Glassware Manufacture for Developing Countries

by Garry Whitby

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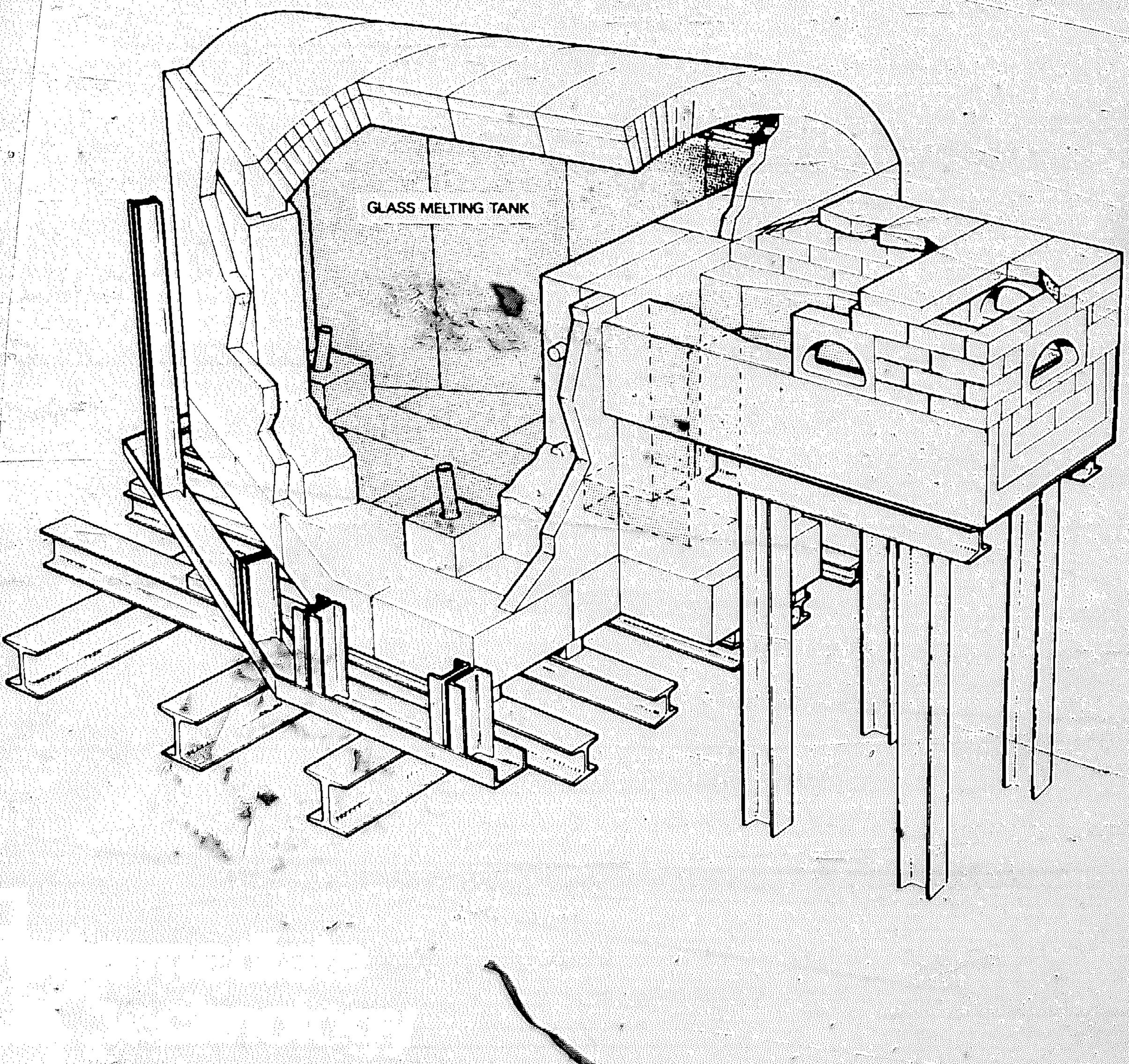

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Garry Whitby

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PREFACE

This publication is intended to assist anyone who is contemplating setting up a small-scale glass factory to produce various glassware items such as tumblers, hurricane lamp glasses, bottles and jars. It aims to give a brief introduction to the processes, the technologies involved, and the alternatives available, so that an initial technology choice can be made based on local needs, conditions and markets. There is a section at the end which gives indicative costings, and typical case studies for an African situation and an Asian situation with a proforma for readers to slot in their own local figures. It should be emphasised, however, that a much more rigid feasibility study must be conducted before investment is sought in a particular situation.

The information has been collected over a period of four years and is based on the experience gained by the Industrial Services unit of the Intermediate Technology Development Group who have actively supported small-scale glass plants in developing countries during this period. It is also biased towards low volume production, typically 5–15 tonnes per day of glass, but does mention the smaller and large scale alternatives.

Garry Whitby
Rugby, 1983

GARRY WHITBY

Garry Whitby is a Chartered Engineer working as an Industrial Adviser with the Industrial Services Division of ITDG. Over the last few years, he has been working on projects to make and form glass in developing countries namely, Sri Lanka and Indonesia.

ACKNOWLEDGEMENTS

The information contained in this publication is based on the experience of the Industrial Services Division of the Intermediate Technology Development Group. Much of the initial planning of the glass project was done by Ian McChesney, then Industrial Adviser with ITIS, and his work with the glass industry in the UK and developing countries has formed the basis of this publication. Ken Marshall assisted with the section on the economics and gave some valuable comments on the publication as a whole.

Thanks must also go to Richard Goeminne and Serge Dal Borgo of Hanrez SA, Les Brown, an independent glass consultant and John Cochrane, the UNIDO glass consultant to the Malawi Government, not forgetting the valuable contribution of Alison Gordon who typed the manuscript.

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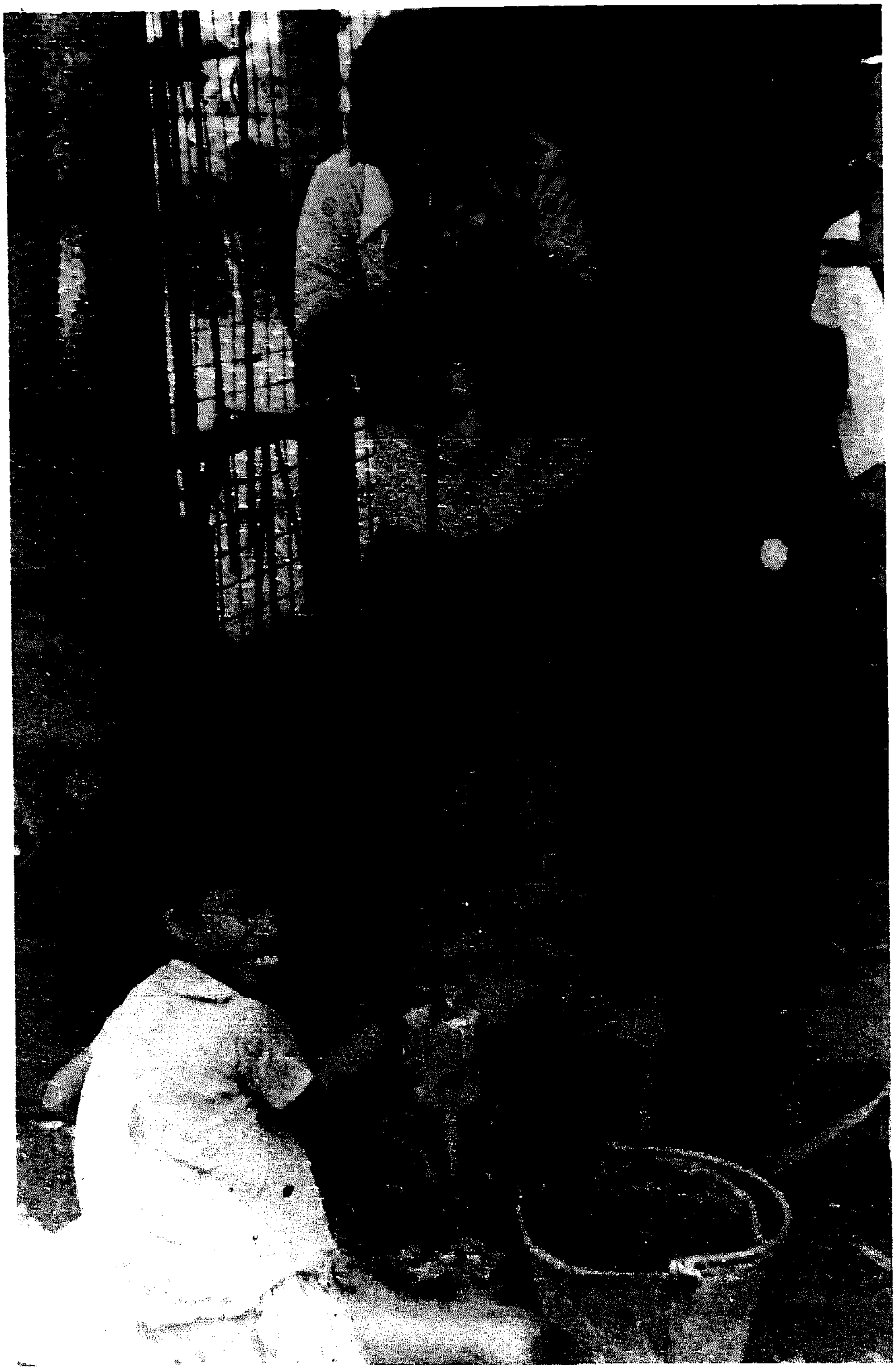


Frontispiece: Traditional mouth blowing of glass tumblers in Sri Lanka.

GLOSSARY

Annealing	: The removal of unwanted stresses in glassware by heating at a suitable temperature, followed by cooling at a controlled rate.
Annealing oven	: Chamber used to hold hot glassware at a suitable temperature until the end of the working shift, followed by controlled cooling.
Annealing lehr	: A tunnel shaped kiln used for the continuous annealing of glassware produced at the furnace.
Batch	: The mixture of raw materials used to make glass.
Continuous tank	: Large tank furnace which is continuously fed with 'batch' and from which molten glass is continuously drawn, often by automatic machines.
Crown	: Roof of the furnace.
Cullet	: Broken glassware which if suitable can be remelted to produce new glassware.

Day tank	Small (0-3 tonnes/day) chamber in which glass is melted overnight and worked out during an 8 hour 'day' shift.
Draw (pull)	Term used to describe the action of taking glass from the furnace.
Forming	The word used to describe the actions which shape the molten glass into the desired article.
Mix-melt (furnace)	Describes any furnace which uses two types of fuel.
Parison	The partly formed body of a bottle or jar.
Pot furnace	Furnace containing one or more pots (crucibles) in which glass is melted.
Refractory blocks	A material is described as refractory when it is manufactured to resist high temperatures.

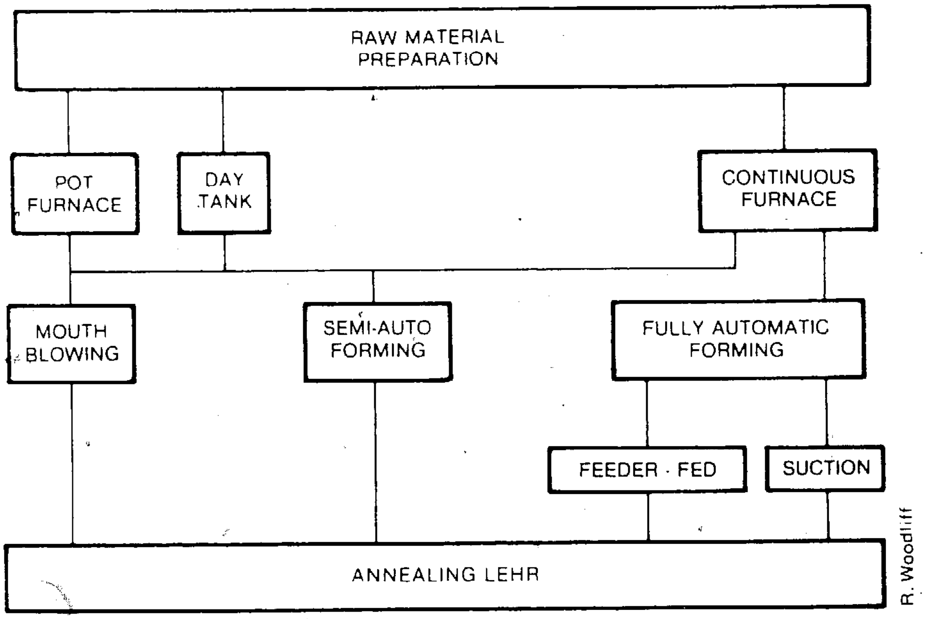
Figure 1: Traditional glass making.

Chapter I

THE GLASS MAKING PROCESS

Briefly and simply, glass is produced by melting a mixture of sand, limestone and soda ash, plus a few minor components, at a temperature of about 1400°C, in a furnace. The molten glass is then cooled to 1200°C which is the best temperature to mould the glass into a tumbler, container or bottle.

Figure ~~2~~ 1: A diagrammatic representation of the processes involved in glass manufacture.



The hot glassware then needs to be cooled under controlled conditions in an annealing chamber before it is ready for use. These different states of the process, raw material preparation, melting, forming and annealing are described in more detail in the following sections.

RAW MATERIALS

Cullet

Without good quality raw materials it is difficult to produce good quality glass. However, a reasonable quality glass can be produced from remelting broken glass, known as 'cullet'. This is common practice in small-scale glassworks in developing countries as it has many beneficial side effects; it creates employment amongst the lower socio-economic groups who can earn a living by collecting discarded glassware and broken glass for sale to the glass manufacturers; it also creates employment in the preparation as it is necessary to clean and sort the cullet carefully into types and to remove foreign matter which will affect quality. Cullet melts at a lower temperature (about 1200°C) than the constituent components of glass, known as 'batch' and this reduces the fuel required by the furnace. Therefore, the glass is produced more economically, but at the expense of quality. The market and type of product to be produced would dictate the suitability of cullet as a raw material. For instance, soft drink bottles on fast-filling lines would probably not perform as well if they were made from cullet, but well-designed tumblers can be very attractive and their aesthetic value enhanced by the characteristics of glass produced from cullet. Careful examination of the market should, therefore, be made before cullet is ignored in preference to batch.

Batch

This is the term used to describe collectively the components which make glass. The exact composition will vary with the different type and colour of glass that can be produced, but generally speaking a better quality glass can be produced by melting its constituent raw materials.

Figure 3: Cleaning and sorting cullet (broken glass) in Sri Lanka.

Table 1: BASIC BATCH COMPOSITION

COMPONENT	ORIGIN	QUANTITY REQUIRED TO PRODUCE 5 TONNES OF GLASS
Sand (SiO_2)	Local	2500 kg
Soda Ash (Na_2CO_3)	Imported	1000 kg
Limestone ($CaCO_3$)	Local	650 kg
Cullet	Waste from process	1000 kg
Minor components (de-colourizers etc.)	Imported	125 kg

Sand is the major constituent of glass. For most developing countries to consider a glassworks there should at least be local deposits of good quality glass producing sands: a silica content greater than 99.6%, and an iron oxide content less than 0.03%, unless amber or green glass is required, in which case colour impurities are not so important. The sand should be sieved so that only particle sizes less than 20, but greater than 100 mesh are used in the process.

Soda Ash is used to provide an alkali in the glass batch, and is found naturally at a number of locations in the world, one such place for example being Magadi in Kenya. Generally speaking, soda ash is the major component which would need to be imported by most developing countries.

Figure 4: Mixing small quantities of batch in Sri Lanka.

Limestone acts as a stabilizer for the sand-soda mixture and reacts quickly with the silica in the melting process. A good limestone should not contain more than 0.1% iron oxide, and like the sand it should be locally available.

These three components, sand, soda ash and limestone, go to make up most of the world's glass production, but minor constituents are found in all glass compositions either through impurities in the raw materials, or because they are deliberately added to produce a different glass type, glass colour or to make the glass more stable.

Good mineral preparation is essential at this stage as this dictates the quality of the glass. It is therefore necessary to pay particular attention to particle size and to thorough mixing of the components. In the case of colourless glass, magnetic separation is also essential to remove trace elements, particularly iron, which would otherwise give the glass an unpleasant discolouration. Careful choice and analysis of the sand deposit available is necessary before a glass plant is set up.

The addition of the minor components to help remove slight discolourations would only have limited success. To mix, for example, 5g of a component amongst 2500kg of sand will present problems. These problems should not be under-estimated, particularly for small-scale producers who are mixing one tonne batches at a time. To eliminate the strong possibility of a variation in the colour of the glass over a production period as a result of slight differences in the batch composition, many glass plants hold back 40% of each prepared batch to add into the next batch they prepare. This practice allows for at least some continuity.

Costs

The cost of the raw materials varies considerably, depending on local transport costs, distance of the deposits from the factory etc., but as a general rule, the most expensive component is soda ash, which accounts for about 75% of the raw material costs, because in most countries in the world it has to be imported. Cost comparisons for different countries are shown in Chapter Three.

Cullet costs also vary considerably depending on labour costs and the demand for broken glass, but they would generally be much lower than batch.

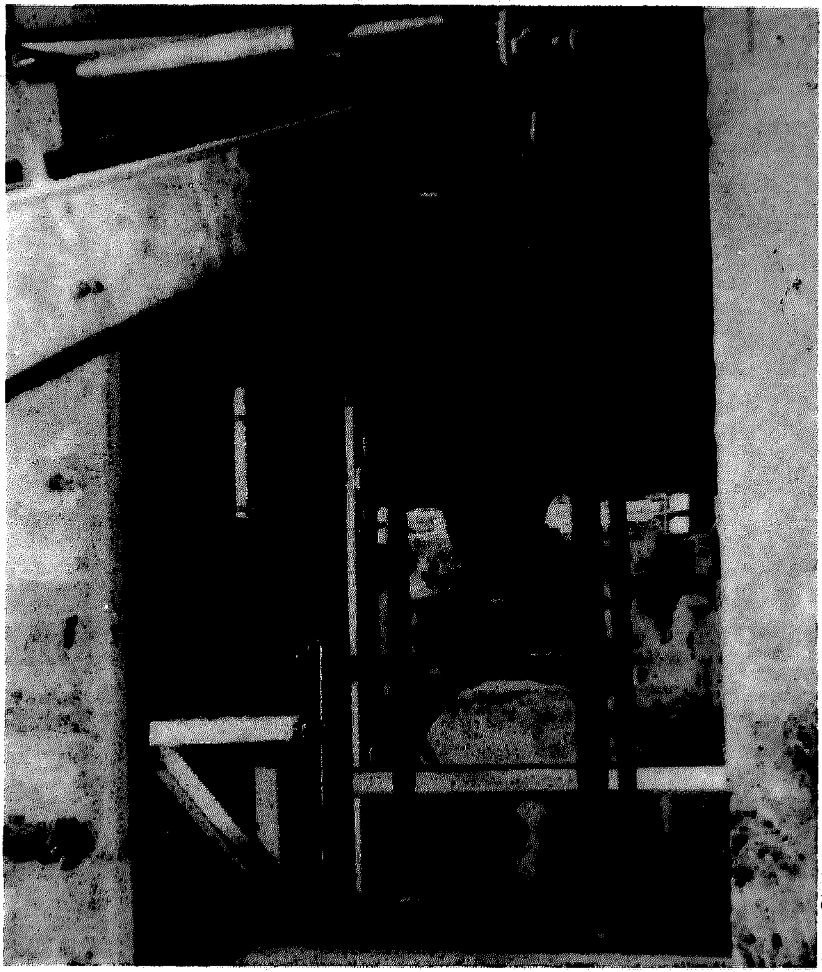

Xavy Glass

Figure 5: A locally made batch charger in Sri Lanka.

Mixers/Chargers/Level Control

Most developed country glassworks have sophisticated equipment to mix the batch, convey it to any one of a number of furnaces and automatically feed it into the furnace by means of a batch charger, which is operated by an automatic level control in the furnace.

Such equipment is expensive, but in an economy where labour rates are high, the cost of such equipment is soon justified. In most developing countries simpler, less expensive, but more labour intensive means can easily be substituted, such as, for instance, the use of a cement mixer to mix batch, or a simple manual hopper to charge the furnace, something which can be operated by an employee who keeps an eye on the glass level. With diligence, quality control can be comparable to the automated plants of most developed countries.

FURNACES

Relatively high temperatures are required to melt glass; cullet, because it has already undergone the chemical reaction, requires about 1200°C, whereas batch still has to undergo the necessary chemical reaction which requires much higher temperatures of between 1400°C and 1500°C, and it has to be sustained at these temperatures to produce satisfactory glass, and then reduced in temperature to 1200°C for the moulding process. Depending on the scale of operation there are a number of alternative types of furnace which can achieve this, and these are discussed below.

Pot Furnaces

The first glass factories, in earlier centuries, used pot furnaces. These were refractory pots which were placed in a heated chamber. The pots were periodically loaded with batch which then melted over a period of time. Once molten, and at the required temperature the glass was then drawn off. Pot furnaces have a limited life, probably about 20 weeks of continuous use, and a capacity of between 250 and 500 kg. The chamber, however, can have a life of 30 years, although this is typically only 3 to 5 years. This method is still used, but mainly by specialist glassware manufacturers, for the production of low volume, high quality glass, such as crystal for example, where fuel economy and high production costs are not drawbacks because a higher price can be charged for the type of glassware produced.

Day Tanks

A day tank is a rectangular chamber made from refractory blocks with a roof, known as the crown. At one end of the chamber is a gas or oil burner and an outlet port which gives a U-shaped flame over the glass surface.

This flame melts the batch and keeps it at the right temperature for working. At the other end there are holes for charging and gathering the melted glass. The capacity is between 2 and 3 tonnes per day, the limiting factor being the amount of glass which can be hand drawn from the tank in a working shift, the temperature in the tank is increased and it is then recharged with batch. Overnight, the batch melts at about 1400°C to assist the chemical reaction to take place, and then cooled to 1200°C for the working shift. The life of the tank is limited again to, typically, 6 to 12 months, before the thermal cycling deteriorates the refractory blocks, as does the varying glass level.

Continuous Furnaces

These are by far the most common furnaces and comprise a melting end and a working end. The melting end is kept at a temperature of about 1400°C to assist the chemical reaction between the batch components which are continuously fed into the melting end. As this melts, it travels along the furnace and into the 'working end' where it cools to 1200°C for the forming process. Normally the two ends are separated by a 'throat' which maintains the necessary temperature difference between the two ends, and prevents the flow of unmelted batch into the working end. The melting end is normally larger than the working end, a design that creates a pressure difference to assist the flow of glass to the working end.

Continuous furnaces are worked on a three-shift basis, giving better capital utilization of the ancillary equipment than with a day tank. Continuous furnace capacities are typically up to 300 tonnes/day in developed countries.

Depending on the local fuel costs, the minimum economic size varies, but in developing countries is normally around 5 tonnes per day. The initial factor

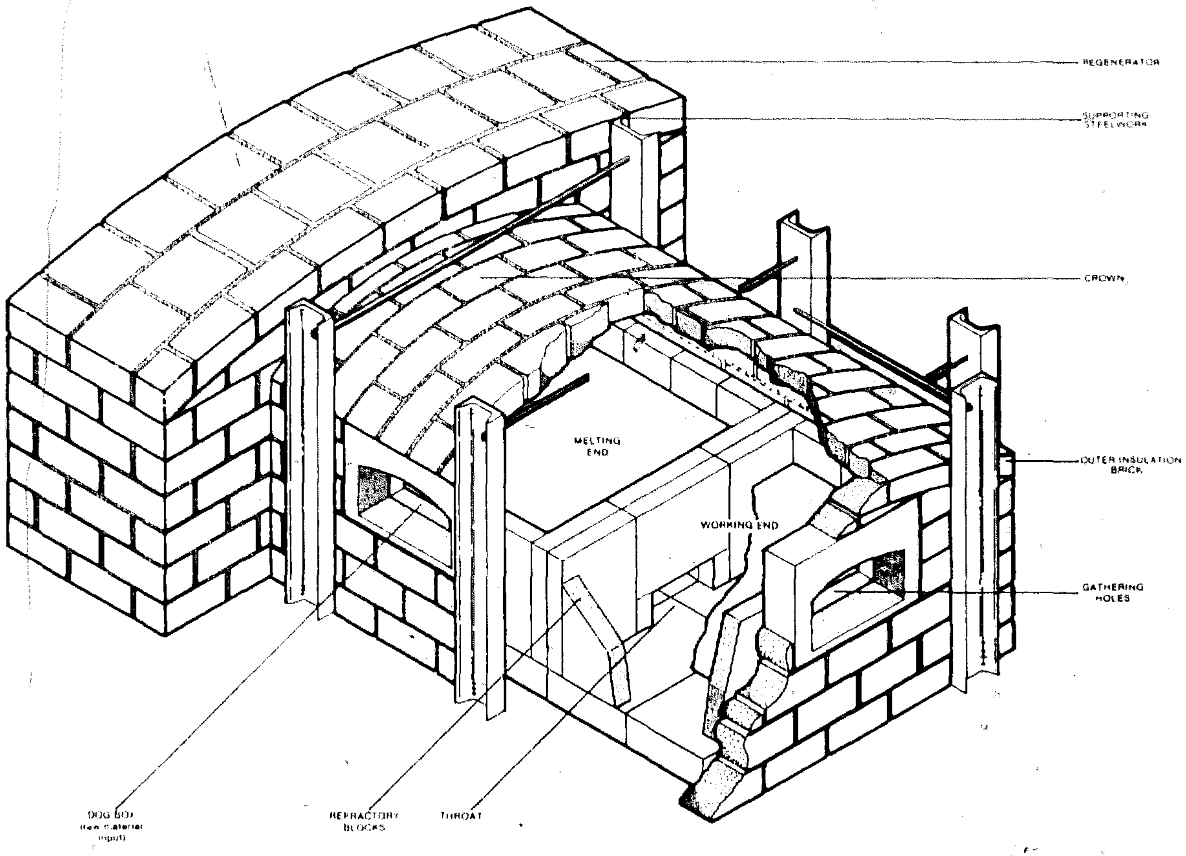


Figure 6: A typical oil or gas fired continuous furnace (not to scale).

R. Woodliff

here is the waste heat radiated from the furnace walls and roof, and the exhaust heat loss up the chimney. Larger furnaces have greater volume for less surface area, and since radiated heat is a function of surface area there is less heat loss per tonne of glass melted in larger furnaces.

Fuel Considerations

The chemical reaction requires very little energy compared to that consumed by the furnace. Most of the energy is used in maintaining the temperature of the refractory block in the furnace. Since heat loss from a small furnace will be proportionally greater than loss from a larger furnace, melting costs are reduced in the larger units, particularly in those furnaces which employ heat recovery devices; such as cross fired regeneration 300 tonnes/day furnaces, and end-fired 5 to 15 tonnes /day furnaces which employ metallic or ceramic recuperators. Without such energy saving devices, much of the heat produced by the oil or gas flame is lost.

Electric heating is, however, far more efficient in purely energy terms because of the way the glass is melted by this technique. Electrodes are introduced through the bottom of the furnace into the body of the glass, and since molten glass conducts electricity, an electric current will flow from one electrode to another, heating up the glass. (To start the furnace an oil or gas flame is used to get the glass in a molten state before it will conduct electricity). The glass surface is covered by a layer of unmelted batch which holds the temperature into the glass and thermally insulates the glass surface, reducing the heat lost through radiation. The batch is melted by the hot glass lying under it, and so, in order to maintain the cold top, it has to be continually replaced.

This then means that electric melting is about three times more efficient in absolute energy terms than oil

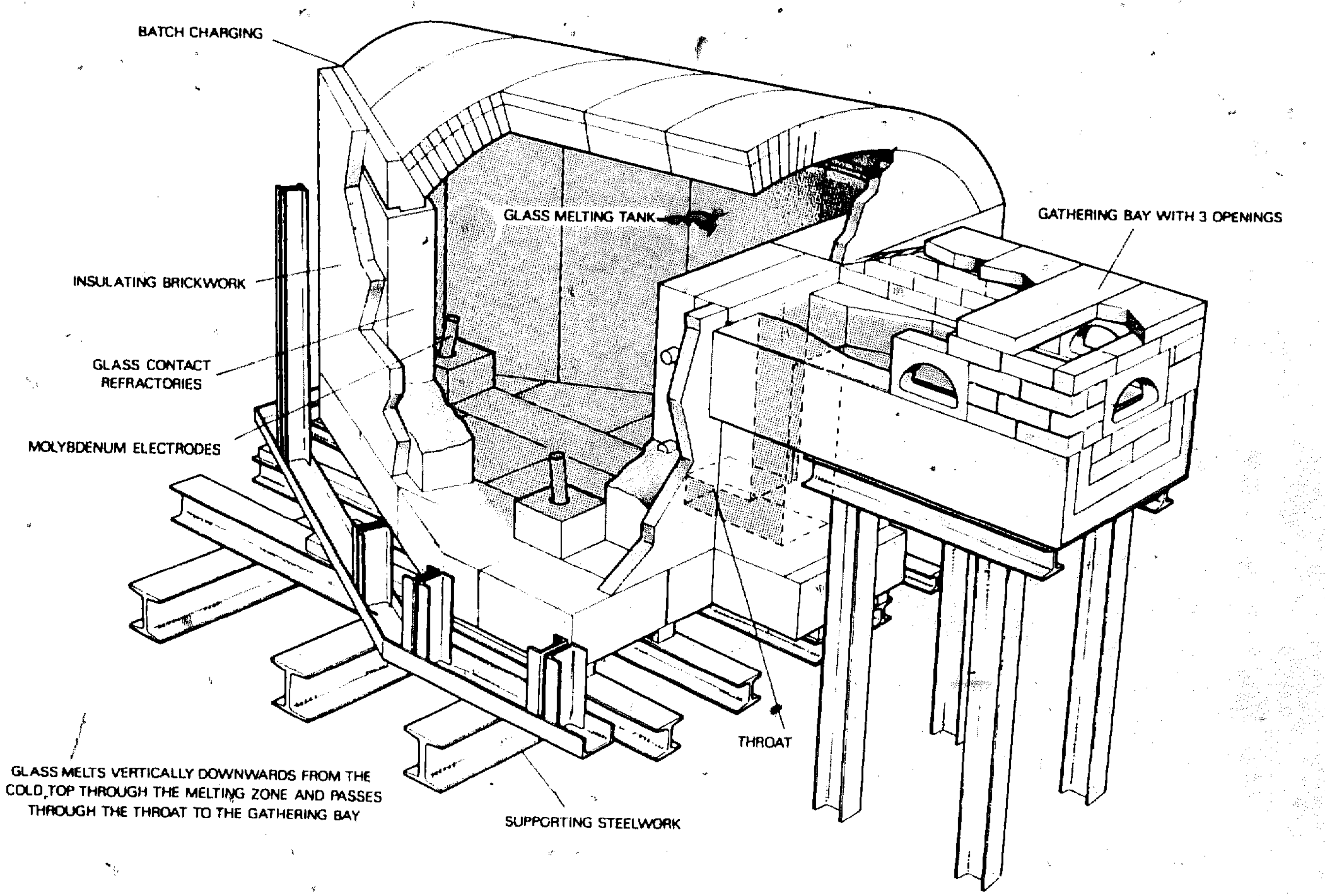
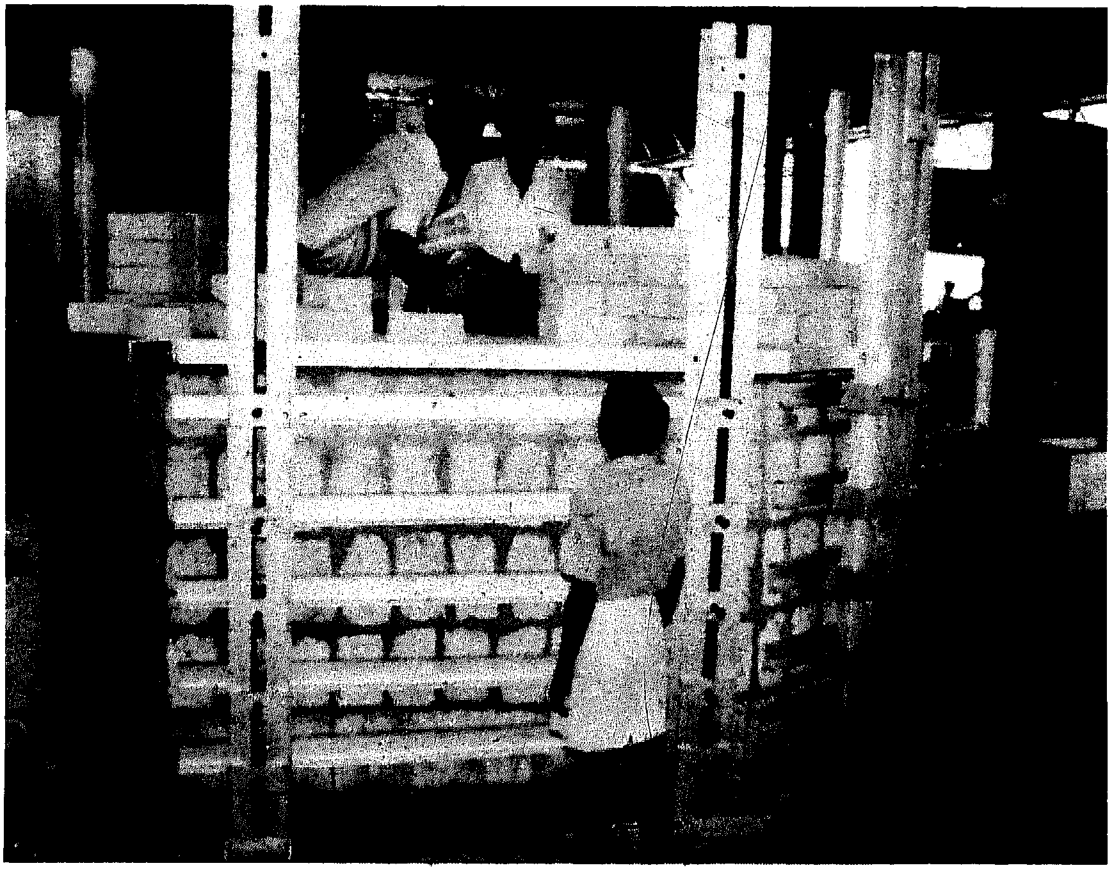


Figure 7: A KTG designed 5 tonnes/day all electric furnace.

KTG.

Figure 8: An electric furnace in operation, and below, the furnace being built by local craftsmen.



or gas, consuming under 50 therms of energy per tonne of glass melted, as opposed to over 130 therms per tonne of glass melted by gas or oil. Table 2 shows the order of fuel consumptions for different fuels.

Table 2: FUEL CONSUMPTION FIGURES FOR DIFFERENT FUELS IN SMALL SIZED FURNACES (5 tonnes/day)

FUEL	CONSUMPTION FOR 5 TONNES OF GLASS MELTED PER DAY	APPROX THERM EQUIVALENT
Oil	450 gallons	650
Coal	3.7 tonnes	925
Gas	2000 cubic metres	700
Electricity	7200 kilowatt-hours (300 kW)	250

Furnaces which are fuelled by both oil and electricity, or by both gas and electricity are known as mix-melters. Mix-melters are common where an increase in the glass drawn from oil or gas furnaces is needed. Such furnaces have electrodes added to boost the energy input and hence increase the rate of melting, which then increases the designed capacity of a furnace. This is typically done with the larger furnaces (60 tonnes/day or over). However, there are circumstances when mix-melting is required to assist electric melting because of the characteristics of the batch composition. If a furnace is melting amber glass with electricity as fuel, for example, a mix-melter is required. It is essential that the furnace has an additional oil or gas burner to apply heat to the top of the glass, because with amber glass a characteristic frothing is experienced. The froth hardens and forms a crust on top of the glass which stops the next charge of batch from joining the already melted glass, and hence from melting. Left to itself, the furnace would thus drain and this would have a detrimental effect on the refractory blocks and the exposed electrodes. The top flame is, therefore, introduced to prevent the froth from becoming hard.

Another consideration with purely electric furnaces is the effect of prolonged power cuts. It is, therefore, advisable to have the facility of a standby generator to take over in the event of a power failure. This need not necessarily affect the economics of electric melting over gas or oil, because of the much greater efficiency of electric melters. The oil required to generate the electricity to melt the glass is similar to, if not less than, that used by direct combustion of oil to melt the glass. So providing the standby does not have to be used too often, the advantage of electricity is maintained.

FORMING

Mouth Blowing

This is the most basic method of forming glass and relies greatly on the skill of the mouth blower to produce the required quality. Each mouth blower is supported by a team of 6 to 8 people who gather glass from the furnace, operate a manual mould, and transport the hot glassware to the lehr for annealing.

Xavy Glass

Figure 9: Mouth blowing two hurricane lamp chimneys in Sri Lanka.

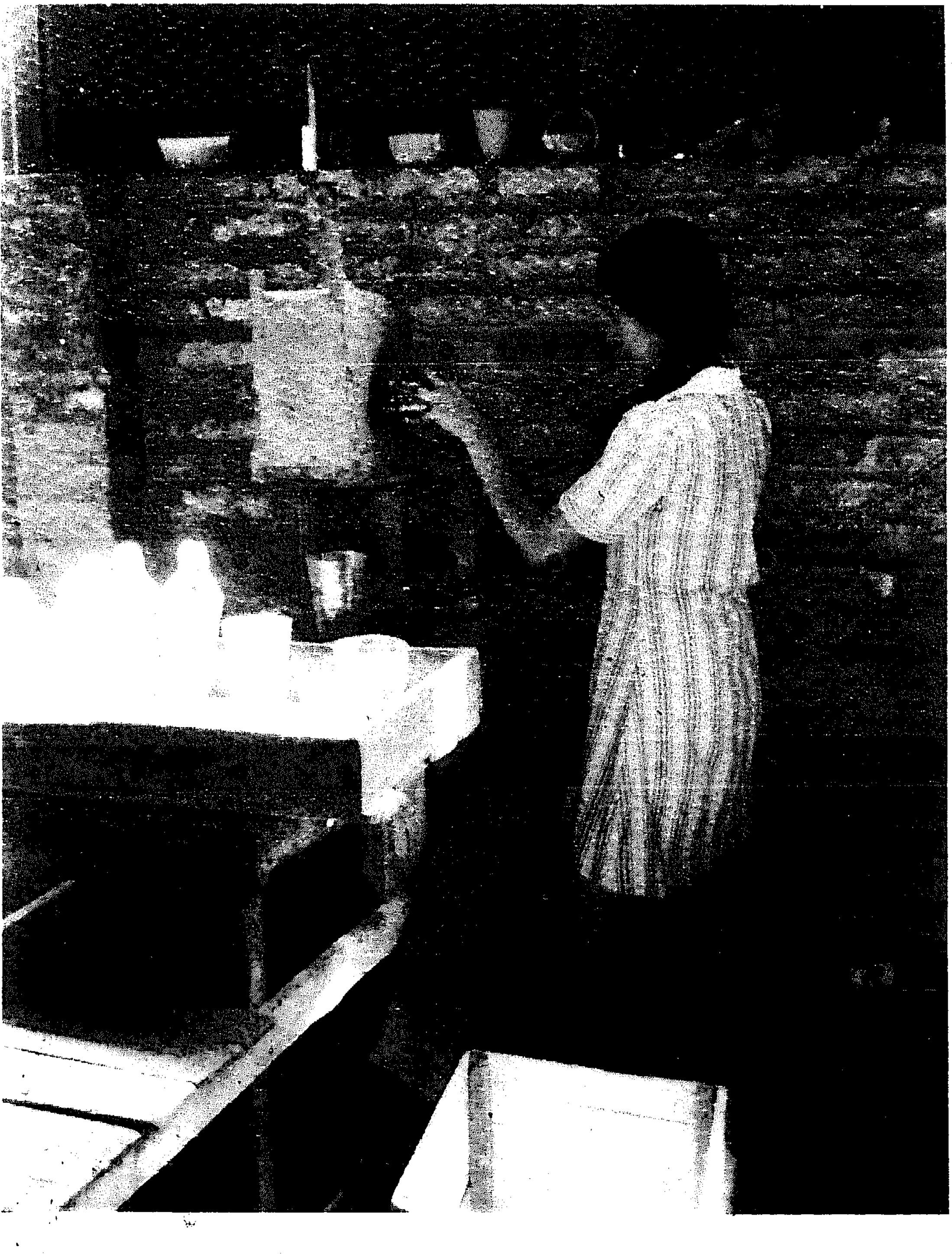


Figure 10: The process of fusing glass to smooth the lip of a tumbler.

A glass gatherer gathers a gob of glass on the end of a hollow tube, by putting the tube into the working end of the furnace, touching the glass surface with the tube and rotating the tube until enough glass has been collected on the end. The quantity depends on the product to be made. A bubble is blown into the hot glass gob by blowing down the hollow tube. The shape of the gob is arranged by skillful operation which involves the mouth blower swinging and/or rotating the hollow tube until the molten glass has taken the preferred shape before it is placed in a hollow mould. The mouth blower then continues to blow the bubble in the glass until the outside has taken up the profile of the mould. The moulding is then left for a few seconds until it is solid enough to be transferred to the annealing lehr where it is removed from the end of the hollow tube.

Once annealed, the product needs to be finished off. This involves removing the top glass section which was attached to the hollow blow tube and then fusing the cut surface with a hot flame to remove sharp edges.

The quality of the finished item depends on the skills of the mouth blower and the production schedule, but very often the quality is not of a high standard.

Defects characteristic of this technique normally consist of uneven glass thickness, which is difficult to control. Glass utilization is characteristically low, the cracked off portion being returned to the furnace for remelting. However, a number of products can be made by this method: bottles (other than mineral and beer bottles because of their normally automated filling methods), tumblers and chimneys for hurricane lamps being the most common.

Semi-Automatic

Semi-automatic forming techniques still require manual gathering of the glass from the furnace using similar techniques to those employed for mouth blowing. The

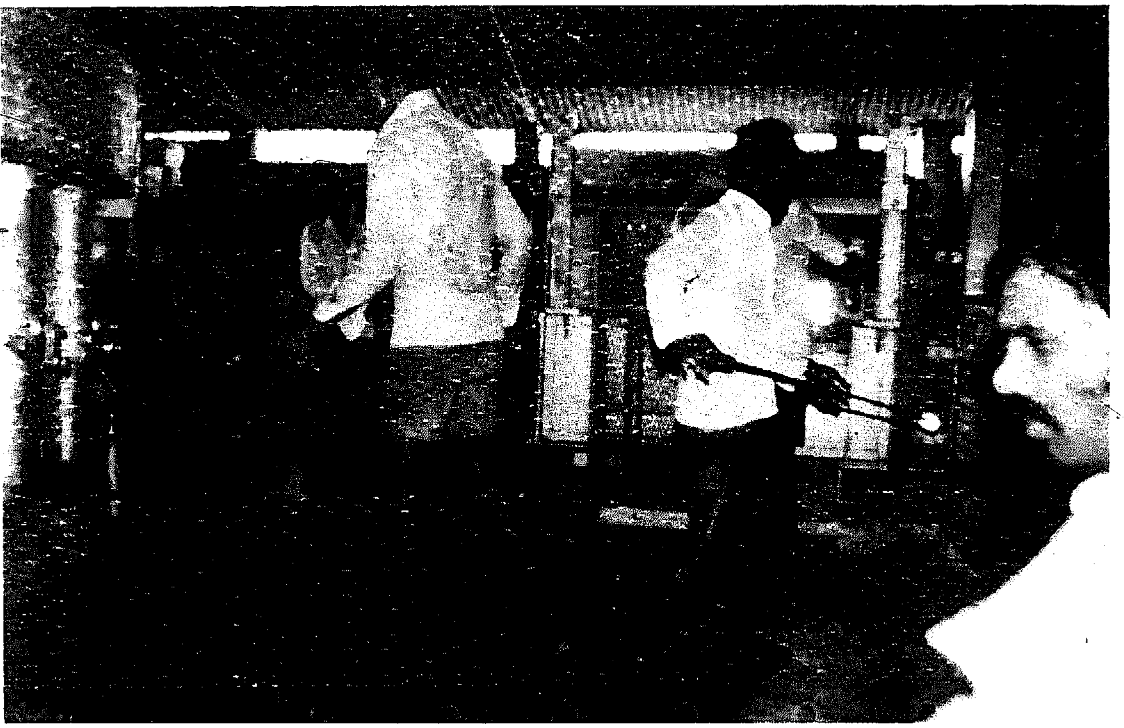
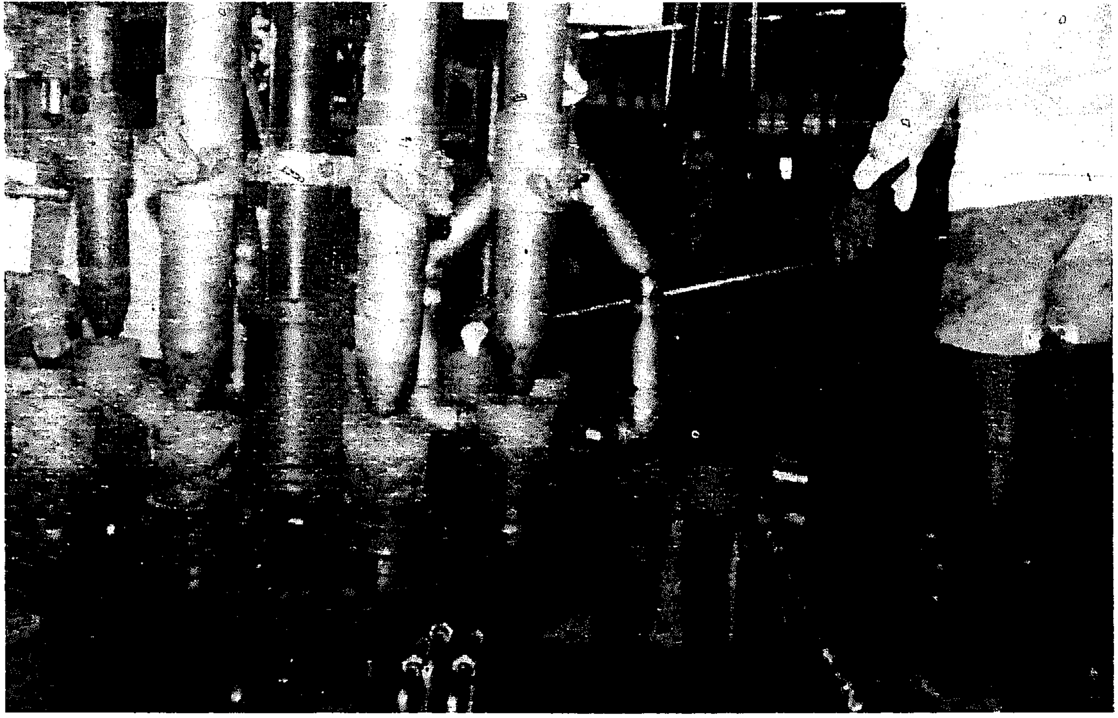


Figure 11: Hand-gatherers feeding semi-automatic press machines in Sri Lanka.



molten glass is then fed into a machine which forms the glass into the glassware object. Several processes are used, depending on the product required; 'press' for tumblers and other open necked items, 'press and blow' for wide necked jars and containers, and 'blow and blow' for narrow necked containers and bottles.

(a) Press Machines

These do exactly what they say. The container is formed by a single action of a plunger pressing on a hot gob of glass in a mould. The skill of the hand gatherer is the most significant constraint. If too much or too little glass is gathered, then the product quality is reduced. This process is used to make items such as tumblers, dishes and ash trays.

(b) 'Press and Blow' or 'Blow and Blow' Machines

The formation of a jar or bottle is a two-stage process. The first stage forms the neck of the jar or bottle and the parison. The term parison is used to describe the partly formed body of a jar or bottle. The second stage forms the body of the container.

For wide neck containers, the neck and the parison are formed by the 'press' action of a plunger. The parison is then manually transferred by the neck ring holder to the adjacent finishing mould where it is fully blown, removed and released from the neck ring for annealing. Hence, the phrase 'press and blow'.

For narrow neck containers, such as bottles, the neck and parison are formed by a 'blow' action. The parison is then manually transferred by the neck ring holder to the adjacent finishing mould where it is fully blown. Hence, the phrase 'blow and blow'.

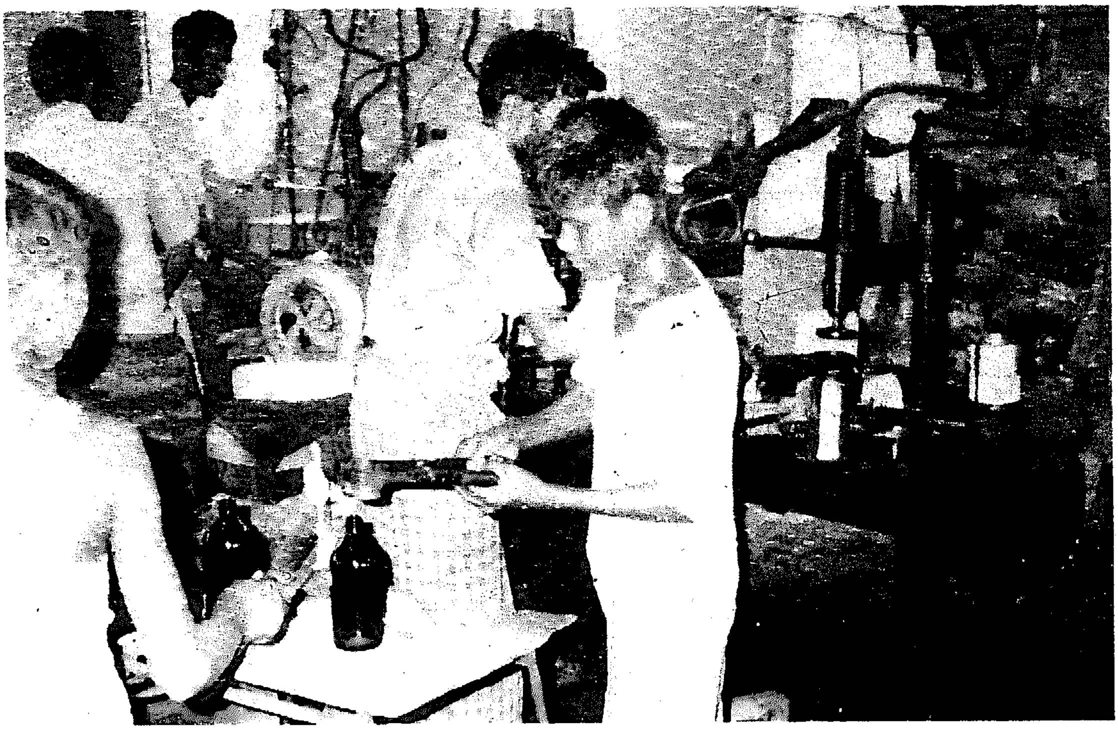
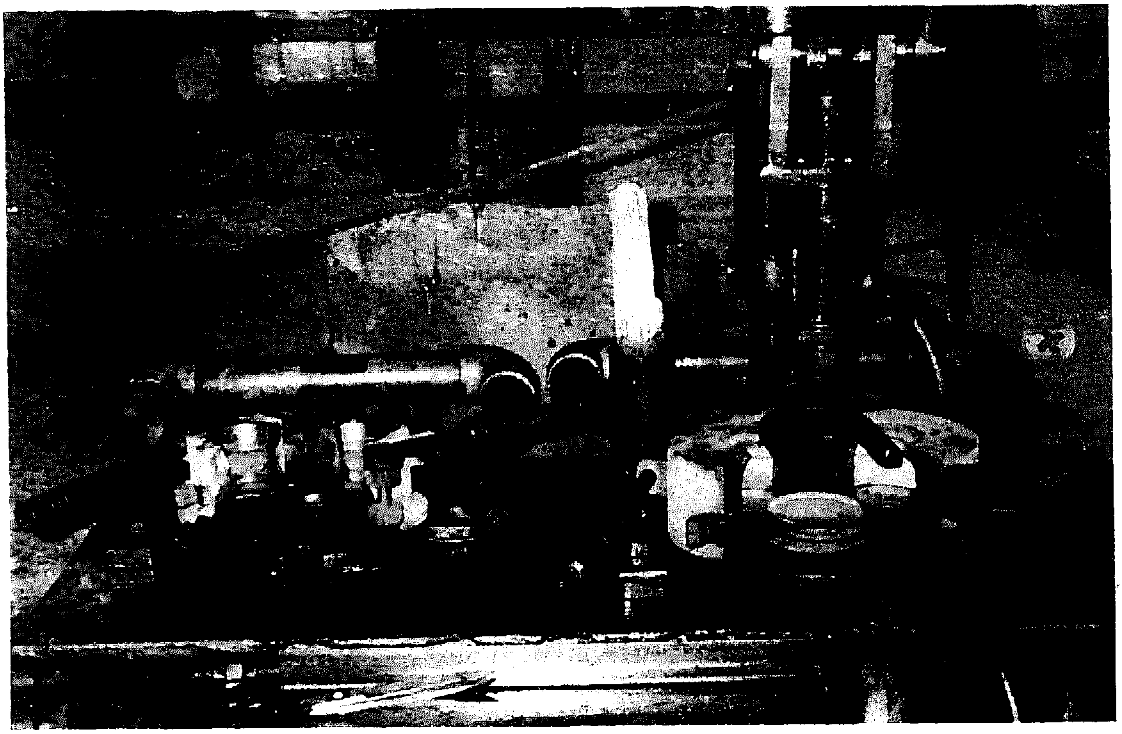


Figure 12: Semi-automatic pharmaceutical bottle manufacture in Bangladesh with equipment detailed below.



Either of these processes result in a better quality neck than that produced by mouth blowing techniques, and a more consistent bottle weight is possible. However, the quality is still reliant on the skills of the hand gatherer, and characteristic defects of semi-automatically produced bottles and jars are loose fitting caps and unequal volumes.

Again this technology has its place in the low volume, highly specialized market, for such products as pharmaceutical bottles, jam jars, ink bottles, etc.

Fully Automatic

For the higher volume market, fully automatic machinery is necessary. This allows for a more consistent product, which can be lighter, and which thus reduces the amount of glass used. There are two very distinct scales of operation; feeder-fed machines, such as IS, R7 and S10 machinery, and suction moulding machines such as Roirant type 'BM' and 'F' machines.

(a) Feeder-Fed Machines

Feeder-fed machines were developed in the 1920's, in which gobs of glass were automatically dropped from the furnace into the machine. Early feeder-fed machines such as the Lynch, used a rotating mould system. This was developed by Hanrez SA of Belgium with their R7, pulling 35T/day of glass, their S10 model pulling 50 to 60T/day and their S10DG111, pulling 100T/day. This was largely overtaken by the development of the individual section (IS) machine. Here the moulding sections are arranged in line and fed individually with a gob of glass from a feeder mechanism delivered from the furnace situated above the IS machine.

IS

Below a certain volume of production IS machine operation becomes less economic because of the cost of setting up the machine for short runs of standard containers. A minimum run of 400,000 to 600,000 bottles would be normal for a four section machine. Depending on the bottle size, the glass drawn by an IS machine can be much less than the capacity of the furnace and so the low utilization affects the profitability of the glass factory. For example, a four section machine producing 100g weight bottles would only need 6 tonnes/day (60,000 bottles/day), but in view of the possible demand for 1000g weight containers the furnace capacity would be installed at 30 tonnes/day. Since only one weight of item can be produced on an IS machine at any time, it is generally considered that a factory will need two four-section IS machines with a furnace capacity of 60 tonnes/day to be able to respond adequately to market demands. Careful consideration of the market demand and product mix is therefore needed when designing a glass factory.

R7, S10, S10DG111

A similar argument is true for this range of machines. The smallest would require a supply of 35 tonnes of glass per day, the largest a supply of 100 tonnes of glass per day. The lack of flexibility with these machines may not be a problem where the glass works is to produce large quantities of the same style of bottle.

(b) Suction Machines

Generally speaking, developing country markets demand a smaller volume of a wider range of products which is not normally suited to the feeder-fed machines. Because of this, single head suction moulding technology has been reintroduced.

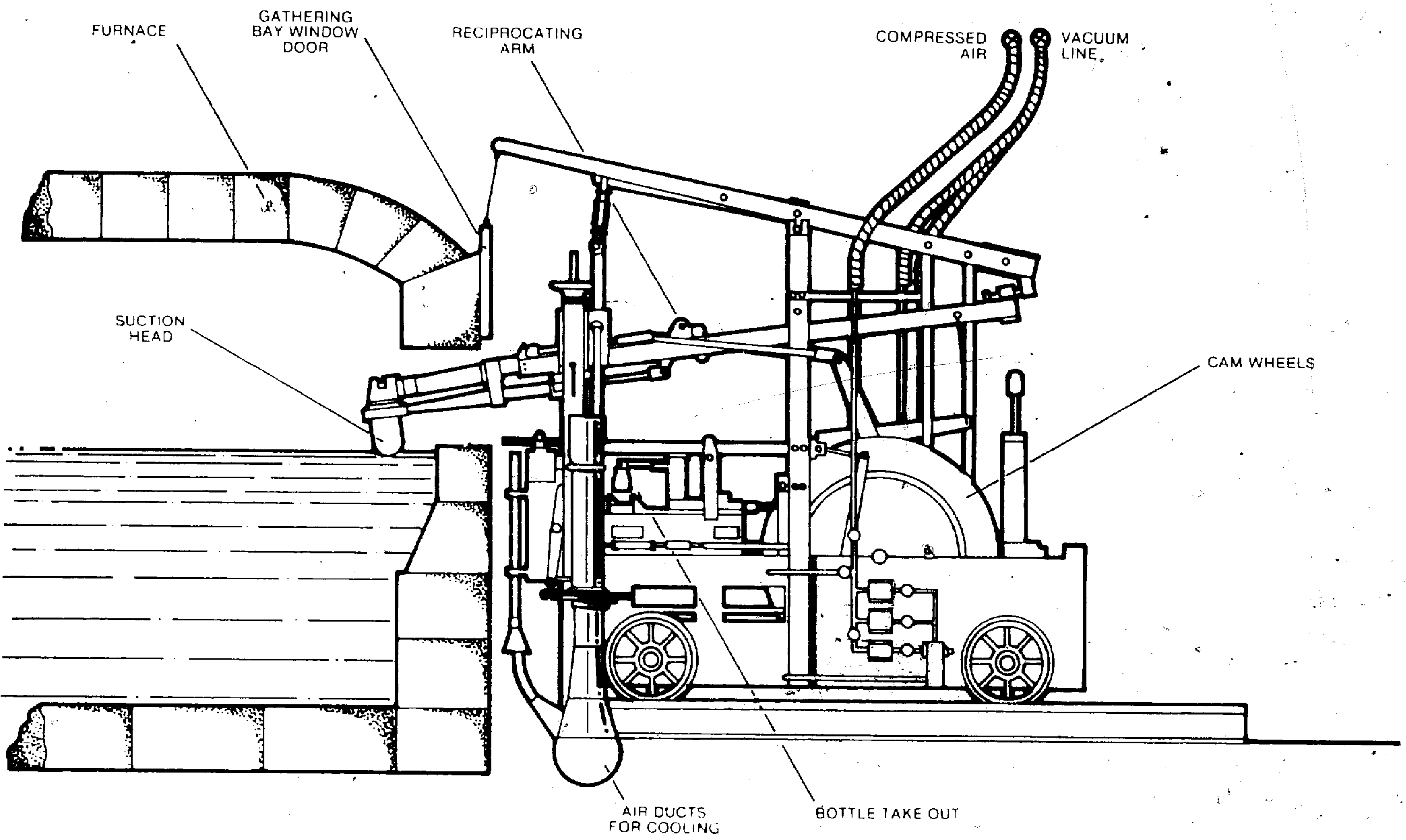


Figure 13: Drawing of the Type 'F' suction moulding machine for producing good quality bottles.

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This machine is ideally suited to lower production runs, and does not require to be feeder-fed. Instead the machine has its own feeder. An arm carrying the neck-ring and parison mould into the furnace, dips onto the glass surface, and the glass is then sucked into the mould by a vacuum. As soon as the parison mould is full of glass, the arm pulls the mould away from the glass surface and a shear blade cuts the remaining glass away from the bottom of the mould. The shear blades remain in this position until the mould is brought back into the machine, in order to facilitate parison blow-back which takes place immediately after the plug (which forms the neck) has been removed. The parison is then automatically transferred by the neck-ring holder to a finishing mould where the bottle is formed by sucking the glass onto the inside of the mould. After a predetermined time the completed bottle is then released for annealing.

There are two types of suction moulding machines the type 'F' and the type 'BM'. The type 'F' (F for flask) produces bottles in the range 40g to 350g, the type 'BM' (B for bottle, M for modified) produces larger bottles in the range 350g to 1500g.

The production rate per day (Pn) depends on the weight of the glass bottle (p) in grammes, and is given by the formula:

$$Pn = \frac{3,450,000}{325 + p}$$

which takes into account an efficiency of 80% for 'F' machines

and

$$Pn = \frac{6,900,000}{1000 + p}$$

which takes into account an efficiency of 80% for 'BM' machines

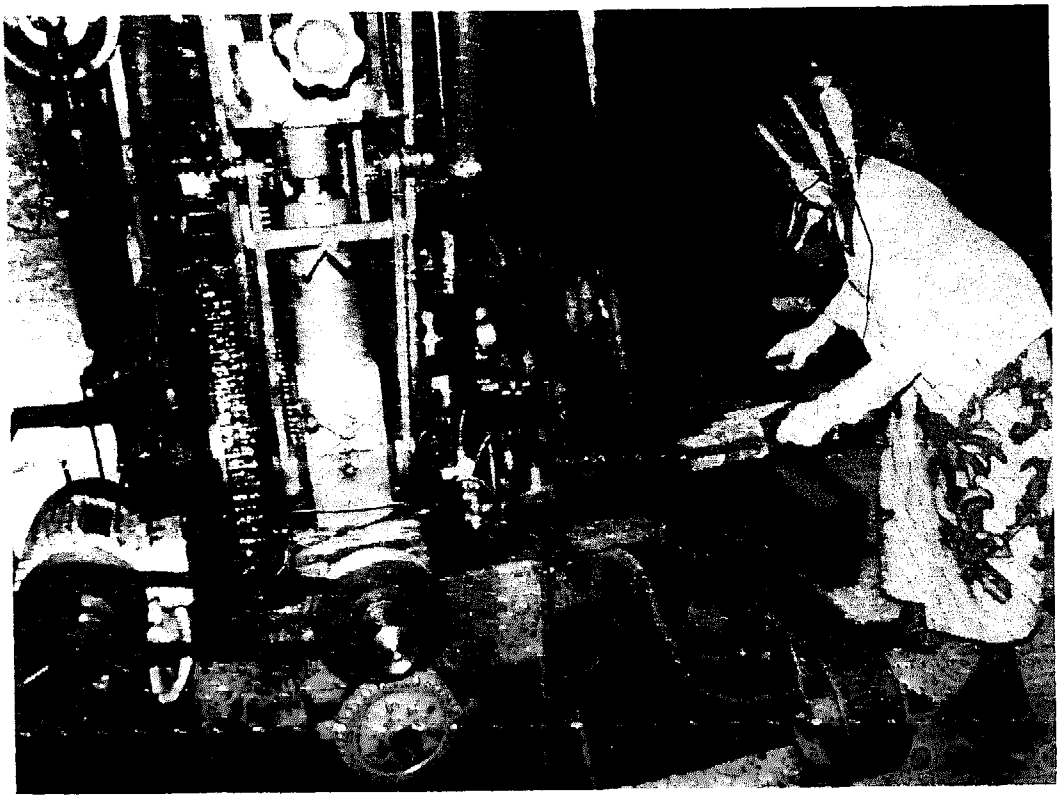
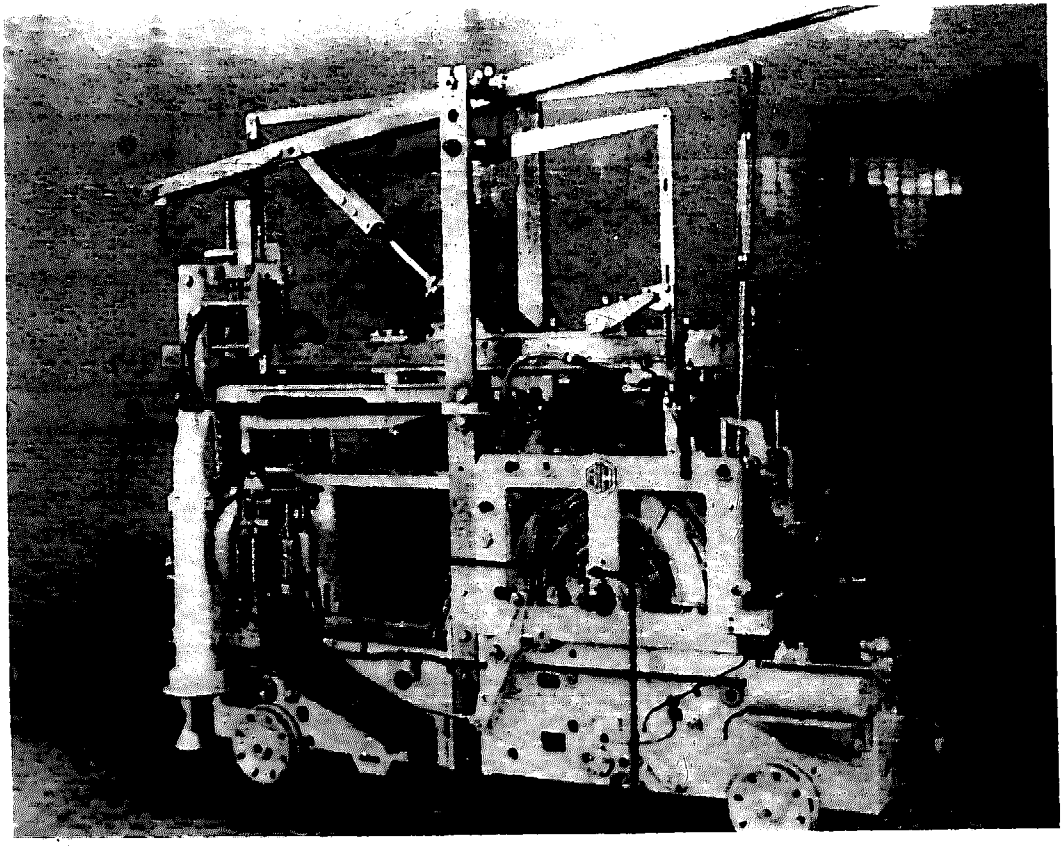


Figure 14: The Type 'F' suction moulding machine in use in Indonesia and (below) Type 'BM' machine.



Hanrez SA

ANNEALING

It is essential that a hot glass object is annealed. This means that the stresses introduced into the glass during the forming process must be relieved by allowing the glass to cool down very slowly. This is achieved either by batches of hot glassware being held in an annealing furnace at approximately 500°C for a period of time, or in a continuous belt annealing lehr where the glassware is placed on a moving belt of some description and is carried through a chamber held at 500°C. The journey time through the chamber (lehr) corresponds to the holding time required.

The bulk of the heat for annealing comes from the heat contained in the items, but at lower production, back up heat can be provided by oil, gas or electricity—the latter being the most common. A 5 tonnes/day operation would require about 50 kW.

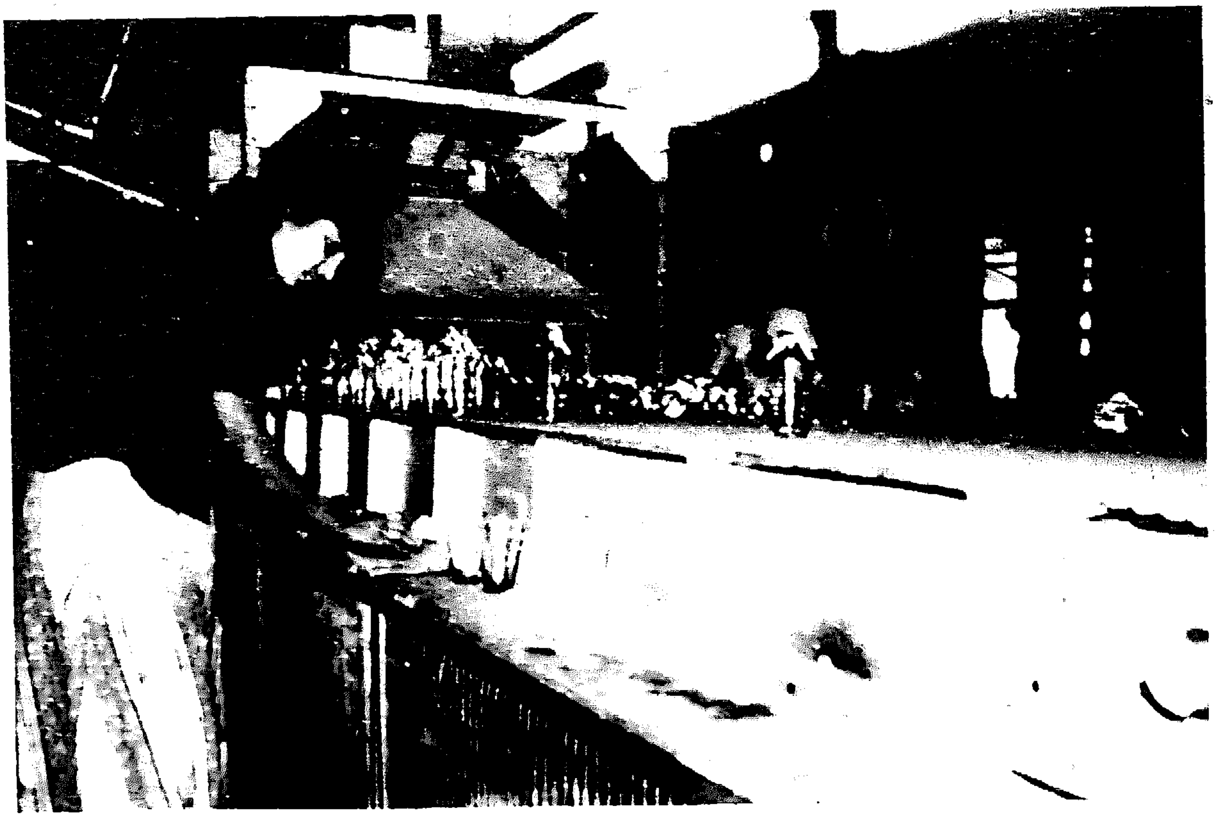


Figure 15: Taking glassware from an Indian-made electric annealing lehr in Sri Lanka (above). Feeding an oil lehr (below).

Chapter II

TECHNOLOGY CHOICE

Market Considerations

The scale of technology and type of process equipment to be used in glassware production obviously depends on the conditions which prevail in a particular country at the time, and those which are projected for the future. Of paramount importance are market conditions which dictate what type of product is in demand. Table 3 summarizes these considerations by examining the implications of a range of different glass product types for raw material inputs and forming techniques.

Column 1 of the table indicates that batch and cullet are both suitable raw materials for all types of containers, except drink bottles which are to be pressure filled and so are best produced using batch. The choice between batch and cullet will be dictated by considerations of quality; batch allowing production of higher quality glassware than cullet. Obviously, the premium earned on items of higher quality needs to exceed the additional cost of the raw material (batch costs per tonne being higher than cullet costs per tonne). One way of achieving economies in production costs without reducing product quality drastically is to use a batch/cullet mix of, typically 80:20 (NB: the cullet referred to here is bought-in waste glass. The batch composition of Table 1 in Chapter One already contains some 20% of internally generated waste glass).

As indicated in Chapter One, the furnace size and type will largely depend on the volume of glassware demanded. Column 2 of the table shows that pot furnaces are used for outputs of 250kg to 500kg per day, day tanks for outputs of up to 3 tonnes per day and, most common of all, continuous furnaces for outputs of 5 to 300 tonnes per day. The actual fuel type used will obviously depend upon considerations of cost and availability, the two

Table 3: CONSIDERATIONS IN SELECTING RAW MATERIALS AND EQUIPMENT

CONTAINERS/ DOMESTIC WARE	(1) RAW MATERIALS			(2) FURNACE	(3) FORMING		
	100% Cullet	Batch	Mixed Batch/ Cullet	C = Continuous D = Day Tank P = Pot	Mouth Blowing	Semi Automatic	Automatic
CONTAINERS							
Drink bottles	NA	S	S	C	NA	NA	IS= 20,000/shift RF= 3,000/shift
Food bottles and jars	P	S	S	C	NA	1,200/shift	ditto
Pharmaceutical bottles	P	S	S	P,D,C,	NA	ditto	ditto
Specialised bottles	P	S	S	P,D,C,	P	ditto	RF only
DOMESTIC WARE							
Tumblers	P	S	S	P,D,C,	P	press	RF and press only
Hurricane lamps	P	S	S	P,D,C,	P	NA	RF only
Trays and dishes	P	S	S	P,D,C,	P	press	NA

INDEX
NA = not applicable
S = suitable
P = suitable for a poor quality ware
IS = individual section and other feeder machines
RF = suction machine type 'F' or 'BM'

NOTES

Continuous	5-300 tonnes/day
Day tank	0-3 tonnes/day
Pot	0.25-0.5 tonnes/day

major factors which dictate the choice between the four main options of oil, electricity, gas and coal.

Column 3 indicates the suitability of the various forming options to each product type. Product quality improves as the technology becomes more mechanized and automatic, with the choice at the automatic level of production stages decided on the basis of cost **and** scale of production necessary. Generally, unit production for mouth blowing will be higher than those for machine forming, making mouth blowing more suitable for producing short runs of either high value products (such as specialist containers like perfume bottles), or products where quality considerations are not paramount.

In general, the interest from developing countries is expressed in production scales of 5 – 15 tonnes per day to produce non-drink bottles. Table 4, therefore, examines automatic forming options in more detail. It shows that automatic suction moulding technology is suited to relatively short production runs of bottles at rates of between 1,500 and 3,000/shift (depending on bottle size). By contrast, feeder-fed technology is suited to considerably longer production runs of up to 20,000 bottles/shift. The investment figure only shows the cost of forming equipment and excludes ancillary items such as a compressor, air lines, and installation costs.

There are many arguments among experienced people in the glass factory as to the relative merits of feeder-fed machines, – i.e., the difference between IS and rotating mould machines, and even stronger arguments about the relative merits of feeder-fed machines and suction machines. Generally speaking, however, feeder-fed machines cost more to install as they require furnaces to be built off the ground to allow for the glass to drop from the feeder into the forming equipment, and they require a separate feeder. Suction machines in contrast, can be installed at minimum cost as they would generally suit most smaller furnaces which are built at ground level, as they have their own in-built feeder mechanism. In addition to this, suction moulding machines are

Table 4: SEMI AND AUTOMATIC FORMING

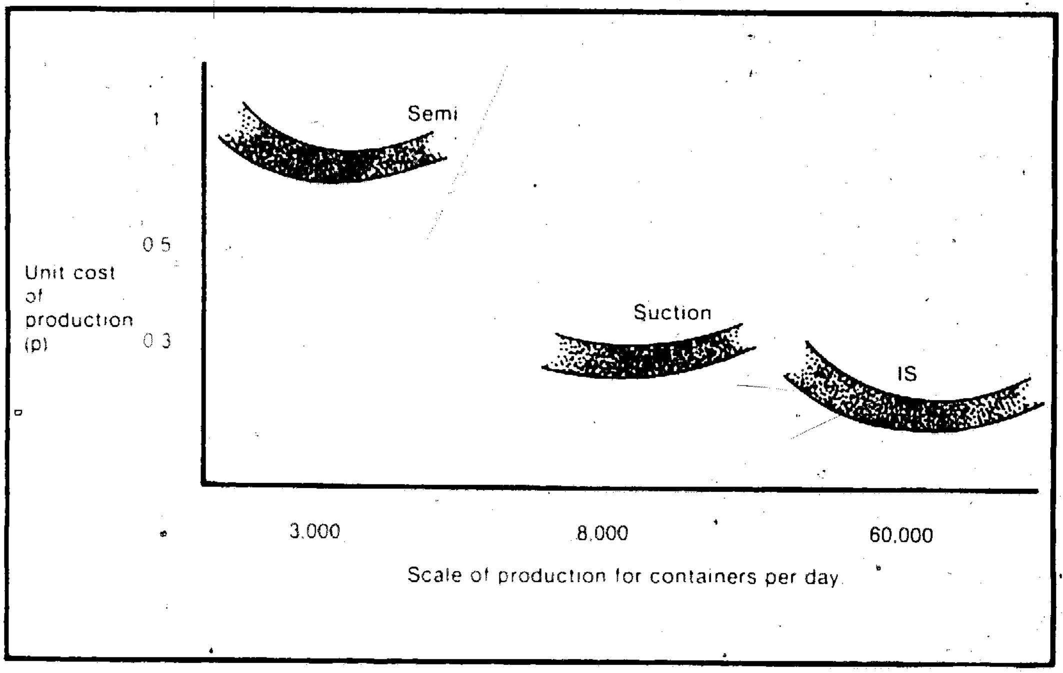
	SEMI AUTOMATIC	FULLY AUTOMATIC		
		Single head suction machine	IS (4 section) machine	R7
Machine costs	£5,500	£35,000	£250,000	£130,000
Manning levels[1]	3	1/2[2]	1	1
Output per shift	1,200	3,000	20,000	18,000
Minimum production time[2]	1 shift	3 shifts	21 shifts	21 shifts
Minimum production run[2]	1,200	9,000	420,000	375,000
Glass wastage	30%	20%	10%	10%

Notes

(1) 1 person looks after up to 3 suction machines
(2) Based on consideration of downtime to change moulds over

easier to operate and require a lower level of skills than feeder-fed machines, which would almost certainly require a greater degree of specialist assistance for a longer period.

Analysis of costs of production from these three options for a range of countries is summarized in Figure 16 which shows that the unit cost of production falls as the scale of production increases up to 60,000 containers per day.



R. Woodliff

Figure 16: Graph illustrating the range of unit forming costs[1] using semi-automatic and automatic forming equipment.

NOTE 1: Unit forming costs are calculated on the basis of capital recovery (15% over 5 years), labour (£0.25 – £1.50 per day), electricity, and maintenance. No allowance is made for the cost of glass.

Equipment Supply

Cost savings can be made by compromising with the quality of the equipment bought. Equipment produced in India, for example, is far cheaper than that produced in the developed countries. However, it is not always of the best quality. For example, an electric lehr from India costs less than one from the UK, but the heating elements tend to burn out much sooner. This does not rule out machines from this source, as better quality elements are obtainable from the UK which could be used to replace the Indian ones, at very little extra cost.

Experience suggests that with a little time and money, equipment from India could be upgraded to the quality of equipment from developed countries, but overall cost would be much cheaper than developed country costs.

Similarly, with furnace design: a furnace can be designed to have a campaign life of 3 years, with the use of expensive, specialized refractory blocks. However, with a combination of cheaper locally made (or Indian) refractory blocks and special blocks, the campaign life will be reduced to say 1.5 or 2 years before a rebuild is necessary. In this time the plant could be expected to have generated enough income to pay for the rebuild, with profits probably equal to those made by a more expensive furnace which lasted longer. Such a decision is purely economic, and so local conditions would dictate which direction to take.

Any glass furnace has a limited life, and the company must make allowance in its financial projections to cover the cost of a rebuild every 2 to 3 years, and in the production forecast to have manufactured a stock of glassware to cover the period in which the furnace is rebuilt, so as not to lose its market share.

Table 5: FUEL TYPE CONSIDERATIONS

For 5 tonnes of glass/day	ASIAN COUNTRY		AFRICAN COUNTRY		– – – – – – – – – – – –	
	Unit Cost (£)	Total Cost (£)	Unit Cost (£)	Total Cost (£)	Unit Cost (£)	Total Cost (£)
ELECTRICITY						
Furnace – 300 kW x 24 hrs	£0.04/kWh	288	£0.04/kWh	288	. . . . . /kWh	. . . .
Lehr – 50kW x 24 hrs	£0.04/kWh	48	£0.04/kWh	48	. . . . . /kWh	. . . .
	£4 (standing)	4	£27 (standing)	27	. . . . . (standing)	. . . .
		340		363		
OIL						
Furnace – 450 galls	£0.50/gall	225	£1/gall	450	. . . . . /gall	. . . .
Lehr – 65 galls	£0.50/gall	33	£1/gall	65	. . . . . /gall	. . . .
		258		515		
GAS						
Furnace – 2000m^3	£0.03/m^3	60	Generally not available in Africa		. . . . . /m^3	. . . .
Lehr – 300m^3	£0.03/m^3	9			. . . . . /m^3	. . . .
		69				
COAL						
Furnace – 3,700 kgs	£100/tonne	370	Generally not available in Africa		. . . . . /tonne	. . . .
Lehr – 65 galls (oil)	£0.50/gall	33			. . . . . /gall	. . . .
		403				

Fuel Type Considerations

The optimal choice of fuel will be dictated by supply considerations in particular, unit cost and availibility. The table opposite presents cost data on four options, electricity, oil, gas and coal, and was used to decide the fuel choice shown in Table 7 of Chapter Three.

A space is left for the reader to put in their own costs so that a decision on fuel type can be made.

Chapter III

INDICATIVE ECONOMICS

Data in this chapter is based on countries in which the author has been involved over a four year period. Particularly strong interest in small-scale glass production has been shown from Malawi, Kenya, Ghana, Mauritius and Botswana in Africa, and from Sri Lanka, Bangladesh, Pakistan, India and Indonesia in Asia. The economic analysis is presented as a proforma profitability statement for an African and Asian country, based largely on data from Kenya and Bangladesh. To allow a more accurate estimate of profitability to be made in different countries, the final column of the analysis is again left blank to be filled in by prospective investors using unit costs from their own country.

The analysis is presented in five tables as follows:

Table 6	Investment schedule
Table 7	Estimate of direct unit production costs
Table 8	Estimate of indirect production costs
Table 9	Estimate of revenue
Table 10	Statement of profitability

Table 6: INVESTMENT SCHEDULE

		ASIAN COUNTRY		AFRICAN COUNTRY		- - - - - - - - - - -	
		Unit Cost (£)	Total Cost (£)	Unit Cost (£)	Total Cost (£)	Unit Cost (£)	Total Cost (£)
LAND AND BUILDINGS							
Land	1 ha	£24,000/ha	£24,000	£20,000/ha	£20,000	....../ha	....
Building	60m x 20m	£75/m^2	£90,000	£75/ m^2	£90,000	....../m^2	....
EQUIPMENT							
Furnace (5TPD)			£71,000		£71,000		....
Lehr	1		£12,000		£12,000		....
Compressor	1		£5,000		£5,000		....
Truck	1		£15,000		£15,000		....
Suction Machines	3	£35,000	£105,000	£35,000	£105,000	......	....
Import Duty		35% on above	£73,000	30% on above	£62,000	..% on above	....
WORKING CAPITAL							
1 month's direct production costs			£10,000		£20,000		....
			£405,000		£400,000		

Table 7: DIRECT PRODUCTION COSTS

		ASIAN COUNTRY		AFRICAN COUNTRY		— — — — — — — — — — —	
RAW MATERIALS							
Sand	2,500 kgs	£12/tonne	30	£60/tonne	150	....../tonne	......
Soda ash	1,000 kgs	£190/tonne	190	£40/tonne	40	....../tonne	......
Limestone	650 kgs	£14/tonne	9	£10/tonne	7	....../tonne	......
Cullet	1,000 kgs	£10/tonne	10	£20/tonne	20	....../tonne	......
Others	(10% of above costs)		24		22		......
FUEL		(gas)	69	(electricity)	363	(..........)	......
PACKING MATERIALS (5% of raw materials)			12		11		......
MAINTENANCE (on equipment)		2% of £281,000 (over 300 days)	18	2% of £270,000 (over 300 days)	18	2% of ...... (over 300 days)	......
LABOUR							
Skilled	14	£0.60/day	8	£3/day	42	....../day	......
Unskilled	52	£0.30/day	16	£2/day	104	....../day	......
Supervisory	6	£2.00/day	12	£5/day	30	....../day	......
DAILY TOTAL			398		807		
ANNUAL TOTAL			£120,000		£242,000		

Table 8: INDIRECT PRODUCTION COSTS

	ASIAN COUNTRY		AFRICAN COUNTRY		— — — — — — — — — —	
	Unit Cost (£)	Total Cost (£)	Unit Cost (£)	Total Cost (£)	Unit Cost (£)	Total Cost (£)
DEPRECIATION						
2.5% of buildings		£2,000		£2,000		....
10% of equipment		£16,000		£16,000		....
25% of vehicles		£5,000		£5,000		....
50% of furnace		£48,000		£48,000		....
ADMINISTRATION						
4 managerial	£750 pa.	£3,000	£4,000 pa.	£16,000	......pa.	....
5 clerical	£200 pa.	£1,000	£1,200 pa.	£6,000	......pa.	....
GENERAL OVERHEADS		£10,000		£20,000		
		£85,000		£111,000		....

Note: General Overheads is an indicative figure for selling and administration costs and includes transport, advertising, post, telephone, etc.

Table 9: ESTIMATE OF REVENUE

		ASIAN COUNTRY		AFRICAN COUNTRY		- - - - - - - - - - -	
		Unit Price	Cost/ Tonne	Unit Price	Cost/ Tonne	Unit Price	Cost/ Tonne
PHARMACEUTICAL BOTTLES							
1 oz size	35 grams	£1.67/100	£477	£3.05/100	£872	..../...	......
4 oz size	100 grams	£2.29/100	£229			..../...	......
8 oz size	190 grams	£4.80/100	£253			..../...	......
SPECIALIST BOTTLES							
28cc ink bottle	65 grams	£2.50/144	£270	£2.90/100	£446	..../...	......
13cc vial	40 grams			£2.52/100	£630	..../...	......
TUMBLERS							
200 ml	200 grams	£7.20/144	£250	£10.08/144	£350	..../...	......
OTHERS							
						..../...	......
						..../...	......
						..../...	......
						..../...	......
Gross output:		5	TPD	5	TPD		... TPD
at 80% capacity utilization		4	TPD	4	TPD		... TPD
at 80% forming efficiency		3.2	TPD	3.2	TPD		... TPD
Net output p.a.		960	TPA	960	TPA		... TPA
Unit selling price (low)		£229/T		£350/T			..... /T
(high)		£477/T		£872/T			..... /T
Revenue (low/conservative)		£220,000		£336,000			......
(high /optimistic)		£458,000		£837,000			......

Table 10: STATEMENT OF PROFITABILITY

	ASIAN COUNTRY		AFRICAN COUNTRY		- - - - - - - - - - -	
Direct production costs	£120,000		£242,000		....	
Indirect production costs [1]	£ 65,000		£111,000		....	
TOTAL ANNUAL COSTS		£205,000		£353,000		....
REVENUE						
(conservative)	£220,000		£336,000		....	
(optimistic)	£458,000		£837,000		....	
PROFITS [2]						
(conservative)		£15,000		(£17,000)		....
(optimistic)		£253,000		£484,000		....
INVESTMENT	£405,000		£400,000		....	
RETURN ON INVESTMENT						
(conservative)		4%		−2%		....
(optimistic)		62%		121%		....

Note: (1) No allowance is made for financing charges (interest on loan)
(2) Profits are shown net of depreciation

CONCLUSION

The analysis highlights the high rates of return which can be earned in both Africa and Asia using equipment derived from European, Indian and local sources as suggested in Chapter Two. Profitability is highly dependent upon market conditions and this emphasizes the need for careful consideration of the product mix chosen by the investors. Any investment plan for such a unit needs to spell out quite clearly the products by type, weight and price, also giving an indication of market size, predicted market share and proposed marketing strategy (ex-factory sales to customers making their own collection, sales to wholesale and/or retail outlets, contract sales to industrial enterprises, etc.) Equally, attention must be given to production costs, in particular to raw materials, fuel and labour, and to the implications of fixed and variable costs for the break-even level of capacity utilization.

Funds will also need to be allocated to the important activity of furnace rebuilds every 2 to 3 years (particularly with continuous furnaces), and in a time of rapid price inflation, carefully constructed cash flow forecasts will be necessary, if the substantial sums of money involved are to be made available.

The costs of a badly-planned and badly-managed operation far outweigh the cost of a feasibility study.

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The Group, an independent charity, helps to introduce technologies suitable for rural communities in developing Countries. The Group is also active in assisting small scale industry in the UK.

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