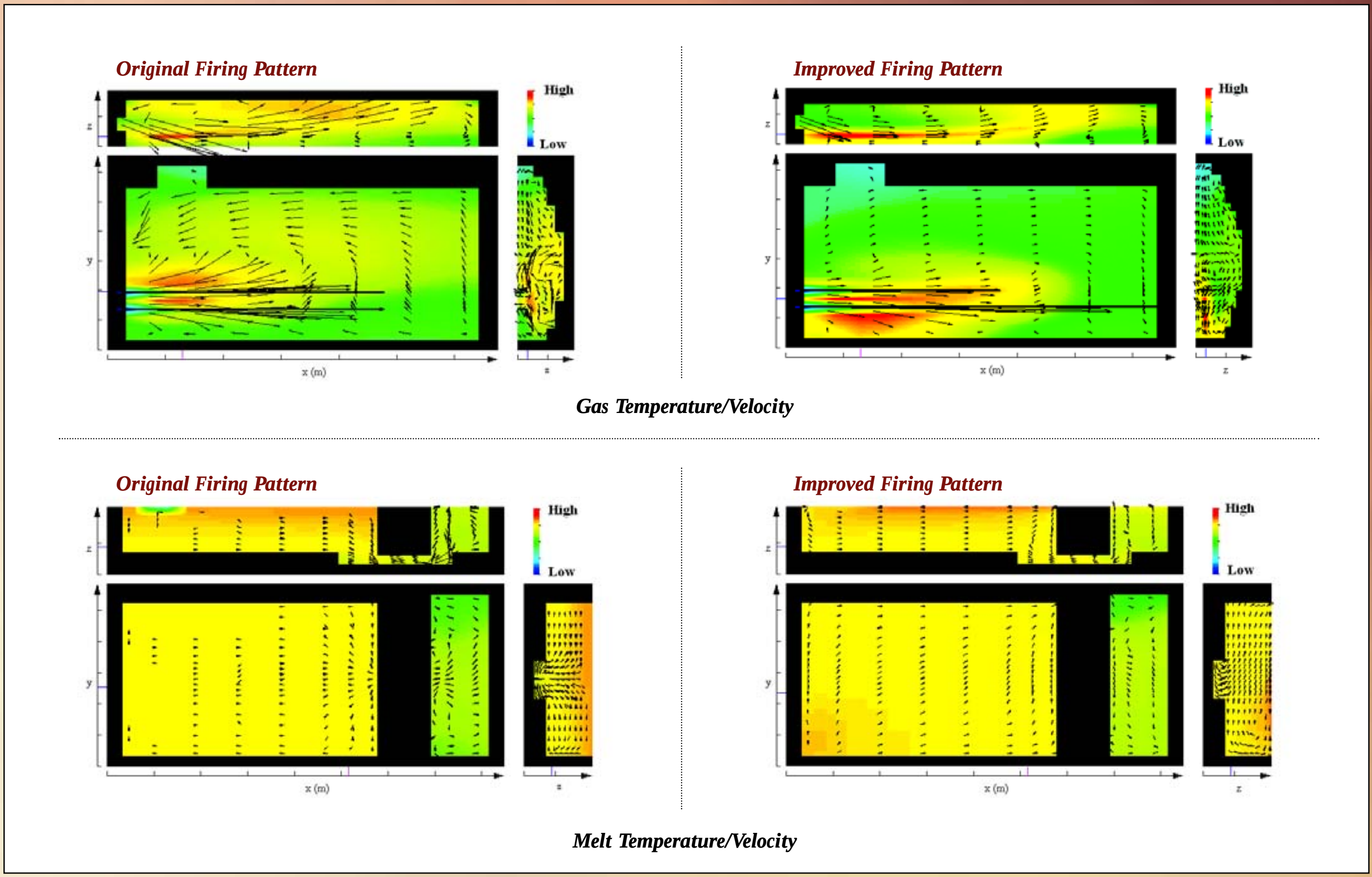

Figure 6: Results of a Sensitivity Study on Firing Pattern in an End-Fired Regenerative Furnace

These studies underscore the fact that the code is now ready for use. A typical outcome from these studies is illustrated in Figure 6, which shows the effect of a slight change in the burner-firing pattern on gas temperature and velocity, along with the ensuing temperature and velocity changes in the melt. The results from this study indicated that the furnace throughput could be increased by approximately 5% while maintaining the desired exit glass melt temperatures.

Code Availability

The GFM (Version 2.0) is available to users at no cost on a trial, six-month basis to expedite its introduction to and use by the industry. Starting April 1, 2004, the no-fee trial license can be accessed on-line from the Argonne Software Shop at http://softwareshop.anl.gov/.

During the trial period, users will be invited to Argonne to learn how to use the code, set up furnace simulations with the preprocessor, and evaluate the computational results with the post-processor. Users will be encouraged to apply the GFM to evaluate/resolve a specific furnace design or operating problem.

One-Time Licensing Fee

At the end of the trial period, users will be required to pay a nominal one-time licensing fee for continued use of the code. The fees for an executable version will range from $10,000 to $30,000, depending on such factors as whether the company is a U.S. or foreign company, site where the code will be used, number of copies desired, and whether the company is a member of the Glass Manufacturing Industry Council (GMIC).

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.

Acknowledgments

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Find Out More

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