

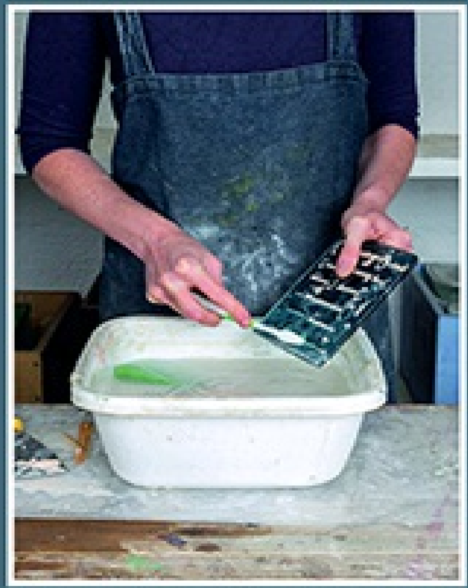

# GLASS CASTING

*Amy Whittingham*

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**Disclaimer**
Safety is of the utmost importance in every aspect of glass casting. The practical workshop procedures and the tools and equipment used are potentially dangerous. Tools should be used in strict accordance with the manufacturer's recommended procedures. The author and publisher cannot accept responsibility for any accident or injury caused by following the advice given in this book.

**Acknowledgements**
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To Plymouth College of Art, the University of Sunderland, Pilchuck and Northlands where I have learned so much – keep being those hotbeds of glass education, championing glass art and encouraging others to practise it.

Finally, thank you to Judith Noble and Mark Radford for getting me to commit to actually writing.

# CONTENTS

**Ivy trunk that was removed. (Photo: Nicola Simpson)**

CHAPTER ONE

# FINDING INSPIRATION AND DRAWING

## Generating Ideas

Generating your own ideas for glass casting is like making artisanal bread. It requires patience and time to prove. To develop depth and flavour, for an intense taste sensation, you want your idea to resonate in you. Spark a few of the senses: sight, touch, taste or balance maybe? But to do that you need to let your idea mature. Through step-by-step projects, I will give you the main ingredients and some ideas to get you started. However, working through the projects with your own ideas will be the food that feeds your soul. It will be what encourages you to keep on trying through those times when your cast (or bread!) doesn't come out as you expected.

My advice on how to generate ideas and find inspiration would be to draw, sketch, paint and photograph. Make models, allow your idea to develop from the first thought that pops into your head. People's thought processes tend to start in fairly similar places. It is the kneading, stretching and exercising of those thoughts that encourage your own creativity to grow.

Whatever you do, only you can be you. Experiment and allow yourself to make mistakes. Something going awry is an opportunity to learn, and sometimes happy accidents can be the best way to explore these processes and discover your inspirational pieces. After all, the fun part is in

the making.

To find inspiration, look in books, magazines and at news stories. I find reading a good source of inspiration as it's easy to relate to a narrative. You could think about current topics of conversations, or visit museums and art galleries. If you are stuck for inspiration, look at what's around you, the place, the people and the objects. There is an abundance of inspirational images and forms. If you are not inspired yet, pick something of interest to you and study it. Close your eyes and try to draw it. Failing that, go for a walk with your sketchbook or a camera. Get out into nature.

It could be that you decide to emulate or replicate something you find; this can be a great exercise in working through the processes. The photographs here show a rather big, beautiful ivy trunk growing through a garden wall; someone decided that it would be a good idea to stop this growing but unfortunately that left a gap in the trunk. The gap became an opportunity, a challenge to cast glass in the same shape to fill it.

On a daily basis I walk under a railway bridge. Lots of cars travel under this bridge too. It's noisy, home to loads of pigeons, and feels somewhat under-appreciated. People travel past, fast, both under and over this bridge on a constant basis. It's easy to overlook the things we see every day. I love this bridge, the walls, the stone, the moss, the dirt. The water trickling down some of the bricks, the mortar, the blank spaces where there used to be posters. I am inspired by the lines, the tone, colour, texture and forms. Sometimes I am too embarrassed to stop and take photographs of this wall. Instead, I started video recording the wall as I walked past. This way I could replay the journey and gain inspiration and ideas from it. With a lot of drawing, I was able to cast my own glass wall.

Inspiration opportunity: ivy growing through the wall. (Photo: Amy Whittingham)

**Brick wall under a railway bridge. (Photo: Amy Whittingham)**

In short, don't be afraid of looking like an artist, you are one! Get out of the house and go somewhere. See if there is anything you notice on the way that piques your interest. If not, when you get there sit and look and draw, look and draw till you get bored of it. Sometimes boredom is where our best ideas come from.

## Drawing

Drawing is an essential part of the design process. Even if it is on a scrap

of paper or a napkin, scribbling it down will allow you to establish your idea. Think of paper like the sieve for sifting flour; you don't need to do this but ultimately you get a better end result. Getting a sketch onto paper will help you to consider the form and visualize how this will look in glass. Drawings will also aid with working out how the form may be translated into glass. Drawing or sketching glass is hard to do on white paper. Try using coloured paper and chalk pencils to create the lighter outlines and highlights that glass forms have. This will help when you are translating your ideas onto paper. Remember there's no pressure for these drawings to be perfect, nobody's going to be scrutinizing them; they are your way of communicating your ideas with yourself. With practice you will find drawing a natural part of the making process.

A great exercise I did with a class once involved all of us going outside and drawing the same building for a set amount of time; in this case it was half an hour. It was such an excellent teaching and learning activity because everyone was so involved in the task with the little time given, they didn't get a chance to be concerned about how they were drawing or how good it was. The self-consciousness of drawing was removed and then quickly replaced by another challenge, the time constraint. On returning to the class each person was given a piece of card and a glue gun. Then there were an additional thirty minutes to cut up and create that drawing in model form. This timed activity had the same effect when it came to the model making. Both drawing and model making became intuitive and more fluid instead of tentative and repressed.

**TRY THIS**

Use coloured paper and chalk pencils or pastels to draw a glass form.

## Model Making

Once you have drawn your idea and have a sketch of what you would like to cast in glass, then you will need to make a model. Glass casting differs from most other glass-making techniques as you are not directly manipulating the material. Glass is placed into an investment mould, in a kiln, and is cast into a form. In order to create a mould for glass you need to make a model of the form in another material first. There are several ways you can do this and this is probably the most frustrating part about working in glass casting. You not only need to have a good knowledge of glass but how other materials work too to be able to create forms that you want. The projects in this book will help build a good foundation of glass-casting techniques and model-making options.

## Maquettes

As glass casting can be an expensive endeavour, it is good practice to try and work out as much as possible about the final form before you embark on the mould-making process. Make a maquette of your sketch in a transparent material to get an idea of what the shape will look like from different angles, as well as help you to figure out how to cast it into glass. Maquettes will determine whether the form will need to be cast in an open mould, or, if the form is more 3D and has undercuts, whether it needs to be a lost-wax cast or a burn-out mould.

When pitching a design for some awards, I created a to-size model of the final glass award in acetate. This enabled the clients to physically connect to my drawing proposal. The model gave an indication of the size and feel of the design and allowed me to check if the angles and measurements would allow the piece to stand upright without tipping over.

Easy-to-use, transparent materials for maquette models are acetate, laminating pouches, used plastic milk cartons, plastic pockets and some transparent food packaging. If you can create the model with a glue gun or sticky tape and some plastic, it is often easier to translate that form into a master model made out of plaster, wax, rubber or clay. If the maquette is made well then it can be used as your master model to take moulds from.

To make a plastic or card maquette more rigid, you can always mix and pour plaster into it. Set plaster when kept damp can be cut, carved, filed and even polished to create completely unique master models. Pouring plaster into a box or old carton will give you a basic form that you can draw on and sculpt.

## Master Model

The beauty of glass casting is that your master model can be created in any material. You can use formers in card, wood, modelling clay, plaster, found objects, rubber, Styrofoam, wax, glass… the list is endless. Spend time sculpting and constructing your master model as this will be the object that gets translated into a glass cast through a series of processes depending on the choice of material and intended outcome. Most master models are the positive form. It is possible to cast the space around the form too; this is known as the negative.

Bear in mind that just because a material looks easy to use doesn't mean that it will be the best one for you to create your master model with. For example, if you would like to create flat surfaces and straight line edges, modelling clay may not be the easiest material to use. Card, glass sheets, acrylic or even plaster can be used to create flat surfaces and straight edges. In the same sense if you wanted to create a fine detailed 3D model, oven-bake sculpting clays are excellent for model-making as you can bake them then cut, file and edit by adding more material and bake again to harden – meaning you can work on all sides of the object without inadvertently squishing the other side.

### TRY THIS

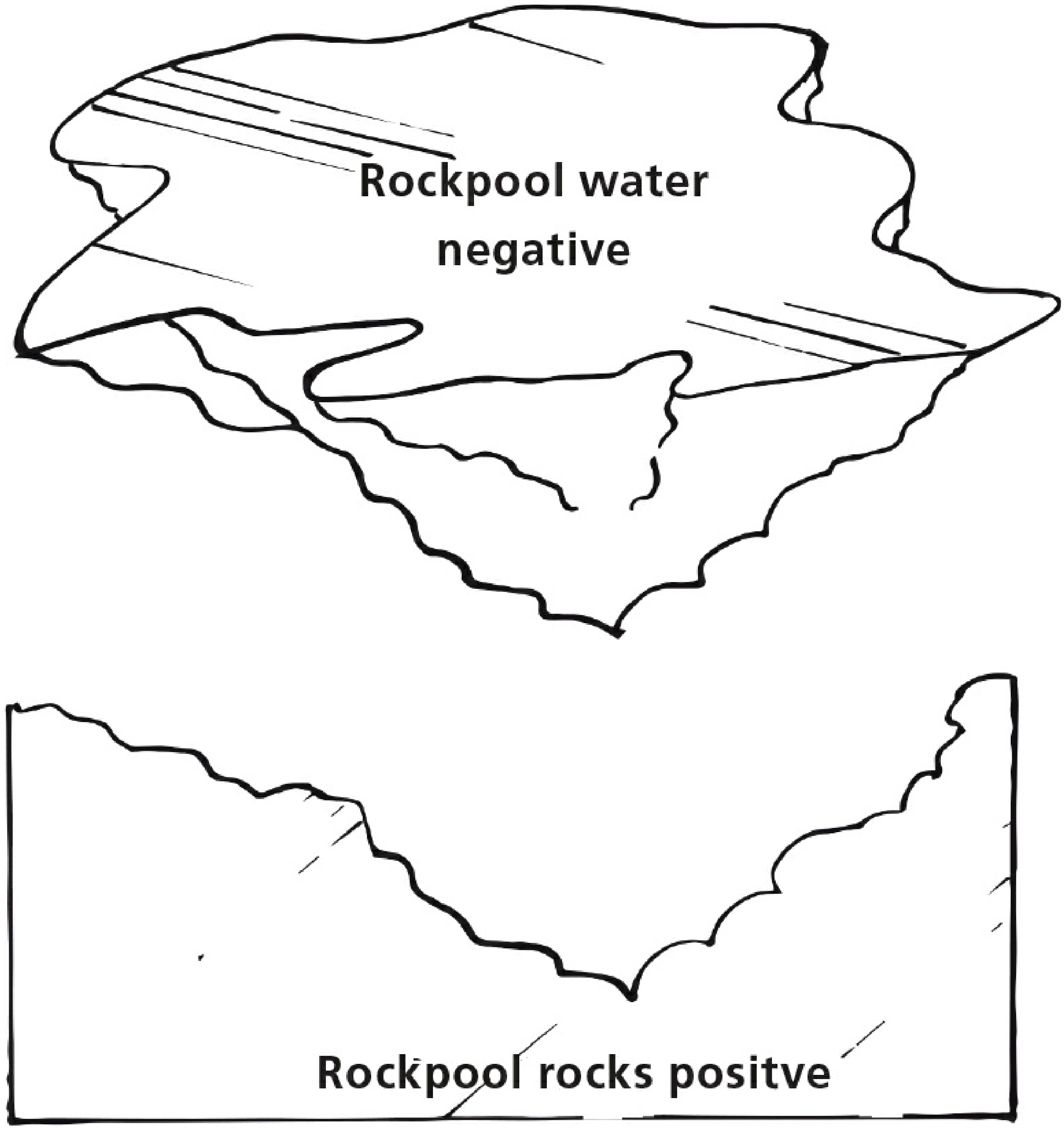
As an immediate model-making exercise, take a found object and sculpt a miniature version of it in card or wax.

**Sculpt a wax miniature version of a spade.**

## Positive and Negative Forms

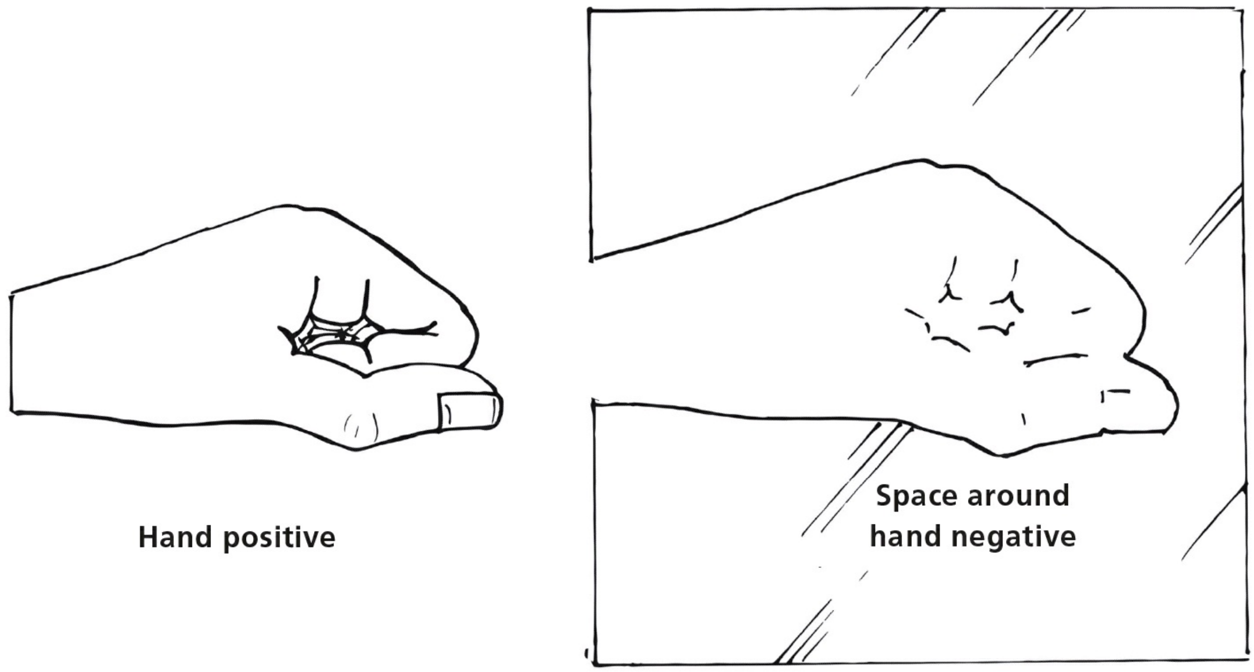
The main thing you will need to note and learn through this book are the materials that can be directly invested to make glass casts, e.g. rubber or clay for open casts and wax for 3D forms (these are covered in the next few chapters), alongside the materials that need other part-moulds making of them to be translated into wax and then invested. As you are making moulds from master models you can also use these materials – plaster, rubber and wax – to work through positive and negative versions of the master model.

Here are two examples to illustrate how this has been used:




**Rockpool, positive rocks and negative pool. (Illustration: Amy Whittingham)**

1. Imagine a rock pool. You could cast in an opaque glass the texture of the rocks in a bowl form, creating a positive of the actual rocks. Or you could cast in clear glass the water in the pool itself, creating a cast of the negative space in the pool.




**Positive hand and negative space around the hand. (Illustration: Amy Whittingham)**

2. Imagine you want to cast a set of hands. You could cast the hands in glass or you could decide that you would like to cast the space around the hands instead. Both of these options would start with the positive hands, then a skin-safe product is used to create a negative mould of them. From this point, the materials you choose to use in the negative mould can be altered. The materials you use depend on whether you are creating a positive version of the hands using wax or a negative cast of the space around them, which could involve using rubber, plaster or investment.

I like to think of it like this: I am either casting the positive form or I am casting the space around the form, which is known as the negative. This can be confusing as essentially each form is physically positive. Don't worry though, the distinction will become evident as we work through the projects in the book. First things first: in the next chapter are some of the basics for setting up your own glass-casting studio.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**Flat lay of health and safety kit. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER TWO

# SETTING UP A STUDIO

## The Basics

Glass casting has the potential to be a bit of a messy business. Having a designated space to make moulds and handle glass in makes casting that much easier. Setting up a studio can be simple, and knowing what materials you are using and having the right personal protective kit to wear means at least you are not putting yourself or anyone else in harm's way. These are the bare minimum requirements you need to be able to create your own studio for casting glass. After discussing these I have also covered some of the bonus items, which are not essential straight away but are luxury extras to aim for. If you have a bit of space and can get access to the four below, you are pretty much good to go on your casting adventures.

- A kiln
- A level surface
- Extraction or ventilation
- Water and drainage system

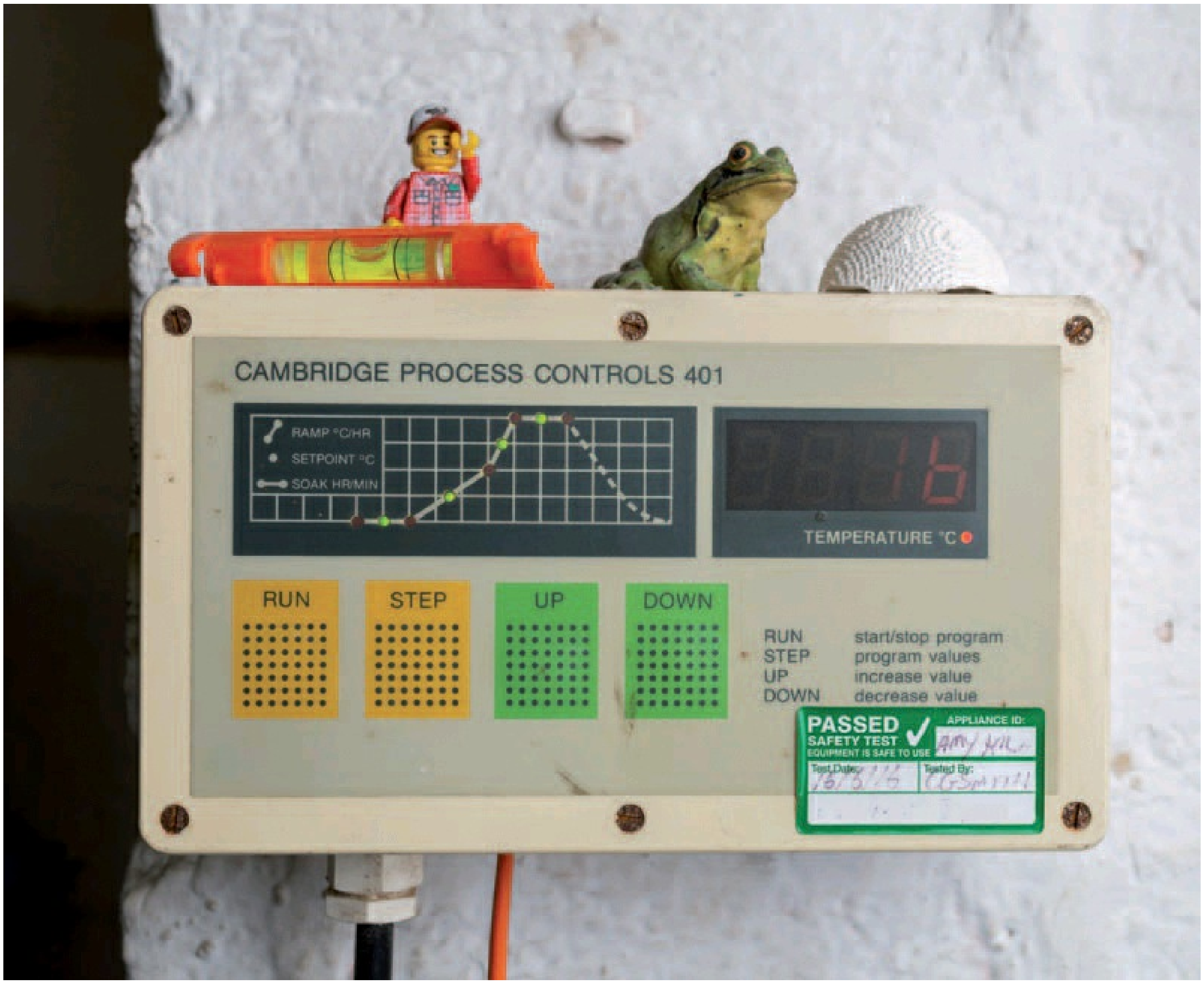
### A Kiln

A kiln is an insulated heating chamber (like an oven) that is capable of going up to temperatures of around 1,000°C (1,832°F). Kilns are available

to buy new and old. They do crop up on online auction sites occasionally, so keep an eye out and do your research. Don't despair though – it isn't essential to have your own kiln. If you don't already have your own, you may find that it is worth contacting local glass makers or artist's studios to see if they hire out space in their kilns. This way you can determine which type of kiln would be good for the glass projects you like to do without that initial expensive investment.

Kilns can be used for firing glass and ceramics, although some glass kilns do not reach the higher temperatures required for ceramic firings. I have mentioned this because unless you are melting your own glass from the raw ingredients, you will not need your kiln to fire up to temperatures this high. The top temperature range required for casting glass, using all types of 'ready-made' glass from bottle glass to Bullseye sheet glass, is unlikely to exceed 900°C (1,650°F). I have an old ceramics kiln that has heating elements around three sides, which works perfectly well for the glass-casting projects I do.

**Front-loading glass kiln at Plymouth College of Art.**




**Kiln controller at Flameworks Creative Arts Facility.**

Investing in a programmable kiln controller is definitely necessary if you want to use your own kiln. Essentially all types of kiln can be used for glass casting as long as they have a programmable controller. The controller and therefore the programme or 'firing cycle' is potentially more important than the kiln in terms of your glass-casting success. This will be covered in more depth within each project, but the firing cycle is used to control the rate of temperature change, so as not to shock and crack the glass as it heats and cools. It may not be obvious when you are thinking about purchasing a new kiln, so double check that it comes with a controller included as some are sold separately.

A lot of glass-fusing kilns have heating elements inside the lid. The heat

from the top allows an even surface on a flat piece of fused glass. Great news, these fusing kilns, known as top loaders, will work for shallow open glass casts and relief moulds. Due to the internal height of these kilns, they may also work for some of the deeper casts, but it is advisable to take measurements before you make any moulds. Measuring the internal dimensions of your kiln is good practice anyway, as you really don't want to go all the way through the mould-making process only to discover that your mould will not fit in your kiln. Take a couple of centimetres off each dimension to ensure that there is still sufficient air flow around your mould within the kiln.

**Top-loading glass kiln at Plymouth College of Art.**

If you are interested in casting deeper moulds, then a front-loading kiln

or deep top-loader may be better for you. These taller kilns have elements that are built into the walls of the kiln and sometimes also in the base. Generally, these kilns will provide a more even temperature for lost-wax and larger casting projects as the heat can penetrate the mould from around the sides, not just the top down. Some kilns may require test firing to determine whether the temperatures need to be adjusted to make allowances for where the heating elements are.

If you are really struggling to find access to a kiln and just want to get started with some of the smaller casting projects for jewellery, then a bead annealing kiln may be the answer. I have a Kilncare one which is tiny but I love it because it has a no-fuss, single-phase 3-pin plug, which can be used at home, and has a controller built-in which is programmable. It has four programmes, where you can amend and store firing cycles to suit your purposes. I use this frequently for small open casts, burn-outs and lost-wax cast jewellery pieces. It’s a great starter kiln as it is so versatile in its uses, from annealing glass beads in lampwork to glass fusing, slumping and casting. I have a friend who even uses hers for enamelling on metal and firing precious metal clay.

**Top-loading 'coffin' kiln at Plymouth College of Art.**

**A level table.**

## A Level Surface

This seems like a really obvious and essential item to be talking to you about, but I found out the hard way how necessary a level working surface can be. Make sure your table top or side is stable and level. An uneven surface can adversely affect any moulds you make and therefore the depth or evenness of the glass you cast into it. This is particularly evident when making open cast moulds. Sometimes this can be corrected in the kiln but it can be a time-consuming step in an already complicated kiln-loading process.

You will need a table with an easy-to-clean surface. Wooden tables will need oiling to create a barrier on the surface in order to make it easier to clean mould materials and spillages off. You can use anything from linseed oil, which can be expensive, to WD40 to coat the table. I recommend

working on plastic or wooden boards (old chopping boards are great) as you can pick them up and clean them with ease and move whatever moulds you make out of the way without disturbing them. I have an additional board that is the same size as my table with carpet glued to one side so that I can easily get this out as a glass-cutting surface and store it out of the way when I am finished. Carpet tiles are also great for this. If I am making a lot of moulds or using silicone that is particularly messy, I will cover the work surface. Thin plastic sheeting or old lino stuck down underneath with gaffer tape works well.


**Extraction.**

## Extraction or Ventilation

As you venture into the exciting world of mould making for glass casting

you will by necessity encounter a lot of dust-causing materials. Some of these materials, particularly investment powders, are incredibly harmful to our lungs with prolonged exposure. In addition to this, when you are firing your kiln some of these materials will give off harmful gases which you won't want hanging around in your studio space either. Therefore, an extraction unit, or a well-ventilated area and a decent respirator, is an essential consideration for your glass-casting studio. If you don't have access to extraction, it is pretty easy to set up a mixing station on a table outside, but make sure while mixing investment powders and silicone that you are wearing a respirator. Also, when not in use the respirator will need to be stored in an airtight container to prolong its working life and effectiveness for the job in hand. Ironically I use a bread bag.

If you are looking to purchase extraction equipment, hydroponics suppliers have a wide range of extractor fans for gas removal from the space you are in. These are not too expensive and are easy to set up with ducting to outside. These extraction units will remove the air in the space, refreshing it every minute or so depending on the equipment specification. They are more effective if attached to a metal hood to funnel the air up and away from you when you are working. They will not remove heavy dust particles. These can be dealt with by a vacuum cleaner set up with a HEPA filter or a more expensive dust particle extraction unit. By creating clean working practices – wearing an apron or jumpsuit, wet-wiping surfaces and storing powders in sealed bags or boxes – you should be able to keep dust creation and exposure to a minimum and therefore reduce any adverse health effects.

**Three buckets – a basic drainage system.**

## Water and Drainage System

Finally, the fourth element on my list for setting up a studio is water and a decent drainage system. The latter is particularly important as plaster and investment material, if continuously washed down the drain, will start to set and eventually block your system. If you are lucky then you may have a tap close to your studio space, but your drainage system can be as simple as three buckets: one bucket for mixing plaster or investment powders in; one for washing the mixing bucket up in; and the third for pouring the dirty water into it. This three-bucket method is essential to protect your drains and the environment. Leave the third bucket sheltered but not covered to settle. I normally leave mine under a work surface or outside. The investment material will sink to the bottom of the bucket and cleaner water can then be syphoned off the top. When bucket number three is starting to

get full, drain as much water off the top as you can and then leave the rest to evaporate. Then you will be able to scrape the solid plaster and investment waste into a bin liner to dispose of with industrial waste. It is surprising how much material collects in the bottom of this bucket. If you do have a sink in your studio, then a sink trap system or a dedicated washing bucket is recommended to avoid blocking the drains.

**IMPORTANT INVESTMENT POWDER SAFETY RULES**

1. Keep powders stored in lidded containers.
2. Work in a ventilated area.
3. Wipe surfaces clean.
4. Wear a respirator.
5. Wear an apron.

## Bonus Items

If you have the four basics – a kiln, a level surface, extraction or a ventilated area, and three buckets – then you are ready to move on to trying some of the projects in the book. Come back to continue reading about the bonus items once you have had a play.

If and when, like me, you get the glass-casting bug, here is an unbiased overview of some extra equipment worth considering to improve your glass-casting projects. A great piece of advice is to invest in machinery that you are going to use most frequently, as the kit you don't need all the time takes up valuable workshop space, and can always be borrowed or hired. These are not in any particular order, and I am not suggesting you need all of them:

- Vacuum chamber
- Glass saw
- Linisher

- Flatbed grinding wheel
- Handheld engraver
- Lathe
- Handheld grinder
- Sandblaster

Most of them are used for ‘cold’ finishing processes and will save lots of your time, sweat and tears when grinding, etching and polishing cast glass, with the exception of the vacuum chamber which is used in the mould-making process.


**Vacuum chamber.**

## Vacuum Chamber

If you are interested in pursuing the challenge of creating precise moulds with fine details on the surface, then a vacuum chamber will greatly

improve results. They can be used to degas both silicone moulds and investment moulds. The vacuum chamber uses a compressor to remove the air from within a sealed unit. The units vary in size: a 20-gallon chamber, for example, measures 275mm × 114mm × 207mm (11 × 4.5 × 8 inches), which is big enough for a bucket with mould mixture to be placed inside and picked out again easily. The increase in pressure within that space forces any bubbles trapped on the surface of a model within your silicone or investment material to expand and rise. I normally use this twice in the investment process: just after I have mixed the material I put the bucket in to degas for two minutes till the mixture has expanded and large bubbles have risen to the top to pop, and then once again after I have poured the mixture over my model for approximately another two minutes. I only use this process for small- to medium- scale moulds that are poured into a container or cup that is larger in height than the volume of mould material required to cover the model. If your container is too shallow, the expansion that happens during degassing will cause the mould mixture or silicone to overflow. Vacuum chambers are also available to hire if you wanted to give one a try.

**Wear eye protection, ear defenders and grippy gloves to feed the glass slowly through the saw.**

**Using a basic tile saw to cut the sprue off cast glass.**

## Glass Saw

All glass saws are water-fed and pretty noisy; always wear ear defenders, grippy gloves and eye protection when using them. Some cheap tile saws have the ability to cut cast glass. Make sure you have topped up the water reservoir, and guide the glass through the blade slowly. As you get towards the end of the cut, slow down even more; sometimes the end bit of glass will break off in an unwanted direction as it is the weakest point. The glass cut will have a rough, slightly chipped edge, which will need to be cold-worked. Allow for this when you mark up your cut line. Once you have finished with the saw, drain out the water and spray the blade with WD40 to keep it from rusting up and to prolong its use. For cutting thick glass on these saws you may need to cut in one direction on one side of the glass then remove the glass, turn it over, line it up and cut from the other side.

This can be the case with awkwardly shaped glass casts too, although it may be easier to use a plaster support by mixing plaster into a plastic bag (with no holes in) and setting it around your object in the position it needs to be in to perform the cut. Alternatively, you can use a multitude of wooden wedges to prop the glass in position.

**Specialist glass saw at Plymouth College of Art.**

There are specialist glass-cutting saws with thin diamond-sintered blades, which are much more expensive and will cut glass like butter. Inevitably the results will still need to be cold-worked as the saws do not polish as they cut. Lost-wax casts will usually have excess glass from the reservoir section, which will need removing unless you can design these into the final form itself.

## Linisher

A linisher is essentially an upright belt sander with water spray to keep your glass cool. It has changeable belts in different grades from rough to smooth. The belts have markings and arrows on them to indicate the specific direction to put them onto the machine; the arrows should go up at the back. The belts are made to work in the direction that the roller spins. When in use, the belts are in tension, otherwise they are best stored hung up next to the machine. Some linishers are fitted with a plate or rollers behind the belt, which you can use to push against. You do need to be able to hold your glass firmly against the machine but you don't need to use too much pressure. You do not need to soak most of the grinding belts before use, but giving the orange polishing cork belt (which appears to be rough) a twenty- to thirty-minute soak will soften it up before use, prolong the belt life and improve its effectiveness. When polishing, pressing up against the plate will help to bring the surface to a polish. Move the piece around so that you are not focused on one point for too long. Heat can build up quickly during the grinding and polishing process. That is part of the reason why these machines are water-fed – to stop the build-up of heat, which can cause cracking.


Bohle
Crompton
SERIES
Bohle

**Linisher at Flameworks Creative Arts Facility.**

**Hold glass firmly to use the linisher.**

**Both flat and curved surfaces can be ground on the linisher.**

Linishers are excellent workhorses for grinding and polishing glass. The downside to these machines is that they are large, expensive and require regular maintenance. The routine is mainly general cleaning or replacing the water and lubricant if it has a recirculating water pump system. Some are mains water-fed, which is something to consider as they require more thoughtful set-up but less attention long term. Due to the water usage, they can also make everything else in about a one-metre radius soaking wet. They need to be positioned in a studio where there is at best floor drainage, especially for a mains water-fed machine, and at worst a mop and bucket. They also need an electrical source that is protected from water spray. Oh, and don’t forget your own water-proofs and wellies.

## Flatbed Grinding Wheel

There are a few main types of flatbed grinding wheel: ones that have a thick steel plate onto which you add grit; diamond-impregnated resin-coated grinding beds; and ones that have a steel plate used with interchangeable magnetic discs. The magnetic ones are similar to the linisher in the sense that the discs can be changed from rough to smooth to allow you to work through the polishing process. The magnetic discs wear down and may need replacing more frequently, but they are cleaner and allow transition through the grades. Both the resin-coated and magnetic flatbeds tend to grind glass faster around the outer edge of the wheel, as the rotation of the wheel is faster the further from the central point you hold your work.


**Flatbed grit grinder at Plymouth College of Art.**

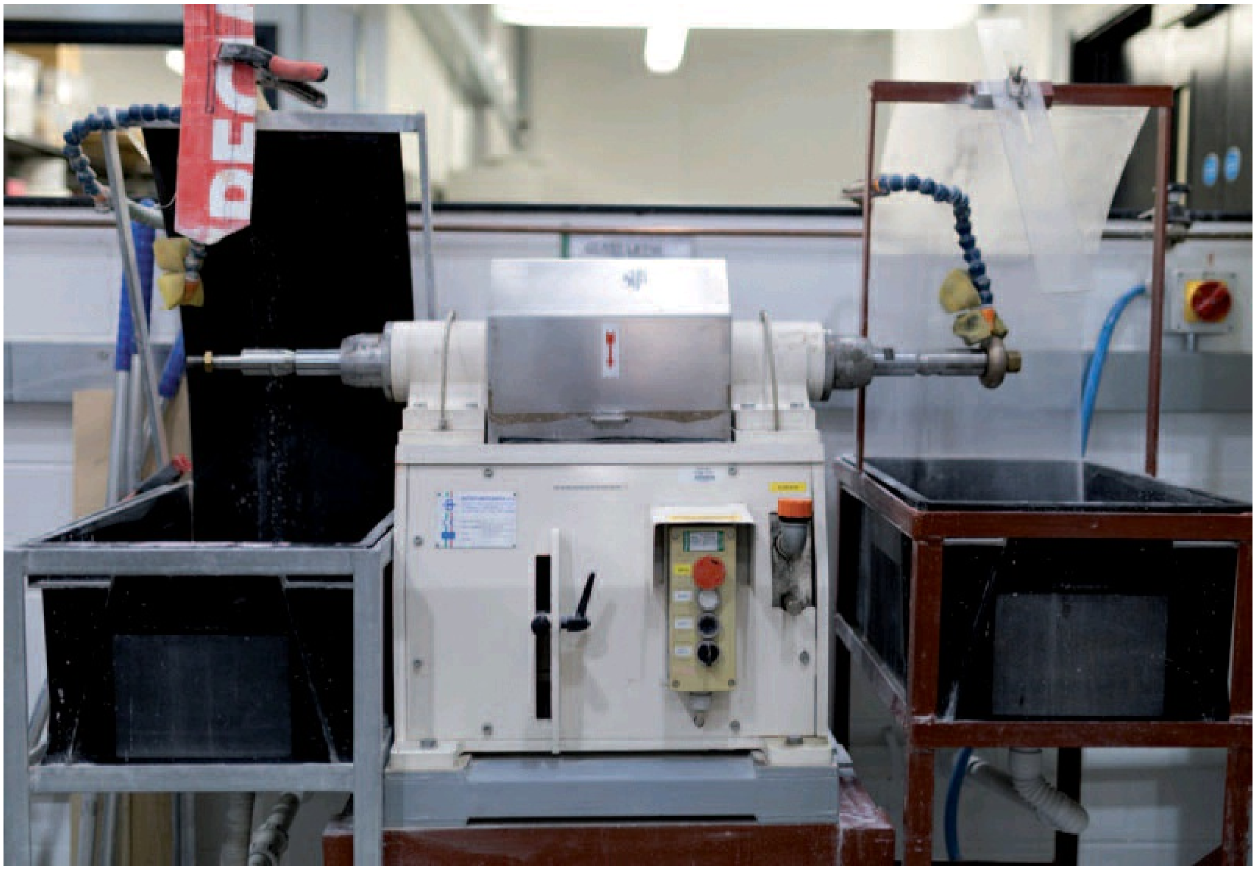
**Flatbed magnetic disc grinder at Plymouth College of Art.**

When working on these machines you need to hold your glass firmly with a medium downwards pressure. Move your glass across the grinding bed and occasionally rotate the piece in your hands so you are not always holding it in one direction.

The grit-grinding wheels tend to wear the glass down faster nearer to the centre of the wheel as this is where the fresh grit and water drip onto the bed. Why would you want a flatbed that only had one grade of grit? Well, if you have a lot of space these machines are industrial in capacity and usually used with the coarsest of grits to remove material and flatten surfaces. Generally, they are considered to be longer lasting and more affordable as the grit aluminium oxide or silicon carbide is a relatively inexpensive material and the steel might only need relevelling once every few years.

## Handheld Engraver

There are various makes of these and some of them are relatively inexpensive. Only ever use a handheld engraver that is cordless or has a flexible shaft attachment. The main consideration is that most are made to be used dry, whereas you will need to use water to keep the glass cool. This way the electrical element of the motor can be kept away from the wet glass processing space, eliminating risks of electrocution or damage to the equipment. Handheld engravers with variable speed adjustments are incredibly versatile: they can be used for engraving processes from etching to drilling holes, and even polishing glass, which requires slower speeds. There are lots of diamond-, metal-, stone-, rubber- and felt-headed bits that you can buy; there are even mini grinding and polishing Velcro disc sets available much like that of the larger handheld grinder, which will take your glass surface from matt to shiny. An adjustable chuck or removable collets in different sizes are essential as some of the brands for these bits come in shaft widths ranging from 2mm up to around 6mm.



**Lathe at Plymouth College of Art.**

## Lathe

There are three types of lathe, with separate applications in glass casting and in cold glass finishing.

- Wood lathes and plaster lathes are perfect for turning your own original master models. Depending on what material you prefer to work with, the wood lathe has the benefit of being able to create fruitwood turning moulds for blowing hot glass into as well. The plaster lathe has the benefit of being able to cottle and pour your plaster blank into the chuck and on the same day turn and carve your form. Both materials can be polished to create smooth surfaces for the best quality when casting moulds from them.
- A glass-grinding lathe can be used for engraving, grinding and polishing.

There is a large selection of diamond-sintered cutting wheels with varying profiles that are available for these lathes, alongside cork and felt wheels that are used for polishing glass with pumice and cerium respectively. With a thin-width wheel, you could easily remove unwanted material from a cast similar (but slower) to using a glass saw.

## Handheld Grinder

There are two types of these hand machines: they do exactly the same job but are powered differently. One type is pneumatic (air powered), which means it is lighter to hold but you will also need to purchase an air compressor to power it. The other type is electric – normally 110v, so it will need an electric transformer. The electric ones weigh double that of the air-powered ones so consider how often and for how long you are going to use it before purchasing.

Both are best used in a wet room or outside. These handheld machines are water-fed so be warned, you will get very wet. They are a great alternative to any of the static polishing machines like the flatbed grinders and linisher mentioned previously. They have interchangeable disks that go from rough to smooth for grinding and polishing. They have been widely used in the stone polishing industry and therefore there are loads of grades of pads for both glass and stone, which I have had no problems interchanging. They are brilliant if you need to polish a glass cast surface that is heavy or cumbersome to hold. With most other machines you hold the piece of glass to the machine, whereas with these handheld motors you move the machine over the glass. If your piece of glass is on the small side (smaller than a 10cm cube) you may need to set it into a block of plaster or clamp the glass down to hold it in place.

There is a definite knack to using these and, as with all polishing techniques, they take a long time to learn. Make sure you wash and clean the glass and pads before and after each use to avoid contamination. The most frustrating thing with these machines comes when polishing a flat

surface, as it is held by you. If you lose concentration, you can end up causing slight rounding on the surface. This can only be corrected by going right back to the start.


**Sandblaster at Plymouth College of Art.**

## Sandblaster

These machines are primarily used for surface decoration of glass after it has been in the kiln, although they can be used before to great effect too. They do the opposite of polishing. If you have a shiny surface and you sandblast it, that surface will then become matt. The most common type of sandblaster for glass studios has a blasting cabinet, compressed air unit and extraction filter. They do take up a lot of space and are quite noisy

when in use. They are also better kept away from any glass pieces that are going to be polished, as the grit (commonly aluminium oxide, not sand) can cause an unwanted scratch on a surface. That said, this is another one of those versatile machines, because there are so many possibilities for surface decoration on cast glass and interior surfaces within cast glass that can be created with sandblasting.

There is an array of materials that can be used to mask the surface of the glass and control the areas that are left exposed to be sandblasted and become matt. These can be as organic and simple as painting on PVA glue, which acts as a resist, or as advanced and digital as using a plotter vinyl cutter to create stencils. There are also companies who will expose specialist photoresist film called Rapidmask or Rayzist (USA) with text or artwork, which will give sandblasting a precise and professional finish for any awards or trophy commissions. I tend to use a sandblaster to even out a surface that I have cut and engraved or to provide a contrast against a polished surface. They are also essential in preparing casts for acid polishing.

Of the bonus items I have mentioned, some are more attainable and realistic than others. As you delve further into the realm of glass casting, there are even more specialist pieces of equipment that are all geared toward time-saving and large-scale production.


easycomposites
share the knowledge
ADDITION CURE
SILICONE RUBBER
910g
Silicone to catalyst ratio:
100 - 10
SF-400
CAPACITY:

**Flat lay of silicone and Gelflex. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER THREE

# MATERIALS

This chapter will give an overview of the main materials used in glass casting, the materials needed after the initial master model-making stage, and how to take these master models through to the investment stages. It will also include some of the health and safety considerations for each material. It is recommended that you request the data sheets and COSHH information from the suppliers and become familiar with them before use. Ultimately you are responsible for creating your own good working practices and ensuring you use these materials safely. Different types of glass, glass preparation and the reusing of these materials are covered in later chapters. Excluding the glass, there are seven main material types used in glass casting:

- Glass investment powders
- Plaster
- Modelling clays
- Wax
- Skin-safe products
- Rubber
- Polystyrene foam

## Glass Investment Powders

In order to be able to cast glass into your desired form, you will need to

make a mould for the glass to flow into. This is known as an investment mould. It acts as a container for the cold chunks of glass to be placed into and then, when heated up in a kiln, melt into. These investment powders are mixed together to form a strong hollow shell that can withstand temperatures of up to 900°C (1,650°F), and afterwards can be easily removed from the surface of the glass that has been melted inside. Investment powders are essentially made up of a setting or binding material (normally pottery plaster) and a refractory material (silica, commonly in the form of quartz, flint or molochite), which is able to withstand high temperatures. A plain plaster mould would crack and break when exposed to temperatures above 40°C (104°F). By adding the refractory material, the even distribution of the two powder particles support each other to withstand the heat in the kiln, creating an investment mould that retains its integrity at glass-casting firing temperatures.

The most basic of investment mixtures is a combination of equal parts water, plaster and silica. Before you rush out and buy all these materials though, there are a few other products available that will go a long way towards ensuring your success as a beginner in glass casting.

## Crystalcast

For the projects within this book, I have used a premixed investment powder called Crystal-cast. It is an undisclosed recipe, presumably a combination of plaster, some form of silica and olivine sand. The premixed refractory and binding ingredients create an excellent product for beginners starting in glass casting. As Crystalcast has been specifically designed for glass casting, with the simple addition of water you are able to quickly make your own investment moulds. The investment material has been developed to provide maximum mould strength with an excellent ability to replicate minute surface details. Once cast, it removes easily from the glass surface, leaving little to no mould residue. As the investment material expands and contracts at a similar rate to glass, it is excellent for both open casts, lost-wax and internal core moulds, without any complicated

changes to the recipe.

## BASIC INVESTMENT MIX FOR GLASS CASTS

Water : Silica : Plaster
1 : 1 : 1
600ml : 600ml : 600ml

## CRYSTALCAST INVESTMENT MIX

Water : Crystalcast
32 : 100
480ml : 1,500ml


**Measure by volume 32 parts water to 100 parts Crystalcast.**

**Add the Crystalcast to the cold water.**

**Mix together until it resembles a smooth, thick porridge consistency.**

With the simple addition of fibreglass strands or mesh in outer layers, Crystalcast can be rein-forced easily for larger scale moulds. Using this product and similar premixed powders eliminates a lot of the risks that can be present when you first start moving into the realms of glass casting.

### Castalot

Once you have practised this process and are feeling more confident with the results, there are lots of alternative investment recipes and products available. Castalot is another premixed investment material that can be used for creating slump moulds and open casts. This product has the benefit of being able to with-stand approximately ten multiple firings; it can be used to create reusable moulds. Be extra careful when creating the form as it must have no undercuts whatsoever, otherwise the glass will not come out of the mould without having to break it.

### *Health and safety for glass investment powders*

All types of silica required to create investment moulds, including those premixed in Crystal-cast, are classed as a carcinogenic. Prolonged exposure can cause silicosis of the lungs. Treat this material with the utmost care and respect. Always wear at least a P3 or FFP3 disposable mask or, better yet, a respirator, and work in a well-ventilated area. Be conscious of not creating any excess dust; this includes not patting down your clothes or apron as the particles will become airborne.

**CRYSTALCAST TOP TIP**

Crystalcast is not to be confused with *Crystacal*, which is an incredibly hard type of plaster.

## Plaster

While plaster is one of the investment powders that can be mixed with a refractory material to create glass casts, plaster on its own cannot be used to cast glass. There are, however, other uses for pottery plaster that warrant mentioning.

## Dry

Plaster powder can be used directly on the kiln shelf, then glass can be slumped onto or fused over it to create textures in the back surface. Glass will not stick to plaster powder. It can be carefully sieved on to a kiln shelf; it is a quick and cheap alternative to kiln wash. Dry plaster can also be used to support cast glass pieces in the kiln. For example, plaster powder can be packed around a small cast piece with a single surface exposed to fire polish; this protects the rest of the glass from the effects of heat and gravity.

## Mixed

Plaster, when mixed and set, is hard and can be lathed, cut, carved, sculpted and polished to create master models and forms to take moulds from. It is also used to make part-moulds (covered in a later chapter) to create waxes for glass casting. If you need a dry plaster block, to recycle clay on, for example, leave it in a warm place for a week and the moisture will naturally evaporate from the material.

## Modroc

Modroc is a flexible gauze that has plaster powder attached to it. Wet this material with tepid water and rub it to activate the plaster. It can be used for master model making by folding and crumpling strips over forms. It will attach to itself and will set hard after ten minutes. It can also be used for creating a hard reinforcement or backing for flexible moulds. Two to three layers of Modroc will support thin skin-safe moulds and rubbers so that

they do not flex and distort when plaster is poured into them.

### *Health and safety for plaster*

As with any powders, try not to allow plaster dust to become airborne. Don't pour mixed plaster down the drain. Do not use plaster to cast from the skin. Plaster sets hard and can cause trapping and burns; as it sets, an exothermic reaction happens which creates heat. There are other materials developed for casting the body, mainly alginate (discussed later in this chapter).

## Modelling Clays

Some modelling clays can be invested in an open cast mould, where the clay is accessible, flexible and easy to remove. All of the clays can be used to make master models. These 3D master forms cannot be used directly for investment moulds as they cannot be steamed or burned out. These master models will need part-moulds taking from them to be translated into wax and then invested for glass casting.

**Pottery clay used for model and mould making.**

## Pottery Clay

This is an inexpensive and quick way to make master models. This clay is also good for sticking a wax model down to a surface and sealing mould walls in order to pour liquid mould mixtures into them. A cheap, smooth, buff clay will easily pick up surface details for mould making. There are some downsides to using clay: make sure that you are thorough when removing clay from any investment moulds as any clay that remains will stick to the surface of your glass and become a blemish on your form. These clay imperfections can be difficult to remove and may require machinery to tidy up the surface of glass casts, either a hand engraver or sandblaster. Whatever pottery clay you decide to use is reusable (*see* Chapter 11 for information on clay recycling).

### *Health and safety for pottery clay*

Most clay bodies have silica in them. If left to dry this creates a dust and can easily be breathed in. Wipe down all work surfaces and tools, rinse out rolling mats and aprons at the end of the day and leave to dry. By cleaning up as you go and working with clay only in its damp form, you will be able to avoid the creation of dust.

## Oven-Bake Clay

Brands Sculpey or Fimo are specially formulated modelling materials that can be manipulated and then fired in your home oven. This material when fired becomes rigid, and sculpting or carving can be continued on the form. If you are looking to improve your model-making abilities, this material will allow you to do that. It doesn't dry out so quickly or have the stickiness and nuances that working with ordinary ceramic clay presents. Once you have baked your master model, you can use either a hot melt rubber, silicone or plaster part-mould to replicate the master and transfer it into a wax.

**SUPER SCULPEY TOP TIP**

You can use a hair dryer to 'bake'-harden Super Sculpey.

## Modelling Plasticine

Newplast and Monster clay brands are similar to the oven-bake clay except that they cannot be baked to set hard. These materials are popular with model and prop makers for their ease of manipulation and sculpting ability. This material is easy to use and will stay in position hard enough to be able to take moulds from it. Again, once you have created your master then you can use silicone or plaster part-moulds to replicate this model. Due to the pliability of this material, hot melt rubber is not a suitable material to use to create a mould; the material will melt and deform. Once

a mould has been taken, modelling Plasticine can be reused time and time again.

## Wax

There are many types of wax on the market with different qualities, which means you can use them for various applications: melting, pouring, painting, carving and modelling. The lost-wax process and being able to burn out wax from investment moulds is essential for translating 3D models into a glass form and will be covered further in the respective Chapters 5 and 6.

Melting wax is best achieved using a double boiling system or bain-marie, a glass (Pyrex) bowl in a saucepan of water. Think melting chocolate but with wax (which unfortunately doesn't smell as nice). You will need to have good ventilation or bring the wax melting process outside, as the fumes can sometimes be headache-inducing. The double boiler is the most effective method of heating the wax evenly and controlling the temperature. It is not recommended to melt wax directly in a saucepan, as it is easy to overheat the wax and wax is flammable; however, it is possible with the use of a thermometer. Alternatively, you could use a slow cooker that is never going to make its way back into the kitchen, or most recently I purchased a beautician's melting pot for waxing, which is perfect for melting small amounts quickly without overheating.

### Microcrystalline Wax

A fairly rigid castable and carvable wax that is easily melted, steamed and recyclable. It is hard to see the surface quality of this wax due to its lack of colour so I recommend adding a dark candle wax dye or pigment to the wax while melting it. Alternatively, it can be mixed with Type B brown wax to add a bit of colour; this also adds flexibility to the material. The recommended melting and pouring temperature for microcrystalline wax is

71°C (160°F).

## Type B Modelling Wax

Available in two colours, brown and yellow; apart from the colour they are exactly the same. Type B is an excellent model-making material as it can be directly manipulated with the heat of your hands to create intricate forms to cast in glass. Using this wax can be quite messy as it gets sticky when warm. Five minutes in a cold place or freezer will alleviate the stickiness and stop the wax from bending under its own weight when it is being manipulated into tall or thin shapes. Wire armatures may be used for reinforcement but ensure that they are completely encased in wax and you will be able to remove them from the mould once the model has been invested. Alternatively, if you need a wire armature in your model but know that it will be tricky to remove, consider using thin copper wire, which could be deliberately left inside the mould, becoming an integral part of the final glass cast. As copper has a similar expansion and contraction rate to glass, it is one of a few metals that can be invested inside glass without causing the glass to crack on cooling.

**Type B modelling wax can easily be manipulated and used to join other waxes.**

Type B modelling wax can be melted and carved. It may also be used to join other types of wax together, plus it can be mixed with microcrystalline and green wax to change and add flexibility to these more rigid waxes.

## Green Wax

This is a hard and rigid wax that is easy to cast and carve with hand tools for the lost-wax process. It melts at a slightly lower temperature to other waxes, around 65°C (149°F), and cools very quickly, making it the perfect wax for pouring into and painting onto rubber moulds for repeatable forms.

It also releases incredibly cleanly from these moulds, picking up minute surface details. It is by far the best wax for use with silicone, Gelflex and alginate moulds that have been taken from the skin. However, if the mould is enclosed sometimes this wax can cool too quickly and trap air bubbles on the surface touching the mould, but at least there is not a long wait between pours to ascertain if the wax poured has been successful.

**TOP TIP**

Silvia Levenson's top tip is to melt a coloured crayon into the wax so that the surface is visible.

## Pink Wax Sheets and Sprues

These come in a range of thicknesses of flat sheets and round sticks known as sprues and are commonly used in jewellery casting and dentistry. They can be cut and shaped easily with a scalpel, and used either to add detail to other waxes or as models in their own right. When you are modelling using these wax sheets, you will need to be very conscious of the thickness of your model and the characteristics of the glass you are going to be casting with. Most types of glass will struggle to flow into spaces much thinner than 2mm. You will need to adjust your firing cycle to lengthen the time at top temperature to accommodate the time it will take for the glass to fill this space and the air bubbles to escape. A lead-based crystal glass will cast into thinner forms but it will still require a longer soak at the top temperature to melt into these thin spaces. The sprues can be attached to undercuts on your model with modelling wax, a candle or small soldering iron and used as air vents for awkward shapes.

**WAX TOP TIPS**

- Wax melted and poured into a mould will shrink by 3–5% in all directions when cooled.

- Rubbing white spirit over the surface of wax with a lint-free cloth will smooth and clean the surface.
- Spraying hairspray over wax and waiting for it to dry before you invest it provides a slightly sticky surface that helps the investment material attach to the wax model.
- Wax will not stick to baking paper or greaseproof paper.
- Painting wax onto a rubber mould gives the best surface detail.

### *Health and safety for wax*

The fumes from wax melting can cause headaches. Work in a ventilated area. Do not let wax overheat and burn as the fumes will get worse.

## Skin-Safe Products

### Alginate

This is used for taking casts from the body and detailed skin moulds. If you have ever had impressions of your teeth taken at the dentist then it's likely that this is the material that they used, which explains why some alginates have a minty smell. The material itself is made from algae, it is non-toxic and completely skin-safe. It comes in powder form and is mixed with water in equal volumes if you are pasting onto a surface, or two parts water to one part alginate if you have a container into which you are immersing a hand, for example. When setting around a hand the material remains slightly elastic, which allows wiggling of fingers and easy removal from the skin. A thin application of petroleum jelly is a good barrier in general, but especially useful if you are applying alginate over eyebrows, eyelashes or the hairline.

**Chromatic alginate** gives you a visual indication of what state it is at, changing colour during the mixing, ready to pour and while it sets. This is pretty fun to use with children.

**Slow-set alginate** takes four minutes to set after it has been mixed; this means that if you are doing a more complicated skin mould you have more time to get a good overall coverage before it starts to set. I prefer to use the slow-set for face casts as I can be thorough and not feel rushed with the application.

**Fast-set alginate** only takes one minute to set, so if you are working with small children this is better as they tend to not be able to stay still for a long time.

Unfortunately, all alginates are only a single-use material: once mixed, poured and set, the mould has a very short shelf-life of a few hours as the moisture within the material begins to slowly evaporate, causing the alginate to shrink. You can prolong usage for a few days by storing it in an airtight container with a damp cloth or in the fridge. Alginate does not stick to itself so it is better to mix more than you think you will need as it’s very difficult to remedy if you haven’t mixed enough. You can use alginate as a quick material to make replicas of objects as well as the skin. It is possible to cut the alginate apart (do not cut alginate next to the body) and then wrap it in tape to join it back together for pouring multiple plaster or waxes into.

**Step 1: Measure equal volumes of alginate and water in separate cups for a thick consistency. Rub petroleum jelly into the skin and hairline areas: eyelashes, eyebrows, etc.**

**Step 2: Pour water into a mixing jug.**

**Step 3: Pour alginate into the water.**

**Step 4: Mix immediately for at least one minute to get rid of all the lumps.**

**Step 5: Apply alginate to the skin.**

**Step 6: After five minutes or when the alginate has set, move skin to release alginate.**

**Step 7: Place alginate in a container or build clay walls to contain alginate.**

**Step 8: Mix and pour plaster into alginate; wax, rubber and investment material can also be used directly in alginate.**

**Step 9: Remove alginate from set plaster.**

**Step 10: Clean up using a craft knife.**

## Skin-Safe Silicone

This is a better option if you need to use your cast more than once, or over a longer period of time, as the silicone will not dehydrate or degrade as the alginate does. There are a few brands of skin-safe silicone – Body Double and ZA22 Thixo Body are recommended. Do not use any silicone for skin moulding unless it has been sold and certified for that use. Always perform a skin reaction test prior to use on anyone. The skin-safe products consist of equal parts silicone and catalyst mixture. There are two types: fast and slow. The fast set will give you a minute of application time for small areas, whereas slow sets in fifteen minutes; this is mostly used for larger casts. They both have a thick consistency that when applied to the skin will not run off. If you haven't mixed enough material, you can mix and add more as it will stick to itself, unlike alginate.

For both alginate and skin-safe silicone, face and large body impressions will require a backing normally of modroc applied on top of the material to support the structure, so that it doesn't deform when removed from the skin. Both will give you a negative impression of the skin you have moulded. Neither material can be used to cast glass directly into. You will have to use other materials in order to translate this into a glass form. The best thing is that with a separator (petroleum jelly, margarine or a silicone release spray) other materials such as plaster, wax, investment, silicone and Gelflex can be poured directly into these skin-safe moulds. It is possible for you to create both a positive or a negative of a skin mould to be cast in glass, with the latter being slightly more complicated. With the negative version of a face or one side of a hand, for example, the cast can be treated like an open cast (*see* Chapter 5). If the aim were to have a block of glass with a negative hand in, this is classed as a core cast and has many more steps (*see* Chapter 9).

### SKIN-SAFE CASTING TOP TIPS

- Prepare everything you need before you start life casting.
- If using silicone, do a small test to check for allergies.
- When face casting, start application around the nose first as you have the most time and control applying around the nostrils at the beginning.
- When applying onto someone, wear gloves for ease of clean-up and for swiftly moving onto application of modroc.

## Rubber

### Gelflex

Gelflex is a hot melt rubber that can be used to create master models for making repeat investment moulds, or repeatable waxes. The melting

temperature of Gelflex is 130°C/266°F. This can be achieved by placing small pieces in a Pyrex jug and heating with an old microwave for one-minute bursts, stirring in between. Due to the temperature required to melt Gelflex into a pourable liquid, it cannot be used for pouring over wax, some plastics, polystyrene, or Plasticine models as they will melt. It is a cheap and reusable material, which is excellent for creating a flexible mould around many other materials. It can be used to take moulds from porous objects of wood and bone, but you will need to use a sealant on the model to prevent the heat from the Gelflex sucking air through the material and causing bubbles to rise to the surface. G4 sealer can be used to prevent these bubbles, which can affect the surface quality of your mould. For this reason, Gelflex is better used for form rather than detail.

There are three colours of Gelflex or Vina-mould (which it is also known as): red is the softest, followed by cream or natural, which is also soft but slightly more rigid, then yellow or blue (depending on where you buy), which is the hardest. The latter is better for moulds with sharp corners and high details that do not require as much movement to remove.

## POSITIVE AND NEGATIVE WORK THROUGH

Alginate (–) → Wax* (+) → Investment material (–) → Glass (+) one-off form.

Alginate (–) → Plaster* (+) → Rubber (–) cold cure Silicone or hot melt Gelflex/Vinamould. It must be an open-sided form or part mould to allow removal of the plaster → Wax* (+) → Investment material (–) → Glass (+) repeatable form.

Alginate (–) → Rubber (+) cold cure Silicone or hot melt Gelflex/Vinamould. It must be an open-sided form or part mould to allow removal of the alginate → Wax* (–) → Investment material (+) → Glass (–) repeatable form.

Alginate (–) → Investment material (+) for slumps, or casts that will need damming, this must be an open-sided form to allow for removal of the alginate → Glass (–) one-off form.

*these materials are editable

### *Health and safety for Gelflex*

When melting this material, wear a mask and work in a ventilated area. Do not allow Gelflex to burn as the fumes turn rather nasty. Wear heat-protective gloves when melting and pouring the Gelflex, as the temperature is approximately 125°C/257°F and will burn the skin.

**GELFLEX TOP TIP**

Pour any remaining melted Gelflex into a clean baking tray and allow it to set. It will be easier to cut up with scissors when you next come to use it.

## Silicone

Silicone is also known as cold cure rubber as there is no heat involved. Most silicones consist of two liquid parts – a rubber and a catalyst – and both are measured (normally by weight) and mixed together to activate the setting and forming of a flexible solid. Most silicones have different flexibility ratings based on their ‘shore hardness’ (the lower the shore rating the softer and vice versa). Silicone, once mixed together, can be poured over most materials to replicate surface details and objects. From these you can create waxes. As there is no heat involved you can pour silicone over wax and all types of modelling Plasticine. Some silicones can take up to twenty-four hours to set, and during this time most silicones will sink into very fine details. When creating moulds to contain silicone, it is best to seal the edges by applying melted wax or using a glue gun. Pottery clay can dry out during the setting time and allow the silicone to leak out of the mould walls. Some silicones require a vacuum chamber to degas the mixture; this removes air bubbles that form around the model and allows the more viscous material to set exactly around a form. These silicones can still be used without degassing; pouring from a height in a thin ribbon helps to remove some of the bubbles created when mixing. All silicones will adhere to porous surfaces, even glass if it is incredibly clean. A wax release spray, silicone-based car maintenance spray or even a thin coating of wax (by

dipping) or petroleum jelly will all act as a separator for silicone.

**SILICONE TOP TIP**

Unmixed silicone will not set.

To ensure you have mixed the silicone thoroughly, pour it into another container and mix again. Set silicone will easily peel off plastic utensils and jugs.

### *Health and safety for silicone*

Wear eye protection, a respirator or mask, and work in a ventilated area or outside under cover. The catalyst has prolonged adverse effects on the lungs. Wear disposable gloves and cover all surfaces, including measuring scales, in a sheet of newspaper, cling film or plastic. Silicone mixing can be messy and will stick to stuff.

## Polystyrene Foam

### White Polystyrene

This is often used as a base for backing flat, textured objects. It adds the much-needed depth to enable room for the glass to be placed into an open cast mould. Stick down with double-sided tape and seal onto your base-board with a seam of clay. Once the investment has set it is easy to cut up the polystyrene and remove from moulds. An alternative to this would be to use a few layers of thick cardboard glued together.

### Blue Polystyrene

This foam can be easily shaped and sanded to create large precise forms for maquettes or master models for direct open casts. It can be combined with wax for additional surface detail. The foam can be cut and removed

from open cast moulds in sections. This creates less contamination on the investment mould surface than if using modelling clay. Glue guns and hot melt rubber will melt this material. Polystyrene is flammable and gives off toxic gas styrene when burned, which is incredibly harmful and affects the nervous system.

There are lots of other materials used in glass casting that haven’t been mentioned. As technology improves, this list will get longer and more complex. This is an overview of the more commonly used materials. It is good practice to know what you are working with; read the data sheets and become familiar with the limitations and risks for each material. Ultimately it is your responsibility to maintain a safe working environment for yourself and others.

**Flat lay of glass in various forms. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER FOUR

# GLASS PREPARATION AND KILN FIRING

The beauty of glass casting is that you don't have to stick to one sort of glass for all your projects, apart from making sure that the glass you use in each mould is compatible. Using different brands for each project gives you an increased palette of colours and variations in the results you can achieve. Eventually you may decide to stick with one brand, but that's down to personal taste.

### THE GOLDEN RULES

Ensure that:

- The glass is compatible, measured and clean
- The mould is sound, dry, level and supported
- The kiln programme is calculated, timed and temperature-controlled for the cast and anneal

## Compatibility

There are several glass brands that have created glass using a combination of soda, lime, ash, lead, silica sand, borax and much more. Not one of these brands is likely to use the same recipe of materials to

create their glass and the qualities they can achieve. The qualities vary from the clarity of transparency in the glass through to vibrancy of colour and range of forms – for example, billets through to sheets, frits, powders, confetti and stringers. The chemical composition of the glass brand that you use will also determine the temperatures that the glass starts to become sticky, bends and then melts to flow into moulds. As it is heavier, glass containing lead will flow into thinner spaces in an investment when casting, and can be acid polished too.

The type of glass also has a rating that indicates how much the glass expands and contracts when it is going through the cooling down process called annealing. This rating is called the coefficient of expansion, COE for short. This figure gives an indication of the minute movement that happens to the glass as it is cooling and setting. Even if the glass wasn't hidden in the kiln, this movement is so tiny that it is not visible to the naked eye. If the number of the COE is high, it indicates that the glass is soft and expands and contracts at a higher rate when cooling. A glass with a low COE – for example, borosilicate glass, or Pyrex – is often rated COE 32 because it is a harder glass that does not expand and contract as much. Boro-silicate glass has been designed for use in scientific vessels, think test tubes and conical flasks; it has the ability to be heated and cooled down quickly. The glass has still been through a kiln-controlled cooling process to remove the stress but the thin scientific vessels won't break when reapplied to heat. It does mean that borosilicate glass is harder and requires more heat to melt and flow. Although it has been used industrially for casting the humungous, highly polished mirror blanks used in observatories, it is not as commonly used as an art casting glass.

If the COE of two glass brands are the same or within two points of each other, it is likely that they may be compatible, although this is not an automatic guarantee. Even though the rates are nearly the same, the chemical make-up of each glass may be wildly different and create invisible stresses between the two glasses. The only true way to assess if a type of glass is compatible with another type is to test it: fuse two pieces together and check the results for any strain with a stress tester (*see*

Chapter 10 for more information).

## Measuring the Glass

Once you have created your investment mould you need to be able to calculate how much glass to put into it. If you have a fairly regular form – for example, a variation of the relief open cast in Chapter 5 – then you can find the volume of glass required by measuring the length, width and depth of the space within the mould. You can then cut sheet glass to no more than 5mm ($^{1}/_{8}$") smaller than these dimensions and place the glass directly into the mould to be cast, layering up sheets of glass till you reach the desired thickness. If the investment mould has deep imprints instead of just surface texture, measure the depth of these; it may mean you need to add extra sheets of glass to increase the thickness of the cast and ensure that these indentations will be covered. To reduce the number of bubbles that get trapped between the layers of sheet glass, you can pre-fire (tack fuse) the glass separately prior to casting within a mould.

### Specific Density

The type of glass that you intend to use is also an important factor. All glass types have a specific density rating, a 5cm/1" cube of lead glass weighs more than a 5cm/1" cube of float glass, as the lead glass contains heavier ingredients. The volume of these two cubes of glass is the same but the weight is different depending on the specific density of the type of glass used. You can use chunks or billets of glass in open moulds. Multiplying the dimensions measured together (length x width x depth) will give you the volume of the space. This figure can then be used to find the weight of the glass required: multiply the volume by the specific density of the type of glass you are using. The specific density (weight) of the glass, for most glass types, is listed in the table. This will help you to determine the amount of glass required. You can also measure the mould by a

method called displacement.

**GLASS BRAND TEMPERATURES AND SPECIFIC DENSITY CHART.**

| | | | Temperature | | | | |
|---|---|---|---|---|---|---|---|
| Glass brand | Forms | COE | Casting | Annealing | Strain | Acid polish | Specific density |
| Banas glass | Billet | | 820°C–860°C/ 1508°F–1580°F | 475°C/ 887°F | 360°C/ 680°F | No | 2.5g/cc |
| Bullseye | Billet Frit Sheet Confetti Stringer Rod Frit Powder | 90 | 825°C–840C/ 1517°F–1544°F | 482°C/ 900°F | 360°C/ 680°F | No | 2.5g/cc |
| Dartington Crystal 24% lead | Billet | | 840°C/1544°F | | | Yes | 3.16g/cc |
| Float | Sheet | 82 | 850°C–900°C/ 1562°F–1652°F | 510°C/ 950°F | 400°C/ 752°F | No | |
| Float compatible | Frit Confetti Stringer Powder | 82 | 850°C/1562°F | 510°C/ 950°F | 400°C/ 752°F | No | |
| Gaffer casting glass (40% lead) | Billet Frit | 92 | 780°C–850°C/ 1436°F–1562°F | 430°C/ 806°F | 390°C/ 734°F | Yes | 3.6g/cc |
| Glasma blowing glass | Billet Cullet frit | 96 | 880°C/1616°F | 510°C/ 905°F | 400°C/ 752°C | No | 2.6g/cc |
| Schott optical glass (various % lead) | Billet | | | | | Yes | 3.1 to 5g/cc |
| System 96 | Sheet | 96 | 880°C/1616°F | 513°C/ 955°F | 476°C/ 889°F | No | |

## Displacement

Displacement is a way to accurately measure the volume of glass you need for your mould. This can be achieved in a few different ways, depending on the material and shape of the form you are casting.

- Like Archimedes in the bathtub, you can measure the volume of the (wax) form you are casting by submerging it into a jug of water and recording the increase in volume caused. Chunks of glass can then be placed into the jug until the level of the water rises by the same amount as the form. The more accurate your measuring jug, the more likely it is that you will have the correct volume of glass.
- Alternatively, once you have invested and removed or steamed the form, you can measure the volume of the water poured into a wet mould. Dry moulds will absorb water and give an incorrect volume. Fill a measuring jug to 1,500ml, pour the water into the mould till it's full. The difference is the volume of glass you need. Again, you can put chunks of glass directly into the jug to bring the water level back up to the 1,500ml line. (With a larger mould, a larger jug and more water are needed.)
- You can weigh the mould and then fill this with water to calculate the weight of the water required within the mould.
- You can multiply either the volume or weight of the water measured (which is the same, 1ml = 1gram) by the specific density of the glass to find the weight of the glass required to fill the mould.

**Measure 1,500ml of water into a jug and set your mould up so it is level.**


**Fill the mould with water to the level you would like the glass to cast.**


**Mark and calculate the difference in volume – this is the volume of glass needed.**

**Place chunks of glass into the jug.**

**Continue to add glass chunks to raise the level of the water.**

**Stop adding glass when the water level returns to 1,500ml.**

## Glass Cutting

Glass cutting as a term can be slightly misleading as it is not possible to cut glass in the traditional sense. The action of glass cutting involves scoring the glass to create a weak point and then applying pressure to the back of the score line to encourage a controlled break of the glass along that line, as opposed to a cut. There are a number of glass cutters available in various shapes, but essentially they consist of a steel or tungsten V-shaped wheel that either needs to be lubricated or is self-oiling. If you are measuring the glass to break it to a specific size, be aware that

the V-shaped wheel is in the middle of the glass cutter and not on the edge where you would draw a marker line. If you are using a straight edge or rule as a guide for your cutter, allow 2mm ($^5/_{64}$") for the location of the wheel.

**Scoring sheet glass with a glass cutter using downward pressure in one fluid motion.**

**For 6mm glass use running pliers lined up with the score line to apply pressure to encourage it to break.**

When cutting thin sheet glass from 2mm to 4mm ($^1/_8$"), it is possible to score the glass on one side, normally the smoothest, flip the glass over and then press down on the back of the glass where the score line is. The pressure of your thumb pushing towards the score line will be enough to break the glass along the line.

Every time you score glass, the action is the same: hold the glass cutter in your dominant hand, holding it like a pencil at about an 80° angle to the glass. Use a rule or your first finger from your other hand to help guide the cutter. Apply some pressure and move the cutter in a smooth, fluid motion in one direction. Normally you can hear the score line form; on some opaque glasses the sound isn't as obvious, but this doesn't mean that you haven't scored the glass. You should be able to see a faint line across the surface of your glass. This is when you will be able to apply pressure on either side of the score line to encourage the glass to break.

An easy way to do this is by putting 3cm (1") of a pencil underneath the glass and in line with the score line; press down on the glass on either side of it. If you are cutting glass that is 6mm (¼") thick, a pair of running pliers lined up with the score line will help you break the glass. The running pliers are the correct way up if they have a sad smile look to them; the part in the middle pushes up and the points on either side push down. You do not need to turn the glass over when using a pencil or the running pliers as they both create an upwards pressure on the score line from the other side of the glass.

For cutting 10mm-thick sheet glass (wear grippy gloves and eye protection), use a brush to wipe WD40 onto the surface of the glass before you score it. Once scored, position the score line in line with the edge of your table. Holding firmly onto the glass, lift and lower with a bit of force to shock the glass so that it breaks along the score line. The sound of this is actually quite loud, but the method is surprisingly effective. Note that the glass will not break if you are trying to cut a small piece, because you need the weight as leverage. There are breaker pliers produced by Toyo with a 16 to 1 power ratio, which will apply enough pressure to break 10mm glass easily, too.

**Applying pressure to the opposite side of the score line to encourage the glass to break.**

### Breaking Billets

For cutting casting billets I find the addition of WD40 helpful here, too. Use your glass cutter to score across one surface and turn the glass over. As the glass is thicker and not uniform in shape it is necessary to hit the glass on the other side with a hammer to encourage the pressure to travel to the score line on the glass. Think of it as the pressure travelling through the glass to push the score line up and split the glass apart. I normally wrap the glass in some newspaper, put it on my concrete floor and tap it with the hammer. It is possible to hold the glass in a gloved hand on the edges and tap it with a hammer; this works sometimes.

## Cleaning the Glass

No matter what glass you use, you will need to clean it before loading it into your moulds or plant pots. Any ordinary glass cleaner will be sufficient, but if you are recycling bottles then an overnight soak in warm soapy water will help remove the labels. There's a product called 'Sticky Stuff Remover' by De.Solv.it for labels, too. Otherwise, you can make up your own glass cleaner using white vinegar and distilled water. For optimum clarity, you do not want any grease or contaminants on your glass before it goes into the kiln; that includes finger-prints. Mould material, stubborn contaminants or devitrification from previous casts will need to be sandblasted or ground off to improve the quality of the next cast. These can cause imperfections, as dirt and grease will become fused to the surface and can cause devitrification to occur. Sandblasted or sawn surfaces will create history lines within glass casts. If you don't want to see these, it is advisable to use new billets or grind and polish the surface to be re-cast.

## Kiln Loading

After cleaning and measuring the volume of glass needed for the cast, it is good practice to dry investment moulds for a couple of days to allow the water to dissipate prior to firing in a kiln. Moulds can be set up on metal racking above a kiln or gentle heat source to aid drying. Moisture in the mould can affect the surface quality of the glass cast and cause damage to the metal elements in the kiln when fired. You can tell if a mould is dry enough once it stops feeling cold to touch. Hold it to your cheek if you are uncertain; if it still feels damp then it is likely to contain moisture. If the kiln has removable bungs it is possible to kiln-dry moulds prior to loading them with glass.

**Measured glass placed into a plant pot ready to dribble cast.**

**Moulds that have been drying on a rack above the kiln.**

**Load the mould into the kiln and adjust it with sand to make it level.**

Once the glass is prepared and clean and the mould is dry, it can all be loaded into the kiln. Ensure the mould is level both from front to back and side to side. Minor adjustments can be made using kiln sand and fibre blanket or props. If the mould is tall or of a medium to large size, then kiln bricks will need to be placed around the mould to support it during the firing.

## Plant Pot and Prop Prep

You can use terracotta plant pots in a couple of ways: as an extension of your sprue or as a reservoir for your glass. You can cut the bottom off a plant pot (using a glass saw/tile cutter) and place it directly on top of your mould to extend the sprue where it is not big enough to put all of the glass in for lost-wax casts. Alternatively, when used as a reservoir a plant pot is filled with glass, propped above and lined up with the investment mould, which allows the glass to dribble into the cast. Before filling the pot with

glass, use sandpaper to smooth the edge of the hole and rinse clean. You can make the hole bigger if required, using one of the glass core grinding bits to approximately 16mm ($^{5}/_{8}$"). You do not have to apply batt wash, but you can. Batt wash will extend the life of the plant pot so it can be used several times. If you don't, glass will stick to the pot and sometimes cause the bottom of it to break off when the glass inside it cools.

After firing, write in pencil what type and colour glass were used to avoid any compatibility issues when re-using these pots. If required, you can make your own reservoirs using investment materials or pottery clay in a similar way to creating a slump mould (see the end of Chapter 5), except with a reservoir you need a hole approximately 16mm ($^{5}/_{8}$") diameter for the glass to dribble out of.

If you are intending to use any kiln props or furniture to dam your moulds or raise the reservoir above your mould, you may well need to apply batt wash to them. The worst case scenario is that the glass overflows from your mould and ends up touching the kiln prop. As it cools, the glass sticks to the prop and a fracture forms in the glass as the kiln furniture contracts at a quicker rate than the glass when the kiln cools down. If you have put a precautionary three coatings of batt wash on the furniture, you will avoid the possibility of a crack in your cast.

## Firing Cycle and Annealing

One of the most essential elements for successful glass casting is the firing cycle. The glass and mould need to go through a controlled set of instructions known as ramps, calculated in degrees per hour (°C or °F) to be heated up and cooled down slowly. Without this control, glass has a tendency to break due to thermal shock. As the glass cools, thermal shock happens when the temperature differs by a few degrees within the glass, from the outer part to the inside or between thick and thin areas, to the extent that it causes a build-up of stress. The cooler glass contracts as it solidifies at a different rate to the hotter part, which is still moving. This

creates tension, which can cause a visible crack or else remains unseen within the glass cast, eventually causing it to break at a later date.

Although glass can be checked for stress, ultimately the aim is to know how to work out a firing cycle that keeps the temperature even within the glass as it cools and avoids creating stress. The controlled cooling part of the firing cycle is called annealing. All glass types have a set annealing temperature, which can be found in the glass brand temperature and specific density chart earlier in this chapter. Information charts or data sheets on the specific annealing and melting temperatures for the brand of glass you are using are easily accessible online from the manufacturers. These annealing charts will give you an indication of the recommended hold time at the annealing stage for the thickness of glass you are casting. The thicker the glass or the larger the discrepancy between thick and thin areas in the form, the longer the hold time at the annealing temperature and the slower the descent from annealing to strain point.

Firing cycles for glass casting will vary and all the ones provided in this book are at best a starting point that will need to be adjusted to suit the kiln, mould and glass specific to your project. If you know that your kiln under-fires, make this adjustment in the programme. If the firing cycle doesn't give you the result you were expecting, approach the process as if it's a science experiment: be logical and pick one variable to change, for example the casting temperature. By changing the temperature in small increments of say 5°C (10°F) you can ascertain if the outcome is comparably better or worse.

### TOP TIP: SIZE MATTERS

Larger = Longer

Firing cycles have at least six to eight ramps/ stages:

1. Initial heat: this can be anywhere between 45°C/hr and 100°C/hr

(81°F/hr to 180°F/ hr), depending on the size of the mould. The increase in temperature is slow for two reasons: to avoid shocking the glass or mould and to remove any remaining physical water from the mould. Keep kiln vents open and hold for at least one hour at around 100°C (212°F) if the mould was still damp when loaded into the kiln.

2. Mould cure: for the second part of the initial heating stage, ramp at a similarly slow rate of around 100°C/hr (180°F/hr) to the mould-curing temperature of approximately 600°C (1,112°F). Holding for at least one hour removes the chemical water within the mould. Those water molecules that have bonded to the investment molecules cause a chemical reaction that hardens the mix; holding at this stage allows the water molecules to react again, strengthening (curing) the mould. This ramp also heats the glass to past its annealing point. After this stage is complete, the kiln vents can be closed.
3. Cast: a slightly faster ramp at a rate of between 100°C/hr to 150°C/hr (180°F/hr to 270°F/hr) up to a casting temperature of anywhere between 810°C (1,490°F) and 880°C (1,616 °F). The hold time can vary depending on the form, volume and thickness. At this stage, the glass will melt and flow into space within the mould. For small open casts, approximately an hour will be sufficient.

### TOP TIP: TEST AND RECORD

Test fire the kiln and the type of glass you are using. Keep a record of successes and failures, so that you can build a set of firing cycles that will provide the best results for each process.

4. Rapid cool (crash cool): to between 650°C to 600°C (1,202°F to 1,112°F). This is where the temperature is lowered quickly, as fast as the kiln can cool (you can help this by opening the kiln vents). This will stop the glass from continuing to melt and move and reduce any devitrification from forming (*see* Chapter 10 for devitrification and anti-sucker).
5. Anti-sucker (buffer): hold at approximately 600°C (1,112°F) to allow

the glass to become a uniform temperature across the entire thickness of the form. This stage mainly applies to lost wax, core casts or large forms due to the heat retained inside the glass. With thinner forms, it is possible to crash cool to the annealing point but this can be risky. Cooling to above the anneal buffers the temperature of the kiln and ensures that the glass will not get too cold too quickly and shock.

6. Anneal: slow cool approximately 10°C/ hr to 40°C/hr (18°F/hr to 90°F/hr) to the annealing temperature and hold. This can be anywhere between 520°C to 430°C (968°F to 806°F); the optimum temperature is specific to each type of glass. The length of time to hold at this point is dependent on the size of the glass. The aim is to allow the glass to remain at an even temperature throughout. It is best to refer to the charts available online.
7. Strain: the gradual cooling of temperature between the annealing point and the strain point at the lower end of the annealing range. This needs to be controlled at a slow rate anywhere between 1°C/hr to 50°C/hr (1°F/hr to 90°F/hr). Between the annealing and the strain is where stress within the glass can occur.
8. Final cool: depending on the thickness of the glass this will still need to be controlled at a slow rate to allow the kiln and the glass to cool evenly. When the kiln has reached room temperature, you will be able to open it and check your cast.

## Preparation

There is a lot of information to take in when you get into the technical side of glass casting. All the sketches and designs you have created will help you to plan ahead and prepare how you approach the casting, enabling you to make choices about which mould-making processes are most appropriate and what brand, colour and form of glass to use. Bullseye glass, for example, has a huge range of forms including billets, frit, sheet, rods and stringers, through to finely powdered glass, which is all

compatible and can be combined in glass casts. However, chucking it all into a glass cast could lead to a hot mess. With due planning and consideration, you can combine powders and stringers and other forms of the same brand to create absolutely stunning glass casts. Something as simple as building layers of a picture using powders and frits and then casting them within a solid form can be really effective.

By using dams (cut-up kiln shelves) you can easily create box moulds in the kiln that glass can be melted into. The main considerations are that the dams and the kiln shelf need to be coated in at least three layers of batt wash, which is left to dry or kiln dried before you can place the glass in (to stop the glass from sticking to these surfaces). The dams need to be held in place by supporting kiln bricks or other kiln furniture. If the dams are not supported, they could move and allow the glass to escape over the rest of your kiln. Place the glass within the dams so that it doesn't touch them. Depending on the depth of the cast, this should stop the glass from creating sharp edges. With this method you can easily cast glass blocks of colours together to create deep cuboid forms. The glass colours will not mix and merge like paint but stay where they are positioned within the mould. This can be particularly effective for using up glass offcuts, as long as they are all compatible with the same COE.

Enamels and decals can be fired onto any glass brand as they are applied incredibly thinly. The pigment particles attach themselves to the glass surface on such a minute scale that they do not cause stress within the glass. You can use enamels or digital decals to add images, create marks or paint details on the surface of glass sheets or billets. Always tack fire the enamel onto the surface first before capping and fusing together. Afterwards, they can be cast into a mould to create internal images within a cast.

There is no right or wrong way to cast with any glass. Start small and experiment. Record the glass, size, firing cycles and materials, capturing as much information as possible. Take pictures or do a sketch. Record what works and problem-solve before increasing your scale; it takes a lot of glass, time, energy and money trying something out on a larger scale.

**Flat lay of spoons and rolling pins. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER FIVE

# OPEN CASTING AND SLUMPING

Open casts are an exciting way to start creating relief and three-dimensional forms in glass. The process allows you to cast anything: from shallow glass panels with lots of detail on the surface to sculptural shaped forms with varying depths. You can create fantastic tonal ranges just by changing the depth of the model when casting in transparent coloured glass. Areas where the model is thick will be where the colour becomes denser and appears to be darker, as there are more molecules in the material for light to be absorbed by. By comparison, in the thinner areas the colour will be paler as light is transmitted more quickly through the thinner form. Using transparent glass means the texture of your cast can be seen through both sides of the glass. If you are using opaque glass, the textured side will become the focus of your glass form, as you won't be able to see the surface detail through the glass. With opaque glass powders and frit, you can highlight textural details in the glass and create gradients of colour.

## Undercuts

Open casting generally means you can remove the model material from the investment mould easily after it has set. The two main characteristics of an open cast are that the form must not have any undercuts and that one whole side of the form (usually the largest) will be fixed onto a baseboard. You will not be able to add detail to the base side of the form as this will become the opening of your cast. An undercut is a part of your form that is

wider than the base or creates an overhang, which will cause the form to become trapped inside the investment mould. To determine if your form has an undercut, look at your form from above; you should be able to see the entire surface. If the form gets thinner towards the baseboard, or the surface undulates underneath itself and there are areas of your form that you cannot see from above, these are classed as undercuts. To double-check a form from the side, you can hold a set square or 90° angle against the baseboard; if the angle of the form is more than 90° there is an undercut. If you can edit the form, remove overhanging material to adjust the angle to less than 90°, then you can continue with open casting. If you are looking to create a form with undercuts, you will need to use a different process: lost-wax casting (*see* Chapters 6 and 7).

## Materials

The form you make for open casting can be created from a host of materials: clay, card, wax, Styrofoam and rubber, to name a few. Most materials can be used as long as they are easy to remove. Some of the more rigid and porous materials, e.g. plaster and wood, can be possible to cast from if the forms are shallow, do not have any sharp angles or surface detail, as you will need to be able to lever or wiggle them off the investment. These materials will also need to be sealed with a release agent and have something that you can hold onto to help remove them. You can use screws fixed into the back of a rigid material as a handle to grip onto while removing the form from the investment. They will, however, still be difficult to remove and may damage the investment mould. It is often easier and sometimes essential to make rubber or wax versions of your form if it is a rigid material, has lots of angles, deep textures or any undercuts.

Once you have an acceptable form attached to a baseboard, you can then build retaining walls all the way around it. Be sure to leave a gap of about 2cm around the entire shape. This will retain the liquid investment

mixture poured into the gap between the walls and your form to create an investment mould. Once removed, the side of your form that was on the baseboard is now the ‘top’ opening of your mould; this is where the glass is placed. Once the investment mould has dried and been loaded with glass, it is put in the kiln and the appropriate firing cycle is programmed for a cast. The ‘top’ becomes an even flat, fire-polished surface on your form. This flat surface can be the base, top or side of your glass piece.

## Getting Started

To start open casting, the simplest and easily accessible material to create your form with is clay. You can use Plasticine as an alternative. If you are using clay, it is easier to remove the clay from your investment mould if the form has been created in layers of clay from the base up. It is much harder and more time-consuming to dig a solid lump of clay out of your investment mould than it is to remove a model that has been built up using layers. The step-by-step project will guide you through how to create a basic open cast by creating a relief impression into the surface of the clay, then through the mould-making process to produce a relief indentation into the surface of your glass. In this project, I have suggested that the glass used to cast with is Bullseye transparent sheet glass. I suggest using one sheet of 6mm and one of 3mm to give a total thickness of 9mm. You can also use three sheets of 3mm or whatever glass you wish to (*see* Chapter 4 for more information on glass types). You will need to adjust the firing cycle for the type of glass you choose. By using sheets of glass the cast becomes a uniform thin flat panel, with minimal cold working required around the edges. This panel can easily be enamelled and slumped (bent) if so desired in an additional kiln firing.

This process uses Crystalcast to create single-use investment moulds which will need to be ‘broken off’ the cast glass once it has been fired and has cooled to room temperature. Some of the Crystalcast can be reused in future mould mixes (*see* Chapter 11). If you like an impression you have

created in a mould, you can pour Gelflex or silicone into it while the investment material is still damp to create a master model that you can make repeat moulds around.

**Select objects that you can use to make impressions in the clay; they will become impressions in the glass.**

**Roll out clay 1cm thick and cut and measure a 15cm by 15cm square.**

## Step-by-Step Open Cast Relief

### What you will need:

| **Materials** | **Essential Equipment** | **Other Equipment** | **Personal Protection** |
|---|---|---|---|
| Clay & two wooden spoons the same size, or two dowels | Baseboard 30cm × 30cm approx | Ruler & a level | Apron |
| Selection of small objects to press into the clay | Rolling pin & thick fabric (old tea towel)<br>Craft knife, spoon | Wax modelling tools<br>Fine paintbrush | Respirator or dust mask |
| Crystalcast | Mixing bucket<br>Measuring jugs ×2 | Cocktail sticks<br>Tweezers | Waterproof gloves |
| Bullseye sheet glass 3mm & 6mm | Washing-up bucket & sponge | Spatula | |

**Roll and cut out the second layer of clay the same size and place on top of the first.**

1. On your fabric roll out a slab of clay to approximately 1cm thick. Use the wooden spoons or dowel on either side of your clay slab as a spacer for the rolling pin and to ensure the clay stays level.

**Push your found objects into the surface of the clay to create a relief impression.**

2. Measure and cut out two 15cm × 15cm squares of clay and place one precisely on top of the other in the middle of your baseboard. Smooth together the edges of the two slabs of clay with your finger or a clay tool so there are no obvious gaps between the two layers.

**Roll out clay to create walls all the way around your relief, leaving a 2cm (1") gap.**

3. Select your objects or texture-making materials and gently press them into the surface of the clay to create an impression no more than 6mm deep. This works best if your clay is slightly air-dried.

**Secure the clay walls to the baseboard and seal them together.**

4. Carefully remove the objects – this may require tweezers – then smooth out any bits of clay that really stick up. It is important to remember that whatever you have in clay will become glass. It’s easier to clean up any bits you don’t like now than it will be later!
5. You will need to create four walls to make the reservoir around your model. This is so that you can pour liquid investment mould mixture over and into the space around the model you have made. Roll out a slab of clay 1cm thick and cut this into strips 6cm wide. Alternatively, you can use float glass, wood or plastic to create the walls. Seal them to each other and the baseboard with clay.

**Alternatively you can use float glass, Perspex or wood to create walls around the clay relief.**

6. Leaving a 2cm gap all the way around the clay model, place the strips (long, thin edge up) around the form, joining them together to build a wall surrounding the model.

**Use clay to seal the walls to the baseboard securely.**

7. Seal the clay walls to each other and down onto the baseboard, using a clay tool or your finger.

**Secure the walls on all four sides.**

8. Wearing your respirator or dust mask, measure 480ml of water in one jug and in the other 1,500ml of Crystalcast by volume. Add them to your mixing bucket in that order and mix until all big lumps have been absorbed. The mixture will resemble smooth, thick porridge.

**If you have a detailed surface, first gently apply the investment mix with a paintbrush, then pour the remaining mix over the relief. Tap the sides of the mould to encourage air bubbles to rise.**

9. If you have a detailed surface on your model, use a fine brush to paint Crystalcast into the details. This will stop air bubbles being trapped within the mould material on the surface of the clay.

**Slowly pour the investment mixture between the retaining walls and the clay relief.**

10. Slowly pour the mixture into the corner space of your mould, stopping to mix in any remaining lumps.
11. You need to agitate the mould to remove any bubbles. I usually do this by gently wobbling the baseboard or banging the table around the mould.
12. Allow at least one hour for the mixture to set. Use this time to wash your bucket, otherwise the remaining mixture will set in it. Finish clearing up any mess, put your dry materials away and maybe have a cup of tea.

**Once set, remove the walls and any excess clay.**

13. When the top of the mould has set, it will be hard and you won't be able to press your finger into the surface. Now you can remove the clay walls from the outside of the mould. This clay can be stored and used again (*see* Chapter 11).

**Turn the mould over to remove the baseboard.**

14. With the mould still on the baseboard, it is helpful to turn the whole thing upside down to be able to remove the board from the mould. If this proves difficult, use a wallpaper scraper inserted gently between the mould and the baseboard around the edges to help release it.

**Using a tool, catch a corner of the top layer of clay.**

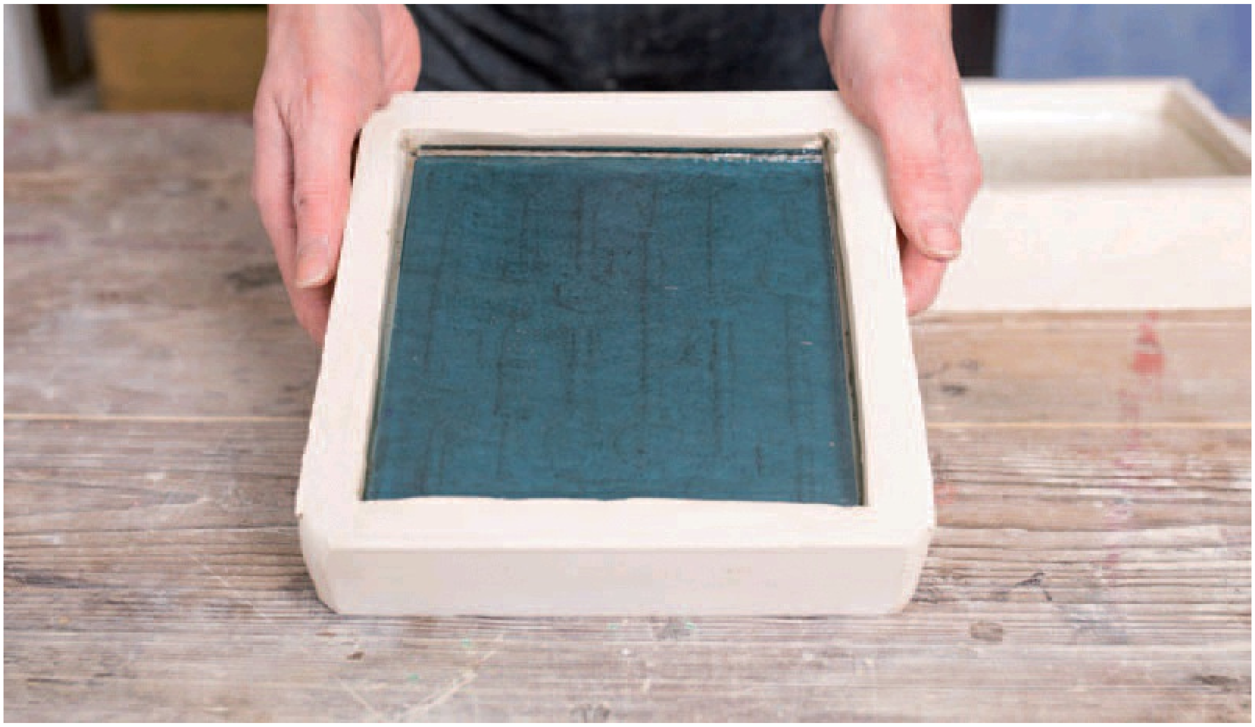
15. With the baseboard removed, you should be able to see the clay model inside your investment mould. With a tool, catch a corner of the top layer of clay and peel it out of the mould. As you have made the model in layers, do this for each layer till all the clay has been removed from the mould.

**Remove the clay.**

16. Any clay residue can be removed by using a bit of excess clay as a grabber, as clay tends to stick to clay. Otherwise, gently use cocktail sticks or other tools to remove the clay, without damaging the surface texture on the investment.

**Remove the clay and sponge clean your mould.**

17. Gently sponge clean the rest of the surface to remove all of the remaining clay, being extra careful around areas of detail. It is essential to clean well as any clay left on the mould surface will stick to the surface of the glass and become an imperfection.
18. If you are using another type of glass than specified in this project, while the mould is still wet you can displace it at this point to calculate how much glass you need (*see* Chapter 4).



**Place the sheet glass into your dry relief open cast mould. It is ready to be loaded into the kiln to cast.**

19. Once dry, your mould is ready to load with the glass. For this project, I have used two sheets of Bullseye, one 3mm transparent colour and one 6mm clear, both cut down to 14.5cm × 14.5cm to fit snugly inside the mould.

## Example Firing Cycle: Bullseye Sheet Glass, Open Cast, 9mm Thickness

| Ramp | Rate per Hour | Set Point Temperature | Hold Time |
|---|---|---|---|
| 1 (Mould Cure) | 100°C/hr (180°F/hr) | 660°C (1,220°F) | 1 hour |
| 2 (Cast) | 150°C/hr (207°F/hr) | 825°C (1,517°F) | 30 mins |
| 3 (Anneal) | ASAP | 482°C (900°F) | 2 hours |
| 4 (Strain) | 40°C/hr (72°F/hr) | 360°C (680°F) | – |
| 5 (Cool) | 100°C/hr (180°F/hr) | 100°C (212°F) | – |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

20. Once this mould has been fired and has reached room temperature,

the mould material can be removed from the glass by breaking the mould with a non-metal tool. While de-moulding, you must wear a mask or respirator (*see* Chapter 10).

## Open Casting Possibilities

Once you have attempted this project, the possibilities for open casting are endless. You could:

- Increase the scale in all dimensions.
- Explore surface pattern with the impressions you make.
- Use other materials, for example wax or silicone for open casting.
- Cast with opaque glass, frits and powders to highlight the textured surface.
- Slump (bend) the cast.

With enough materials and kiln space, you can amend the scale of your open casts, both in length and in depth. The main things to consider when making the casts larger, especially deeper, are the programming and annealing cycle. Thicker glass will retain more heat in its centre during the firing. It has to be properly controlled during the cooling stages, as there will be a larger discrepancy in heat between the internal and outer surfaces. Where the glass touches the mould, and the open face, are where the most heat is lost. Scaling up requires a longer time in the kiln to cool down uniformly and not cause internal stresses that will make the glass break. It is often helpful to work out the adjustments required to the annealing part of your firing cycle, and the length of time this will be in the kiln for, to give you an indication of how long it will be before your glass has cast. Each glass manufacturer has annealing charts publicly available online as each type of glass has different annealing temperatures and internal stress tolerances which determine the rate by degrees of annealing. For more on annealing, refer to Chapter 4.

You could use any manner of material or objects to create impressions in the clay. You could even model your own forms with an oven-bake clay, then fire the forms so that they are solid and press them into the surface. Exploring patterns with the impressions also provides a whole new aesthetic. The material that you use for the open cast doesn’t have to be clay at all; you could go back through this process with wax or rubber as long as one side is attached to the baseboard and can be removed from the investment.

If you prefer to work with the relief surface as the ‘top’ of the glass, casting with opaque glass and using frits and powders will highlight the textures. Open casts can be left as they are, cold-worked or they can be slumped (bent) to alter the shape.

**Key bowl, button bowl and toy bowl created in relief open cast moulds and slumped into a ceramic mould in a separate kiln firing.**

## Slumping

The action of relaxing (bending) glass into a former in the kiln at a low temperature allows you to change the shape of flat sheets or casts without losing surface texture. All types of glass can be slumped, and generally it is one of the last processes performed in the kiln. All casting and fusing happens at a higher temperature and therefore needs to have been achieved prior to slumping. Fused flat sheets and relief casts will require a similar firing cycle. Thicker casts will need more consideration when programming both the ascent and descent due to the annealing process.

### Example Firing Cycle: Bullseye Glass Slump, 9mm Thickness

| **Ramp** | **Rate per Hour** | **Set Point Temperature** | **Hold Time** |
|---|---|---|---|
| 1 (Initial Heat) | 50°C/hr (90°F/hr) | 550°C (1,022°F) | – |
| 2 (Slump) | 350°C/hr (630°F/hr) | 660°C (1,220°F) | 15 mins |
| 3 (Anneal) | ASAP | 482°C (900°F) | 2 hours |
| 4 (Strain) | 30°C/hr (54°F/hr) | 360°C (680°F) | – |
| 5 (Cool) | 100°C/hr (180°F/hr) | 100°C (212°F) | - |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

Things you can do while slumping: you can paint on low-temperature enamels and they will fire on during the same firing as a slump. You can also fire-polish sandblasted surfaces during a slump (this is covered in more depth in Chapter 10). Generally, a fire polish is held for a short time at a high temperature past the slumping point, and with testing (in your own kiln) it can achieve the same bends while making the surface shiny.

### Formers

You can create simple formers that glass can be slumped over or into by just using powdered plaster shaped directly on the kiln shelf. These will tend to be basic as wherever you place the glass will flatten the powder

slightly with the weight of it. You can also buy standard pre-made ceramic slump moulds that come in a variety of shapes and sizes. Prior to use, all ceramic moulds need to be coated in batt wash (shelf primer), which is brushed on three times in alternating directions, and then glass can be slumped and easily removed afterwards. These moulds can be used over and over again but check the batt wash coating before every use. When the coverage starts to become uneven, wash this off, leave to dry and apply again.

If you have access to a ceramic kiln you can make your own ceramic slump moulds to shape your glass casts into, remembering they are for form, not a surface texture, with no undercuts or dramatic steep curves. You need to use new earthenware clay (not recycled). Wedge it and roll the clay out on some cloth between two spacers to get an even flat surface approximately 6mm thick. Then you can rest it over some scrunched-up newspaper, cardboard shapes, cartons, bowls… any shape you can think of, you can probably encourage the clay to take on that shape. Protect surfaces with a sheet of newspaper. Trim and sponge the clay to your desired form, leave it to air-dry for a few hours till it's leather hard, then lift the form off and sponge the edges. Clay will shrink by approximately 10% once it has completely dried and is ready to be fired. This is something you will need to consider if you are trying to make an exact size. Programme the kiln for a (very) low bisque firing of 950°C (1,742°F) for fifteen minutes to fire the clay. Once it has cooled it can be coated in shelf primer and used for glass slumping.

You can also create your own slump moulds with excess mixed investment material. Silicone cake or bread moulds are great as a back-up for hand building onto or pouring into with the excess mould material if you have mixed too much. These can be used directly as slump moulds or carved and shaped (while damp) to cast, slump or fuse glass onto. As with casting, the investment material will only withstand one or two firings as the composition of Crystalcast or ordinary plaster and silica mixes will weaken.

## Example Firing Cycle: Earthenware Clay Low Bisque

| Ramp | Rate per Hour | Set Point Temperature | Hold Time |
|---|---|---|---|
| 1 | 50°C/hr (90°F/hr) | 600°C (1,112°F) | - |
| 2 | 150°C/hr (270°F/hr) | 950°C (1,742°F) | 15 mins |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

**Flat lay of waxes. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER SIX

# LOST - WAX CASTING

Lost-wax casting is a traditional technique for creating three-dimensional sculptural forms in materials that are not malleable, or carved, or sculpted by hand easily. Historically lost-wax was developed for metal casting, which is where the process has acquired its name – as the wax form would have been invested and then burned out of the mould, and therefore lost. Although it has a similar starting point to metal casting, the method and investment materials vary greatly due to the delicate nature of the glass heating and cooling (annealing). Glass as a material is difficult to sculpt directly even in a hot blowing studio, at a lampworking torch or in relief with a handheld engraver. Wax is versatile and easier to manipulate. Whatever form or surface texture the wax takes will be directly translated into the glass by the lost-wax casting process.

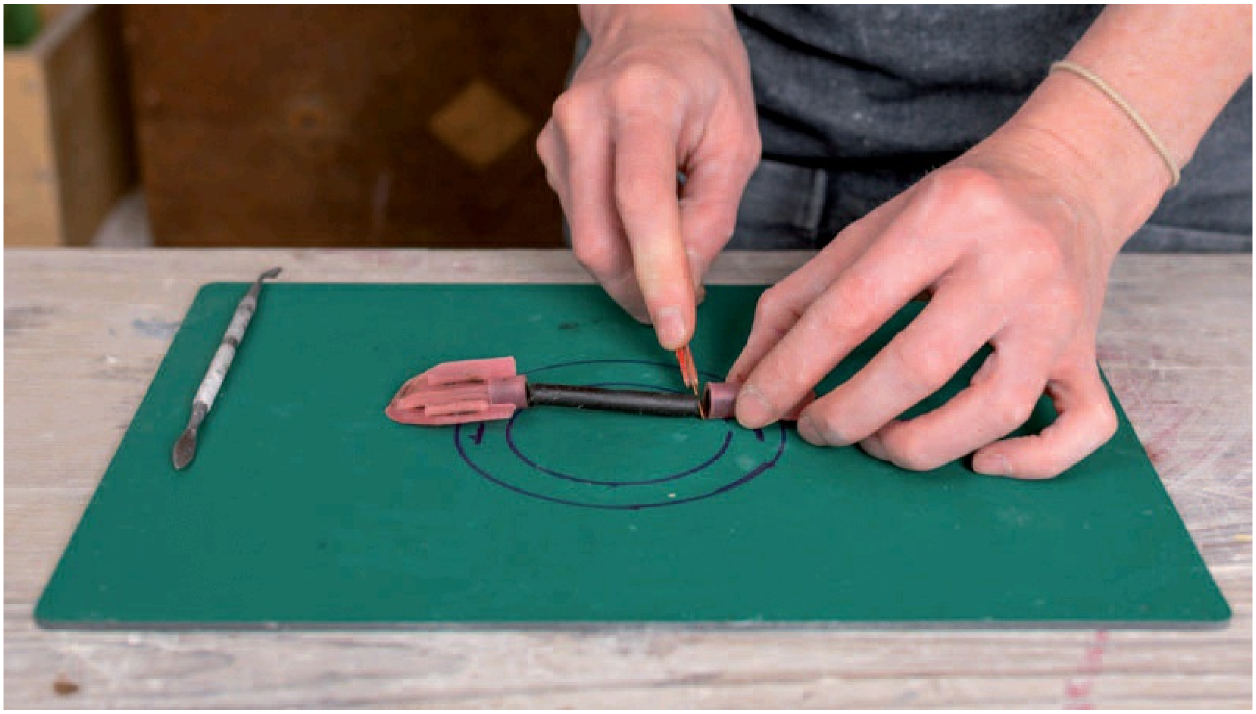
The waxes used for glass casting all have low melting temperatures (*see* Chapter 3). Intricate or sculptural wax forms can be invested and then gently steamed out to remove the wax from within the mould. Steaming the wax will create a negative space in your investment mould for the glass to flow into with the aid of heat and gravity. You need to consider how the glass is going to travel downwards into your form. Unlike the open casting process which has a large opening to place the glass into, lost-wax casts can have a relatively small point of entry for the wax to be steamed out of, and the glass to then be melted into.

**TOP TIP**

Whatever form you have sculpted in wax will become glass. Any imperfections in the wax will appear in the glass too. It is easier to correct, change and smooth wax than it is glass.

With this in mind, you will need to create a sprue or reservoir, which is a cone- or funnel- shaped piece of wax or clay that is connected to the model by the small point, with the wider end attached to the baseboard. The sprue will become a negative space within the top of the investment mould for the cold glass chunks to be placed into. During the firing process, the glass will then flow downwards into the negative space created by the wax within your investment mould. If your wax model is small then it's likely your glass point of entry will be small too; don't go any smaller than the width of a pen.

As glass flows into your mould, the air that is displaced needs to be able to flow out. A small point of entry could mean that the air travelling past or even through the glass as bubbles do not have enough time to escape. This can result in an incomplete glass cast. Even at casting temperatures glass is more viscous than treacle, so an air bubble moving through the glass will take a long time. Wooden skewers, cocktail sticks, cotton thread or even thin pink wax sprues (sticks) attached to points on your model (with wax) and then to the base-board (with wax/clay) will create vents for the air bubbles to escape out of the mould easier. The vents are also required in places where the wax model has undercuts or will require the glass to flow horizontally. If you are not sure whether your model needs air vents, hold the wax upside down; a change of perspective can help to identify where vents may be needed. If you are still not sure, add some anyway, the glass will not flow into the channels these vents create as the space is too small. They do not need to be removed from the investment mould before firing as they will burn away during the process and they shouldn't negatively affect the outcome of your cast.



**Model a miniature version of a familiar object in wax. Adjust the size of your model; some models can be cast in sections.**

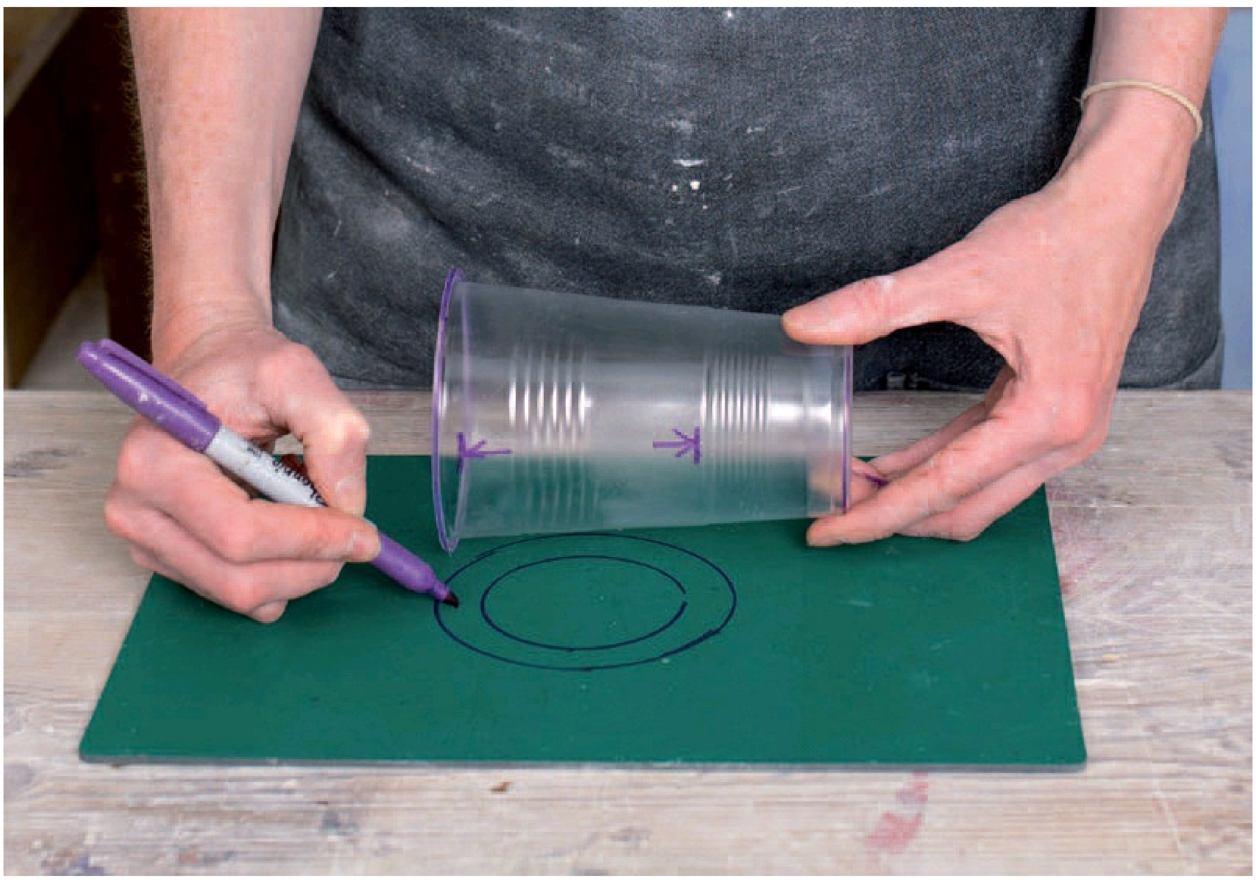
## Getting Started

There are several ways to start lost-wax for glass casting. By far one of the easiest ways is to use Type B modelling wax, which is as easy as Plasticine to manipulate. The step-by-step 'little lost-wax' project will guide you through using this wax to help you create a simple form to invest in a mould to cast glass in. It is much easier to manipulate the wax than it is to fix things once the model has been cast in glass. Spend time on this and get the shape right. Once you have had a go at this step-by-step, it is possible to scale up your model and create moulds using the hand-building technique, which uses fewer materials (this is covered in the next project).

### Step-by-Step of 'Little Lost-Wax' Casting Using Type B Modelling Wax

What you will need:

| **Materials** | **Essential Equipment** | **Other Equipment** | **Personal Protection** |
|---|---|---|---|
| Paper & pencil | Disposable cup | Board or cutting mat | Apron |
| Type B modelling wax | Mixing bucket | Wax modelling tools<br>Craft knife | Respirator or dust mask |
| Clay | Measuring jugs | Rolling pin & thick fabric | Waterproof gloves |
| Crystalcast | Wallpaper steamer | Cocktail sticks, wooden skewers or cotton thread | Heat-protective gloves |
| Glass | Washing-up bucket | | |



**Step 1: Draw around the top and bottom of a plastic cup for model parameters.**

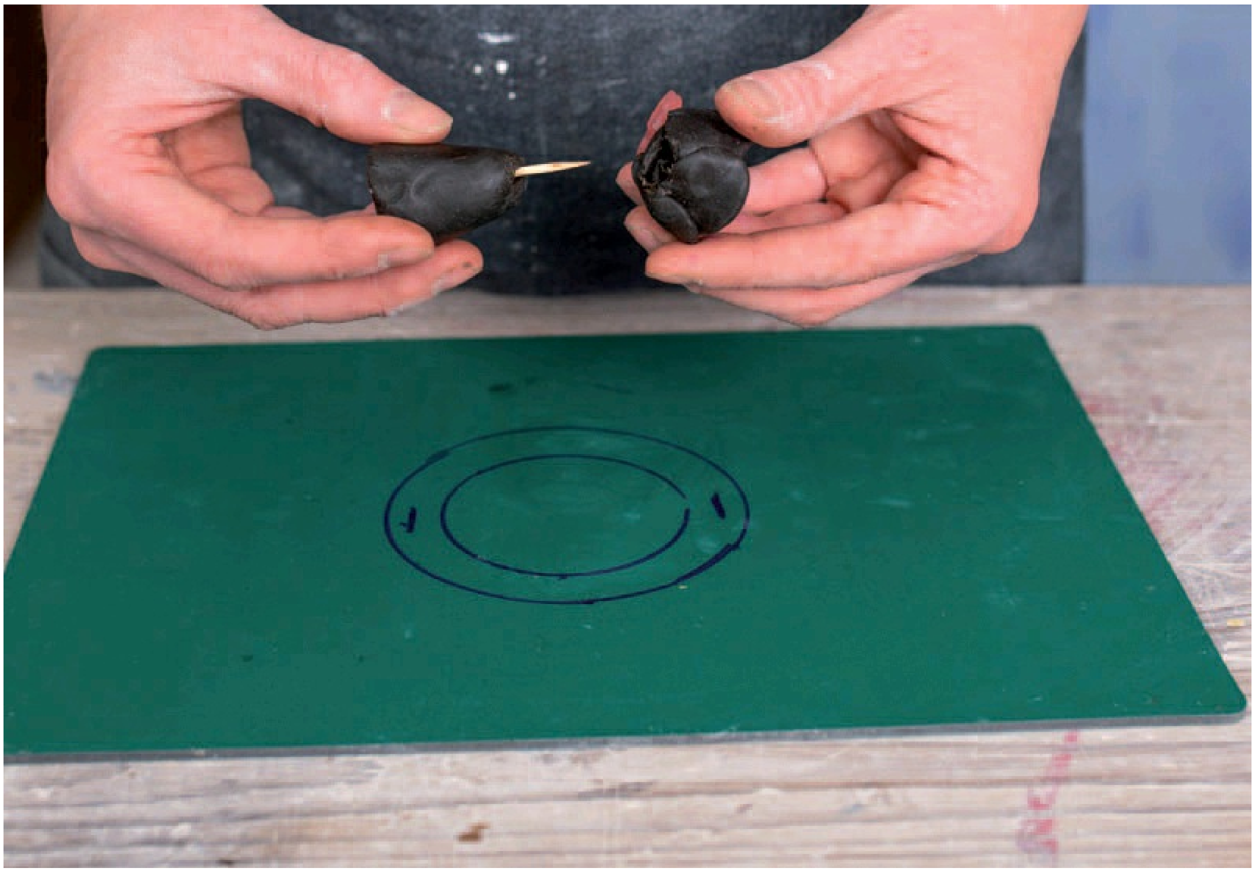
1. Take the disposable cup, put it on your paper and draw around both the top and the bottom of the cup. This will give you a visual guide to the parameters of the size that your model can be. It needs to fit within the top half of the plastic cup.
2. On your board roll a small handful of the Type B modelling wax into a solid 3D cone for the sprue, approximately 4cm high, 1cm width at its thinnest point and 4cm width at its widest.
3. Put the sprue into the cup, widest side down, to check that it fits without touching the sides.
4. You can use the paper to draw an idea of what you would like to make in glass. For this task, I suggest you model a miniature version of a familiar object. If you are struggling to find inspiration, read Chapter 1.

**Step 5: Model any shape you like with Type B modelling wax.**

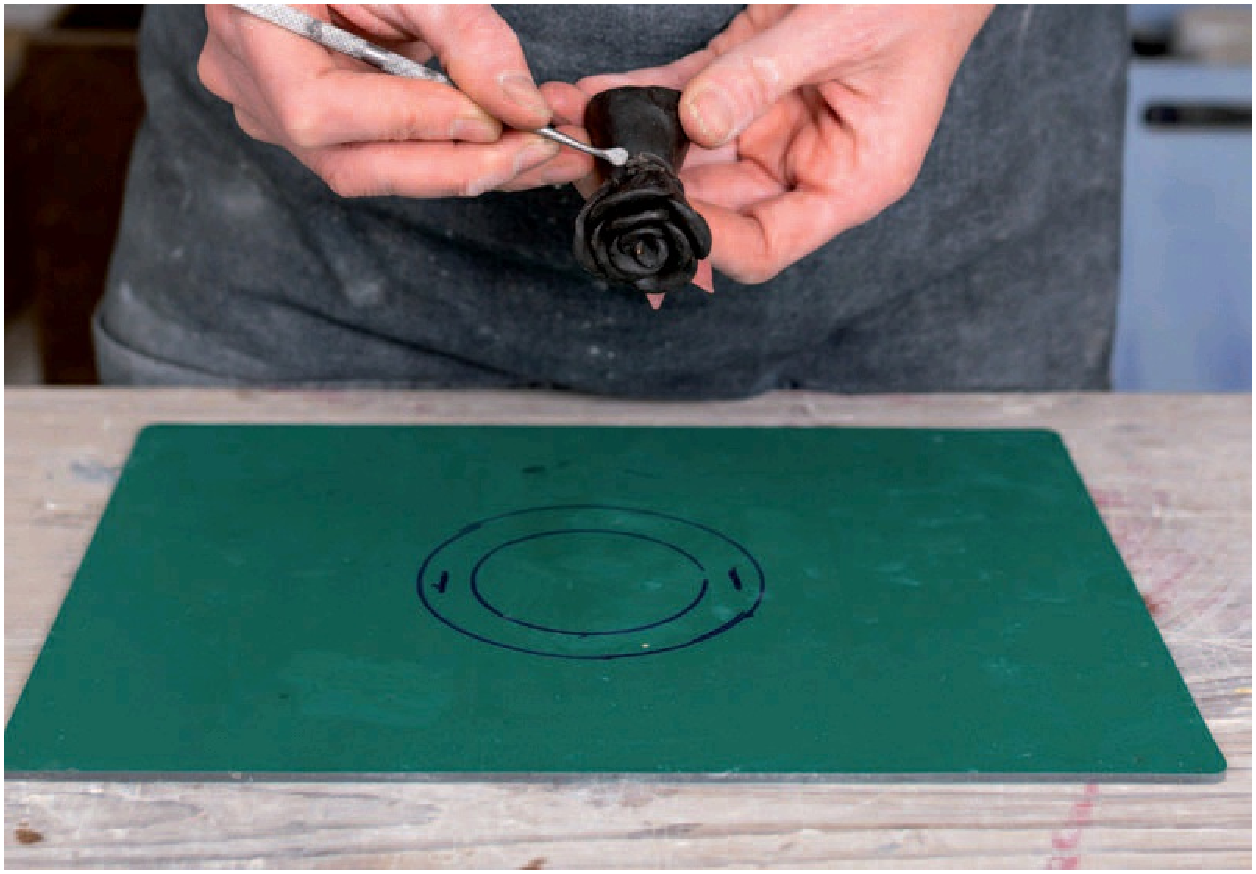
5. With warm hands, the wax is easily manipulated. While you are modelling there is naturally a back or base to the form. Your model will

need a point where the sprue is attached as this will become the space where the glass is placed to flow into your model.

6. The form you create in wax can be made up of lots of smaller parts that you stick together; this wax can also be carved using wax tools to get the 3D shape you desire. Try to keep the thickness to more than 2mm ($^{1}/_{16}$") to guarantee that the glass you use will be able to cast into the form.



**Step 7: Create a sprue in wax or clay and connect the smaller end to the back or base of the model. Use a cocktail stick to secure the connection.**



**Step 7: Use more wax to smooth in the join between the sprue and the model.**

7. Use a cocktail stick to attach the thinnest point of the sprue to your model. Smooth in the join with extra wax.

**Step 8: Place the combined wax model and sprue into the cup, making sure it doesn't touch the sides.**

8. Check the size against the space in the cup you are using to ensure that the model attached to the sprue will fit inside it without touching the sides or sticking out above the top. Adjust your model if this is the case.

**Step 9: Check that the sprue is stuck to the bottom of the cup so that the wax model will not float when mould mixture is poured around it.**

9. As wax floats, try lifting your model to make sure that the sprue and your model are stuck to the bottom of the cup. If they are not attached to the cup, create a small ball of clay and squish it into the bottom. Then press the sprue into the clay; this should hold it down.

**Step 10: Now you are ready to mix and pour the investment material.**

10. You are now ready to invest your wax model.
11. Wearing your respirator, measure 96ml water and 300ml Crystalcast; add them to your mixing jug in that order.
12. Mix until all big lumps have been absorbed. The mixture will resemble thick, smooth porridge.

**Step 13: Slowly pour the investment mixture around the sides of your model.**

13. Slowly pour the mixture into your cup – not directly over the top but around the wax.

**Step 14: Agitate the mould and encourage air bubbles from within the mixture to rise to the surface.**

14. You need to agitate the mould to remove any bubbles. Do this by gently tapping the cup or banging the table.
15. Pour any excess mixture into a separate tray.
16. Wash your bucket immediately, otherwise the leftovers will set in it.
17. Allow at least one hour for the mixture to set. Use this time to clear up any mess and put your dry materials away, etc.
18. You’ll know the mould has set when you can no longer press your finger into the surface. Now you can remove the plastic cup from the outside of the mould.

**Step 19: After an hour remove the plastic cup from around the investment mould.**

19. Using a craft knife, cut down the length of one side of the cup and push on the bottom of it to remove the mould. These cups are reusable with a length of parcel or duct tape to seal them back together.
20. Gently remove the clay sprue and sponge the interior of the mould clean.

**Step 21: Remove any clay and clean with a sponge.**

21. Remove all traces of clay used. This is essential as any clay left in the mould will stick to the surface of the glass and become an imperfection.

**Step 22: Now you are ready to steam or burnout the wax from the mould.**

22. Now you are ready to steam the wax out of your mould.

## Step-by-Step of Steaming Out Wax

## Example Firing Cycle: Gaffer Glass Little Lost-Wax Cast (approx 500g glass)

| Ramp | Rate per hour | Set Point Temperature | Hold Time |
|---|---|---|---|
| 1 (Mould Cure) | 75°C/hr (135°F/hr) | 600°C (1,112°F) | 1 hour (vents open) |
| 2 (Cast) | 150°C/hr (270°F/hr) | 840°C (1,544°F) | 2 hours |
| 3 (Buffer) | 200°C/hr (360°F/hr) | 540°C (1,004°F) | – |
| 4 (Anneal) | 20°C/hr (36°F/hr) | 430°C (806°F) | 3 hours |
| 5 (Strain) | 10°C/hr (18°F/hr) | 310°C (590°F) | – |
| 6 (Cool) | 40°C/hr (72°F/hr) | 250°C (482°F) | – |
| 7 (Cool) | 80°C/hr (144°F/hr) | 100°C (212°F) | – |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

**Step 1: Set up a bowl or bucket of water with a rack on top. Position and secure the steamer hose. Place your mould upside down on top of the rack.**

1. Turn your mould upside down on a rack above the steam hose and a bucket with some water in it to catch the run-offwax.

**Step 2: Cover the mould in plastic to contain the steam and quicken the process.**

2. Cover the mould in plastic bags or sheeting.

**Step 3: Check the progress of the steaming.**

3. Steam for thirty-minute intervals.
4. Turn off the steamer and wear heat-protective gloves to remove the mould from the rack.
5. Run the mould under cold then hot water; this will set the wax and make it float out of the mould. If there appears to be a lot of bits of wax floating in the water, you may need to steam the mould for longer.
6. There should be no bits of wax floating up when you pour water into the mould. Visually check that all the wax is removed from the mould, otherwise you risk contaminating the glass.
7. While the mould is wet you can displace it to measure the amount of water needed to fill the mould (*see* displacement in Chapter 4). Note down the volume of water as this will be the volume of glass needed to

fill the mould later.

8. Dry the mould.
9. Select and weigh the glass you wish to use and place in the sprue of this mould. For this project, I have used Gaffer casting glass. Load the investment mould into the kiln and fire.
10. *See* Chapter 10 for de-moulding and finishing.

## Lost-Wax Possibilities

### Scaling Up Lost-Wax Casting

Once you have cast some little lost-wax forms, you may want to increase the scale of your wax models and glass casts. It is easier to scale up gradually – as you progress you can work through any problems as they arise. There are many approaches to creating medium-sized wax models no bigger than 15cm/6" in all dimensions. Plaster and rubber part-moulds (covered in Chapter 7) can be used to create multiples. Type B modelling wax can be used to join waxes, or a heated tool or soldering iron will melt waxes together. You can also add cast or lampworked glass pieces to the wax model, as long as it is compatible. This glass needs to stick out of the wax so that the investment mixture will encase the additions and hold them in place.

Mixing and pouring investment moulds has its benefits and limitations. The benefits are that pouring takes less time and with the use of a vacuum chamber can recreate precise surface definition. The limitations can be the cost of scaling up. Naturally larger forms equals more glass, but the excess space around forms requires more materials and the investment mould also needs to be able to support the extra weight of the glass in the kiln. With a single-skinned poured mould, if a crack appears in the mould it is likely to travel, allowing the glass to escape. As you scale up, it may become more economical to use a plant pot positioned above the mould instead of increasing the size of the sprue within the investment. By hand-

building investment material onto the wax, the moulds can be created in layers (at least two) that closely follow the form, reducing the volume of excess materials. Strengthening materials (fibreglass and grog) can also be added to outer layers of the investment without affecting the glass surface. If a crack appears in a hand-built mould, the outer layers are more likely to stay intact and the crack will not travel because the layers have been created separately.

## Step-by-Step of 'Lost-Wax' Casting and Hand-Building

What you will need:

| **Materials** | **Essential Equipment** | **Other Equipment** | **Personal Protection** |
|---|---|---|---|
| Prepared wax models (*see* part moulds) | White spirit and cloth<br>Hairspray | Baseboard | Apron |
| Type B modelling wax | Cocktail sticks, wooden skewers or cotton thread | Wax modelling tools<br>Craft knife | Respirator or dust mask |
| Clay | Measuring jugs<br>Mixing bucket | Rolling pin & thick fabric | Waterproof gloves |
| Crystalcast (Fibreglass strands for larger moulds) | Wallpaper steamer | Small paint brush for details | Heat-protective gloves |
| Glass and precast glass | Washing-up bucket | Wallpaper scraper | |

**Additional cast or lampworked glass pieces can be added to wax models. They must be compatible and protrude from the wax to be surrounded by investment material and held in place when the mould is steamed out.**

1. Construct a medium-sized wax form, no bigger than 15cm/6" in all dimensions, and amend any imperfections at this stage.

**Assess how the glass will flow into the form: downwards and at an extreme right angle to the tips of the toes for these feet.**

2. Displace your wax model in order to calculate the volume of glass required.

**Attach cocktail sticks or cotton thread to the wax extremities and undercuts, then connect these to the baseboard or sprue to create air vents that will aid the glass to flow into the form.**

3. Create a sprue using wax or clay roughly the same size as your model. Ensure that it is large enough to hold the volume of glass required for the object. Attach the small point of the sprue to the base of the wax form using cocktail sticks to secure the join.
4. Assess the flow of glass. Where there are obvious undercuts you will

need to add cocktail sticks, skewers or cotton thread to the wax extremities, which may require the glass to travel upwards. Connect these from the wax to the baseboard or sprue.

5. Using a clean cloth and white spirit, clean up the wax. Spray with hairspray and allow to dry. This step is not essential.
6. At this stage, you can cottle around the wax (make sure this is really secure for larger volumes of liquid investment) and pour your mixture or follow the instructions for hand-building.

## Hand-Building

When hand-building, always measure and mix small amounts of investment material and apply it in layers. This will allow you enough time to apply an even coating of the investment material onto the whole of your wax form. Then you can immediately measure and mix more investment material for the next layer. If you are trying to apply a large amount of investment all in one go, the mixture can often end up setting in the bucket before you have managed to use it all.

1. Draw a line on the baseboard 2cm around the entire model.
2. Wearing your respirator, measure and mix 320ml of water and 1l of Crystalcast into a smooth, thick porridge consistency. Use a soft brush or your fingertips (wearing waterproof gloves) to push the investment mix into fine details and apply the mixture to the surface of the wax.
3. Keep rotating the model and applying the mixture, which will continue to run off.
4. Lift the baseboard to see if you have missed any bits of the underneath. At this stage, the join between the model and the sprue can become weak as the mould material makes the model heavier. It is important to make sure this is supported and covered in investment.
5. Continue to apply the mixture. It will run off the wax for some time until the investment starts to set. At the first stage keep trying to cover all

of the visible wax and the sprue. Do not worry about the coverage being neat.

6. Repeat steps 2 to 5 two or three times till an even coverage of mould material has been achieved and the entire wax form is no longer visible. For larger sized moulds add a tablespoon of chopped fibreglass strands to these outer investment mixtures.
7. Allow at least one hour for the investment material to fully set. Use this time to clear up any mess, wash your bucket and put your dry materials away, etc.
8. When the mould has set, insert a wallpaper scraper between the baseboard and the mould to gently release it.
9. If there is any clay in the mould, gently remove it all and sponge clean.

**Step 10: Mix and pour the investment material. Add fibreglass stands if hand-building.**

10. Now you are ready to steam or burn the wax out of your mould. (For

burn-outs, *see* Chapter 8.)

The volume of glass and firing cycle will need to be calculated based on the scale of your wax model and the type of glass you are using. Below is an example firing schedule for Gaffer glass. However, all glass brands have specific annealing schedules online that you will need to consult to ensure that your cast is successful. *See* Chapter 4 for more information on the stages of firing cycles.

| **Ramp** | **Rate per hour** | **Set Point Temperature** | **Hold Time** |
|---|---|---|---|
| 1 (Initial heat) | 50°C/hr (90°F/hr) | 100°C (212°F) | 1 hour (vents open) |
| 2 (Mould Cure) | 75°C/hr (135°F/hr) | 600°C (1,112°F) | 1 hour (vents open) |
| 3 (Cast) | 150°C/hr (270°F/hr) | 840°C (1,544°F) | 4 hours |
| 4 (Buffer) | 200°C/hr (360°F/hr) | 600°C (1,112°F) | – |
| 5 (Anneal) | 20°C/hr (36°F/hr) | 430°C (806°F) | 6 hours |
| 6 (Strain) | 8°C/hr (14°F/hr) | 310°C (590°F) | – |
| 7 (slow cool) | 16°C/hr (28°F/hr) | 250°C (482°F) | – |
| 8 (Cool) | 65°C/hr (117°F/hr) | 100°C (212°F) | – |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

**Pepper/capsicum showing undercuts. (Photo: Nicola Simpson)**

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# CHAPTER SEVEN

# PART - MOULDS

As you progress in lost-wax glass casting you may want to scale up, increasing the size of the wax objects or creating repeatable casts. One way of doing this is to create a part-mould of a master model. In this chapter, there are two step-by-step projects to guide you through the making of part-moulds, one for plaster and one for silicone. Multiple waxes can be poured into both of these for lost-wax casting. Start with waxes of simple forms that you can then add detail to or carve to transform into glass. Microcrystalline wax is great for this as it can be easily melted and poured into pre-existing shop-bought silicone moulds like the ones used for baking, or it can be poured into the part-moulds that you make yourself.

## Plaster Part-Moulds

Health and safety information for plaster can be found in Chapter 2. Plaster part-moulds must be wet or damp to ensure that the wax will not stick to the surface. Normally part-moulds are created from positive models. These master models can be made from any materials; plaster, plastic, wood, rubber, clay, natural materials and found objects all work. Plaster will stick to plaster and porous surfaces, for example cloth. To help prevent this, these materials, particularly plaster, will need to be coated in a release agent. You can use three coats of soft soap on plaster, wax release spray, or alternatively silicone spray for car maintenance; washing-up liquid or a thin layer of petroleum jelly (on cloth) will act as a barrier too.

**Draw lines on the master model to divide it into parts.**

## Undercuts

When dividing up your master model, the main thing to check for are undercuts (these are explained further in Chapter 5). You want to make sure that the plaster is going to lift off the master with ease. If you have an undercut, this can get trapped in the plaster and make the model difficult to remove. One way to avoid this is to draw dividing lines on the master model. Imagine the curve of a ball once you get to halfway – that's where the plaster part dividing line needs to be drawn. If you go further than halfway, the ball will not come out of that side of the plaster as it becomes locked in by the hard set material. Looking for shadows is another good way of working out where to draw these lines. Also, think about how many

sides your model has and therefore how many parts your mould will need to be. Depending on your master model, you may only need a two-part mould.

Take, for example, a banana: you can draw a line down the middle along its length, and it will be easy to separate into two parts and cast. In comparison, a bell pepper (capsicum) may not have any easy two-part dividing point and could turn into a five or more parts mould once you draw lines where all the undercuts are. Be careful to include any undercuts between the stalk and the pepper. For ease, fill small undercuts with clay; this will become wax that can easily be carved away again afterwards.

## Sprues/Pour holes

While looking at your master model, it is a good time to plan where the sprue or pour hole for the wax is going to be. It is generally easier to put the sprue half and half on your dividing marker pen line. In the case of the banana, this could be placed at one end as a continuation of the stalk or in the middle. With a more complicated master model consider where the base (or back) is or the best location for the glass to flow into the form. For the pepper you may not want to place the sprue on the under-neath as this will then remove the detail that the bumps create; the sprue will also be harder to remove and tidy up if you want to stay true to the original form. You could place the sprue on a smoother side, which will be easier to saw off and then grind back into shape. Another example would be if you had a four-legged toy animal: you may choose to have four sprues, one from each foot, or you could just have one sprue on the animal’s back.

Once you have drawn lines on your model, you can pick a side to work on first. Bury the model into some clay up to and level with the line all the way around, approximately 3cm wide. Try to make the clay surround as flat and neat as possible as this will become a seam in the plaster mould. Add one half of the sprue for the wax from the model to the edge of the clay (the other half will be created with the other part). Cottle (build walls) around the clay high enough to contain liquid plaster approximately 3cm

(1") above your model. When cottling, make sure you use lots of clay to seal and clamps to secure these walls as plaster will leak through small gaps.

## Plaster Spills

Unfortunately, sometimes spills do happen, and for that reason it is handy to have some extra clay or plaster powder on hand to stop any leaks that appear when you are pouring plaster. Plaster powder will set on the leak and block it. If the leak is more of a cascade, put your plaster bucket on the floor and scoop as much as you can back into it. Reinforce your walls with more clay; if it's a big mould then you may need to use some bricks or plaster blocks to provide some weight on the outside of the mould. If you have time, you may be able to pour the plaster back into your mould. If it has started to set, scoop it out into the bin, clean up and start again.

## Calculating the Volume of Plaster

When ready, you need to calculate the volume of plaster that you need to mix to fill the space. You can do this by measuring the length, width and depth of the space, before multi-plying these together to get the entire volume of the area. Then measure the dimensions of your model and multiply those together to get an approximate volume of that. Subtract the volume of your model from that of the volume for the mould and you will then know the volume of the space that you need to fill. For all of these measurements, it is best to work in centimetres as these translate directly into millimetres, for example, $300cm^3$ = 300ml or $1,000cm^3$ = 1,000ml.

You can also estimate the volume of plaster required visually by referencing the volume of something that is familiar to you, for example, a one-litre jug or a 330ml drink can. Imagine how many of those jugs or cans it would take to fill the space. If, like me, you like to work in imperial measurements, I have a strong memory of 1-pint milk bottles from when they used to be delivered door to door. I find that I can visualize how many

of these would fit into the space to estimate how many pints I need of mould mixture. The volume you estimate is the amount of plaster you will require; it is better to err on the side of too much plaster than not enough.

**PLASTER MIX RATIO BY VOLUME**

1 part cold water to 1.5 parts plaster.

## Plaster Mixing

Many years ago a colleague told me a great story about the best way to mix plaster, and this has been the most fun and helpful way by far of remembering what to look for when preparing this mixture. The story is that you are feeding ducks at the pond (sprinkling plaster into a bucket of cold water), the pond starts turning into a marshland, and then the marshland starts to dry up and look like a dry, cracked riverbed. At this point stop feeding the ducks, especially if the riverbed starts looking mountainous (then you have gone too far!).

**Gently sprinkle the plaster into cold water.**

**Continue to sprinkle the plaster as the water fills up.**

**When the water has soaked up all the plaster, stir gently.**

Wait a couple of minutes for the plaster to soak into the water and then you can stir it. As the plaster has been sprinkled into the water there are not likely to be many lumps. Stir gently till there are no lumps. The consistency should be similar to double cream. Now you can pour your plaster through a sieve (or not) into your mould or start to apply the plaster to the surface of your model if you are hand-building (you can use a paintbrush). Pausing slightly to allow the plaster's consistency to become similar to that of cottage cheese will help you manipulate it to stay on your model. Either use your hands, a spatula or wallpaper scraper to scoop the plaster and reposition it until it starts to set.

Hand-built moulds are preferable on larger models to save materials. For example, if you are casting a sphere, there will be a lot of wasted plaster if you create a box cottle to pour the plaster into. Hand-building will also save on the weight of the final mould too. In this case, scrim or

modroc can be used as reinforcement and layered into these types of hand-built part-moulds. Clean the bucket, paintbrush, sieve and any spoons used straightaway as set plaster is tough and sometimes impossible to remove. Do not clean any of these in a sink as the plaster will block the drains; have a spare bucket available for cleaning (*see* Chapter 2 for more information on this).

Plaster takes approximately forty minutes to set. Once set, the plaster will be slightly warm and hard. Turn the mould over and, without releasing the master model from the plaster, carefully remove the clay. Clean up and carve out at least four location natches (round dips) into the middle of the plaster surround; you can use a coin, tool or a teaspoon for this. These need to be smooth and not create any under-cuts. Put the clay sprue back into the mould. This time you will be making the other side of it so you have somewhere to pour your wax in. Cottle around your mould, remembering to seal the seams and clamp up all the edges. Using a paintbrush in a circular motion, apply a bubbly coat of soft soap to the surface of the plaster, including in the natches, and then wipe it off with a clean, damp sponge. Apply soft soap in this manner at least three times to stop the new side of plaster sticking to the one you have just made. Alternatively, you can use washing-up liquid or petroleum jelly as a release agent for the plaster. Once this has been applied then you are ready to mix and pour the next side of your part mould. Continue to do this till you have the required number of sides to accommodate the complexity of your master model.

Once all the parts have been cast in plaster, you should be able to remove your master model with ease and see that all the sides fit back together again with a single sprue (pour hole) for wax. This plaster part-mould will need to be immersed in some water and removed, then it is ready to be used.

Rubber inner tubes from bicycles are easy to use to tie part-moulds together. Alternatively, you could use clamps to ensure that wax will not leak out of the seams. Wait for the wax to set cold before removing it from your mould. The main benefit of part-moulds is that you are able to make multiples of the same object as you can keep pouring additional waxes into

them. This wax is easy to carve and sculpt if you would like to make each wax different. You may need to clean up the seams before investing these wax models; any imperfections in the wax will be worse in the glass and harder to smooth out. Simple wax tools are great for the tidying up of these models.

## Step-by-Step of Making a Two-Part Plaster Mould

What you will need:

| **Materials** | **Essential Equipment** | **Other Equipment** | **PPE** |
|---|---|---|---|
| Permanent marker | Cottling boards & clamps | Board | Apron |
| Simple form like an egg or orange | Mixing bucket | Clay modelling tools<br>Craft knife | Respirator or dust mask |
| Clay | Measuring jugs | Rolling pin & thick fabric or newspaper | Waterproof gloves |
| Plaster of Paris | Washing-up bucket | Wallpaper scraper | |
| Release agent, soft soap or washing-up liquid | A penny or teaspoon | | |

### *Part One*

1. Using the permanent marker pen, draw a dividing line on your egg or orange along the halfway point. Check that you can just see the marked line around the object face on from both sides. If you can see any shadows, you may need more than two parts or to use a flexible mould material (see next step-by-step).
2. Roll out some clay into a block that's 3cm (1") larger than your egg/orange on all sides.

**Step 3: Place the master model on the clay and draw around it. Remove the clay from underneath the master.**

3. Place the egg/orange on top of the block of clay in the middle and draw around it.

**Step 4: Push the master model into the hole created in the clay and smooth the clay around the form up to the halfway line.**

4. Dig out the clay from within the shape that you have marked to remove the middle and press your egg/orange into this space, ensuring that the top surface of the clay around the object stays perpendicular.

**Step 5: Create a clay cone and cut in half to form one side of your sprue.**

**Attach half the sprue to the clay and smooth down the edges.**

5. Decide where and add half of the sprue (clay cone).
6. Using a clay tool or your finger, flatten and seal the clay around the sprue and the egg/ orange along the marker pen line so there are no gaps.
7. Smooth the clay surrounding the egg/ orange with a damp sponge.

**Step 8: Cottle around the clay.**

**Use clay to seal the sides together. Pay attention to all the edges.**

8. Cottle (build walls) around the clay, sealing the gap between the wall and the clay with thin neat sausages of clay pressed into the seam with a finger. This should form a liquid-tight dam for you to pour plaster into.

**Step 9: Coat porous master models with a release agent.**

9. Clean your object; if it is porous, coat the object (egg) in a thin layer of petroleum jelly.

**Step 10: Mix and pour the plaster to cover the master model by about 3cm (1”).**

10. Measure and mix your plaster. The consistency should resemble double cream.
11. Pour your plaster through a sieve into the corner of your mould. Allow it to set for at least forty minutes.
12. Wash the mixing bucket and any tools used straightaway.

## *Part Two*

**Step 13: After forty minutes when the plaster is set, remove the walls.**

13. Once the plaster has set, remove the walls and turn the whole mould over.

**Step 14: Gently remove the clay block from around the plaster and master model.**

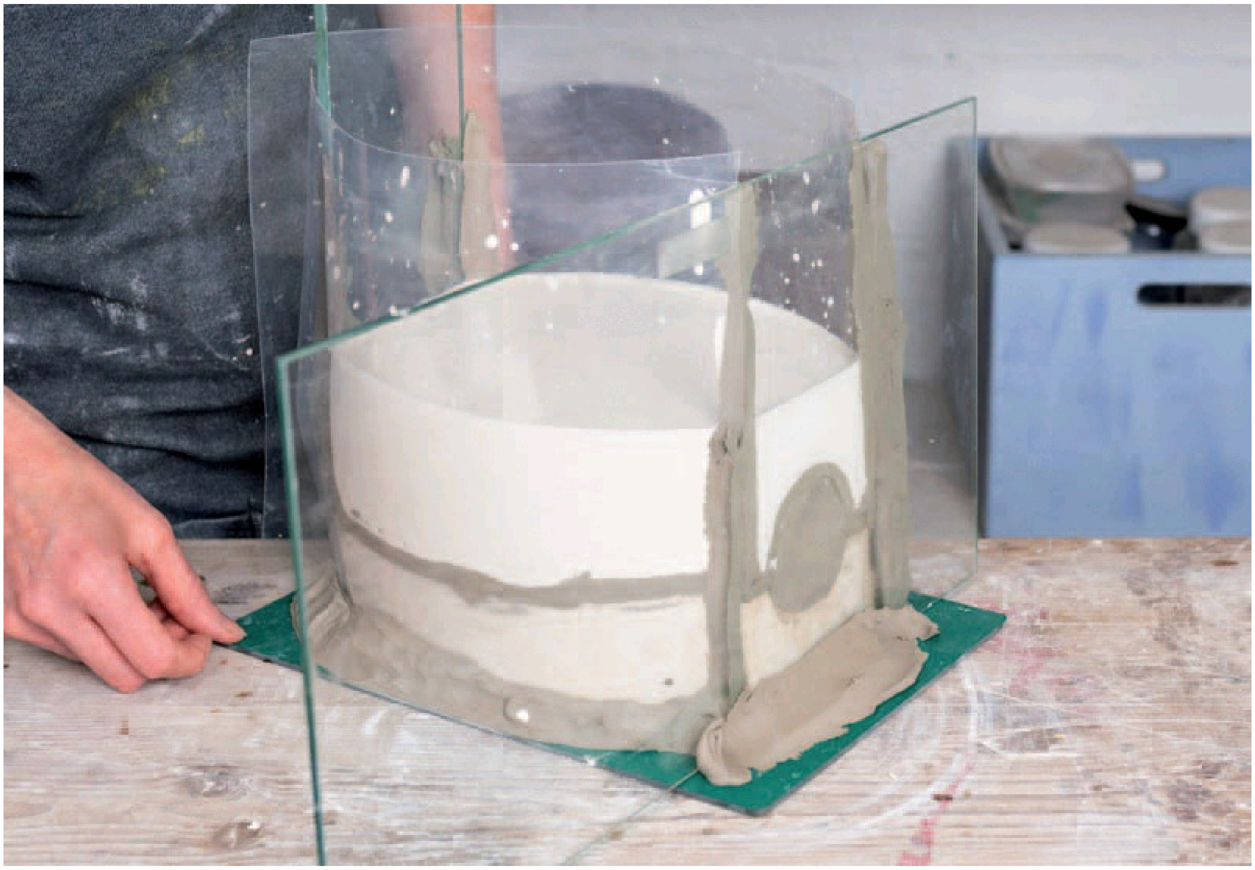
14. Carefully remove the clay from the plaster without removing the master from the plaster.
15. Clean the plaster with a damp sponge and tidy up any bits that aren’t flat using a scraper.
16. Replace and add to the sprue (clay cone) to make it complete.

**Step 17: Clean the plaster, create location natches (dips) in the plaster with a teaspoon or tool. Put the whole sprue in position, then don't forget to apply release agent to the plaster and the master model if porous.**

17. Using a penny or a teaspoon, dig a circular dent into the top surface of the plaster to create a location natch; create at least two or three more around the object.
18. Apply a release agent (soft soap or petroleum jelly) to the surface of the plaster (and the object if it is porous) so that the next section will not stick to it. Ensure that the surface is still smooth to touch.

**Step 19: Cottle the mould, use clay to seal all the edges, then mix and pour the plaster.**

19. Cottle the mould again, sealing neatly between the walls and the set plaster to form a dam and making sure that the walls are higher than your object by at least 3cm (1").
20. Mix and pour the plaster into this side of the mould, leaving at least another forty minutes for it to set. Wash up anything with liquid plaster into your designated bucket.



**Gently tap the edges or wiggle the baseboard to encourage bubbles to rise to the surface of the plaster.**

**Step 21: After forty minutes remove the cottling walls, clay seals and the clay sprue.**

21. When this side has set, remove the cottling walls and the clay before gently parting the two sides of your mould. Then remove the sprue and the object at the same time.

**If the mould is difficult to prize apart, gently push a wallpaper scraper between the two parts. Once apart, remove the master model.**

**Step 22: Clean up the plaster part mould and soak so it can be used to pour wax into.**

22. Clean up your mould to remove all residual clay. Put the parts back together, tie them together with a rubber band or string, and dampen with water. Now it is ready to pour wax into.

**TOP TIP**

Used bicycle inner tubes make excellent bands for holding part-moulds together.

## Silicone Part-Moulds

Similarly to plaster, silicone will stick both to itself and porous materials like cloth. It will also not release from glass if the glass is clean and free from

grease. It is essential to use a release agent to stop this happening. Mould releases for silicone, as well as the ones mentioned previously for plaster, can be as cheap and simple as using a bit of margarine rubbed thinly onto the surface; essentially you need to ‘grease’ the silicone to stop the next lot sticking to it. It is also possible with silicone moulds to do a single pour mould that encases all sides of your model, except the one attached to the base-board which will act as your pour hole. With this type of mould, the silicone will need to be cut in a zig-zag along one or two sides of the object to be able to remove the object and later the wax from the silicone. The reason for creating a zig-zag cut line is to aid the silicone to lock back into place rather like the purpose of the natches on a part-mould.

Some silicones take twenty-four hours to set. In this time it will settle and create an exact negative replication of the surface of your object. Sealing mould walls for silicone with clay can sometimes lead to leaky moulds. The clay seals dry out before the silicone has fully set, allowing the silicone to drip out onto the surrounding surfaces. To avoid this, always make silicone moulds in a tub, or use parcel tape, a glue gun or melted wax to seal the walls around the master model.

## Step-by-Step of Making a Two-Part Silicone Mould

What you will need:

| **Materials** | **Essential Equipment** | **Other Equipment** | **PPE** |
|---|---|---|---|
| Permanent marker | Plastic tub/plastic walls, glue gun, parcel tape | Board | Apron |
| More complicated form or found object | Weighing scales | Wax modelling tools<br>Craft knife | Respirator or dust mask |
| Clay | Measuring jugs & stiff spatula | Rolling pin & thick fabric or newspaper | Waterproof gloves |
| Silicone & catalyst | Silicone release spray (margarine) | Plastic sheet or newspaper | |

1. You have already determined that this model has a few undercuts and therefore will need a flexible mould material to allow safe and successful removal of the object from the mould.
2. Decide whether this is a single pour or part-mould.
3. For a silicone part-mould follow the steps 1 to 7 for plaster-part moulds.
4. When you have levelled the clay around your model, push the end of a pencil into the clay 1cm from the model and 1cm deep in four or five locations around the model, to create the location natches.
5. Cottle around your clay. For your walls either use a pre-existing plastic tub to place your object and clay into, fill the gaps and excess space with clay, or use plastic or glass plates as walls around the object and parcel tape, a glue gun or wax to seal the walls together.
6. Place newspaper or plastic on the table to protect your surface from unmixed silicone.
7. Wear a respirator, eye protection, an apron and disposable gloves.

**Highly textured surfaces will be replicated easily with silicone.**


**Step 8: In a clean jug weigh the desired amount of silicone for your mould.**

8. Accurately weigh the silicone and then the catalyst in separate tubs.

**In a separate clean jug or cup weigh the amount of catalyst needed for the silicone.**

**Step 9: Gently add the weighed amount of catalyst to the silicone.**

9. Pour the catalyst into the silicone, being careful not to splash. Mix them together thoroughly.

**Thoroughly mix the catalyst and silicone together.**

**Step 10: To ensure you have mixed these together thoroughly, pour into a separate jug and mix again.**

**To avoid creating air bubbles, pour the mixture from a height in a thin ribbon into the gap between the model and the tub or cottle.**

**Cover the entire master model in silicone for a one-part mould.**

**After twenty-four hours when the silicone has set, it can be easily removed from the cottle or tub.**

**For single poured silicone moulds cut a zig-zag into the side of the mould to be able to remove the master model.**

10. Pour the mixture into another jug and mix again to ensure that you have mixed it all. Now it is ready to pour into your mould.
11. Leave silicone to set in a ventilated area overnight. The silicone will peel off the jugs and spatula with ease once set.
12. Once the silicone has set, remove the walls. If you used a glue gun, a craft knife will be required. For part moulds, turn the mould over and remove the clay from the parts that are covered. Do not remove the model from the silicone.
13. Clean all the surfaces, remembering to include or replace the sprue. Cover the silicone in a release agent of your choice.
14. Rebuild the walls around the silicone and seal.
15. Follow steps 6 to 11 again to create the second part of the mould.
16. When the mould has completely set you will be able to remove the walls and prize the two silicone sections apart. Remove your object

and tape the silicone back together to pour wax or investment materials into it.

## Part-Moulds: The Possibilities

Investment material can be poured directly into silicone to create slump moulds, cast moulds and even the internal core for hollow moulds. Core casting will be covered further in Chapter 9. As you scale up your model making, you need to use more materials. You can add a thixotropic solution to thicken silicone, then apply a thin coating of silicone at least 5mm (¼") thick to an object to pick up the surface detail and use plaster as a backing to reinforce the silicone, so that you have a sturdier mould that has been made in a more cost-effective manner. Plaster is cheap, hard and strong, and silicone is expensive and flexible. Using a thixotropic additive with the silicone when mixing it will change the consistency of the material, essentially making it less runny (thicker) so that it can be applied rather like butter icing on a cake, although I wouldn't attempt to make it that neat. The main thing about making the plaster casing is that although the silicone may be flexible enough to be a one-part mould and handle a few undercuts, the plaster jacket will not. It will still need to be made as a part-mould, especially if there are under-cuts.

**The zig-zag will act like the location natches created in part moulds to ensure the mould lines up when it goes back together.**

**With the silicone held back together, wax or other materials can be poured in.**

## Hot Melt Rubber

Part-moulds can easily be made with Gelflex or Vinamould in a similar way to silicone. Thicker material wood or glass will be needed to cottle the mould as the rubber will melt some plastics. As long as the first side of the rubber is cold and clean, it doesn't need a release agent to stop the second part of the mould sticking to the first. Once the rubber has melted, allow it to cool slightly before pouring it onto itself.

**Flat lay of materials that can be burned out. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER EIGHT

# BURN - OUTS

The burn-out process is originally where lost wax got its name. Wax is invested in moulds for casting, then it is burned and therefore lost from the mould. Alongside wax, most natural materials and some man-made ones can be invested and then removed by firing the mould in a kiln at a temperature of 700°C (1,292°F) for a few hours. Dense materials and models with intricacy will take longer to burn out than simpler forms. The strength and quality of investment are important factors. The mould needs to be able to withstand two kiln firings, one to burn out the object and the other to cast the glass into it.

## Materials

Before you start, there are some materials that are not suitable for this process. They include all the types of modelling clays, rubbers, plasters and some more advanced types of 3D printed objects that are produced in plaster-based powders. Ordinary petroleum-based plastics cannot be burned out of moulds due to the toxic fumes they produce. All of these materials would need to be replicated in a plaster or rubber part-mould and then wax to burn out and cast them into a glass form.

Materials that can be burned out from investment moulds include: cardboard, wax, rope, fruit, vegetables, wood, PLA (polylactic acid) and castable resin 3D printed models. The best thing is you can combine these materials by using superglue or Type B modelling wax to create completely

unique forms.

To avoid confusion PLA is an (eventually) biodegradable plastic made from corn starch and does not give off the harmful fumes that petroleum-based plastics release when burned. Even though these gases are not toxic, extraction is still recommended when burning out PLA from a mould. In fact, extraction or ventilation is beneficial for all types of material burnouts due to the gases released during the process.

**PLA3D printed robot ready for investment to be burned out. Robot printed by the FabLab at Plymouth College of Art.**

## Getting Started

Similarly to lost-wax, you will need to consider the following: the thickness of the model, where to put the sprue for the piece, the direction of flow for

the glass and which type of glass to use to ensure a complete cast. If there are any undercuts they will need air vents. Calculating the volume of glass required for the burnout must be done before investment. Once you have burned out the material, the mould cannot get wet as it will weaken. As most natural materials are porous and 3D printed objects are hollow, they are not easily displaced in water. However, putting the item in a sandwich bag or similar and submerging that will allow you to calculate the volume of glass needed. You can also weigh a wax model and multiply that weight by the density of the glass you are going to use (*see* table in glass preparation, Chapter 4) for an approximate weight of glass required.

For highly detailed surfaces you can start by flicking or using a paintbrush to apply the investment mixture onto the object. Long term you may want to consider investing the form in a cup or container and using a vacuum chamber to remove any air bubbles from the surface.

For larger burn-outs or less detailed surfaces, hand-building Crystalcast in multiple layers (usually two or three) over your model will create a strong investment mould to withstand two firings at high temperatures. For larger forms, the addition of fibreglass strands in the outer mould mixture or a wire mesh around the mould will provide extra support. These additional layers of investment material give larger moulds the strength to hold a larger capacity and therefore a heavier weight of glass.

After investing the model, remove the sprue and clean the opening with a sponge. This is the last time you will be able to remove any clay debris from the mould. The mould needs to be placed upside down in the kiln, propped up off the kiln shelf to allow heat to circulate around and into the mould. A burn-out cycle is normally set up and put on overnight because of some of the gases that are released during the firing cycle.

After the model has been burned out, wait till the mould has cooled for safe removal from the kiln. You will need to gently remove any remaining ash from the mould. It may be that you have access to a compressed air unit, in which case use a low setting of around 20 psi and direct this into the mould to release any ash from the surfaces. If you don’t have one of these, wearing a pair of safety glasses hold the mould up on its side and

blow into it gently. Make sure your eyes are covered so that you don't get any ash in them. Whatever you do at this stage, the mould is in a vulnerable state so be careful when handling it. Do not put any water near the mould once it has been fired!

## Mould Cracking

If a small hole or minor crack lines have appeared in the surface of the mould after the burn-out firing, you have an opportunity to reinforce them. You can add an additional layer of mould mixture by hand-building it onto the mould. In extreme cases, use binding wire to hold the mould together before the additional investment coating. When adding this extra layer, as the mould has already been fired the mould mixture needs to be a bit runnier with more water as the liquid will be sucked into the existing dry mould. Unfortunately, this will not make the crack lines within the mould disappear; it is likely that they will be visible on the surface of the cast glass. During the cast firing glass may still escape through the original cracks, but at least with an additional layer of investment the glass will have nowhere else to leak to and more importantly it won't ruin the kiln. To be extra cautious, put the mould into a bed of kiln sand surrounded by kiln bricks or in a terracotta plant pot to support the mould.

## Step-by-Step of Burn-out Mould

What you will need:

| Materials | Essential Equipment | Other Equipment | Personal Protection |
| --- | --- | --- | --- |
| Clay | Cup or container | Cottle boards or plastic | Apron |
| Natural material or object to burn out | Mixing bucket | Wax modelling tools<br>Craft knife | Respirator or dust mask |
| Crystalcast | Measuring jugs × 2 | Rolling pin & thick fabric or newspaper | Waterproof gloves |
| Glass | Washing-up bucket & sponge | Cocktail sticks or cotton thread | |

1. Displace your natural material or object and record to calculate the volume of glass needed (put it in a plastic bag to do this if it is porous).

**Step 2: Create a sprue out of clay to prepare the mushroom for investment.**

**Securing the mushroom to the sprue with a cocktail stick to bridge the two.**

2. Create a solid cone shape for the sprue using wax or clay roughly the same size as your model. Ensure that it is large enough to hold the volume of glass required for the object. Attach the sprue at the base point of the form, using cocktail sticks to secure the join between the two.
3. Assess the flow of glass. Where there are obvious undercuts you will need to add cocktail sticks, skewers or cotton thread to create air vents from the object's extremities to the baseboard or sprue. *See* lost-wax casting, Chapter 6, for further clarification.
4. Using a clean cloth, clean your object, spray with hairspray and allow to dry. This step is not essential.

**Smooth down the edges between the mushroom and the sprue.**

**Step 5: Cottle with flexible plastic, tape and seal to the baseboard with clay, wax or a glue gun. Make sure there is a 2cm gap all the way around the object to be invested.**

5. At this stage, you can cottle the model. Be sure to leave a 2cm (1") gap between the model and mould walls.
6. Mix and pour your mould mixture. If your shape is uneven consider hand-building the mould to save on materials.
7. When the mould has set, remove the cottle and thoroughly clean off any clay.
8. Set the mould inside the kiln upside down. Place on kiln props so it is held above the kiln shelf. Add kiln sand to the shelf for protection from ash.
9. Remove bung from kiln and programme for burn-out firing.
10. Once the mould has cooled to room temperature then you can remove the mould, blow out the ash and place back in the kiln the right way up

with the sprue at the top.

11. Load your mould with glass and fire using a schedule appropriate to the glass you are using on a lost-wax firing cycle. For an example, *see* Chapter 6.

## Example Firing Cycle: Burn-Out Mould, Vents Open and Extraction On

| Ramp | Rate per Hour | Set Point Temperature | Hold Time |
|---|---|---|---|
| 1 (Initial heat) | 45°C (81°F/hr) | 100°C (212°F) | 2 hours |
| 2 (Mould Cure) | 75°C/hr (135°F/hr) | 600°C (1,112°F) | 1 hour |
| 3 (Burn-out) | 150°C/hr (270°F/hr) | 740°C (1,364°F) | 1½ hours |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

**Smaller natural materials like strawberries can be set up on clay sprues.**

**These small strawberries can be invested within plastic cups to save the time of cottling.**

As with the little lost-wax casting step-by-step, it is possible to find smaller natural materials for the burn-out process that can be invested in a similar way by using plastic cups to hold the mould mixture. *See* the photographs for how I set up some strawberries, which I burned out and cast. The separate green leaves were created on a lampworking torch and attached later with silicone glue.

**The strawberries were invested, burned out and then cast in a mixture of transparent red Glasma glass; the leaves were made on a lampworking torch and added later.**

**Kiln set up with plant pot for core cast. (Photo: Nicola Simpson)**

CHAPTER NINE

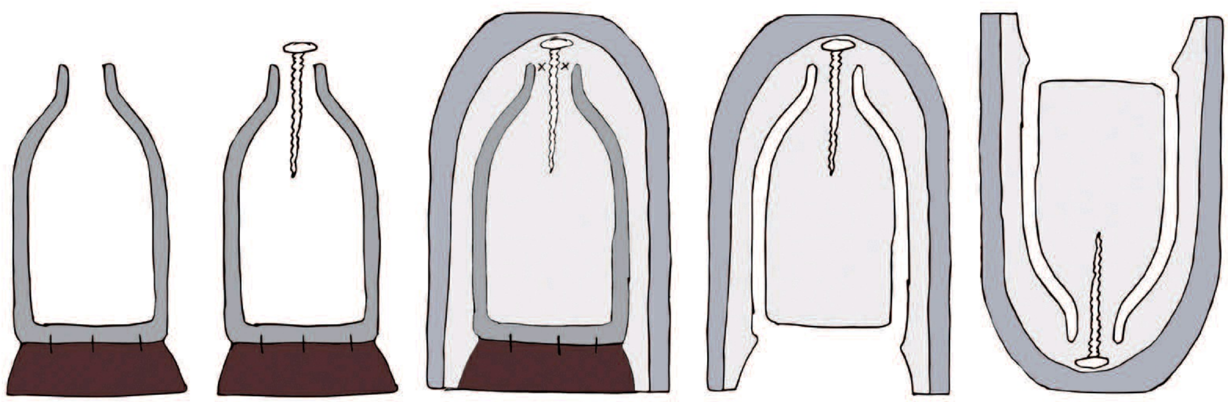
# CORE CASTING

Core casting is the term used for creating a hollow form referred to as negative space or void within a glass cast. You will need to have tried some of the other techniques of glass casting before attempting this process. Having worked through the previous step-by-step projects, you will have an understanding of glass casting and the reliance on gravity for the glass to flow and fill the moulds to create solid objects. It will be clear too that the form of the wax will become glass, so if the wax is hollow you should be able to cast glass into exactly the same hollow form. There are a few nuances with this thinking, though; just because you have a hollow wax doesn't mean that the casting process for creating a hollow glass is not without its challenges.

There are two distinct types of core casts: open hollow forms (think bowl) and almost entirely enclosed cores (think bottle). The main point is that the core needs to be connected to the outside mould material and that connection needs to be reinforced. For more open forms you can use grog or fibreglass strands in the investment mixture and follow the shape of the form by hand-building your mould. For enclosed cores, you need to use a screw or metal wire as reinforcement. The purpose of putting a screw or wire within the connection between the core and the rest of the mould material is to stabilize, strengthen and bridge this otherwise weak point in the mould. When the glass is flowing into the cast as a heavy liquid, it can easily move and break the core from its point of contact. If the core connection is broken, the core can become completely detached from the

rest of the mould and float inside the glass cast. There is then no way to control how the form ends up. With a connection that is bridged with metal, the liquid glass is not likely to move or break the mould core.

Crystalcast for core moulds works well without having to change the mixture or the volume of water used. A point to note if you are using a plaster and silica mix is that the investment materials you use for the core need to be made of a softer consistency for the inside of the mould. You can adjust this by increasing the volume of the modifier (silica) and reducing the binder (plaster) by the same volume. In a normal 1 : 1 : 1 mix the ratio may change to ¾ plaster : 1¼ silica : 1 water. There is still enough binder for the mixture to set but the additional modifier weakens the mix. This does two things: it allows the glass to expand and contract around the soft core and it is easier to remove the soft core from inside the glass cast. A normal 1 : 1 : 1 investment mixture for the core is too rigid for the surrounding glass; when it contracts as it cools, it may cause the glass to break against the core.



**Wax core cast bottle form with metal screw placed in the opening to bridge the gap between the inside 'core' and the outside investment mould. (Illustration: Amy Whittingham)**

## SOFT INVESTMENT MIX FOR INSIDE CORE OF GLASS CASTS

Water : Silica : Plaster

1 : 1¼ : ¾
600ml : 750ml : 450ml

There are several ways of approaching core casting:

- Constructing a hollow wax.
- Slush casting a wax.
- Creating the core.

## Constructing a Hollow Wax

This is by far the easiest way to approach core casting. There are so many types of wax with a whole range of characteristics and you can use any combination to construct a hollow form, be it a vessel or otherwise. Extruded wax sprues can be woven to create forms; these can be combined with other waxes.

Microcrystalline wax can be poured onto greaseproof paper to form sheets of wax that, alongside sheet dental wax, can be joined together. Type B modelling wax can be used to join waxes together and it can be manipulated to create hollow forms on its own. A small tipped soldering iron is an excellent tool for joining waxes together and smoothing out any gaps. Alternatively, heating the tip of a metal wax tool in a candle will do the same job. You could prepare part-moulds of other forms, cast a few of them in wax and attach, melt or construct them together into a hollow form. Through this construction process it is important to remember that you are modelling both the inside (negative) and the outside (positive) of the form. There are a wealth of possibilities with modelling, repeating forms and building them in wax.

**Wax will not stick to greaseproof paper.**

**Creating textured wax sheets.**

**These wax sheets can be melted or joined with brown wax to create hollow forms.**

## Step-by-Step Core Cast of Constructed Wax

What you will need:

| **Materials** | **Essential Equipment** | **Other Equipment** | **Personal Protection** |
| --- | --- | --- | --- |
| Five textured wax sheets | Screw or wire for bridging | Cottle boards or plastic | Apron |
| Clay | Mixing bucket | Wax modelling tools<br>Craft knife/scraper | Respirator |
| Crystalcast and fibreglass strands | Measuring jugs ×2 | Rolling pin & thick fabric | Waterproof gloves |
| Glass | Washing-up bucket & sponge | Cocktail sticks or cotton thread | |

1. Cut the thick textured wax sheets into five 10cm x 10cm (4" x 4") squares.
2. With the texture on the outside, join these sheets together at the corners with Type B modelling wax or by using a soldering iron. Create a box with five sides and one open side, which will be the top opening for the core.
3. Gently displace your wax construction and calculate the volume of glass required.

**Step 4: Set up the constructed hollow wax on a bed of clay, making sure it is secure. This is going to be dribble cast using a plant pot.**

4. Create a sprue using wax or clay roughly the same size as your model. Ensure that it is large enough to hold the volume of glass required for the object unless you plan to use a plant pot to dribble cast the glass. Attach the model to the sprue using cocktail sticks and secure the join.

**Step 5: Consider where the bridging screw needs to be placed; suspend it with copper wire attached to excess wax if possible.**

5. Set up your bridging screw with copper wire or be ready to hold it in place while the investment mix is setting.
6. Assess the flow of glass – are there any obvious undercuts where you will need to add cocktail sticks, skewers or cotton thread? Look out for extremities that may require the glass to travel upwards.

**Step 7: Clean wax with white spirit.**

7. Using a clean cloth and white spirit, clean your wax.

**Step 8: Spray wax with hairspray.**

8. Spray with hairspray and allow to dry.
9. At this stage, you can cottle the model; be sure to leave a 2cm (1") gap between the model and mould walls.

**Step 10: Pour the investment mix into the hollow space and hand-build around the outside.**

**Hand-build the investment mixture around the wax.**

**Scooping up the mixture that runs off to put it back onto the wax.**

**As the investment begins to set, the material will stay on top of the wax to create the mould.**

10. Mix and pour your mould mixture or hand-build the mould in layers with an even coverage (don't forget the bridge). Add fibreglass strands to the second layer of the mould; if your shape is uneven, hand-building this will save materials.

**Step 11: After an hour gently remove the baseboard from the investment mould. Remove the clay sprue and clean thoroughly before steaming or burning out the wax.**

**After the wax has been steamed out you will be able to see the investment core within the**

**mould.**

**Displace the investment to ascertain the volume of glass required.**

11. After an hour remove the sprue, steam, clean, dry and prepare the glass for casting.

## Firing Cycle: Banas Glass Core Cast (approx. 1 kg glass)

| Ramp | Rate per Hour | Set Point Temperature | Hold Time |
|---|---|---|---|
| 1 (Initial heat) | 45°C/hr (81°F/hr) | 100°C (212°F) | 1 hour (vents open) |
| 2 (Mould cure) | 50°C/hr (90°F/hr) | 600°C (1,112°F) | 1 hour (vents open) |
| 3 (Cast) | 125°C/hr (225°F/hr) | 860°C (1,580°F) | 4 hours |
| 4 (Buffer) | 200°C/hr (360°F/hr) | 600°C (1,112°F) | - |
| 5 (Anneal) | 20°C/hr (36°F/hr) | 475°C (887°F) | 4 hours |
| 6 (Strain) | 10°C/hr (18°F/hr) | 350°C (662°F) | - |
| 7 (Slow cool) | 20°C/hr (36°F/hr) | 250°C (482°F) | - |
| 8 (Cool) | 60°C/hr (108°F/hr) | 100°C (212°F) | - |
| | OFF | Keep kiln closed to below 80°C (176°F) | |

**Core cast vessels finished to 400-grade grit and treated with 'Invisible Shield'.**

## Slush Casting a Wax

Slush casting wax is a process predominately used in bronze casting as a

way of creating hollow wax forms. For glass, a damp-plaster or rubber part-mould that you have made already can be used to pour melted wax into as an easy way to create a slush cast wax form. You can completely fill the part-mould with wax and after five minutes pour the wax back out of the mould again. Repeat this till an even coating of wax at least 6mm (¼") thick is achieved. Or you can pour or paint melted wax onto the surface of a mould; painting it on initially will allow the wax to pick up minute details. Alternatively, you can pour one-third of the wax into a part-mould, then move and rotate the entire mould to slush the wax around. This process can be time-consuming. If you have it, use green wax as it is the quickest one to set.

Once you have a hollow wax from slush casting, set this up so that the opening of the hollow is facing upwards and the opposite end of the wax is the side that is attached to the sprue. This will allow the investment mix to be poured into the hollow, and a bridging screw or wire to be held in place while the mixture sets around the outside of the wax. The downside to slush casting wax to create hollow forms is that you have no control over the exact thickness of the entire wax and the shape that the internal form (negative) will take. Sometimes there can be obvious pour lines inside the wax. Depending on your aesthetic, this may be desirable or not. If the glass you are using is opaque, the results will be similar to metal casting and these 'imperfections' from the slushing process won't be noticeable. If you are using transparent glass, then this is something to take into consideration as you are creating the form. Transparent glass will show any imperfections on the inside of your form. This may lead you to pursue ways to control the internal form (negative) by creating the core.

## Creating the Core

In order to create a core cast, sometimes it is necessary to create the form of the core along-side creating a model of the outside of the object. This is a more advanced approach to core casting. With this technique you

are in control of both the inside and outside forms, the positives and negatives. To begin with, the most obvious of considerations is that the form of the core (the negative) must fit inside the outside form (the positive). Next, there will need to be a point where the forms join: the connection mentioned at the beginning of this chapter. This could be the opening of a bottle, if you want to create a vessel, or it could be at the back or side of the form for a more concealed opening. Artists sometimes make a separate positive form that fits into this opening hole, essentially blocking it. This could be thought of simply as a stopper but could also be a positive continuation of the (negative) core form within the glass.

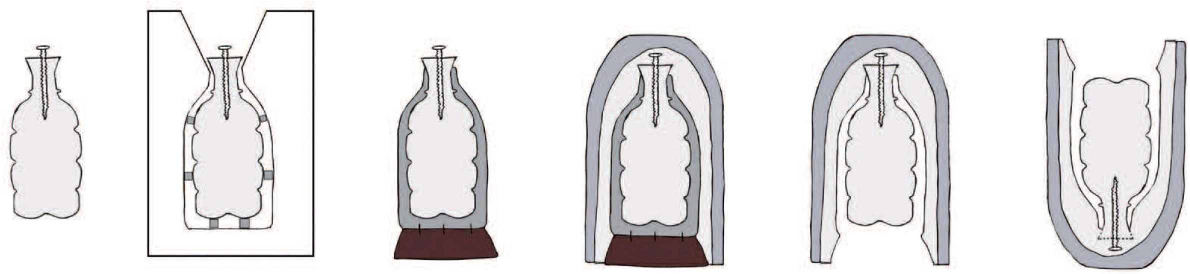
To start off with this method of core casting, you need to create a model of your core. There are a few ways to approach this: either carve a simple form from investment material or use an existing part-mould and cast investment material into it. Fill an existing part-mould including the sprue with investment material, set up a screw or wire in the top, ensure this is embedded and partially sticking out. Plaster part-moulds will work as long as you have used a release agent on the surface of the mould. A plaster part-mould will not withstand more than four or five pours of investment into it. The investment mix, like plaster, expands slightly as it sets and this puts pressure on the plaster mould. As both the investment material and plaster are hard surfaces, the plaster starts to deteriorate every time it is used. Rubber moulds work well for casting repeatable core forms in investment material with little to no degrading of the surface. It is important to remember the golden rule while you are creating your core (*see* box).

## THE GOLDEN RULE

Always reinforce the connection between the investment core and the investment mould.

Once you have removed your investment core from the part-mould, you need to be able to position this within your positive wax form. Making sure the sprue part of the core and the screw or wire remain protruding from

the wax, this will be the point where the new investment mix attaches to the core. The positive part of the cast can be achieved through wax construction or by positioning the investment core within another larger part-mould. Use wax spacers made from brown wax or set and measured wax blocks to prop and hold the core where you want it to be within this second part-mould. Pour wax around the core to secure it into place and create the positive. These spacers are essential when you want to control precisely the position of your core within the cast. The wax that is surrounding the core does not need to be solid but needs to be sealed around the core to hold it in place. You must not allow any investment mix to leak between the core and the wax. Attach a sprue of wax to the end that is opposite to where the core and screw protrude from the wax, secure the sprue to the baseboard and invest the entire form.



**Plastic bottle shaped form inside a glass bottle core cast. Create the investment core form in a part mould and place this within another larger part mould using wax spacers to position the core. Pour wax in the gap to create a controlled core within the wax for a core cast. (Illustration: Amy Whittingham)**

As you have a screw and some of the investment material sticking out of the wax, the next layer of investment will attach to this and ensure the core is connected and securely held in place. When you go to steam out your wax, you will be able to see the core inside your mould. The core should be stable and not move within the mould.

## Core Cast Possibilities

There are so many possibilities with this technique, especially once you start thinking about the form of the inside space (negative) and the outside space (positive). Potentially core casting adds at least an additional two surfaces to the glass form, not to mention reflective surfaces if the cast were to be polished. Having a grasp on the journey through positives and negative forms will improve your approach to core casting. This is a technically challenging method of glass casting but many artists are working in different ways with this technique. It takes a bit of practice and technical proficiency to master.

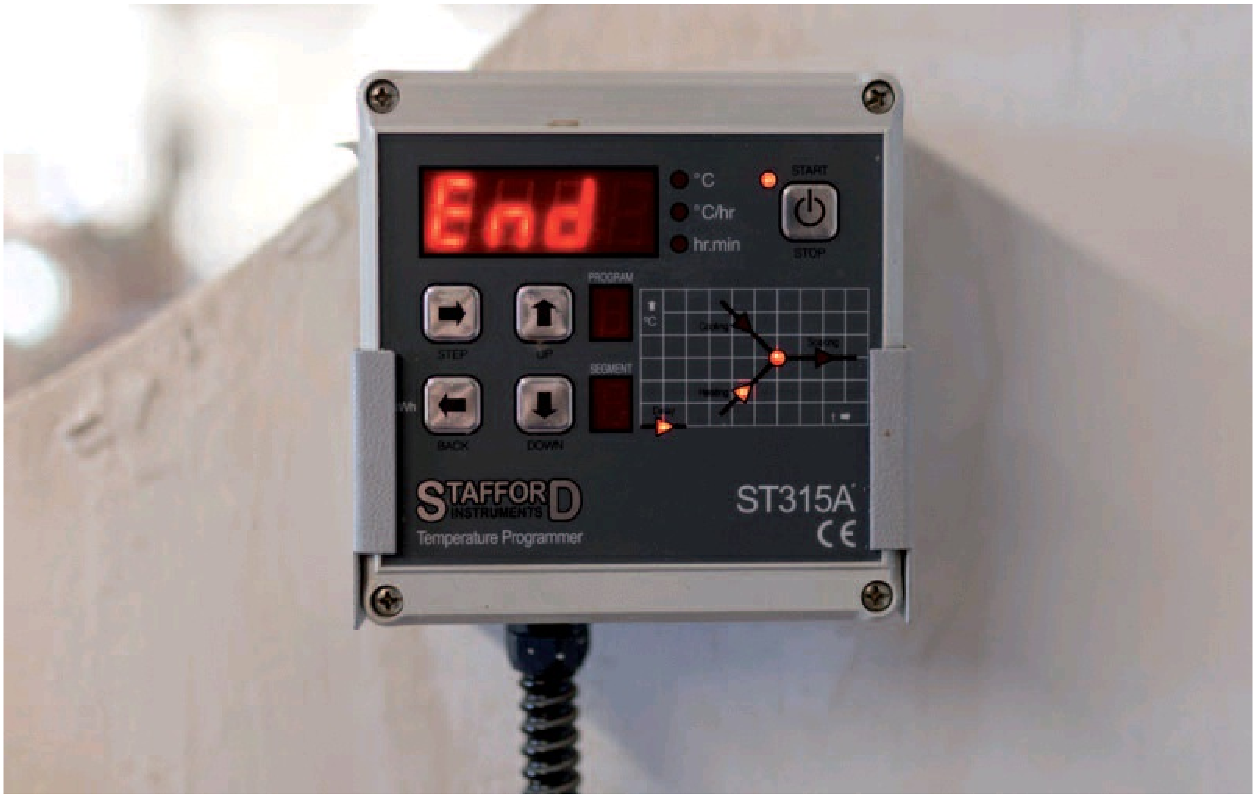

DREMEL

**Flat lay of hand finishing equipment. (Styling: Zephia Hood and Nicola Simpson)**

CHAPTER TEN

# DE - MOULDING AND FINISHING

Finally, the controller is flashing END; you can press the stop button one more time to check the temperature of the kiln. If the temperature reads below 80°C (176°F), after all your hard work and patience you can open the kiln briefly to take a peek. The anticipation of discovering if your glass cast has worked is a present to most cast glass artists. Once the controller is showing that the kiln is at room temperature, the cast is ready to be unpacked from the kiln. If the glass cast is on the thick side, always err on the side of caution; leave the cast for at least another twenty-four hours to allow the glass to fully equalize in temperature before de-moulding. Remember that the temperature of the kiln and the surface of the glass can be different from the temperature inside the glass. After all this time you do not want to (thermal) shock the glass. If you have to remove the glass from the kiln because you need to load the next moulds, put a thick fibre blanket or vermiculite board on the top of the glass or wrap the entire mould in a newspaper to retain some of the heat so that it can be removed from the kiln. Wear heat-protective gloves if the moulds are still hot to touch.




**Finally, the controller is flashing END.**

**Step 1: Sneak a peek inside the kiln to see if your glass has cast.**

## De-Moulding

### *Important health and safety for de-moulding*

Regardless of how you remove your investment mould, this material still consists of silica and is harmful when breathed in. Always wear a respirator and work under extraction or in a ventilated area. Wear gloves to protect your hands from any sharp edges.

**Step 2: Wear a respirator and gloves to protect your hands from sharp glass edges.**

**Step 3: Carefully excavate or soak the investment material off the cast.**

**Step 4: Scrub clean the glass with a soft brush.**

Once the glass surface is cool to touch, it is ready to be removed from the mould. There are a couple of ways to approach de-moulding glass. You can excavate or you can soak. If the mould is for a core cast, there is a risk of the investment material expanding within the core when soaked to an extent that it can cause the glass to crack. For that reason, it is advisable to excavate as much mould material as possible and then soak in water when there is room for the remaining material to expand.

If you can remember the shape of your original model, this will help when you come to excavate it. Be extra careful and use non-metal/ slightly flexible tools when removing the investment material from around delicate or thin areas of your cast; these are the most vulnerable and likely to break when de-moulding. The used investment powder is known as ludo and can be saved and reused in later projects (*see* Chapter 11).

Once you have removed the bulk of the investment material from your

glass cast, you can soak it in water and clean it with a soft brush. Old toothbrushes, bottle brushes, pipe cleaners, cocktail sticks and skewers are handy for this task. Sometimes you will find that there are contaminants or tough bits of mould material attached to the surface of your glass, and these can be hard to remove. Soaking the casts for a few hours in any sort of acidic liquid – for example, vinegar, lemon juice or cola – can help loosen and in some cases dislodge contaminants. Some artists use brick acid, but take precautions when using this; wear gloves, safety glasses and work in a well-ventilated area. If particularly stubborn, a handheld engraver will grind these contaminants away.

## Finishing

Personally, I prefer glass casts that are not highly polished. How glass comes out of a mould is not particularly polished or glistening, but it has its own unique qualities that are a signature of the technique. When casting, the glass has flowed into the mould during the peak of the firing cycle; it has relaxed into this new form with the aid of gravity. The heat in the kiln has radiated through the sides of the mould but not enough to polish the surface of the glass that it is touching. Sometimes there will be areas that have a sheen to them, but you may find the piece isn't shiny enough. If this is the case, read on. There are a few approaches to finishing your glass casts, all of which will involve some elements of cold-working:

- Hand lapping
- Grinding and polishing with machines
- Fire polishing
- Acid polishing

Cold-working is used as a general term for grinding and polishing glass, as all of the processes involve working with cold water to lubricate the glass and stop any heat build-up that could shock and crack your cast.

## Hand Lapping

You have to take a systematic approach to hand grinding, which is more commonly known as hand lapping. Grinding a glass cast by hand is satisfying but the most labour-intensive and time-consuming process, and getting a truly flat mirror polished surface by just hand lapping is near to impossible. However, if you are approaching this process completely by hand then you can expect to at least achieve professional-looking, finely ground surfaces that look exceptional and have a sheen to them.

For flat surfaces, you can set up a grinding area for hand lapping in your studio or on a spare desk at home. Although the beginning of the process is incredibly noisy, once you get past that first stage you can comfortably work through the grades. It is the most financially economical route for finishing, but be aware that it can be costly with regards to your time. Essentially you will need to source three pieces of 6mm (¼") float glass approximately 30cm (1ft) square or larger than your casts to use as grinding plates. Add a few grades of grit and some elbow grease and you are heading towards a shinier surface.

### Bevel the Edges

You will need to bevel the edges of the glass plates and the cast you are working on to avoid both cutting yourself on the sharp edge and that edge scratching your cast. A bevel is a 45° angle worn on the sharp edge of a piece of glass. By bevelling the edges, you are removing the weakest point of the corner, which is the point that can sometimes chip while you are grinding. You can use a diamond hand pad with water at a 45° angle to the glass to give the edges a bevel.

**TOP TIP**

For a cheap hand pad alternative, you can use flat glass cut to approx. 5cm (2”) square, add water and your chosen grade of grit, and use in a circular motion on the surface or edge you

are grinding.

## Grinding Grits

Commonly used grits are aluminium oxide and silicon carbide and they vary in price and particle size. The minimum grades of grit you need are 80, 120, 200 and 400. The number of the grade refers to the size of the particles: the higher the number, the smaller the particle size. As with sandpaper you need to start with the lowest grade of grit, which is the coarsest. Generally, it is easier to start with an 80 grade, even if the surface appears to be flat. If you are buying grit that is measured in microns, the rating system is different. To give a couple of examples: beach sand is 100 microns and bacteria is 2 microns. Either way, work from coarse to fine.

**Step 1: Set up a clean working space and mark up the glass surface to be ground.**

**Step 2: Use the coarsest grade of grit to start with. Add water and liquid soap to help lubricate the grinding process.**

**Step 3: A figure of eight motion across the whole of the glass and a lot of elbow grease will grind the surface flat.**

**Step 4: Thoroughly check you have ground the entire surface before moving onto the next grade of grit as you will not be able to polish out missed corners or scratches.**

Create a clean workspace, put newspaper or a tea towel underneath your clean glass plate, add grit and clean water and use a permanent marker pen or chinagraph pencil to draw a cross-hatch across the surface of the glass you are going to grind. With the 80 grade, using a touch of washing-up liquid or soap will ease the initial stickiness of the glass-on-glass motion. Wear ear defenders for this first stage. Work in an even figure-of-eight motion, moving the glass cast across the whole surface of the float glass through the grit and water. You do not need to apply any pressure as the grit will wear down the surface. When you can hear the scratching noise is not as prominent, add fresh grit and water. As you work the cast across the float glass, it will push some of the grit off the sides. As long as it is not contaminated, you can reuse this by scooping it back

onto the plate. Do not do this when you start using finer grits as this will be an easy way to accidentally pick up contamination and scratch your glass.

Once your cross-hatching has disappeared, clean and dry your cast and visually check that the surface is uniform. Be thorough with your examinations of the cast; sometimes you can feel whether the surface is uniform more than see that it is. If you struggle to see the surface, find a good light source and a magnifying glass. It is incredibly easy to miss a corner and not notice till later. If anything, it is better to spend longer hand lapping with the coarser grades of grit as it will improve the surface finish of your piece. Casting creates bubbles so these are something that you will learn to love. If there are any bubbles on the surface of the glass, be sure to remove the grit from these.

**TOP TIP**

A squirt from a water spray bottle will remove grit from surface bubbles.

## Working Through the Grades

You can move onto using the next grade of grit when you are certain that the cast surface is evenly ground. Wash and thoroughly clean all surfaces including the float glass plate, and label it with the grade of grit you were using in a corner. This makes the grinding plate easier to identify the next time you do some hand lapping. Replace the newspaper or towel and be extra vigilant. Flip the float glass over to use the other side for the next grit or a fresh sheet of glass for each grade to avoid creating scratches and cross-contamination. Once you have got this far, the last thing you want to do is catch a scratch from the previous grit. Take care to check the bevelled edges of the cast; they will need grinding with the same grade to keep the cast even. Cross-hatch the surface of your cast again before you start; if you have a chinagraph pencil you don’t need to wait for the surface to be dry before drawing on it. Hand-lap with the next grade till there are

no cross-hatch marks left or surface pitting from the previous grit. Skipping a grade is not an option because the finer grit will take longer to remove the previous surface created by a coarser grit, and it may leave pitting that will become visible as a cloudy surface when you attempt to polish. Continue with this clean and check routine to work through to the finer grades.

## Finishing at 400 and Sealing the Surface

Once you have finished using the 400-grade grit, the even matt surface created by hand lapping is an acceptable finish for cast glass. If you have used a handheld machine at 400, sometimes the surface will still have a few scratches on it, which will make it appear as if it is not finished. If you have achieved a uniform surface, you can stop grinding at 400 and move on to polish or use a product on the surface. There are various approaches to ‘seal’ the surface of glass that has been ground to a 400 grade or sandblasted. A thin application of Invisible Shield rubbed in with a lint-free cloth, splashed with water and then buffed, microscopically seals the ‘pores’ of the glass. Sometimes this needs a couple of applications but will give the surface a sheen and stop it from picking up fingerprints. A ceramic floor tile protective coating, available from most hardware stores, seals and protects the glass from fingerprints and creates a sheen on the surface too. Or alternatively, car dash-board shine with a high silicon content or a thin wipe of oil (baby or essential) can be used if you would prefer a non-permanent coating. Again, these products will leave the glass with a sheen that gives a satin-etched look. If the pieces are to be worn, natural skin oils will create the same sheen on the cast surface too.

## Grinding Curved Surfaces by Hand

By using diamond hand pads with water, you can work curved glass surfaces from rough to smooth in a pretty quick fashion. You are not going to get a smoother surface any faster if you put more pressure on the hand

pads or negate the water. The water acts as a lubricant and stops the small particles of glass dust from becoming airborne and breathable. They are colour coded; work through them using a circular motion on the glass in order of rough to smooth.

**HAND PADS: COLOUR ORDER OF USE**

Grinding ⇛ Green (60) ⇛ Black (120) ⇛ Red (200) ⇛ Yellow (400)

Polishing ⇛ White (800) ⇛ Blue (1,800) ⇛ Orange (3,000) ⇛

Stop, clean and check the surface before moving on to a smoother grade. While grinding, use a marker pen to highlight areas that need to be worked on. For shinier surfaces, there are fine, resin-coated pads that you can move onto to transform the surface from a dull matt to a polished sheen.

If the cast has acute curves or detailed surfaces, there are smaller diamond tools available, or else rolled-up old linisher belts work well if you have access to them. At a push, you can roll and shape the rougher grades of silicon carbide or aluminium oxide wet and dry sandpaper, though these are the least effective method and you will end up using a lot of the sheets as the glass is a very hard surface to grind. Once you get to an even ground surface, there are diamond abrasive material versions of the hand pads produced by Eve that can be used for getting into those curved or awkward spaces.

## Machine Polishing

If what you wish to achieve is an even mirror shine polish, on a small scale a handheld engraver with rubber points or detachable Velcro pads will polish surfaces. Otherwise, medium- to large-scale polishing will require specialist cold-working equipment that you can either hire or invest in. For

more information on these machines, read the bonus items at the end of Chapter 2. The Contemporary Glass Society website has a list of equipment and studio hire for cold-working equipment in the UK. When working with machinery, you will need to work systematically through the grades in the same way as for hand lapping – cleaning, checking and cross-hatching as you progress.

Once you have reached the 400 grade, you can jump to an 800 grade for a finer finish before moving on to a cork wheel with pumice or a felt wheel with cerium or both in that order. Both of these approaches require a small amount of cold water mixed in with the powder to create a paste which is applied to the glass and buffed off by holding the glass with a medium pressure against the spinning wheel. The friction of the wheel and the pumice or cerium paste on the surface of the glass creates heat, which polishes the surface. It is important to move the point of contact for the wheel across the glass so that there isn't a concentrated area where the heat builds up. If too much heat is created in one area, the temperature difference within the glass can cause a crack. Check the surface regularly. Work in one direction, then rotate the glass 90° to work from the other side but in the same direction. Stop every so often to allow the glass to cool and check the surface to see if and where you need to continue.

## Fire Polishing

There is a shiny finish which glass is more often associated with, which can easily be attained while fusing, lampworking and glass blowing. All of these processes involve the surface of the glass being in direct contact with heat. There-fore, it stands to reason that you can polish cast glass by using heat. This process is called fire polishing – it can be tricky but it's possible.

Although it sounds as if you need to go out and buy a big flame-throwing torch, this is not the case! There is no actual fire involved in fire polishing glass. Fire polishing would probably be better-named kiln polishing, but it doesn't sound half as much fun. If you have done some

fused glass before, you may already be familiar with this process. With fused pieces of glass, fire polishing is quite simple as the glass is often flat and therefore not likely to distort in the kiln. Cast glass, on the other hand, is likely to need support in the kiln to be able to fire polish one surface. If the form is thick, the weight of the glass will play a big deciding factor into whether you choose to risk fire polishing the piece or not.

Essentially fire polishing involves heating the glass at a low fusing temperature for a short period of time to 'melt' the surface particles. The temperature used is, however, higher than the slumping temperature of the glass, so therefore it is important to be prepared for the glass to change shape slightly. Taller items are likely to deform using this process. Old plaster powder, when packed around and underneath the glass, will provide some support, leaving the top surface exposed to be polished. The plaster will not stick to the glass surface but it will prevent fire polishing; make sure the top surface is clean, and use a dry paintbrush to remove any powder. Alternatively, controlled fire polishing and slumping of a cast glass can be achieved during the same firing. This can be really effective for those flat relief casts in Chapter 5.

To prepare your glass for fire polishing you will need to:

1. Cut, engrave and grind any surfaces to remove the unwanted excess glass. Grind surfaces through the grades to a 400 grit. Or cut, engrave and sandblast all surfaces to be polished.
2. Clean and degrease the surface of the glass.
3. Place in the kiln, support any areas around and underneath the side to be fire polished using plaster in its powder form.
4. Programme the kiln to heat slowly up to and 50 degrees beyond the annealing temperature of the glass, then as fast as possible to the fire polishing temperature with a maximum hold of three to four minutes.
5. Open the kiln to crash cool it, dropping the temperature to just above the annealing point and then anneal as normal.

### APPROXIMATE FIRE POLISH TEMPERATURES

| | |
|---|---|
| Bullseye | 710°C (1,310°F) |
| Dartington | 650°C (1,202°F) |
| Gaffer | 630°C (1,166°F) |
| Glasma | 725°C (1,337°F) |

There is another way to fire polish, which includes the use of a hot glass studio: pre-heating the cast overnight and then having it picked up and temporarily flashed into a heating chamber to melt the outer surface. Once the desired level of polish is achieved, the piece is placed back into a kiln to anneal. This can be a risky process as the outer surface of the glass becomes much hotter than the internal temperature. If you have access to these facilities, it is worth exploring further.

There are a couple of specific restrictions to this process. Firstly, if the furnace glass is incompatible with the cast glass, it can cause the cast to shock as the piece cools down. Secondly, the weight of the cast piece is a consideration. Large pieces will be too big and heavy to control when on the end of a hot-glass blowing iron.

## Acid Polishing

Acid polishing is not something you do at home. The process uses an incredibly dangerous combination of hydrofluoric and sulphuric acids that are carefully handled in a strictly controlled environment. There are only a couple of companies in the UK who still process acid dipping. Two companies that acid polish glass for artists are Cumbria Crystal and Wessex Crystal.

You need to decide that you intend to acid polish your glass cast before

you cast it. It cannot be used as a back-up option for polishing if you haven't used the right type of glass to begin with. The posting and dipping turnaround time can also add a week or two to your finishing time, so prior planning is required. The costs and timing of this are additional factors, especially if you are working to a deadline. The glass you use to cast with must have at least a 24% lead content in order to be acid polished. The good news is that Dartington Crystal and SCHOTT are among a few companies in the UK that sell clear casting crystal at 24% lead. Also, all the colours of Gaffer casting crystal have a minimum of 42% lead oxide except one, uranium green, which is a completely leadless casting glass that Gaffer have produced. Uranium green is the only colour that is not compatible with the rest of the casting range as it requires higher casting and annealing temperatures. Due to the lack of lead in its make-up, uranium green cannot be acid polished.

The liquid acid is gradually heated and kept at a warm 50 degrees. The glass, your glass, is placed in special plastic cages and dipped into the acid. For larger glass casts it may be necessary to gradually warm up the cast in a water bath prior to acid dipping. This will be done to avoid thermal shock. The mixture of acids chemically reacts with the lead component in the surface of the glass, changing the surface from a slightly opaque matt to a shiny transparent. Once the glass has been dipped in the acid bath, it is removed and placed in a water bath to wash off the residue created from the reaction.

In preparation for acid polishing, you will need to pay attention to the surface of your cast. The glass needs to be sandblasted and clean before it can be sent for acid polishing. Cut, grind and engrave any excess glass. Inspect the surface, grind it through the grades to a 400 grit if you want the result to be smooth. Although acid polishing makes the surface of the glass smooth on a molecular level, it will not magically make the entire surface uniformly smooth. If there is texture on your cast the surface will become shiny and the texture will remain. Amongst other things, these acids are capable of dissolving metal too, so be warned that any copper wire inclusions that are not completely trapped within the glass will disappear.

## Etching Cream

This can be purchased and used in your studio. There are various brands of etching cream, and some have a better effect on glasses than others. Armour etch works best on float (window) and bottle glass; Banas, Gaffer and Dartington polished surfaces will etch too. With Bullseye glass the etch needs to be applied a couple of times to achieve any sort of even coverage.

Clean your glass and position it in a tub or tray. Get some bicarbonate of soda handy too for neutralizing the acid afterwards. Find a paintbrush and old plastic pot that you can write on with a permanent marker, as these will become your acid equipment. Wear a face mask, eye protection and disposable gloves, and work in a ventilated area. Have a jug at the ready with water in.

If you want a general coating, you can thickly paint the etching cream directly where you want the acid to etch the surface of your cast. Similar to sandblasting, you can use sticky back plastic or vinyl to cut shapes out to mask where you don't want the acid to work on the surface of the glass. This gives you a more accurate application. Paint the cream thickly onto the surfaces and leave for one minute, after which time use the brush to agitate the cream in all directions and add more to the areas that have dried out. Leave for another two to four minutes, agitating occasionally for a more even etch. Create a mixture of bicarbonate of soda and water in your pot and pour this over the etching cream on your glass. There will be some fizzing as the acid is neutralized. Use the brush to rub the bicarb in and wash the acid off, then rinse the whole lot down the sink knowing that the acid has been made safe.

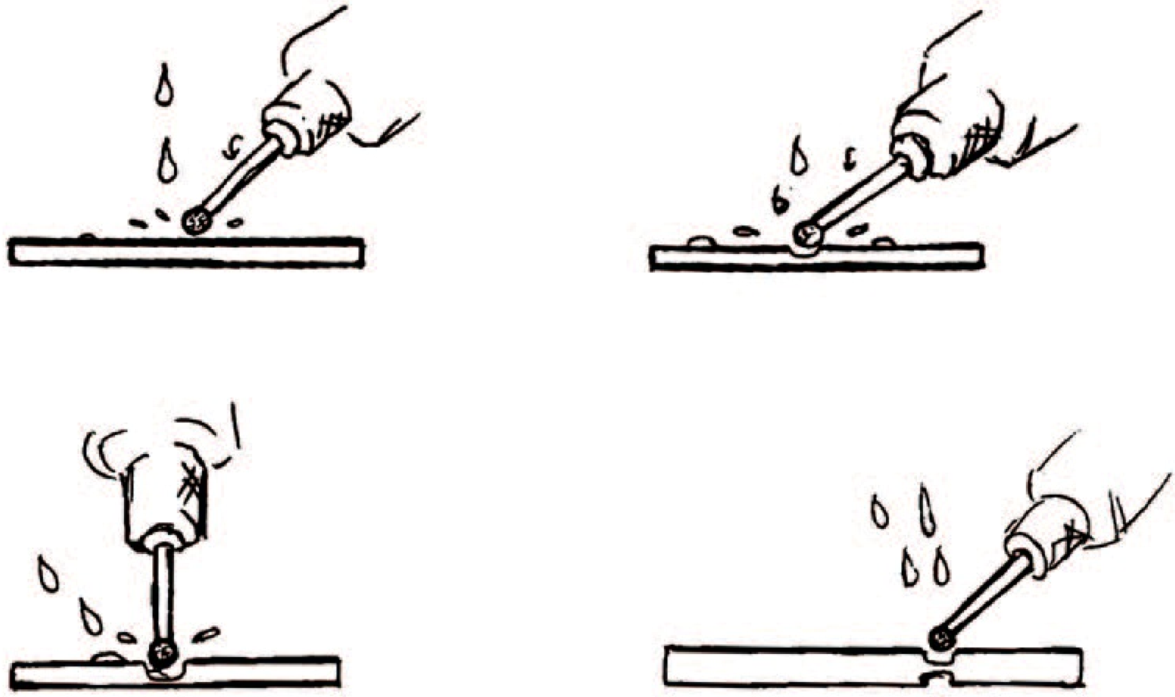
## Drilling Holes

It is easier to approach this by forgetting how other materials are drilled

and recognizing that glass has to be finely ground to remove material as opposed to drilling in the traditional sense. Glass will chip and break easily if it is approached too aggressively. The addition of running water lubricates the grinding process, reduces the airborne glass dust and keeps the glass cool to stop it from cracking. There are a couple of approaches to drilling holes in cast glass:

1. Using a cordless handheld engraver with a drip water feed set-up is by far the easiest way to start grinding a hole in the glass. More information on these can be found at the end of Chapter 2. To start grinding a hole, select and load a diamond-coated ball burr the size of the hole required into the engraver. At a slow speed hold the bit at a 45°angle to the glass; this will allow you to create a dip in the glass that the ball burr can sit in. Once the dip has become established, you can change the angle of the bit to 90 degrees and continue to grind the glass through. For thick pieces, it can take a while to grind all the way through the glass. Turn the glass over, line up the bit and start to grind from the other side; this will help to reduce chipping and feels quicker.

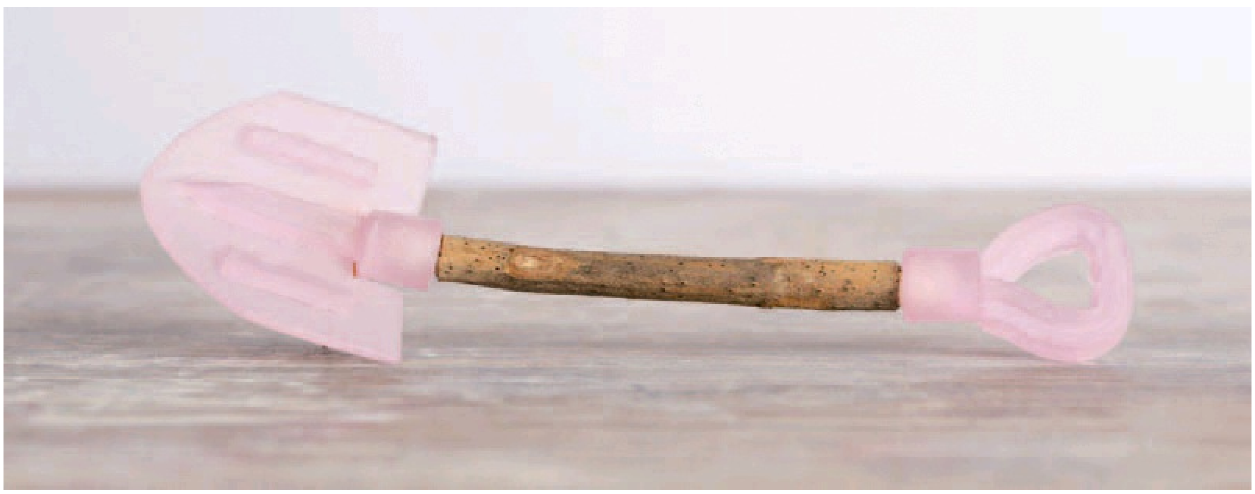

**When using a handheld engraver to grind off contamination or drill holes, hold at a 45° angle to stop the engraver from wiggling all over the glass surface.**



**Approach the glass at a 45°angle to start grinding a hole using a cordless handheld engraver. Straighten up to 90°angle once the hole has been established. For thicker glass you may need to turn the glass over, line up the hole and grind from the other side. (Illustration: Amy Whittingham)**

2. Using an adapted static pillar drill with the addition of a stainless steel water chuck and a circulating water pump. This is mainly used for creating holes in large, flat surface areas. There are various hollow tube-shaped diamond-sintered drill bits, which range from 3mm up to 100mm for standard wall-sized bits. These diamond core bits allow water to run through the middle of them, cooling the glass. The glass must be held securely or clamped down. The drill bit must be perpendicular to the glass surface and lowered slowly with the pressure released every couple of seconds to reduce frictional temperature build-up. These drills bore holes through glass by grinding a circular core out of the glass. This core can sometimes break off within the tube of the drill bit, in which case it will need to be removed

from the machine and pushed out immediately with a thin metal rod. Take care when approaching the final part of the drilling process. Ease up on the pressure as too much force at this stage can result in substantial chipping around the back of the hole. The back of the hole and potentially the front will need to be ground again with a diamond-coated countersink to remove the chips. To avoid this, with flat glass and a keen eye you can bore halfway through the glass and then turn it over and line up the hole from the other side. This does take some practice. Changing your point of view when you are getting the hole and the bit to line up will help with this.



**Holes were drilled into the glass spade approximately 6mm/¼" deep using a handheld engraver to enable the wooden stick to be pushed securely into each end and complete the piece.**

## Problem Solving

### Cracked Glass

If a crack has appeared in your glass cast and the cause was obvious, e.g. a kiln prop, then you can remove the problem (the kiln prop it was touching), remove any excess glass if you can and re-fire the cast in the kiln. Amend the firing schedule as you do not need to cast the piece again,

only fuse the glass back together. Reduce the top temperature and time to accommodate for this.

If a crack has appeared in your glass and there is no obvious external cause, it could be that the annealing part of the firing cycle was not long enough to accommodate the size and type of glass casting. If the mould is not damaged, you can re-fire this again using a similar firing cycle to melt together the crack, adjusting the programme so that the glass anneals for longer.

If you have de-moulded the glass and part of it has broken off the rest of the cast due to an accidental breakage or because of the annealing cycle, it may be possible to fix this if the break was clean and you have all the pieces. Clean all the pieces, use superglue to temporarily stick the cast back together, then set it up as you would have originally with the sprue attached to the baseboard and re-invest the entire form. This mould can then be fired on a similar firing cycle to fuse the glass back together again. Reduce the top temperature and length of time at this point, and slow down the anneal (increase the hold time) to avoid the glass breaking again.

If your glass or the mould is severely cracked, it is likely that the glass you have used is incompatible or you have used a plaster-only mixture instead of Crystalcast or an investment mix with silica in.

## Stress Tester

In order to ascertain if two types of glass can be fused or cast together, always do a test fuse. Set one up in the kiln by overlapping the two types of glass one on top of the other and then fuse firing. A test fuse works best with transparent glass. A stress tester can be as simple as a couple of plastic polarized sheets or lenses (some sunglasses have polarized lenses). Orientate them so one is at a right angle to the other and you will see the directional polarization; at right angles they are blocking both directions of light and appear dark. Place one lens either side of your glass with a torch or similar bright light source behind. A white halo will appear around any areas of stress in the glass. The test glasses could look

perfectly fused together on the surface but actually be under a lot of stress due to their incompatibility. Unfortunately, this is not often visible to the naked eye and will sometimes appear weeks or even months after the piece has been cast.

## Devitrification

The formation of a frost-like structure on the surface of the glass is called devitrification and is considered a flaw. It is often caused by contaminants on the glass that encourages these crystals to grow. It can also be caused by putting the glass into wet moulds. In future, make sure your glass is clean and your mould is dry. Float glass is prone to devitrification due to the manufacturing method that leaves a thin almost invisible coating of tin on one side, known as the tin side. Bohle sells tin side detectors so you can work out which side (the one that appears milkiest) is the tin side. If the tin side is left up in the kiln, devitrification is more likely to occur.

Devitrification can also occur when the glass is held at a high temperature for a long time. After top temperature, some programmers enable you to set the rate for the descent to ‘as fast as possible’ to the annealing temperature. Some artists will crash cool their kilns by opening the kiln after it has reached the top temperature to aid with the cooling process, while making sure to close the kiln again before it reaches the annealing temperature of the glass. To remedy devitrification on glass casts, you can remove the frosting by grinding the surface to 400 and fire polishing, or grinding and polishing with machines.

## Suckering

This is especially prevalent with thick glass and enclosed lost-wax forms. It happens when the glass on the outside of the form is cooler than the glass on the inside of the form. Instead of causing stress, which is one of the other outcomes of a heat discrepancy, the cooling glass contracts away from the mould surface, pulling the glass in on itself and causing an indent

known as a sucker. Suckering can be avoided by slowing down the descent in temperature from the casting temperature down to the annealing point. Programme in an anti-sucker soak at 600°C on the descent to reduce this occurrence (*see* Chapter 4).

## Mounting Cast Glass

Glass casting is a versatile beast and there are plenty of approaches to the process. One of the best things about glass casting is that through the mould-making process other materials and their uses become far more appealing to utilize and even combine with glass. Glass casting requires a familiarity with mixing investment materials and working with binders and refractory materials. There are other products available that can be mixed and poured in a similar way to create final pieces, stands or mounts for glass casts.

Jesmonite is one of those materials. Essentially it is a harder plaster mixed with a polymer resin-based liquid that has magnificent strength, longevity and even in some brands weather-resistant properties. As the chemical reaction is not an exothermic one, when this mixture sets it does not give off any heat and has a minimal expansion and contraction, meaning glass casts can be positioned into a plastic, silicone or rubber mould as Jesmonite is poured in and it will set around the glass. Jesmonite can also be drilled, cut and polished much more easily than glass.

**Glass will not crack as Jesmonite sets around it to create stands or mounts for artworks.**

**Glass cast sprues that can be reused. (Photo: Amy Whittingham)**

CHAPTER ELEVEN

# REUSING MATERIALS

This is a brief overview of how to reuse materials in your studio. Most materials can be reused or used economically to create sustainable working practices. Long term these tips will save you money and hopefully lower the negative environmental impact of glass casting. When reusing these materials, some will require testing on a small scale before being used for larger scale, more expensive projects.

## Glass

Glass is by far superior to plastic, which is why so many artists are drawn to using it. It is also completely recyclable. If you have cast glass that didn't have the intended outcome, you can break it up and use the material again in another mould. It can be cathartic to reuse glass that hasn't worked the first time around. You can also use old bottles or other glass objects in your moulds. You need to thoroughly clean the glass so that there is no contamination, which may mean sandblasting or grinding the surface of casts to remove previous mould material. Any sandblasted surfaces and outline forms of the glass used will create history lines, known as vailing, visible within a transparent cast. Intentional vailing and bubbles within the glass could be something you plan into your design. Breaking the glass into smaller chunks will create more vails and bubbles, and this affects the transparency of the glass, moving it closer to an opaque. Consider if opacity is a quality that you would like to have in your

work; if not, use the largest chunks possible.

In order to reuse glass in new casts, you need to know what type of glass it is. Keeping old casts or cut-off sprues in labelled tubs will help identify which glass you have. Be conscious not to mix glass brands together as they will not be compatible. If you wanted to cast with bottle glass, collecting bottles from the same tipple will ensure that they are at least from the same source of glass. Test fire first to determine compatibility and temperatures needed for your firing cycle. Some bottle glasses have a high melting point of approximately 900°C/1,652°F, which makes the glass difficult to cast and can result in an opaque surface. When re-firing, some glasses are more susceptible to devitri-fying than others, float glass in particular. Too much devitrification will start to change the structure and integrity of the glass itself, turning the glass opaque and brittle, and making it more susceptible to breaking.

## Glass Investment Powders

The fired investment material removed from your glass cast is commonly known as ludo. Store ludo in lidded containers for future use in glass casting and pâte de verre processes. When handling, always wear a respirator.


**When de-moulding glass casts, wear gloves and a respirator.**

**Keep the fired investment material, also known as ludo, in a lidded container for future use.**

## Ludo

Ludo can be added to new plaster silica investment mixes as a filler. Up to one-third of the total powder needed can be replaced by ludo; the volume of water required stays the same. For an ordinary water, silica, plaster (1 : 1 : 1) mixture mentioned in Chapter 3, two parts of the original basic mixture are powder; the total volume of powder is then divided by three to calculate how much of each type of powder (silica, plaster and ludo) is needed. By adding ludo you are reducing some of the volumes of new materials and reusing old.

Ludo needs to be broken down into powder form. Do this either by grinding through a sieve or using an old food mixer. It can be soaked in water, which is the safest way to avoid creating silica dust, but you will need to make an adjustment for the additional water in your mould mixture. Dry ludo powder can be used as a packing material for supporting the inside of pâte de verre casts. It can also be piled on kiln shelves in the same way as dried plaster to create slumping forms.

**BASIC GLASS INVESTMENT MIX WITH LUDO**

Water | Silica : Plaster : Ludo
1 part (volume of water) | 2 parts (total volume of all powders)
600ml | 1,200ml
600ml | 400ml : 400ml : 400ml

## Crystalcast

It is possible to add Crystalcast ludo powder into fresh Crystalcast investment mixtures too by using no more than one-third pre-fired material. This mixture will enable you to reuse some of the waste material while requiring slightly less of the new. There can be a slight loss in surface detail when adding Crystalcast ludo, so it is more suitable for outer layers of investment moulds. In this case, the total volume of Crystalcast is divided by three to calculate one-third for the maximum volume of Crystalcast ludo that can be added to the remaining two-thirds of new Crystalcast.

Have a simply lined tray set up ready to pour excess investment mix into. Label the tray to ensure it is kept separate from other materials, especially plaster. The set, level, excess investment block can be carved into and used with glass frits and powders for relief detail moulds. You can also tape together some plastic or card containers that can be filled with the spare mix, or have an upturned bowl coated in petroleum jelly that you can hand-build excess mix onto. These can be used to slump glass into or

drape over in the kiln.

**CRYSTALCAST INVESTMENT MIX WITH LUDO**

Water | Crystalcast : (Crystalcast Ludo)
32 parts (volume of water) | 100 parts (total volume of all powders)
480ml | 1,000ml : 500ml

## Plaster

At best, dry unmixed plaster has a six-month shelf life once the bag has been opened. Instead of throwing away old plaster you can use it dry, *see* Chapter 3. Line a tray or plastic tub that is at least 5cm/2" deep with cling film or sheet plastic; cover the sides too. If you overestimate the volume of plaster needed for a part-mould, you can pour the excess into this pre-lined tray. Over time, keep pouring any excess amounts into this tray, trying to keep the plaster level; it will stick to itself. When the tray is full, remove the plaster block and let it dry. This can be used to recycle clay on.

**Pour excess plaster into a plastic lined tray to create a plaster block for clay drying and recycling.**

## Modelling Clay

### Pottery Clay

This can be reused multiple times; it needs to be kept in an airtight container or bag. Clay left in the open will dry out and become hard over time, but you can reuse this clay by soaking it in water. The clay will become soggy, and to return it to a usable state the excess water needs to be removed. This is where the block made with excess plaster is useful. Place the wet clay onto your dry block. The plaster will absorb the water from underneath the clay while the exposed air side dries out too. After about four to eight hours this clay should be moist but not sodden. It can be handled without being sticky or too dry and wedged back into a usable shape. Throughout this process, remove any bits of plaster as these can be an unwelcome sharp surprise when you come to use the clay next. Clay

that has been used for mould making can no longer be used to create ceramic objects, as when fired any contamination will cause the ceramic to explode in the kiln.

### Ceramic Slump Moulds

These moulds are strong and durable, and with care and attention they can be reused almost indefinitely. Be sure to coat them well with kiln wash, check the coating between firings, and top up if necessary. If not properly cared for and checked, small to large chunks of the ceramic mould can fire onto the glass, resulting in potentially cracked glass and the end of the usable life of your slump mould.

### Oven-Bake Clay

Super Sculpey can be added to. So you could use a previous model to build onto and bake again.

## Wax

By steaming out investment moulds you will be able to retain most of the wax. It will be full of bubbles, contamination, water and weird shapes from dripping out of the mould. With care, this can be melted down to be reused. Put a lid on the melting pot, wear eye protection and keep the temperature low (around 65°C/149°F) to allow the wax to melt calmly. If it is bubbling, turn it down as the residual water can start to boil and will splash up, spraying hot wax. Once melted, allow the wax to cool slightly; it will float on top of the water and other heavier contaminants will sink. Gently pour the top wax into old plastic or silicone containers to set. As you do this, watch for a line of yucky stuff underneath the wax to appear, then pour this into a separate container to be disposed of. Once the melting pot is empty but still warm, wear a glove and with newspaper wipe

around inside the pot to clean any remaining yuck out.

## Rubber

### Gelflex

These moulds can be cut up into pieces, melted and reused a number of times unless they get burned in the melting process. Add a bit of new Gelflex to the mix when reusing the old. If you melt too much Gelflex, pour it into a metal tray or even better onto a large metal surface so that it spreads out as a thin (6mm) layer. It will be easier to cut up with scissors if it is thinner. Any of the Gelflex colours can be mixed together, but bear in mind this will change the rigidity and characteristics of the rubber.

**Step 1: Chop up old set silicone.**

**Step 2: Mix silicone and catalyst together.**

**Step 3: Transfer into another container to ensure it is thoroughly mixed.**

**Step 4: Add up to a third chopped-up set silicone.**

**Step 5: Mix in the chopped-up silicone. Now it is ready to pour over the model.**

## Silicone

Once the silicone has been mixed with a catalyst and set, it will never return to a liquid state. As such it takes a bit of creativity to be reused. As new mixtures will stick to old, excess set silicone and redundant moulds can be cut into shapes to be used as natches in silicone skin or part-moulds. Set chunks can be pushed into new silicone moulds where there isn't quite enough mixture, which will increase the volume and slightly raise

the level of the liquid. By weight, up to one-third finely cut-up pieces of set silicone can be added to new mixtures. Stir them in when you are ready to pour. This will increase the overall volume of silicone, while reusing the material and costing less in new mixture.

## Sundries

### Kiln Wash

This can be bought from most studio glass suppliers, and it is reusable on the moulds or kiln shelves as long as it remains intact. You should be able to see if it has been scratched off at any point. Wash the kiln shelf or slump mould, allow to dry, and recoat with three layers when necessary.

### Kiln Sand

This can be reused over and over. Be sure to wear a mask when you sweep it out of your kiln due to its silica content. Store it in the original bag or any sort of lidded container.

# GLOSSARY OF TERMS

**Annealing** Slowly cooling glass using temperature control to allow all the stresses within the glass to settle into a (close to) even distribution by maintaining an equal temperature within the entire glass form.

**Annealing point** The specific temperature at the top of the controlled cooling range; this varies for each glass brand.

**Bevel** A 45° angle ground from the sharp edge of glass sheets or casts.

**Binding agent** A material that sets after being mixed with a liquid, usually water.

**Burn-out** Using a kiln to remove material from an investment mould with heat.

**Casting** A high-temperature kiln process in which glass is melted into space within an investment mould.

**Cold-working** Any processes performed on glass without heat, ranging from grinding to polishing by hand or machines.

**Core** The internal form created in investment material, which becomes the void in a hollow glass cast.

**Cottle** Walls of a non-porous material such as clay, plastic, wood or metal, which are used to build a frame around a model. The walls are normally sealed with clay, wax or a glue gun so that investment mixture can be poured over the model and between the walls.

**Crash cool** A process of opening the kiln to allow the temperature to drop faster than the kiln could achieve naturally.

**Diamond-sintered** Hardened metal with diamond dust added to prolong grinding usage.

**Fettle** To clean up a clay or wax model and remove any excess material.

**Finishing** *See* Cold-working.

**Fire polished** Heating the glass in a kiln just enough to melt the top surface, making it shiny.

**Firing cycle** A set of temperature changes and holds that are programmed into a controller to automatically adjust the heating and cooling of a kiln.

**Flatbed grinder** Rotating wheel used with grit to grind and shape glass.

**Flatbed kiln** A shallow heating chamber used to heat, fuse, slump and cast flat glass.

**Front-loading kiln** A type of kiln with a door on the front that has heating elements around the sides and in the door.

**Fusing** A kiln process in which two or more pieces of glass are melted to stick together.

**Grit** Coarse to fine metal powder, normally silicon carbide or aluminium oxide, used for grinding glass.

**Grog** A form of ceramic refractory material that can be added to the outer layers of glass investment moulds to strengthen the mixture.

**HEPA filter** Stands for High-Efficiency Particulate Air, and means that the air being pumped back out of the vacuum cleaner is filtered to a high standard so that the airborne particulates are not being recirculated in the room.

**Investing** The process of mixing and pouring a plaster and silica (or

variation) mould mixture over a form for glass casting.

**Investment** A mould to cast glass into.

**Kiln** A heating chamber similar to an oven used to melt glass at higher temperatures.

**Lampworking** Small-scale manipulation of glass using a flame.

**Lehr** Heating chamber used in hot glass studios to control the cooling process of glass.

**Lost wax** The process of removing wax from an investment mould via steaming or burning out in a kiln.

**Ludo-** Or luto, is pre-fired investment mould material.

**Master model** The original form created in any material that you take part-moulds from to create replicas in wax for glass casting.

**Natches** Location keys for part-mould making. Positioned in the border around your master model on one side of a mould are dips in the surface and on the other side in exactly the same place there are small protrusions which fit into the dips. These allow the mould to join back together in exactly the same place every time.

**Open casts** Investment moulds made over forms that can be easily removed. They have a large opening for the glass to be placed in.

**Plaster blank** Plain block of plaster that can be used to dry clay on or carve into.

**Programmable controller** A digital kiln controller that allows you to change the rate the temperature changes over time, the set points and the length of time the temperature is held at.

**Punty iron** Steel rod used in glass blowing to collect hot glass on.

**Refractory material** Investment powders containing silica used in the glass mould-making process.

**Respirator** Half-face flexible silicone mask with additional filters to reduce inhalation of airborne particulates.

**Scrim** Medium-mesh cotton fabric that can be used as reinforcement within plaster moulds.

**Silicone** Two-part flexible rubber and catalyst; when mixed together it is used for creating replica moulds of complicated master models.

**Single phase** High amperage electrical supply.

**Slumping** A low-temperature kiln process which allows the glass to bend, sag or relax into or over a former.

**Slush casting** Pouring wax into a part-mould before moving it around and then pouring it out again to form a skin of wax.

**Strain point** Lower end of the annealing cycle that is specific to each glass brand.

**Test firing** An investigative kiln programme to check that the temperatures and glass react how you want them to.

**Thermal shock** A dramatic temperature change within glass that creates a large difference across the form and results in a crack where the hotter glass has started to expand while the colder glass has remained rigid.

**Thixotropic** Solution that is added to thicken a mixture to make it spreadable rather than pourable.

**Top loader** A type of kiln that opens from the top and has elements in the

lid.

**Undercuts** Where the surface of an object starts to disappear underneath or behind itself when viewed from one direction, for example, an egg.

# LIST OF SUPPLIERS

## Mould making Materials Suppliers

**Alec Tiranti**

www.tiranti.co.uk

**Bentley Chemicals Ltd.**

www.benam.co.uk

**CTM Pottery Supplies**

www.ctmpotterssupplies.co.uk

**Glassworks Services**

www.glassworksservices.co.uk

**Gold Star Powders**

www.goldstarpowders.com

**Luminar Glass Products (Zircar)**

www.luminarglass.com

**MB Fibreglass**

www.mbfg.co.uk

**Modulor**

www.modulor.de/en

**Scarva Pottery Supplies**

www.scarva.com

**South West Industrial**

www.industrialplasters.com

**Special Plaster**

www.specialplasters.co.uk

## Glass Suppliers

**Banas Glass**

www.banasglass.com

**Bullseye Glass**

www.bullseyeglass.com

**Creative Glass Guild**

www.creativeglassguild.co.uk

**Creative Glass UK**

www.creativeglassshop.co.uk

**Dartington Crystal**

www.dartington.co.uk

**Gaffer Glass (UK) Ltd**

www.gafferglass.co.uk

**Glass Studio Supplies**

www.glassstudiosupplies.co.uk

**Pearsons Glass Ltd**

www.pearsons-glass.co.uk

**Schott UK Ltd.**

www.schott.com

**System 96**

www.system96.com

**Warm Glass**

www.warm-glass.co.uk

## Engraving Tools and Sandblasting Grits/Resist

**B&H Services**

www.bandhservices.co.uk

**Cousins UK**

www.cousinsuk.com

**Crystal galleries**

www.crystalgalleries.co.uk

**DK Holdings**

www.dk-holdings.co.uk

**Eternal Tools**

www.eternaltools.com

**H.S. Walsh**

www.hswalsh.com

**Key Abrasives**

www.keyabrasives.co.uk

**Kilncare**

www.kilncare.co.uk

# Acid Polishing UK

**Cumbria Crystal**

www.cumbriacrystal.com

Unit 4, Canal Head, Ulverston, Cumbria, LA12 7LB +44(0)1229 584400

**Wessex Crystal**

Unit 4, Silver End Industrial Estate, Brierley Hill, West Midlands, DY5 3LA +44(0)1384481390

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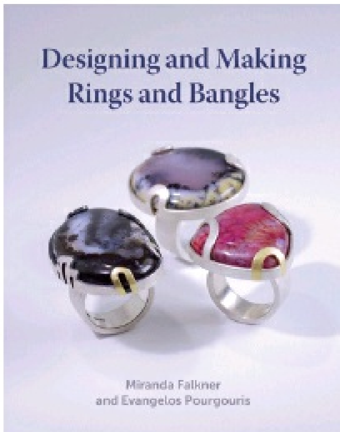


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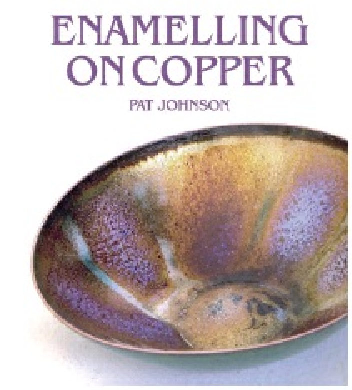


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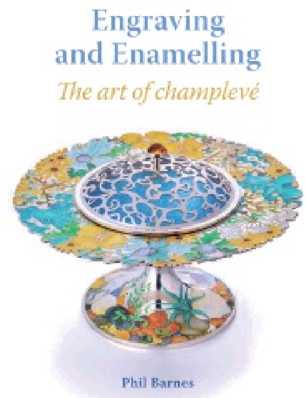


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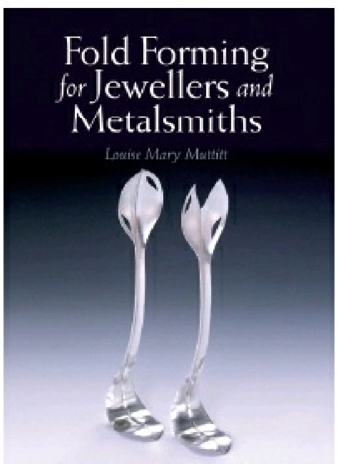


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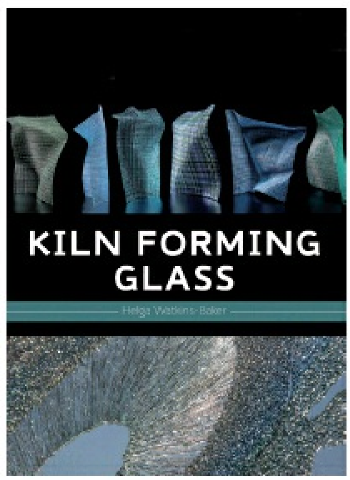


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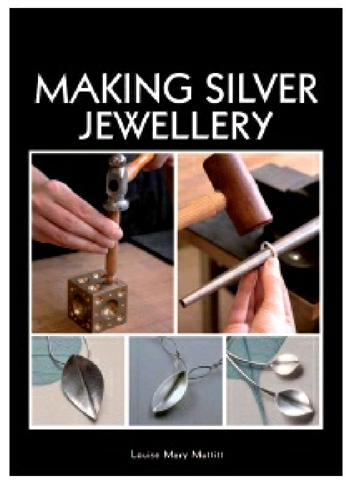


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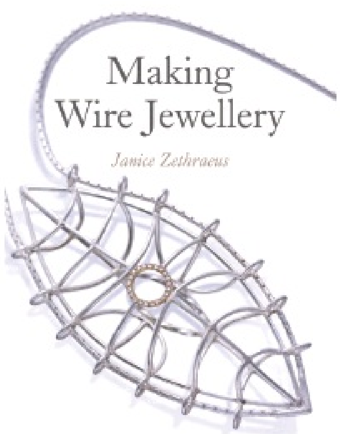


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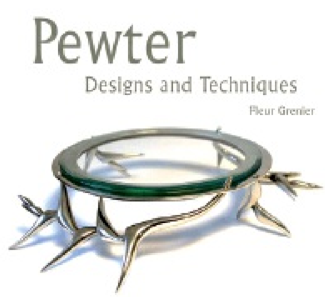


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