So far as they involve distinct manufacturing processes, these varieties of glass will be here noticed in the above order. Such of the divisions as result from the application of special methods of ornamentation, and as come under the head of art glass, do not fall within the scope of this article.

Crown Glass.—This, with sheet or cylinder glass, forms all ordinary blown window glass. Both varieties are precisely the same in composition, being a mixture of sodic and calcic silicates, and differ only in the manner in which the sheets of finished glass are produced. The raw materials employed for this and all other kinds of glass vary within rather wide limits, and, as already explained, the form in which the sodic and calcic compounds are used may also be varied. The following composition of batch for window glass must therefore be regarded as only one out of very many mixtures in use :—

Sand, purified	100 parts
Chalk, or limestone	35 to 40 ,,
Sulphate of soda	40 to 45 ,,
Cullet	50 to 150 ,,

To these materials a minute proportion of white arsenic and peroxide of manganese, as bleaching agents, may also be added.

Crown glass was, in the early part of the present century, the only form of window glass made in Great Britain, and consequently it was generally recognized as English window glass, having been manufactured only on a very limited scale in any other country. Since the introduction of sheet-glass making, the crown-glass industry has steadily declined, and now its manufacture may be regarded as practically a thing of the past, not more than one or two crown furnaces being in operation. Seeing that it possesses little more than an historical interest, it is now unnecessary to enter into much detail as to the processes employed in the manufacture of crown glass.

The metal being brought to a proper condition for working, the "gatherer" dips into the pot of metal an iron pipe or tube, 6 or 7 feet in length, of the shape shown in fig. 6, heated at that end which takes up the glass, and, by turning it gently round, gathers about $1\frac{1}{2}$ lb

Fig. 6.—Blowing Tube.

of liquid glass on the end of it. Having allowed this to cool for a little, he again dips the rod into the pot, and gathers an additional quantity of from $2\frac{1}{2}$ to 3 lb. This is also permitted to cool as before, when the operation of dipping is again repeated, and a sufficient quantity of metal, from 9 to 10 lb weight, is "gathered," to form what is technically called a table or sheet of glass. The rod, thus loaded, is held for a few seconds in a perpendicular position, that the metal may distribute itself equally on all sides, and that it may, by its own weight, be lengthened out beyond the rod. The operator then moulds the metal into a regular form, by rolling it on a smooth iron plate, called the "marver," a term corrupted from the French word *marbre*. He then blows strongly through the tube, and thus causes the red-hot mass of glass to swell out into a hollow pear-shaped vessel. The tube with the elongated sphere of glass at the end of it is then handed to the "blower," who heats it a second and third time at the furnace, pressing the end, between each blowing, against the bullion bar, so called from the part thus pressed forming the centre of the sheet or "bull's eye," and by the dexterous management of this operation, the glass is brought into a somewhat spherical form. The blower now heats a third time at the "bottoming hole," and blows the metal into a full-sized flattened spheroid. When this part of the process has been completed, and the glass has been allowed to cool a little, it is rested on the "casher box," and an iron rod, called a "pontil" or punty rod, on which a little hot metal has been previously gathered, is applied to the flattened side, exactly opposite the tube, which is detached by touching it with a piece of iron, dipped beforehand in cold water, leaving a circular hole in the glass of about 2 inches diameter. Taking hold of the punty rod, the workman presents the glass to another part of the furnace called the "nose hole," where the aperture made by its separation from the tube is now presented and kept until it has become sufficiently ductile to fit it for the operation of the flashing furnace. Whilst here, it is turned dexterously round, slowly at first, and afterwards with increasing rapidity; and the glass yielding to the centrifugal force, the aperture just mentioned becomes enlarged. The workman, taking great care to preserve, by a regular motion, the circular figure of the glass, proceeds to whirl it round with increasing velocity, until the aperture suddenly flies open with a loud ruffling noise, which has been aptly compared to the unfurling of a flag in a strong breeze ; and the glass becomes a circular plane or sheet, of $4\frac{1}{2}$ feet diameter, of equal thickness throughout, except at the point called the bullion or bull's eye, where it is attached to the iron rod. The sheet of glass, now fully expanded, is moved round with a moderate velocity until it is sufficiently cool to retain its form. It is carried to the mouth of the kiln or annealing arch, where it is rested on a bed of sand and detached from the punty rod by a shears. The sheet or table is then lifted on a wide pronged fork, called a faucet, and put into the arch to be tempered, where it is ranged with many others set up edgewise, and supported by iron frames to prevent their bending. From 400 to 600 tables are placed in one kiln. A sketch of the interior of a crown-glass house, during the progress of these operations, has been given in Plate VI., fig 2. The kiln having been clayed up, the fire is permitted to die out, and the heat diminished as gradually as possible. When the glass is properly annealed, and sufficiently cold to admit of its being handled, it is withdrawn from the oven after the removal of the wall built into the front of the arch, and is then quite ready for use. The largest sized tables of crown glass made will cut into slabs 30 inches across, from which squared pieces measuring 38 by 24 or 35 by 25 inches may be obtained.

Sheet Glass, as already mentioned, is the same in composition as crown glass, which it has now entirely supplanted. The success of sheet glass is due principally to the fact that it can be produced in sheets of much greater dimensions than is possible in the case of crown glass ; it is free from the sharp distorting striæ and waves common in crown class ; there is no loss of glass as there is with the bull's eye of crown ; and modern improvements effected in the manufacturing process leave little distinction in brilliancy of surface between the two qualities. Sheet glass is made on the greatest scale in Austria, Germany, and Belgium, and it was long distinguished in the British market as German sheet glass. In 1832 Chance of Birmingham and subsequently Hartley & Co. of Sunderland introduced the manufacture into England, and in the hands of these firms, as well as of others who followed in their footsteps, the industry prospered and developed, till it has now attained dimensions equal to those it has reached in most of the Continental nations, where the art was long established before it came into use in England.

Sheet-glass making involves two principal operations,—(1) the blowing of the cylinder, and (2) the opening, flattening, or spreading of the glass. The structure and internal arrangements of the melting furnace is practically the same as in the case of crown glass. The ordinary type of oblong furnace usually contains 10 pots—5 in each side of the fire-grate—each pot being of a capacity of about 1 ton or 22 cwt. of metal. Radiating from the work-holes, and raised about 7 feet above the floor level, or a correspondingly deep sunk pit, are ten long stages with an open space between each sufficient to allow the workman to swing about his long tube freely in forming the elongated cylinder of glass. Fig. 7 is a ground plan of a common sheet-glass furnace and staging of planks *c*, at the extremities *d* of which are placed a tub of water and a wooden moulding-block. Instead, however, of having these stages erected in front of the melting furnace, it is now a common practice to gather and block the glass at the melting furnace, and to blow it in front of a separate oblong reheating or blowing furnace, from each opening of which the wooden stage runs out over a pit excavated to the depth of 7 feet or thereby. Common bricks may be used for the construction of this reheating furnace, as the heat required in it is by no means intense.

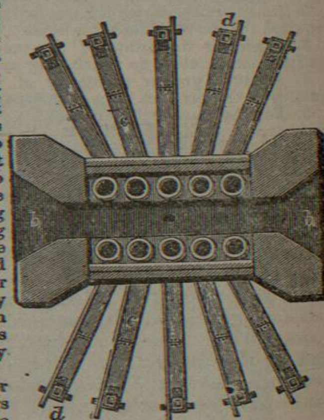

Fig. 7.—Plan of Sheet-Glass Furnace.

Blowing.—The charge or batch requires about 16 hours to melt, and other 8 hours are consumed in cooling it to the working consistency. When the metal is ready for working, the workmen take their stations, each having his own pot and stage and also an assistant, and commence making the cylinders. After gathering the quantity of metal required (which on an average amounts to 20 lb), the workman places it in a horizontal position in the large hollow of a wooden block (fig. 8), which has been hollowed so that, when the workman turns the metal, it shall form it into a solid cylindrical mass. In the meantime, the assistant, with a sponge in his hand, and a bucket of water by his side, lets a fine stream of water run into the block, which keeps the wood from burning, and also gives a brilliancy to the surface of the glass. The water, the moment it comes in contact with the glass, is raised to the boiling point, and in that state does no injury to the metal ; but it is only when the metal is at a high temperature that such is the case; for, whenever the glass is cooled to a certain degree, it immediately cracks upon coming in contact with water. When the workman perceives that the mass of metal is sufficiently formed and cooled (fig. 9), he raises the pipe to his mouth at an angle of about 75 degrees, and

commences blowing it, at the same time continuing to turn it in the wood block, till he perceives the diameter to be of the requisite dimensions (fig. 10), which are usually from 11 to 16 inches. The workman then reheats this cylindrical mass, and, when it is sufficiently softened, commences swinging it over his head, continuing to reheat and swing till he has made it the desired length, which is commonly about 45

Fig. 8.

Fig. 9

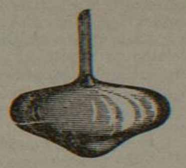

Fig. 10.

inches. It is now a cylinder of say 45 inches long by 12 inches in diameter, one end being closed, and the other having the pipe attached to it. The workman begins to open the end which is closed, for which purpose he encloses the air in the cylinder, by stopping the aperture of the pipe with his finger ; and then placing the close end of the cylinder towards the fire, it becomes softened, while at the same time the air within is expanding, and, in about thirty seconds, the softened glass at the extremity of the cylinder gives way, forming an aperture as in fig. 12. The workman then turns the cylinder round very quickly, and, by keeping the opened extremity warm at the same time flashes it out perfectly straight as at *g*, fig. 13. If the burst edges are ragged in appearance they are trimmed by cutting with a pair of scissors before finally expanding. The bursting of the end of a thick heavy cylinder has to be determined by allowing a glowing drop of glass to fall on the spot to be burst before presenting it to the fire.

Fig. 11.

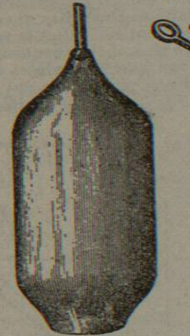

Fig. 12.

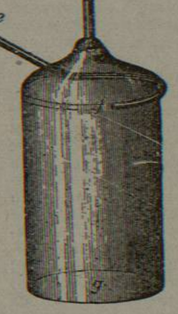

Fig. 13.

The other end, which is attached to the pipe, has now to be cut off, and is done in the following manner. The workman, having gathered a small quantity of metal on the pontil, draws it out into a thread of about one-eighth of an inch in diameter, laps it round the pipe end of the cylinder, and, after letting it remain there for about five seconds, withdraws it suddenly, and immediately applies a cold iron to the heated part, which occasions such a sudden contraction, that it cracks off where the hot string of glass has been placed round it. Another method is to draw a semi-cylindrical rod of iron *e* (fig. 13) heated to redness around the line *d* of desired fracture, and a drop of water then allowed to fall on the line so drawn determines its fracture. The stages in the development of a cylinder to its full length are illustrated in figs. 9 to 13.

Flattening.—The cylinder so blown and detached is now allowed to cool ; and, previous to its flattening, the burst extremity being thinner than the remainder, and slighly contracted at its edge, has to be removed to the depth of about 2 inches. For this purpose the cylinder is placed vertically in the jaws of a cutting instrument, having a diamond cutter, pressing by a spring, inside the glass (fig. 14). The cutter moves by small wheels on the table on which it is placed, and being pushed around the cylinder it makes an accurate cut of uniform height. The cylinder has then to be split longitudinally to allow it to be opened out to a flat sheet. To accomplish this the practice was formerly to lay the cylinder horizontally on a bench, and draw a red-hot iron two or three times along the inner surface at the line of desired fracture. Now the splitting is done with a diamond cutter fixed in the cleft of a stick and (fig. 15) guided from end to end of the cylinder by a straight-edge K laid within it. The cylinder is now ready to be taken to the flattening kiln, which consists of two chambers built together, the one for flattening the cylinders, the other for annealing the sheets, the former being kept at a much higher temperature than the latter.

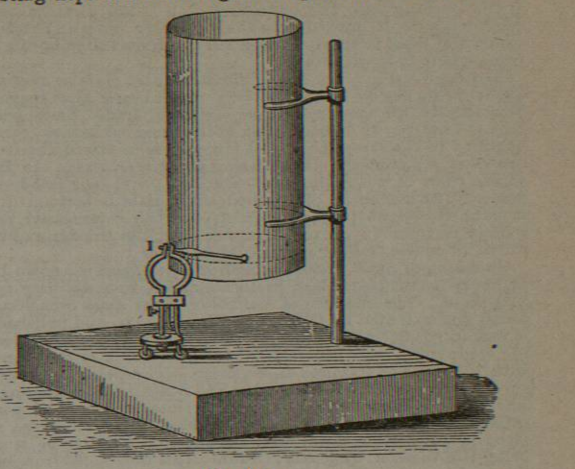

Fig 14.

The cylinder, after being gradually reheated, is placed in the centre of the flattening oven, upon a smooth stone, with the split side upwards. In a short time it becomes softened with the heat, and

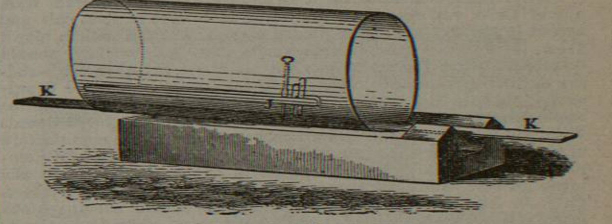

Fig. 15.

by its own weight falls out into a flat square sheet of 45 inches by 36. The flattener, with a piece of charred wood, rubs it quite smooth, and then places it on edge in the annealing arch, where it remains about three days to be annealed.

In the arrangement of the flattening and annealing ovens numerous improvements have been effected, which have resulted in greatly increased smoothness and uniformity of the glass, and in considerable economy of time and labour in the operations. Fig. 16

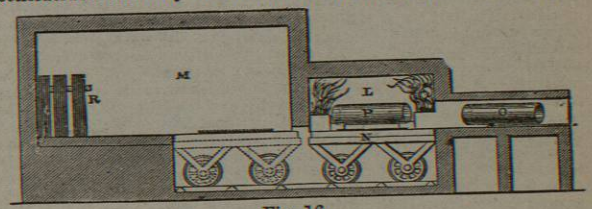

Fig. 16.

shows a section of a flattening (L) and annealing kiln (M) in common use. The split cylinder O is introduced and gradually pushed forward so as to be uniformly heated till it reaches P, the flattening stone or table, mounted on a movable waggon N. On this waggon after it has been flattened it is carried into the annealing arch M, as shown by the dotted outline. Here in a less heat it gradually stiffens, till it is ready to be moved by a forked tool to a horizontal position on the bed of the annealing oven. The waggon then goes back to the flattening arch, and when it is reintroduced with another sheet, that previously flattened is ready to be piled up on edge at R, and thus the work proceeds till the annealing oven is filled, when it is closed up and allowed to cool down by slow degrees. Chance Brothers & Co. of Birmingham are the introducers of a system of continuous flattening and annealing furnaces. This they accomplish by means of two contiguous circular kilns having revolving soles. the fires being arranged and the inside partitioned so that the split cylinder gradually approaches the greatest heat, where the flattening takes place, and then passes round in a decreasing temperature till at the opening into the annealing arch it has attained sufficient consistency to be moved into the yet cooler annealing arch, round which the sheet is slowly carried till it arrives fully annealed at the point where it is withdrawn.

Although the average size of finished sheet glass as now made is about 50 inches by 36 inches, very much larger sizes may be and occasionally are produced, the extreme trade limit being 85 inches long by 49 broad; but both these extremes cannot be obtained in the same sheet, and few workmen attain the dexterity necessary for properly manipulating the larger sizes. In Belgium sheets from blown cylinders measuring 10 feet by 4 feet have been made. The thickness of finished sheet glass is estimated by the amount it weighs per square foot, and the commercial range of weight is from 15 oz. to 42 oz. per foot, the thicker and heavier kinds, of course, selling at the highest price.

Polishing of Sheet Glass.—Polished sheet glass is known in commerce as patent plate glass, to distinguish it from ordinary polished cast-plate. The practice of polishing sheet glass was first introduced and patented by Chance of Birmingham, and polished sheet is now in considerable demand for photographic purposes, for framing engravings, and generally where a fine true surface combined with lightness or thinness is requisite. The polishing process involves two operations—smoothing and finishing or polishing. The smoothing is done on a thick slab of slate, which must possess a surface as smooth and level as possible. This is covered with a piece of wet cotton cloth, and, the sheet of glass to be smoothed being laid thereon, by gentle pressure all air is expelled from between the surfaces, and the atmospheric pressure then keeps the glass firmly in position. The process of smoothing and the subsequent finishing are from this point the same as in the case of ordinary plate glass, under which head these operations will be detailed. It is only selected plates of fine clear metal that are used for polishing.

PLATE GLASS is manufactured by a process entirely different from any of those yet described, consisting as it does of glass cast and spread in sheets. As plate glass is invariably thicker than blown sheet, it is of the utmost consequence that the "metal" should be prepared from the purest possible materials, and that the founding or melting should be done with great care to ensure the expulsion of air bubbles. It is only thus that the fine clear homogeneous and flawless plates aimed at in the manufacture can be produced. Formerly the French excelled all other nations in the manufacture of plate glass, and the manufactures of the great St Gobain Company yet command the highest prices in the market; but the increased care which has now for about a quarter of a century been given in England to the purity of materials, and the ingenious machinery which has been devised for polishing plate in England, have resulted in placing British-made plate glass on a level with the best productions of France.

The following is given as an example of the materials employed for the preparation of fine French plate:—

White quartzose sand	100·0 parts
Sodic carbonate	33·3 "
Lime (slaked)	14·3 "
Manganese peroxide	0·15 "
Cullet	100·0 "

The materials are melted in furnaces and pots of the ordinary construction, but in some cases the melting pots are of greater capacity, and contain charges of from 2 to 2½ tons. In French establishments, and in many others, two forms of pot are placed within the furnace—(1) the ordinary melting pot, and (2) a pouring pot or *cuvette*, quadrangular in form, made of the same material as the melting pot, and capable of holding sufficient metal for casting a single sheet of the superficial extent and thickness desired. Melting pots and cuvettes are placed side by side in the furnace, and the molten mixture is ladled with copper or malleable iron ladles from the pot into the cuvette, in which it is allowed to clear before casting. In some works, however, the molten glass is poured direct from the melting pots, and in other cases it is ladled to the casting table from the huge melting pots with large malleable iron ladles.

The casting table is a heavy thick flat table of cast-iron, of a length and breadth exceeding the size of the largest plate of glass which may be cast on it. At one end is placed a heavy cast-iron roller, the full breadth of the table, and fitted to roll the whole length of the table by means of spur wheels working into gearing along its sides. The cast-iron roller determines the thickness of the glass by the height at which it is caused to roll above the table, and that height is regulated by placing narrow strips or ribs of metal of the required thickness of the glass along the edges of the table on which the two extremities of the roller bear as it revolves. The breadth of the plate again is determined within the limits of the table by the two sides of the "gun," an apparatus consisting of two plates of cast-metal, placed in front of the roller, and bolted together by cross bars at a distance apart which can be easily altered and adjusted according to the breadth of plate the apparatus is intended to control. The edge of the plates abutting against the roller are accurately fitted to the roller curvature, and thus they and the roller form three enclosing sides for the molten mass poured on the table, and as they travel forward they carry in front of them all the semi-fluid mass except the uniform layer which represents the distance between the moving surface of the roller and the surface of the casting table on which the glass is spread. As the glass does not instantly solidify the moment the roller has past over and spread it into a sheet, the edges generally assume a rounded and somewhat wavy cast-like appearance. Immediately the plate has sufficiently solidified to bear moving, it is taken to the annealing furnace, the heat of which has been carefully raised to the proper pitch. The sole of the annealing oven on which the plate is to rest (for with large plates any piling on edge is impracticable) must be as smooth and level as possible, since the still semi-plastic mass moulds itself to the surface on which it is laid. As the oven only accommodates a single plate of the largest dimensions, and since the annealing process occupies several days, a large number of ovens, occupying a great space and involving the expenditure of much labour and fuel, are needed in works where many plates are cast. In dealing with plates of small size they may be laid horizontally on the furnace bed for a little till they come to the furnace temperature, after which they are piled up on edge in twenties or thirties, leaning against a range of iron bars running across the furnace. When the plates have been deposited in the annealing oven, the openings are all carefully stopped up, and the furnace with its contents is cooled by slow degrees down to a temperature at which the glass may safely be withdrawn and exposed to ordinary atmospheric influences. The cooling of such furnaces is now hastened as far as the safety of the plates and the completion of the annealing will permit by allowing cold currents of air to pass under their sole.

The plates, as withdrawn from the annealing oven, have a very irregular, rough, undulating surface, and although the glass is perfectly pure, they have, owing to their uneven surface, no transparency. In this condition they constitute the "common rough plate" of commerce, and as such they are extensively used for the glazing of roofs, for floor and cellar lights, and generally in positions where light without transparency is requisite.

Polishing.—When the annealed plates are withdrawn from the oven they are carefully examined for any defects, such as spots, air-bells, &c., which they frequently exhibit. If serious defects are found, the plates are cut into the largest pieces which can be obtained free from flaws, and the selected pieces are then submitted to the operations of polishing, consisting of—(1) grinding, (2) smoothing, and (3) polishing. Various forms of machine have been devised and introduced for effecting these operations. The grinding and smoothing table invented by Mr Daglish of Ravenhead works consists of a great revolving flat table A (fig. 17), with a strong fixed bar CE, stretched across it about 10 inches above its surface, to which two runner-frames B, B, shod with iron, are pivoted at Q. The glass to be ground is cemented with plaster of Paris on the surface of the table, and the runner-frames rest on that surface. When the table A is set in motion, each oblong runner-frame B has communicated to it a revolving motion also, owing to the excess of friction brought into action by the more rapid revolution of the outer edges of the revolving table. The effect of these compound revolutions is that every point of the surface of the glass is equally and uniformly abraded, when the apparatus in revolution is fed with sharp sand and water. When a level surface is thus prepared, the smoothing process is next begun on the same table, the only difference being that emery powder of increasing degrees of fineness is substituted for the sand, and as the operation approaches completion the utmost care must be exercised as to the purity and uniformity of the emery, seeing a single particle of grit would effectually destroy the smoothness of a whole plate. The quality of the emery is thus of essential consequence, and an ingenious apparatus is brought into use for arranging the sizes by means of a current of water of diminishing velocity, obtained by passing a uniform stream with agitation successively through cylinders or troughs of increasing

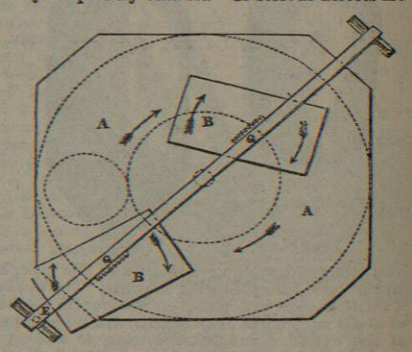

FIG. 17.—Plate-Glass Grinding Table.

size. In these troughs the emery powder is deposited in increasingly fine division, according to the growing capacity of the trough and the consequent slow replacement of its contents. The last touches of the smoothing process can only be given by the hand, which at once detects any appearance of grittiness. Both sides of the glass are in succession submitted to these operations, after which it is again bedded in plaster and fixed on the polishing table. The polishing is done with reciprocating rubbers, covered with fine felt, and supplied with rouge (peroxide of iron) in a liquid state. While a reciprocating motion is communicated to the rubbers, the table itself moves backward and forward in a transverse direction, so that all parts of the plate are equally brought under the polishing influence of the rubbers. About 40 per cent. of the weight of the rough plate is removed in the three polishing operations.

Ordinary finished plates vary in thickness from about ¼th to ⅜th inch, and the largest sizes measure about 17 feet by 9 feet 6 inches. The great St Gobain Company of France quotes regular prices up to 324c. (10 feet 8 inches) by 204c. (6 feet 8 inches), beyond which size the price becomes special. In the Paris Exhibition of 1878 that company showed a silvered plate 24 feet by 14 feet, the largest piece of plate glass which has hitherto been polished.

Rolled Plate.—A form in which unpolished plate glass is extensively employed is the patent rolled plate, originally made by Hartley & Co. of Sunderland. The surface of the casting table on which the rolled plate is spread, instead of being smooth and plain, is engraved or otherwise indented with fine lines, grooves, or flutes, or it may be with small squares, lozenges, or even ornamental patterns, and the glass, of course, takes on its lower surface an accurate impression of any such pattern. Rolled plate is now very largely used for partitions, and in places where obscure lights are required. Such plates are always cast comparatively thin, and of moderate size, so that a large number may be piled in the annealing oven. They, as well as certain qualities of coloured glass, are cast by ladling the molten metal from huge pots which may contain about 2½ tons of material. By this ladling numerous "air bells" are enclosed in the glass, but the circumstance does not affect the durability and usefulness of the glass.

FLINT GLASS OR CRYSTAL.—The name flint glass originated in the circumstance that at first the silica used in the manufacture of this variety of glass was in the form of ground flints. The industry belongs characteristically to the United Kingdom, where it was first established on a large scale, and to the present day flint glass is much more extensively manufactured in England than in any other country.

Flint glass is a compound entirely different from those above described, consisting as it does of a silicate of potassium and lead. As is the case with all kinds of glass, its composition and the proportion of ingredients used in its preparation vary widely. The average composition of a batch has been stated thus:—

Fine white sand	100 parts.
Minium (red lead)	66 "
Refined potash	33 "
Nitre	10 "
Cullet	60 to 100 "

Small portions of bleaching ingredients, as white arsenic or manganese, are also sometimes added. Purity of materials is of the utmost consequence in the manufacture of flint glass, which is prized in proportion to the transparency, uniformity, sparkle, and freedom from colour of the metal; and, as finished objects are in many cases massive, defects of colour are very obvious. Flint glass is much more fusible than the kinds destitute of lead; it possesses great brilliancy, owing to its high refractive and dispersive power, but being comparatively soft its surface is easily scratched and dulled. It is also slowly corroded by alkalies, and contact with solutions of sulphides blacken it. Its specific gravity varies according to the proportion of lead it contains; and, as the silicate of lead tends to sink when the glass is in the molten state, Faraday found glass from one melting to vary from 3·28 to 3·85, and in another instance from 3·81 to 4·75. The higher the specific gravity of the glass the greater is its refractive power and consequent brilliancy.

Flint glass is in no case used for architectural or structural purposes, but its purity and lustre peculiarly fit it for table glass, ornamental objects, glass globes and lustres, and for imitations of gems and precious stones. For the latter purpose a dense glass called strass, appropriately coloured when necessary, is employed, and a glass of still greater density and refractive power is used for optical puposes. The softness of flint glass adapts it for engraving, cutting, and polishing; and these methods of ornamenting the finished glass are very much employed.

The special covered form of pot (fig. 2, *supra*) and the arrangement of the furnace have already been alluded to. Plate VI., fig. 1, represents the various arrangements, tools, and processes connected with a flint-glass house, the building in the centre being the large cone or chimney built over the furnace, which is seen through the arches *a*. At 5 and 6 men are seen at the working holes withdrawing metal from the pots on their long iron tubes; 7 is the marver on which the gathering is rolled till it acquires a circular shape; at 8 a blower is seen in process of expanding a gathering of glass by blowing; and at 9 a servitor or second man is attaching a post or lump of metal he has gathered on a pontil or punty to the end of a blown globe of glass. The two masses of glass are thus united together, and that attached to the hollow tube is separated by touching it, near to where the tube enters the globe, with a small piece of iron wetted with water. By this means the glass cracks, and a smart blow on the iron tube completes the disunion. The workman now takes the punty from his assistant, and laying it on his chair arm, rolls it backward and forward with his left arm, while with his right he moulds it into the various shapes required, by means of a very few simple instruments. By one of these, called a pucellas, the blades of which are attached by an elastic bow like a pair of sugar-tongs, the dimensions of the vessel can be enlarged or contracted at pleasure. Any superfluous matter is cut away by a pair of scissors. For smoothing and equalizing the sides of the vessel a piece of wood is used. After the article is finished it is detached from the punty and carried on a pronged stick to the annealing oven.

The annealing oven or leer for flint glass is a low arched furnace, generally of considerable length, with several openings at each end between which narrow lines of rails run. On these rails, small waggons, or trays mounted on four wheels, are placed, and the articles to be annealed are filled into such waggons. They are slowly pushed to the hottest part of the chamber, and passing that point they very gradually approach the cold end of the oven, from which they are withdrawn fully annealed. As each waggon is withdrawn at one end, another is entered at the other so that the line from end to end is kept constantly full. The ordinary method of gradually decreasing the temperature around the articles stationary in the leer is also practised.

Flint-Glass Cutting, Engraving, and Etching.—The sparkle and brilliancy of flint glass is developed by the process of grinding and polishing technically called glass-cutting. In fig. 18 is seen a representation of a glass-cutter's mill, *a* being the pulley and band communicating motion to the mill *b*, which is made of wrought

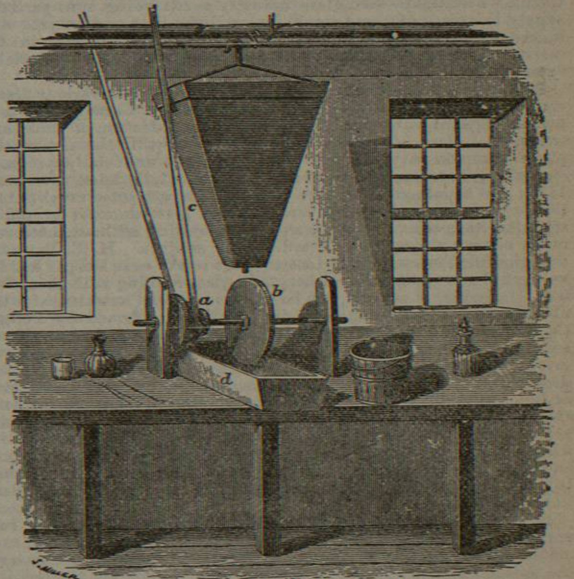

FIG. 18.—Glass-Cutter's Mill.

or cast iron. Over it is suspended a wooden trough or cistern *c*, containing a mixture of sand and water, which is fed on the wheel as required for the operation of grinding. Smoothing is done on a wheel of fine sandstone to which water alone is applied, and for polishing, a wooden wheel supplied with emery, and finally with putty powder (oxide of tin), is employed. The trough *d* under the wheel receives the detritus of the grinding and other operations. The articles are held in the hand, and applied to the mill while rotating. The punty marks are ground off tumblers, wine-glasses, and the like, by boys holding them on small stone mills. Ground or obscured glass is made by rubbing the surface with sand and water. Iron tools fixed on a lathe and moistened with sand and water are used to rough out the stoppers and necks of bottles, which are completed by hand with emery and water. Engraving is the production of ornamental surfaces by a fine kind of grinding mostly done with copper discs revolving in a lathe. Etching is variously done by