BULLSEYE BOX CASTING

Reverse-Relief Kilncasting in an Assembled Mold

This TipSheet describes how to create a reverse-relief cast glass object with the optical clarity of a furnace casting, using plaster/silica design elements in an open-faced mold assembled from vermiculite board and other refractory materials. There are several advantages to this process:

- Less waste than traditional kilncasting processes
- The majority of the molds will be reusable
- Molds will be of uniform thickness, allowing for uniform heating and cooling
- Molds will not fail at casting temperature (one of the most common concerns in kilncasting and the reason there is such a boggling array of mold recipes in use)
- Cleaner and more predictable results than kilncasting in most of the traditional methods
- Extremely easy to repeat for the purpose of making editions or production work

Ted Sawyer, *Speak*, 2003, 19.5 x 19.5 x 4 cm

Ted Sawyer, *Speak* (detail), 2003, 19.5 x 19.5 x 4 cm

Where You Are Going: The Finished Piece

The end result will be a solid block of glass with relief imagery in the back of the piece that when viewed through the flat front creates a nearly holographic image. The top surface of the piece will be glossy and smooth. If carefully planned and executed, the top perimeter will have a soft, bullnosed edge. Occasionally, some coldwork may be necessary or may enhance the finished work. The finished block will measure about 19.5 x 19.5 x 4 cm. These dimensions may be enlarged by adapting the general guidelines and adjusting the firing schedule.

Rafael Cauduro, *Tzompantli D*, 2002, 100 x 57 x 5 cm

ORIGINS OF THE METHOD

This method of kilncasting developed as an outgrowth of an artist exchange project in our Research & Education department with Mexican artist Rafael Cauduro. Cauduro had originally come to the factory to work in methods known as Painting With Light, but quickly became intrigued with kilncasting and began to make large-scale cast glass sculptures using traditional "monolithic" or one-piece refractory molds. The fabrication, handling, and technical challenges posed by making and firing these molds ultimately led the R&E team, assisted by Ray Ahlgren of Fireart Glass*, to begin researching other ways of building the molds. After the project concluded, the research continued. This TipSheet details the process we subsequently developed.

* Ahlgren was one of Bullseye's founders and instrumental in the company's early explorations of kilnformed glass. Fireart Glass specializes in large-scale fusing and multiple production methods with an emphasis on architectural work and limited-edition lighting. More information at fireartglass.com.

MATERIALS NEEDED

Glass

Because clarity is essential to creating a reverse-relief casting, we recommend using any of Bullseye's casting tints in billet form. Because they have smoother surfaces and less surface area by weight than other forms of glass, billets will trap less air than frit, powders, or sheet glass, and therefore create fewer bubbles in the final piece. Billets are preferable not only for the clarity they produce in the finished casting, but also because they are easy to handle, cut, and load into the mold. Our casting tints are formulated to gradually transition in color saturation as they go from thick to thin, making them ideal for this and other casting processes.

Other materials

- Clay and tools for modeling design elements
- Metric scale
- Metric ruler
- Accu-Cast 880 Alginate Blue or similar moldmaking material
- Mixing containers
- Bucket of water for initial cleanup
- Bucket of water for rinse
- Bullseye Vermiculite Board (8240)
- Stainless steel (deck) screws
- Bullseye Investment (plaster/silica) (8244) or similar refractory investment material
- Fiber paper (7036)
- Petroleum jelly
- Oil-based soap
- 946 ml food storage box, or equivalent
- Garbage can with liner
- Self-lubricating glass cutter
- Hammer

NOTES ON METRIC MEASUREMENTS

For the sake of simplicity, all units of measure in this TipSheet are metric. The decimal format of the metric system and its direct and simple translation from length to volume to weight in water makes it a superior system for studio work.

IN THE METRIC SYSTEM

1 cubic centimeter (cm^3) of water =
1 milliliter (ml) of water =
1 gram (g) of water

If the interior of an empty box measures 20 x 20 x 2.5 cm, then this interior has a volume of 1000 cm^3. 1000 cm^3 of water is equal to 1000 ml of water, which is equal to 1000 g of water. Bullseye glass is 2.5 times denser than water, so it would take 2,500 grams of Bullseye glass to fill this same volume.

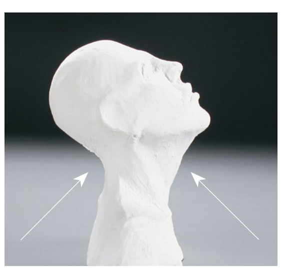
THE PROCESS

MAKING A MOLD FOR MULTIPLE COPIES OF A MODEL

Preparing a model using clay or a found object
Prepare a model no larger than 5 x 5 x 3 cm using either water- or oil-based clay. This model will be used to make the design elements that will create the reverse-relief imagery in the final casting. Water-based clay is usually softer than oil-based clay, can be modeled very quickly, and can be reused and recycled. However, it will dry out over time and will shrink as it does so. Oil-based clay is usually firmer, does not dry out, holds fine detail very well, is reusable, and releases very easily from most mold materials, including alginate, rubber, and silicone.

Found objects may need to be coated with a mold release, such as petroleum jelly or oil-based soap.

For this particular process, the model itself should have minimal undercuts. Undercuts on found objects can be filled in with clay. The very bottom portion of these design elements will end up being submerged in investment material to hold them in place in the final casting process, so plan accordingly.



Arrows indicate undercuts.

Preparing to pour a mold
Place the model into a box with a minimum of 15 mm of space all around it; a 10.5 x 10.5 x 9 cm flexible plastic food storage box with a slight draft to the sides works well. The box serves as a containment system into which you will pour the alginate to make the mold. Use petroleum jelly to secure the model to the bottom of the box to keep it from moving or floating when you pour in the mold material.

Types of flexible mold material for casting multiple copies
Accu-Cast 880 Alginate Blue mold compound is a type of alginate that is fairly easy to mix and sets in 5-10 minutes. It is somewhat weak with a short working life and will dry out and shrink over a couple of days, but if kept in a sealed container and treated carefully, it will usually last a few weeks.

RTV Rubber (Room Temperature Vulcanizing) is activated at room temperature but can have long set times and often takes 24 hours to cure into a very durable, very strong material.

For the sake of expediency, we have used Accu-Cast 880 Alginate Blue to illustrate this TipSheet.

Mixing Accu-Cast 880 Alginate Blue mold compound
Measure the containment system—including 1.5 cm above the model in the calculation. For our specific box and model, this is 10.5 x 10.5 x 4.5 cm, which equals 496 cubic cm, which means that it will take 496 grams of water to fill the box to the appropriate level. The manufacturer of Accu-Cast 880 Alginate Blue mold compound recommends mixing it 3 parts water to 1 part Accu-Cast 880 Alginate Blue by weight and adding the mold compound to the water, but we have had success mixing it 4 parts water to 1 part Accu-Cast 880 Alginate Blue by weight and adding the water to the Accu-Cast 880 Alginate Blue. For our project, then, we will need 496 grams of water and 124 grams of Accu-Cast 880 Alginate Blue. We get the best

results mixing this with a spatula in a bowl using a folding, not a beating motion, to avoid creating bubbles in the mix. Work in a well-ventilated area and wear a NIOSH-approved respirator whenever working with powdered materials.

Pouring the Accu-Cast 880 Alginate Blue

Be certain that you are working on a flat and level surface. Pour to one side of the object in a flowing motion to keep air from getting trapped on the surface of the model. Vibrate the worktable so that the air bubbles don't get stuck to the model.

Cleanup

Using water immediately makes a mess. Allow the remaining Accu-Cast 880 Alginate Blue to dry in the container and then immerse in a bucket of water for initial clean up. Once cured, it is possible to peel the Accu-Cast 880 Alginate Blue out as a skin. Never pour into a sink.

Removing the mold from the containment system

Turn the box upside down on the worktable and squeeze the flexible walls to let air into the sides until the mold drops out. Turn the mold over again and squeeze and push it carefully to remove the clay model. You now have a flexible mold for pouring multiple copies of your model in another material.

MAKING DESIGN ELEMENTS OUT OF REFRACTORY MOLD MATERIAL

Many different refractory mold (or "investment") materials and recipes exist. We use a simple mixture of 50% #1 Casting Plaster and 50% silica flour (295 mesh), mixed by weight.

Measuring mold material

Measure the original model and overestimate its size. It's better to discard some inexpensive investment than to run out and have to mix more in haste. Our model is roughly 5 x 5 x 5 cm = 125 cubic cm. Referring to the Investment Ratio chart on page 8, we can add together the amounts of material needed for voids of 100, 20, and 5 cubic centimeters to get the proper quantities of water and investment required for our 125 cubic centimeter void. This means that we will need 80 grams of water and 140 grams of investment. Weigh these materials in clean, dry buckets. Remember to work in a well-ventilated area and wear a NIOSH-approved respirator whenever working with powdered materials.

Mixing investment material

Steadily sift all of the required investment into the water. An island of dry material will begin to form once you have sifted most of the material into the water. Allow the investment to become fully saturated. If left alone, the investment can sit for quite some time. Once the mixture is saturated, dip your hand in and break up any chunks. Feel the consistency. It should have a creamy texture. Mix the investment by hand for 3-5 minutes or with an electric mixer/drill for 1-2 minutes. This will cause the plaster to begin to work so that it will subsequently set.

Pouring the mixed investment into the mold

Be certain that you are working on a flat and level surface. If you have a lot of fine detail, begin by brushing some investment mix into the details in the mold, which will break the surface tension so the mix can go into the details. Aim for one place in the mold and pour in a flowing motion to avoid creating bubbles. Once you have finished pouring, vibrate the work surface to make certain that no air is trapped within the details of the mold.

Cleanup

Clean investment mixing buckets right away. Old plaster in mixing buckets, on hands and/or on tools can cause subsequent batches of investment to set before you have a chance to pour them. Use dark colored buckets so you can easily spot old plaster in them. Never pour investment into a normal sink as this will clog the drain. Pour excess investment into a garbage can that has a liner in it. From there, have two buckets of water to use in your cleaning operation: one bucket for cleaning and scrubbing the mixing buckets and one bucket for rinsing them. When these buckets become too filled with waste investment to continue using them, allow them to settle, then pour off the excess water and dispose of the waste investment in garbage bags.

After investment has set up

It usually takes 5-20 minutes for the investment to set. Lightly touch the surface of the investment to test its hardness. Once it has set, the plaster/silica design element can be removed the same way the clay model was. Immediately after setting, the design element will still be a little soft, which means that it can be easily modified with simple clay tools. After the design element hardens, it can still be modified, but you may need to use power tools for the sake of speed.

Store the alginate/Accu-Cast 880 Alginate Blue mold in a closed container for later use, to keep it from drying out.

BUILDING THE BOX MOLD WITH VERMICULITE BOARD

Vermiculite board

Vermiculite has a bad reputation because it is often mined in the same places as asbestos, which can contaminate the vermiculite. Bullseye Vermiculite Board comes from a mine that is certified asbestos free. It is stronger, more durable, and less expensive than most fiberboard and can be cut and tooled like wood or particle board. Work in a well-ventilated area and wear a NIOSH-approved respirator whenever generating dust.

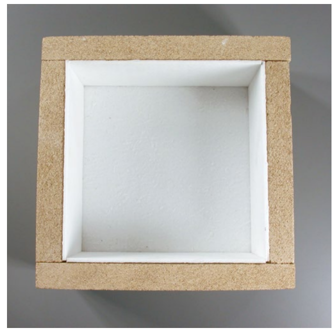
If you want your finished piece to be level and square, it is important to cut the vermiculite boards accurately. Also, pre-drill and countersink screw holes so the board does not bloat or blow out when you screw it together. Use stainless steel screws to put the mold together as they will hold up to repeated firings without flaking. Do not use galvanized steel screws because upon firing, the galvanization will release toxic fumes and the screws will flake and cause contamination in your kiln.

Cut two long side boards at 25.5 x 9 x 2.5 cm, two short side boards at 20 x 9 x 2.5 cm, and one base board at 25.5 x 25.5 x 2.5 cm. Lay the boards out as an open box and pre-drill holes in the flat surface of the long side boards to connect them to the ends of the short side boards using a bit that has a diameter slightly smaller than the diameter of the stainless steel screws. Be sure to drill your holes on center to avoid blowing out the side of the board. Then screw the sidewalls together. Next, set the base board on top of the assembled side boards and pre-drill holes to join it to the sides, and then screw it together. Then take the entire box apart and fire the vermiculite board at a rate of 500°F (278°C) per hour to a temperature of 1580°F (860°C) or about 55°F (30°C) higher than the temperature at which you will cast the glass. Hold at that temperature for half an hour, then crash cool the kiln.

Once the boards are cool, take them out and reassemble the sides using the stainless steel screws. Cut a piece of 3 mm fiber paper at 25.5 x 25.5 cm and set it on the base board, then set the assembled sides on top of the fiber paper, and screw the box together. Line the side walls with 3 mm fiber paper, making sure that it fits tightly, without bowing or leaving gaps in the corners.

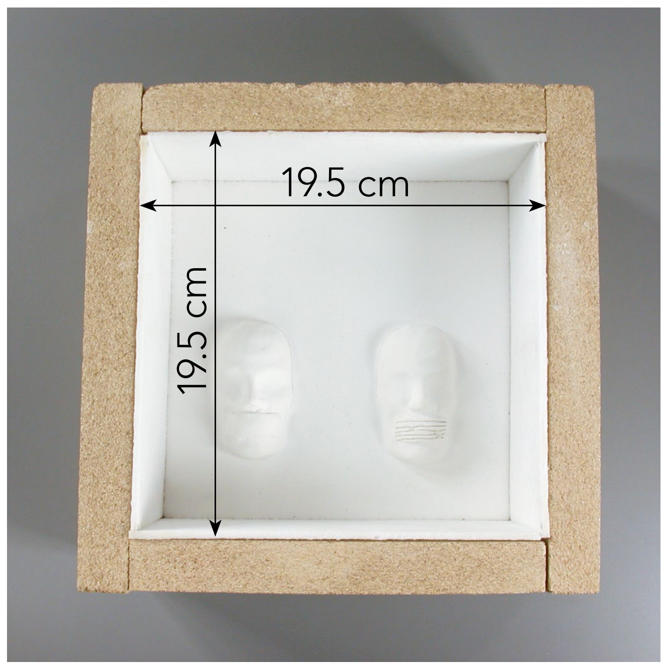
AFFIXING DESIGN ELEMENTS WITHIN THE BOX

The design elements must be held firmly in place for the glass casting process. To hold them, a shallow layer (or "bed") of investment is poured into the bottom of the box around the design elements.



Hydrate the plaster/silica design elements by soaking them in water until the bubbles quit rising (5-10 minutes). This helps to keep the plaster/silica bed from sucking in around the design elements due to differences in humidity. Arrange design elements on the interior base of the box. Check once again to make certain that your work surface is flat and level.

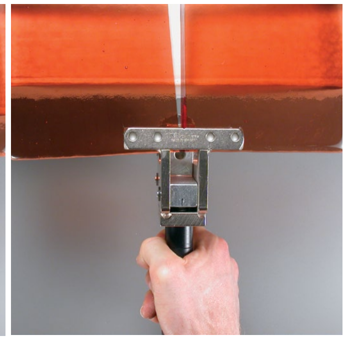
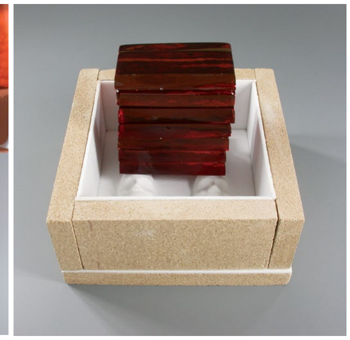
Measure the inside of the box to determine the appropriate amount of investment material needed. Our box is 19.5 x 19.5 cm, and we need enough investment to fill it about 0.5 cm deep. Thus, the investment needs to fill a void that is 190 cubic centimeters. The investment (plaster/silica) mixing table on page 8 has a batch listed for 200 cubic cm. This will be more than enough.



Mix the investment according to the previous directions and pour it quickly and evenly. Avoid pouring the mix directly onto the design elements or the side walls. Vibrate the work surface to assure that the investment levels out.

Set the box mold aside for 24 hours to make sure that all of the plaster/silica components of the mold have cured to an adequate hardness. As with the design elements, you may choose to modify the affixing layer of investment.



SELECTING GLASS

You may select any form of Bullseye glass to fill the mold (billet, cullet, sheet, frit, etc.), but the form that you select will have a direct impact on the clarity of the casting. The smaller the form of the glass, the more air bubbles in the finished piece, and the less optical clarity. Powders and fine frits will create so many air bubbles that even our Crystal Clear (001401) will appear milky white and opalescent when used at this 4 cm thickness.

Because this is a reverse-relief casting and the intention is to see the imagery created by the design elements through the surface of the finished piece, using billet will give you the desired clarity.

Calculating glass to fill the mold

Measure the inside of the box mold. Then figure out the cubic volume. Use a specific gravity of 2.5 for Bullseye glass to calculate how much glass will be needed to fill the mold to the desired thickness. (Bullseye glass is approximately 2.5 times heavier than water.)

OUR BOX MOLD:
19.5 x 19.5 x 4 cm (desired thickness of casting) =
1521 cm^3 1521 x 2.5 =
3802.5 (grams of glass needed)

This does not account for the displacement of glass caused by the design elements.

If you would like to account for the displacement caused by the design elements, or if you have an irregularly shaped mold, you can use rice for a more precise measurement. Fill your mold with rice to the desired thickness of the casting. Then remove the rice and decant it into a container. Level the rice, and then mark the level. Remove the rice from the container, and weigh the container. Then fill the container with water up to the former level of the rice, and weigh it again. Subtract the weight of the container to get the weight of the water. It will take 2.5 grams of Bullseye for every gram of water.

Cutting the billet

Use a self-lubricating glass cutter to score the billet. It will take about the same amount of pressure required to score 3 mm sheet glass.

It is always easiest to break the score if it is made along the centerline of the piece of glass. In other words, cut the billet in half, then in half again, to get the appropriate sizes to fill the mold.

Hold the billet low and over the table. Find the score line and break with large running pliers. Or hold the billet in a gloved hand and use a hammer to open the score by tapping on the back of the glass underneath the score line. (This does not take a lot of force. A tap exactly under the score line will cause the score to open cleanly.) Always wear eye protection.

Loading the glass into the mold

Clean and dry the glass thoroughly, making sure to remove labels. Any glass that is going to be lower than the thickness of the final piece can be against the mold wall, but be careful not to indent the fiber paper because it will create a bump on the finished glass piece. Stack the rest of the glass into the center of the mold.


Loading the mold into the kiln

Make sure that both the kiln and the mold are level. Set the box mold on kiln furniture/posts, establishing three points of contact at least 2.5 cm from the floor of the kiln. This will allow heat to circulate all around the mold. To intentionally create a wedge shape, set the mold up on an angle. However, make certain that you have enough glass to cover the design elements and that you adjust your annealing schedule to accommodate for the thicker area in the casting. If, for example, you would like a wedge that is 5 cm on the bottom and 2.5 cm on top, you will want to support the end that will be thicker on 2.5 cm kiln furniture, and the thinner end on 5 cm kiln furniture, and then calculate the glass as if you were casting a rectilinear volume with a thickness of 3.75 cm.

FIRING THE PIECE

Vent the kiln at least up to 1100°F (593°C) to make certain that all of the moisture has escaped. Plan to be present when the kiln is at casting temperature, to visually inspect the piece to make sure the casting is going as planned. If unwanted bubbles are present on the surface or just below the surface of the piece, plan to extend the hold at casting temperature until the bubbles have burst and healed.

Firing schedules provided are specific to the Paragon GL24AD kilns used in our Research & Education studio. All kilns fire differently. You may need to adjust the firing schedule for your specific kiln and project.

After the entire firing cycle is complete, we recommend leaving the piece in the kiln at room temperature for at least a day before taking it out to divest it.

Typical Cycle

STEP	RATE (degrees/hour)	TEMPERATURE	HOLD
1	100°F (55°C)	200°F (93°C)	6:00*
2	100°F (55°C)	1250°F (677°C)	2:00
3	600°F (333°C)	1525°F (830°C)	1:00**
4	AFAP***	900°F (482°C)	6:00
5	12°F (6.7°C)	800°F (427°C)	:00
6	22°F (12°C)	700°F (371°C)	:00
7	72°F (40°C)	75°F (24°C)	:00

* This time can vary. Set the time to ensure you will be in the studio to close the vents, and then be present when the casting reaches process temperature to allow for a visual inspection.

** Visually confirm. The casting may take more or less time to properly form.

*** Allow kiln to cool at its natural rate with the door closed.

CLEANING THE FINISHED PIECE

Remove the piece from the kiln and disassemble the box mold. Remember to wear a NIOSH-approved mask while handling the fired fiber paper and investment materials. Watch out for any sharp points where the glass has clung to the side walls of the mold.

The investment can be removed from the glass with a variety of tools, such as dental instruments, wooden picks, nylon brushes, and wood carving tools. Wooden tools are ideal for carefully removing broad areas of investment, and metal tools should be used delicately to clean fine details. A nylon bristle brush and forced air are also great tools for cleaning areas of residual investment. Most of the investment should be removed from the glass before submerging it in or scrubbing it with water. While water can be used to rinse away residual investment, we have found that scrubbing the glass with vinegar and/or CLR (a household product used for dissolving stains from calcium, lime, or iron oxide deposits) helps to break down the investment material.

Remember that you can create a very different effect if you decide to coldwork and/or polish your piece. The optical qualities can change substantially, especially with coldworking on the edges.

Ted Sawyer, *Speak* (detail), 2003, 19.5 x 19.5 x 4 cm

DIRECTIONS FOR DETERMINING VOID VOLUME

A. Decide your shape (square, rectangle).

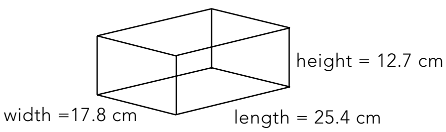
B. Set up your coddles. Leave space (about 5 cm) around and above project.

C. Use formulas to find the volume of your void (inside of coddles).

Square & Rectangle

Formula: length x height x width

Example:

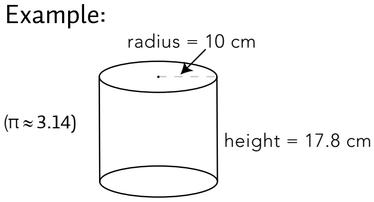


Volume: 25.4 x 12.7 x 17.8 = 5,741.9 cm^3

Cylinder

Formula: π x radius^2 x height

Example:



Volume: 3.14 x 100 x 17.8 = 5,589.2 cm^3

Notes

- Charts are not equivalent. (10,000 cm^3 is significantly less volume than 10,000 in^3.)
- Add together any combination of chart listings to best fit your project size.
- The investment recipe we have used is: 50% 295 mesh silica flour + 50% #1 Casting Plaster by weight.
- This chart uses a 1:1.75 ratio (water:investment).
- The investment ratio is suitable for many casting projects.

Imperial Investment Ratio

VOID SIZE	WATER WEIGHT	INVESTMENT WEIGHT
1 in^3	0.02 lbs	0.04 lbs
2 in^3	0.05 lbs	0.08 lbs
3 in^3	0.07 lbs	0.12 lbs
4 in^3	0.09 lbs	0.16 lbs
5 in^3	0.12 lbs	0.20 lbs
6 in^3	0.14 lbs	0.24 lbs
7 in^3	0.16 lbs	0.28 lbs
8 in^3	0.19 lbs	0.32 lbs
9 in^3	0.21 lbs	0.36 lbs
10 in^3	0.23 lbs	0.40 lbs
20 in^3	0.46 lbs	0.81 lbs
30 in^3	0.69 lbs	1.21 lbs
40 in^3	0.93 lbs	1.62 lbs
50 in^3	1.16 lbs	2.02 lbs
60 in^3	1.39 lbs	2.43 lbs
70 in^3	1.62 lbs	2.83 lbs
80 in^3	1.85 lbs	3.24 lbs
90 in^3	2.08 lbs	3.64 lbs
100 in^3	2.31 lbs	4.05 lbs
200 in^3	4.63 lbs	8.10 lbs
300 in^3	6.94 lbs	12.14 lbs
400 in^3	9.25 lbs	16.19 lbs
500 in^3	11.57 lbs	20.24 lbs
600 in^3	13.88 lbs	24.29 lbs
700 in^3	16.19 lbs	28.33 lbs
800 in^3	18.50 lbs	32.38 lbs
900 in^3	20.82 lbs	36.43 lbs
1000 in^3	23.13 lbs	40.48 lbs
2000 in^3	46.26 lbs	80.96 lbs
3000 in^3	69.39 lbs	121.43 lbs
4000 in^3	92.52 lbs	161.91 lbs
5000 in^3	115.65 lbs	202.39 lbs
6000 in^3	138.78 lbs	242.87 lbs
7000 in^3	161.91 lbs	283.34 lbs
8000 in^3	185.04 lbs	323.82 lbs
9000 in^3	208.17 lbs	364.30 lbs
10000 in^3	231.30 lbs	404.78 lbs

Imperial: Water weights on this chart are derived by multiplying the size of the void by 0.02313.

Metric Investment Ratio

VOID SIZE	WATER WEIGHT	INVESTMENT WEIGHT
1 cm^3	0.64 g	1.12 g
2 cm^3	1.28 g	2.24 g
3 cm^3	1.92 g	3.36 g
4 cm^3	2.56 g	4.48 g
5 cm^3	3.20 g	5.60 g
6 cm^3	3.84 g	6.72 g
7 cm^3	4.48 g	7.84 g
8 cm^3	5.12 g	8.96 g
9 cm^3	5.76 g	10.08 g
10 cm^3	6.40 g	11.20 g
20 cm^3	12.80 g	22.40 g
30 cm^3	19.20 g	33.59 g
40 cm^3	25.59 g	44.79 g
50 cm^3	31.99 g	55.99 g
60 cm^3	38.39 g	67.19 g
70 cm^3	44.79 g	78.38 g
80 cm^3	51.19 g	89.58 g
90 cm^3	57.59 g	100.78 g
100 cm^3	63.99 g	111.98 g
200 cm^3	127.97 g	223.95 g
300 cm^3	191.96 g	335.93 g
400 cm^3	255.95 g	447.91 g
500 cm^3	319.94 g	559.89 g
600 cm^3	383.92 g	671.86 g
700 cm^3	447.91 g	783.84 g
800 cm^3	511.90 g	895.82 g
900 cm^3	575.88 g	1007.80 g
1000 cm^3	639.87 g	1119.77 g
2000 cm^3	1279.74 g	2239.55 g
3000 cm^3	1919.61 g	3359.32 g
4000 cm^3	2559.48 g	4479.09 g
5000 cm^3	3199.35 g	5598.86 g
6000 cm^3	3839.22 g	6718.64 g
7000 cm^3	4479.09 g	7838.41 g
8000 cm^3	5118.96 g	8958.18 g
9000 cm^3	5758.83 g	10077.95 g
10000 cm^3	6398.70 g	11197.73 g

Metric: Water weights on this chart are derived by multiplying the size of the void by 0.63987.

BULLSEYE GLASS CO.