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### Pate de verre process

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ROCHESTER INSTITUTE OF TECHNOLOGY

A Thesis Submitted to the Faculty of  
The College of Fine and Applied Arts  
in Candidacy for the Degree of

MASTER OF FINE ARTS

PATE DE VERRE PROCESS

By

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June 29, 1987

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## INTRODUCTION

The intent of this thesis is to present a concise summary of the basic processes involved in the *pâte de verre* method of casting glass. The *pâte de verre* process allows one to cast practically any conceivable form into a glass object. Prior to beginning, however, one should give some consideration to the entire process -- its possibilities and its limitations.

Beginning with making glass frit, the techniques covered include experimentation on combining glass frit with ceramic frits to achieve a variety of surfaces not normally available with one glass formula. The ingredients of the plaster mold used to contain the glass frit as it is fired will change based on different properties of each constituent and the effects each has in combination with the other materials and on the glass. Individual personal style and experimentation are the best determinant of which plaster formula and method of casting the mold will produce a superior glass casting.

The final stage in the *pâte de verre* process is firing the mold which has been packed with frit to a high enough temperature to melt the glass. The kiln is held for a period of time at the high temperature to allow the frit to fuse completely, flow into and fill the mold.

The pâte de verre process is flexible, allowing one to sculpt glass into forms not normally achieved with other glass-working processes. The glass casting, once fired, takes on characteristics that evoke other media — marble, quartz, stone — quite unlike our normal associations with glass. Yet the piece retains that quality of glass I find most fascinating and alluring — the ability to capture the light that passes into the glass body and reflect it back out. It is these characteristics — the enduring appearance of material and the hint of life and glow from within — that enable my sculptural work to begin to speak about life and its struggles, our fragility and our strength.

## CHAPTER ONE

### Glass Frit

Any glass can be used to make the frit needed for Pâte de Verre. Starting from raw batch formulas allows one to make the necessary adjustments for 'personalizing' the glass to accommodate various conditions and variations in finished results. Plate glass, vitrolite, neodymium and pure color bars have been used with varying degrees of success. The glass used most often in the following experiments was Gabbert cullet.

### Making the Glass Frit

The glass frit is melted in a furnace and then scooped and dropped by the ladleful into a large stainless steel container filled with clean water. Iron flaking from the steel ladle will cause black impurities in the frit and thus in the final piece, so only the cleanest and hottest glass in a pour is used. Any glass left clinging to the ladle is emptied into a separate bucket and discarded. The pouring of hot glass slowly into cold water causes the glass to shatter and fragment into small bits which when cool and dry are then sifted to remove the smallest particles. The larger chunks can be ground by hand using a mortar and



pestle type method, but impurities from the container or crusher could contaminate the frit, a problem discussed below.

Another method of obtaining frit is to grind the cullet using a gravel crusher or similar machine. Most of the frit used in this research was ground using a Buffalo Hammer mill and a Muller crusher. Using these machines caused rust and flecks of steel/iron from the hammers and machine interiors to be mixed with the grinding glass. The result was a great deal of discoloration in the frit, particularly obvious after firing. This problem is solved by soaking the freshly ground frit in a 10% solution of sulfuric acid for approximately one hour, which dissolves the iron. Once into solution, the iron contaminants can then be washed off. Repeated rinsing of the frit in clear, clean water is necessary to remove all traces of the acid solution; this inevitably results in the loss of a great deal of the finest glass particles. Finally to neutralize any remaining acid, the glass is soaked in water in which baking soda has been dissolved.

The glass, once cleaned and dry, is then sifted. Most of the sculptural work is made with a frit consisting of glass particles that are 30 mesh in size (about the same appearance as sugar) plus varying additions and combinations of 15 mesh (larger) and 100 mesh (smaller) particles. To obtain the varying sizes of the frit, the crushed glass is sifted (always wearing a respirator) using various sizes of aluminum screening fit into wooden frames. Each size of the graded frit is kept separately and used for different purposes.

The clarity of the glass in the form, different textures and surface treatments are controlled by using the different frit sizes. The finer frits trap more air bubbles that after firing present areas of greater opacity and milkiness. Firing pea-sized chunks of clear glass in a mold results in a very translucent 'marbled' glass that resembles quartz.

For color, Kugler and Zimmermann glass powders are used, thoroughly mixing small amounts (spoonfuls) of the color into bowls of moist clear glass frit until the desired color is achieved. With opal (opaque) powders, the color seen in the bowl is very close to the color of the finished glass casting. Using transparent or dark colors requires testing, as the transparent powders usually result in much stronger hues after firing. A good palette of colors is made by combining colored powders and "thinning" them with clear frit. The glass color can also be altered by using combinations of colored powders and different sizes of the clear glass frit. Using the finely ground powders with the larger mesh frit gives a mottled appearance to the final glass casting.

### Ceramic Frit

A ceramic frit is a glassy material produced by mixing all or part of the constituents of a glaze or enamel, melting the materials, pouring into water and grinding the fractured particles very finely. This process eliminates all or most of the toxic effects of any of the

chemicals (especially lead, barium, borax and soda ash), rendering the raw materials relatively safe.

The addition of ceramic frits is seen as a way to introduce other chemicals with desirable properties (especially lead) safely into the glass frit. There is a wide range of commercially manufactured ceramic frits available on the market today, all formulated for specific purposes. The chemical analysis, coefficient of expansion, firing range or fusion point, of each frit is available upon request from the manufacturers. Examining the specifications and ingredients enables selection of a frit which adds only those qualities desired.

Experiments were conducted by casting several similar forms in the same method and firing the molds to the same temperature following similar firing schedules. The positive forms were small wheel-thrown cup-shapes that had cones added as stems which also acted as the reserve sprues. The same molding formula was used and four cups were cast in each round mold. The samples were fired in two firings both taken to 1600°F at the same rate, and held for the same soak period at the highest temperature. The annealing period was also the same. Each sample consisted of a different combination of glass and ceramic frit.

The following represents the results of the tests using some of the ceramic frits determined by chemical analysis to contain desirable properties. All characteristics of the resultant samples are compared to one sample made using pure glass frit that had not been soaked in acid to

remove iron contamination from the grinding machines. The fired control sample was an overall green color with large green and brown specks scattered throughout the body — the result of the iron contamination in the uncleaned frit. The glass particles were fused, but still granular, not solid. The piece as a result had a rough surface texture which was soft; the surface of the body and any raised areas were easily scraped away.

### Ceramic Frits Tested

Ferro 3419 (G-23). All samples were an overall gray color with black iron streaks; marble-like body texture; mold lines not too visible; numerous bubbles inside samples and foam on surface — resulting from the ceramic frit bubbling or maybe boiling.

5% - Well fused lip; slight gloss at shoulder; short iron streaks (an indication of the fluidity of the glass in the firing); numerous bubbles throughout piece with fewer in sprue.

10% - Well fused with an almost translucent lip; overall nice semi-gloss surface; some foam on surface; short iron streaks.

15% - Nice texture but with less gloss and more foam on surface; long iron streaks; bubbles throughout piece making it mostly air.

20% - Not tested.

Ferro 3496. All samples were an overall gray color with black and green iron specks; mold lines very obvious; did not fuse sufficiently.

5% - Granular lip; hardly fused, rough texture with some foam on surface; iron specks visible though they did not move or streak.

10% - Granular lip; barely fused; faint gloss on surface; long iron streaks.

15% - Granular lip; rough texture, but fused; glossy surface; translucent; medium length iron streaks.

20% - Granular lip; rough texture; fused but still granular; foamy surface; glossy; translucent; medium length iron streaking.

Pemco 545. All samples were an overall dark gray color with black streaks and foam on surface.

5% - Granular and translucent lip; well fused; overall gloss on surface; trapped bubbles at sprue top; very long iron streaks.

10% - Smoothly fused lip; less gloss on surface; air bubbles and foam trapped at sprue top; long iron streaks.

15% - Well fused; soft gloss on surface; bubbles (but no foam) at sprue top; foam at shoulder; very long iron streaks.

20% - Well fused with evenly textured and smooth surface; very soft feel to surface; small bubbles and foam at sprue top; very shiny sprue top; specks of iron but no streaks.

Ferro 3110. All samples were an overall green color with green iron specks; very apparent mold lines; considerable leakage.

5% - Lip poorly fused; very rough surface texture overall (even at sprue); short iron streaks; trapped air bubbles in stem.

10% - Granular lip; rough surface texture overall (even at sprue); translucent lip and shoulder; foam and trapped bubbles at sprue top; unusual folding of 'skin' at surface of sprue.

15% - Granular lip; rough surface overall; some gloss at shoulder; foam and folding of skin at sprue surface.

20% - Lip granular in appearance but well-fused; rough surface; satin gloss at shoulder; translucent lip and shoulder; foam on sprue top.

Ferro 3466. All samples were an overall very pale grey color with inconspicuous black iron specks. Incompatibility of ceramic frit with glass indicated by fracturing and checking throughout all samples, increasing as ceramic frit percentage increases.

10% - Well fused throughout into piece; surface texture exactly reproduces even the intricate details of the mold; glossy surface; distinct mold lines.

20% - Somewhat less fused at lip; accurate reproduction of mold; semi-gloss overall.

20% with addition of 1% Kugler color powder - Similar to 20 and 30% samples, with more pronounced body fracturing.

30% - Somewhat less fused at lip; accurate reproduction of mold; semi-gloss overall; distinct mold lines; iron specks more noticeable, but did not appear to move or streak during firing; entire sample full of fractures and checks.

Ferro 3304. - All samples were an overall light grey body color with black iron specks; well-fused and very translucent. Excellent



reproduction of surface of mold; very obvious mold lines. No obvious bubbling of frit or trapping of bubbles.

10% - Almost transparent at lip; surface has some sheen; very solid body.

20% - Some evidence of ceramic frit incompatibility seen in cracking of lip; satin gloss; some foam on surface.

20% with addition of 1% Kugler color powder - Glossy surface; no apparent incompatibility.

30% - Semi-gloss surface; incompatibility indicated by several checks originating at lip and extending into body of sample.

### Making the Paste

The glass frit is mixed while dry with the desired proportion of ceramic frit by weight. A small amount of water is added to just moisten the frit and any desired colors are mixed to the desired hue (the moisture acts to allow a more true color of the ground glass color powders to become apparent). Next the binder is added to form the paste.

### Binders

Binders can be of any number of materials or chemicals which have the ability to hold the moist frit particles together while the mold is being filled, and which will leave no residue behind after firing. Gum arabic, pine oil, linseed oil, and sodium silicate are all recommended

and used in other processes to achieve similar results. Plain water works as well, or better than other agents, and is certainly less expensive and always available.

Enough binder or water is added to the frit to allow the particles to hold together while being pressed into the mold and to stay in place while other areas of the mold are being filled. The paste should be thick enough to hold the frit to the side of the mixing bowl when it is pressed against it. Adding too much binder, especially water, causes more moisture that will have to be expelled later from the mold.



## CHAPTER TWO

### The Positive Form

Forms that can be made in glass using the pâte de verre process are virtually unlimited, quite unlike the restrictions to be found in other casting or off-hand blowing processes.

The original positive form can be made of anything (i.e., clay, wax, soft rubber, paper, etc.), and in any shape which will allow for later removal from the plaster mold. The focus of the following research has been on using clay to create the positive forms; clay being easily manipulated and capable of being worked and re-worked for a relatively long period of time. Different states of clay hardness allow for the creation of very different surfaces and textures, all of which are extremely readable in the final glass casting. There is no need to allow the clay to harden before casting the plaster mold from the model; in fact, the softer the clay the easier it is to remove from the plaster mold.

Prior thought and careful planning are essential to insure successful results. The first restriction to come into consideration is the realization that no matter how small-grained the frit is and how tightly the mold is packed with the frit, the glass as it melts will

lessen in volume. Therefore, the mold, and thus the model, must be designed to either have a large reserve sprue attached above the piece or an opening into which glass can be added directly to the form during the firing. Usually one sprue is enough, but some forms could require several reserve sprues, especially if it has 'limbs', narrow joints, or projections from the surface.

The size limits of the available annealing facilities must be considered as well. The mold to be fired will be considerably larger than the actual glass form desired. The annealer has to be large enough to allow for ample air circulation around all sides (top and bottom included) of the proposed mold while firing. This is to insure uniform heat distribution around and penetration into the mold. If the annealer is uneven in heat distribution, especially if it is hotter at the top, the glass in the reserve sprue at the top of the mold could melt much faster than the glass within the mold. This will result in trapped air and uneven or incomplete filling of the form.

Some shapes are much easier to achieve (successfully) than others. Glass will not flow uphill; gravity is what pulls the molten glass into the mold. Bowl-shapes and cones in general allow the glass to flow down uniformly and fill the mold well. Positive forms generally are made excluding high points or areas where glass will be required to flow up in order to completely fill them. However, molten glass, like water, tends to seek its own level. If there is enough glass above such an area and a vent has been added to allow trapped air to escape, these high points

will fill. If through necessity one must include such areas in the form, extra sprues added on top of or very close to the highest points will provide the additional glass necessary to achieve a complete fill.

Adding vents in several places will help solve many problems if it can be determined where trapped air pockets are most likely to occur. Areas that require vents are (1) long stretches where the glass must flow horizontally, (2) extremely narrow or thin 'limbs', (3) shoulders of vessels or forms, and (4) anywhere there is an abrupt change in direction and thus flow of the glass.

Vents are made in several ways depending on where they are needed. They can be as simple as tiny holes drilled into the completed plaster mold. Alternatively, they can be made of a variety of materials which can be pulled out of the plaster after it has set, or which will completely burn out during firing, leaving paths for the air to escape. If the vents are to be left in the mold during firing, complete burn-out is essential to prevent clogging. Only materials which will not absorb the water and plaster, which could prevent burn-out, are used. Small pieces of smooth wood (toothpicks, tiny dowels, etc.) which have been oiled make excellent vent paths. They can be pulled out of the plaster after the mold has been completed, and before firing. Plastic straws are another possibility. These solid materials are attached directly to the positive form, extend to the retaining wall (the outside edge of the mold), and are cast in place in the layers of plaster.

Once the positive form is complete, with sprues and vents attached, the entire object is almost ready to be cast in plaster. Some type of release agent, such as oil or talc, is usually spread on the surface of the model to prevent the plaster from sticking. Though not absolutely necessary, a release agent does aid in clean removal. Without it, a thin residue may be left in the mold, especially from clay, which can and will attach (though usually not bind) to the fired glass surface, often appearing as an orange surface. Any type of release agent on the clay form will affect the surface texture if not carefully applied. Thick oils (petroleum jelly, lard) can be thinned by heating gently, and brushed on with a large natural hair brush. Care is taken to apply the oil evenly and completely so as not to add any unwanted texture with the application of the release agent. As the oil cools, any runs and drips can be seen and smoothed out. Shortening is also available in spray cans, which can be very convenient in application, though expensive.

Vaseline, lard, shortening in spray cans, and baby oil have all been tried with varying results. Each varies in convenience and expense but all have similar effectiveness.



### CHAPTER THREE

#### The Mold-making

There are several different types of molds possible depending on the form and design of the desired finished piece and methods used when firing. Solid, unseamed molds can be used with wax models which will be melted or burned out. Alternatively, the mold can be cast in several layers, which can be separated after they have set and then reassembled. While solid molds are definitely stronger, the use of small plaster layers allows the easiest access for removal of the clay and subsequent packing of the frit into the mold. However, the thinner the plaster layer (particularly if less than one inch thick), the weaker it is and the more likely it is to crack when handled. Cracks in the plaster layers show up later on the glass casting as raised lines on the surface or as pronounced as 'wings' or thin protrusions of glass which result from molten glass seeping down into the cracks.

After planning and deciding how to cast the piece, the positive or model is placed on a greased surface, or a surface which can be later removed from the mold, i.e., thin plastic, clay, or a wooden bat used in ceramics.

A water-tight dam is built around the prepared clay form using clay, plastic, reinforced tar paper, or even a wooden frame, allowing for about 1"-1½" of plaster wall thickness. Excessive thickness in the mold walls will not increase their strength, and can result in problems seen later when firing. Greater plaster thickness has more moisture which must be vented off. A longer and slower time period is required for heating up which can result in those areas surrounded by the increased plaster thickness to not reach temperature when the rest of the mold does. Areas of fused glass near areas of unmelted glass in the cast form are an indication of this type of problem. Once the positive form has been prepared, the plaster mixture can be made.

### Ingredients

The basic ingredients of a plaster formula will depend on the type mold to be cast and how high the temperature of the firing will go. Each ingredient in combination with the others adds different properties to the mold, the most desirable properties being body strength, thermal shock resistance and not combining with or affecting the surface of the glass. Often differences in percentages of the ingredients can create more desirable molds. The following are a few of the most common ingredients found in pâte de verre molds.

Plaster. Basically plaster is a hydrate of calcium sulphate, made by calcining gypsum. There are several different types of plaster available, each developed for a different purpose. Moulding plaster is the

type referred to in the following formulas, unless otherwise indicated. Pottery plaster is not recommended as a substitute; it has been formulated to absorb moisture, while moulding plaster is designed to have greater body strength, and reproduce accurately fine detail. It is extremely important to use fresh plaster. Plaster absorbs moisture, even from the air, and the older a bag of plaster, the greater the moisture content it will have before one begins to use it. Reliable dealers can provide the manufacture date, or it can be found printed on each bag of plaster.

Silica.  $\text{SiO}_2$ . (Also called flint). Silica occurs in nature as an oxide and in a great variety of silicate minerals. Essentially all have the same chemical composition although they vary in crystal size and impurity content. Pure silica melts at an extremely high temperature ( $3119^\circ\text{F}$ ). When added to plaster (which begins to break down at the high firing temperatures, above  $1440^\circ\text{F}$  or  $800^\circ\text{C}$ ) silica combines to form a more refractory body structure, thus adding strength to the mold. In addition, silica increases the thermal expansion in a formula, which adds thermal shock resistance, and reduces the shrinkage inherent in the drying and firing of straight plaster mixes.

Alumina.  $\text{Al}_2\text{O}_3$ . A white aggregate, alumina is insoluble in water. It is very refractory, having a fusion point of approximately  $3,600^\circ\text{F}$ . In ceramics, alumina is used to control the mattness or brilliance and the opacity of glazes; it also is used to prevent glaze devitrification. In pottery bodies, alumina raises the maturing temperature point of the

clay which gives a longer firing range. In the plaster mold mixtures, several of these qualities are desirable. Small amounts (15%) of alumina added to the mixture tend to give the unfired mold strength, especially appreciated if one has to take apart, clean, and reassemble several layers of a fragile mold.

Kaolin. (China clay) A pure, finely grained white-firing clay, kaolin has an extremely high fusion point which, when added to plaster mixtures, acts as a refractory and gives strength to the mold. However, clay incorporated into the mold mixture results in some dulling of the surface of the cast as the glass will fuse with the clay it comes into contact with.

Vermiculite. Large-grained garden vermiculite is made of organic materials and mica. Vermiculite when heated undergoes a considerable volume increase, a property which makes it useful as a thermal insulation material. It adds porosity to the mold for moisture and heat dispersal and absorption. Alternatives include ground heavy paper (particularly paper toweling), finely chipped wood or saw-dust, even wood or rag pulp; all can be added to the plaster formula to open up the otherwise dense mixture. These materials can be ground with water in a household blender. A small addition of ground ceramic fibre, or Fibre-frax, works as well. No more than five percent of any of these materials is used to increase the porosity of a mold.



Previously fired mold material is another addition to consider. After a firing, chunks of the mold are ground and sieved to obtain a powder of similar consistency and particle size as the fresh materials it will be mixed with. Additions of more than ten percent create a slightly softer mold surface (which could be a problem if one has to do any scraping out of the positive form), though the overall strength of the mold itself is retained. The pre-fired mold material also helps to open up or lessen the density of the mold. It seems to enable the plaster to separate more easily from the shrinking glass as the mold cools, thus preventing possible stress. Too great an addition of pre-fired mold will cause a spongy mold. Thirty percent has proven to be the limit.

#### Plaster Formulas

Depending on the form being cast, the particular plan of casting to be used, and the type of firing, the plaster formula will change. Each different shape or model requires special consideration as does the final results that one is seeking. There are no set rules nor is one formula always better than another. Personal experience and experimentation is the best way to discover the "ultimate formula".

The following begins with a few recipes used by other artists who have done experiments using pâte de verre and is followed by the formula considered a personal favorite.

## Argy-Rousseau's formula--

Moulding plaster	28%
Calcined kaolin	22%
Kaolin	3%
Ground sand	10%
Grain sand	37%

Measured by weight, this mixture produces a very soft mold which damages easily. It was designed to be cast unseamed around wax forms, and then coated with a second plaster layer which acted as a container in case the soft inner mold cracked. The mold was packed with a low-melting glass Argy-Rousseau developed and fired to approximately 1380°F.

## Frederick Carder's formula--

Plaster	100
Flint	100
Kaolin	20
Fibre-Frax	2
Heavy paper	2

These proportions are calculated by weight with 170 cubic capacity of water. The paper and fibre-frax are ground with water in a blender, sieved to remove large particles, and drained. After the other materials are combined with and absorbed into the water, the pulp is added. The mold is designed for use with wax models and unseamed molds fired to 1470°F (800°C). Corning Glass Works to this day uses his original formula.

Certainly the simplest, easiest, and least expensive, the following formula is considered a standard mix.

Plaster	50%
Silica	50%

Variations of ten percent either way are common, as are additions of vermiculite or other porous material to this otherwise dense mixture. The mold is relatively strong but somewhat brittle, a factor to consider when casting multiple layers of plaster. The mold mixture provides a clean and easy release from the glass casting. After firing, the mold breaks apart readily (caution must be used in lifting the mold from the kiln as it could fall apart). Soaking in water will dissolve any remaining mold material in areas that are surrounded by glass or caught in intricate details or texture.

Experiments beginning with the above formulas led to the following formula.

Plaster	40%
Silica	30%
Alumina	15%
Pre-fired mold	15%

This a very strong mold; thin layers (one inch thick) can be cast and removed from the mold without breaking. It withstands the high temperature of firing (1600°F) and the long firing periods at those high temperatures (often 8 to 12 hours). The mold releases cleanly from the glass casting; even in areas almost completely surrounded by shrinking glass, the mold material will compact rather than provide resistance.

The glass surface reflects accurately the original model, even to areas being somewhat glossy (a characteristic hard to achieve and reproduce through this process).

### Mixing the Plaster

Though many people alternate adding estimated cupfuls of the plaster with cupfuls of the other materials to the water, experimentation has shown that a stronger and more consistent mold will result if the materials are weighed and dry-mixed prior to combining them with the water.

In a narrow and deep plastic bucket, room temperature water is added to a level approximately one-third less than the amount of liquid plaster needed to make the first layer of the mold. The ability to judge how much water to use comes with experience, if not through volumetric calculations. The temperature of the water is very important to the setting time of the plaster mixture. Cold tap water will slow the process considerably, while warm to hot water can cause the mixture to begin to react too quickly, even before it is thoroughly mixed.

The pre-mixed dry mold mixture is added to the water using a sifter or filtered slowly through the fingers into the center of the bucket. An island is created eventually in the center. Once the island begins to form, the dry mix is spread around the edges as well as being sifted into the middle until the island is solid. At this point there is enough

plaster added to the water and no further additions of the plaster mixture are necessary. If too much plaster is added to the water the mix could begin to set prematurely and the resulting mold will be weak because there was not sufficient moisture to react with all the plaster particles.

The mixture must be consistent; some initial stirring from the bottom to the top of bucket will mix and smooth out all lumps. At this point, any porous material is added. Vermiculite is added until the mixture looks or feels like thin oatmeal. There is constant stirring from now until the plaster is ready to pour, but done carefully and gently to avoid the addition of air bubbles into the mixture. Air pockets become trapped in the setting plaster, and can result in the mold cracking, or worse, exploding during firing. Mixing using a hand drill or other such mechanism has been recommended by some mold makers but personal experience has shown that less air is added to the mixture when mixing by hand as well as a greater attunement to that specific batch of plaster being made. Mixing the plaster should take between five and ten minutes before the temperature begins to rise and the mixture begins to set. Any shorter period of time would indicate the use of too much plaster to water, or too warm water, while longer mixing times could indicate not enough plaster to water, too cold water, or even old plaster. The vermiculite will lose its tendency to float as the plaster mix begins to thicken; it is now ready to pour.

## Casting the Mold

The plaster mixture is poured very slowly into the mold allowing it to flow into all negative spaces without trapping air. After pouring the mix, the whole mold is tapped and agitated gently to allow air pockets to rise and escape. Excess plaster is added to areas not fully filled. The surface of the plaster is 'tapped' gently with the fingers to smooth out the surface. However, once the plaster starts to harden all of these actions must stop in order to prevent the addition of any stress into the mold.

After the plaster has set part or all of the barrier wall is removed and two or three small notches are cut into the top edges of the plaster; these act as keys for exact re-alignment when reassembling the layers later. A layer of some type of resist is applied by brush to the top surface of the plaster which acts as a release agent between the plaster layers.

The different aspects of resists should be considered. Lard or vaseline when spread on absorb into the surface and create a small (or nonexistent) space between the plaster layers, which can be harder to separate. Clay slip when used to separate the layers is spread on thicker, which makes it easier to see the different layers after the entire form is cast. The clay makes it easier to insert a tool into the separating space to pry the layers apart. The clay slip if left on the layers acts as a barrier during firing to prevent the molten glass from



spreading into the mold's seams. However, the clay will come into contact with the molten glass and could effect the surface of the casting.

The release agent must completely cover the plaster surface, including all negative spaces and surfaces. All plaster splatters or dribbles from pouring are cleaned from the exposed clay positive as well as from the surface of the previous layer. These splatters of plaster will not adhere to the next layer of plaster which is poured on top of them. When the mold is cleaned out later these areas will be loose and fall out creating air pockets, new surface texture or unwanted detail to the glass form.

Each successive layer is made following the same procedures: measure, mix, pour, allow to set, cut keys, apply release agent. Keys should be cut on each layer in the same relative position; this is especially important when working with narrow layers to avoid creating extremely thin areas. Pouring the layers is done as quickly as possible. The mold layers are not be allowed to dry between each pouring because plaster shrinks as it dries, which could result in imperfect fit of the layers.

For some types of mold (if the piece is hollow, i.e., a bowl or cylinder shape), the final layer to be poured is the base of the mold and includes the core of the piece. Plaster is poured directly into the

bowl until it is filled and then an additional inch thickness is poured for the base.

Another method for casting a bowl form requires casting the outside form of the bowl in plaster. After the plaster is set and the positive form removed, the interior of the bowl form is packed with frit and plaster is poured directly on top of the packed glass to form the core. This method results in a free-floating core and can be used quite effectively because the glass/plaster surface creates quite a different texture on the casting. However, plaster tends to float on molten glass, and care must be taken to ensure that the plaster will remain in place.

Once the final layer is completely set, the retaining wall is removed and the mold cleaned, scraping off any plaster which may have slipped down over the previously cast layers, and making sure all keys and layers are obvious. If the positive is made of clay, the whole mold is flipped over and the clay carefully extracted from the first layer of plaster. Each layer is removed as it is cleaned out (a thin spatula or putty knife is inserted between layers to separate them) and set aside to dry as the next layers are cleaned.

If the positive model is made of wax, the mold is placed inverted into the annealer and heated slowly to 200°F. A pan is placed directly under the opening of the mold to catch all melting wax, protecting the annealer floor. Burn-out takes several hours.



### Packing the Mold with Frit

Starting with the bottom layer, the fritted glass is packed into the mold as firmly as possible, filling all negative spaces. Various implements or tools (spoons, dental tools, wooden dowels, etc.) are used to help force the frit into the smaller places and to pack down the frit. The back of a spoon is used to burnish the finest frit into the mold layer by layer. Within the mold, areas that are very tiny and/or hard to fill require using only the smallest size frit available. Large regions can be filled with the larger grained frit, especially if some smaller mesh frit is mixed with it. The smaller the frit to start with, the more glass that can be packed, and more firmly, into the mold. The more glass already packed into the mold, the fewer air pockets that will be present and the fewer additions that will have to be made during the firing. Packing molds very solidly and using a small frit size also results in only minor bleeding at the joints or edges of areas of different colors.

The frit should be moist; using a water spritzer can help pack the particles tighter. However, adding too much water to the plaster mold creates more moisture that will have to be vented off later, possibly causing the mold to crack. As each layer is packed, the next is added on top and filled, until the entire mold is reassembled. Extra frit is mounded on the top of the opening to the form and into all extra sprues.

At this point, the entire mold is wrapped in a wire mesh (fireplace screening works well). The wire mesh must be made of ungalvanized metal to prevent dangerous fumes being created during firing. A small amount of the mold material is mixed (excluding the vermiculite) and applied directly to the wired mold. Between  $\frac{1}{2}$  - 1" thick, this plaster/wire layer acts to support the mold while it is firing.

## CHAPTER FOUR

### The Firing Cycle

The firing schedule used depends on the thickness of the plaster mold and the glass inside. Molds must be taken up to temperature slowly to prevent stressing the plaster which will cause the molds to crack or break apart. Heating too rapidly results in uneven heating of the mold and could cause the moisture remaining in the plaster to turn to steam. If the steam cannot escape through the mold (either because the mold is too dense or the heat rising too quickly and unevenly throughout the mold), the pressure generated could possibly explode the mold. However, it has been found that heating too slowly allows the fluorine-based opaque Kugler color powders to fume, mix with the water being released from the plaster and form dangerous hydrofluoric gases which can accumulate in the studio.

The following schedule is used as a basis from which appropriate alterations are made to accommodate each specific piece. Several molds can be fired at the same time if they are of the same general size and thickness. Extra time is added to the firing schedule for each additional mold in a firing. The following has proven effective for molds of approximately one and one-half inch thickness of mold material surrounding a casting eight to ten inches in diameter, though of not

more than one inch in actual glass thickness. Whether an electronic programmable controller is used or the temperatures are controlled manually, the schedule remains the same in order to achieve consistent and predictable results.

Once the kiln is loaded with the mold(s), the doors are left open a small amount and the kiln controls turned on. The mold is warmed gently at first to allow all moisture to evaporate without cracking the plaster. The temperature is maintained at 200°F for several hours, with the kiln doors and all vents left slightly open. The test for remaining moisture is to place the hand in front of the door and escaping heat; if humidity is felt, the molds are not completely dry.

Once the molds are dry, the kiln is set to climb to 900°F at a rate of 100° per hour. The doors and any vent holes are left cracked open for any remaining steam release. Dehydroxylation, or the expulsion of chemical water (water chemically combined with the mold materials), begins at approximately 840°F. The mold is soaked at 950°F for approximately two hours with the kiln doors closed to insure that the heat has penetrated completely throughout the mold. Then the heat is increased from 950° to 1100°F at 50° per hour. The quartz inversion point occurs at approximately 1060°F. At this point the quartz crystals change from alpha to beta quartz, with a resultant expansion. Passing through this point too rapidly will cause the mold to crack.

The kiln and mold are taken from 1100° to 1600°F at a rate of 75° per hour. The mold is soaked at 1600°F for ten to twelve hours. In this period extra frit is added a little at a time to the mold until the level of glass in the mold does not sink lower. Once the mold cannot take any more glass, a final soak follows in which the doors of the kiln are kept closed to allow the entire mold and any additions of frit to even out in temperature.

The higher the temperature in the kiln, the more fluid the glass becomes. The glass settles into the mold, draining the upper areas and sprues. Air bubbles are able to move up and out of the glass more easily as the glass begins to flow. Because of the increased fluidity, there is also a greater probability that areas of colored glass will creep into neighboring regions, especially if the frit was not packed firmly to start with.

### The Annealing Cycle

It is in the cooling down that devitrification occurs. To prevent this, the kiln is cooled as quickly as possible to 1100°F by opening and closing the doors. To prevent stressing the glass casting, thin sheets of Fibre-frax cloth are spread over mold sprue openings and all exposed areas of glass. Care must be taken to avoid shocking the kiln shelves and molds. The annealer cools down to 1100°F in about twenty minutes. To allow the thick mold and the core of glass to even out in temperature, a soak at 1100°F of at least four to six hours follows. The beta to

alpha quartz inversion occurs between 1100° and 750°F, with a resultant rapid shrinkage occurring during this transition. The kiln is dropped to the annealing point (950°F) over a period of four hours, again to insure a slow and even cooling.

The annealing soak is determined by the thickness of the glass and the plaster mold combined. The standard formula is to soak the form one hour for every one-quarter inch of thickness. The rate at which the kiln is dropped from 950° to 750°F is again in relation to the annealing soak. Generally, it can be figured to be about one-quarter of the soak period, i.e., if the annealing soak was thirty hours, the rate of change to 750°F (a drop of 200° over a period of seven and one-half hours) would be 27° per hour. Once the kiln has reached 750°F, the rate of change is increased. The temperature controls and heat are turned off when the kiln has reached 250°F; the mold cools to room temperature at its own rate. The fibre-frax cloth is removed, and the mold is allowed to stabilize without being disturbed for several hours.

The mold is carefully removed from the annealer and the plaster gently broken away from the glass casting. Any further finishing work on the glass is done after the casting has set undisturbed for four or five days to allow complete stabilization. Any plaster caught in texture can be removed from the glass casting by soaking the whole form in room temperature water. The plaster generally falls away from the glass or is scrubbed off using a toothbrush.



## Results

The final results one obtains from the pâte de verre process will vary considerably. If the highest temperature attained is changed 25°, or the length of the high temperature soak is altered, or even if the grain size of the frit is changed, the resultant glass casting will be very different from other castings. Once again, it is personal style, individual working methods, and one's vision of the final form that determines what results will be obtained.

The most consistent effect obtained by the methods I chose to work with was that of denying the fact that the material I was working with was glass. The glass surfaces in direct contact with the plaster mold appear devitrified, losing their gloss (usually having a matte surface) and transparency, as well as the hard edges normally associated with glass. The pieces take on a stone-like appearance; the surface is finely textured, its coloration uneven and mottled, as is the body underneath. Seams and fine lines appear irregularly on the surface, suggesting healed cracks, veins, or scars. Despite the alterations to the glass in the pâte de verre process, the quality most unique to glass is retained — the ability to reflect light from within the piece. The forms generally remain translucent and, when well lit, glow from the light reflecting within the piece. I find that these characteristics add vital expression and meaning to my sculptural work.

## CHAPTER FIVE

The work of art is therefore only  
a halt in the becoming and not a  
frozen aim on its own.

El Lissitzky

The Sculptural Work

As are most children, I was brought up with fairy tales. Not only did fairy tales entertain and put us to sleep, they functioned to teach us right from wrong, to spot the difference between the good guys and the bad and that fighting for the good often was difficult and took its toll. We learned to distinguish between princely toads and wolves disguised as sheep, evil ogres and friendly spirits, between kind neighborly women and evil witches offering sweets.

The body of work created during my thesis research is influenced by my current fascination with fairy tales in their original forms. In studying the literature one finds that the tales and legends told throughout the world have similarities in their basic themes and contain threads of details running through them which link such culturally different areas as the tales of China with those of Persia and Northern England.



Violent, with death and defeat prevalent, full of sexual innuendo, the original forms of fairy tales have been softened over the generations through repeated telling as bedtime stories and, most recently, by their visualization through Disney Studios. In any form, fairy tales and the strong images they invoke are influences we retain throughout our lives in that we either understand and/or identify with the story characters, the struggles they face, or the lessons taught.

Myths and fairy tales — tradition — help us to deal with and understand reality. But tradition must be assimilated and evaluated as our culture and reality changes.

Like Snow White, each child in his development must repeat the history of man, real or imagined. We are all expelled eventually from the original paradise of infancy, where all our wishes seemed to be fulfilled without any effort on our part. Learning about good and evil — gaining knowledge — seems to split our personality in two: the red chaos of unbridled emotions ...; and the white purity of our conscience ....As we grow up, we vacillate between being overcome by the turmoil of the first and the rigidity of the second....Adulthood can be reached only when these inner contradictions are resolved and a new awakening of the mature ego is achieved, in which red and white coexist harmoniously.<sup>1</sup>

The universality of the images and ideas conveyed by legends and fairy tales and their mutual understanding across ages and cultures can help us to communicate our own struggles and fears if we use those images from the stories to represent and express our own feelings. My sculptural work is an attempt to communicate personal experiences, the

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<sup>1</sup>Bruno Bettelheim, The Uses of Enchantment: Meaning and Importance of Fairy Tales, (New York: Alfred A. Knopf, 1977), p. 214.

struggles and obstacles faced and the emotions felt during the duration of my time spent working on my masters program and thesis research.

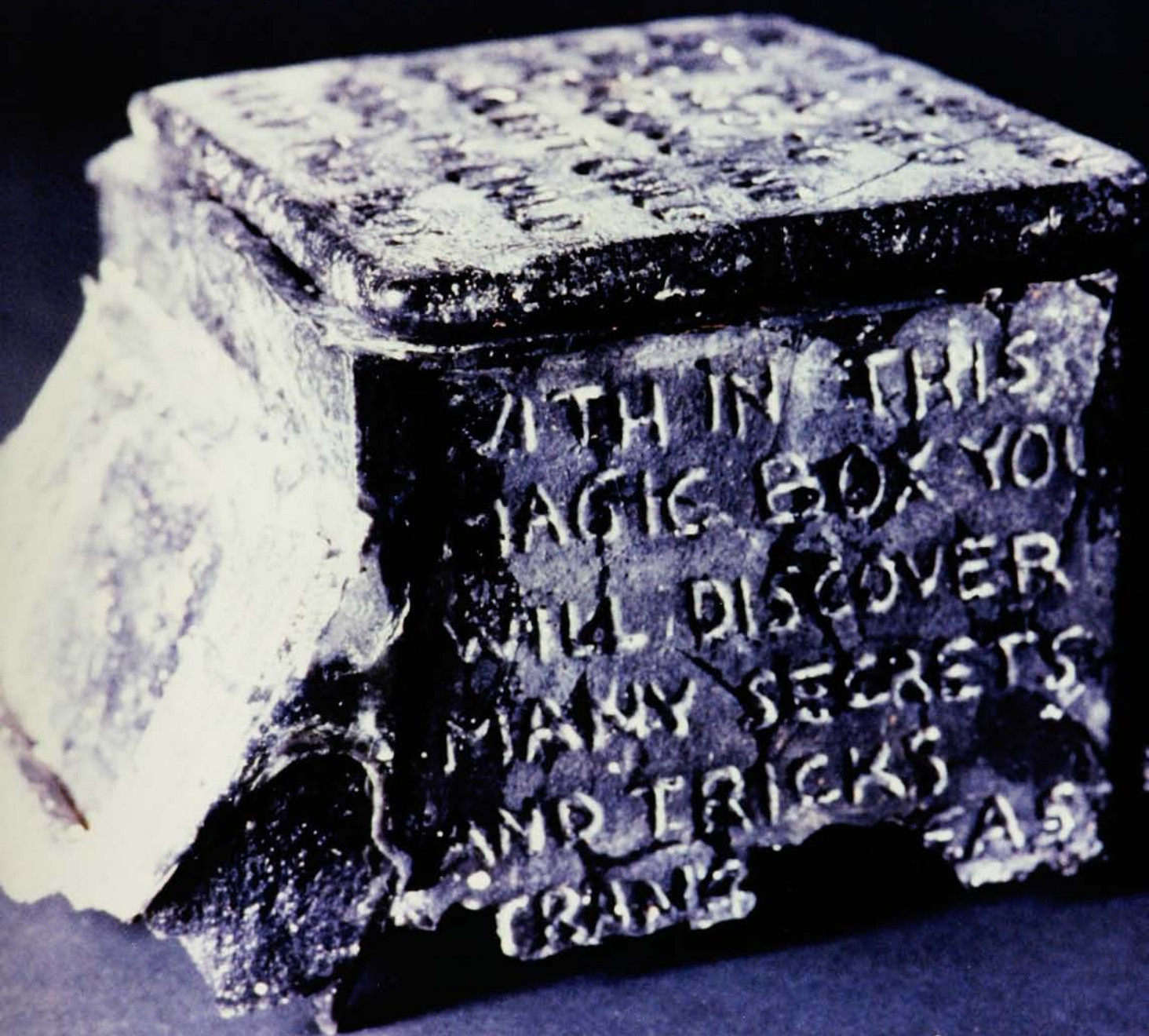
### Self-portraits and Statements of Personal Fears

Each sculpture begins with a human figure. Whether physically present in the piece or referred to (as in Cinderella's Nuclear Boot), the figure can compel the viewer to identify with and associate ideas and personal experiences with those referred to in the sculptural forms.

The forms, once whole, take on a new appearance after the pâte de verre process. The surface is devitrified and opacified. No longer glassy, it is still translucent; brittle yet solid. There has been extreme heat from the environment to which the piece was exposed to (as there would be in a nuclear explosion) and yet despite its flaws and the obvious evidence of deterioration, the form has resisted (as we might all wish after the holocaust). The form alters in the melting temperatures and, once finished, retains that melted yet preserved quality in the finished form. It has held its basic shape and integrity and, as evidence of its victory in not succumbing to the harsh environment, stands before us. The struggle is evident; the strength is inherent and prevailing. Cinderella's Nuclear Boot and The Magic Box (see illustrations #1 and #2) are both fore-titled After the Ball: a reference to the not so elegant scene after a nuclear explosion.



1. After the Ball: Cinderella's Nuclear Boot



2. After the Ball: The Magic Box



Untitled (yet referred to as Fairy Godmother) represents many emotions, one of which is the disillusionment one experiences throughout life when we realize the treasure is unobtainable, the wish will not come true, and that no one can rescue us from the unpleasantness offered up in our world. The decaying feminine figure is seated beside two classical cups -- one is broken (see illustration #3). The piece also speaks of aging as much as it does of shattered dreams.

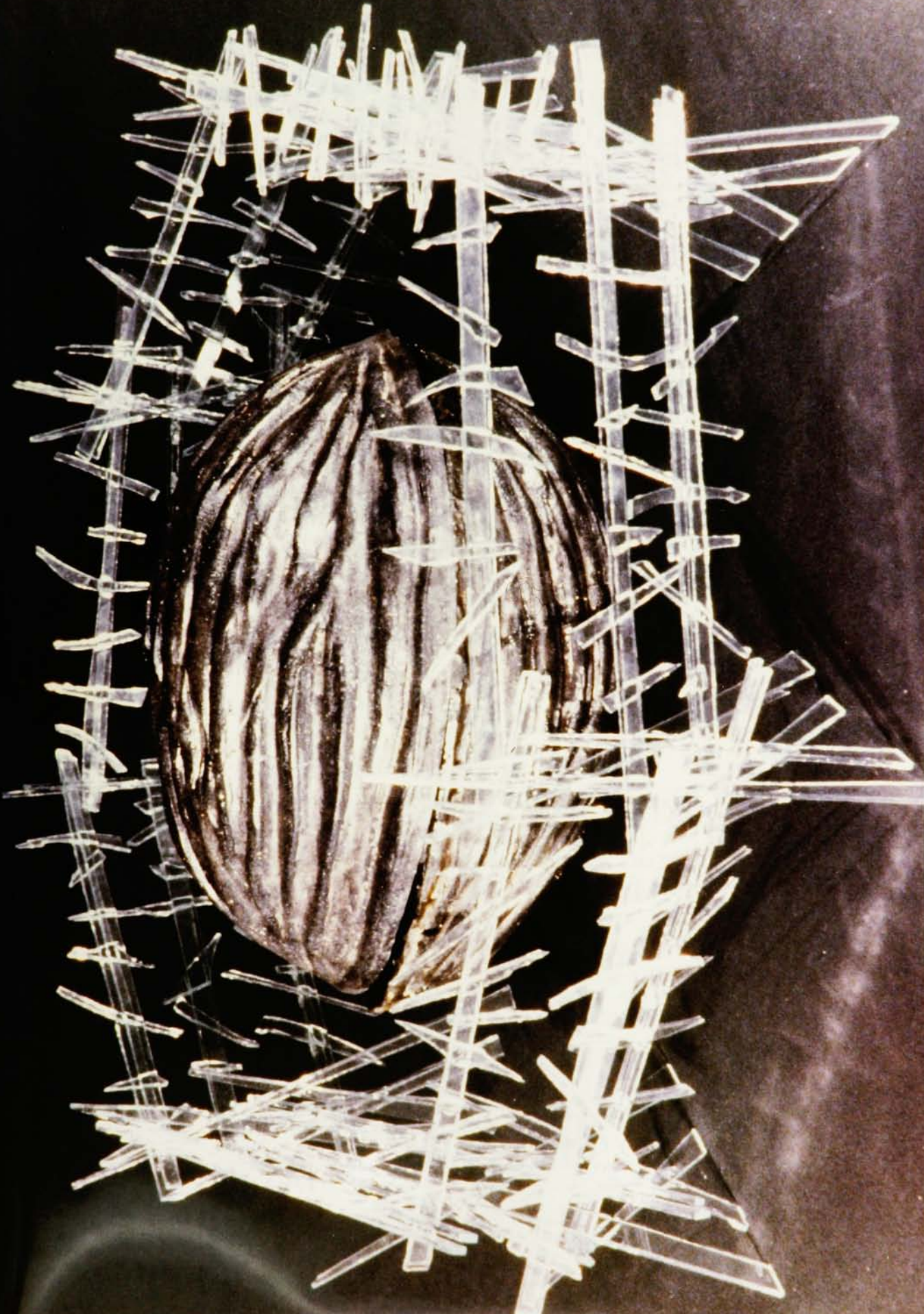
Thumbelina: 15-2-87 symbolizes the withdrawing nature in us when encountering extreme difficulties or threats to ourselves. A wall of sharp and dangerous glass which shifts at the slightest touch surrounds safe territory (see illustration #4). And yet that same hard-edged and threatening fence prevents easy escape from within. Is everything necessary for a happy life contained within the shell? Can a healthy existence be maintained when one is so isolated from the outside? Actually the glass barrier is fragile itself and could be breached without inflicting fatal injury -- a symbol only.

The figure in Sleeping Beauty lies within a glass case, almost a coffin shape (see illustration #5). We know she is not dead because of the attitude of her pose, yet the entire glass case and pedestal appears cracked and aged. A great deal of time has passed since she was encased or the environment has been harsh.



3. Untitled





4. *Thumbelina*: 15-2-87

...the adolescent dream of everlasting youth and perfection is just that: a dream....If we do not want to change and develop, then we might as well remain in a deathlike sleep. During their sleep the heroines' beauty is a frigid one; theirs is the isolation of narcissism.<sup>2</sup>

We know from the stories that when the proper amount of time has passed, the case will be opened and the figure made accessible. Prince Charming will come, maturity (physical or emotional) attained, or inner harmony and self-fulfillment reached.

The image of the Magic Mountain (see illustration #6) as well as the forms of much of my other sculptural work has come from my dreams. Carl Jung, in 1939, talked about living the symbolic life. Von Franz explains Jung's ideas by saying that we are now

all caught in rationalism and that our rational outlook on life includes being reasonable and that this reasonableness excludes all symbolism. [Jung] goes on to show how much richer life is for people still embedded in the living symbolism of their religious forms.... one can find the way back to some living symbolism — not to the lost symbolism, however, but to the still living function that produces it. We get to it by attending to the unconscious and our dreams. By attending to one's dreams for a long time and by really taking them into consideration, the unconscious of modern man can rebuild a symbolic life. But that presupposes that you do not interpret your dreams intellectually and that you really incorporate them into your life.<sup>3</sup>

What Jung recommended was to take a recurring or dominant dream symbol and reproduce it somehow, to relate to it in some real manner. I, too, practice trying to stay with the symbols of my dreams for a day

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<sup>2</sup>Ibid., p. 234.

<sup>3</sup>Marie Louise von Franz, An Introduction to the Psychology of Fairy Tales, (Zurich: Spring Publications, 1979), p. 70.

or more, to make physical the images that I might visualize them better and to try to see where it is that they fit within the reality of my life.

The pâte de verre process enabled the realization of these sculptural statements by allowing the creation of glass forms which would have been impossible or extremely difficult to produce with any other glass-working technique. And yet the glass is not just glass, but has taken on qualities of stone and marble and the classical associations that accompany these materials. Glass itself is enduring, with ancient roots and an honored position in history, as are the gods and goddesses we worship, the myths and traditions with which we live.





5. Sleeping Beauty



6. The Magic Mountain



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