No feature of the economic life in Australia is more provocative of thought than the growth of the glass industry. From a very small beginning, the industry now operates in every mainland State and New Zealand, supplying both countries with almost every form of glass requirements made to-day, under the most modern methods of manufacture, and providing this country with an industry which is equal in every respect to any other in any part of the old world.

When I say that this industry has been developed from the old style of glass working, which has hardly been altered from the year 50 B.C., to a modern industry, in the space of approximately twenty years, it can be regarded as a striking tribute to the forcefulness of Australians when called upon to exercise their resources to overcome almost insuperable difficulties in their efforts to modernise an industry, which now produces a wider range of glassware than any other separate Company in the world.

Before going on to the modern methods employed, a few facts concerning the early history of one of the oldest known substances should prove interesting. Glass, as we see it daily, is just one of the many commercial metals known to mankind, but when viewed from scientific and technical angles, it becomes very interesting and important.

The basis of ordinary glass is approximately 74% silica, 16% sodium and 10% calcium. The composition, however, varies, and other materials are added for colouring and decolourising.

There are many legends and theories concerning the discovery of glass. Early writers say that some Phoenician mariners were driven ashore on the sands at the mouth of the River Belus by a storm, and they made a fire on a hearth of soda blocks or natron on a sandy beach, the fire being so intense as to cause fusing of the silica, and leaving a glazed substance, from which the first idea was developed.

One other legend, which may be the most likely to be correct, is that of the burning down of a corn store, the ash being in composition approximately that of use in commercial glass.

Until lately Egypt was generally recognised as the original home of glass, but Sir Flinders Petrie, however, definitely states
that the Egyptians learnt the art from some earlier and external people, but as the question is one dealing with the happenings of 7000 years ago, at the dawn of history, it is likely to remain an unsolved problem, or, at least, one with an uncertain answer. Even so, the earliest specimens now known to the world came from Egypt, and were made somewhere in the region of 3500 years ago. The slide which I am about to put on shows an example of the Egyptian art as an ornament in coloured glass which was made somewhere about 1370 B.C.

Transparent glass was unknown because of difficulties, the major one of which was the lack of heat, and, owing to the fact that the blow pipe was not introduced until a much later age (50 B.C.), the articles made were very small and expensive. The Romans used glass for more domestic purposes than we do to-day. Lacking fine porcelain, they fashioned glass objects to take its place for household use.

They also did some very beautiful work, as witness the famous Portland Vase, which is made of cameo glass, and which, as we all know, has had a very stormy career.

This cameo glass is fashioned or made by applying numerous layers of glass on top of the original foundation, and then cutting away the outer coat to form a decorating pattern. When we realise that in making this laminated glass great care is necessary in producing two glasses of an exactly similar co-efficient of expansion, because, as we all readily understand, where two or more glasses are combined, the co-efficient of expansion must be correct, otherwise breakage would very quickly occur, it will be seen that the Egyptians had mastered quite an appreciable amount of knowledge in the art of glass making. In itself this vase is beautiful, as will be seen from the slides. This same method of laminated glass applies particularly to-day to lighting bowls or shades, which are brought into contact with heat from some of the high-powered electric globes that are used on the inside, whilst they are in contact with atmospheric temperature on the outer surface.

The first glass furnaces were constructed in the form of a beehive, and were made of fireproof clay. Inside were placed a number of fire clay crucibles or pots, in which the raw materials were melted. They were fired with wood, consequently all glass factories were built in or near the forests. Owing to the crude method of building these furnaces and the bad refractories and fuel used, the temperature was limited, thus necessitating the manufacture of a very soft glass, that is, low in silica and high in alkali. The melting results were uncertain, and the glass
blowers were called to work any time of night or day, when the glass happened to be ready for working. This same practice was in force in glass factories in Australia less than 50 years ago. Improved pot furnaces are still in world-wide use for production of glassware, such as crystal and rich-coloured glass.

In 1615 the English Government prohibited the use of wood in glass furnaces. This brought about the removal of all glass factories from the forests to the coal-bearing districts; thus it will be seen that owing to the fear of forests being worked out, and timber becoming a scarcity, a benefit was conferred on this industry, as it was forced to use coal, which necessitated alterations of furnaces, with the resultant benefit that a higher temperature was obtained, and enabled better glass to be made.

As we are aware, glass is formed by fusing silica with active mineral solvents, such as alkalies, earthy bases, or metallic oxides. Silica used in early glass making was gained by crushing or grinding flint stones, and so it became known as "flint" glass.

Much more data and many interesting details could be related about early glass manufacture, but, as my previous paper dealt mostly with the origin and history of glass, the object of this paper to-night is to give an insight into more modern manufacture and methods.

By way of interest, I will read for you a few of the most commonly used batch mixtures:

*Dark Green*

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1000 parts</td>
</tr>
<tr>
<td>Soda Ash</td>
<td>200</td>
</tr>
<tr>
<td>Potash</td>
<td>120</td>
</tr>
<tr>
<td>Lime</td>
<td>140</td>
</tr>
<tr>
<td>Potassium Chromate</td>
<td>10</td>
</tr>
<tr>
<td>Copper Oxide</td>
<td>20</td>
</tr>
<tr>
<td>Iron Oxide</td>
<td>10</td>
</tr>
<tr>
<td>Borax</td>
<td>20</td>
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</tbody>
</table>

*Ruby*

<table>
<thead>
<tr>
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<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1000</td>
</tr>
<tr>
<td>Soda Ash</td>
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</tr>
<tr>
<td>Potash</td>
<td>150</td>
</tr>
<tr>
<td>Lime Spar</td>
<td>150</td>
</tr>
<tr>
<td>Selenium</td>
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</table>
Amber—

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1000</td>
</tr>
<tr>
<td>Soda Ash</td>
<td>250</td>
</tr>
<tr>
<td>Saltecake</td>
<td>80</td>
</tr>
<tr>
<td>Lime Spar</td>
<td>225</td>
</tr>
<tr>
<td>Sulphur</td>
<td>15</td>
</tr>
<tr>
<td>Arsenic Oxide</td>
<td>5</td>
</tr>
</tbody>
</table>

and the necessary amount of carbonaceous ingredient for colouring.

Lead Glass—

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>53.55%</td>
</tr>
<tr>
<td>PbO</td>
<td>32.34%</td>
</tr>
<tr>
<td>K₂O</td>
<td>12.82%</td>
</tr>
<tr>
<td>Na₂O</td>
<td>3.34%</td>
</tr>
</tbody>
</table>

 Remainder made up of arsenic and various other constituents for the purification of the glass.

Of all industrial arts, bottle manufacture has been the slowest to change from hand to machine methods, the main reason for this being that the skill and delicate handling needed to form glass to the required shape seemed too much to expect from a machine. Secondly, molten glass, owing to its intense heat and rapid physical change from the plastic to the solid state, made observations of the characteristics of the glass in these rapid changes very difficult. Added to this, of course, was the hostility of the glass worker to anything mechanical.

As mentioned before, the blowpipe first came into being about 50 B.C., and glass was first made in England in the region of 676 A.D., but it was not until 1888 that the first attempt at machine design was commenced.

It is generally believed that the first bottle machine originated in America, but it is pleasing to be able to state that such was not the case. The first machine was designed and built in England by one, Ashley of Castleford, in 1888. It was the crude type of machine, but was the forerunner of some of the most intricate machinery in the world to-day. It was followed in the next few years by various makers in Europe and America, and all these machines were of a semi-automatic type and of a very simple principle.

The possibilities of machine-made bottles being thus proved, and the demand increasing all the time, made it quite evident that these slow single-mould and blank machines must be speeded up in their production output; but, owing to the fact that there
is a limit to the amount of ware that one unit will produce, it became necessary to introduce more units to the machine. This addition meant the designing of a new type of machine, and it was from this step that all the modern machines of to-day came into being.

It is a strange feature that bottle making at this juncture was divided into two distinct lines of thought and practice for the initial stages of handling the glass, one being the use of vacuum to draw the molten glass into the primary mould, and the other being the delivering of a gob, or a pre-determined mass of molten glass, to the primary mould, from an automatic glass feeding and shaping device.

I should like to bring before your notice one or two of the totally automatic bottle machines. Although fundamentally the same principle applies, these machines differ a great deal in appearance and mechanical design from the machine hitherto mentioned. They are known as the suction type, because, instead of the parison mould being fed by a gob of glass from a feeder, it is filled by vacuum.

The Owens automatic bottle machine is a continuous rotary machine, electrically driven, and consists of a number of arms, or what are commonly known as “heads,” supported by and located radially around a central shaft, mounted on a travelling frame or carriage. Each of the heads is a complete unit, and carries a finishing mould, parison mould, neck mould, and a plunger for forming the neck or mouth, the mechanical movements of the various component parts of each head being actuated by stationary cam paths on the fixed framework of the machine.

The central shaft and the projecting arms therefrom, supporting the heads, are hollow castings, and provided with outlets controlled by butterfly valves. Through these ducts air is circulated for cooling the moulds, the air being supplied by a high-pressure fan with a capacity of about 12,000 cubic feet of free air per minute. The machine is equipped with two motors, one for raising and lowering the vertical adjustments, and another for driving. There are six standard types of Owens machines, having from six heads for medium small or medium large ware, to ten arm machines for small and large ware respectively, and fifteen arm machines also for small and large ware. In addition, special machines are built for the manufacture of large water bottles. The first type of this machine to be built was the six-arm, but it was soon found that on large orders for a particular bottle, where the additional mould expense was justified, a machine with a greater number of units
or heads would make greater production possible, and it was therefore decided to build a machine with ten arms. After several years, the same reason seemed to justify a still greater number of units per machine, and the fifteen-arm machine was accordingly built. There are, however, very few kinds of bottles used in sufficiently large quantities to justify the mould expense and operating difficulties of the fifteen-arm machine, and this size has not therefore been generally used. The ten-arm machine is the most economical size, although there are many orders of small quantities where the cost of manufacture is less on the six-arm than on the ten-arm machine.

Now, in operation, the machine is set adjacent to an auxiliary furnace, which furnace is composed of a combustion chamber over a revolving pot. The revolving pot is 10 feet in diameter, and carries glass to a depth of eight inches, this being supplied or fed continuously from the refining tank of the melting furnace.

A portion of the revolving pot projects approximately 16 inches beyond the walls of the combustion chamber, exposing a segment of the glass surface. The gathering moulds of the machine dip into this exposed molten glass consecutively as the machine rotates, and as each mould dips into the glass a vacuum is automatically created in the mould, sucking the glass up into it, and thereby forming the parison. The machine and the pot rotate in opposite angular directions, so that over the small path in which the mould is dipping into the glass the linear movements of the two are in the same direction, although the mould is travelling rather more rapidly than the glass beneath it, thus keeping in contact with hot, unchilled glass.

As the mould rises and moves away from the glass, a knife automatically cuts off the string of glass which remains attached, dropping that portion not in the mould back into the furnace. Whilst the knife is in position, a slight puff of air consolidates the parison. During the rotation of the machine the parison mould opens, leaving the parison exposed, suspended by the neck-ring mould.

The open finishing mould is situated at the extremity of a hinged arm, and rests upon small bearing rolls, which run on a cam path. At the feeding position this track is so situated that the finishing mould arm hangs downwards and allows of clearance between the mould and the pot. Beyond this point the track slopes upwards, and the mould in its rotation is thus raised until it is on the level of the parison, which is at this stage freed from the parison mould. When the finishing mould has risen it is gradually closed by means of toggle arms actuated
by rolls running on a second cam path, the operation being so adjusted that the closed mould now surrounds the parison.

Compressed air is admitted at this stage, and the bottle is blown. The cam track once more dips, and the finishing mould descends, the halves afterwards opening to free the finished bottle. The latter is prevented from falling by the action of a knock-out arm, which moves over and holds the bottle upon the base-plate of the mould. At a further stage of the rotation, whilst the finishing mould is still depressed, the carrier passes a shaped receiving trough, and the bottle slides down on to a table for conveyance to the lehr. This particular machine is capable of immense production, as many as 4000 to 5000 bottles per hour being produced.

For certain kinds of bottles, and on sizes below three ounces in capacity, much greater production is possible by means of what is commonly known as the plural mould operation. This is where either two or three bottles are made at one time in one mould on each head, the mould being a compound of two or three single moulds, in which case it practically doubles or triples the figures given.

To illustrate this, there was an actual case of a bottle of quarter-ounce capacity being made three in each mould on a ten-arm machine. The machine operated at six revolutions per minute, and over a period of ten days running actually produced an average of 10,080 marketable bottles per hour, or 1680 gross per day.

The question is sometimes asked as to the reason why the Owens type machine has not been introduced into Australia. The above figures satisfactorily supply the answer.

The first step in bottle manufacture and all glass manufactur- es is the correct preparation of the raw material. The sand, upon arrival from the deposit, is elevated into a silo, from where a continuous flow of sand is passed through a machine, which delivers a continuous stream of sand into a revolving screen, where it is washed with water, which separates all lumps and vegetable matter from it.

This screen is cylindrical in shape, and revolves on the same shaft as the spiral flight from the feeding machine. The sand and water passes through the mesh of the screen, whilst vegetable matter and lumps gradually find their way out through the open end of the screen. It is then passed over specially-constructed gravity separation tables for further classification, during which the impurities are removed, and from there it is
dried in centrifugal driers, and thence to the silos and the mixing room.

The other raw materials are ranged inside in silos, on the bottom of which are provided doors for discharging the raw material into the combined weighing and mixing machine, which is electrically operated. This batch from the mixing room is discharged into a hopper, and from there, on to a conveyor, and elevated and conveyed to hoppers at the end of the furnace.

In some cases the batch is delivered direct into a specially-constructed box, which holds about one ton.

These boxes are transferred to a monorail system and taken to the furnace, where the completed batch of one ton is discharged in the correct amounts on top of the already molten glass. In the case of the batch going to the stationary hoppers at the end of the furnace, it then gravitates to the batch stokers, which consist of a spiral flight revolving in a tube at a speed necessary to maintain the constant glass level in the furnace. The furnace or tank in which the batch is melted is usually of the regenerative or recuperative type, although direct coal fire, oil, or electricity can also be used.

Producer gas, however, is the main fuel used for the melting processes, although quite a quantity of town gas and fuel oil is used for auxiliary purposes. The gas producer is of the suction type, and will gasify up to 30 tons of coal per 24 hours. The gas is passed from the producer into a dust collector, and from there along a steel flue, lined with fire brick and insulating bricks, to the downcast at the furnace. From there it passes through a specially-constructed reversing drum, and on to the furnace.

The furnaces are built of refractory material, and are generally about 40 feet long by 20 feet wide in the melting end of the furnace, and 20 feet wide by 15 feet long in the refining or working end, the depth of glass being usually from three to four feet.

The gas is admitted through side ports, either side alternatively being used as inlet for air and gas, or the outlet for the products of combustion. The working and melting ends are separated by means of a partly-submerged bridge, at the bottom of which is a throat about 10 inches by 12 inches, through which the melted glass must flow to gain access to the working end, and from there it passes through ports in the front wall to the automatic feeding device, which on a tank of the above dimensions number about seven. These automatic feeders are mounted at the outer end of a projecting fore-hearth or subsidiary tank which, in turn, forms an extension of the main melting furnace,
and there the glass is treated to a correct working temperature to suit the particular job being made. The work of these feeders is to deliver into the primary mould a gob of glass approximately the same shape as the mould into which it falls. The subsidiary tank or feeder fore-hearth is situated in such a position that the glass can freely flow into it, although surface impurities are kept back by obstruction blocks. At the end of the chamber, remote from the tank, is the orifice through which the glass is extruded, below which is situated a pair of shear blades. A cylindrical plunger, made from refractory material, passes through the roof of the chamber and into the glass directly above the orifice. The upper end of the plunger is held by a mechanism which imparts to it a reciprocating and revolving motion. The glass reaches the extrusion orifice at the required working temperature, and, owing to its viscous state, has a tendency to a gob formation rather than to flow out in a thin liquid stream. The earlier types of feeders were of the continuous flow type, and it is very difficult to control the glass to give anything like the proper shape required, but on the later feeders means to control the glass, and so give the correct shape to the drop, were instituted.

Whilst the primary mould on the machine below comes into position, the glass is held back inside the orifice by the upward movement of the aforementioned plunger. When the plunger reaches the top of its stroke, its upward influence on the glass is practically finished, and the glass begins to run forward and fall, and as the drop becomes heavier, it stretches out. At this point the plunger rapidly descends, and forces out more glass, which prevents undue thinning, and also helps to determine the shape required. The plunger reaches the bottom of its stroke and the upward movement is repeated, and so thinning the back of the drop through which the shears are correctly timed to cut. This has the effect of keeping the flowing glass from running on to the shears. Immediately the drop is severed, the glass is held in the orifice until the next parison mould takes up its position below. The severed drop now falls through the air into the waiting parison mould, which is in an inverted position. The forming machine shown on the accompanying slides is an American type, and consists of two separate tables, each of which revolves round its central column. On one table are situated six parisons or primary moulds, and on the other six finishing moulds. The reason for the primary moulds and finishing moulds is because the container to be made must be made in two distinct steps, each step having its own series of operations. The primary mould takes the glass in the first place and works it into the correct shape and temperature for
the finishing mould, just as in the old style hand working the bottle maker gathered the glass on the end of his pipe, and worked it on a stone or marver until the shape and temperature were approximately right for the final blowing, but with the introduction of machines the desired effect is derived by the use of the blank mould.

Returning to the description of the machine: The tables have an intermittent movement, but rotate and pause at the same time, and each time turn through an angle of 60°. The machine is air driven, and controlled in all its movements. All individual operations are timed by air valves, which supply the air at the correct moment to the cylinder controlling these movements.

Both sets of moulds are hinged, and open and close mechanically, and all the moulds project over the edges of the table, and the central vertical axis of the parison and blow moulds, when closed, coincide at the point of transfer. The ring mould itself is hinged, and opens independently of the parison mould, serving to suspend the parison between the time it is left by the parison mould and enclosed by the blow mould. The bottom plate of the blow mould is rigidly fixed and independent of the rest of the mould which, however, on closing, fits tightly round it.

The parison mould, although fixed radially, can revolve about an axis at right angles to the vertical axis of the mould, thus allowing the parison to be inverted. The intermittent rotation of the machine is derived from the reciprocating action of a rack driving a gear wheel common to both tables; at every station the tables are indexed to ensure correct position.

Immediately the glass settles in position in the parison mould, a puff of compressed air from the feeder trips a valve, which brings a blow-head down on to the top of the primary mould, and the glass is forced down and compacted into the neck of the parison mould and around the plunger, thus completing the external formation of the neck ring and the bore. The table moves on to the second position, and it is while this movement is being carried out that the parison mould returns to its correct position, that is, it revolves on its horizontal axis through 180°, making a complete turnover.

Compressed air is admitted from the top, and the bottom of the parison is sealed with a baffle plate, and thus the glass is then blown to the shape of the parison mould, which is the shape pre-determined to give equal distribution of glass, when transferred to the finishing mould and blown.

The table then moves to the third station. The blank mould opens, leaving the glass suspended by means of the neck ring.
At this point the bottom plate of the blow mould is directly beneath the suspended glass, and the two halves of the finishing mould close around it. The ring mould opens simultaneously with this operation, and the glass is then entirely free from the first table, and continues its journey around the second. At two succeeding stations on the blow mould table blowheads descend on to the top of the bottle and admit compressed air into the parison, and so blow the bottle.

Finally, the mould opens, and a pneumatically-operated ‘take-out’ places the bottle on a moving conveyor, which carries it under the mechanical stacker. From there it is picked up and placed into an annealing oven, known as a lehr. These mechanical stackers have only been in operation a year or two. Previously the stacking was done by hand.

The lehr consists of an endless wire mattress belt, which is drawn through a long tunnel built up of cast iron sections and heavily insulated. At the front end of the lehr is situated a fire-box, kept at an even temperature by a thermostatically-controlled oil burner. An induction fan is situated at the back end of the lehr, which induces a draft from the fire-box, thus causing a gradually diminishing temperature along the lehr, and naturally, as the bottles are slowly conveyed through it, they are not subjected to any sudden change of temperature, which would either break or set up bad strains to weaken the bottles. Sorters take the bottles from the lehrs and pack the quality ones in crates ready for prompt delivery or storage in the warehouses.

Window Glass—

Window glass is of two distinct varieties—sheet glass and plate glass. And, although sheet glass is now mechanically made, as late as 1928 hand methods still existed in Europe. The original method of making sheet glass was to gather on the end of an iron a large ball of glass, which, by skilful handling, was spun out into a flat disc. It was then broken off the pipe and annealed. This glass could always be distinguished by the thick piece left where the gathering iron was attached.

The Franco-German method was introduced some time later, in which process a cylinder was blown of a length corresponding to the length and circumference equal to the breadth of the sheet required, and it was found possible in this way to make sheets 6 feet 6 inches long by 3 feet 6 inches wide without undue exertion. The pipe used was of the usual type, but possessed a very large nose-piece. To commence the process, the nose of the pipe was heated and dipped into the glass and rotated once or twice, so that a small amount of glass was withdrawn.
Rolling and pressing on the marver, coupled with gentle blowing, served to shape the gather into a small sphere. When the metal was sufficiently cool, it was again dipped into the glass and rotated, whereby a second gathering of molten glass was obtained. The shaping of the glass was then accomplished as it rested upon the post and suitably moulded with a wooden shaping tool, kept moist by occasionally dipping in water. When the glass was sufficiently set, a third gathering was made, this being usually sufficient for small cylinders, but where large sheets had to be made, up to five gatherings were often necessary, each being treated in like manner to the second.

An assistant then took the pipe, and then, by rotating it in a fork, and also shaping the glass upon the special wooden block, obtained a parison which was ready for further treatment. The thin upper wall close to the pipe was then chilled sufficiently to retain its shape, and this determined the diameter of the cylinder. On the other hand, the lower part of the wall was still thick, and remained fairly soft. The parison was then partly introduced into the “glory-hole” (which is a little furnace), so that the thicker portion only was heated, the pipe being rested upon the hook in the partition and rotated.

When the heated portion was sufficiently softened, the whole was rapidly withdrawn, the pipe being vertically over the pit, and by a swinging pendulum-like motion the parison was caused to elongate, partly under its own weight, and partly due to strong blowing down the pipe. By this means a cylinder with a wall of fairly even thickness was obtained. Should the lower portion of the cylinder have cooled before the parison was of sufficient length, it was again heated in the glory-hole, and the swinging process repeated. The next step consisted in opening the end of this long cylinder. For this purpose a rod was dipped into the pot, the small gathering of hot glass so obtained being brought against the centre of the closed end of the cylinder, whereby the glass was softened at this point. The cylinder was then rapidly thrust into the glory-hole, and the hole in the other end of the pipe closed with the hand. By this means the enclosed air was heated, which expanded and blew a small hole in the end of the cylinder where the glass had been softened. The glass was once again removed, rested upon the fork, and an assistant enlarged the hole so obtained by means of specially constructed tools. Again was the glass heated in the glory-hole, with slow rotation, until, when red hot, it was rapidly withdrawn and swung into the pit, when the lower end opened out to the same diameter as the rest of the cylinder. The blowing was then completed, the cylinder laid upon a special stand, the glass
close to the pipe touched with a cold iron, and the pipe freed and removed by striking it a sharp blow.

For cracking off the neck of the cylinder two methods were available. If the walls were thin, it was sufficient to draw a thread of hot glass and wrap it around the desired point, when at once, or on touching the glass with the moist finger, a clean crack was obtained. In the case of thicker glass, an iron tool was heated and drawn around the shoulder, followed by a drop of water, when the desired result ensued.

As a preliminary to flattening, the cylinder had to be sprung open lengthways. The cylinders were cut by means of a long red-hot iron drawn along the inside and wedges of wood were placed at each end to prevent the severed parts from springing together. These wedges later burned away in the flattening oven.

In order to flatten out the cylinder after springing open, it was introduced into a special furnace, heated sufficiently to soften, then stroked down upon a smooth, flat fireclay slab until it was quite flat, after which it was slowly cooled to anneal. Attempts at drawing sheet glass in the form of cylinders were made in 1885, but it was not until 1905 that a commercially successful process was obtained. The process consisted in dipping a hot "bait" into a drawing pot containing the molten glass, and, when the metal was attached to this bait, withdrawing it at a sufficient rate to form a cylinder of glass of uniform thickness and diameter. To prevent the cylinder wall from falling in before it had cooled sufficiently as the draw continued, air under pressure was admitted to the interior, the air pressure being so regulated as to keep the wall vertical. When complete, the cylinder was cracked off by so rapidly increasing the rate of drawing that the wall became exceedingly thin, when it could be broken away from the pot with ease.

When it is considered that cylinders up to 30 feet long were drawn, it will be understood that the lowering of the cylinder was no easy matter, and was most easily performed by pulling aside at the bottom by means of a rope and trolley, then lowering the bait until the glass rested upon a rack of semi-circular bearing arms. At this stage it was cut into lengths of five feet by means of an electrically heated wire, split, opened and flattened as in the hand method. The cylinder method of drawing sheet glass was not only laborious, but gave a product liable to many faults, whilst the sizes of the sheets were naturally limited.

Later the idea of drawing a continuous flat sheet was conceived, and the first success in this process was obtained by E.
Fourcalt, a Belgian, whose method was to draw the sheets vertically from the tank.

The greatest difficulty in drawing a flat sheet of glass was that, owing to the surface tension being overcome by the gravitational pull on the molecules, the sheet would become narrower, until such time as it broke off. To overcome this, the glass must be given an upward velocity at the drawing point in order to counteract the gravitational tendency.

In order to produce the upward movement, Fourcalt uses a float, a long trough of refractory material having, along its base, a split parallel to the length of the trough. The trough is caused to sink somewhat in the glass, and by two U-shaped arms the depth of penetration can be adjusted. Glass is therefore forced through the slit at any desired rate. If so left, the glass would fill the inside of the trough to the level of the liquid outside. This, however, is prevented by seizing the glass as it emerges from the opening by means of a bait and drawing it off in sheet form. The trough, by its weight, is thus constantly forcing a ribbon of molten glass under pressure through the slit, and the sheet remains uniformly of the same size in section as the aperture through which it is drawn. Two water-cooled tubes against the sides of the slit serve to cool the glass as it emerges.

The drawing machine is placed above the drawing pit, in which the glass is regulated to the correct working temperature. These machines are rectangular iron towers about 30 feet high, through which passes a framework, with a series of asbestos rollers set in pairs. The rotation of these rollers serves to draw up the sheet as it is formed, and the first pair is situated at about three feet from the surface of the glass. Each roller upon the right is given the same rate of movement by means of a vertical shaft and two bevelled gear wheels. The rollers on the left are carried on bell-crank levers, with counterpoises, in order to press them upon the glass, and they engage with the gears of the opposite rollers by long-toothed pinions, which allow for variations when glasses of varying thickness have to be prepared. Inclined sheets, the upper edges of which are on the level with the rollers, serve to prevent radiation of heat, and also to prevent any pieces of broken material falling when the glass above is cut. The gearing is driven electrically, giving a rate of movement varying from 9 inches to 45 inches per minute, a rheostat serving to regulate the rate to within one inch per minute. It is found convenient to keep the temperature of the drawing chamber or well at approximately 2000° Fahr.
To start the machine, the direction of rotation of the rollers is reversed, and a metal bait passed downwards through them to the float. The latter is then pressed down to give a flow of the desired rate, and the wheels are driven in the normal direction. The glass bait introduced picks up the molten metal and draws it up through the rollers, which are caused to rotate at the speed at which the glass emerges from the slit below.

As the glass emerges from the top of the rollers, or from the top of the machine, a platform is provided which enables a man to walk along with a cutting tool, and the sheet is then cut off at the desired length for handling, or for any special orders. The cutting tool cuts in the usual way, and the sheet above the cut is held by two men, who lift the cut sheet from the main body and transfer it to moving platforms, from which it is taken to the cutting benches.

The rate of working is approximately 45 inches per minute for glass 16 oz. weight, with a corresponding diminishing of speed with increase of thickness of the glass drawn, so that sheets a quarter of an inch thick are usually drawn only at the rate of 9 inches per minute. Sheets can be drawn up to 9 feet and 10 feet wide, and are uniform in thickness and brilliant with a fire-polished surface. The slow, even cooling, with no contact with chilling materials, gives a glass free from strain, which can be cut without trouble with a diamond or cutting machine.

The composition of window glass has to be very carefully worked out, because window glass, probably more than any other glass, has to be of a very durable nature, and to be able to withstand the severe weathering it obtains in every installation.

Whilst on the subject of window glass, I will briefly describe the method adopted for figured rolled glass. This is done by means of a rolling machine, the pattern of which is engraved on a circular roller, so that a continuous pattern is applied to the glass.

Crystal Glass.

Of all glass, probably the most attractive, and the one that has retained its hold on the public fancy is the ordinary clear handcut crystal. From time to time attempts have been made to introduce highly-coloured, and also delicately-coloured glass, but, whilst there has been a certain demand, it has never remained as a permanent fancy for the people. The charm of a gleaming piece of pure cut glass has an irresistible appeal for most people, and as most of you, whilst
quite familiar with the finished product, have perhaps not had an opportunity of seeing the actual production, I thought it worth while to bring along samples which should be of interest in so much as they will show the various stages through which a piece of cut glass passes before reaching the condition as seen by the average public. The article in question is a decanter, and here you will see some glassware which shows quite clearly the progress of the work.

I do not know that there is anything particularly modern about the cutting of glass, but, as it is a phase of glass industry, it is worth a few minutes’ consideration.

Proceeding further into the realms of modern methods, we now come to a machine for making glass tumblers.

(The lecturer briefly described the machine.)

This machine takes care of the heavier type of tumblers, but there is still another machine in operation which is a wonderful piece of mechanism, which has been built for light wall tumblers. On both these types of machines the finished product, after being annealed, passes through various finishing stages, namely, cracking off, grinding, glazing and etching.

*Refractories.*

You have seen that the mechanical side of this industry has progressed to such an extent as to be reasonably efficient in its mechanical state, but there are quite enough troubles in other phases of the industry which help to counteract the benefits and smoothness of operation from the mechanical side. The one thing above all others that is being sought after in this industry today is a suitable refractory. I refer to the blocks of which the furnaces are constructed, the thickness of which is 12 inches, and the size of the blocks anything from 3 feet by 12 inches square, to 3 feet long and 2 feet 6 inches high; in fact, all shapes and sizes of refractory-ware.

The temperature at which the glass is melted, reaching, as it does, 2900° F. in the case of Pyrex, is high enough in itself to test the quality of refractories, and when the fluxes necessary in the melting of glass are added, it will be quite understood that the test of a refractory is a very severe one, probably the most severe of all industries, and a search for the ideal material for the work goes on.

Improvements have been made, particularly over the last eight or ten years, and much money has been spent. A process requiring the electric melting and casting of blocks of suitable
shapes has been commercially developed, but at a cost almost prohibitive for general purposes.

Without a feeling of "talking out of school," I am pleased to be able to say that an Australian company has recently acquired the rights for what is the most perfect commercial refractory yet produced, it having all the advantages of the electrocast block, at considerably lower cost. The installation of the necessary plant is being gone on with, and we hope early next year very substantial savings will be made through its introduction. When it is realised that an ordinary glass furnace contains in the region of 300 tons of molten glass, it can be quite conceded what cost and damage would eventuate if the refractories failed to stand the pressure, and allowed the glass a free access amongst machinery and buildings. A window glass tank would probably contain twice as much molten glass as an ordinary glass tank.
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