(*Students' Paper, No. 179.*)

"Emery Wheels and Emery-Wheel Machinery."¹

By WALTER OSMOND ROOPER, Stud. Inst. C.E.

EMERY is a mixture of corundum and oxide of iron; corundum itself is alumina, with a little silica. Sapphire and ruby are corundum in its purest form, slightly tinged with iron oxide. In a less pure state, corundum is found in many places, and is then valuable only for commercial purposes.

The emery beds of most importance are those situated in Turkey and Asia Minor; considerable quantities of emery are found near Smyrna and Ephesus. The material takes its name from Cape Emeri, a promontory in the Isle of Naxos, where there are considerable deposits. In 1871 large beds of corundum were discovered in North Carolina; their existence having been betokened by the presence of numerous waterworn pebbles in the beds of the adjacent rivers. These beds have been worked commercially, and the corundum extracted, crushed, and used for grinding and polishing. Emery is obtained from surface workings, and the presence of the emery is generally indicated by the dark red colour of the ground above it. The prospectors strike steel rods sharply into the ground where they expect the existence of emery, and by examining the points of the rods can easily detect its presence. The mineral is broken up into lumps weighing about 1 cwt. each. If hard to break, a fire is lighted round the refractory lump, and on cooling blows are resorted to again. The lumps are then carried to the coast by railway, or on mule-back, and the material reaches England chiefly as ballast: thus freight is an insignificant item in the cost. The Turkish and Greek governments generally let the right to raise and dispose of the emery to English capitalists.

The specific gravity of emery ranges from 3·75 to 4·28, and the colour from dark grey to black; there is an impure variety of corundum blue grey to brown in colour. Much of the commercial emery is artificially coloured, and is often mixed to a small extent with ground iron slag; some buyers insist upon the adulteration.

¹ This communication was read and discussed at a meeting of the Students, on the 25th of April, 1884, and has been awarded a Miller Prize.

Analysis of emery shows that it is composed of from 60 to 80 per cent. of alumina, 8 to 33 per cent. of iron oxide, together with a small quantity of lime water and silica.

Taking sapphire as a standard at 100, corundum from the Carolina mine has an abrasive power of from 90 to 97, and the best Naxos emery from 40 to 57 only. This would make it appear as if corundum were far superior to emery for grinding purposes; however, this is not the case on account of the peculiarity of the fracture of the latter. Every grain of emery breaks with a rough conchoidal surface, and presents numerous sharp points, be the lump large or small; even flour-emery exhibits this markedly when examined under the microscope. Corundum on the other hand, although breaking into pieces with many sharp points, exhibits also plane and curved surfaces. It is owing to this that corundum is not more extensively employed in the manufacture of grinding-wheels. Thus emery will cut its way into the material operated on, while corundum will grind and tear, and only perform the work in consequence of its being of a harder nature.

The next point to consider is the preparation of emery on its arrival in this country. It is first treated in the emery-mills; stone crushers reduce the large lumps to pieces about the size of a hen's egg, and these in turn are reduced in a stamping-mill, or are ground in a horizontal revolving mill with cast-iron circular grinding-plates. Naturally the life of these plates is not long, and frequent renewals are necessary. The fragments of emery are then passed between chilled cast-iron rolls, and ground or crushed again, then sifted through sieves. During these operations a portion of the emery is separated from the lumps in the form of dust, which collects on the top of beams and other places. This emery dust is all carefully preserved, and under the name of flour-emery is useful for polishing. Levigation is another process employed for separating the coarse grains from the fine emery. Six cylinders, about 3 feet high, are ranged in a row, and are in communication with one another at the top by means of metal pipes. Water mixed with emery from the rolls is introduced into the first vessel. The heavy grains sink, while the lighter ones remaining in suspension pass over into the next vessel. The process is repeated throughout the range; the last vessel containing the finest emery. There are now in this country a fair number of emery-mills, but in America the trade is of greater magnitude and more importance. Emery-crushers generally manufacture emery-cloth as a branch of their business, as also the

flour-emery. The chief use of flour-emery is for making knife-polish, of which enormous quantities are sold. By far the largest demand for grain, or crushed-emery, is for the manufacture of emery grinding-wheels, which of late years have become familiar objects in most engineer's shops. Emery-wheel makers in this country do not as a rule crush emery. During the last ten years many classes of emery wheels have been introduced.

The emery wheels best known in England now are the "silicate" or "grey" wheel, the "vulcanite" or "black" wheel, the "shellac" or "red" wheel, the "union" wheel, and the "tanite" wheel.

The silicate wheel was invented by Mr. Frederick Ransome, Assoc. Inst. C.E., who has perfected the method of manufacture. He employed silicate of soda as the base of the wheel; emery wheels were made for some time by the Ransome Patent Stone Company, in conjunction with their artificial stone and grind-stone business. The process consists first in the preparation of the silicate of soda. Beach flints, mostly brought over from France, and used in preference to English flints on account of their being associated with less chalk, are placed in a steam-jacketed boiler; caustic soda is added, and steam turned on. After some hours the dissolution of the flints is complete, very little solid residue being left. The liquid is then allowed to settle and run into a tank, where it is evaporated down to a consistency much like that of treacle, but as clear as sherry. This will remain liquid if properly made. Emery of the required degree of fineness is united with this silicate of soda in a mill, and a thorough mixing obtained; this "pug" is then pressed into moulds by hand-pressure. The disk produced would naturally harden by itself in time, but in order to save time it is baked, and is then complete and ready for use.

The manufacture of black or vulcanite emery wheels requires heavy and costly machinery. The base is india-rubber, oxidized oil, or other similar material. This is intimately mixed with the emery in steam-heated rolls (horizontal hollow cylinders); afterwards calendered to exact dimensions, and squeezed into moulds in a powerful hydraulic press. The disks are then cured in the same manner as vulcanized india-rubber goods; after which they are ready for use.

What is known as the red wheel is made with shellac as a base, and although the process is now considered old fashioned, excellent wheels for some classes of work are the result. Shellac is heated in an iron pot, the emery, which has been previously heated, is introduced, and the whole is well mixed by hand with iron spoons.

The pug is then put into moulds and squeezed in a hydraulic press; afterwards the disks are baked at a low temperature.

The tanite and union emery wheels are made in America; the methods employed in their manufacture are kept secret, and jealously guarded. In the tanite wheel a solution of leather, and in the union wheels oxychloride of magnesium, are the binding materials. The tanite wheel has the reputation of being the best made in America.

Emery wheels have been described as circular files which never grow dull. As previously mentioned the emery grains throughout the wheel retain their cutting power; and if these grains are cemented together with a proper binding material, an emery wheel can be worked until 90 per cent. of its original weight has been worn off. A file is useless before 5 per cent. of its weight has been used up, and when being worked is driven by manual labour at a speed of 90 feet per minute. An emery wheel penetrates without difficulty into the hardest metals, some wheels even cutting chilled iron or hardened steel more easily than soft iron, and it is driven by steam at a peripheral velocity of about 1 mile per minute. In using emery-wheels successfully it must be borne in mind that as the wheel wears away the revolutions per minute must be increased, so that as nearly as possible the same surface speed may be maintained upon the periphery of the wheel. The economy of emery wheels in the operation of fettling or trimming castings is very marked, and this relates not only to economy in tools, but also in the saving of time. American foundries, and many English ones, are well supplied with emery fettling machines.

An emery wheel keeps its size and shape far longer than a grindstone, and very little practice is required to use it successfully. It is a common thing to see a grindstone, 24 inches to 18 inches in diameter and 18 inches wide, slowly rotating in a trough, while men push and shove their tools against it to make any impression. It has been stated by an eminent firm of engineers in London that an emery disk as a tool grinder lasts out six 4-foot grindstones, and only requires truing once a month, against the weekly truing up of a stone. They calculate the cost of keeping an emery-wheel tool grinder in order as one-fifth of that formerly expended upon the maintenance of grindstones, and the time occupied in grinding tools one-half of that formerly required. In grinding tools, if very large quantities of metal have to be removed, it is best to grind them quickly, and to

ignore their temper, rehardening them afterwards; but if only slight amounts, then the grinding should be gentle, and their temper will not suffer. Carpenters' planes can be ground by an emery wheel with ease after a little practice.

In this country many persons have failed in the use of the emery wheel owing to insufficient knowledge. Experienced men, who will take many precautions in fixing a lathe or planing-machine, will erect an emery machine anyhow, and then allow it to be used by any one. A very simple machine is sufficient, but it must be rigid, on a good foundation, having long bearings protected from dust, and must be so steady when in use as to be absolutely without tremor or vibration. A wheel should be mounted true and between two washers, screwed up moderately tight, never by driving the wheel on to a square spindle with a mallet, and tightening up the nut with a long-handled spanner. Care should be taken to run the wheel so that the nut tends to tighten itself upon the spindle. Attention should be given to keep the emery wheel true. In large factories one man should have charge of all the emery wheels, and should make his rounds at intervals to true the emery wheels with a diamond-tool. This tool consists of a small black diamond set in the end of a $\frac{1}{2}$ -inch steel bar, about 8 inches long fastened on a handle. In truing, the rest is fixed close to the wheel, and on a level with its centre. The diamond-tool is then held firmly on the rest, and the point is gradually worked backwards and forwards until the projecting parts are removed, and the wheel runs true. The difference in working with a true wheel and one running out of truth can hardly be imagined by those unaccustomed to emery-wheel grinding. In the latter case grinding is a disagreeable duty, and the jar and vibration render the task of holding on the work very irksome. It is not by heavy pressure that the most and quickest grinding will be effected; the article merely requires holding up well and constantly against the wheel. Intelligent users soon get accustomed to feel the bite.

The most economical speed for emery wheels is about 4,000 to 5,000 lineal feet of circumference per minute. Some wheels are driven faster than this, and with good results; but owing to the jar which occurs if the wheel runs out of truth in the slightest degree, and to the necessity of such rigid foundations, a speed of 5,000 feet is seldom exceeded with success. There is, however, no doubt that the faster a wheel is run the more is the work accomplished.

Too much pressure on certain classes of emery wheels induces

heat; and the melting of the india-rubber, or other substance used as the cementing medium, produces a glaze upon the cutting surface. By changing the metal being ground, as for example copper after iron, this glaze may generally be removed. In the case of wheels made with silicate of soda, or oxychloride of magnesium as the cementing medium, pressure only raises the temperature of the work, and does not injuriously affect the wheel. Experiments have been made with a view of ascertaining the utmost speed at which an emery wheel would run without bursting, but all the wheels tried have stood the utmost test applied. On the rare occasions when wheels have burst, the cause has invariably been traced to unsteady bearings, improper adjustment of the wheel in the first instance, or an article being jammed between the wheel and the rest. But it is well known that far fewer accidents arise from the bursting of emery wheels than from the bursting of ordinary grindstones.

It must not be forgotten that as different shapes and varieties of steel tools are necessary for different operations upon a lathe or planing machine, so different classes of emery wheels are required for different purposes, and it is the best economy thus to apply them. One class of wheel should be kept for one class of work whenever practicable. Wheels can be made hard or soft, rough or smooth, slow cutting or quick cutting; as a rule, fast-cutting wheels have a rough surface, and slow-cutting a fine one. As in the case of an ordinary grindstone, the faster a wheel cuts the faster it will wear away. A wheel can be made so hard that after six months' usage no wear to speak of will have taken place; but the amount of work such a wheel would have turned out would be infinitesimal, compared with that which a softer wheel would have done, and the money and time lost in working the hard wheel would have purchased many soft ones.

In the machinery for mounting emery wheels, first comes the tool-grinder, a common object in large works, and invaluable for putting a fine cutting edge on tools, grinding them to template, or reducing them quickly. The emery wheel, generally of a fine grade, is mounted in a small cast-iron trough cast on a pedestal, extra long bearings are provided, and a cap which will completely cover the upper half of the wheel, excepting 3 or 4 inches where the rest is fixed a little above the centre of the wheel-level. A continuous water-supply is provided by means of a small pump, and a tank within the pedestal. The cap serves to keep the water from flying off the wheel whilst rotating.

The emery surfacing-machine has only been introduced lately.

It is probably an English idea, although modifications have been introduced from America. A cast-iron box, with a top movable in a vertical direction, has long bearings across it. In these runs the spindle upon which the emery wheel is fixed. The movable top of the box has a hole cast or ground in it, just large enough to admit a small portion of the periphery of the emery wheel to protrude, so that the wheel is otherwise entirely boxed in. A small fan revolves at the bottom of the box, and collects all the dust and cuttings which follow the wheel, thus helping to keep the surface of the table clean. By means of a screw adjustment the table can be raised or lowered, and a greater or less amount of wheel exposed. The article to be ground is passed backwards and forwards on the table top over the protruding part of the wheel. As the table is exactly true, only the projecting parts of the article can be touched by the emery wheel, and thus flat surfaces are rapidly attained. A steel key, which would take a fitter half an hour to complete, can be ground true by an emery wheel in five minutes. The top of the table should consist of a ground chilled plate. Slide-bars for locomotive engines, after being case-hardened, are generally ground true in a special machine. The bar is cramped down in a horizontal trough, which moves backwards and forwards under the emery wheel. This with its spindle runs at right angles to and above the trough. The bearings are supported by horns from the machine standards. The emery-wheel spindle, in addition to its rotatory motion, has a cross-travel, so that during the forward and return journey of the slide-bar, every portion of it comes into contact with the emery-wheel. The trough has a reciprocating motion like a planing-machine table. Dust from the wheel and slide-bar gets into the bearings, and soon wears them down, so that great attention is necessary. Mr. W. Adams, M. Inst. C.E., of the London and South Western Railway at Nine Elms, put in some metallined bearings which have answered admirably, and have run without oil or renewal for four years. During that time his machine has surfaced seven thousand and forty slide-bars, and the wheel, which was 24 inches in diameter at starting, has only worn down to 22 inches. The lateral travel of the machine is $3\frac{1}{2}$ inches, and it moves across once to about every thirty revolutions of the spindle.

Crank-pins after case-hardening are trued up at the Nine Elms works by means of emery wheels. A pin is placed in an ordinary lathe, and driven at a low speed. A 14-inch by 2-inch emery wheel is fitted up solidly on the slide-rest, and is driven off a wide drum on a counter-shaft, the small pulley on the emery-wheel

spindle being provided with flanges to keep the driving strap on. Case-hardened and chilled rolls are trued up in the same manner, and this method of removing the superfluous metal from such hard material has proved very successful, not the least advantage being that no stoppages for fettling tools are necessary.

In railway and repairing shops, where new ends are brazed upon old boiler-tubes, emery wheels are useful for removing the scurf from the joint, and reducing it to the required diameter.

Pulley-grinding is another common use to which emery wheels are put. Cast-iron pulleys are often ground just so that their hard surface is removed, and a tool can enter without being injured immediately. Wrought-iron pulleys are almost invariably ground in a large surfacing lathe, the emery wheel running on the rest, and being driven from an overhead drum. This is no doubt an economical way of getting up wrought-iron pulleys, and through its adoption lighter iron can be used for the rim of the pulley than if it were going to be turned true with a tool.

The long knife emery-wheel sharpener is for grinding and sharpening the knives used by paper-makers, tobacco-cutters, and book-binders. The knife is fixed in a slide-rest, which has a self-acting rectilinear motion in front of the emery wheel (generally here a large sized one), which runs in long bearings at the back of the machine, with its spindle parallel to the knife. As the knife is only ground by the periphery of the wheel, a certain concavity dependent upon the size of the wheel is produced upon the edge of the knife. This concavity is so small that it is ordinarily disregarded. In an American machine recently introduced this defect is remedied by using an emery cup-wheel, fitted on to the end of the shaft, which runs at right angles to the knife, and thus performs the grinding with its face, and produces a flat surface.

The ordinary fettling machine for foundry- and yard-work consists of a heavy vertical cast-iron box 2 feet by 3 feet by $2\frac{1}{2}$ feet high, with two long bearings on the top, and a steel $1\frac{3}{4}$ -inch spindle running in them. The driving-pulley is often keyed on the spindle between the bearings, and two heavy emery wheels overhang on each side. Sometimes one emery wheel is fixed in the middle of the machine between the bearings and pulley outside. Such a machine is invaluable for dressing heavy castings, and is also useful in girder-work for taking off the arisses left by the saw, and for cutting the bevel of the T iron stiffeners. A smith takes from three and a half to four minutes to cut the bevel of a 3-inch by 4-inch T, and a man can grind off the bevel with an emery wheel in from one to one and a half minute, saving at the

same time the wages of a striker, and the cost of repairing sets. Smaller fettling-machines are made for lighter work, and these are generally bolted down to the bench, or on to a stand made for them. Agricultural and other engineers who have a variety of small articles to get up find emery wheels very useful.

Coming to lighter work, the emery-tape machine is a handy tool. It consists of an upright frame 5 feet high, with a stout spindle running in one long bearing 12 inches from the ground. At one end of this spindle are fixed the fast-and-loose pulleys for driving, and at the other end the emery-band driving-pulley, 2 feet or more in diameter and flanged, of a width corresponding to the width of the largest emery-band it may be desired to use. Guide-pulleys to hold the band up to its work are provided on the side of the machine, and an adjustable flanged pulley for tightening the band at the top of the frame. The band consists of an endless tape prepared exactly in the same way as emery cloth. It is made in various widths. The driving-pulley is generally urged so that the emery-band has a surface speed of 3,000 feet per minute. Implements of irregular forms can be readily polished on this machine, and the band can be worked either wet or dry. Emery-wheel saw-sharpeners are now familiar objects in most saw-mills, and their economy over the old process of sharpening by hand is obvious.

In conclusion, it may be well to mention that, in order to ensure success in the use of emery wheels, plenty of power must be provided. No experiments, it is believed, have been made with the object of ascertaining the exact power required to drive any particular size or class of emery wheel; but it may be assumed that a 14-inch emery wheel will take as much power to drive it properly as a large lathe.

Small as is the use of emery wheels at the present time, it will not be rash to predict that in a few years every engineer's shop in this country will be well supplied with emery-wheel machinery.