DICTIONARY OF GLASS

DICTIONARY OF GLASS

Materials and Techniques

Second Edition

CHARLES BRAY

A & C Black • London

University of Pennsylvania Press • Philadelphia

This edition 2001

First published in Great Britain 1995
A & C Black (Publishers) Limited
37 Soho Square, London W1D 3QZ

ISBN 0-7136-5792-8

CIP catalogue records for this book are available from the British Library and the U.S. Library of Congress

First published in the United States by University of Pennsylvania Press, Philadelphia, Pennsylvania 19104

ISBN 0-8122-3619-X

Front cover illustration: 'Conversation piece' by Charles Bray

Back cover illustration: 'Shrine for Mickey Mouse' by Finn Lyngaard

Frontispiece: The Lycurgis Cup. This is a cup made from green glass with a mainly open work frieze. It shows the effect of colloidal dispersion to good effect as it changes to a wine colour when viewed by transmitted light. It depicts the death of Lycurgis and dates from the 4th century BC.
Photograph courtesy of the British Museum

Designed by Jo Tapper
Cover design by Dorothy Moir

Typeset by Falcon Oast Graphic Art Ltd, East Hoathly, East Sussex
Printed and bound in Italy by Editoriale Lloyd S.R.L.

Publishers note: All information herein is belived to be accurate, however, neither the author nor the publisher can accept any legal liability for errors or omissions.

CONTENTS

LIST OF COLOUR PLATES

Between pages 128 and 129

PREFACE

This book is intended to be a source of reference for individuals operating in small glass workshops and studios, and for teachers and students. It concentrates on the fundamentals and gives the necessary background information on the materials, processes and techniques relating to glass-making, particularly emphasising those affecting individual glassmakers and small group enterprises.

It should be possible to use the book both for individual study and as a source of quick reference. It is therefore presented as a dictionary of key words and phrases which proceed to short articles. Related articles are cross referenced. As far as possible, the language has been left simple and non-technical and has been accompanied by numerous illustrations. Scientific and technical information has been limited to that considered to be necessary to provide a basic understanding of glass processes and developments. Temperature conversions from°C to °F have been rounded to convenient figures.

The book is intended to be a companion book to *The Potter's Dictionary of Materials and Techniques* by Frank and Janet Hamer and the format is similar. Ceramics and glass share many common source materials and many similar functions. They differ considerably in making processes and in the fact that ceramics relies heavily on the behaviour and characteristics of crystalline forms whilst glass evolves from crystalline materials but becomes an amorphous non-crystalline solid. Nevertheless, there is a fascinating relationship between the two materials which frequently emerges simply as a totally different change of emphasis or usage.

To most people, glass seems to be a very common and simple material. In many ways this is so as it can be made in the most basic circumstances from very simple and plentiful materials. It is also produced in great quantities by the glass industry, particularly for windows and containers. In fact, it can be most complex. It has a technology which is constantly developing and embracing more and more aspects of material science. Despite its apparent simplicity, it constantly throws up its own problems. Whenever a definition of its behaviour is made, there is almost always some exception or proviso to the rule. This is part of its fascination and to most people operating with glass there is a constant challenge and a need to be aware that the material does present a degree of unpredictable behaviour. This can be apparent both in the studio and in the most highly developed industrial situations.

The book by Frank and Janet Hamer has been a constant source of reference both in its content and in the manner of its presentation. The other major sources of information have been the various journals of the Society of Glass Technology and the book, *Conservation of Glass* by Roy Newton and Sandra Palmer which moves considerably outside the limits which might be suggested by its title and is a wealth of information on many aspects of glass and glass-making.

I am indebted to the late John Stirling FSGT for the provision of various notes and information on glass structure and its basic chemistry.

I must also express my gratitude to the various people who have been kind enough to read and to check the text, to offer corrections and to provide additional material, in particular, to John Henderson FSGT who has covered the technology and to Vincent J. Craven who, with great patience and application, has proof read the whole text.

ABBREVIATIONS

A	Ampere
At No	Atomic number
AW	Atomic weight
BS	British standard
°C	Degrees Centigrade or Celsius
CF	Conversion factor
cm	centimetre (s)
cu	cube (cubic)
cwt	hundredweight (s)
D	Density
EMF	Electromotive force
°F	Degrees Fahrenheit
fl oz	fluid ounce (s)
ft	foot – feet
gall	gallon (s)
gm or g	gram (s)
H	Hardness on Mohs' scale
Hz	Hertz
Imp	imperial measure
in	inch (es)
J	Joule
°K	Degrees Kelvin
kg	kilogramme (s)
l	litre(s)
lb	pound (s)
lm	lumen
lx	lux
m	metre (s)
MF	Molecular formula
ml	millilitre (s)
mm	millimetre (s)
mol	mole
MW	Molecular weight
N	Newton
oz	ounce (s)
pt	pint (s)
qt	quart (s)
s	second (s)
SG	Specific gravity
UK	United Kingdom
US or USA	United States of America
V	Volts
W	Watts
wt	weight
yd	yard (s)

A

ABRASION

The technique of using abrasive wheels to cut shallow decorative areas in glass. It also refers to the process of using hard particles and stones in various ways to cut or matt the surface of glass or to shape glass objects.

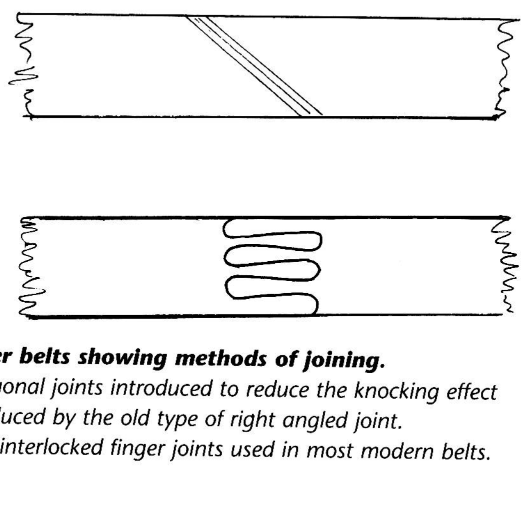
ABRASIVE BELTS (LINISHERS)

These came into use in the early 1950s when suitably waterproof adhesives became available and enabled the grits to be glued successfully to a linen base. Early belts suffered initial problems in finding a method of joining a length into a suitable loop which could be fitted to, and which would not wander on, the pulleys in use. At first, the problem was solved by joining the belt with a diagonal cut which at least eased the other problem of a thick ridge travelling around and hitting the glass. The ridge still existed but the fact that it was now diagonal seemed to have the effect of reducing the impact. Many ready-made belts are still joined in this way with the overlapping ends suitably thinned to avoid the formation of a ridge. Latterly, belts have been joined with a system of interlocking fingers. Belts are now available in a wide range of sizes and grits, and cork belts are also available for polishing purposes.

Early machines were mostly massive affairs meant to take over or to complement the role of the horizontal grinding mill in factory production. However, currently several manufacturers make relatively small machines ideally suitable for studio production. Another recent development is the belt which is faced with diamonds and fits on to a circular rubber wheel which can either be given its own horizontal shaft or fitted on to a glass-cutting lathe. This is an admirable tool as it can be used at speed, it cuts very quickly and, because of the rubber backing, has sufficient flexibility to be less likely to damage the glass than the hard, abrasive-type of wheel.

a

b



Linisher belts showing methods of joining.
a. *Diagonal joints introduced to reduce the knocking effect produced by the old type of right angled joint.*
b. *The interlocked finger joints used in most modern belts.*

ABRASIVE WATER JET SYSTEMS

The use of water jet cutting systems has increased dramatically in recent times. They offer considerable advantage in the rapid cutting of complex shapes and are readily adapted to industrial production methods. They will cut glass of considerable thickness and one company quotes the successful cutting of glass blocks 12 inches (30 centimetres) thick. The aspect that would interest most artists is that the cutting angle need not be at the standard 90° and can be varied to produce almost any angle of cut. They are very useful in cutting other materials and can be readily used for cutting most refractory materials.

If abrasive particles are fed into the water stream as it leaves the nozzle, the system then uses the water as a driving force rather than as the cutting medium and the possibilities are enhanced.

Garnet is the abrasive most commonly used but combinations of silica sand and olivine, which are rather cheaper and suitable for cutting glass and softer materials are also used. Hard abrasives such as silicon carbide and alumina are sometimes used for the harder refractories.

The cutting is often carried out under a thin layer of water or in sprayed water directed at the cut. This is to stop damage to the surrounding glass areas from stray fragments of abrasive.

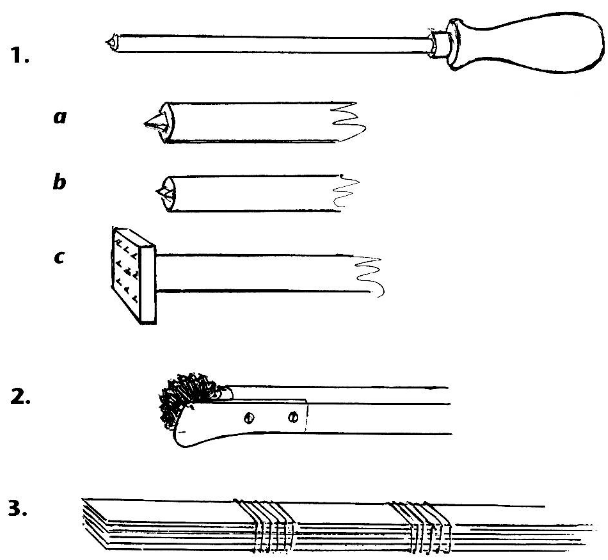
Water jet cutting can be carried out on most materials and there is some scope for determining the finish required. Unfortunately, at the moment this is a costly operation, which is likely to be out of reach of most small workshops. As the systems develop it may, in time, become a viable and exciting possibility.

ABRASIVE WHEELS

Wheels for grinding and cutting glass were traditionally, apart from soft iron wheels which were fed with sand, made from natural stones. The Romans used such wheels (often of considerable size), which they obtained from such places as Naxos, Egypt, Crete and Armenia. They are still popular with many craftsmen but they have been largely superseded by manufactured stones and by diamond wheels. Natural stones are still quarried and are preferred by many craftsmen who tend to have particular likes and dislikes. Most of the natural stones that are quarried in Britain are exported to the USA. Particularly fine stones came from areas of Scotland and even now they are preferred by many craftsmen to the manufactured replacements, particularly when they need something which will carry out a difficult or fine

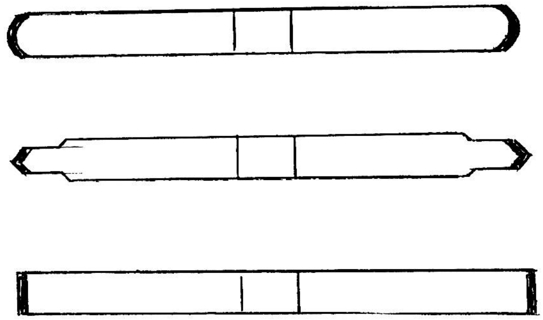
Natural stone wheels.

piece of work. There was a considerable demand for these from Germany where, to the probable and justifiable annoyance of the Scots, they were rather unfortunately, known as 'Engländer' whilst, perhaps more logically, the manufactured stones were known as 'Amerikaner'.



Stone dressing tools.
1. *Diamond dressing tool. These can be fitted with different points as in:*
- ***a.*** *Common pyramid point.*
- ***b.*** *Chisel point.*
- ***c.*** *Multiple point.*

2. *The most common type of dressing tool composed of a series of steel discs with hardened teeth held together in a clamping handle.*
3. *A series of old hacksaw blades bound together with wire. This makes a cheap but effective dressing tool and is a type which has been used successfully for many years.*

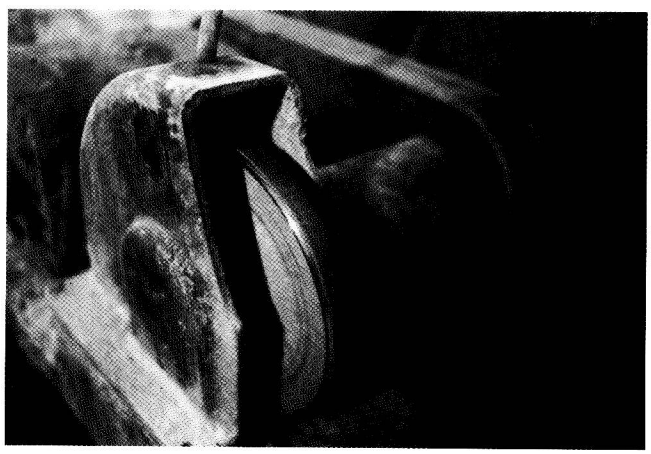


Diamond wheels showing three common profiles.

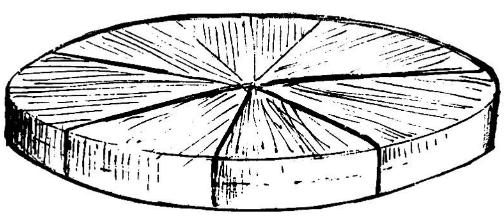
These artificial stones are made in the same range of materials as those of the grits and powders, namely silicon carbide (Carborundum, Urundum) and Alumina (Bauxilite, Corundum). The grain size is determined by the size of a mesh through which it will pass. For use on glass, the normal suitable range would be from 80 (Coarse) to 400 (Fine). The wheels are bonded by a variety of materials, the most common being known as 'Ceramic Bond' in which the abrasive is vitrified together with clay and similar materials. Others are bonded with resins, rubber or shellac.

The hardness of the bond is coded from 'A' (soft) to 'Z' (hard). The grades in the centre of this range would be those normally used for glass. Wheels are stamped with a code which provides a quick identification. For instance, A 200 P V would indicate that the stone was made from alumina with a grit size of 200. The letter P would indicate a medium grade of hardness and V would show that it had a vitreous bond.

Modern wheels are manufactured to close tolerances but after being used for some time, they need to be re-profiled. This is carried out by running the wheel at a medium speed for its size against an abrasive dressing stick, or more commonly, against a diamond dressing tool. A rest for the dressing tool must be used to keep the point steady against the wheel at a level just below that of the spindle and there must be a constant flow of water or coolant running on to the wheel to provide cooling. Silicon carbide grains on



Coarse diamond wheel used for roughing out glass forms.



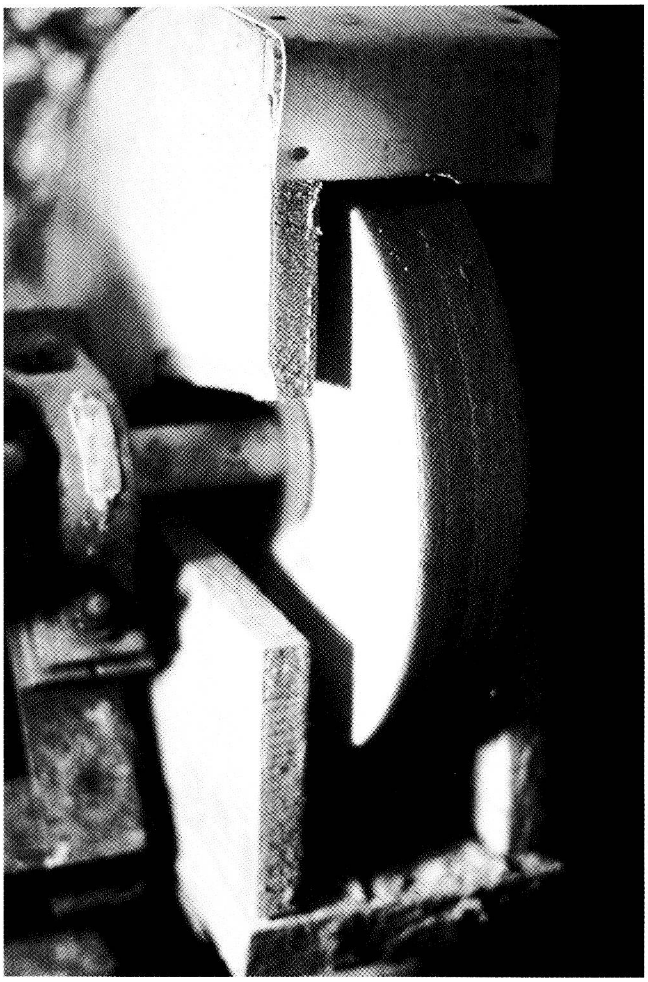
Wooden wheels. *These are usually made from a diffuse porous hardwood such as willow or poplar. Sometimes they consist of a straight slice across a bole or, more commonly, from sections glued together as shown.*

wheels tend to wear under pressure whereas bauxilite grains abrade to leave a surface of fresh cutting points.

Diamond wheels are rapidly replacing other abrasive wheels. They are much more expensive than both the natural and the manufactured abrasive wheels but they cut more efficiently. They also do not require any pressure which relieves the operator of a surprising amount of strain, and apart from the occasional need to clean the surface with a corundum stick to remove embedded particles, need little attention. In use there must be a constant and adequate supply of water, preferably including a suitable coolant. A diamond wheel consists of a metal disc to which diamonds have been sintered on to the working surface, or have been embedded in a suitable soft metal matrix. They are available in many sizes and profiles off the shelf but the manufacturers can supply wheels to a required specification very quickly.

There are statutory regulations relating to the use of abrasive wheels. These deal with the various safety aspects and

The bristle wheel once popularly used with pumice for initial polishing operations.



Composite fibre wheel currently the most popular for use with pumice.

are essential reading for anybody wishing to use them. Some European documents currently available are:

'Safety in the use of abrasive wheels', published by the Health and Safety Executive and obtainable from H.M. Stationery Office.

'The European Safety Code FEPA GB 12-87 for the care and protection of abrasive wheels'. Obtainable from the Universal Grinding Company of Stafford, England, who also publish an admirable small handbook called *The Grinding Data Book* which they currently supply free to applicants.

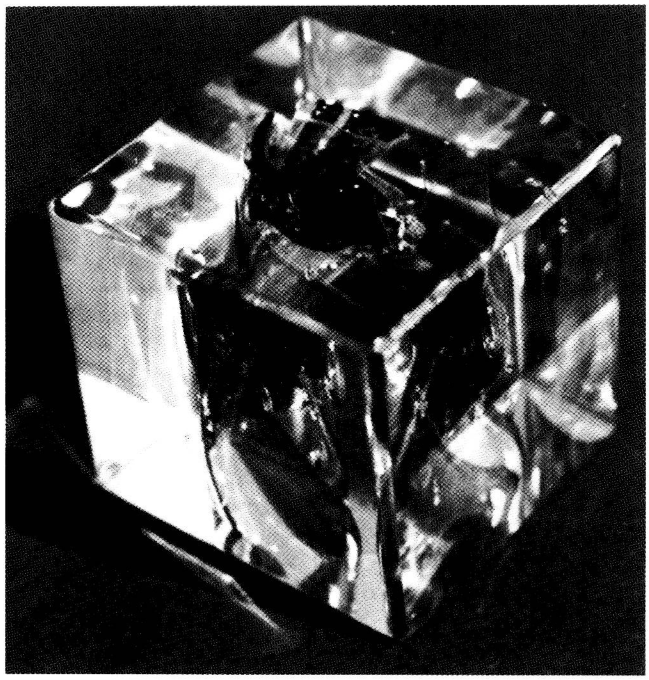
See also Journals etc. on p. 246.

In the past, the same company also offered one-day courses covering the requirements of the abrasive wheel regulations.

There are several other publications which are relevant. Some are produced by the Health and Safety Executive, some by the British Standards Institution and some by H.M. Stationery Office. They are all normally available from branches of H.M. Stationery Office.

Polishing wheels tend to be of materials which act as a vehicle for pastes containing polishing abrasives.

Felt polishing wheels. *These are of two types: brown, coarse felt suitable for pumice and white felt which is now the most common type used for final polishing.*



A paperweight cut and then polished.

Traditionally they were made either of bristles or of wood which was made from a slice across a log of poplar or made up from segments of the same material.

Cork wheels appeared in the late 1920s and became very popular. Initially they were cut from a segment of bark but soon progressed to being made from ground cork bonded together with waterproof glue. They are now being rapidly replaced with wheels made from polyurethane and bonded cloth but cork wheels will remain in some demand as many people still prefer them. These wheels are used mainly with applications of wet pumice which, particularly on hard glass, gives a polish adequate for most purposes. Contrary to common opinion, soft lead glass is more difficult to polish than a harder glass.

Finer polishing tends to be carried out on felt wheels using rouge (iron oxide), green chrome oxide, tin oxide, polishing grade alumina and latterly cerium oxide. Cerium oxide and commercial powders based on this material are the most popular materials for fine polishing at the current time.

Soft polishing wheels comprising rubber or silicone bonded powders are also becoming more readily available and increasingly popular. Wide discs or belts containing finely impregnated diamond dust are increasingly available as a replacement for the pumice and other materials leading up to the final polishing.

ABRASIVES

Materials for grinding and polishing stones and metal have been used almost since the beginnings of human existence so it was a natural progression that the same materials would eventually be used for exactly the same purpose when glass started to be produced. As glass grinding requires the use of progressively finer particles, it is remarkable that work of such wonderful quality was produced in relatively primitive times when the necessary sorting, crushing, levigating and grading of abrasives must have presented huge problems with the meagre facilities which were available. The patience and skill of many of the craftsmen must have been considerable.

Even in the early part of the 20th century sand was probably the most common grinding material. When it had been used for grinding glass, the resulting slurry was usually collected and sieved to allow for further use as a finer grinding material. The process continued until a fine mud known as polishing blue was left to be used on wooden wheels made from segments of poplar or lime for polishing purposes. We are lucky that in the present age, manufactured materials of specific quality and grade are readily and cheaply available, completely removing the need for all the hard work of preparing finer abrasives from the slurry.

The most common of these is silicon carbide, produced commercially as 'Carborundum' and 'Urundum'. It is made by heating a mixture of sand, fine coke and sawdust together with a little salt to a temperature of 2400°C (4350°F) in a long electric furnace in the form of a trough which could be more than 15m (59ft.) long and fitted with silicon carbide electrodes. The salt helps to counter the impurities in the coke and the sawdust burns out to leave a sufficiently porous mixture which will allow any gases to escape. The resulting core of silicon carbide is removed on cooling and then crushed and graded to provide a wide range of grits and powders.

The other material in common use is bauxilite. This is made by fusing bauxite, a soft, clay-like material consisting largely of alumina, in electric furnaces and then crushing and sorting it into a similar range of grits and powders.

There are conflicting opinions on the relative merits of the two materials but most craftsmen soon establish a personal preference. One advantage of bauxilite, a white powder sometimes sold as alumina, is that it does not become so obvious as silicon carbide which is black or dark grey when it becomes trapped in cracks and crevices. Also, if silicon carbide is not thoroughly cleaned from glass which is used for casting or fusing, it can cause discoloration, bloating and localised reduction.

Diamond is the hardest abrasive currently available. It is normally used on wheels or specific tools but finds occasional use as a powder.

Boron nitride and boron carbide are very hard. They are recent additions to the list of abrasives and they tend to be used on wheels and rarely as powders.

Corundum is a naturally occurring impure form of alumina known generally as 'Emery'.

Mohs' scale of hardness is often used as a table of comparison for abrasive materials and is based on the ability of a material to scratch the surface of those lower down the scale. See **Mohs' scale**.

Another scale which refers to the penetration hardness of a material is one which is becoming more popular in relation to the use of abrasives. It is as follows:

Material	*Hardness*
Diamond	8000
Borazon (cubic boron carbide)	4700
Boron carbide	2750
Silicon carbide	2500
Titanium carbide	2450
Alumina	2100
Tungsten carbide	1900
Garnet	1350
Silica	1800

Finer abrasives are used at the polishing stage. The most common of these are:

Pumice	A form of volcanic ash.
Tripoli	A siliceous earth which breaks down to finer particles under pressure.
Rouge	Fine iron oxide made from decomposed iron sulphate.
Ceri-rouge	A composite, commercially-prepared material containing both cerium oxide and iron oxide.
Chrome oxide	Often used together with rouge.
Zirconium, tin and magnesium oxides	Used for finer polishing.
Cerium oxide	Used for extremely fine polishing.

Pumice is a natural form of foamed volcanic glass and most of it is imported from the Lipari Islands, north-west of Sicily. It is available in various grades from rough, which is used on wooden wheels for pre-polishing, to fine and very fine grades which will achieve a bright polish on hard glass. It is composed of approximately 70% silica, 15% alumina and the remainder of sodium and potassium oxides.

Tripoli powder was for a long time the material normally used to follow the application of pumice. It is very fine and can produce the various health problems associated with siliceous dust so nowadays it is largely replaced with polishing grade alumina.

There are several manufacturers who produce specific ranges of prepared polishing powders largely based on cerium oxide and containing appropriate suspension agents. These are rapidly taking the place of the natural grits. Cerium oxide reacts chemically with silica molecules on the glass surface. This interaction between the polishing wheel and the powder causes the surface to deform plastically.

Glass grinding and polishing is essentially a wet process because of the dangers inherent in generating heat in the glass. Various grits for grinding are used mainly on wide, horizontally rotating cast steel wheels or in shallow reciprocating cast steel pans. The water also ensures that problems of dust are minimal. Polishing powders are also used wet but they are usually applied to the wheels in the form of a wet slurry. This again minimises the dust problem but particular care should be taken with Tripoli powder as this is siliceous and an appropriate mask should be worn when handling the dry material. An efficient exhaust system is also recommended.

A recent innovation in the process of using abrasives has seen the introduction of very high pressure water jets, sometimes fed with abrasive powders, for the cutting of thick glass sheets. This system has an advantage in that it can be used to cut glass at any angle.

ABSORBENT

Material which can take in liquids by capilliary action.

ABSORPTION

The taking up of a gas by a liquid or the taking up of a liquid by a solid. Absorption is different from adsorption in that the adsorbed material penetrates most of the absorbing substance.

ACCELERATOR

A material which speeds up a chemical action. In some circumstances it can act as a catalyst. Often used in mixtures of epoxy resins to hasten the setting times.

ACID

Glassworkers tend to think of acid as referring to the material used for acid etching. Chemically, it is a compound which has a tendency to lose (donate) positive electrical charges called protons (i.e. hydrogen ions) when it reacts chemically. It can react with various non-acidic materials (alkalis and amphoterics) to form salts.

Silica and boric oxide are technically bases and are sometimes noted as being weak acids in the founding process.

Glass has good resistance to many acids, the obvious exceptions being those of phosphoric acid (H_3PO_4) and hydrofluoric acid (HF) which readily eat into the surface of most glass and as a result are used for both etching and polishing.

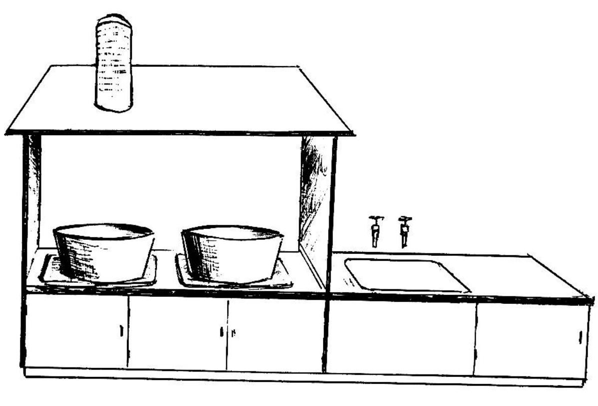
ACID CUT BACK

This is a term used to describe the process of producing designs in relief by etching away some of the glass with hydrofluoric acid. See **Acid etching**.

ACID ETCHING (ACID EMBOSSING)

This process involves the use of hydrofluoric acid or various mixtures containing or derived from hydrofluoric acid. It cannot be over-emphasised that this is an extremely dangerous material for which the most stringent safety precautions are mandatory. It is certainly not an appropriate material for casual use in a studio. This acid attacks both flesh and bone. It moves into the flesh and whatever is applied to counter it often only succeeds in following its path. It also releases fumes which are both toxic and corrosive.

It may be difficult to understand such a strong emphasis on the dangers when it is obvious that huge amounts of etched glass, some of it astonishingly complex and beautiful, have been produced over the years. Much of this is bound to suggest exciting possibilities to glassworkers, many of whom are bound to be tempted to explore them. Some, like Ann Wolff will produce wonderful work and the example of such results can only increase the temptation to other artists to follow her lead. If there is a decision to proceed on an experimental basis or if the number of articles to be etched is small, it could be advantageous to do all the preparation in the studio and then to pass the glass on to a specialist firm for processing. To proceed individually towards establishing a continuing production, it becomes essential to ensure that the studio is comprehensively equipped with professionally-made extraction facilities, including a hood over the etching area to remove corrosive fumes, plastic trays, wide-mouth plastic containers for the acid and suitable storage and working facilities. A plastic ladle is useful but if a metal one is all that is available it should only be used if it is first coated with wax.



An acid etching compartment suitable for the small studio. *It comprises a cabinet fitted with doors (not shown) which can be closed between operations whilst the acid is in its container, two plastic containers including one for acid and another for water, both set into splash trays and an extractor system. Outside the compartment there should be a sink with good washing facilities and a container with a suitable alkaline neutralising solution. Lockable storage cupboards could be situated under the working area.*

It is also essential to check the latest safety recommendations with the appropriate authority, to work slowly and deliberately and to proceed with some caution. Good washing-down facilities, full protective clothing including boots and face mask together with a recommended alkaline neutralising solution in case of accidents are essential.

One of the problems with acid etching is that different recipes are used on different glasses. That which gives a polished finish on one type of glass may only succeed in matting another. As a general rule, four parts of water to one of 60% strength hydrofluoric acid will give a good working etch with time to control the depth achieved. However, for really deep etching, called 'Rotting' in the trade, two parts of water to one of HF (hydrofluoric acid) is usual. It is important to add the acid to the water and never the other way round. The mixture of one part of acid to four parts of water should achieve a depth of approximately 1.5mm in two hours. A recipe from Scandinavia suggests the use of three parts hydrofluoric acid (60%), five parts of water and one part of sulphuric acid (90%).

If a matt surface is required then there are other possibilities. Various finishes were commonly applied to electric light bulbs. One of the solutions which is used for producing a satin matt etch on soda-lime glass is:

hydrofluoric acid (60%)	1.0 kg	Alternatively	112 lb
ammonium bifluoride	0.2 kg		116 oz
sulphuric acid (95%)	0.2 kg		116 oz
Another for pearl etch is:			
hydrofluoric acid (60%)	550 g		20.0 oz
ammonium bifluoride	400 g		14.5 oz
ammonium carbonate	200 g		17.3 oz
hydrated lime	275 g		12.7 oz
sodium carbonate	275 g		12.7 oz

The procedure followed for light bulbs is as follows: The glass is washed with hot water. The etching mixture is then sprayed on or the glass is dipped into the solution and allowed to stand for about 20 seconds before further washing in hot water.

The process for producing decorative etching on glass usually involves the use of resists or stencils. The resists most commonly used are based on mixtures of beeswax and resin but there are many variations. One recipe for a brushing resist suggests the use of equal parts of paraffin wax and motor oil kept warm on a hot plate to maintain a consistency that allows the mixture to be brushed easily to a fine edge. The usual procedure is to dip heated glass into molten resist mixture and when this has set, to scrape away the wax to expose the glass surface where the etched area is required. Some cleaning of the exposed surface may be required and this can be carried out by the careful use of methylated spirit or similar solvent. Once this preparation is complete the glass is immersed in the hydrofluoric acid until the requisite amount of attack is achieved. The depth and type of finish would relate to the strength of the acid, the temperature, the type of glass and the length of the immersion. It is also common practice then to remove more of the resist, to repeat the procedure to produce varying depths and types of finish.

Many glass artists using acid are concerned with the process of etching through layers of underlaid or overlaid colour on bowls, bottles etc. When etching underlaid bowls (with the thin layer of the colour on the inside), it is simply a matter of filling up the bowl to the required level with the acid, leaving the acid to work for an appropriate time, removing the acid and rinsing off to ascertain the depth achieved and then repeating the process as necessary until the result is satisfactory. Overlaid pieces need to be placed in a plastic container and sealed as necessary to prevent the acid reaching the inside areas. Then the plastic container is filled with the acid to the necessary level, and the removing, rinsing, checking and repeating stages carried out as before.

The resists in general use are of three types: those based on wax, those based on liquid bitumen and those based on lead foil. The wax resist is normally a simple mixture of beeswax stiffened as necessary by adding some resin. Softer mixtures are achieved by adding tallow, lard or as suggested earlier, oil. Some artists have experimented successfully with painted PVA-type adhesive solutions and paints and there is an increasing use of the various types of cling film and fablon.

There are lots of old resist recipes about as the various workshops producing decorative etching all had their own distinct formulae. These almost always involved the use of various waxes, tallow, pitch and sometimes resin. Occasionally some pigment such as brunswick black would be included to make the work of scraping away the resist clearer. Variations in the resist would exist in the same shop to allow for the nature of the application. Some glass would be dipped. Sometimes the resist would be brushed on and there would be a different recipe used simply for re-touching a resist. A typical recipe for a dipping resist is:

1.0 lb	or	450 g	Russian tallow
1.0 lb	or	450 g	Burgundy pitch
4.5 lb	or	2.25 kg	Madagascar wax
4.5 lb	or	2.25 kg	White wax

When a painted resist was required, it was normal to use a solution of bitumen which was brought to the desired consistency by adding sufficient solvent consisting of methylated spirit or turpentine to the thick and sticky material to make the bitumen sufficiently fluid for it to be applied as a paint. If used today some practice is needed in the application of this mixture. Good brushes are essential. The results from the freedom of expression which can be achieved by the skilled use of this method can be most rewarding.

Large-scale and very precise work was often carried out by adding a layer of thin lead foil. The procedure for using this is a little more complex and involves covering the glass with an even layer of bitumen. A piece of lead foil sufficient to cover the design is then coated with a layer of soft wax and placed wax side down on to the bitumen so that it can be rubbed down with a muller or smooth wooden block until it is completely and evenly attached. The design can then be transferred to the foil which can be cut and the waste lead removed as necessary and in appropriate sequences to achieve the required results. Again, some practice is necessary to produce an even layer which will adhere to the glass but which will allow parts to be peeled off cleanly after the design has been cut.

After cutting and when the pieces have been removed, it is usual to burnish the edges of the cuts slightly to prevent seepage and to clean the surface of the glass with methylated spirit to remove any residues of wax or bitumen on the surface to be attacked. Some degreasing can be carried out if necessary, and when complete, the glass immersed in the acid.

Etching cream is much easier to use than the hydrofluoric acid mixtures for occasional work and with no free hydrofluoric acid involved, much safer. It is still a toxic material and requires careful handling but the viscosity is such that the dangers from splashing are unlikely. The use of this material produces what is known as 'White Etching' or 'French Embossing' and one popular formula is:

ammonium bifluoride	1 kg	alternatively	2.25 lb
sugar	1 kg	alternatively	2.25 lb
barium sulphate	125 g	alternatively	4.5 oz
demineralised water	1 l	alternatively	1.75 pt

The sugar in this recipe is included to increase the viscosity of the mixture. A common name for this mixture is 'Sugar Acid'. It is available commercially prepared as gel in tube form and, as it works slowly, it is fairly easy to control. Again, as the danger from splashing is negligible because of its viscosity, it is very much safer to use than the various etching acids based upon hydrofluoric acid.

A variation on sugar acid is a recipe which was commonly used for etching designs or names on to drinking glasses in the process known as badging. This involved preparing what was called 'Fluorine Liquid' by filling a plastic jar or bottle with ammonium bifluoride crystals and then pouring in hydrofluoric acid (40%) to a level just above the top of the crystals. This was shaken gently for a few minutes before being left to stand for about two days. A second mixture was then made, known as gum tragacanth mixture. This involved mixing together:

107 g	or	0.25 oz of charcoal or lamp black
170 g	or	6 oz of gum tragacanth
114 g	or	4 oz of ammonium hydroxide (specific gravity 0.880)
280 g	or	10 oz of water

This was put into a jacketed saucepan and simmered gently until reduced to about half its volume.

The badging paste was then made by putting into a wooden or plastic bowl two ounces of powdered rice starch and slowly adding two ounces of the fluorine liquid. This was mixed with a spatula until the whole was quite stiff and had a smooth surface. To this was then added one and a half ounces of the gum tragacanth mixture and the whole stirred again until it was smooth. One tenth of an ounce of magnesium oxide was added, stirred in well and left to stand for about an hour. Ten cubic centimetres of ammonium hydroxide was then added, stirred in and the whole mixture thoroughly stirred again before being stored for use.

This badging mixture was used by scraping it into a design engraved onto a copperplate and transferred by a thin piece of acid-free paper to the glass surface. This produced an etched design in about a minute. If the mixture became too stiff in storage it would be thinned by adding a jelly made by mixing together two ounces of sodium hydroxide (specific gravity 0.880), four ounces of water and one ounce of gum tragacanth, the whole being stirred thoroughly and stored for use. See also **Graal**.

ACID POLISHING

When glass is attacked by hydrofluoric acid, the surface is usually left fairly transparent whilst the various etching mixtures tend to produce some matting. Some variation in the finish on a piece of work can often be produced by matting a complete area, applying a suitable resist to the areas to be left matt and then immersing the piece in polishing acid to give a bright polished finish to the unprotected areas. The usual proportions for polishing acid in Britain are:

demineralised water	3 parts
sulphuric acid (95%)	2 parts
hydrofluoric acid (60%)	2 parts

Acid polishing became very popular with the producers of cut glass as its use meant that lots of time and effort previously spent on hand and mechanical polishing was saved. It is now the normal procedure in industry for polishing cut glassware and a few artists use it to soften a sandblasted surface. A very light application is usually all that is necessary to produce a fine matt finish which is easier to clean than an ordinary sandblasted surface.

In British industry the normal procedure is to use a short immersion in the strong polishing mixture as outlined above whereas in Continental Europe the usual practice has been to use a series of immersions gradually becoming more prolonged, in a much weaker solution. The initial immersion would be for about 5 seconds and followed by a 30 second rinse in a water bath kept about 10°C hotter than that of the acid. This would then be followed by further immersions, the last one being for about one and a half minutes; all the immersions being followed by the same 30 second rinse. The glass would be kept moving whilst in the acid and thoroughly washed on completion.

Polishing acid needs to be at a temperature of at least 40°C (104°F) to be effective.

There has recently been a move to use fluorosulphonic acid as a regenerating acid for the polishing of lead crystal. In industry where there is sufficient production to justify it, there has been a move to introducing lasers for polishing glass.

One sugar acid mixture which is popular in Britain for polishing lead based glass is:-

Warm distilled water	12 *l* or 3.1 gallons
Fine sugar	10 kgs or 22 lb.
Ammonium hydrogen sulphide	10 kgs or 22 lb.

This mixture works slowly, often taking a few days, is good on lead crystal but will only frost soda-lime glass. To make up the mixture it is necessary to wear all the appropriate safety equipment to guard against splashes and fume. The ammonium hydrogen fluoride crystals are stirred vigorously into 10*l* of boiled and preferably distilled water. The sugar is then stirred into 2*l* of boiling water and poured on to the ammonium hydrogen fluoride mixture

ACID STAMPING

The use of a stamp to produce a logo or trademark on glass by the use of etching acid.

ACIDIC OXIDES

In glassmaking these are usually considered as those which display acidic properties in the founding process. They are:

silica	(SiO_2)
phosphorous pentoxide	(P_2O_5)
boric oxide	(B_2O_3)
titania	(TiO_2)
tin oxide	(SnO_2)
zirconia	(ZrO_2)
ceria	(CeO_2)
vanadium oxide	(V_2O_5)
germania	(GeO_2)

others with weak acidic properties are:

antimony oxide	(Sb_2O_3)
arsenic oxide	(As_2O_5)
praseodymium oxide	(PrO_2)

ACIDING

A term used by stained glass artists to describe the process of using hydrofluoric acid to eat through layers of flashed