fastened as usual to the davits of the *Urgent*, while I occupied a second boat nearer to the stern of the ship. He cast the plate as a mariner heaves the lead, and by the time it had reached me, it had sunk a considerable depth in the water. In all cases the hue of this plate was green, and when the sea was of the darkest indigo, the green was the most vivid and pronounced. I could notice the gradual deepening of the color as the plate sank, but at its greatest depth in indigo water, the color was still a blue green.

Other observations confirmed this one. The *Urgent* is a screw steamer, and right over the blades of the screw there was an orifice called the screw well, through which you could look from the poop down upon the screw. The surface glimmer which so pesters the eye was here in a great measure removed. Midway down, a plank crossed the screw well from side to side, and on this I used to place myself to observe the action of the screw underneath. The eye was rendered sensitive by the moderation of the light, and still further to remove all disturbing causes, Lieutenant Walton had the great kindness to have a sail and tarpaulin thrown over the mouth of the well. Underneath this I perched myself and watched the screw. In an indigo sea the play of colors was indescribably beautiful, and the contrast between the water which had the screw blades for a background, and that which had the bottom of the ocean as a background, was extraordinary. The one was of the most brilliant green, the other of the most lustrous ultramarine. The surface of the water above the screw blade was always ruffled. Liquid lenses were thus formed, by which the colored light was withdrawn from some places and concentrated upon others. The screw blades in this case replaced the plate in the former case, and there were other instances of a similar kind. The hue from an indigo sea was always green at a certain depth below the surface. The white bellies of the porpoises showed the same hue, varying in intensity as the creatures swung to and fro between the surface and the deeper water. In a rough sea the light which had penetrated the summit of a wave sometimes reached the eye. A beautiful green cap was thus placed upon the wave when the ship was in indigo water.

But how is this color to be connected physically and philosophically with the suspended particles? Take the dinner plate which showed so brilliant a green when thrown into indigo water. Suppose it to diminish in size until it reached an almost microscopic magnitude. It would still behave substantially as the larger plate, sending to the eye its modicum of green light. If the plate, instead of being a large coherent mass, were ground to powder sufficiently fine, and in this condition diffused through the clear sea water, it would send green to the eye. In fact, the action of the suspended particles, which the home examination revealed in green sea water, is in all essential particulars like the plate, or like the screw blades, or like the foam, or like the bellies of the porpoises. When too gross, or in too great quantity, the suspended particles thicken the sea itself visibly. But when sufficiently small, but not too small, and when sufficiently diffused, they do not sensibly interfere with the limpid greenness of the sea itself. They then require the stronger and more delicate test of the concentrated luminous beam to reveal their presence.—*Tyndall*.

TILGHMAN'S PROCESS OF CUTTING HARD SUBSTANCES.

BY COLEMAN SELLERS.

How to cut or carve, mechanically, hard substances, such as stone, glass, or hard metals, in an expeditious, accurate, and economical manner, has always engaged the attention of engineers. At the present time, the rapidly increasing cost of manual labor makes improvements in this direction more needful. The discovery and utilization of opaque crystallized carbon, cheaper than transparent diamonds, but perhaps equally durable, has gone far in this direction. Now, Mr. B. C. Tilghman, of Philadelphia, comes forward, and shows that a jet of quartz sand thrown against a block of solid corundum will bore a hole through it $1\frac{1}{4}$ inches in diameter, $1\frac{1}{4}$ deep, in 25 minutes, and this with a velocity obtainable by the use of steam as the propelling power, at a pressure of 300 pounds per square inch—a remarkable result, when we consider that corundum is next to and but little inferior to the diamond in hardness.

At the stated meeting of the Franklin Institute, held February 15, 1871, the resident secretary, Dr. W. H. Wahl, introduced this invention, illustrating his description of it by practically cutting or depolishing the surface of a plate of glass by a sand blast of very moderate intensity. Various examples of hard substances cut, depolished, and carved into shape, were displayed. In the discussion which followed the presentation of this very remarkable discovery, Mr. Robert Briggs, in his interesting remarks on the subject, took occasion to say that it had been long remarked that window glass, exposed to the wind-driven sand, near the seashore, soon loses its polish, and cited some other well known examples of the erosion of surface when exposed to a continued stream of moving particles. When we think of the many such examples, and consider that engineers have had continually to make provision against this well known cutting effect, it seems surprising that it should not have been turned to some good account before this.

Mr. Tilghman's attention seems first to have been directed towards cutting stone, or hard metal, by a jet of sand impelled by steam escaping under high pressure. His early experiments were, I believe, with very high pressure, but as he progressed in the knowledge of results obtainable with various velocities, a great use for this process seemed to develop itself in sand driven by moderate air blasts, and applied to grinding or depolishing glass for ornamental purposes.

For grinding glass he uses a common rotary fan 30 inches in diameter, making about 1,500 revolutions per minute, which gives a blast of air of the pressure of about 4 inches of water, through a vertical tube 2 feet high by 60 inches long, and 1 inch wide.

Into the top of this tube the sand is fed, and falling into the air current, and acquiring velocity from it, is dashed down against the sheets of glass, which are slowly moved across, about an inch below the end of the tube. About 10 or 15 seconds exposure to the sand blast is sufficient to completely grind or depolish the surface of ordinary glass; so that sheets of it, carried on endless belts, may be passed under this one inch wide sand shower at the rate of 5 inches forward movement per minute. In the machine in use for this purpose, the spent sand is reconveyed to the upper hopper by elevators, and the dust made by the sand blast (which might otherwise be a source of annoyance to the workmen) is drawn back into the fan, and thence passes with the wind into the blast, and again mingles with the shower of sand upon the glass.

By covering parts of the glass surface by a stencil or pattern of any tough or elastic material, such as paper, lace, caoutchouc, or oil paint, designs of any kind may be engraved.

There is a kind of colored glass made by having a thin stratum of colored glass melted or "flashed" on one side of an ordinary sheet of clear glass. If a stencil of sufficient toughness be placed on the colored side, and exposed to the sand blast, the pattern can be cut through the colored stratum in from about 4 to 20 minutes, according to its thickness.

The theoretical velocity of a current of air, of the pressure of 4 inches of water, he calculates, is (neglecting friction) about 135 feet per second; the actual velocity of the sand is doubtless much less.

If a current of air of less velocity is used, say about 1 inch of water, very delicate materials, such as the green leaves of the fern, will resist a stream of fine sand long enough to allow their outlines to be engraved on glass. By graduating the time of exposure with sufficient nicety, so as to allow the thin parts of the leaves to be partly cut through by the sand, while the thicker central ribs and their branches still resist, the effect of a shaded engraving may be produced.

The grinding of such a hard substance as glass by an agent which is resisted by such a fragile material as a green leaf, seems at first rather singular. The probable explanation is, that each grain of sand which strikes with its sharp angle on the glass, pulverizes an infinitesimal portion which is blown away as dust, while the grains which strike the leaf rebound from its soft elastic surface.

The film of bichromatized gelatin, used as a photographic negative, may be sufficiently thick to allow a picture to be engraved on glass by fine sand, driven by a gentle blast of air.

For cutting stone, the inventor uses steam as the impelling jet; the higher the pressure, the greater is the velocity imparted to the sand, and the more rapid its cutting effect.

In using steam of about 100 pounds pressure, the sand is introduced by a central iron tube, about $\frac{1}{2}$ inch bore, while the steam is made to issue from an annular passage surrounding the sand tube.

A certain amount of suction of air is thus produced, which draws the sand through the sand tube into the steam jet, and both are then driven together through a tube about 6 inches long, in which the steam imparts its velocity to the sand, and finally strike on the stone, which is held about an inch distant from the end of the tube.

At the spot struck a red light is visible, as if the stone were red hot, though really it is below 212° Fah. The light is probably caused by the breaking up of the crystals of the sand and stone.

The cutting effect is greatest when free escape is allowed for the spent sand and steam. In making a hole of diameter but slightly greater than that of the steam jet, the rebounding steam and sand slightly interfere with and lessen the efficiency of the jet.

Under favorable conditions, using steam which he estimated as equal to about $\frac{1}{4}$ horse power, at a pressure of about 125 pounds, the cutting effect per minute was about $1\frac{1}{2}$ cubic inches of granite, or 3 cubic inches of marble, or 10 cubic inches of soft brown sandstone.

By means of flexible or jointed connecting tubes, the blast pipe is made movable in any direction; grooves and moldings of almost any shape can thus be made, or, by means of stencil plates, letters or ornaments can be cut either in relief or intaglio, with great rapidity in the hardest stone.

At a high velocity, quartz sand will cut substances much harder than itself, as before stated. With a steam jet of 300 pounds pressure, a hole $1\frac{1}{4}$ inches in diameter was cut through a piece of corundum, $1\frac{1}{4}$ inches thick, in 25 minutes.

A hole 1 inch long and $\frac{1}{2}$ inch wide was cut through a hard steel file, $\frac{1}{2}$ inch thick, in 10 minutes, with a jet of 100 pounds steam.

A stream of small lead shot, driven by 50 pounds steam, wore a small hole in a piece of hard quartz; the shot were found to be only very slightly flattened by the blow, showing their velocity to have been moderate.

Among the curious examples of glass, cut by this sand blast, was shown a piece of ordinary window glass, which, having been partially protected by a covering of wire gauze, had been cut entirely through, thus producing a glass sieve, with openings of about $\frac{1}{2}$ of an inch, the intervening glass meshes being only $\frac{1}{8}$ of an inch wide. This seems to have been produced more as a curiosity than for any practical purpose. Should such a sheet of perforated glass be required, it is questionable if it could be produced for a solid sheet by any other method.

A microscopic examination of the sheet glass, depolished by this process, shows a succession of pits formed by the blows of the impinging grains of sand, and looks more uniform than do surfaces ground by any rubbing process.

This steam sand jet has already been introduced to clean cast iron hollow ware, previous to tinning the interior. Heretofore, the interior surface has been turned, it having been found necessary to remove a thin shaving in a lathe to obtain a clean surface. The surface is cleaned more rapidly by the sand blast, and even more perfectly, because it penetrates into any holes or depressions which the turning tool could not reach. It is also probable that the sand striking the particles of plumbago, which separate the particles of metallic iron in ordinary gray cast iron, will remove them, and thus expose a continuous metallic surface to take the tin.

In this relation I might note, that about twenty-five years ago, some experiments were made in Cincinnati, at the establishment of Mr. Miles Greenwood, by my brother, Mr. George Escol Sellers, with a view to making tinned hollow ware of ordinary gray iron. He made a machine for scouring the inside of the pots and kettles with sand and water; afterwards the still wet, scoured surfaces passed into the chloride of zinc solution, and thence into the molten metal, and were uniformly turned. For some reason, the process was not continued, and now it is only recorded as an abandoned invention, never before made public. The wet sand grinding could not, in this case, have been so efficient as Mr. Tilghman's sand blast.

To speculate on the various uses to which this process may be applied, would not serve any good end, and would take up too much space. With this discovery we can hardly help recurring to the works of the ancients, and wondering if some such process could have aided the workers in the stone age, or could have been used in carving the Egyptian hieroglyphics. It has been noted by those familiar with the cutting or dressing of stone, that some materials, such as granite, are very much injured or "stunned" by the blows of the cutting tool, and after being hand dressed, a thickness or perhaps from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch has to be ground away, to produce a solid uniform surface. By this sand cutting process the surface is not injured, is not "stunned," and is ready for polishing at once.

One curious fact connected with its use is, that when a surface, to be cut in intaglio or otherwise, is partially protected by templates of metal, these templates curl up under the blows of the sand, so that paper patterns are really more durable than patterns cut from brass. Sheet steel, cut into shape and then hardened, will also curl up under the blows of the fine particles of sand, unless protected by sheets of yielding material. Fine lace will protect glass during the depolishing process, and leave its designs in polished lines on a ground surface.—*Journal of Franklin Institute*.

The Great Sun Spot of June, 1843.

Prof. Daniel Kirkwood, in *American Journal of Science*, writes that one of the largest and most remarkable spots ever seen on the sun's disk, appeared in June, 1843, and continued visible to the naked eye for seven or eight days. The diameter of this spot was, according to Schwabe, 74,000 miles; so that its area was many times greater than that of the earth's surface. Now it has been observed, during a number of sun spot cycles, that the larger spots are generally found at or near the epoch of the greatest numbers. The year 1843 was, however, a *minimum* epoch of the eleven year cycle. It would seem, therefore, that the formation of this extraordinary spot was an anomaly, and that its origin ought not to be looked for in the general cause of the spots of Schwabe's cycle.

As having a possible bearing on the question under consideration, let us refer to a phenomenon observed at the same moment, on the first of September, 1858, by Mr. Carrington, of Redhill, and Mr. Hodgson, at Highgate. "Mr. Carrington had directed his telescope to the sun, and was engaged in observing his spots, when suddenly two intensely luminous bodies burst into view on its surface. They moved side by side through a space of about thirty-five thousand miles, first increasing in brightness, then fading away. In five minutes they had vanished. . . . It is a remarkable circumstance, that the observations at Kew show that on the very day, and at the very hour and minute of this unexpected and curious phenomenon, a moderate but marked magnetic disturbance took place; and a storm, or great disturbance of the magnetic element, occurred four hours after midnight, extending to the Southern hemisphere."

The opinion has been expressed by more than one astronomer, that this phenomenon was produced by the fall of meteoric matter upon the sun's surface. Now this fact may be worthy of note, that the comet of 1843, which had the least perihelion distance of any on record, gradually grazed the solar atmosphere about three months before the appearance of the great sun spot of the same year. The comet's least distance from the sun was about 65,000 miles. Had it approached but little nearer, the resistance of the atmosphere would probably have brought its entire mass to the solar surface. Even at its actual distance, it must have produced considerable atmospheric disturbance. But the recent discovery that a number of comets are associated with meteoric matter, traveling in nearly the same orbits, suggests the inquiry whether an enormous meteorite, following in the comet's train, and having a somewhat less perihelion distance, may not have been precipitated upon the sun, thus producing the great disturbance observed so shortly after the comet's perihelion passage.

THE locomotive which George Stephenson constructed in 1814 would travel only four miles an hour. In 1825, six miles an hour was the standard speed.