CHAPTER SEVEN

Slumping & Sagging

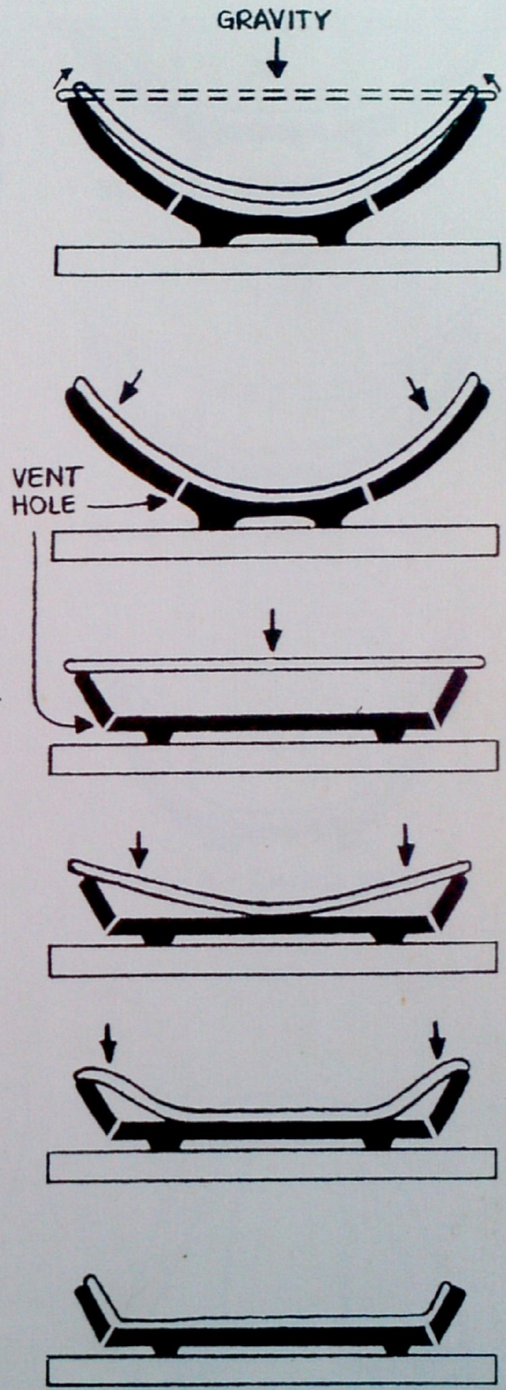
Slumping and sagging glass are processes of the use of heat and gravity to change the shape of a flat tile to a three dimensional form. These terms are similar in meaning and are often used interchangeably, leading to confusion. Because words are tools of communication, clarification of specific terms is necessary.

Slumping is nearly synonymous with sagging, however, slumping usually implies a bending *without noticeable change* in the thickness of the cross section of the glass. By keeping the temperature as close as possible to the fiber softening point (but high enough to allow downward movement), noticeable stretching is avoided.

Sagging is the downward sinking of glass, caused by its own unsupported weight as the glass softens when heated. We refer to sagging as a process whereby the thickness of the glass cross section *changes noticeabiy* due to stretching.

Glasses are often referred to as hard or soft. Harder glasses generally slump at higher temperatures and at a slower rate than soft glasses. Window glass and GNA glass are considered hard glasses. Some Bullseye glasses are hard, such as white, pink opal, and green opal. Others are soft, such as black and most Bullseye cathedrals. This means that different glasses, even from one glass manufacturer, can vary. Spectrum and Wasser glass are relatively soft glasses.

Glass melts or moves when exposed to heat work, not just temperature. A beef roast can be cooked at 400°F for three hours to achieve doneness or at 300°F for five hours to achieve the same doneness. It is heat work that cooks the roast. It is heat work, time and temperature, that should be controlled when sagging or slumping glass.



SLUMPING

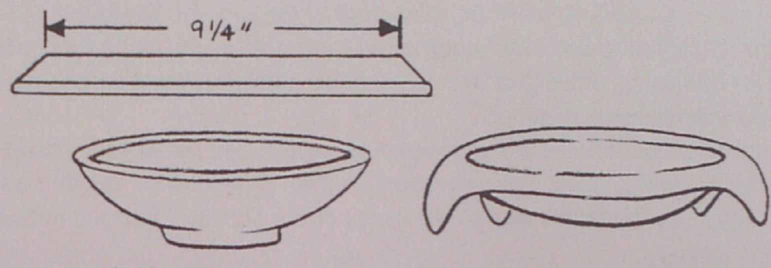
When a tile is placed over a mold and fired between 1300°F and 1350°F, the glass will slump and conform to the shape of the mold. Slumping should be done slowly. It is often necessary to slow the temperature rise of the kiln at 1300°F to allow heat soaking of the glass. This will even the temperature across the pre-fused tile, resulting in better, more even conformation to the mold.

Glass slumps first where the most weight is unsupported. Edges that overhang a mold will turn up as the middle sinks down, unless the overhang is great. As the slump progresses, the edges fall and the mold fills. In a square mold, the corners always fill last.

Vent holes are necessary in all nonporous molds. Vent holes should be placed in the areas of the mold that fill last. The center of the bottom always fills first, therefore is not the proper place for venting air trapped between the glass and the mold.

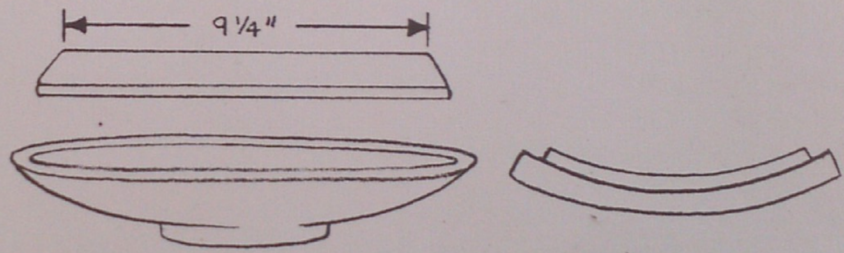
Opposite page: Fused glass deep slumped bowl, 18" diameter, Tim O'Neill.

When a 9 1/4" tile is slumped over an 8-3/4" shallow bowl mold, the four corners of the square tile fold over the outside of the round mold, creating triangular feet on a round bowl. If the triangular areas outside the round mold are not large enough to touch the kiln shelf they will turn back under the lip of the round mold, trapping the mold and making release impossible.



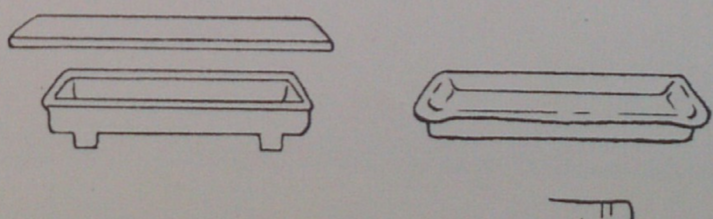
8 3/4" MOLD

When a tile of the same size, 9 1/4", is slumped into a 12" round mold, the result is quite a different shape, because the tile fits totally inside the 12" mold. Much of the shape of a finished piece depends on the size and shape of the original tile, in comparison to the size of the mold.

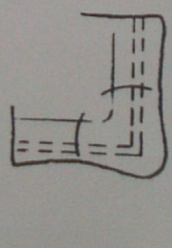


12" MOLD

A third shape is created when a 9 1/4" tile is slumped over a 8 1/2" square mold. Since a mold of this shape has corners, more time at slumping temperatures is necessary to allow the glass time to fill the mold cavity, because there is more glass that must fit into a constricted area. These three examples are very basic, but should be observed and understood before trying the use of more complex slumping molds.

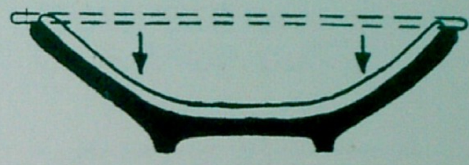


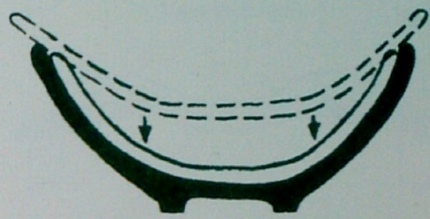
THERE IS TWICE AS MUCH GLASS TO FIT INTO A CORNER THAN THERE IS ALONG A SINGLE EDGE



Some slumped forms require the use of more than one mold. A deep bowl is just about impossible to slump in one firing using a single mold. A couple of things are likely to happen when an attempt is made to slump a large circular blank into a deep bowl all in one firing. The blank may stretch more on one side than the other, causing an off-center bowl with one side as much as two inches shorter than the side opposite. Or the glass may stretch on one side and ripple on the other, making an irregular, wavy lip.

To avoid these problems, a series of three progressively deeper and narrower bowl molds are used, in order to maintain control of the glass thickness and shape. To accomplish a deep bowl slump, the first slump is done into a platter mold, the second into a bowl of intermediate depth, and a third into a deep bowl with a flared lip.

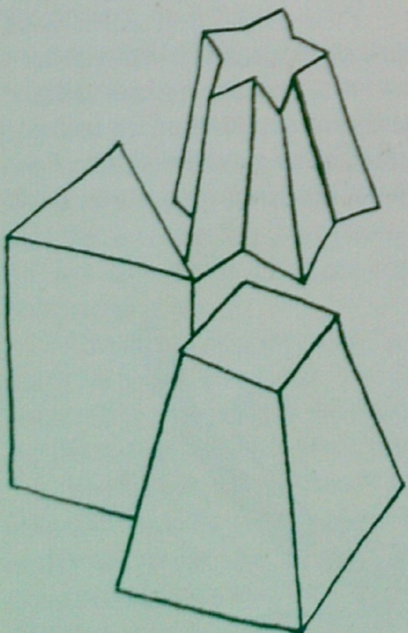

MOLD 1 - FIRST SLUMP

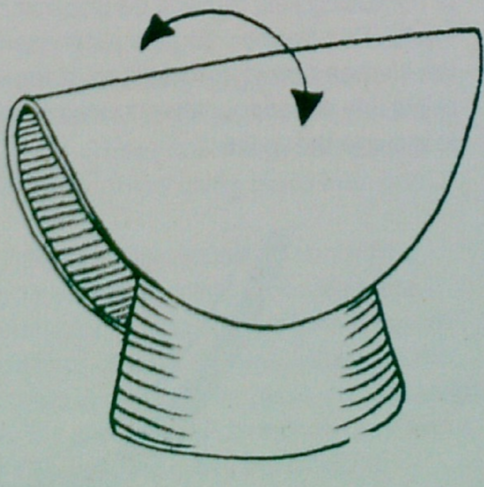

MOLD 2 - SECOND SLUMP


MOLD 3 - THIRD SLUMP

Draping glass over a tall form is a slumping process because, even though the glass folds back on itself, it does not change noticeably in thickness. There is a lot of chance and whimsy involved in draping. A blank of the same size, placed over the same mold, will almost never fold and drape the same way twice. There are similarities, but not many duplicates. It is a lot of fun to do a study of the variations, as in the following experiment.

Place a square or circular glass blank, in the kiln, over a metal or ceramic mold taller than one half the width of the blank. Heat the kiln very slowly; it is very easy to thermal shock a piece of glass that is supported only in the center. The glass will first fold in half forming a taco shell, then the two highest edges will fold down dividing the taco shell in half, forming quarters. At times it will fold into thirds and then sixths. Some control is possible by shaping the top of the drape mold.





AVOIDING THERMAL SHOCK

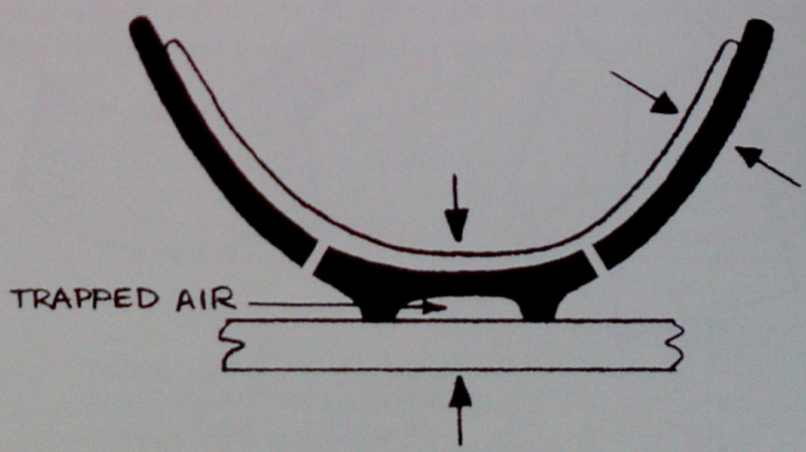
When slumping and then annealing a slumped form in (or over) a mold, there are three problematic areas to be aware of. Consider a typical slump: a pre-fused 9 1/4" circle to be slumped into a 9" bowl mold. The circular blank is 1/4" thick and has a design of different colors. It will be fired in a top element fusing kiln.

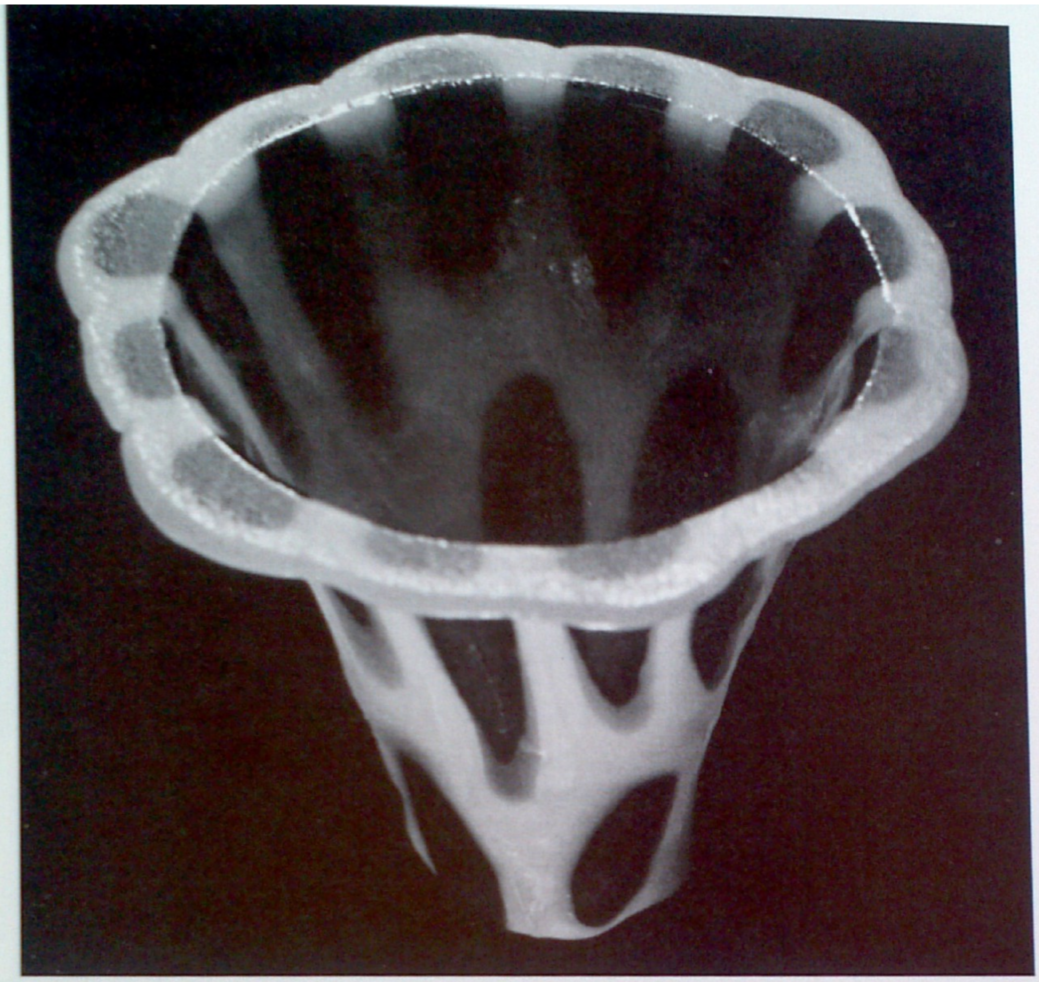
The first thing to notice is that different colors absorb heat at different rates. Black absorbs heat much faster than white. Secondly, the air trapped between the glass blank and the mold acts as an insulator. Thirdly, if the mold absorbs heat faster (or slower) than the glass, the glass will be affected where it touches the mold. For these reasons, it is important to raise the temperature in the kiln slowly to avoid thermal shock. A rule of thumb is to allow 10 minutes for each one inch of blank width between room temperature and the strain point of the glass. For Bullseye glass this would mean taking approximately 90 minutes for a 9" blank and 120 minutes for a 12" blank, to heat the glass to 900°F, safely past the strain point. This applies to tiles comprised of up to two and a half volumes of glass, ie. two layers plus design pieces.

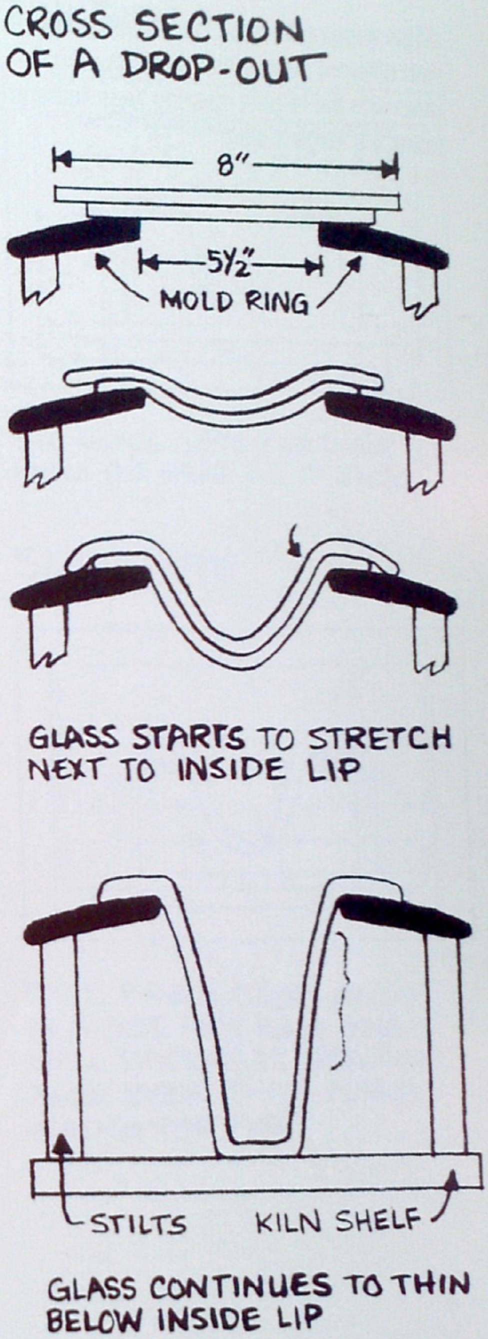
Glass that has not been fused flat, and has thick and thin textured areas has a greater tendency to thermal shock than does a piece of glass of even thickness. Glass that is supported in the center, such as a mask or a draped lamp shade, has a tendency to thermal shock. Moisture in the mold and uneven mold thickness may cause thermal shock. If any of these conditions exist, add more time to the initial temperature rise.

After the slump is completed there is the potential for uneven cooling during annealing, due to the mold configuration, mold placement, or unevenness in mold material. The most important attribute of a slump mold is that it have even wall thickness.

If the mold has a foot and has been placed on a kiln shelf or the bottom of the fusing kiln, air may be trapped between the foot of the mold and the shelf. This trapped air acts as an insulator and will keep the bottom center of the slumped bowl from cooling at the same rate as the elevated sides. To avoid this situation, place molds on small stilts or broken pieces of kiln shelf to elevate the mold.







SAGGING, THE DROP-OUT

The basic "drop-out" glass form is made by sagging two or three layers of glass through the center hole of a donut-shaped mold. This process is often carried out during one firing. The glass blanks placed on the mold, at one time, laminate together (fuse, but not fully) as they sag through the hole in the donut-shaped mold. The glass stretches until it reaches the kiln shelf and flattens, forming the bottom of the vase. There are many variations of this process, some using pre-fused discs and others using more than one hole in the mold.

The shape of a drop-out form is affected or developed by controlling many factors. These are: the glass composition, the rate of the sag, the shape of the opening in the mold, the distance the glass sags before reaching the kiln shelf or kiln floor, and the location of heat sources within the kiln.

The sagging (and slumping) properties of a particular glass are uniquely linked to its composition; glass of a specific composition stretches or deforms under its own weight, as affected by gravity, at a rate and temperature determined by its composition. Bullseye black 0100 and white 0113 slump at different temperatures, approximately 50°F apart. These two glasses also move at different rates; black moves rapidly and white moves slowly. This one example of two Bullseye colors may be extreme, but should point out that even when compatible glasses are used, large variations may exist.

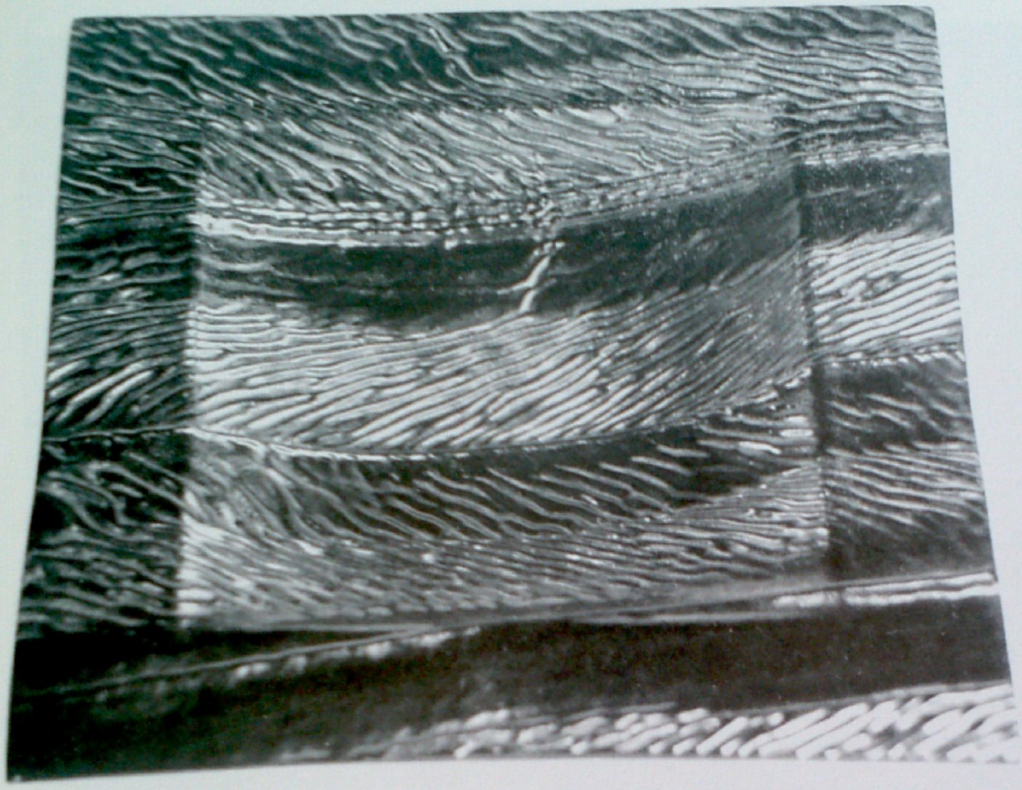
Window glass (1/8 inch float process glass) sags through a drop-out mold at a temperature 100°F above the sag point of Bullseye and 125°F above the sag point of Spectrum. The slumping properties of a glass are not determined by the coefficient of expansion of a glass but by other characteristics of glass composition.

Therefore, concise temperature information cannot be stated for the drop-out process. In general, the drop-out process is carried out between the temperatures of 1300°F and 1400°F, over a period of 45 minutes after the glass starts to move. The shape and size of the mold as well as the distance of the drop affects the time it will take and the shape of the finished piece.

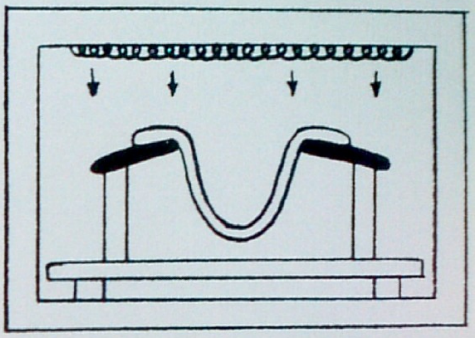
The temperature at which various glasses start to move or deform also depends on the amount of time spent in reaching that temperature. If GNA glass is heated to 1350°F over a two hour period it will start to sag through a 5 1/2" opening; if heated to the same temperature in 1 hour it will not. GNA will start to sag at approximately 1375°F to 1400°F, if the temperature rise is greater than 20°F per minute. And once it starts moving, it will drop through the mold opening at a faster rate than that of GNA heated more slowly, resulting in a loss of control.

Glass sagging through four flower molds with different sized stem openings. The mold with the largest opening sags first and forms the longest stem.

The slower the temperature rise after the glass starts to move, the more control you will have, resulting in a more even wall thickness in the finished piece. The time spent in the slumping zone has the greatest effect in achieving control. As a rule of thumb, a firing rate of not more than 5°F rise in temperature per minute should be maintained after reaching 1200°F. This can be varied depending on the hardness of the glass and the size and shape of the mold.

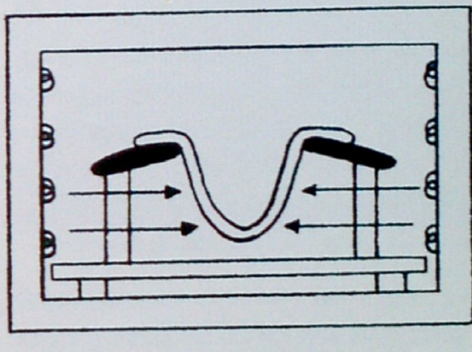


TOP FIRE



THE GLASS GETS FURTHER FROM THE HEAT AS IT SAGS

SIDE FIRE

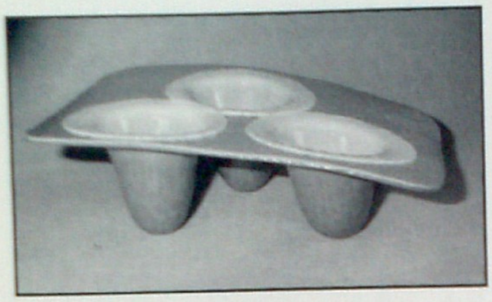


WHEN FIRING DROP-OUTS IN A SIDE FIRE KILN, THE WALL THICKNESS REMAINS MORE EVEN THAN WHEN FIRING TOP FIRE

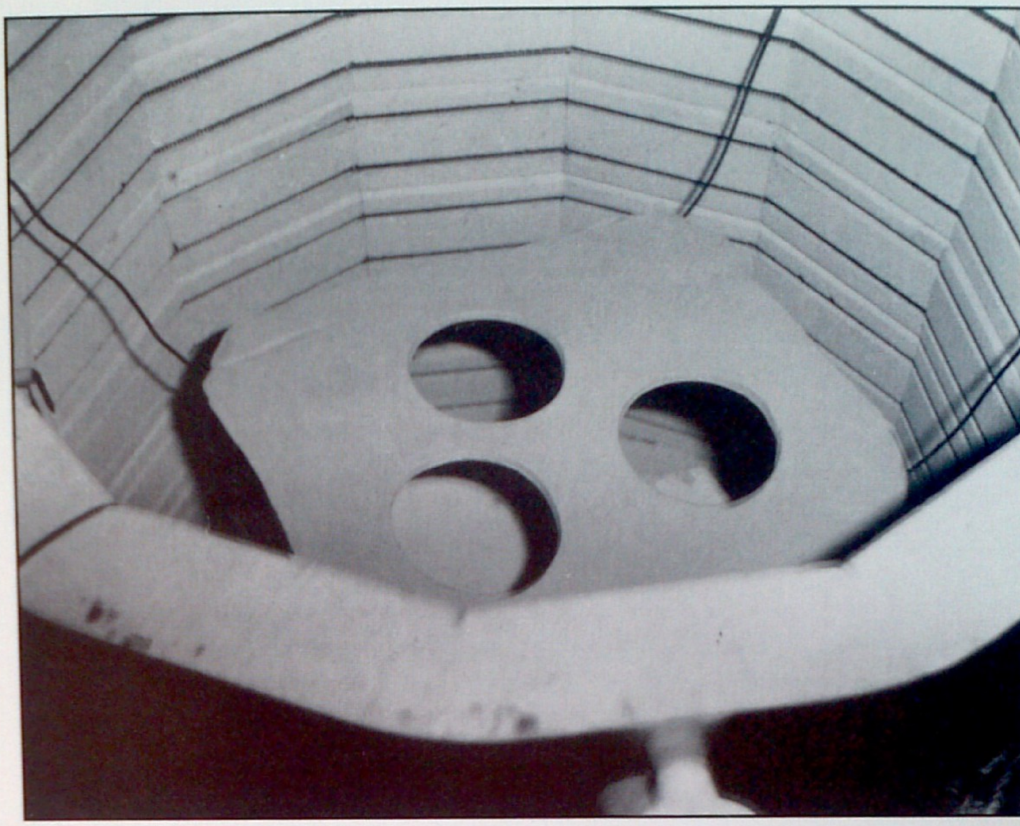
A top fired fusing kiln is not the best kiln for sagging glass. This can be easily understood once you see the product from different types of kilns. For discussion purposes let's say we are going to slump two 8" glass blanks through a donut shaped mold with a round 5 1/2" opening that has been stilted 6" above the kiln floor. If a top fired kiln is used, all the heat radiation from the top of the kiln heats the glass evenly until it starts to move. As the glass sags through the opening in the mold it moves further away from the heat. The glass closest to the top of the kiln stays hotter and stretches thinner, the thinner glass accepts heat faster and the result is paper thin glass just under the lip of the finished form.

This is not the case when the elements are on the sides of the kiln or on the bottom half of the kiln. A ceramic kiln with two rings (such as Skutt 818), where the elements can be controlled separately (upper and lower elements), is an excellent kiln for accomplishing the drop-out process. As the glass starts to sag, the upper elements can be turned down and the lower elements can be turned up. This heats the glass more evenly as it moves through the opening and drops toward the bottom of the kiln. Many small front-loading kilns are on the market that have elements only on three sides of the kiln. These kilns heat the glass unevenly and often cause the finished form to be off-center and uneven because the glass stretches less on the door side where there is no heat source.

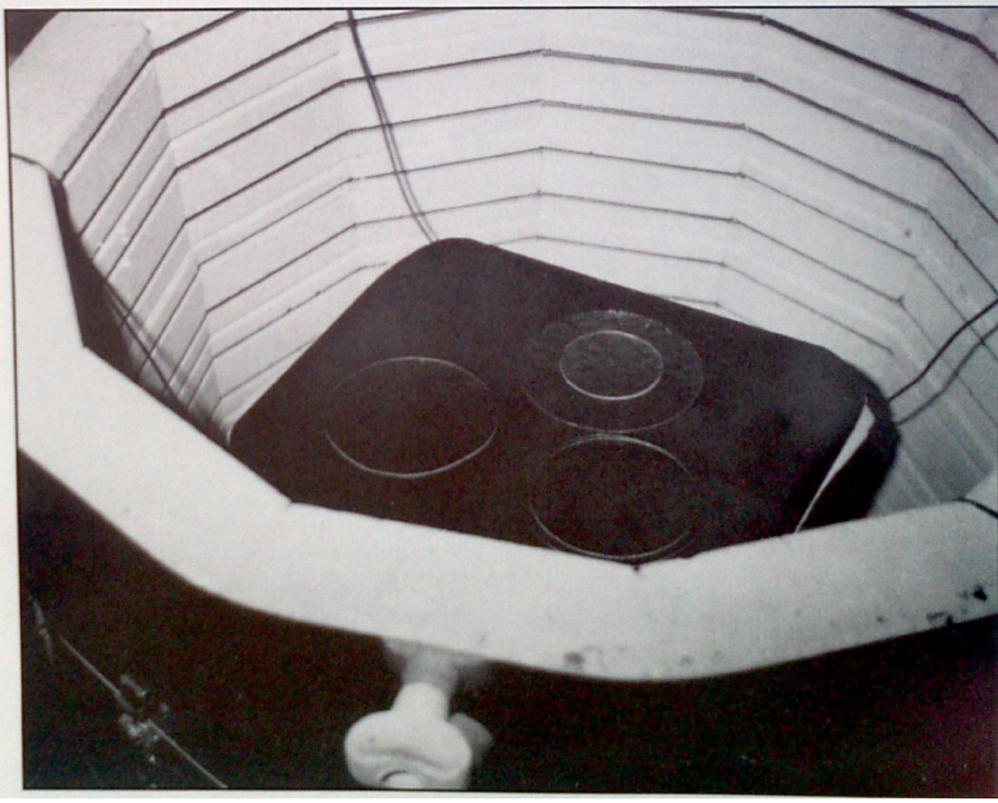
The heat source configuration (position of elements) in the kiln affects control of glass movement. This is not to say that a special kiln is necessary for the drop-out or air mold process. By slowing down the heating rate just as the glass starts to move, control can be gained in any kiln.



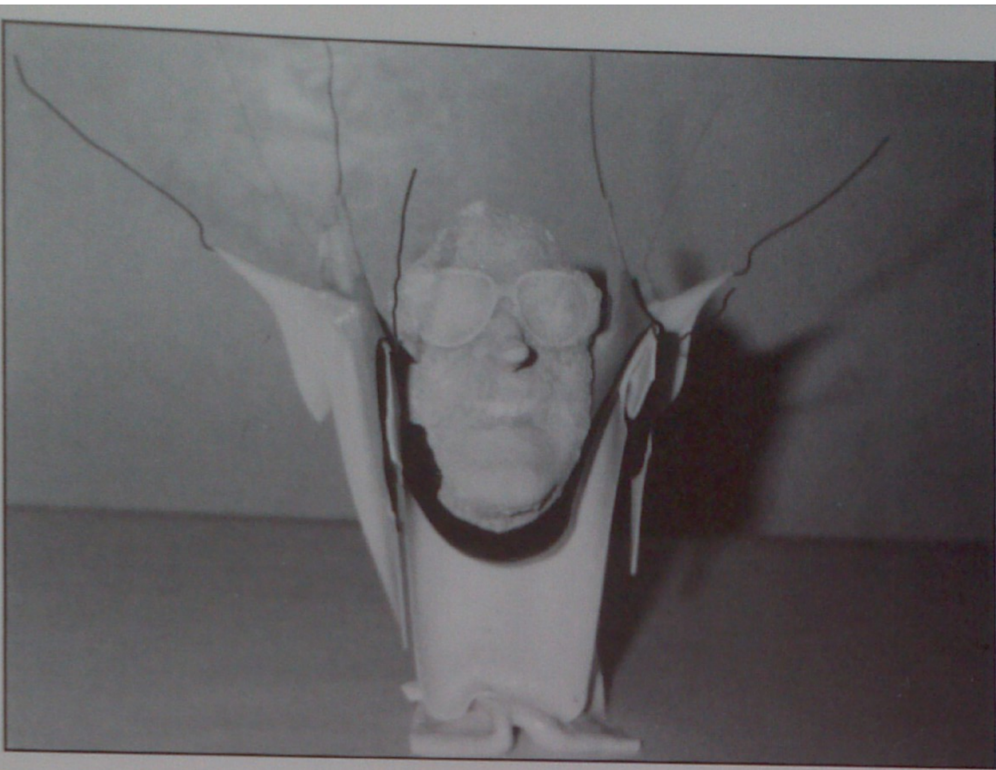
Completed sagged form with three bowl shapes, 15" x 22".



A bisque clay slab with three openings is suspended on wires supported from the top edge of the kiln. The lid holds the wires in place. A kiln shelf is placed under the suspended mold.



Two layers of glass, with a third layer of cut circles placed on top, covers the suspended clay mold. After the glass has sagged and cooled to 1200°F, the wires are released, lowering the mold away from the glass, to keep the glass from entrapping the mold.



Sagged sculpture with copper wire left in place. Cast face was glued in place after sagging.

Glass sculptural form, 14" x 25", created by sagging glass over copper wire suspended from outside top edge of kiln.

SAGGING THROUGH STRETCHED WIRE

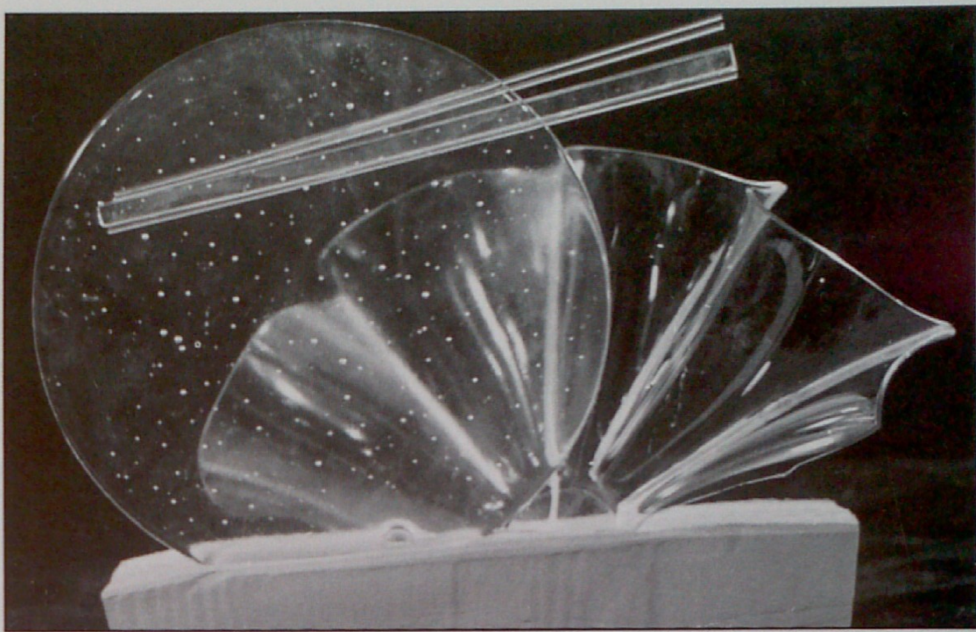
Stretching copper wire across a side-fire kiln, then placing glass over the wire and sagging the glass, can create an unlimited variety of forms. Functional bowl forms, vases and sculptural forms can be made with this process.

Heavy gauge copper ground cable can be obtained at most hardware stores. The copper wire should be coated with a heavy coating of shelf primer. Mix the shelf primer 1 part to 2 parts with water to make a heavy, creamy paste. After placing the wire in the kiln, heat it to 200°F, then paint one thick coat of primer over the wire. Let it dry completely before placing glass on top.

Wire can be attached to the kiln by placing it between the top of the kiln and the lid or by placing the wire between the rings of a multiple ring kiln. Stretching wires across a heavy metal frame that sits inside of the kiln or drilling holes through the side of the kiln is also a possibility.

The glass to be sagged can be multiple layers of any glass or pre-fused glass blanks. If some areas have more glass, the extra weight will cause the glass to sag faster in those areas. Forms made with this process can be cut apart and reassembled, adding infinite variety to sculptural forms.

Some wires oxidize, leaving a black residue on the glass. This can be removed with sandblasting. Wire can be wrapped with fiber paper, and held with staples.



Constructed, clear, sagged forms cast into Ultracal base.

Annealing wire sagged forms is very direct, since most glasses will anneal by just letting the kiln cool at its natural rate. The wire cools at a similar rate to the glass and is affected by the glass, since there is no other mold to cause uneven cooling. Annealing is not usually a problem, no matter how large the glass piece.

AN OVERVIEW

Glass tiles ready to be slumped are usually larger, thicker and often more uneven than during initial fusing and this glass is effected by the mold and the material it's made from, so more attention must be given to the even heating of the glass to avoid thermal shock. Understanding how glass heats, and the factors that affect its heating rate, can often be best understood by drawing a diagram of the glass on the mold in the kiln. This visual representation should include an indication of materials that could affect the thermal gradient within the glass. Such a diagram and observation of the glass during firing will prevent more potential problems than can be covered in any book. The following general notes should be considered for all slumping and sagging situations.

1. Thermal shock is cause by *uneven heating or cooling.*
2. Whenever possible, molds should be uniform in thickness.
3. Vent holes should be placed in the parts of the mold that will fill *last* - not always the lowest points within the mold cavity.
4. Shelf primer should be applied to all molds and allowed to dry.
5. Steep, vertical sides should be avoided when creating mold shapes, but can be achieved with multiple slumps.
6. Molds should be *level* before firing.
7. Molds should be slightly elevated from the kiln floor.
8. Slumping and sagging should be performed slowly, maximizing control over the movement of the glass.