

**ADMINISTRATIVE INFORMATION**

1. **Project Name:** Energy-Efficient Glass Melting - The Next Generation Melter
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5. **Date Project Initiated:** September 15, 2003
6. **Expected Completion Date:** September 30, 2006

**PROJECT RATIONALE AND STRATEGY**

7. **Project Objective:** The objective of this project is to demonstrate a high intensity glass melter, based on the submerged combustion melting technology. This melter will serve as the melting and homogenization section of a segmented, lower-capital cost, energy-efficient Next Generation Glass Melting System (NGMS). After this project, the melter will be ready to move toward commercial trials for some glasses needing little refining (fiberglass, etc.). For other glasses, a second project Phase or glass industry research is anticipated to develop the fining stage of the NGMS process.

8. **Technical Barrier(s) Being Addressed:** This project addresses the need to improve glass melting efficiency and lower emissions using a reliable melter that produces glass of equal or higher quality to current industrial glass. Savings include 23% fuel and oxygen, 23% CO<sub>2</sub> and CO, 30% NO<sub>x</sub>, and 80% of capital cost compared with oxy-gas tank melters. The NGMS melter overcomes the limitations on both rapid heat and mass transfer using submerged combustion melting in an externally cooled tank.
9. **Project Pathway:** This 3-year project is focusing on demonstrating and modeling the melter. GTI, working with glass industry partners, will build and operate a 1 ton/h SCM unit. Product glasses will be analyzed, and a complete NGMS system designed. Other work will include CFD and physical modeling and evaluation of the use of exhaust gas for oxygen production using Oxygen Transport Membranes. After this project, the melter will be ready to move toward commercial use for fiberglass and glasses needing little or no refining. A Phase II project is anticipated to demonstrate rapid refining of other glasses before integration with the melter and scale-up of NGMS for these glasses. Other compatible and useful technologies, many already available, include waste heat recovery, batch handling and charging, control, sensors, and NGMS scaling.
10. **Critical Technical Metrics:**
- Construction and operation of a 0.5 to 1 ton/h SCM unit producing industrial glass compositions
  - Complete analysis of glass samples, along with energy use and emissions determinations
  - CFD and physical modeling of the SCM unit
  - Design of a demonstration-scale NGMS using the SCM unit for the melting and mixing step

## **PROJECT PLANS AND PROGRESS**

### **11. Past Accomplishments:**

- Initial working CFD model written and tested
  - Fluent code modification needs identified and changes being implemented
  - initial CFD model for flow patterns (batch melter with no feed or discharge) Dec., 2004
  - Hydrodynamic model of pilot-melter configurations and matching physical modeling unit - April 2005
  - Pilot-scale SCM model cases extended to include temperature profiles, glass viscosity, continuous feed and product discharge - July 2005
- Design pilot scale melter
  - Complete 1 ton/h melter designed (feeding system, discharge, sample collection, gas cleaning, control, sensors, cooling water, etc.
  - Testing with 'older' batch SCM unit to be complete in September, 2005. Testing using all system components except melter (feed system, baghouse, instrumentation, control system, discharge pipe)
  - Design of 0.5-1.0 ton/h melter furnace completed in July 2005. Final engineering drawings and fabrication underway. Fabrication completion - Oct. 2005.
- Procure equipment for pilot scale melter
  - All major pieces of equipment ordered except melter panels and final burners.
  - Steel, electrical, mechanical, oxygen, water, instrumentation, control systems all completed - March 2005.
  - Continued instrumentation upgrading to monitor as many data points as possible, including melt temperature and melt depth.

- Testing with lab-scale version of SCM using glass batch
  - Three glass compositions - soda-lime, E glass, and LCD glass - were selected by consortium members as covering the full range of glasses melted industrially (in terms of difficulty in melting)
  - Semi-batch tests (up to 800 lb. product glass) with soda-lime and LCD glasses
  - Elemental and photo-micrographic analysis of product glasses
  - Design of platinum discharge pipe to provide controlled, continuous melt discharge from batch-scale and pilot-scale SCM units
  - Fabrication, installation, and initial testing of discharge pipe along with needed transformer, thermocouples, and voltage measurement
  - Tests with discharge pipe on lab-scale SCM scheduled for first half of September, 2005 using soda-lime, E glass, and LCD glass batch
- Physical Modeling
  - Physical modeling dimensionless group calculations completed
  - Design of scaled physical model complete, with testing scheduled for Aug. 2004.
  - All physical modeling completed by March, 2005. Various rectangular, circular, and octagonal cross sections tested along with wide range of burner patterns. Hydrodynamics studying using glycerin and dye.

12. **Future Plans:**

Year	Mile-stone	Milestone Description	Planned Completion
1	1	Initial working CFD model written and tested	Sept. 2004
1	2	Design pilot scale melter	June 2005
1	3	Procure equipment for pilot scale melter	Sept. 2004 - Oct. 2005
2	4	Fabricate pilot scale melter	Oct. 2005
2	5	Prepare test plan	March 2005
2	6	Complete pilot scale melting tests and collect samples	March 2006
2	7	Complete all sample analyses	April 2006
3	8	Modify melter as needed	May 2006
3	9	Complete second test series	July 2006
3	10	Finalize CFD modeling and physical modeling	Aug. 2006
3	11	Complete OTM analysis	June 2006
3	12	Complete development plan	Sept. 2006

13. **Project Changes:** No project changes in the last year. All needed sub-contracts and the glass industry Consortium Agreement are in place. All glass companies in the consortium have provided strong support through providing glass batch, designing the new discharge pipe, supplying the discharge pipe transformer, CFD modeling, review of project findings and pilot melter design, support during all glass melting tests, and analysis of product glasses. Project emphasis has remained on 1) testing with the lab-scale SCM unit in preparation for pilot-scale design and fabrication, 2) design and fabrication of the pilot-scale submerged combustion melter, 3) physical modeling related to pilot melter design, 4) improvement of CFD modeling code, 5) CFD modeling of SCM configurations, and 4) planning for auxiliary work including OTM evaluation and testing of glass properties relative to submerged combustion.
14. **Commercialization Potential, Plans, and Activities:** This project is Phase I of an NGMS development program. The team expects SCM will be ready to move toward commercial production of insulation fiberglass and glasses needing little refining after this project. A Phase II project or glass industry research will be needed to demonstrate rapid glass refining and integration of SCM with rapid refining.

While pilot-scale melting and glass analysis are critical first steps, the project team was formed and organized to create practical technology that the industry will use in its day-to-day operations. Commercialization of this technology is the goal of this project. A consortium of the glass company team members has been formed. This consortium, along with GTI and other team members, has been organized so that any innovations developed will be able to be immediately applied by the industry consortium members without further legal entanglements. The industry team consists of representatives from every company who will champion this technology inside their respective organizations. Every supplier or partner to this project, including GTI, has agreed to give royalty and payment free intellectual property (IP) licenses to every member of the industry consortium to commercialize. GTI holds exclusive world-wide rights to the submerged combustion melting technology (outside the former Soviet Union) and has agreed to grant royalty free access to SCM to the glass company consortium members.

The glass company consortium will make the technology available to the domestic glass industry. A three tier approach is planned consisting of 1) royalty-free access for glass company consortium members on this project, 2) reduced royalty rates for GMIC member glass companies in recognition of GMIC support and marketing, and 3) negotiated licenses for all other glass companies. This approach will ensure the NGMS energy savings, capital cost savings, pollutant reductions, and process efficiency gains can be exploited by the entire American glass industry.

15. **Patents, Publications, Presentations**

Patent Application, Process and Apparatus for Uniform Combustion Within a Molten Material, submitted to U.S. Patent Office, April 2004.

"Submerged Combustion Melting", Glass Researcher article, 2004.

"Submerged Combustion Melter". presentation at 78th An. Conf. of German Scty. of Glass Tech., Nuremberg, Germany, June 8, 2004.

"Submerged Combustion - Implications to Future Glass Melting", presentation at ACerS GOMD, Cocoa Beach, FL, Nov. 12, 2004.

16. **Budget History and Projection, \$000:** The table below shows project funding levels through August 2005. Cost share reflects spending in cash from other sponsors as well as in-kind support from glass industry partners.

Phase / Budget Period			Approved Spending, \$K			Actual Spending, \$K		
			DOE Amount	Cost Share	Total	DOE Amount	Cost Share	Total
	From	To						
Year 1	10/03	9/04	1311	850	2161	1192	178	1370
Year 2	10/04	9/05	1335	300	1635	1408	872	2280
Year 3	10/05	9/06	1186	300	1486			
<b>Total</b>			<b>3833</b>	<b>1450</b>	<b>5283</b>	<b>2600</b>	<b>1050</b>	<b>3650</b>