Technology Brief

REFRACTORY MOLDS FOR GLASS SINTERING

Key Words	
Materials:	Crushed glass.
Technologies:	Glass Sintering.
Applications:	Molded glass products.
Market Goals:	Cottage-industry, high-value uses for locally recovered glass.
Abstract:	Investigation of mold materials, release agents, and heating schedules suitable for glass sintering.

Recovered container glass can be formed into marketable products by filling a refractory mold with powdered glass and heating the glass and mold to a high temperature so that the glass sinters (or bonds) to take the shape of the mold. The process creates high value-added uses for recovered container glass. Since the open mold is packed at room temperature, the production methods are fairly simple, not capital intensive, and thereby particularly appropriate for cottage industrial development. Moreover, since the process can use locally-generated feedstock, it also eliminates the cost of transporting the recovered glass to distant markets.

This technology brief discusses the results of an assessment to investigate different mold materials, surface release agents, and different heating schedules to improve release characteristics and produce molds suitable for multiple use cycles without sticking to the glass product, or breaking.

Glass Sintering

Manufacturing ground glass products involves several steps. First, the design shape of the product is formed into a model. Molds - the castable refractory shapes that mirror the final design of the product - are cast from the model. Second, ground glass is placed in the mold (both fine and coarse grinds can be used). Third, the mold and glass powder is heated to sinter the glass. Finally, the glass shape is cooled and then removed from the mold. The process requires precise engineering of both mold materials and mold design to match the glass type, the product application, and scale of the operation.

A mixture of plaster of paris and silica sand can be used as a one-time mold material. The plaster of paris degrades during high temperature exposure and the mold can be broken away from the cast piece. However, for economic and practical reasons, it is desirable to have a mold material that can be used several times to produce multiple pieces.

Industrial materials called castable refractory concrete are widely used for furnace linings and multiple-use mold materials in metallurgical and ceramic industries. These materials consist of a refractory hydraulic-setting cement phase, typically compounds of calcium oxide and aluminum oxide called calcium aluminates, and an aggregate material. The concretes are generally classified according to their aggregate as silica- or alumina-based materials. The type of aggregate largely determines the temperature capabilities and thermal expansion characteristics of the refractory. These castable refractory concretes were the subject of the testing in this project.

Material and Process Trials

Recovered container glass ground to 6 mesh (3.36 mm opening) and 20 mesh and smaller (0.84 mm opening) were used in the trials.

Two general types of castable materials were used in this investigation. The first type contained fused silica as the

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aggregate and the second type contained calcined kaolin or fireclay grog as the aggregate.

A thermal gradient furnace and a uniform temperature furnace were used to investigate the flow and sintering characteristics of various glasses and to determine the glass/mold interactions as a function of temperature.

Issues for Successful Mold Production

During this project, the use of castable refractories for glass molding sometimes resulted in glass sticking to the mold so that either the glass article or the mold broke while separating the two. It was discovered that several technical issues affected successful mold production and use. These include the design of the mold, the preparation of the mold material, and the compatibility between the mold material and the glass feedstock.

The design of a reusable mold must be such that there are no undercuts or reverse entries that would prevent removal of the solidified glass article after heat treatment. A smooth, nonporous surface on the refractory mold is also essential for glass release. Therefore, the mold must be prepared from a model material that ensures such smoothness. Flexible polyurethane and well sealed wood (for small production runs) make good model materials. Vibration should be used when processing to help the mold material form to the model. It is also important that the moisture content of the castable refractory concrete be closely controlled to avoid a mix that is too stiff or too wet.

Compatibility between the mold material and the glass feedstock must be considered. Differences in the thermal contraction characteristics of the glass and the refractory mold must be reconciled with the design of the mold such that the glass article does not lock in or become stressed during cooling. Different time-temperature relations, that is, the heating schedule, affected glass release from the mold. Above 920^{o}C the glass becomes fluid, wetting the mold and becoming firmly attached to the mold surface.

Assessment Findings

Molds made from castable refractory cement can be used for a number of cycles to sinter dense glass articles from powdered recovered container glass provided the mold surfaces are smooth and pore free, and the time-temperature cycle is closely controlled.

Industrial grade castable refractory with a fireclay or calcined kaolin aggregate is suitable for mold fabrication. High temperature refractories with high purity alumina aggregate or special low expansion refractories with fused silica aggregate are not required. However, it is essential that the castable refractory is able to produce a smooth, pore free surface against a model.

The refractory molds can be used for repeated casts without wear or damage provided the mold surface is smooth and minor defects are repaired between runs.

The one-inch thick glass charges saw a reduction in thickness by a factor of about 0.6 and very little reduction in lateral dimensions. The difference in shrinkage between the glass and the refractory on cooling is approximately 0.2% with the glass shrinking more than the refractory. Differential contraction during cooling should be considered when patterns exist in the mold structure.

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For More Information

For a copy of the report, *Refractory Molds for Glass Sintering (GL-95-1),* call the CWC subscription line at (206) 587-5520. For more information call CWC at (206) 464-7040, email info@cwc.org, or visit the CWC Internet Website at www.cwc.org.

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