TIPSHEET 3

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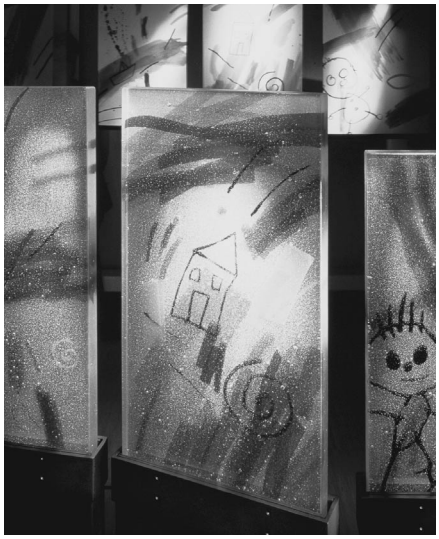
WORKING DEEP
STACK FIRING FOR IMBEDDED IMAGERY

This issue of Bullseye's TipSheet will introduce you to ways to float imagery and color within thick blocks of clear glass. Thick glass castings have resulted historically from pours of furnace glass or by kiln-melting glass chunks or frits. The method we will call "stack firing" results instead from the fusing of multiple layers of clear sheet glass on which are imbedded lines and fields of colored glass. This method is direct, simple and allows greater control of line quality than is achievable with other techniques. The reader is assumed to have a basic knowledge of glass fusing methods.



Silvia Levenson, "Un Mondo Migliore." 16 glass blocks for fountain installation, Northbrook, IL. Each block 19" x 35" x 1 3/4" (483 x 889 x 44mm)

After the Northbrook project we scaled down those methods and incorporated them as segments of our beginning and intermediate kilnforming classes. TipSheet 3 will lead you through both versions of stack firing: Single-Fired Stack and Double-Fired Stack.

The primary technical challenges involved in this working method are

- the control of trapped air (bubbles)
- restraining the glass flow at full fusing temperatures
- extended heating and cooling cycles
- the minimization of cold-working to the finished project.

WHERE YOU'RE GOING: THE FINISHED BLOCK

Whether achieved through one firing or two, the end product will be a solid block of clear glass with internal imagery and color as complex or as simple as your personal style dictates. The bottom and sides of the block will have a faint matte iridescent finish. Its top face will be glassy and smooth with a soft bullnosed edge. It will measure about 8" x 8" x 1 3/4" (203 x 203 x 44mm). These dimensions may be enlarged or reduced by adapting the general guidelines and adjusting the firing schedule.

ORIGINS AND EVOLUTION OF THE METHOD

As with most techniques that develop at Bullseye, the methods we will describe evolved from an artist project at the Bullseye factory. Italian artist Silvia Levenson was commissioned to produce a series of large glass blocks for a fountain in Northbrook, Illinois. The extensive equipment and technology required that Levenson engage the services of Bullseye's research and education department to produce the work. We, in turn, asked Ray Ahlgren* to develop a method and oversee the production of the fountain blocks.

WHAT YOU NEED TO GET THERE: THE MATERIALS

Glass: Because clarity is essential when working deep we recommend using a very bright clear—one without a blue, green or yellow tint: *Bullseye's #1401-30F. 1401-30* is a non-lead crystal clear sheet glass which will not muddy or mask your internal colors or lines. "-30" refers to the *flat,* double-rolled variety. This flatter sheet will help to minimize air entrapment and the resulting bubbles.

* Ray Ahlgren, owner of Fire Arts Studio in Portland, Oregon, was one of Bullseye's three founders and instrumental in the company's early explorations into kilnformed glass. Fire Arts specializes in larger scale fusing and multiple production methods with an emphasis on architectural and limited edition lighting.

For the bottom and four side walls use *#1401-37* or *1101-37.* These are Bullseye clear glasses with a faint silver iridescent finish. Alternatively you may select colored irid side pieces to create a contrasting frame around the block. The iridescent finish will give a cleaner release from the fiber paper or shelf separator than will the raw glass which tends to pick up minute particles of fiber or powder.

The interior imagery will be created out of *cut sheet, frits, powders and stringers* of colored glass.

Other materials: During firing the glass stack will be restrained from flowing outwards by *refractory dams*. These may be made of *mullite clay* (sawn up kiln shelves) *or ceramic fiber board*. The stack will sit on a mullite clay shelf which may be primed with *shelf separator* or covered with *fiber paper* or *ThinFire*. The upright dam walls will also require fiber paper strips to separate the glass from the refractory dams.

The Process: Single-Fired Stack

Glass blocks may be created in a single firing, but because of the potential for air entrapment, this method is not recommended for blocks larger than 8" (203mm) square.

Cut List
For a block that will measure approximately 8"x 8"x 1 3/4" (203 x 203 x 44mm) after firing, cut the following pieces of glass:

1401-30F Crystal Clear sheet
13 @ 7 3/4" x 7 3/4" (197 x 197mm)

1401-37F Crystal Clear
(or any colored glass with iridescent finish):
4 @ 7 7/8" x 1 7/16" (200 x 36mm)
1 @ 7 3/4" x 7 3/4" (197 x 197mm)

Cut **4** pieces of 1/8" (3mm) thick fiber paper to each measure: 8 3/16" x 1 3/4" (208 x 44mm)

Cut **4** dams from mullite clay shelf material, ~5/8" (16mm) thick or more, or from rigidized ceramic fiber board, ~3/4" (19mm) thick or more, that measure at least: 9" x 2" (229 x 51mm)

Consider Your Design
Sketch out your design on tracing paper, using one sheet of paper for each layer of glass that will hold your imagery. Use these as a guide as you build your glass stack.

Remember that *less is more* in this process. Avoid large amounts of colored sheet glass, frit or stringer within the interior. The clear block can quickly become muddy and chaotic.

If you use colored sheet glass for your imagery, plan to cut the forms *into* the clear glass just as you would create the parts for a stained glass window. Avoid laying a colored sheet glass form on *top* of the clear square. Instead, cut that same form out of the clear square and replace it with the colored form so that you keep all layers as flat as possible.

You may include as many or as few layers of imagery in the block as you wish as long as you keep the bottom two (2) and top three (3) layers free of any cut pieces.

Layering the Image: Avoiding Bubbles
Once you have your design, begin to build the stack.

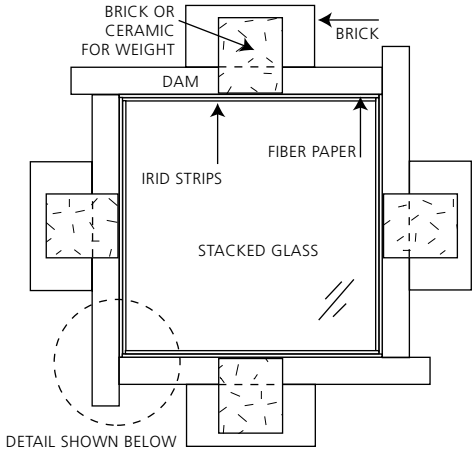
Place the square of clear irid glass irid side down onto a piece of thin cardboard (slightly larger than the sheet glass) on your worktable. Then place a single layer of clear on top of the irid square. When you later transport your stack to the kilnshelf, the cardboard will allow you to gently slide the stack onto the shelf with minimal jarring of the glass.

Depending on the complexity of your design you may begin to compose directly on the second layer or stack up a few more squares of the clear glass. Keep the total amount of glass used for inclusions to no more than the equivalent of a single layer of sheet glass. If you add more than that, remove a layer of clear in order to keep the total volume of glass relatively constant.

Finish the stack with *at least* 3 full layers of clear that do not contain cut pieces or frits. Using fewer layers of full sheets at the top of the stack can result in bubbles rising through and breaking on the surface.

As you design each layer, consider how the air will escape out the sides during firing. Avoid encircling areas with "barriers" of sheet glass, frit or stringer. Design in "escape routes" by which air can move laterally from the center of the block to the edges. Air which does not move out laterally during the first stages of firing will be trapped in the interior and rise up as bubbles during the later stages. These bubbles can break through the surface and eventually erupt as craters on the surface of the block.

Once all layers are composed, tack them into place with a light glue or holding agent to keep them in place during transport to the kiln.



LAY-UP VIEWED FROM ABOVE

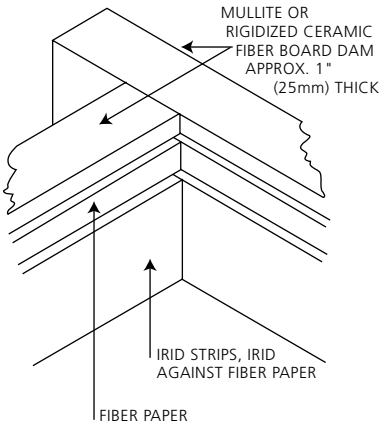
Building the Side Walls and Dams: Restraining the Flow

Because glass which is higher than 1/4" (6mm) will flow outwards when fired to a full fuse, the glass stack must be surrounded by a dam of refractory material. At the same time it must be prevented from sticking to that material.

For dams we use strips of 1" (25mm) thick rigidized ceramic fiber board on all four sides. Other refractory materials—soft brick, fire brick, or strips sawn from mullite clay shelves—may also be used to build your dams. Behind the dams you will need additional support in the form of bricks or other heavy refractory materials. Otherwise the outward pressure of the melting glass will push out and/or topple the dams.

You will also need brick or refractory weights on top of the dams. We use 1.5 lb. (681 g) per dam. Without them the glass can seep out at the base and side seams.

You will use strips of 1/8" (3mm) thick ceramic fiber paper to prevent the glass from sticking to the dam walls. The fiber paper must fit properly at all joints. Sloppy fiber paper joints will also result in glass seepage.



CORNER DETAIL

On a level shelf in the kiln construct your first corner of support bricks, dams, fiber paper and irid. Check that the irid side of the glass faces towards the fiber paper. Make sure the construction is perfectly square. Then transport your stack to the kiln. Gently slide the glass stack up against the two dam walls. If you've transported it on cardboard it will slide easily onto the shelf and into place.

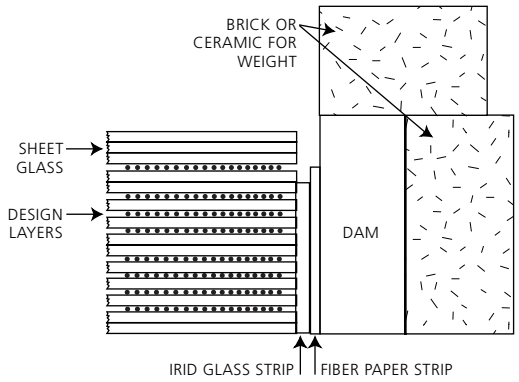
We recommend using ThinFire on the shelf because it gives the cleanest release and also allows the glass to be moved about on the shelf without scratching through the shelf primer.

After positioning your stack into the first corner, construct the two remaining sides with irid strips, fiber paper, dams and brick supports.

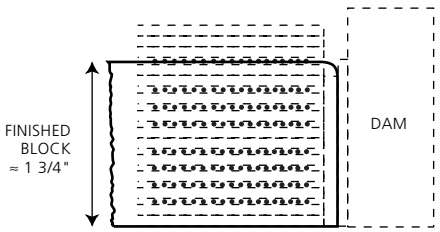
It is not necessary to clean the interior pieces of glass in your stack. It is imperative, however, that your top sheet of clear glass is spotless. Any finger prints, oil smudges or dust on the top surface will fire into the block.

Check that the stack is well aligned with all sheets of glass directly above each other. Weight the tops of the refractory dams with pieces of kiln shelf or brick.

Fire according to Schedule #1, *Single-Fired Stack,* on page 5.



CROSS-SECTION OF SINGLE-FIRE STACK



CROSS-SECTION OF FINISHED BLOCK

Top Edge Detail: How to Avoid "The Grind"

Once the kiln has reached room temperature (not before!!), remove the block. It should have a top surface that rolls cleanly into a bull-nosed edge. This is because the total *volume* of your interior glass stack was designed to be higher than the upright side strips by about 5/16" (8mm). As the glass stack melted, it flowed outwards just enough to meet the upright sides but not flow up against the dams.

Often during the initial lay-up the sheet glass stack will look much too high relative to the irid edges—certainly higher than 5/16" (8mm). However, unless you have exceeded the recommended amounts of frit, stringer, cut sheet (the equivalent of 1 layer) in your design elements, this will not have been a problem. *The upright irid edges being too high is always more of a problem than their being too low.*

The Process: Double-Fired Stack

As just shown, it is possible to create the glass block in a single firing. However, you will have more control and fewer problems with trapped bubbles and distorted imagery if you pre-fire your image layers.

Fire to a full fuse, ~1450°F (788°C) or higher, double layers of clear onto which your cut pieces of thin glass, frits, powders or stringers have been placed. Keep the decorative parts at least 1/2" (13mm) away from the edge of the clear sheet to prevent its flowing out of square.

Fire according to schedule #2, *Pre-Fired Layers of Double-Fired Stack,* on page 5.

You may create up to four fused "design layers" (8 layers of clear). This allows for two clear layers at the bottom, three clear layers at the top, and a single clear layer somewhere else within the stack.

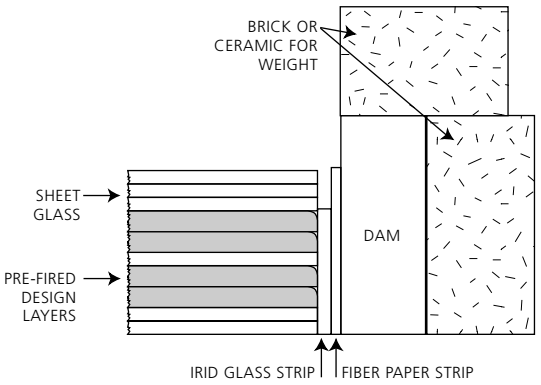
After you have created these initial design layers, try stacking them up different ways to test whether the final piece will work out as you like. The advantage of the double-fired stack is that you have an opportunity to see the piece at this stage and make changes. Furthermore, you can work on the very top layer of the stack, increasing the possibilities for creating depth.

Building the Double-Fired stack

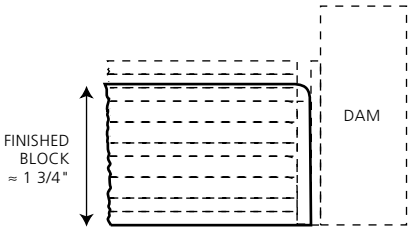
Build the side walls and dams to restrain the flow of the glass in the same fashion as you would for a single-fired stack. The stack of pre-fired layers will be considerably lower than the total stack for your single-fired project. Remember to place the iridized sheet on the bottom of the stack with the irid coating face down against the shelf.

As with your single-fired stack, be sure the top surface sheet is thoroughly clean of film, oil, or dust.

The suggested firing schedule for the second firing is #3, *Second Firing of Double-Fired Stack,* on page 5.



CROSS-SECTION OF DOUBLE-FIRE STACK



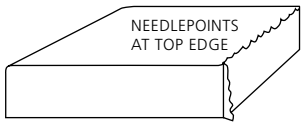
CROSS-SECTION OF FINISHED BLOCK

Trouble Shooting

If you have followed the directions given here your fired block will have a smooth top surface, bullnosed upper edges, clean sides and 90° corners.

PERFECT PROFILE

A block which does not match this perfect profile can result from one or more of the following conditions:



FLASHING AT CORNER

Needlepoints at the top edge can occur for several reasons. If you have failed to center the top pieces of sheet glass and they are in contact with the fiber paper along the dams, they will catch along the fiber paper as the glass melts. Needlepointing can also occur when the iridescent sides are too tall in relation to the stack of glass that they surround. Be certain to cut the iridescent sides 5/16" (8mm) shorter than the total height of your fired stack of glass:
14 layers ≈ 1 3/4" (44mm) - 5/16" (8mm) = 1 7/16" (36mm) irid sides.

Firing Schedules

1 Single-Fired Block

FAHRENHEIT

RATE (°F/HR)	SET POINT TEMPERATURE (°F)	HOLD TIME (HR:MIN)
400	1250	3:00 A
600	1500 B	:20
AFAP C	960	3:45
12	740	:00
24	655	:00
120	75	:00

CELSIUS

RATE (°C/HR)	SET POINT TEMPERATURE (°C)	HOLD TIME (HR:MIN)
222	677	3:00 A
333	816 B	:20
AFAP C	516	3:45
6	393	:00
13	346	:00
66	24	:00

2 Pre-Fired Layers of Double-Fired Block

FAHRENHEIT

RATE (°F/HR)	SET POINT TEMPERATURE (°F)	HOLD TIME (HR:MIN)
450	1250	:45
600	1480 B	:10
AFAP C	960	:30
210	700	:00
400	75	:00

CELSIUS

RATE (°C/HR)	SET POINT TEMPERATURE (°C)	HOLD TIME (HR:MIN)
250	677	:45
333	804 B	:10
AFAP C	516	:30
116	371	:00
222	24	:00

3 Second Firing of Double-Fired Block

FAHRENHEIT

RATE (°F/HR)	SET POINT TEMPERATURE (°F)	HOLD TIME (HR:MIN)
400	1250	1:15 A
600	1480 D	:10
AFAP C	960	3:45
12	740	:00
24	655	:00
120	75	:00

CELSIUS

RATE (°C/HR)	SET POINT TEMPERATURE (°C)	HOLD TIME (HR:MIN)
222	677	1:15 A
333	804 D	:10
AFAP C	516	3:45
6	393	:00
13	346	:00
66	24	:00

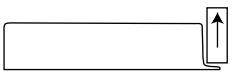
A A longer soak is necessary for the Single-Fired Stack than for the Double-Fired. More time is needed to "squeeze" any trapped air from the interior of the design layers in order to avoid bubbles.

B Process temperatures and soak times will vary from kiln to kiln.

C "As Fast As Possible" will be whatever cooling rate results from the kiln power being cut by the controller. We do not advocate crash cooling. Leave your kiln closed, allowing it to cool naturally to the anneal soak temperature.

D The slightly lower temperature and slightly shorter soak on the Double-Fired Stack compensates somewhat for the heat work that has already gone into this glass in the pre-firings.

Flashing at the corner seams happens when the fiber sides and/or the dams are not properly sealed in the lay-up process, or when dams are not properly buttressed from behind. Once again, the molten glass at top temperature has enough force to actually push a dam outwards. Be sure to sufficiently reinforce your dams with fire bricks or other weighty materials. Also, if the irid sides have been cut too long, the edges will have a similar problem that is not unlike flashing. Be sure that there are no overhanging edges in the assembled stack.

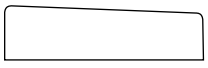


FLASHING AT BOTTOM EDGE

Flashing at the bottom edge is the result of the molten glass flowing under the dam. This typically happens when the dam is not sufficiently weighted from the top. The molten glass actually causes the dam to float upwards, and then flows under the dam.

BUBBLES BREAKING SURFACE OR UNDER SURFACE

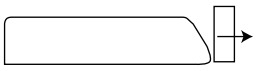
Bubbles erupting through the surface are often the result of having piles of frit or sheet glass between layers that are closest to the top. Bubbles may also result when colored sheet glass elements have not been very carefully intercut with clear. When making a block in a single firing, try to have at least three sheets of clear on top of the design layer closest to the top of the stack, and take extra care that cut pieces fit together tightly.



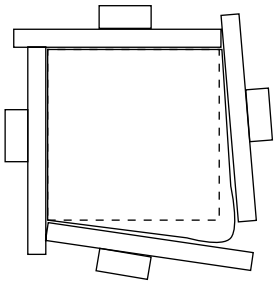
KILN SHELF NOT LEVEL

DAMS NOT VERTICAL–FINISHED BLOCK WON'T SIT VERTICALLY

Uneven thickness most often is the result of a shelf that is not level. Be certain to level your shelf before you begin building on it, and then check the level after you have completed the stack.



Improperly braced or non-vertical dams will result in a block with inclined sides.



PUSHING OUT WALLS

Weak bracing will also likely allow the dams to be pushed outward and the block to flow out of square.

If the *glass sticks to the shelf,* it is usually because there was not a sufficient shelf separator such as kilnwash or fiber paper between the glass and the shelf. Never re-use a coat of kilnwash, but rather scrape it off and prepare every shelf anew for each firing. The glass is also more likely to stick to the shelf when it is fired too hot. Try to avoid temperatures in excess of 1500°F (816°C) for times in excess of 20 minutes. For a foolproof clean surface, use ThinFire paper.

If the edges of all the glass in the stack appear to be "highlighted," it is because the irid sides were set up with the irid coating facing inward. Make certain that all irid surfaces face outwards towards the fiber paper when setting up the stack.

Finishing

The techniques outlined in this TipSheet will result in a finished block with clean, rolled edges and crisp corners. If the block has sharp edges and/or needlepoints, grinding may be necessary. There are many tools and methods available for grinding glass, and they range widely in cost and size. The most basic, a sickle stone, will knock off sharp edges, but will leave a rough, abraded look. A belt sander or lapping wheel will do the job quickly, right up to a polish, but both are large and fairly expensive tools. Handheld diamond pads in grit sizes from 70 - 3500 do a wonderful job of everything from a rough grind to close to a polish.

Display

We worked with a local metalworker to fabricate the simple base pictured here. Smaller blocks can be used as paperweights, larger blocks work well as tops for end tables, really large blocks make incredible dividing walls, countertops, or even stair treads!

If you would like additional TipSheets for use in classes or distribution to your organization, they are available from Bullseye for 20¢ per copy plus shipping.

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