FILE-MAKING

We shall introduce this article with some admirable observations on the progress of mechanical discovery, exemplified in an account of machines for cutting files, by Mr. Wm. Nicholson.

"The folly and consequent distress of pursuing experiments in chemistry, for the sole purpose of commercial advantage, has been repeatedly observed, both by public writers, and in private life. The obscurity which attends the processes of this art, the imperfections of theory, and the seductions of hope, have united to lead men in pursuit of medicines of uncommon powers, and agents which should convert the cheaper metals into gold and silver. It is a subject of no wonder, to those who have not suffered their mental habits to be vitiated by these seductive analogies, that difficulties and disappointment should attend the life of a man thus employed. But mechanics have, in general, been more favourably regarded. A number of simple and admirably useful effects are produced by the operation of machines. We daily see improvements produced by means easily understood. The mechanic, who endeavours to strike into a new path, finds he can reason from what has been done before him, and usually begins his work with a conviction that the results he is desirous of obtaining will infallibly happen. Hence it is, that a prodigious number of new schemes find their way into books, on which both the author and the reader set a high value, and of which the futility is discerned only by a few practical men. Some of my readers have supposed this source of information to be much more productive than it really is. A very slight inquiry concerning new machines and inventions, whether they have been carried into effect, and whether they have superseded the old methods of operation, will immediately strike out of the list of valuable articles not less than nine-tenths of the objects to which the public attention is solicited. And if it be asserted, that the description of such abortive projects might be of use to afford hints to speculators, I must take the liberty to observe, that it is a most serious thing to engage in a new invention, and a no less serious duty in the editor of a public work, to be well assured of the value of what he recommends or suffers to recommend itself to his readers. From views of this kind, it has appeared to me, that I should do some service to an active set of men, some of whom have effectually served this country, if I were concisely to point out the course of mechanical invention, in order that those individuals only may be induced to engage in it who possess the acquisitions and means to do it with some effect.

"We will therefore suppose a very acute theorist, who is not himself a workman, nor in the habit of superintending the practical execution of machinery, to have conceived the notion of some new combination of the mechanical powers to produce a determinate effect; and for the sake of perspicuity, let us take the example of a machine to cut files. His first conception will be very simple or abstracted. He knows that the notches in a file are cut with a chisel, driven by the blow of a hammer, by a man whose hands are employed in applying these instruments, while his foot is exerted in holding the file on an anvil by means of a strap. Hence he concludes, that it must be a very easy operation to fix the chisel in a machine, and cause it to rise and fall by a lever, while a tilting hammer of the proper size and figure gives the blow. But, as his attention becomes fixed, other demands arise, and the subject expands before him. The file must be supported upon a bed or mass of iron, of wood, of lead, or other material: it must be fixed either by screws, or wedges, or weights, or some other effectual and ready contrivance: and the file itself, or else the chisel, with its apparatus for striking, must be moved through equal determinate spaces during the interval between stroke and stroke, which may be done either by a ratchet-wheel or other escapement, or by a screw. He must examine all these objects, and his stock of means in detail; fix upon such methods as he conceives to be most deserving of preference; combine, organize, and arrange the whole in his mind; for which purpose, solitude, darkness, and no small degree of mental effort, will be required. And when this process is considerably advanced, he must have recourse to his drawing-board. Measured plans and sections will then show him many things which his imagination before disregarded. New arrangements to be made, and unforeseen difficulties to be overcome, will infallibly present themselves. The first conception, or what the world calls the invention, required an infinitely small portion of the ability he must now exert. We will suppose, however, that he has completed his drawings. Still he possesses the form of a machine only; but whether it shall answer his purpose, depends on his knowledge of his materials. Stone, wood, brass, lead, iron forged or cast, and steel in all its various modifications,

are before him; the general processes of the workshop, by which firmness, truth, and accuracy, are alone to be obtained; and those methods of treatment, chemical as well as mechanical, which the several articles demand:—these and numberless other practical objects call for that skill and attention, which may either lead to success, or, by their deficiency, expose him to the ignorance or obstinacy of his workmen. If he should find his powers deficient under a prospect so arduous—if he cannot submit to the severe discipline of seeing his plans reversed, and his hopes repeatedly deferred—if unsuccessful experiment should produce anguish without affording instruction, what will then remain for him to do? Will he embitter his life by directing his incessant efforts, his powers and resources, to a fascinating object, in which his difficulties daily increase; or will he make that strong exertion of candour and fortitude, which will lead him to abandon it at once?

"These are the inevitable stages of operation through which every inventor in mechanics must pass. To the mere habit of viewing objects in new lights, the habit which leads to the outline of invention, he must add the power of disposing his notions in the form of an individual engine or instrument; and he must himself become a workman, capable of discerning the means by which his ideas may become realized in the proper materials. It may perhaps seem as if I had selected an instance of difficulty, and indulged my imagination in a sketch of obstacles seldom likely to be met with. This, however, is far from being the case. Nothing seems more simple and easy at first sight, than to make an engine to cut notches in a piece of steel; and a very ingenious person, in the American Phil. Trans., has accordingly given an accurate design of an engine for that purpose, which no doubt he thinks must succeed. But manufacturers well know the value of such an engine, and have long ago I attempted to make it by that and various other methods without success. That engine in particular, promising as it appears, is utterly incapable of working, for several reasons, scarcely to be discovered but by practical men, but which cannot with sufficient brevity be here detailed. And with regard to general obstacles in the detail of inventions, I am so far from magnifying them, that I am warranted by much experience, as well on my own behalf, as that of others whose plans and operations have come before me, to affirm, that no mechanical invention really new was ever brought to its complete or perfect state, at so small a charge as three times the cost of the finished engine, exclusive of the incalculable labour of the contriver." Phil. Journ. 4to.

Many useful tools have been invented for performing mechanical operations, which consist of a number of wedges or teeth, which may be conceived to stand upon, or rise out of a flat or curved metallic surface. When these teeth are formed on the edge of a plate, the instrument is called a saw, (see Sawing); but when they are formed upon a broad surface, it constitutes what is denominated a file. The comb-makers use a tool of this description, called a quonet, having coarse single teeth, to the number of about seven or eight to an inch. Fine tools of this description are called floats. When teeth are crossed they are called files; and when, instead of the notches standing in a right line, a number of single teeth are raised all over the surface, it is called a rasp. Files are cut upon the surface with a sharp edged chisel. In rasps, the tooth is raised with a triangular punch. The file is adapted for working metals, but the rasp is more fitted for wood, bone, and horn. Files are distinguished by being single or double cut. The single cut file is simply cut once over, and is employed for filing brass, and the softer metals. A second course of teeth is cut to form the double cut file, crossing the first diagonally. This kind is best suited to iron and steel.

The steel employed for files requires to be very hard, and in consequence undergoes a longer process in the conversion (see Steel). It is said to be double converted. The very heavy files, such as smith's rubbers, are made of the inferior marks of blistered steel: the more delicate kind, such as watch-makers' files, being made of cast steel. The steel is previously drawn at the tilt, into rods of suitable size. The flat and the square files are made wholly with the hammer, and the plain anvil. Two workmen, one called the maker and the other striker, are required in the forging of heavy files; the smaller being forged by one person only. The anvil is provided with a groove, for the reception of bosses or dies, which are used for the purpose of forging the half-round and three-angled files. The halfround boss contains a hollow which is the segment of a sphere, less than half a circle. That used for the triangular files has a hollow consisting of two sides, terminating in an angle at the bottom. In forging the halfround file, the steel is drawn out, as if intended to make a flat file. It is then laid in the die, and hammered, till the under side becomes round. The steel for the triangular file is tilted into square rods. The part to form the file is first drawn out with the hammer, as if intended to form a square file. It is then placed in the die with one of the angles downwards, and by striking upon the opposite angle, two sides of the square are formed into one, and consequently a three-sided figure produced. By successively presenting the different sides to the action of the hammer, the figure is rendered still more complete. In forming the tangs of most files, it is necessary to make the shoulders perfectly square and sharp. This is performed by cutting into the file a little on each side with a sharp instrument, and afterwards drawing out the part so marked off, to form the tang. After forging, and previous to being ground and cut, the files require to be annealed. This process is generally performed by piling up a great quantity together in a furnace for the purpose, and heating them red hot; suffering them afterwards to cool slowly. This method of annealing files, or indeed any other articles, in which great hardness is requisite, is very objectionable, since the

surface of steel, when heated red-hot in the the open air, is so liable to oxydation. A superior method of annealing is practised by some file-makers, and since the hardness is a file is so essential a property, the process ought to be generally adopted. This method consists in placing the files in an oven or trough, and filling up the interstices with sand. The fire is made to play on every side of the vessel, as gradually and uniformly as possible, till the whole mass becomes red-hot. The fire is then discontinued, and the whole suffered to cool before the cover is removed from the trough. Another evil may however arise from keeping steel red-hot even in a close vessel for too great a length of time. It assumes a kind of crystallization, under which its tenacity is much impaired. Steel annealed in this way, is perfectly fiee from that scaly surface acquired in the open air; and if each corticle be perfectly surrounded with the sand and the cover not removed before the steel is cold, the surface will appear of a silvery white colour. If the steel be suspected to be too kind, from containing too little carbon, powdered charcoal may be employed instead of sand, or sand mixed with charcoal. In this case the files should be stratified alternately with the charcoal, in order that the extra-conversion may be uniform.

The next thing is to prepare the files for cutting, by making the surface to contain the teeth as level as possible. This was formerly effected by means of files, and the process is called striping [stripping]. The same is still practised by the Lancashire file-makers, and by others not having convenience for grinding. The greatest quantity of files, however, are ground to prepare them for cutting. The stones employed for the purpose are of the sand-stone kind, the texture of which is compact and sharp, but rather rough. They are of as great diameter as can be used with convenience; and about eight inches broad over the face. When used, the surface is kept immersed in water. The grinder sits in such a position as to lean over the stone, while its motion is directly from him. Its surface moves at about the same speed with those used in grinding cutlery. Since the object in grinding files is to make the surface as even and flat as possible, and as this cannot be done so completely upon a small stone, the stones of the file-grinder are laid aside when they are reduced to a certain size, and are employed for grinding other articles. Though grinding is by far the most expeditious method, it does not give that truth to the surface which can be effected by filing. If the price of the articles would admit, however, it would be well to render the surface more even by the file after grinding. If the surface be not flat, it is obvious, that when the file is used for filing a large surface, those teeth in the hollow parts of the file will not be brought into action. It is from attention to this circumstance, and to the care in annealing and hardening, that the Lancashire file-makers have generaly excelled. They are, however, confined chiefly to the small articles, since the larger files would not pay for the process of striping [stripping]. The tools of the file-cutter consist of an anvil placed upon a block of such a height that the man sits to his work. He has also a piece of lead alloyed with tin, on which he lays the files when one side is cut. The chisel and hammer are of such size as the size and cut of the file require. He is also provided with a leather strap, which goes over each end of the file and passes round his feet, which are introduced into the strap on each side in the same manner as stirrups are used. The file-cutter, therefore, sits as if he were on horseback, holding his chisel with one hand, his hammer in the other, at the same time he secures the file in its place by the pressure of his feet in the stirrups.

Great pains ought to be taken in preparing the edge of the chisel. It is, in the first place, hardened and tempered by heating it gradually till it appears of a yellowish brown. It is next ground very true to form the, which is afterwards finished upon a Turkey stone with oil. It is not required to be very sharp, the bottom of the tooth requiring to be rather open, to prevent file from clogging with the substance to be filed. The edge is also required to be very smooth, in order that it may slip easily upon the surface of the file: this is is also facilitated by slightly greasing the surface. From this advantage the worker, after mahing one tooth, is enabled by feeling only, to form at its proper distance the succeeding tooth, by sliding the chisel close up against the back of the preceding one.

In the double cut files, the first set of teeth, which the workmen call up-cutting, are, previous to cutting the second course, filed slightly upon the face, in order to allow the chisel to slide freely. The single-cut file is more durable than the double-cut, and ought to be preferred for all purposes exception for iron and steel. The same method is employed in cutting the rasp. The workman is, however, guided completely by his eye in regulating the distance of the teeth from each other. The rasp ought to be cut in such a manner that no one of the teeth may stand opposite to another; this not only allows the rasp to cut faster, but makes the surface either of wood or other substance much smoother.

The operation of simple file-cutting seems to be of such easy performance that it has fo almost two centuries been a sort of desideratum to construct a machine to perform that, which is not only done with great facility by the hand, but with wonderful expedition. We are told that a lad not very much experienced in the business will produce, with his hammer and chisel, nearly three hundred teeth in a minute. With respect to the machinery, it is said, that a Frenchman named Mathurin Jousse, in a work entitled "La fidelle Ouverture de l'Art de Serrurier," published at La Fleche, in Anjon, so long ago as the year 1627, gives a drawing and description of one, in which the file is drawn along by shifts by means of wheel-work, and the blow is given by a hammer. There are several machines of this kind, or at least

to effect the same purpose in the "Machines Approuvees par l'Academie Royale de Paris": there is also one published in the second volume of the Transactions of the American Philosophical Society, of which we shall give some account, as we shall of another for which Mr. William Nicholson obtained a patent in the year 1802; premising that the principal requisites in a machine for file-cutting, are that the metal from which it is manufactured should be steadily supported, and the chisel adapted to the face without any unequal bearing.

The American machine consists of a bench of well seasoned oak, and the face of it planed very smooth; and a carriage on which the files are laid, which moves along the face of the bench parallel to its sides, and carries the files gradually under the edge of the cutter or chisel while the teeth are cut. The carriage is made to move by a contrivance somewhat similar to that which carries the log against the saw of a saw-mill. The lever or arm, which carries the cutter, works on the centres of two screws which are fixed into two pillars in a direction right across the bench. By tightening or loosening these screws, the arm which carries the chisel may be made to work more or less steady. There is likewise a regulating-screw, by means of which the files may be made coarser or finer: also a bed of lead, which is let into a cavity formed in the body of the carriage, somewhat broader and longer than the largestsized files; the upper face of this bed of lead is formed variously, so as to fit the different kinds of files which may be required.

When the file or files are laid in their place, the machine must be regulated by the screw to cut them of a due degree of fineness. This machine is described as being so simple, that when properly adjusted a blind person may cut a file with more exactness than can be done in the usual method with the keenest sight; for by striking with a hammer on the head of the cutter or chisel all the movements are set at work; and by repeating the stroke with the hammer, the files on one side will at length be cut; then they must be turned, and the operation repeated for cutting the other side. This machine may be made to work by water as readily as by hand, to cut coarse or fine, large or small files, or any number at a time: but it may be more particularly useful for cutting the very fine small files for watchmakers.

We shall now give an account of the machine, for which Mr. Nicholson obtained His Majesty's letters patent.

"My machinery," says the patentee, " consists in four essential parts, suitably constructed and combined together; namely, First, a carriage or apparatus, in or by which the file is fixed or held and moved along, for the purpose of receiving the successive strokes of a cutter or chisel. Secondly, the anvil, by which the file is supported beneath the part which receives the stroke. Thirdly, the regulating gear, by which the distance between stroke and stroke is determined and governed. And, fourthly, the apparatus for giving the stroke or cut. The four several parts are supported by, or attached to a frame or platform of solid and secure workmanship, either of wood or metal, or both, according to the nature of the work intended to be performed, and the judgment and choice of the engineer. The carriage is a long block of wood, or metal, of the figure of a parallelipidon, or nearly so, having a portion cut out between its upper and lower surfaces to admit the anvil to stand therein, without coming into contact with the carriage itself. The said carriage is made of such a length that the excavation here described shall be considerably longer than the longest files intended to be cut; and it is supported upon straight bearers from the platform, upon which by projecting pieces, or slides, or wheels, or friction-rollers, it can be moved endwise in a straight lined direction, without shake or deviation. At one end of the said excavation is fixed a clip resembling an hand-vice for holding the file by its tail or tang; and in the opposite end of the said excavation there is a sliding block or piece, which being brought up to the other end of the file does, by means of a notch or other obvious contrivance, prevent it from being moved sideways. The said clip is so fixed at its head or shank by means of an horizontal axis on gudgeons and sockets, that the file is at liberty to move up and down, but not sideways or a-twist. In this manner it is that the file being fixed in the carriage is pressed down upon the anvil by a lever and weight proceeding from the platform, and bearing upon the face of the file by a small roller of wood, ivory, bone, or soft metal. The anvil is solidly fixed on the platform, and may be of any suitable figure which shall be sufficiently massy to receive and resist the blow; but its upper part must be so contracted as to stand up in the excavation of the carriage and support the file; and the upper part of all must be constructed in such a manner that it shall fairly apply itself to the under surface of the file, and support it without leaving any hollow space, not withstanding any casual irregularities of the said surface. I produce this effect by making a cavity in the anvil of the figure of a portion of a sphere, not much less than an hemisphere, and in this cavity I place (with grease between) a piece of iron or steel made exactly to fit, but of which the lower surface is a greater portion of the sphere, and the upper surface flat and plain. The file rests upon this last flat or plain surface, which is either faced with lead, or (in preference) a slip of lead is put under the tile and turned round the tang thereof, so as to move along with it. It is evident that the upper or moveable piece of the said anvil will, by sliding in its socket, accommodate and apply itself constantly to the surface of the file, which is pressed and struck against it. Or, otherwise, I make the concavity in the upper moveable piece, and make the fixed part convex: or, otherwise, I support the upper part, or in some cases the whole of my anvil upon opposite gudgeons, in the manner of the gimbals of sea compasses: or, otherwise, I form the upper part of my anvil cylindrical, of a large diameter, supported on thick gudgeons, the axis

of the said cylinder being short, and at right angles to the motion of the carriage: or, otherwise, I form only a small portion, namely, the upper extremity of my anvil of a cylindrical form as aforesaid, and cause the same to continue motionless by fashioning the same out of the same mass as the rest of the anvil, or fixing the same thereto. And in both the last-mentioned cases of the cylindrical structure I fix the head or shank of the clip (by which the tang is held), not by a single axis or pair of gudgeons, but by an universal joint or ball and socket, so that the file becomes at liberty to adapt itself not only upwards and downwards, but also in the way of rotation or a-twist, and supplies the want of motion in the anvil by the facility with which itself can be moved in the lastmentioned manner.

"The regulating-gear is that part of the machinery by which the carriage, and consequently the file is drawn along. It consists of a screw revolving between centres fixed to the platform, and acting upon a nut attached to the carriage with usual and well known precautions for working of measuring screws; and the nut being made to open by a joint when the carriage is required to be disengaged and slided back. And the said screw is moved either constantly by a slow motion from the first mover, or (which is better) by interrupted equal motions, so as to draw the carriage during the interval between stroke and stroke. And the quantities of those respective equal motions may be produced and governed at pleasure by wheel-work applied to the head of the screw, or by the well known apparatus used in the mathematical dividing engine for circles; or by various other contrivances well known to workmen of competent skill, and therefore unnecessary to be described at large: or, otherwise, the motion of the carriage may be produced by a toothed rack from the carriage drawn by a pinion; and this pinion moved by a ratchet-wheel on the same arbor moved by a click-lever, which shall -gather up and drive a greater or less number of teeth, according to the coarseness or fineness of the file; and the clicklever itself maybe moved by a tripping piece from the first mover, or by various other evident means of connexion: or, otherwise, the said carriage may be moved by a small cylinder, and rope or chain constantly acting: or, otherwise, the said motion may be effected by a train of two or more wheels, suffered to move by any of the escapements used in time-pieces, and the fineness of stroke may be regulated either by changing the wheels as in the common fuzee engine, or by the greater or less frequency of escape during each turn of the first mover. And in every case I prefer a counter-weight to the carriage, acting either constantly against, or constantly in the direction of its motion; though this is not absolutely necessary when the work is well executed. I may also observe, that it is possible to construct my said machinery by fixing and rendering motionless that part which I hove called the carriage, provided the other three principal parts be made to move instead of the carriage itself; but I consider this disposition as less eligible than that which requires the carriage to be moved. The apparatus for giving the stroke or cut, consists of a chisel, which is held between the jaws of a mouth-piece or claws resembling a strong hand-vice without teeth. One of the jaws is made very stout, and the chisel is formed narrow from edge to back, and wide from side to side, and has a semi-circular protuberance on its back, which rests in a circular notch in the strong jaw aforesaid; and there are two or three bended flat rings or washers of iron or metal under the thumb-screw of the said mouth-piece or claws, which prevent the chisel from becoming loose by the stroke: or, otherwise, the said chisel may have a notch, or a hole, instead of a protuberance, to meet a correspondent part in the mouth-piece or claws; but I prefer the first-mentioned construction. By the construction of the chisel as here mentioned and fixed, the edge of the said instrument is at liberty to apply itself fairly from side to side of the file notwithstanding any winding or irregularity, whatever may be the fineness of the cut upon a broad surface. The mouth-piece, with its chisel, is firmly fixed in another piece, which by its motion gives the stroke. This last-mentioned piece may either be a lever or a moveable carriage between upright sliders; but I greatly prefer the lever. The chisel must be so fixed that the moving piece shall carry it fairly edge-onwards to the file without scraping or slapping in the least; and the obliquity of the stroke may be adjusted by fixing the centres of the lever either higher or lower at pleasure, or by inclining the last-mentioned sliders. The lever may be raised and let fall (or the other chisel apparatus moved) by a tripping-piece or snail-work, or other usual connexion with the first mover; and its power of stroke may be increased by the addition of a weight, or by the action of a spring; which last method is of excellent use, and may (if required from the varying breadth of the file) be made to increase or diminish its power during the run by several easy and commonly used methods or contrivances for pressing more or less against the spring. Or, otherwise, the lever, or holding- piece, may be kept immediately above the file by the reaction of a slight spring, of weight, and be struck by a hammer moved and acted upon by the first mover, as aforesaid: and to this method I give the preference, because the lever will then have less strain upon its pivots; or, the said lever may even be supported by spring-joints without any pivots or centres at all. Or, instead of a hammer, the blow may be given by a ram, or a fly and screw, but I give the preference to the hammer. The lever may move in a vertical circle immediately over the file, or in an oblique circle at right angles to it, or at any intermediate angle consistent with the foregoing instructions: and the chisel may be set with its edge at any angle whatever, with the line of the length of the lever; but, in general, I have set the lever in the first-mentioned position, and have varied the angle between the chisel-edge and the lever, according to the intended slope

of the cut upon the face of the file. The edge of the chisel must be sharpened to such an angle as the intended cut and strength of burr may require. Lastly, I describe the general action of the said machinery as follows: 1. The file being prepared as usual for cutting, must be fixed in the clip of the carriage, and the sliding-block brought up and fixed, to steady its other extremity. 2. The nut of the screw being then opened (or the other regulating gear disengaged,) the carriage is slided to its place, so that the chisel may be situated over that part of the file which is to receive the first stroke. 3. The nut is then closed (or the other regulating gear connected) and the small roller of the pressing lever is made to bear upon the face of the file. 4. The first mover being then put into action, raises and lets fall the apparatus for giving the stroke by which the file receives a cut. And, 5, immediately afterwards, or during the same action, as the case may be, (according to the construction as before described,) the regulating gear moves the carriage, and consequently the file, through a determinate space. 6. The cut is then again given; and in this manner (the strength of cut being duly proportioned to the space between cut and cut,) the file becomes cut throughout. 7. The file is then taken out and cut on the other side. 8. The burr is then taken off, or not, as the artist may think best; and the cross-strokes are given over the surfaces as before. And the said machinery, by certain slight, necessary, and obvious changes in the structure and disposition of the chisels, and some other of the parts thereof, is adapted to manufacture all other forms and descriptions of files, whether floats, rasps, half-round, three-square, or any other figure or denomination.

Three things are strictly to be observed in hardening files; first, to prepare the file on the surface, so as to prevent it from being oxydated by the atmosphere, when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough, that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult. The first object is accomplished by laying a substance upon the surface, which, when it fuses, forms as it were a varnish upon it, defending the metal from the action of the oxygen of the air. Formerly the process consisted in first coating the surface of the file with ale-grounds, and then covering it over with pulverised common salt. After this coating becomes dry, the files are heated red-hot, and hardened; afterwards, the surface is lightly brushed over with the dust of cokes, when it appears white and metallic, as if it had not been heated. This process has lately been improved, at least so far as relates to the economy of the salt, which, from the quantity used, and the increase of duty, had become a serious object. Those who use the improved method are now consuming about one-fourth the quantity of salt used in the old method. The process consists in dissolving the salt in water to saturation, which is about three pounds to the gallon, and stiffening it with ale-grounds, or with the cheapest kind of flour, such as that of beans, to about the consistence of thick cream. The files only require to be dipped into this substance, and immediately heated and hardened. The grounds or the flour are of no other use than to give the mass consistence, and by that means, allowing a larger quantity of salt to be laid upon the surface. In this method, the salt forms immediately a firm coating. As soon as the water is evaporated, the whole of it becomes fused upon the file. In the old method, the dry salt was so loosely attached to the file, that the greatest part of it was rubbed off into the fire, and was sublimed up the chimney, without producing any effect. Some file-makers are in the habit of using the coal of burnt leather, which doubtless produces some effect; but the carbon is generally so ill prepared for the purpose, and the time of its operation so short, as to render the effect very little. Animal carbon, when properly prepared and mixed with the above hardening composition, is capable of giving hardness to the surface even of an iron file. The carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoe-makers and curriers is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to mix with the salt. Let about equal parts, by bulk, of this powder, and muriate of soda, be mixed together, and brought to the consistence of cream, by the addition of water. Or mix the powdered carbon with a saturated solution of the salt, till it become of the above consistence. Files which are intended to be very hard, should be covered with this composition previously to hardening. By this method, files made of iron, which in itself is insusceptible of hardening, acquires a superficial hardness sufficient to answer the purposes of any file whatever. Files of this kind may be bent into any form, and in consequence are rendered useful for sculptors and die-sinkers.

The mode of heating the file for hardening, is by means of a fire similar to that employed by common smiths. The file is to be held in a pair of tongs by the tang or tail, and introduced into the fire, consisting of very small cokes, pushing it more or less into the fire, for the sake of heating it regularly. When it is uniformly heated of a cherry colour, it is fit to quench in the water. An oven is commonly used for the larger kind of files, into which the blast of the bellows is directed, being open at one end for the purpose of introducing the files and the fuel. After the file is properly heated, for the purpose of hardening, it should be cooled as quickly as possible; this is usually done by quenching it in

the coldest water. Clear spring water, free from animal and vegetable matter, is best calculated for the hardening files.

When files are properly hardened, they are brushed over with water and powdered coke, when the surface becomes clean and metallic. They may likewise be dipped into lime-water, and dried before the fire as rapidly as possible, after which they should be rubbed over with olive oil, in which is mixed a little oil of turpentine while warm, and then they are finished.

In the operations of filing, the coarser cut files are always to be succeeded by the finer; and the general rule is, to lean heavy on the file in thrusting it forward, because the teeth of the file are made to cut forwards. But in drawing the file back again for a second stroke, it is to be lifted just above the work, to prevent its cut cutting as it comes back. The rough or coarse-toothed file, called a *rubber*, serves to take off the unevenness of the work, left by the hammer in forging. The bastard-toothed file, as it is technically called, is to take out too deep cuts and file-strokes made by the rough file. The fine-toothed files take out the cuts or file-strokes which the bastard file made, and the smooth file those left by the fine file.