Testing Washed Bottles for the Creation of Glass Fusing Kits

RECYCLING TECHNOLOGY ASSISTANCE PARTNERSHIP
ReTAP

NIST MEP
Environmental Program

TESTING WASHED BOTTLES FOR THE CREATION OF GLASS FUSING KITS

FINAL REPORT

PREPARED FOR:

CWC
A division of the Pacific NorthWest Economic Region (PNWER)
2200 Alaskan Way, Suite 460
Seattle, WA 98121

December 1998

PREPARED BY:

Skookum, Inc.

This recycled paper is recyclable

REPORT NO. GL-98-2

ACKNOWLEDGMENTS

CWC is a nonprofit organization providing recycling market development services to both businesses and governments, including tools and technologies to help manufacturers use recycled materials. CWC is an affiliate of the national Manufacturing Extension Partnership (MEP) – a program of the US Commerce Department's National Institute of Standards and Technology. The MEP is a growing nationwide network of extension services to help smaller US manufacturers improve their performance and become more competitive. CWC also acknowledges support from the US Environmental Protection Agency and other organizations.

TABLE OF CONTENTS

Page

APPENDICES

1.0 INTRODUCTION

The use of recycled glass as a raw material for manufacturing products by fusing finely crushed glass is a growing area of interest by small businesses. Glass fusing consists of placing finely crushed glass into a mold and then heating the glass to approximately 1500° F. At that temperature, the glass particles fuse, or sinter, into a solid mass and take the shape of the mold. In the past, the CWC has investigated and researched raw materials used to make permanent molds for fusing glass (see CWC report GL-95-01, "Refractory Molds for Glass Sintering").

Skookum, Inc., is a business in Port Townsend, Washington, that employs developmentally handicapped clients in business enterprises. The company also operates the Jefferson County Recycling Center, where collected recycled materials are sorted. Beginning in 1996, Skookum established a division within the corporation dedicated to washing wine bottles for resale to the wine industry. That business generates a significant amount of waste in the form of bottles that have been washed, but cannot be sold because they are the wrong style or have surface blemishes.

On one occasion, some of Skookum's washed waste bottles were crushed and then used by a small glass fusing company as a raw material. Those bottles were found to fuse more cleanly than other post-consumer glass bottles. It was assumed that the process for washing the bottles, which consisted of a caustic (usually sodium hydroxide) soak followed by several clean water rinses, resulted in a glass that was cleaner, and therefore contained less inorganic particles to inhibit the glass fusing process than the unwashed bottles. In addition, technical literature established that devitrification of glass requires inorganic sites around which crystals form. Cleaner glass may inhibit devitrification, with coincident loss of gloss, as a result of having fewer sites for initiation of crystal growth.

This information prompted Skookum's management to consider whether it might be possible to find markets for washed bottles in the nascent glass fusing crafts industry.

In 1997, Skookum responded to a CWC Request for Proposals with a plan requesting support in assembling and testing glass fusing crafts kits. The target market for the kits would be high schools and ceramics supply stores.

This report presents a summary of the glass fusing process used to create the glass fusing kits, instruction sheets written for inclusion in the kits, and a cost analysis of the materials used in kit production. The costs are described both as the project was implemented and assuming production scale.

2.0 SUMMARY OF GLASS FUSING PROCESSES

2.1 GLASS FUSING PROCESS

The following steps were necessary to create the glass fusing kits:

- Collecting and color sorting the wine bottles.
- Washing the bottles in the wine bottle washing machine.
- Breaking the bottles for volume reduction and shipment.
- Having the broken glass ground into four different mesh sizes.
- Testing the fuseability by making tiles.
- Designing and testing the kit.

2.1.1 Collecting and Color Sorting Wine Bottles

Collected recycled materials were sorted at the Jefferson County Recycling Center (operated by Skookum, Inc.) and some of the wine bottles used for this study were recovered from this recycling center. In addition, collections were made by placing a labeled, public drop-off bin in front of the Skookum Environmental Services Recycling center in Port Townsend, WA. The drop-off was popular with the public and produced cleaner containers than those recovered from the recycling center.

Several of Skookum's developmentally disabled workers were trained to sort the bottles by color and to remove trash and unusable bottles; unusable bottles included bottles that were too large for the washing machine and those that had debris inside the bottles. The colors chosen for the kits were Deadleaf Green, Emerald Green, Bright Green, and Clear.

2.1.2 Washing the Bottles in the Wine Bottle Washing Machine

Skookum's bottle washing machine was manufactured in Austria. While the machine is fairly new, it is temperamental and prone to breakdowns, which are expensive and time consuming. The general washing process is as follows. First the bottles are soaked in a hot caustic solution to kill bacteria and remove labels. Then the bottles are rinsed several times with clean water. The bottles are carried through the process on a moving belt with "cradles."

Washing bottles for resale to the wine industry has proven to be more technically challenging than originally expected. The heated, two percent caustic soda soak does not remove the pressure sensitive labels on many American wine bottles. This necessitates the rewashing of many of those bottles. In addition, if bottles are dusty, the machine does a poorer washing job. In general, washing the bottles is highly labor-intensive with high maintenance costs. For a more complete description of bottle washing, see CWC report GL-97-12, "A Model for a Bottlewashing Plant."

If washing glass for fusing became a full-time operation, washing individual bottles may not be the most efficient procedure. A more cost-effective method might be to break the bottles first, then wash them in a continuous process. This would eliminate the need to handle the bottles individually. It may also be easier to remove labels through a combination of screening and washing of crushed bottles than washing whole bottles.

2.1.3 Breaking the Bottles for Volume Reduction and Shipment

Glass breakers are common in the recycling industry for volume reduction of recycled glass prior to shipping. For this project, a glass breaker was used to break the washed bottles into pieces that were approximately one to two inches in diameter. The pieces were loaded into fiber bags that hold approximately one ton of glass.

2.1.4 Having the Broken Glass Ground to Four Different Mesh Sizes

After crushing, the glass was shipped to TriVitro Corporation, a Seattle, Washington, company specializing in glass grinding for various specialty markets, especially sandblasting abrasives. To prevent cross-contamination from other kinds of glass, TriVitro used a separate crushing line dedicated to fusing glass to process the glass for this project.

TriVitro processed the glass and generated the following grades (sizes are given in Standard U.S.Mesh):

- 3 x 6 mesh;
- 6 x 20 mesh;
- 20 x 50 mesh; and
- 50 mesh minus.

Each grade was made in the four colors previously mentioned. In all, 16 separate glass grades and colors were produced.

2.1.5 Testing the Fuseability

The CWC has published four "Best Practices in Glass Recycling" covering different aspects of the glass fusing process. Within the *Best Practices in Glass RecyclingManual* see the following:

- **Fusing Recycled Glass** **GL3-04-01**
- **Permanent Molds for Fusing Glass** **GL3-04-02**
- **A Simple Vibratory Compaction Table** **GL3-04-03**
- **Simple Particle Packing** **GL3-04-04**

These Best Practices are excerpted in the instruction sheets section of this report. A number of books have also been written on glass fusing as an art and a craft (for examples, see References). However, it is important to understand that the type of glass that is generally used in arts and crafts is quite different from recycled container glass. Soda lime glass used for container manufacturing "devitrifies," or returns to the crystalline state, very easily upon reheating. This can result in dull and uneven tiles.

Two individuals with experience fusing container glass were selected to test the fuseability of the washed, graded glass samples. Samples and test results were to be used to confirm the efficacy of the glass for fusing and as a basis for the instruction sheets. Tiles measuring 4"x4" were chosen as the test standard; each tile weighed about 200 grams. Samples of the glass were heated in standard electric "potter's" kilns with electronic digital controllers at various heating and cooling rates to a variety of maximum temperatures. This was done to optimize the fusing process with this particular glass and to develop straightforward instructions for fusing the washed bottle glass using commonly available equipment.

Following the initial testing, confirmation tests were run by local ceramic artists and high school ceramics classes with similar results. The most common concerns involved temperature control and variations from the suggested firing schedules. This feedback confirmed the fact that each kiln performs differently. Therefore, any person interested in trying kiln fusing should initially run a number of tests to confirm the best profile for the specific kiln.

There was positive feedback from the high school testers and many comments concerning how clean the ground glass was; feedback on the mold material was also positive. Some of the testers preferred using one-time plaster molds and these also worked well.

2.1.6 Designing and Testing the Kit

The kits were designed to be sold primarily to high school ceramic departments and through ceramic supply stores. There are 16 bags in each kit and each kit contains a different size and color of ground glass. Of the 16 bags, 12 contain two pounds each of the coarsest ground glass. The other four contain one pound each of the finest ground grade (of which there is less material produced in the grinding process). There is also a three-pound bag of premixed mold material in each kit. An instruction sheet, describing the basic glass fusing process, is also included in the kit.

3.0 COST ANALYSIS

When Skookum was washing wine bottles for resale to the wine industry, the company determined that the sorting and washing process cost 25 cents per bottle, including labor and facilities expenses. On average, 1,400 wine bottles weigh one ton. Therefore, Skookum's cost for washing is about $350 per ton.

3.1 ESTIMATE OF COSTS

The following is an estimate of Skookum's direct expense for each kit, projected to production volumes (See Appendix 2 for actual expenses of this project):

Washed glass (.25/pound x 28 pounds)	$ 7.00
Glass grinding (on contract w/TriVitro)	
[$300/ton = .15/pound x 28 pounds]	$ 4.20
Glass transport (.10/pound x 28 pounds)	$ 2.80
Kit packaging	$ 3.00
Kit literature	$ 2.00
Moldmaking material	$ 2.00
Kit assembly	$ 2.00
Direct management	$ 2.00
Direct kit cost	**$25.00**
Defective kits (20%)	$ 5.00
Total direct kit cost	**$30.00**

At 200 grams per 4"x4" tile, each kit will make 63 tiles. Interviews with retail sales organizations and crafts people determined a reasonable retail price of $95. This implies a wholesale price of $47.50. Given direct costs of $30.00 for kit materials and assembly, $47.50 may be a feasible wholesale cost.

In addition, it may be possible to develop an aftermarket of people who have learned the process and only want to buy glass for tilemaking in specific sizes and colors in bulk.

4.0 INSTRUCTIONS FOR THE FUSING KITS

Instructions that would be included in each kit consist of four sections that cover: (1) colors and grades; (2) moldmaking; (3) kiln casting; and (4) recommendations.

4.1 COLORS AND GRADES

Included in the kit are four colors of glass, each in four grades. The colors are Clear, Dead Leaf Green, Emerald Green, and Bright Green.

4.1.1 Glass particle sizes and characteristics:

3x6 Coarse: Tiles made from this grade will have the clearest, most transparent crystal appearance. Some tiny air bubbles will be captured inside the tiles. There may be internal cracks and occasional surface bumps. This size is better for decorative objects than for tiles because the clarity will reveal mounting adhesive through the tile.

6x20 Medium: Tiles made from this grade will have excellent clarity and good surface gloss. There will be some bubbles captured within the tile. This grade is good for both tiles and art objects.

20x50 Fine: Tiles made from this grade will have less clarity and will be translucent rather than transparent. The tiles will have excellent surface gloss and less internal bubbles. This is the best single size for all-around fusing work.

-50 Extra Fine: Tiles made from this grade will be opaque with good surface gloss and have a fine-grained texture. Because it is so fine, any possible contamination will also be very small. It will also shrink more in thin tiles.

4.1.2 Combinations of grades

Combining 6x20, 20x50, and -50 is not recommended; the large 20x50 particles do not flow into the surface, leaving a rough or mottled look.

Combining 20x50 and -50 is recommended as the best all-around fusing glass. It combines the glassy qualities of the 20x50 fine with the fault resistance of the -50 fine (mix a ratio of 2:1 Fine:Extra Fine).

4.2 MOLDMAKING

These are general instructions for making simple molds (square tiles, simple shapes) out of the mold material provided in the kit. The mold material is a mix of calcium aluminate cement and fused silica aggregate, with a ceramic additive to give a fine-grain texture. These molds can be reused many times, are lightweight, and easy to clean for reuse. For other mold mixes, see References.

1. Prepare a pattern of the object to be cast in glass. Make a "master" tile to be reproduced in glass out of a piece of something soft, like foamboard or clay, to the shape desired. To make the master, use something soft because the mold material shrinks as it dries. Hard materials will get stuck when the mold dries. Also, because the glass sand will shrink when fused, use a 3/4" thick pattern if you desire a 3/8" thick finished tile. Make the edge of the pattern slightly angled to facilitate easy removal of the pattern from the cast mold. In addition, the master cannot have any undercuts because the fused glass piece must drop directly out of the mold. The cast mold is made in the mold box.

2. A mold box is a base with four sides that is strong enough to hold wet mold mix and can be easily disassembled to remove the mold; painted scrap plywood works well. The sides can be nailed, screwed together, or tightly bound with adhesive duct tape. Single-use mold boxes can be made out of pieces of cardboard cut, bent, and taped to make a box. The master pattern is secured to the bottom of the box; screws work

best, but other methods, like two-sided carpet tape, will work as well. The size of the box should be large enough so that the center pattern has at least a 1/2" clearance from the outer walls all the way around, including the top. Before filling the mold box with cement, coat the inside with vegetable oil, as this will help with releasing the mold from the master after it hardens.

3. Measure out enough dry mold mix to fill the mold box, plus a little extra.

4. In a separate container, add water to the mix a little at a time and stir until the mix is completely wet. It is important not to add too much water because this will weaken the mix. Use just enough so that the mix will work comfortably and settle into the mold.

5. Fill the mold box to the top with the wet mix. Tap the mold box to remove any bubbles and trowel the exposed surface to make it smooth; this will help it to shed less grit later. At this time, the back of the mold can be inscribed with a name, date, number, etc.

6. Allow the mold to dry for about eight hours and then remove it from the mold box.

7. Pre-fire the mold in the kiln and soak (leave at temperature) at 1700° F for one hour. This proofs the mold to withstand the fusing temperature of glass.

8. Before filling the mold with glass, apply a mold release (Self Primer for Glass™) to the mold. Alumina hydrate mixed with water can also be used; mix it until it is the consistency of paint and then brush on the mold. The release agent should then dry before using. These products can be purchased at ceramic supply businesses. As these molds can be reused many times, reapply the mold release as needed. The mold should be cleaned after use with a putty knife or steel brush.

4.3 KILN CASTING

1. Apply the mold release and fill the mold with the glass color or color mixtures desired. The coefficients of expansion for all colors of this glass are well matched and will generally give no problems of defects. See Section 1 for grade compatibility.

2. Load the kiln with molds, making sure to leave space around each mold and one or two inches from the kiln walls.

3. Start the firing using the established firing schedule and the programmed kiln controller. Four suggested firing schedules, in order of best test results, are as follows (See Appendix 1):

   - Heat to 1550° F as quickly as possible; soak for 15 minutes; turn off the kiln and cool naturally.

   - Heat at 500° F/hour to 1550 ° F; soak five minutes; turn off the kiln and cool naturally.

   - Heat at 500° F/hour to 1600° F; soak five minutes; turn off the kiln and cool naturally.

   - Heat at 500° F/hour to 1650° F; soak for five minutes; turn off the kiln and cool naturally.

4. Monitor firing and adjust temperatures as necessary. It may help the glass to stay "glassy" if the kiln is manually “crash cooled" from the highest temperature down to 1050° F if the kiln and controller are unable to cool quickly. As there are many different types of kilns, operators will have to determine this.

5. Wait until the kiln is completely cooled before removing the molds.

4.4 RECOMMENDATIONS

1. After removing the tiles, they can be cleaned several ways. Rinsing the tiles with water will remove most of the mold release that may have stuck to the tiles. If needed, soaking the tiles in vinegar will also help with mold release. In addition, abrasive pads may be used to scrub the surface. If there are sharp points around the edges, they can be removed with a grinding wheel. Always wear goggles and gloves and follow safe shop practices. Experiment with these tools and processes to find the one most suitable.

2. For best results, fire together only those molds filled with glass of the same particle size, range or combinations.

3. Unused glass should be kept away from mold mix, ceramic dust, grit, metal, plastic, wood or organic contaminants. Unused mold mix should be kept in sealed dry containers; stir dry mold mix before using.

4. Keep kiln and mold mix areas clean to prevent contamination of glass in open molds or storage containers.

5. Maintain and handle molds carefully to prevent grit and dust from contaminating the glass.

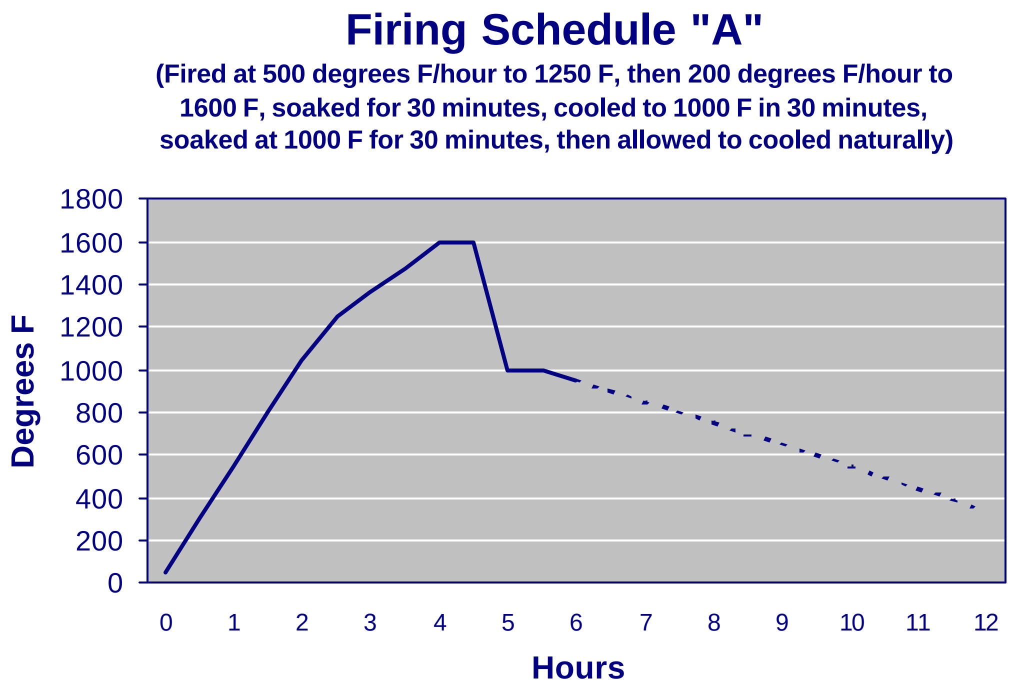
6. Keep good records of firing schedules and results to diagnose problems and improve skills.

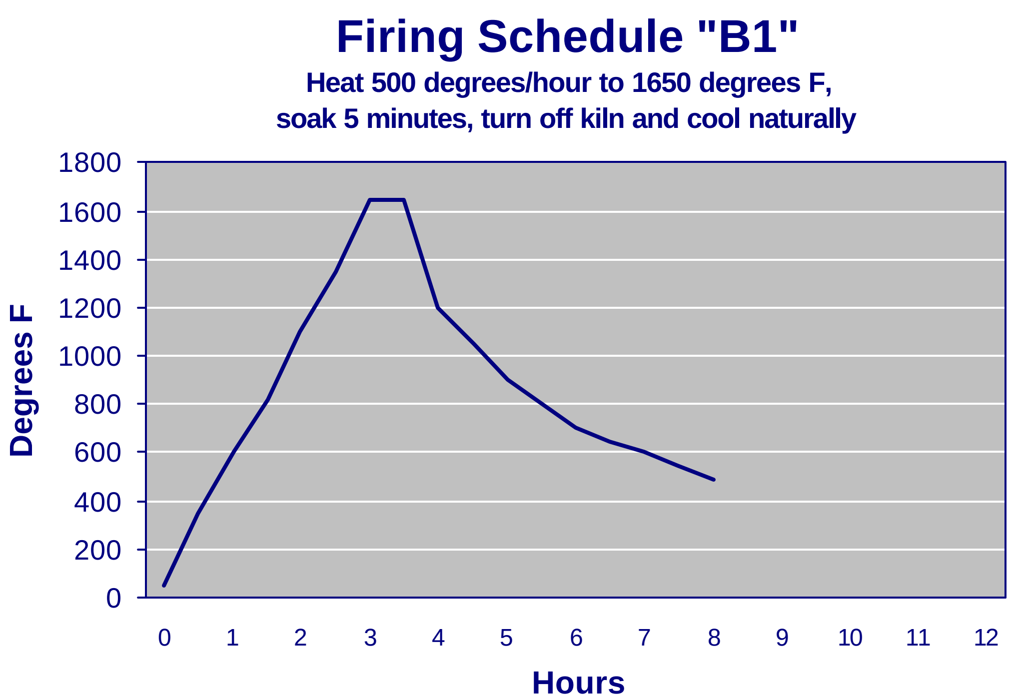
5.0 REFERENCES

1. Cummings, Keith, *Techniques of Kiln-Formed Glass*, A&C Black, London, 1997.
2. Lundstrum, Boyce, *Glass Casting and Moldmaking*, Vitreous Press, 1989.
3. McGregor and Schoerer, *Contemporary Kiln-Formed Glass*, Bullseye Glass, Portland, 1992.

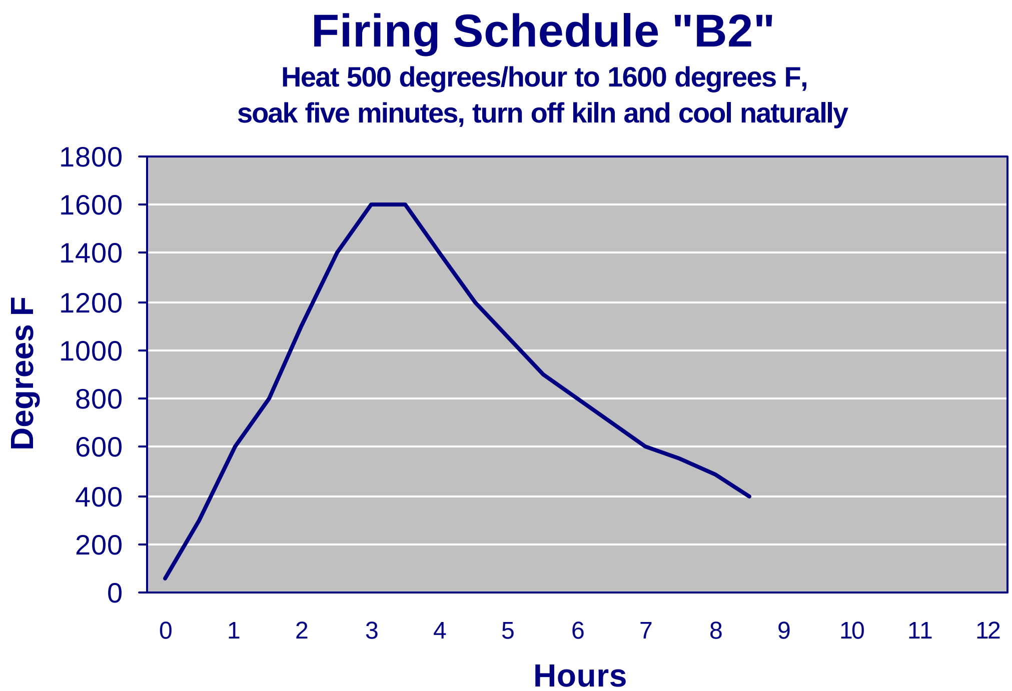
APPENDICES

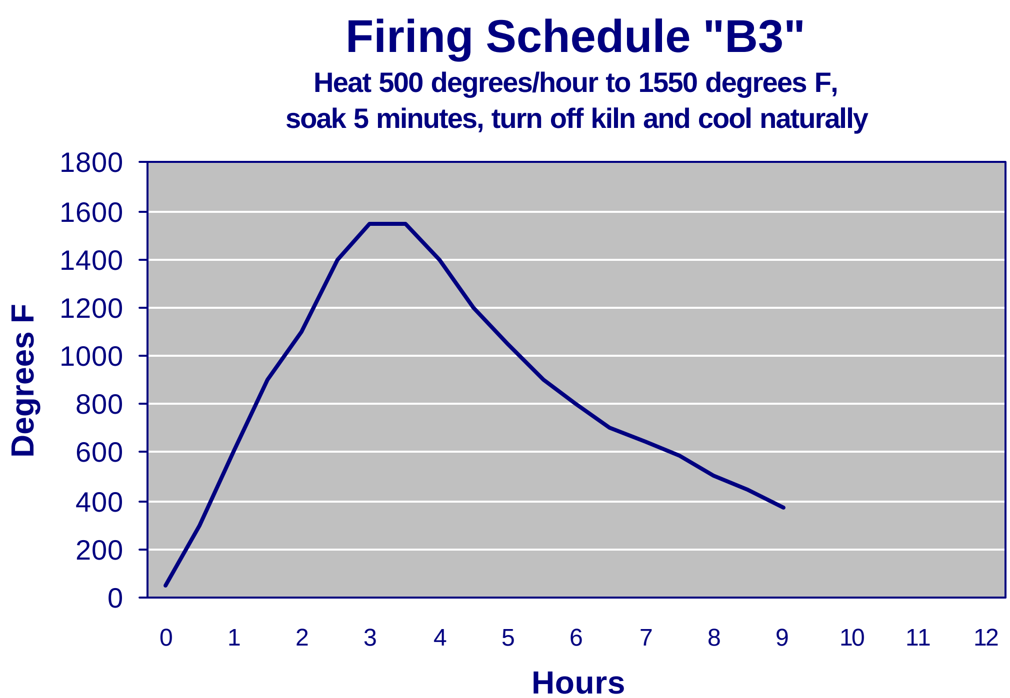
APPENDIX 1: FIRING SCHEDULES





APPENDIX 1: FIRING SCHEDULES





APPENDIX 2: GLASS FUSING PROJECT ACTUAL COSTS

CTED CONTRACT NO. S97-220-039

	BUDGET	ACTUAL
Direct Labor-Supervisory	$5,200	$8,700
Packaging Development	$300	included in direct labor & general supplies
Consumable Material	$2,500	
Kiln Consultants	$2,500	$1,180
Design and Layout Services	$2,000	included in direct labor
Glass Grinding	1680 pound for 60 kits	$420
Mold Mix		$100
Freight In		$287
Electricity		$260
General Supplies		$1,015
Washer Fuel		$281
Building Lease		$1,220
Repairs & Maintenance		$1,007
Freight Out		$74
Small Tools & Equipment		$286
Travel Expense		$63
Utilities		$426
TOTALS:	$12,500	$15,319

APPENDIX 3: SAMPLE OF TILE EVALUATIONS

TILE EVALUATION

Tile No.: 52:1a_ Color: Clear___ Grain Size:_3x6__ Firing Schedule:_#2__

Firing No.: _52_______ Weight:_154g_____

Contamination:__Green Glass_______ Devitrification:________________

Surface Texture: __Fused, flowed, particles still visible_________________________

Faults: Poor corners, blips on screen____

Clarity: Opaque Translucent Transparent Clear Crystal

Edges: __Spikey_____ Corners: _Uneven______

Mold Release: _Did not stick to_ shelf primer Mold Side Surface: ___Grainy_______

NOTES: Might do better at higher temperatures on longer soak.________________

TILE EVALUATION

Tile No.: 52:1b_ Color: Clear___ Grain Size:_3x6__ Firing Schedule:_#2__

Firing No.: _52_______ Weight:_172g_____

Contamination:__Green Glass_______ Devitrification:________________

Surface Texture: __Fused, flowed, particles visible_____________________________

Faults: Blips on surface____

Clarity: Opaque Translucent Transparent Clear Crystal

Edges: Rough, spikey_____ Corners: Fair_______

Mold Release: _Did not stick to_ shelf primer Mold Side Surface: ___Grainy_______

NOTES: Might do better at higher temperatures on longer soak.________________