made secure, an operation which would certainly present some difficulty in deep water. The shield and tube being once in position, the masonry of the tunnel is commenced, the bottom being first constructed, then the sides, and lastly the roof, the new masonry being always within the strong iron sides of the shield. When the other side of the channel is reached the operation is finished, in the same manner as it was commenced, in the dry cutting. At the conclusion of the operation the waterproof tube lies beneath the floor of the tunnel, and all around it, protecting the cement until it is thoroughly set.

THE SAND BLAST.

On Tilghman's Patent Sand Blast for Cutting, Grinding, Engraving, and Ornamenting Glass, Stone, Wood, Iron, and other Hard Substances.

Paper read before the British Association at Bradford. We may mention here, also, that at the very successful *soirée*, held by the British Association at Bradford, a sand blast apparatus of Mr Tilghman's was shown in action, the necessary blast being furnished by a small Root's blower, provided by Messrs. Thwaites & Carbutt, of Bradford. These well-known blowers seem excellently adapted for supplying blast to the sand-engraving apparatus, and we understand that they are now being regularly adopted for that purpose.

The cutting, grinding, engraving and ornamenting of glass, stone, wood, iron, and other hard substances are operations requiring a considerable expenditure of time and labour, and some of them a vast amount of skill.

The object of Mr. Tilghman's invention is to economise time, and reduce the amount of skilled labour required to produce ornamental patterns and architectural devices in stone and other hard substances. The invention is based upon the idea that if grain or sharp sand are driven with a certain velocity against a hard surface, such as glass, stone, wood, or iron, such surface will be gradually cut away. The action of the sand on the hard surface of the glass or stone is very rapid; and if a sheet of plain polished glass be subjected to the sand blast it will be quickly depolished or ground; but if a portion of its surface be protected by covering it with some suitable material (cut to any particular pattern or device) all those parts so covered will remain intact, while the exposed surfaces will be ground or cut away by the impact of the sand.

The sand is fed into a jet or current of steam at from 60 lb. to 120 lb. pressure, or a blast of air may be used. The blast of steam or air carrying with it the sand is directed upon the surface of the stone, glass, wood, or metal, which it rapidly grinds or wears away.

The machine employed resembles a Giffard's injector. The central tube is supplied with a jet of steam or a stream of air under considerable pressure, and sand is used instead of water the grains of sand being projected forward with a velocity proportioned to the pressure of the steam or air, or carried along by the steam.

In the stone-cutting machine the sand is introduced by a central iron tube, such as that shown at Fig. 1, page 226. This tube is about $\frac{1}{8}$ in. bore, and the steam issues through an annular passage ($\frac{7}{16}$in. external, and $\frac{5}{16}$ in. internal diameter) surrounding the sand tube. A tube of chilled cast iron is fixed as a prolongation of the steam passage, and serves as the gun or tube in which the steam mixes with the sand, and imparts velocity to the latter. The central sand tube is connected by a flexible tube and funnel, with a box containing dry sand, and the outer annular tube is connected by another flexible tube with a steam boiler. The apparatus is thus entirely movable, and can be held or moved in any direction either by hand or by machinery, and can be made to cut upwards or downwards, or at any angle of inclination.

Fig. 1, on page 226, is, as has been stated, a sectional view of the simple steam jet for acting on or incising stone, slate, granite, or wood. The operation of this machine is as follows: Steam of about 60 lb. pressure per square inch is turned on, and rushes with great velocity through the steam tube into the annular tube of the injector; this causes a suction of air through the central tube.

A stream of sand of about a pint per minute is let fall into the funnel, and is carried along by the current of air or steam, and is drawn into the annular jet of steam, and driven by it at a high velocity, and strikes upon the stone

To cut an ornament or inscription in relief upon a flat surface of stone, a pattern of iron is fastened to the stone. The movable jet pipe is made to traverse to and fro over the surface of the stone, which is placed at a distance of 8 in. The stone is mounted on a carriage which has a slow motion in a direction at right angles to that of the jet pipe, so that every part of the surface is thus exposed to the action of the sand. A cast-iron pattern about three-sixteenths of an inch thick may be used 100 times to produce the same pattern. If made of malleable iron it will last about four times as long. A pattern made of caoutchouc, if held 24 in. to 30 in. distant, will last a long time, but if placed only 8 in. or 10 in. from the jet-pipe, it will be cut through in a few minutes.

To cut a flat or curved surface of a block of rough stone, a narrow groove or channel is first cut by holding the jet-pipe about 1 in. from the side of the stone, and making it move steadily along the desired line, which may be either straight or curved. When the groove has been cut about an inch deep the overhanging lip or edge of stone is to be broken off by the hammer. The jet-pipe is then advanced an inch, a new groove is cut, and the overhanging part is broken off, and so on. Balusters have been thus roughed out of a block of granite by a single series of cuts.

To cut a long deep channel vertically or horizontally in a bed of rock, as in quarrying, two jet-pipes are used, making two parallel grooves about 3 in apart, leaving a projecting pin or lip of the stone between them, which is broken off by a wedge-shaped tool. The jet-pipes are then advanced and new grooves cut. The sand employed is of the ordinary quality used for sawing stone, the harder and sharper the better. In cutting hard rock about one-tenth of the sand is reduced to powder, but the rest can be again used.

Small shot or grains of cast iron, of about one-twenty-fifth of an inch diameter, and in place of the sand, have been found to cut granite more rapidly, probably because they are not broken by the shock, and the whole force of the blow is thus expended in disintegrating the stone, instead of being partly wasted in crushing the grains of sand.

When the object is to cut or engrave in fine lines, or to grind away only small quantities of the material the blast of air from an ordinary rotary blower or fan is used as the propelling medium, and the machine shown at Figs. 2 and 3, page 226, is employed, and driven by an air blast of the pressure of 4 in. of water, will completely grind or depolish the surface of glass in ten seconds.

If the glass be covered by a stencil of paper or lace, or by a design drawn on any tough elastic substance, a picture will be engraved on the surface of the glass, the sand cutting on the bare parts, but being rebounded from the elastic lace or paint without touching the surface beneath. Photographic copies by chromated gelatine from delicate line engravings, have been thus faithfully reproduced on glass.

In the machine for grinding and engraving glass, shown at Figures 2 and 3, a rotary fan drives a current of air downward through a vertical jet-pipe 15 in. deep, and 36 in. long by $\frac{1}{2}$ in. wide, at a pressure of about four-tenths of a pound per square inch. Into the top of this jet-pipe a thin regular stream of sand is made to fall, which being caught by the rush of air, is driven down with it through the pipe, or long narrow channel, and shoots out against any substance placed beneath.

A set of caoutchouc tapes moving horizontally at a speed of 8 in. per minute, and about 4 in. below the jet-pipe, will carry forward sheets of glass 3 ft. wide beneath the sand blast. This glass will come out on the other side perfectly ground or depolished, although each spot of their surface has been exposed to the action of the sand during less than four seconds. The sand after striking the glass flies off at an angle, and is picked up by an elevator, and returned to the sand-box on the top of the machine ready to be again used.

If we apply the sand blast to a cake of resin on which a picture has been produced by photography in gelatine, or drawn by hand in oil or gum, the bare parts of the surface will be cut away to any desired depth. The lines left in relief will be well supported, their base being broader than their top. An electrotype from this matrix can be printed from an ordinary press. The sand blast has been applied to