MACHINERY'S REFERENCE SERIES

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No. 48

A Dollar's Worth of Condensed Information

Files and Filing

SECOND EDITION

Price 25 Cents

CONTENTS

The Industrial Press, 49-55 Lafayette Street, New York
Publishers of MACHINERY

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CHAPTER I

TYPES OF FILES*

A piece of high-grade crucible steel, forged to shape, ground, cut and carefully tempered, forms that tool so indispensable to the mechanic—the file.

The file maker is no longer compelled to forge his blanks from stock of unsuitable proportion, but receives from the steel manufacturers stock of the required cross-section to make all standard shapes. This reduces the forging to a minimum, it being only necessary to cut the stock to the required lengths, to draw down the point and form the tang, the latter operation being very rapidly performed under power hammers.

The National Association of File Manufacturers prescribes to the steel makers the forms of cross-sections they require. Consequently, all makers of file steel can furnish any section correct to gage. In Fig. 1 are shown the correct cross sections of steel for flat files, even

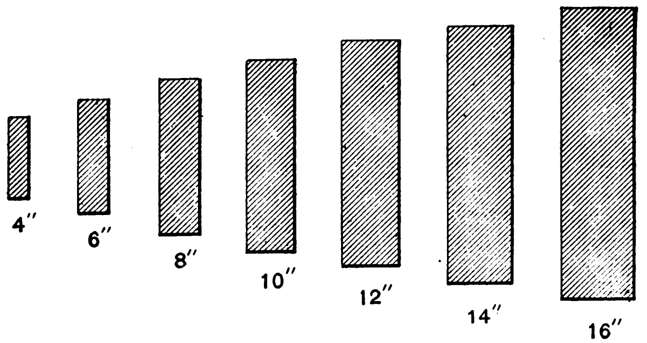

Fig. 1. Cross-sections of Steel Bars for Flat Files, from 4 to 16 Inches Long

inch lengths, from 4 to 16 inches. In Fig. 2 are shown the cross-sections of file steel for all the shapes in general use. Each section is for an 8-inch file, full scale. The names of the files made from steel of these sections are, referring to the numbers in the figure: 1, "Hand"; 2, "Flat"; 3, "Mill"; 4, "Pillar"; 5, "Warding"; 6, "Square"; 7, "Round"; 8, "Half-round"; 9, "Three-square"; 10, "Knife"; 11, "Pit-saw"; 12, "Crossing"; 13, "Tumbler"; 14, "Cross-cut"; 15, "Feather-edge"; 16, "Cant-saw"; 17, "Cant-file"; 18, "Cabinet"; 19, "Shoe-rasp"; 20, "Rasp."

It will be noticed that many of these files are named from the form of their cross-section, and that those so named are the ones most used for general work, whereas the others receive their names from the spe-

* MACHINERY, February, 1898.

cial character of the work they are expected to be used upon. It will be noted that the stock for files of rectangular cross-section may be classified as to thickness as follows: "square," the thickest; "pillar," "hand," "flat," "rasp" and "warding." As to width, "hand" is the widest; "flat," "rasp," "mill," and "warding" are the same width; "pillar" materially narrower, and "square" the narrowest.

The "half-round" is not a full semi-circle, the arc being about one-third of the full circle. On the other hand, the "pit-saw" is a full half circle in section.

The "three-square," "cant-saw" and "cant-file" differ in section in their angles, the former having equal angles, 60 degrees, and equal

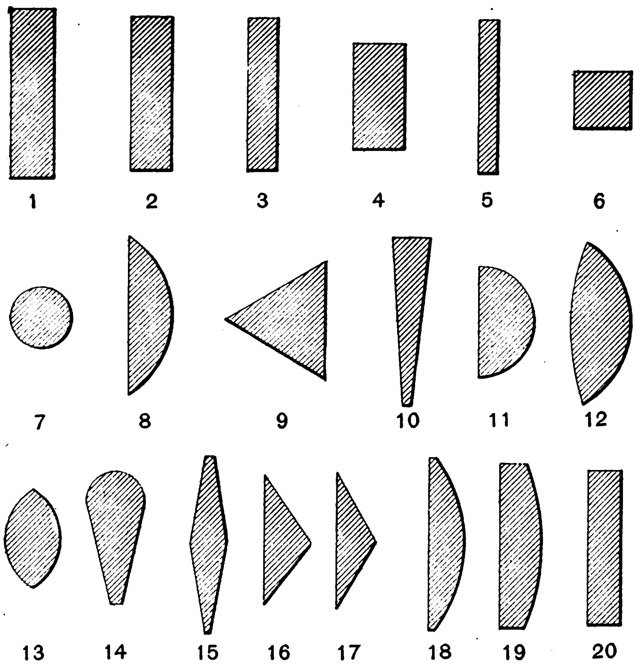

Fig. 2. Sections of Files in General Use

sides, the next 35—35- and 110-degree angles, and the latter 30—30- and 120-degree angles.

The length of a file is measured from point to heel, and does not include the tang. The tang is usually made spike shaped to receive a plain ferrule handle. Some makers modify the form of tang to fit patented handles.

As forged, the blank for a "hand" file, Fig. 3, is parallel in thickness from heel to middle and tapered from middle to point, making the point about one-half the thickness of the stock. The edges of the blank are usually left parallel. They are, however, sometimes drawn in slightly at the point.

The "flat" file blank, Fig. 4, is parallel in both of its longitudinal sections from heel to middle and tapered in both sections from middle to point, the thickness of point being about two-thirds and width about one-half that of the stock.

For the "mill" file the blank is parallel in thickness from heel to point, and usually tapered to about three-fourths the width of the stock. The "mill" file is often made blunt—that is, of equal width and thickness throughout its length.

The blank for the "warding" file is tapered in width from heel to point and is of uniform thickness. Aside from width, the "pillar" file is similar to the "hand" file. The "pillar" file is also made in

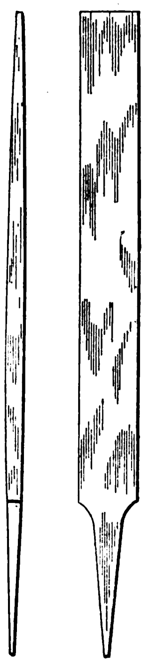

Fig. 3. Forged Blank for Hand File

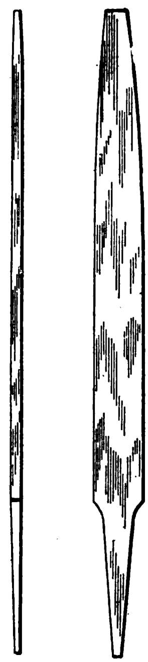

Fig. 4. Forged Blank for Flat File

narrow and extra narrow patterns, the extra narrow approximating a square in section.

The "three-square," "square" and "round" are also made in slim and blunt forms. The "slim" is a file of regular length, but smaller cross-section, and the "blunt" of equal cross-section from heel to point, being either "slim" or regular.

After forging, the blanks are thoroughly annealed in annealing furnaces, the operation taking from twenty-four to thirty-six hours. When the blank comes from the furnace, it is twisted and scaly, and must be subjected to a "straightening" process, after which the scale is removed by "grinding" on very heavy grindstones. The blanks are next draw-filed to make them perfectly smooth and even, after which they are ready for the cutting.

Files are classified under three heads—"single-cut," "double-cut" and "rasps." The "single-cut" file—or "float," as its coarser cuts are sometimes called—has surfaces covered with teeth made by single rows of parallel chisel cuts extending across the faces at an angle of from 65 to 85 degrees with the axis of the file. The size of this angle depends on the form of the file and the nature of the work it is to perform.

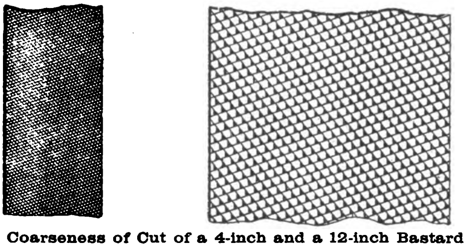

Fig. 5. Coarseness of Cut of a 4-inch and a 12-inch Bastard File

The "double-cut" file has two rows of chisel cuts crossing each other. The first row is, for general work, at an angle with the axis of the file of from 40 to 45 degrees, and the second row from 70 to 80 degrees. In the "double-cut" finishing files the angle of the first cut is about 30 degrees, and the second from 80 to 87 degrees with the axis of the file. The "double-cut" gives a broken tooth, the surface of the file being made up of a large number of small oval-pointed teeth inclined toward the point, and resembling in shape the cutting end of a diamond pointed cold chisel.

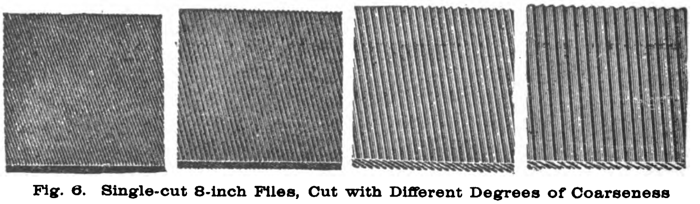

Fig. 6. Single-cut 8-inch Files, Cut with Different Degrees of Coarseness

In the rasp the teeth are entirely disconnected from each other. They are round on top, and are formed by raising, with a punch, small portions of stock from the surface of the blank. The machinist seldom has use for a rasp, as it is intended for filing the softer materials, as wood and leather.

The regular grades of cut upon which the coarseness of a file depends are "rough," "coarse," "bastard," "second-cut," "smooth" and "dead-smooth." The "rough" file is usually single-cut and the "dead-smooth" double-cut. The other grades are made in both double and single cut. These grades of coarseness are, however, only comparable when files of the same length are considered, as the longer the file in any cut, the fewer the teeth per inch of length. This is shown in Fig. 5, where a 4-inch and a 12-inch "bastard" file are placed side by side for comparison.

The relative degrees of coarseness for the different cuts are shown, for the "single-cut" in Fig. 6, and for the "double-cut" in Fig. 7, a portion of an 8-inch file being taken in each case.

The value of a file depends entirely upon three things—quality of stock from which it is made, the form of its teeth and the temper.

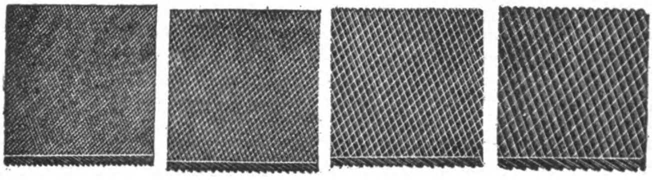

Fig. 7. Double-cut 8-inch Files, Cut with Different Degrees of Coarseness

The stock should be of the very best, as tool steel is seldom put to any use where its lasting qualities are more severely taxed.

It is only within the past few years that machine-cut files have come prominently upon the market, it being generally believed that a file to be first class must be hand cut. In Fig. 8 are shown portions of two 14-inch flat "bastard" files; of these one is hand and one machine cut. The difference between these cuts is so slight that only an expert, with the files rather than their pictures before him, could tell, with any degree of certainty, which was the hand and which the machine cut.

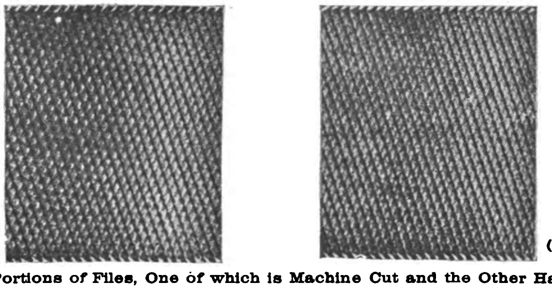

Fig. 8. Portions of Files, One of which is Machine Cut and the Other Hand Cut

It was once thought that the great trouble with machine-cut files was in the perfect uniformity of the teeth. In a hand-cut file the width and spacing of the teeth depend entirely upon the skill of the workman; and no matter how carefully he does the cutting, irregularities of a thousandth of an inch, more or less, will occur in the spacing and in the angle at which he holds the broad chisel that forms the teeth. These slight variations, it was believed, caused the teeth to be of uneven height and irregular outline. These irregularities were very faithfully reproduced in the increment machine-cut files.

It has been stated that it is difficult to make a file having teeth of uniform height and outline, as in the case of the ordinary machine-cut file, take hold of the work. The reason for this is that so many teeth present themselves to the work surface that the workman must exert great pressure on the file to make them bite. With the file having teeth of irregular height, fewer will come in contact with the work, and the pressure required to make them take hold will be correspondingly light. As these long teeth wear down, the shorter ones will begin to do work; but the file will, of course, not cut so freely as when new. Again, in using the file with teeth of uniform height, it will, when pushed to the work, produce, at the start, grooves which will grow deeper as the file is moved forward, and, due to the broad cut, will be quite certain to vibrate and "chatter." On the other hand, the uneven teeth of the hand- and increment-cut files will so adapt themselves to the surface of the work that only a few teeth at any particular point in the length of the file will cut. The metal left between these teeth will be removed by the teeth following, perhaps a

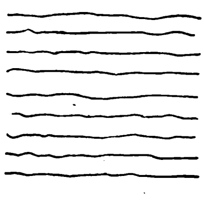

Fig. 9

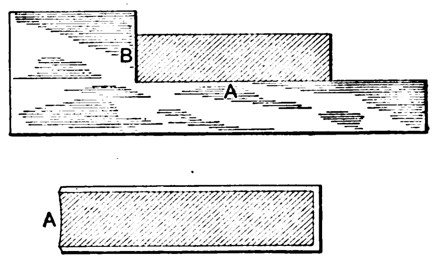

Fig. 10

dozen or more rows of teeth being required to finish the cut started by one. This is shown, for a "single-cut" file, in Fig. 9, where the several irregular lines represent as many tooth outlines drawn on an exaggerated scale. These teeth come successively to the work, and if all their high points were brought together they would form a straight line, as shown, which would be the outline of the resulting cut. The opinions regarding the objections to machine-cut files, as stated above, have, however, been questioned by file makers of long experience. This subject is more thoroughly dealt with in Chapter V.

The cutting of an increment-cut file consists in the forming of the teeth by a chisel operated in a machine, and so controlled that the spacing between teeth may be increased or decreased, the same being subject to a small amount of irregularity, as well as a slight variation in the angle of the teeth with each other. As manufactured by one company, the spacing of the teeth from point to middle is increased, and from middle to heel decreased. Another leading manufacturer increases the pitch from point to heel. It will be understood that the increment of space is very small. In a 12-inch "bastard" file, having teeth spaced progressively wider from point to heel, the pitch of teeth at heel is about 0.01 of an inch greater than at the point, which makes the average increase per tooth about 0.00003 of an inch.

In machine-made files the cutting is very rapidly performed, the chisel receiving from 500 to 3500 blows per minute, depending on the weight of the file being cut. The blank is cut from point to heel, and when turned over is placed on lead strips to protect the teeth already formed.

After cutting, the files are inspected and assorted as to quality. They are then hardened, any material change in shape due to hardening being rectified at the time of tempering, after which they are ready for final inspection. This consists of trying each file on a piece of hard steel and making sure that it is free from temper cracks. They are next coated with oil and wrapped in oiled paper, to prevent rusting, after which they are packed in boxes, ready for the market.

The teeth of a file remove metal by a shearing cut. This is most apparent in the "single-cut" files, where the teeth have lateral length; but is equally true of the pointed tooth of the "double-cut" file.

A file bites freer on work having a narrow surface than a wide, be-

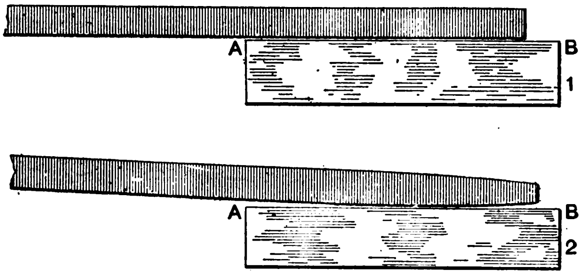

Fig. 11. Comparison between Action of Straight and Tapered File

cause fewer teeth come in contact, at any point in the stroke, with the work surface, and consequently less pressure is required to make the file bite. On very thin work the teeth of a "double-cut" file bite so freely that the danger of breaking them is great. For work of this character the long tooth of the "single-cut" is best adapted, as its form gives it greater strength, and the shear of the cut is smoother, one tooth commencing to cut as another leaves. On the broad surfaces, however, the teeth of the "double-cut" have the advantage.

A file is "tapered" when it is thinner at the point than at the middle, and is "full tapered" when thinner at point and heel than at the middle. The reasons for thus tapering a file are, first, to reduce the number of teeth that come in contact with the work, and, second, to enable the operator to file a straight or plane surface. The first reason is obvious; the second is shown in Fig. 11. If the file is perfectly straight, as shown in 1, the motion in order to produce a plane surface on the work must be absolutely parallel to this surface. This the most expert mechanic can scarcely be expected to do, and the result will be work rounded at the edges *A* and *B*. If the file is tapered, its surface will be slightly convex, as shown in 2, and if moved entirely across the surface, straight work will result. The workman will experience little difficulty in accomplishing this, as he can allow the motion of the file to deviate slightly from a straight line, and still not cut away the edges *A* and *B*. If the file is not moved clear across the work, a concave surface will of course result.

The hardening is certain to distort the file somewhat, and it will, as a result, usually be found to have more "belly," as this convex quality is called, on one side than on the other. It is the side having the most "belly," and the highest part of that, that the careful mechanic will always select for use in his most particular work. This high point he readily finds by running his eye along the edge of the file from point to heel.

In filing the non-fibrous metals, as cast-iron and brass, sharper files are required than for work on steel and wrought iron. Broad surfaces require, as indicated above, sharper files than narrow ones. The systematic workman will therefore use his new files on broad surfaces of cast iron and brass, next on the narrow, and when dulled to such an extent as not to readily take hold of these metals, he will use them for work on wrought iron and steel, and finally, when too dull for efficient work, may be used for smoothing up and removing the hard scale from castings and forgings.

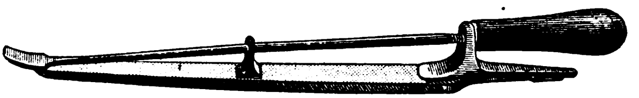

Fig. 12. Special Holder for File when Filing Wide Surfaces

A new or good file should never be used on rough castings, as the scale of cast iron is often very hard, and will ruin the file after a few strokes. The edge of the file can be used to advantage for this work, as it is seldom used for other purposes.

When the file is pushed endwise across the work, it is called cross filing. The work is performed on the forward stroke and the file released from all cutting duty on the return stroke. It should not, however, on the return stroke be raised from the work, except at such times as may be necessary to examine the condition of the surface. As the file is pushed forward, it should be given a slight side motion, and after a number of strokes the direction should be changed, so as to make the file marks cross at quite an angle. This will increase the cutting of the file, and will keep the work true by preventing deep grooving.

The handle of the file in cross filing should be held in the right hand, preferably with the end of the handle seated against the palm and the thumb extended along the top. The point is held under the ball of the left thumb, the fingers pressing upward against the lower side. In using thin files the downward pressure at heel and point may spring them until they are concave instead of convex to the work surface. In this case the point must be so held between thumb and fingers that the fingers exert an upward pressure under the point, and the thumb a downward pressure a few inches back from the point, which will tend to make the file more convex to the work surface. It is a tiresome way to hold the tool, but will at times be found necessary.

When the surface of the work is broad, a surface holder must be used. Fig. 12 shows a device which is used a great deal for this purpose.

In filing broad surfaces the work should be placed low, thus enabling the operator to reach all points of its surface and to put the required pressure on the file. For work held in the vise or on the bench, the surface being filed should be at about the height of the workman's elbow, so as to give the forearm holding the file handle an almost horizontal motion. If the work is fine and delicate, it is preferable to hold it higher, as it can then be more readily inspected.

In draw filing the motion of the file is at right angles to its axis. It is firmly held in both hands at heel and point, the handle usually being removed. In draw filing the metal is removed much slower than in cross filing, with the same cut of file; but the surface left is smoother, is not so apt to be scratched in the operation, and will take a better finish. Draw filing requires less skill than cross filing, the beginner being able to produce very creditable work after comparatively little practice. Cross filing, on the other hand, requires skill and experience when smooth, plane surfaces are to be made.

The character of the work and the surface required will determine the coarseness of the file the mechanic will select for performing it. The "bastard," "second-cut" and "smooth" are the cuts most used by the machinist on general work. The "rough" and "coarse" cuts are used mostly on the softer metals where a large amount of stock is to be removed quickly. The fine-cut files will take hold of the harder metals better than the coarser files, and will leave the surface smoother.

The file must be kept free from the cuttings which lodge between the teeth. When lodged too firmly to be removed by tapping the edge of the file against the vise back, they should be scraped out with a soft wire file card or brush. When working on wrought iron or steel, cuttings will lodge so firmly that they cannot be brushed out, but must be picked out with a soft iron scorer. They will often project above the teeth and cause deep scratches in the work. This annoying trouble is called "pinning." It may be lessened somewhat by thoroughly chalking the surface of the file, which also prevents its cutting so freely.

When filing work in a lathe, care must be taken not to run the surface filed too fast. It must be remembered that, ordinarily, the motion of the file on the work is comparatively slow—say, forty strokes per minute, of perhaps 8 inches each. As the file is cutting only about one-half the time, the actual velocity of cut in this case would be not far from 50 feet per minute. The intermittent motion of the cut prevents the teeth becoming extremely hot. In filing revolving work, the number of strokes per minute will not be so great, but the length of stroke will be somewhat increased; so the actual cutting speed due to the motion of the file will not be much less than in cross filing. To this must be added the speed of the work, which will vary from 50 to 100 feet per minute. It will be understood that, in filing stationary work, a comparatively short length of the file's surface is cutting, whereas in filing rotating work, nearly all of the file's length is brought into use at each stroke, which offsets largely the disastrous effects on the teeth due to too high a cutting velocity. The file must not be held stationary, allowing the work to revolve to it, as in that case a few teeth do all the cutting and leave a grooved surface. As the file is moved forward, it should, as in cross filing, be given a small amount of lateral motion, first to the right and then to the left, causing the file marks to cross at quite an abrupt angle. Rotating work should be filed as little as possible, in order to obtain the desired finish, it being almost impossible to retain the cylindrical truth of the work if filed too much.

A safety edge on a file is one having no teeth. The safety edge enables the mechanic to file one or two surfaces, *A*, intersecting at right angles, without injuring the other *B*, as shown in the upper view in Fig. 10. The safety edge on a new file should always be passed over a

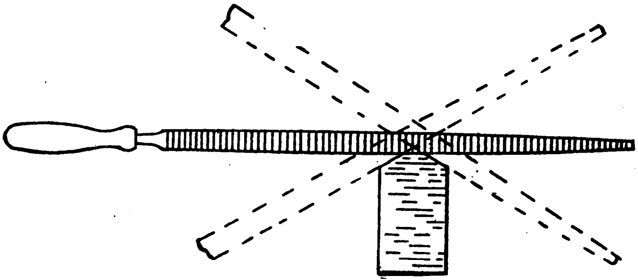

Fig. 13. Method of Removing Metal Quickly by Filing

grindstone or emery wheel before depending on its "safety," as in the cutting of the sides the stock is expanded over the edge, making a slight concave, as shown at *A*, in the lower view in Fig. 10. While the points of the teeth do not, in cutting, form out full over the safety edge, the roots of the teeth do, and they are very apt to scratch the surface the edge is expected to protect. A very satisfactory safety edge is made by grinding the teeth from the edge of a full cut file.

When a large amount of metal is to be removed quickly, the file may be used at different angles, as shown in Fig. 13. This decreases the area of cut and increases the bite of the file. A new file should never be used for this purpose, as the keen edge of the teeth would be broken off. All work surfaces, especially if narrow, should be held as near the top of the vise jaws as possible, thus preventing vibration.

Good workmen will keep the files they are using in a rack or drawer, so arranged that they cannot come in contact with each other. When we consider the amount of metal a file will remove under favorable conditions, we are impressed with the expense of the tool when improperly used. Far too many are ruined through carelessness.

CHAPTER II

HOW TO HANDLE A FILE*

Probably no branch of the machinist's trade requires more skill than the proper handling of a file. To make a file cut smooth when desired, and to make it cut where you want it to, and at no other place, is an art worth cultivating by all the younger men of the trade. It is possible to train an apprentice to operate a lathe, planer, or milling machine, and do good work on it, in much less time than it takes to teach him to do good filing. Probably this is the reason that most of the filing and fitting is done in the shops by the older class of mechanics.

Filing a Flat Surface

In filing a flat surface the choice of file depends on the degree of flatness and finish required. For a really flat surface, the writer would use a square file with which to do the first filing, and a pillar for the finishing. If one has to get along with one kind of a file for all kinds of filing, the writer would prefer the square safe edge file to all others. The reason for this is that the square file has more "belly" to it, and possesses greater stiffness in the direction of applied pressure in proportion to its bearing surface on the work than any other, and, being narrow, requires less pressure to make it "bite" into the work.

In order to file straight it is necessary that the file "hold its cut," any slipping or sliding over the surface being fatal to straight filing. Whatever kind of a file is used, the downward pressure should be sufficient to cause the file to bite and hold its cut, and with a wide flat file such as a hand file or one that has become dulled by use, this pressure becomes so great as to make straight filing extremely difficult. The square file requires less pressure, is under better control, and responds to the "touch" and "feel" of the operator better than any other. The pillar file is next to the square as regards the foregoing points, and for some cases might be preferred. The writer would here offer the suggestion to file makers that for flat surface filing, the hand and pillar files should have more "belly," being thicker in the center than as at present made, and that the curvature should be made uniform from point to heel. With such a file we could do more and better work, and do it easier than with the present styles. Another point, but on which there may be some doubt, is that in a double-cut file the cuts across both ways should be of equal depth, so that the diamond shaped squares left by the chisel marks stand out sharp and distinct. The writer can give no definite reason for this, except that he instinctively prefers such a file to one which has somewhat the appearance of a single-cut file.

* MACHINERY, August, 1908.

To file a surface flat it is necessary to "cross file" it, that is, file it in different directions until the tool marks are eliminated and the desired degree of flatness obtained. This cross filing is most important, and is a prime factor in the production of flat surfaces. By frequently changing the direction of file marks, the operator can see at all times just where the file is cutting. If it is desired to lower any part of the surface after testing with the square, straight-edge, or mating piece, the file should be made to cut across the marks left by the previous filing. The cross marks then serve as an indication of the amount being taken off. After cross filing, the surface will have the appearance shown in Fig. 14.

When using a square or pillar file for the cross filing, it should be given a slight side motion while making the cutting stroke. It should be lifted *clear* of the surface on the back stroke, care being taken not

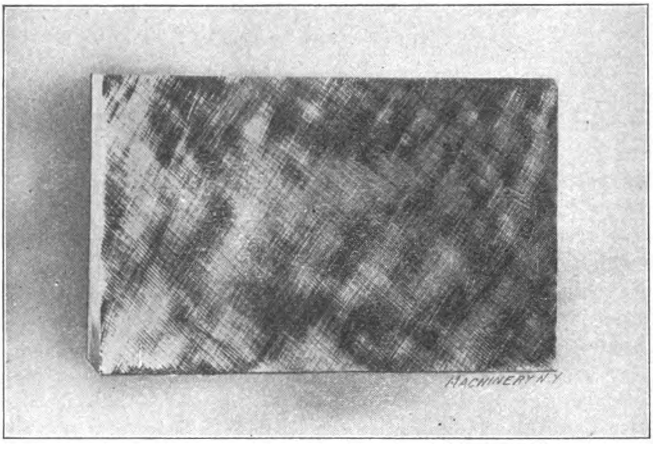

Fig. 14. Cross-filed Flat Surface

to have it come up with a sweep and down with a sweep, but the path should be like that indicated by Fig. 16. If the surface is to be finished, then go over it lightly in one direction just taking out the cross marks. For this purpose a new file is best, second-cut, smooth or dead smooth, according to the finish desired, but previous to using the file, it should be rubbed down lightly with a flat Arkansas oil-stone. A new file often has a few teeth projecting above the general surface, especially at the corners, and this light stoning takes them off so that the file is more likely to cut without scratching. It might be mentioned that the last cross filing should be done with as fine a toothed file as that used for finishing, so as not to have deep scratches to take out in the final filing. For this finishing, "straightaway" filing is to be preferred to draw filing, because of being quicker and leaving the corners in better shape than the draw filing; but, of course, there are many surfaces on which draw filing must be used. If the surface has been properly filed, a very few strokes with emery cloth will "lay the grain," giving it a uniform appearance, and with corners sharp like knife edges.

To prevent pinning when filing soft steel, some mechanics use chalk on the file, others use oil. In the writer's opinion, chalk is a poor substitute for oil; the only case where it would possibly have any advantage would be with a dull file. However, one might about as well think of shaving with a case knife as trying to file straight with a dull file. The file is like all other wood- or metal-cutting tools; if it is to cut where you want it to, it must be sharp. Care should be taken, however, not to use too much oil; a good plan when using a fine file is to oil it and then draw it through a piece of waste. This at once cleans the teeth, and leaves sufficient oil on the file. After it has been used

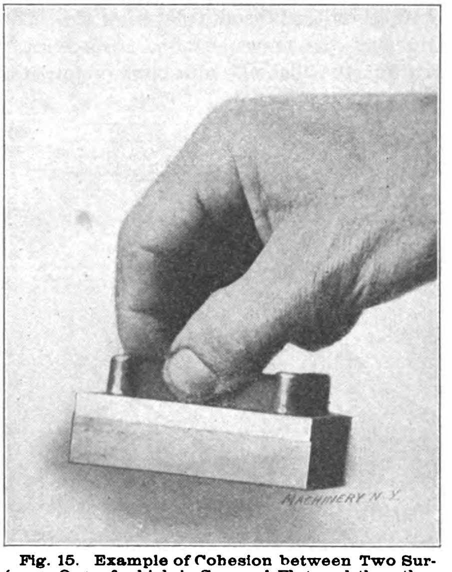

Fig. 15. Example of Cohesion between Two Surfaces, One of which is Scraped Flat and the other filed to fit it

a little while, it should be again drawn through the waste to clean out the chips. No file card is necessary.

The half-tone Fig. 15 shows two pieces held together by atmospheric pressure. One piece is a small cast iron surface plate 3 × 2 inches, ribbed as shown, the other is a steel block of the same size, but ⅝ inch thick. The surface plate was scraped to a master plate and the steel block filed to fit it. These surfaces are *dry*, not wiped off with greasy waste, but washed with gasoline and dried with a clean cloth.

Nearly all of the foregoing can be summed up in a single sentence: *For flat surface filing use a sharp file and localize its cutting action.*

Filing a Concave Surface

For filing a concave surface such as shown in Fig. 17, an ordinary half-round file will do for roughing; outside of that it is a poor tool.

A square file, as shown in Fig. 18, is much to be preferred, as it will "lay to the surface," and make it possible to get the the surface straight cross-wise with much less effort than with the half-round file. The file should be held straight across, and swept round the curve while it is being advanced, sweeping it both ways to insure a smooth curve. To be sure, the file is cutting only on its corners while being used this way, but it is surprising how much work these corners will do, how little pressure is required to make the file cut, and how easy it is to keep it from rocking.

The crossing file is, however, a more scientific tool for this kind of work than the square. It should be used with the flattest side next to the surface, or, in other words, the radius of curvature of the file should be *greater* than that of the surface being swept out, as indicated in Fig. 19. The only difference between this file and the square file is that the former has more bearing surface on the work. The essential point is that the file has a bearing along its two edges, and

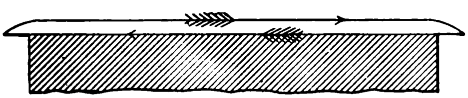

Fig. 16

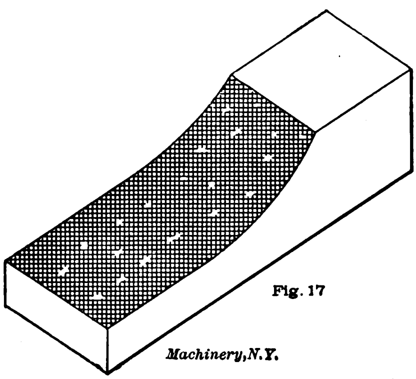

Fig. 17

Machinery,N.Y.

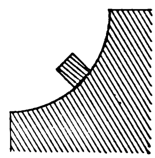

Fig. 18

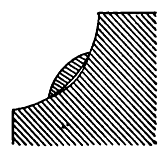

Fig. 19

Figs. 16 to 19. Methods and Tools for Filing Flat and Concave Surfaces

not in the center. After the piece has been brought to shape and dimensions by cross filing, it can be finished by draw filing, using a half-round or crossing file with radius of curvature *less* than that of the surface. It will often be found a help, if there is any tendency to get the surface high in the center, to use a scraper made of a three-cornered file to ease off the center a little. The scraper is ground as shown in Fig. 20, and used the same as when scraping out a babbitted box. A little oil should be used when scraping steel.

Filing a Convex Surface

The same general principles as just explained are adhered to in filing a convex surface. If the piece is of such shape that the file can be held at an angle with the axis of the curved surface, that is, not straight across, then the cross filing can be done by making the stroke of the file go partly around the curve as well as across, practically no side motion being given the file. If, however, the nature of the case prevents this kind of a stroke, the file should be held straight across, and then given a little side motion to carry it around the curve, while its motion in the direction of its length is straight across. When the surface is thus properly cross filed, it can be finished by draw filing if the grain is to run with the curve, or by straightaway filing, if the grain is to be across.

Filing out a Slot in a Boring Bar

Ordinarily it is a difficult job to file out a square hole or slot through a bar, principally for the reason that one cannot see the place of application of the file. It is a great help after the hole has been roughed out, to take a flat scraper with a good square end, and scrape out the corners and the central portion of the flat surfaces as at *A* and *B*, Fig. 21. The metal can be removed just about as fast with a scraper as

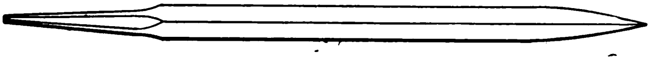

Fig. 20. Three-cornered Scraper made from an Old File

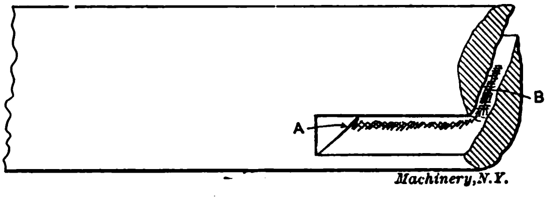

Fig. 21. Filing a Rectangular Slot

with a file (sometimes faster), and by hollowing out the center and corners a little, the file will have a bearing on the outer edges, which renders it easy to prevent rocking. For this work the writer again prefers the square file, and always gives it a side motion whenever possible, cross filing the surface to keep it true. When filing through a hole, use the file without a handle, firstly, because of the danger to the eye should the file handle slip off, and secondly, because it is largely a matter of "touch" to ascertain what the file is doing, and the "touch" is much more sensitive without the handle.

A few good scrapers, say a half-round, triangular, square, flat, and round, of different sizes, with square ends, are very handy tools to have around when doing vise work. They can be used to help the filing along by squaring out corners, easing a place off a little here and there, and will prove time-savers in many ways.

CHAPTER III

EXAMINING AND TESTING FILES*

In discussing the question of files, it may not be out of place, and it should certainly be of interest, to consider briefly the properties of files in general, and more particularly, the characteristics of good files. While a file is one of the oldest and most ordinary tools of the mechanic, and one with which every machinist is supposed to be perfectly familiar, it is yet the one tool about which the average machinist knows the least, when the fundamental principles of its construction and operation are considered, and with which he is usually less efficient than with almost any tool he uses. In former years this last condition did not exist in nearly as great a degree as at present, for the reason that hand tools were used to a far greater extent. Apprentices were early taught their proper use, and in time became very expert and efficient, particularly with the cold chisel and hammer and the file. It has been well said that "the range of usefulness of a good file is only limited by the skill and efficiency of the operator."

Although the file is one of the oldest tools, it is one whose simple design and primitive construction has seemed to defy all attempts to improve it, except in the form of its teeth and the methods of its manufacture. Machines have been invented to do much of the work of filemaking, which was formerly performed by hand, but still many thousands of files are annually made by the same primitive hand methods that were used hundreds of years ago—the cold chisel and hand hammer.

Characteristics of the File

The file, like many other tools, has three distinct and important characteristics which demand attention of the manufacturer, the buyer and the user, if quality is to be taken into account, namely; first, the quality of the steel of which it is made; second, the form of its teeth, no matter whether cut by machine or by hand; and third, the temper, no matter by what process it has been hardened.

The first of these questions, the quality, and hence the price, of the steel used, should cut as little figure in producing a really good file as in producing any other good tool. Yet there is more than a suspicion, from the most casual and superficial test, that there is a great deal of poor steel used in the manufacture of files.

The form of the teeth, as will presently be shown, may vary considerably in different specimens, or they may appear, in an ordinary examination, to be very nearly alike, but when it is considered how little variation there may be between the teeth of a good file and those of a comparatively worthless one, this point assumes much importance.

* MACHINERY, October, 1907.

The tempering of files is another process in which much ingenuity and study is required. A good process, properly applied, may partly save a poorly made file and produce a fairly efficient one, while a poor or defective process, or one inefficiently handled, will ruin a file of excellent material and, so far, of good workmanship. The tempering should be so performed as to produce *hard*, and at the same time *tough*, teeth, and as nearly as possible *uniformity* of temper over the entire surface of the file, from heel to point.

The essential features and characteristics of files, to which it is advisable to give attention, in a systematic examination and practical test of files of different lengths, forms and cuts, will now be taken up in regular order.

Correctness of Form of File Blanks

With the exception of the edges of such files as are called "hand," or "pottance," "equaling," "pillar," and a few special forms, having the same width throughout their entire length, there should be no absolutely straight lines lengthwise of a file. All these lines should be convex. The amount of this convexity on the sides of the well-made flat, square, round and taper (triangular) files, is substantially 0.08 inch per foot, that is, a six-inch straight-edge placed on the file and touching it at the center will show a space of 0.02 inch open at each end. On the edges of such shapes as half round, crossing, knife, etc., this convexity will be about twice this amount. Special curved files are, of course, excepted. Deviations from these limits should be observed, and files having concave lines, short bends, etc., should be rejected, except when they are to be used on very ordinary or rough work.

Transverse surfaces, nominally flat, should be very slightly convex, more nearly straight on fine cut files than on ordinary kinds. Those having concave surfaces should be rejected.

Surfaces which should be the arc of a circle, such has half-round, crossing, round, etc., may be tested for correct form by laying them into drilled holes of various diameters in a thin plate of iron or steel. It will be found that a cheaply made file will hardly ever conform to a true arc, but is liable to have flat places on its surface, which, when in use, will not come into proper contact with the work.

Triangular files may be tested for form with a 60-degree thread or center gage, and the corners of square and flat files with a thin steel square. It will be surprising to note the many inaccuracies that will be brought out by these tests.

Not only the *form*, but the *finish* of blanks should be examined. It will usually be found that American-made files have a finish much superior to that of imported files, in which will be found deep scratches and furrows that detract not only from the appearance, but from the efficiency of the file, particularly in the finer qualities.

The blank must not only be thoroughly annealed, but it must be evenly annealed. If there are hard and soft spots, it is evident that, in the cutting, the chisel will sink deeper in the soft than in the harder portions, thus making an uneven cut and a file comparatively worthless for good work.

Correctness and Uniformity of Teeth

The variation in the number of teeth per inch on the different sizes, shapes and cuts, as well as on files of different manufacturers, is quite considerable, ranging in files of 14 inches long and shorter, from 20 to over 200 per inch. On ordinary machinist's files, made in this country, the following is a fair average, *viz.*, bastard cut from 20 to 25 per inch; second cut, 30 to 40; smooth, 50 to 60; dead smooth, 70 to 80.

Of the finer files, whose grade of cutting is indicated by numbers, the Grobet Swiss files are as follows: No. 0, 40 to 70 teeth per inch; No. 1, 75 to 88; No. 2, 58 to 104; No. 3, 100 to 130; No. 4, 120 to 160; No. 6, 200 to 220.

Of the American-made files of similar shapes and sizes as the Grobet files: No. 0, 35 to 60; No. 1, 55 to 75; No. 2, 80 to 95; No. 3, 90 to 120; No. 4, 125 to 135; No. 6, 160 to 200. It will be noticed that there is more regularity in the American system of numbers than the foreign. There is yet room for an improvement, similar to that made in this country in the old-time wire gages.

The form of the teeth is a matter of much importance. If we ana-

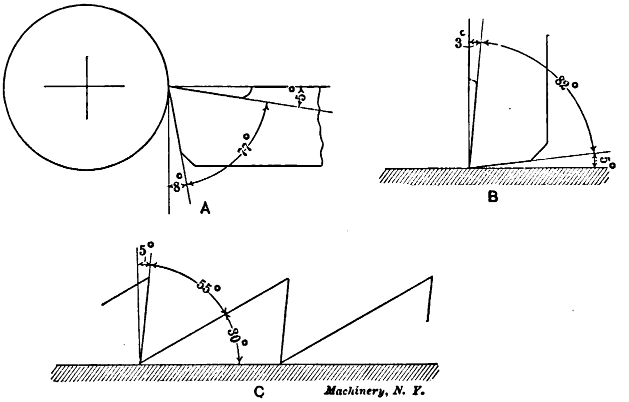

Fig. 22. Cutting Angles of Planer Tool, Lathe Tool and File

lyze the form and action of a file tooth, we find it to be a straight knife or cutter as, for instance, a broad lathe or planer tool, whose face angle (or top rake) and whose cutting angle (or relief) will determine the amount of pressure necessary to cause it to cut, and which frequently (in the planer tool) has its line of cut set at an angle to the line of motion (as a file tooth), to cause it to cut easier and smoother. If this cutting edge is very thin and sharp, it is evident that the necessary pressure is very much reduced, while it may be so thick and with so little relief as to slide over the work, even under greatly increased pressure.

In the case of the file we have a large number of similar cutting edges, and consequently a proportionately large increase of pressure necessary to produce the desired effect. For this reason, and from the fact that the available pressure is greatly limited, the cutting edges must be comparatively thin and sharp, and the cutting angle (or relief) must be very acute. For instance, in Fig. 22, at *A*, is shown the proper angles for a lathe tool, and at *B*, those for a planer tool.

At *C* are given the ideal angles for file teeth. While these file teeth angles are desirable and would make an excellent file, they are too difficult to produce mechanically to make them practical. If the teeth of files were formed by a tool traveling parallel to their cutting edges, we might produce any angle desired. But this is not practical. The teeth are formed with a rather obtuse-angled chisel, which raises a portion of the metal above the surface being cut, making, as well, a depression below it. This action of the chisel produces the effect seen at *A*, Fig. 23, where *b* is the face of the blank to be cut; *a*, is the bottom of the cut, and *c* is the point of the tooth as thrown up by the cut.

It will be seen that the face angle, instead of being 5 degrees in favor of a sharp edge, as at *C*, Fig. 22, and being able to cut with a lighter pressure, is thrown back 5 degrees from a vertical line, thereby losing 10 degrees. The cutting angle is rendered more acute, and, instead of the 30 degrees shown at *C*, Fig. 22, a tangent to the curve at the cutting edge shows 33 degrees, thus compensating to a considerable extent for the change of the face angle. At the same time, the angle of 55 degrees for the cutting edges, Fig. 22, becomes 62 degrees (57 + 5 = 62).

There is one other element that enters into this condition and modifies it considerably—the cross-cutting of the file. It may here be remarked that many mechanics fall into the error of supposing that the cross-cutting *follows* the regular cut, while in fact it precedes it, as a strong magnifying glass will readily show.

The influence of this cross-cutting is shown at *B* and *D*, Fig. 23. At *B* the darker shaded portion of the section of the tooth is due to the cross-cutting and when seen from the front causes the tooth to assume the rounded form shown in section at *D*, while in a single-cut file the edge of the tooth would appear as a straight line, as at *C*. The cutting edge of a cross-cut file is quite thin, the angle being changed from 62 to 47 degrees, and it is this delicate but very useful keen edge that is soon lost by rough usage and too much pressure on a new file, or by careless handling, allowing files to come into direct contact with each other. It is the custom with many manufacturers to reduce these sharp edges or points somewhat, either by a fine file or emery stick, or similar means before tempering, or by a sand blast in the cleaning process after tempering. One reason for doing this is that these fine points are not all of the same height and therefore give the file a tendency to "scratch" when first used. This is avoided by leveling them down. The better process is to use pulverized clay instead of sand in the cleaning blast.

At *E*, Fig. 23, is shown a cross-section of the teeth of a poorly cut file. In this case the angle of the edge of the cutting chisel is too acute, the pitch of the teeth is too short, the blow too heavy, and the consequent result is that the extreme points of the teeth are turned over in a "burr" which, by the tempering process, will necessarily be much harder than the thicker parts of the tooth, and will soon break off. This may be seen by standing with one's back to the source of light, holding the file on a level with the eye and looking lengthwise at it from the point to the tang, the broken points of the teeth being seen as small glistening spots or fractures.

In examining and testing files the pitch and form of the teeth will call for much careful attention, as much may be learned from their characteristics when viewed through a magnifying glass, which should not be over a half-inch focus.

Uniformity of Temper

There are various simple methods of testing a file for uniformity of temper that will readily suggest themselves to a mechanic, the most common being by means of the end or corner of a smooth piece of steel

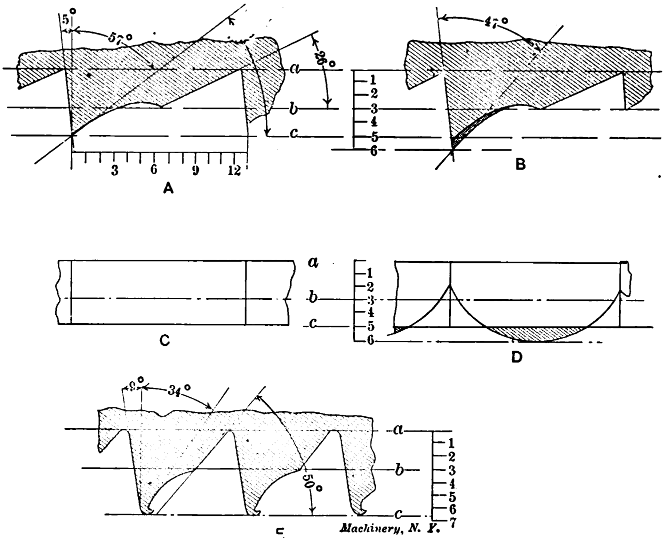

Fig. 23. Shapes of File Teeth

hardened very hard and not drawn to temper. This may be rubbed or drawn for a short distance over the file teeth at various points on the surface of the file, and the results examined with the aid of the magnifying glass. To one accustomed to such work the results will be very conclusive, the points of the file teeth being distinctly bent over where the temper is too soft.

Durability on Metals of Different Degrees of Hardness

If we were to establish a file-testing plant it would probably include, as an important factor, a filing machine particularly designed for testing the durability of files on different metals. In this machine provision would be made for a reciprocating motion of the file to be tested; a device for feeding to the file, the end of the metal to be filed up and a recording apparatus which would indicate, by a curved line traced upon a ruled sheet of paper, the number of strokes of the file, the amount of metal cut away, etc.

A machine of this character has been constructed and used in Manchester, England, and is described in the next chapter. It is claimed that it has been established, by the use of this machine, that with English files there is a great difference in the efficiency of the two sides of the files, amounting in some cases to 30 to 1.

In testing the durability of files by hand, comparative tests will, of course, have to be made by the same man, as no two men will handle a file exactly alike. Each file may be used for 500 strokes, then examined under the magnifying glass, and the results noted. Then 500 strokes more, and again examined, noted, and so on until the file refuses to cut. The amount of metal filed away should be weighed carefully. These tests should be made on cast iron, wrought iron, soft steel, and steel hardened and drawn so that it will require a fairly good file to cut it at all.

By using pieces half an inch square, having one-quarter of a square inch area, and carefully measuring the length before and after each 500 strokes, the careful saving and weighing of the filings may be avoided.

Strength and Elasticity

These two qualities may be tested at the same time. A convenient arrangement for holding files during these tests is to use any kind of a vise with jaws in a horizontal instead of a vertical position.

These tests consist essentially of clamping the tang in the vise and suspending known weights upon the point, noting the degree of flexibility for elasticity, and the weight necessary to finally break the file to ascertain the relative strength. A good file should bend to the extent of 5 degrees without breaking, and some will bend several degrees more. Those breaking at 2 degrees are too brittle for practical us. If long, slim files break at 3 degrees they should be rejected, as the workmen are likely to break them before they are half worn out.

CHAPTER IV

FILE-TESTING MACHINE*

In the last chapter simple directions for testing files without an apparatus have been given. The following description gives an account of the Edward G. Herbert file-testing machine, which was invented in 1905. This machine was designed to give a perfectly reliable mechanical test of hand files and an autographic record of the results produced by each file tested. The machine has revealed an extraordinary difference of quality in files, some files being worn out after filing away less than 1 cubic inch of iron and cutting at the rate of only 1 cubic inch per 10,000 strokes, while the best files (size not given) remove 12½ cubic inches of metal and cut at the rate of 5 cubic inches per 10,000 strokes.

The publication of these results some time ago created a sensation in the English file trade, and a public file-testing department was established, and the testing machines were supplied to a number of file makers. The surprising and perhaps, in some cases, painful results obtained by these testing machines at once stimulated file makers to improve their product, and the result has been a general improvement of English files.

The extent of the improvement will be noted from the diagram Fig. 24, being the record of the files tested since the introduction of the file-testing machine. Curve 2 indicates that over 45 cubic inches of iron were removed and 160,000 strokes were made before the file ceased to cut. Still better results have been obtained since these results were recorded, files now being made which cut at the rate of 8 cubic inches per 10,000 strokes, and as much as 55 cubic inches have been removed by one side of a single file. Thus, the file-testing machine is directly responsible for an increase of efficiency of very nearly ninefold in the best files, and the end is not yet.

Fig. 25 shows the general construction of the machine. It automatically tests files of any size from 4 to 16 inches and draws a diagram, at the same time indicating the work done in cubic inches. The sharpness of the file is shown by the rate of cutting, and the durability, by the number of strokes taken before the file ceases to cut.

The file *A* to be tested is held between two head-stocks $B\,B_1$, on a reciprocating table *C*. Head-stock *B* is provided with a nut and hollow-squared screw *D* for holding the tang of the file and exerting end pressure. Head-stock B_1 has a slide and a hand-wheel *E*, whereby the file may be adjusted with its working face parallel to its direction of motion.

* MACHINERY, December, 1907.

The reciprocating motion of the table is obtained from the pulley and main shaft through a pair of bevel gears, driving a T-slotted crank disk. A crank-pin, whose position in the T-slot can be varied according to the stroke required, carries a slide block of rectangular form, which slides between two vertical bearing surfaces in an extension of the table *C*, and serves to drive the latter to-and-fro. The driving mechanism is inside the box frame of the machine and entirely protected from the filings. The machine is started and stopped by a clutch operated by a handle *F*.

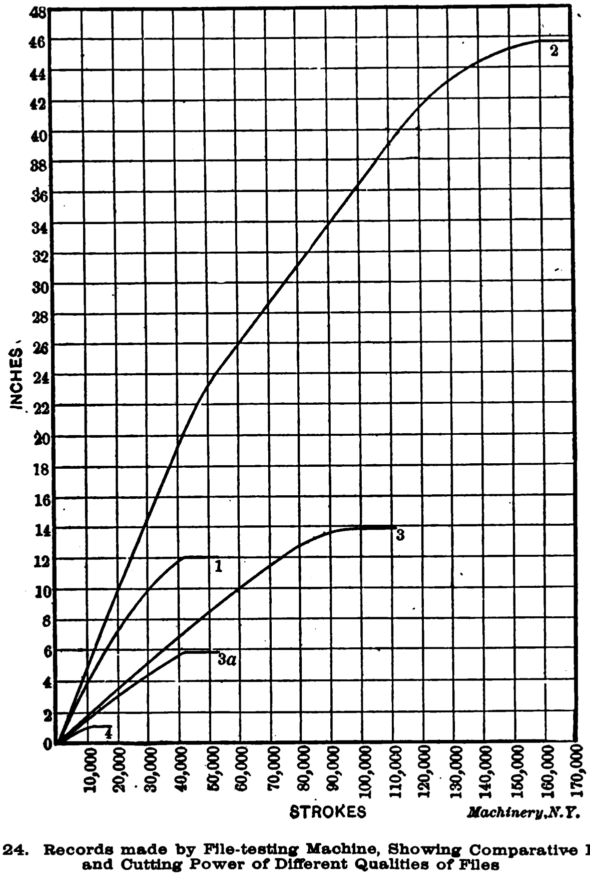

Fig. 24. Records made by File-testing Machine, Showing Comparative Life and Cutting Power of Different Qualities of Files

The test bar *G* is supported in a horizontal position on grooved rollers, and is pressed against the file by a weight *H* and a chain passing over a pulley and under the bar, to the far end of which the chain is attached. The support rollers are grooved to accommodate the chain. The bar is drawn out of contact with the file during the back stroke of the latter, by means of a clutch lever having two hardened jaws embracing the test bar. At the commencement of the back stroke, motion is communicated from a cam on the crank-shaft to the outward end of the clutch lever, causing it to tilt and grip the test bar after the manner of a spanner. A slight continuation of the same motion causes it to draw back the test bar, which is again released at the commencement of the forward or cutting stroke. A spherical weight *J* with a threaded stem, is supported by the head-

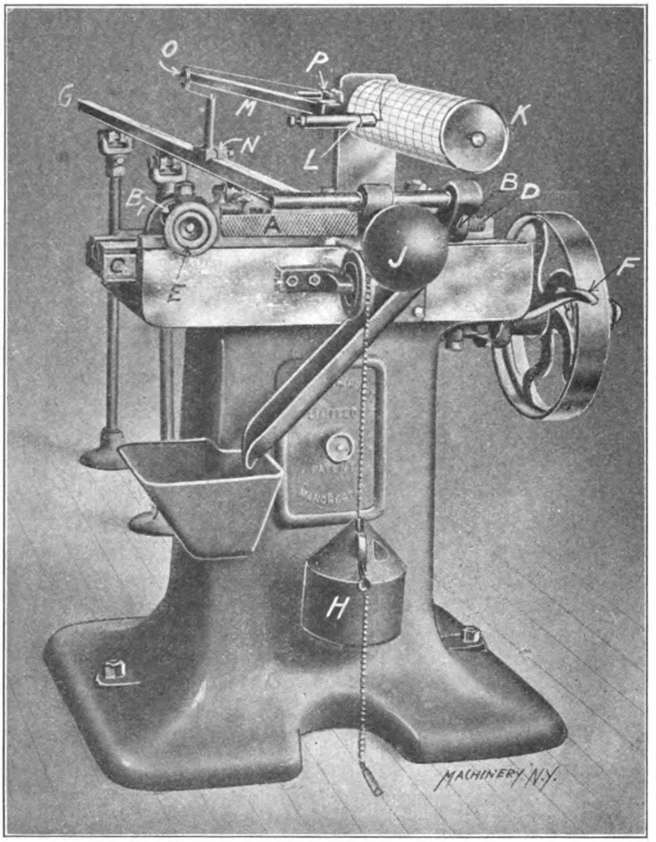

Fig. 25. File-testing Machine, Built by Edward G. Herbert, Ltd. Manchester, England

stock *B*, and, of course, reciprocates with the file. The end of the stem rests against the back of the file, and the inertia of the weight prevents the chattering and jarring of the file which would otherwise take place. The drum *K*, round which is wrapped the diagram sheet of squared paper, is driven from a cam on the crank-shaft through a pawl and ratchet wheel and a train of reducing gears, so as to make one revolution to 120,000 strokes of the file. A pencil *L* is pressed against the paper by a light spring, and is carried on a bar *M*, capable of sliding longitudinally in a fixed bearing. A block *N* is attached to the test bar, and a chain is attached to this block, and, passing over a pulley *O* on the pencil bar, is held by a fixed terminal *P*. It is evident that as the test bar is filed away it is moved forward by the weight *H*, and a given movement of the test bar causes the pencil to move forward by half that amount. The diagram sheet is graduated in half inches, each of which represents one inch filed off the test bar. The circumference of the drum is 12 inches, and as it revolves under the pencil each inch represents 10,000 strokes of the file. At the commencement of a test, the pencil is set to zero, and, as the drum revolves and the test bar is filed away, a curve is drawn by the compound motion of the drum and pencil. This curve is a complete picture of the life of the file from the commencement of the test until the file is worn out and ceases to cut, the slope of the curve indicating the sharpness or rate of cutting, while the vertical and horizontal ordinates give, respectively, the total amount of work done by the file, and the number of strokes required to do this work and to wear the file out. For example, in Fig. 24, Curve 2 shows that the maximum rate of cutting took place during the first 15 inches. The efficiency slowly decreased up to 42 cubic inches, when it dropped off rapidly. Cessation of cutting took place at the beginning of the short horizontal line.

On the same diagram, Curve 1 was made from a file of good average quality, as usually supplied by the same makers. It cut quickly, but soon wore out, showing that it had sharp teeth, but was made of poor steel. Curves 3 and 3*a* were made from the two sides of another file. The durability was fair, but the rate of cutting was slow. These diagrams indicate that the file was made of good steel, but had poorly shaped teeth. These diagrams are also interesting in showing the great difference that may exist between two sides of a carelessly made file. Curve 4 was made with a very bad file. It was practically worn out after having removed 1 cubic inch of metal, and 10,000 strokes were required to remove even this small amount.

CHAPTER V

MAKING SWISS FILES IN AMERICA*

Most of the tools a machinist or tool-maker uses have nothing of great difficulty or mystery connected with their making. Any good tool-maker, if necessity demands, would feel competent to make for himself a twist drill or a micrometer caliper, even though these tools are seldom made for personal use, being almost invariably purchased. There is a different feeling in the case of files, however. A good file is treasured by the man who owns it. He looks upon it with friendliness, and respect as well, for while he can buy files by the thousand (good, bad and indifferent) from people who make a business of making them, he would not be able to make one himself. The matter of cutting those fine teeth, so well formed and regular, and yet so delicate as to be in the finer sizes almost invisible, and afterwards the hardening of the tool to the proper degree without injuring the sharpness of these multitudes of little teeth, he feels to be beyond the range of his ability. File makers, in general, have rathered catered to this idea of mystery. Their shops are surrounded by high fences and the visitor gets no further than the office. Their catalogues are full of little hints and suggestions of the complicated special machinery used, and the secret and mysterious formulas and processes followed in the annealing and hardening departments.

In the face of all this mystery, the American Swiss File and Tool Co. of Elizabethport, N. J., embarked in the manufacture of files, and not merely in the making of ordinary hand machinists' tools of the coarser grades, but those of finest and most delicate shapes, in which the Swiss makers had hitherto held undisputed preëminence; and while it is not to be supposed that there is no further improvement possible in the methods employed, yet the company has already succeeded in building up a business which is limited in extent only by its ability to get good workmen, and it is to-day turning out a product which at least equals the best that is produced abroad.

The one point of superiority of European hand-cut files over American machine-cut ones, is in the matter of uniformity in size and sharpness of teeth; the advantage of the hand-cut file is not due, as many have supposed, to a quite different condition—the irregularity of the spacing. The reason why it is possible, usually, to obtain more regular shaped teeth from hand cutting done by skilled workmen is that, until now, the best methods of annealing with the best and most uniform tool steels produced uneven results. In the machine, whenever the chisel comes to a hard spot, a shallower cut is made; when it

* MACHINERY, September and October, 1907.

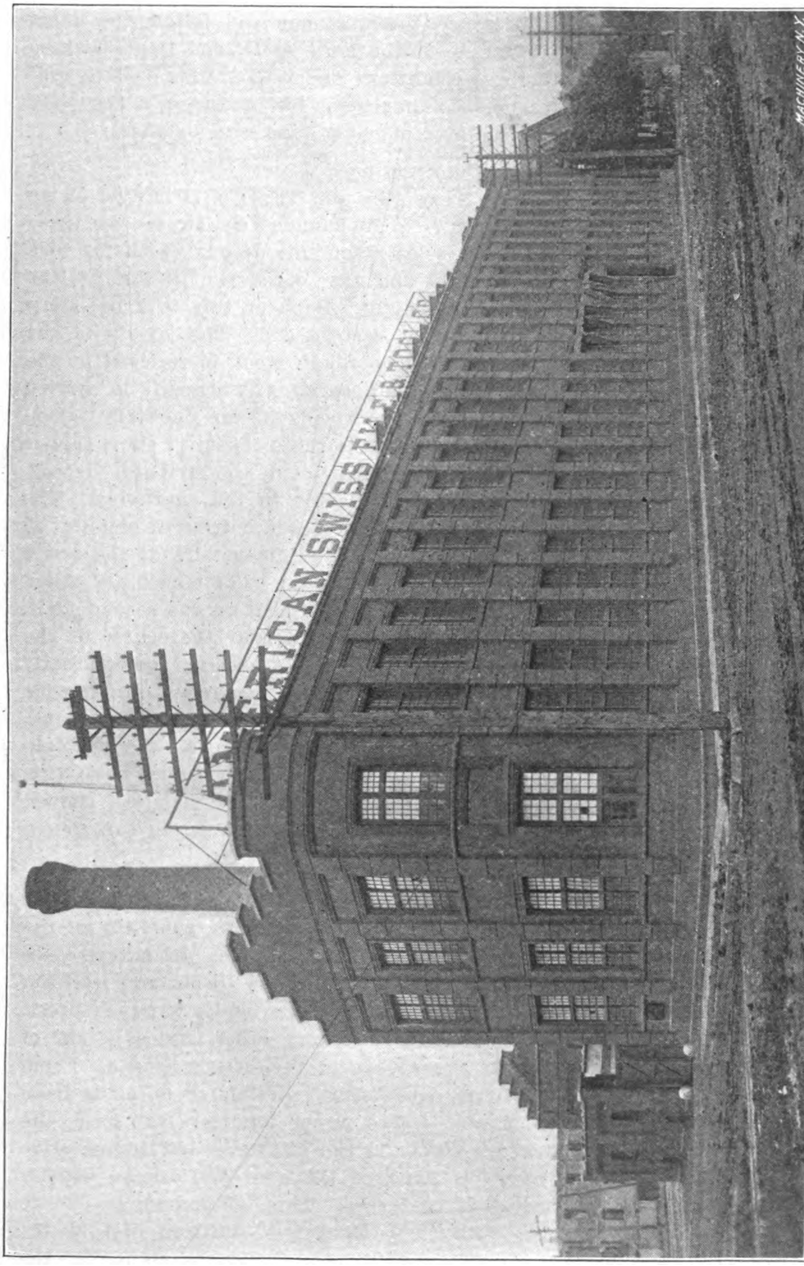

Fig. 26. Plant of the American Swiss File and Tool Co., Elizabethport, New Jersey

comes to a softer spot the cut is deeper, and the tooth sharper. In cutting a file by hand, however, the workman can follow the effect of his chisel, striking it harder in the hard spots, and lighter where the metal is soft. With these conditions understood, it is evident that uniform annealing is the prime requirement for producing a first-class file of the high grade required by tool-makers and watch-makers.

The Buildings

The plant of the American Swiss File and Tool Co. is located on an irregular tract in Elizabethport, N. J., bounded by streets on three sides. The place was specially selected on this account with the idea of having it always open to light and air. As shown in Fig. 26, the main building is two stories in height. Back of this is a one-story building, with a power plant at the eastern end. The lay-out of the departments is shown in Fig. 27. The rough stock is received at the shipping door at the front of the main building, whence it is carried through into the stock- and cutting-off rooms in the one-story extension. From here the cut stock is taken to the blacksmith shop, thence to the annealing room, the grinding department, the stripping department and the blank storage, all as indicated in the engraving. The teeth are formed by either of the two processes of cutting or etching, as will be described later. The cutting is done downstairs at the north end of the building, while the blanks which are to be etched are taken to the room directly above the cutting department on the second floor. After cutting, they go to the hardening room near the center of the main building, and from there are taken to the packing room directly above. It will be seen from this that there is a complete circuit with no loops or backward movements, from the receiving of the raw material to the delivery of the finished goods. All the rooms are of ample size for an equipment of three times the present capacity, so this increase can be made without disturbing the arrangement shown. Having the general plan of the works thus before us we can follow the process from step to step.

Blanking and Forging

The raw material received comes in various forms, generally of the exact shape of the "amid-ships" section of the file. In a few cases sheet stock is used for thin flat files of various forms and uniform thickness. These are punched in blanking dies under a punch press. For half-round, round, square, barrette and other styles, stock of appropriate shape is cut in the shears to the proper length. From here it is taken to the forging department. In this room, aside from the noise which is unescapable where power hammers are used, the thing which first strikes the visitor is the clearness and comparative coolness of the air. There is none of the dust and smoke usually associated with the operation of forges. This, of course, is due to the use of gas furnaces with their smokeless, dustless fuel in the place of the coal forges ordinarily found. A furnace stands at the side of each smith, and a very small and inconspicuous affair it is.

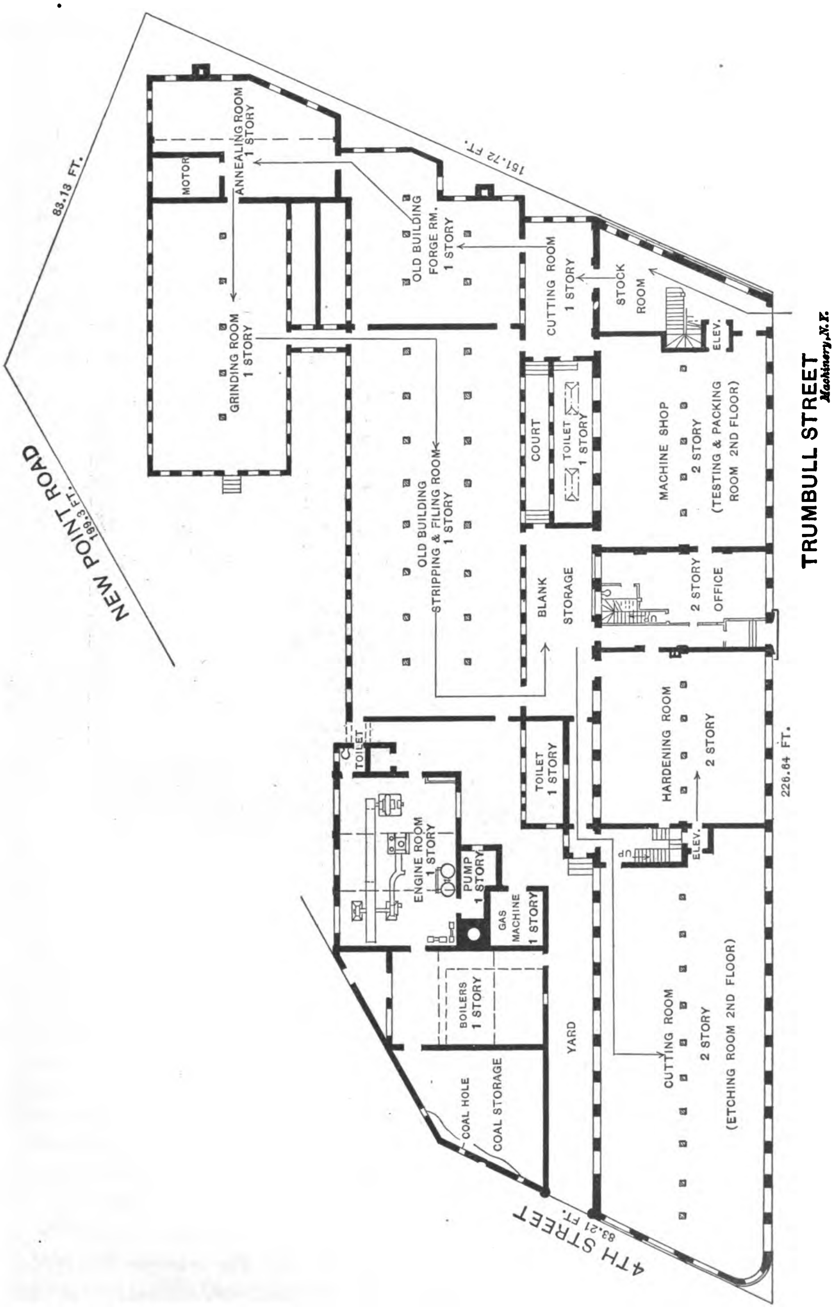

Fig. 27. Plan of the Shops of the American Swiss File and Tool Co., Showing Route of the Work

A firebrick lining in an iron casing with four legs to stand on, with piping and burners for gas and air, is all there appears to be to the apparatus. The furnaces are quite small, being only just wide enough for the length of the files being heated. The uniformity of the temperature throughout the whole area of the furnace is remarkable, there being no difference visible to the eye in color anywhere within the heated area. The first operation is the forming of the tang. Then the blanks are reheated, and worked to the proper shape under dies. The face of each die is made in three sections. That on one side of the die is used for breaking down the stock, that on the other side for bringing the edge of the stock to approximately the right dimension, while the central section is used in forming the sides or faces of the blank. The workmen handle these with great rapidity and dexterity, changing the work quickly from one side to the other, and

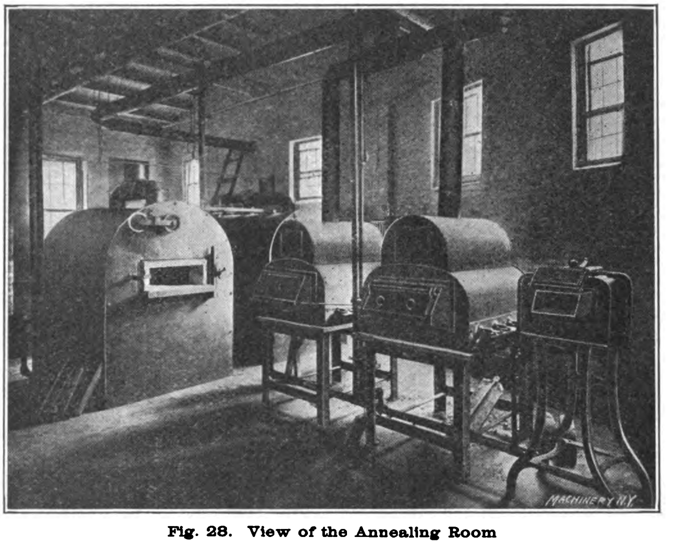

Fig. 28. View of the Annealing Room

back again to the middle, turning and re-turning the blank until it is formed to the shape determined by the dies. It is impossible to form some shapes correctly under the power hammer. The barrette, and the point of the half round, for instance, have to be finished by drop forging. The former shape of file is struck up from a round blank. The amount of scale found around the hammers and drop presses is very small—an indication of the non-oxidizing quality of the flame in the gas furnace. Each workman has a private supply of cool air from the pressure service which he can direct on himself in whatever way best suits his convenience and comfort.

Annealing

As stated in the beginning, the secret of fine file making lies primarily in the matter of annealing. This is the next operation after the forging. One might expect from the importance of this part of the work to find elaborate precautions taken. One would suppose that the blanks would be packed with charcoal in cases having covers luted with fire-clay; such precautions are generally considered necessary to get even heat and freedom from oxidation. Nothing of this kind is seen in Fig. 28, which shows a general view of the annealing room. There are here, as shown, a number of gas furnaces of various sizes. The big ones are for big files, and the little ones, for little files. The blanks are packed in the furnaces, unprotected, exposed to the direct action of the flame. The precaution of packing them with the tangs outward and the points inward is taken, but otherwise the metal is not shielded in any way. The flame is lighted and kept going at a temperature of 1500 degrees Fahrenheit, for about four hours, ordinarily; then (the doors being carefully closed) the work is allowed to remain over two nights and one day, until it is perfectly cool. There is a very slight, thin scale resulting from this heat treatment, but no pitting or corrosion. What little scale there is comes from air which leaks in during the cooling process, the flame itself being absolutely non-oxidizing. It would be difficult to find a better commercial test of the excellence of the fuel gas process used, than this.

The uniformity of annealing obtained is the result of the fulfillment of severe simple conditions. There must be a constant quality pressure and amount of gas, and a constant pressure and volume of the air mixed with it. With these mixtures determined, the nature of the flame and the temperature will be constant. Too much cannot be said about the composition of the flame. The vaporized naphtha used is free from injurious elements, such as sulphur, and is provided with a slight under-supply of oxygen, so that there is no danger of any of that element combining with the metal. The furnace must be so built that the heat is evenly distributed throughout the whole of the interior. The file on the bottom of the pile must be heated under the same conditions as the one at the top. The ends and sides of the furnace must each be subject to exactly the same degree of heat. With these points carefully looked out for, and with the matter of time of exposure to the heat attended to, it only remains to provide the proper steel to be able to get the same results day in and day out, in the annealing of file blanks. For the finest work, the company has been unable, sad to say, to find an American steel which will give good results. The best that can be obtained varies in composition and resulting hardness from one bar to another, and from point to point in the same bar. The necessity for uniform hardness in the annealed blank involves in this case the necessity of patronizing a foreign firm instead of a home industry.

Grinding and Stripping

In order to form sharp teeth of uniform height, it is necessary to provide a smooth, even surface to start with. To produce this surface the blanks are first ground and then draw filed or "stripped." The files with flat cutting surfaces have these ground on automatic machines. A near view of one of these machines is shown in Fig. 29. At B is a grindstone of large diameter, revolved at suitable speed and traversed slowly back and forth by a cam, to equalize the work across its face. The files, shown at A, are ranged in a row, with suitable backing and supports, on the flat plate or holder G. This frame or holder is dropped in a vertical position in slide D, and pressed up against the face of the revolving grindstone B by the rollers E and the adjusting screws operating them. The mechanism which reciprocates slide D up and down, so that the blanks are ground from

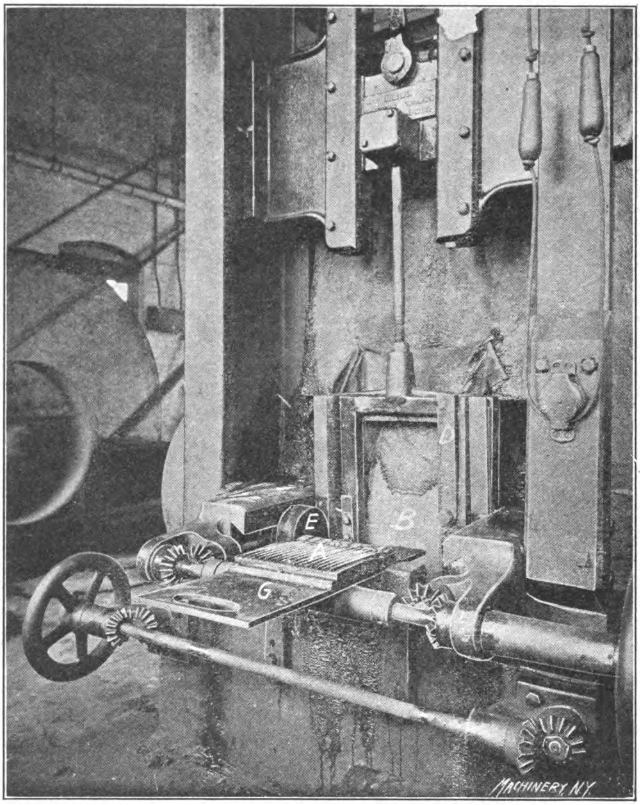

Fig 29. Machine for Grinding Flat Files

one end to the other, is then started. In the machine shown this motion is operated by an adjustable crank at the top of the machine, connected to crosshead C. The matter of grinding a frame full of blanks is one of a few strokes and a few seconds only. The wheels used are five or six feet in diameter, and means are provided in the machine for keeping them constantly trued.

This machine grinding is done on flat surfaces only. On round surfaces the grinding is done by hand. In Fig. 30 may be seen workmen engaged in this operation. Most of them are working on half-round files. As may be seen, they are sitting on wooden blocks in front of large grindstones, all except the man in the foreground, being astride of a board with a steel hook or holder on the end of it, which holds the work down to the wheel. The weight of the workman thus furnishes the pressure needed for grinding. The smallest and finest files, whether flat or round, are ground by hand on carefully trued wet emery wheels.

The surface produced by this grinding is not quite good enough for the purpose desired, so the finishing touches are given by draw filing or "stripping." Both flat and round surfaces are finished in this way, and all burrs are removed from edges and corners. The men work at benches, with the blanks supported by their ends in wooden blocks. For stripping flat surfaces, new machines have recently been

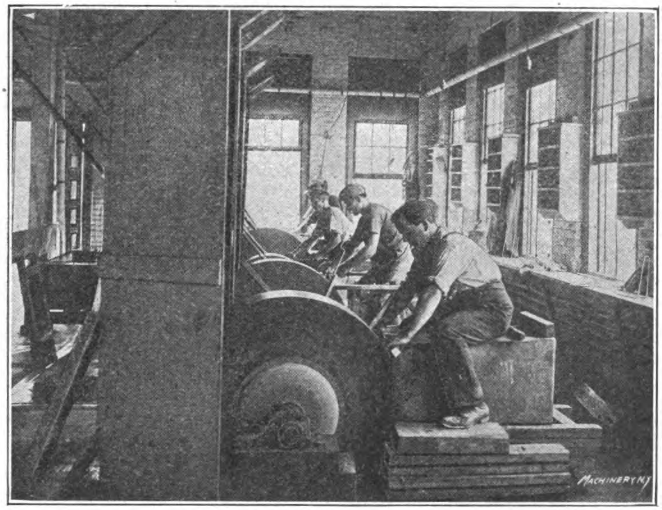

Fig. 30. Grinding Round File Surfaces by Hand

introduced. One of these is shown in Fig. 31. The blanks, *B*, are held in suitable holders. These holders are pressed upward by levers and weights against the cutting files *E* in slide *D*. This slide is moved in and out for the stroke, being carried by saddle *G*, which slides along ways on the under side of overhanging arms *H H*. It is also traversed back and forth to distribute the action over the full length of the cutting files by a drunken screw at *F*. The work is relieved from contact with the files on the back stroke. It might be expected that it would be a matter of some difficulty to avoid "pinning" in a case of this sort. This is not often met with, however. In the first place the files are made specially for the purpose, with plenty of clearance. Besides this, the pressure on the work is unvariable, being determined by the weights and levers mentioned. A workman, even though expert, might momentarily use more pressure than he ought to on his file, so as to cause it to tear the steel and get the broken particles wedged or "pinned" in the teeth. With a machine, having once found the conditions necessary to avoid this trouble, these conditions may be preserved indefinitely, and the trouble practically avoided. When it does occur, perhaps once a day, the blank thus injured has to be reground and refiled.

Flat files are ground and stripped on all of their cutting surfaces before going to the cutting department. On files having sharp edges, however, such as half-round, barrette, and other shapes, this course is not followed. On a half-round file, for instance, the flat surface is stripped; then the first cut is taken over it, and it is returned to the stripping room to have the round surface finished, which then, in

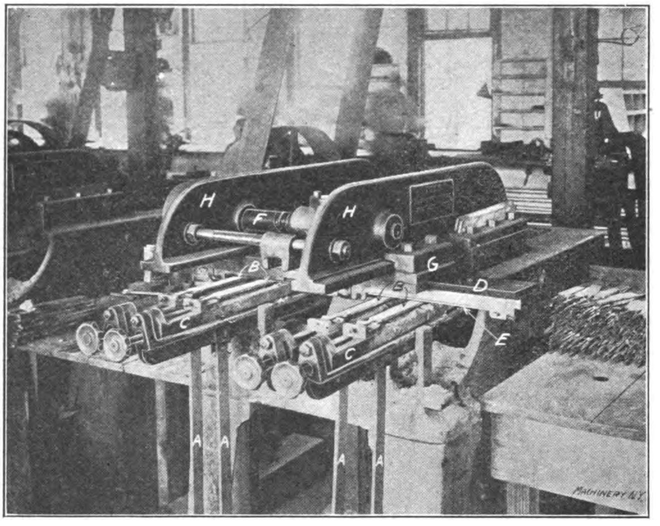

Fig. 31. Stripping Machine for Draw Filing the Blanks

turn, is treated with the first cutting; after this the second cut is given to the flat side, and then to the round side. This working first on one side and then on the other, on a blank having sharp edges, is necessary to keep the teeth perfect in shape clear out to the edge. If one side were finished completely before the other was touched, the edges would be turned over, away from the surface last finished, making a sharp burr on the side which was cut first.

After the blanks have been stripped, they are taken to the blank storage, awaiting their turn at the cutting machines.

The File-cutting Machines

Those files which are to be machine cut are taken to the cutting room, located as shown in the plan in Fig. 27. There is a noticeable absence of noise in this department, compared with what the writer has

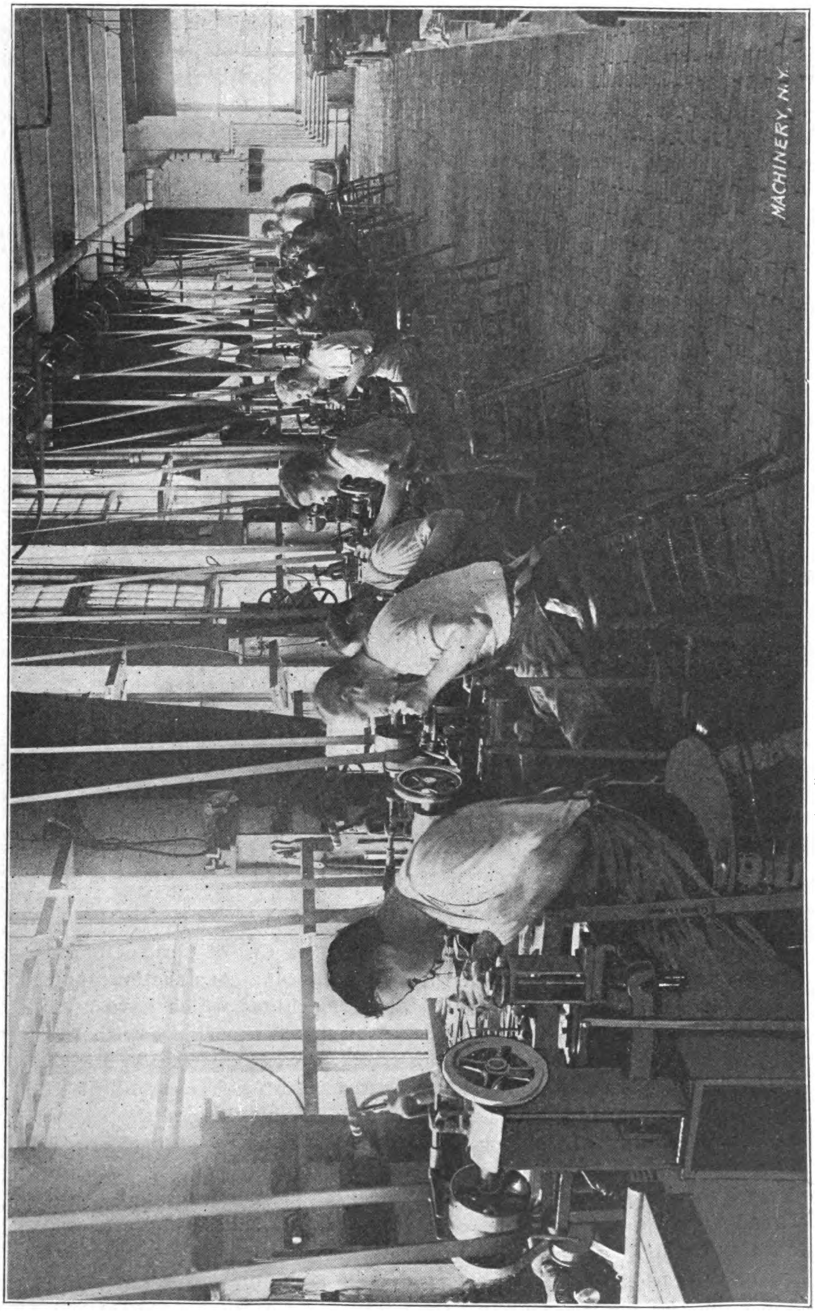

Fig. 32. General View of the Cutting Department of the American Swiss File and Tool Co.

met with elsewhere; conversation was easily possible with everything going at full blast. This freedom from noise is attributed to the care with which the foundations of the file-cutting machines were laid. They go down 2 feet below those of the building foundations. There is a row of these monolithic bases extending the full length of each side of the cutting room. Only about one-third of the space reserved for these machines is as yet filled. Fig. 32 is a partial view of that side of the room in which the equipment of machines has been completed. The curtains shown hanging from brackets on the wall are used to prevent cross lights, at times when the sun is shining in such a way as to offer difficulties on this score. In order to see just what he is doing, it is necessary for the workman to have the light shining on his work from the front.

Three designs of file-cutting machines are in use in this room. There are the original machines with which the business was begun,

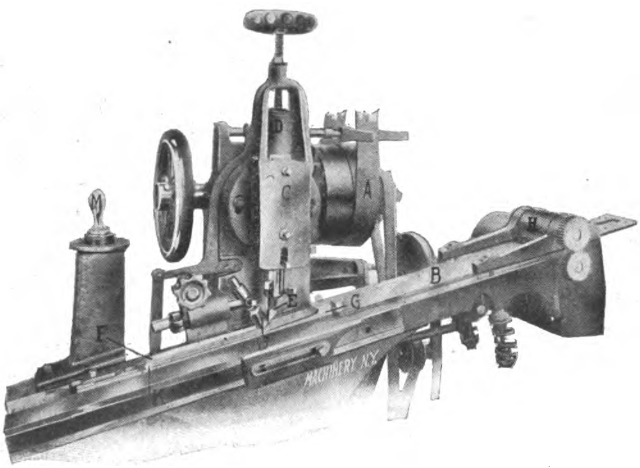

Fig. 33. File-cutting Machine

made by an American firm, the Hess Machine Co. of Philadelphia; then there is a German machine of quite different construction; and in Fig. 33 is a picture of one of the latest machines which have been installed. This embodies the results of the firm's experience with the two previous types. A file cutting machine provides, essentially, means for striking a series of rapid blows with a suitably formed chisel to any desired depth, and means for feeding a file blank past the chisel at such a rate of speed as to give the desired spacing of the tooth.

The machine shown is driven by the belt and pulley at *A*. A cam is keyed to the driving shaft which, through a lever, raises the ram in head *C* against the resistance of the India rubber spring *D*, and allows it to fall again freely. The chisel *E*, held in the end of the ram, is thus able to deal a series of very rapid blows on the blank beneath it, the shaft revolving at a high rate of speed, and the cam having several lobes or teeth. The work *F* is laid on a holder *G*, resting on the inclined bed of the machine. It is fed along under the chisel, being drawn by a plate *B*, which is clamped between friction rolls at *H*. These rolls are driven at a uniform rate of speed, through gears and belting, from the main shaft of the machine. No provision is made for varying the spacing in a file, the makers believing that there is no virtue in the "increment" cut, but that there is a decided advantage in having the file uniform from end to end.

The presser foot *J*, under the influence of a weight, follows the work just in front of the chisel and holds it firmly down to the holder *G*. The latter has a cylindrical bearing on a seat in the bed, so that on flat files the blank is free to adjust itself under the presser foot until the surface is parallel to the cutting edge of the chisel. In the case of half-round files, the holder is rocked by handle *K* to bring any part of the surface desired under the influence of the chisel. The distance between the work and the chisel may be altered by crank *M*,

Fig. 34. Etching the Teeth in Files

so the depth of cut may be varied at will. This is important, and much of the skill of the cutter lies in his adjustment for depth of cut. It is a vital requirement that the teeth be uniform from end to end. On a tapering file, such for instance as the flat side of a half round, a blow on the point of the file of the same force as that delivered in the middle section, where the blank is widest, would make so deep a cut as to almost sever the blank. The workman, then, in running from the point to the heel, starts in lightly, increasing the force of the blow by adjusting the crank *M* as the width of the blank changes. The setting of the bed on an angle as shown, and the continuous feeding of the blank while the blows are being struck, has the effect of opening up the teeth as the chisel leaves each cut.

Etching of Teeth in Files

Most mechanics are familiar with the idea of file-cutting with a chisel by hand or machine, but how many of them are aware of the fact that great quantities of the files they use are not made with the chisel at all, but by a grooving process somewhat akin to knurling, and known as "etching"? The workmen shown in Fig. 34 are employed on this work. The file being treated is laid in the holder as shown, where it is steadied and guided by the workman's left hand. With his right hand, by the handle which it grasps, he operates the etching tool attached to the swinging framework. This tool is a triangular bar with file teeth cut in each of its three edges. Any one of these edges may be presented to the work. The cutting of these teeth is an art in itself. They have to be made with uniform depth and regularity, since it is necessary for the teeth to "track" in the

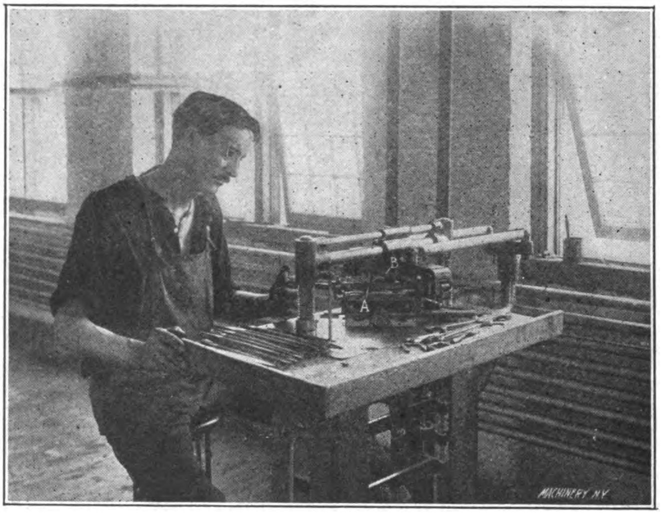

Fig. 35. "Etching" Machine

grooves previously cut in the work. The etching tool is simply swept back and forth across the work at the proper angle and with the proper degree of pressure, as determined by the foot of the operator bearing down on the stirrup shown hanging from the handle. The teeth on the edge of the tool cut and trace out the grooves which are to form the teeth of the file. Simple as the process sounds, it requires a high degree of skill. No little training is necessary to give the steadiness of movement, evenness of pressure, and sureness of positioning needed. The process, as practiced here, is an improvement over that employed in Switzerland, where two operators are required, one to hold the blank and the other to guide the tool, using both hands for the purpose. In the case of round and half round surfaces, the tool is swept across the blank in a series of strokes from one end to the other on one portion of the surface. The blank is then rotated a trifle and the operation repeated, and so on until the whole surface is covered. So well must the etching tool be made, however, and so careful is the work, that the teeth are continuous throughout the whole surface.

A machine is being tried out in this shop for performing this operation. It is shown in Fig. 35. It duplicates the motions of the workman in the hand operation. The work is held at *A* and the etching tool at *B*. The tool is swept back and forth across the work on the angle desired for the tooth, the pressure being relieved on the back stroke. The blank is turned from time to time, if the surface is curved, so as to bring the whole area of the file under the influence of the etching tool. The process bids fair to be successful.

The shape of the file is the consideration which determines whether a blank shall be etched or cut with the chisel. A flat surface cannot

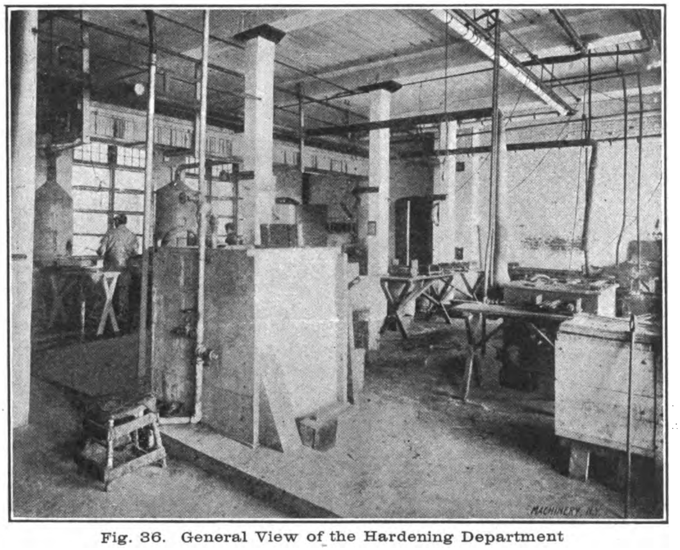

Fig. 36. General View of the Hardening Department

be etched, nor is there any need for it. On round surfaces, however, particularly where it is necessary to preserve accurately the outline of the blank, etching is preferable to cutting. In a round file, the action of the chisel throws up the stock in such a way that the shape is polygonal, rather than round, when the file is completed. In etching, on the contrary, the process is that of cutting out the metal, leaving the original contour undisturbed. The workman cuts in with his etching tool only enough to bring the teeth to a sharp edge, without bringing this edge below the original surface. For this reason, in any curved shape where an accurate outline is desired, etching is the process used. Teeth coarser than No. 1 cannot readily be formed in this way, owing to the difficulty of applying enough pressure, and at the same time guiding the tool with precision.

The Hardening Department

After the forming of the teeth, either by cutting or etching, the maker's name and the number are stamped on the file, and the extreme end, where teeth are not perfectly formed, is sheared off. Then the file goes to the hardening department. As before remarked, much mystery is made by some file-making firms of the heat treating process. There is no mystery visible here, nothing but an application of common sense and long experience in the hardening of tool steel. The equipment of the room consists of two hardening furnaces, with lead baths, suitable brine tanks and brine cooling apparatus, and appliances for cleaning the files by a steam blast carrying a powdered earthen material. This is all shown in the general view of the hardening room, Fig. 36.

In hardening, the following procedure is adopted: A boy stands at the left of the furnace man, as shown in Fig. 37, the furnaces them-

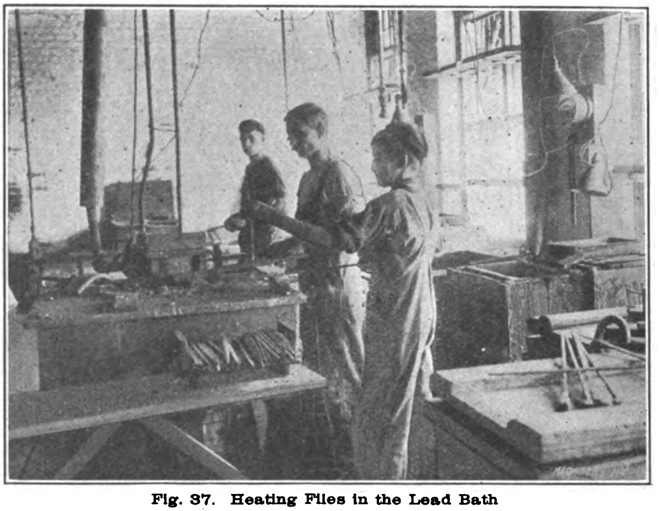

Fig. 37. Heating Files in the Lead Bath

selves appearing at the right of Fig. 36. The boy has at his left a pile of the files to be treated, and on the table back of him a supply of iron handles with sockets having holes pierced in them to match the tapered shanks of the files. At regular intervals, at such a rate as to always keep a certain number of files in the furnace, he inserts the snank of a file in the socket handle, which he lays on top of the furnace with the file hanging down into the pot of melted lead. The surface of the lead is covered with coke dust, to prevent oxidation, and the temperature is kept constant at about 1600 degrees by a Bristol pyrometer.

As each piece of work becomes thoroughly heated, the operator removes it, plunges it into the brine tank and then into the lime water, where it is cleaned, and then holds it for a moment under a steam jet. This latter heats it so that it dries immediately, thus obviating the danger of rusting. In small files especially, the transfer from the furnace to the brine tank has to be made very quickly, in order to prevent cooling before the water is reached. For this reason two tanks are provided. The small one, close to the furnace, is for small files, which cool too rapidly to permit a long journey through the cool air. The large one, a little further back, is used for larger work. The body of water in the large tank does not heat up so rapidly, and there is less danger of cooling with these files in carrying them the greater distance required.

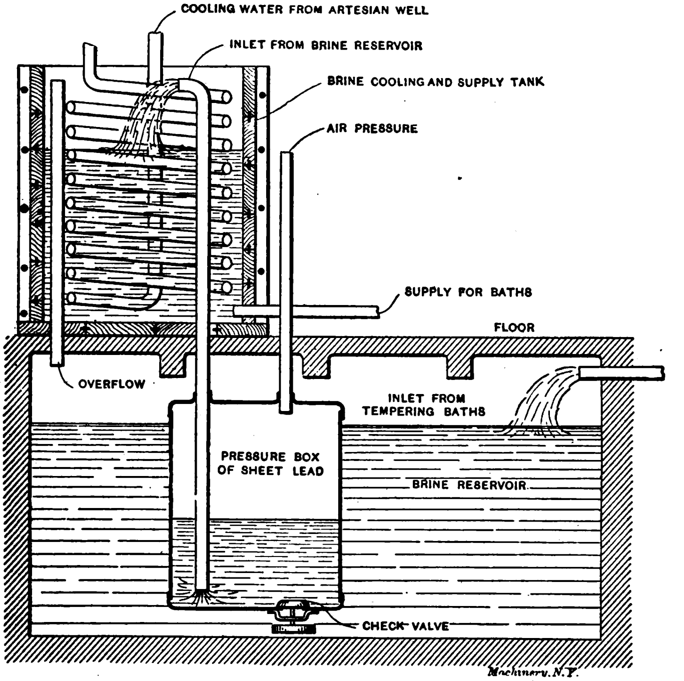

Fig. 38. Diagram Showing Apparatus for Storing, Cooling and Transferring Brine

The Bristol pyrometer seems to do its work very accurately, is comparatively inexpensive in first cost, and in the renewal of the "elements," or that portion of the instrument which is subjected to the heat it is desired to measure. In this work, however, the pyrometer is used fully as much for keeping the temperature from fluctuating as it is for indicating absolute temperature. The condition of the work, as to color and hardness, is the prime consideration. When the bath is of such a temperature as to give the required color and hardness, the pyrometer reading is noted, and the bath is tried from time to time to see that that temperature, whatever it may be, is kept constant.

The provision for furnishing a cool supply of brine is worth noting. The apparatus used is shown, diagrammatically, in Fig. 38. The underground reservoir contains a saturated solution of salt and water. This tank is of wood, on which, of course, the brine has no injurious effect. Located within it is a box of sheet lead, with an inwardly opening valve of the same material at the bottom, and an air supply pipe and an outlet pipe, also of lead, entering the top. The latter of these two pipes comes nearly to the bottom of the box. The operator at either of the two hardening furnaces, by pulling a cord, can open a three-way valve, which admits air under pressure at the top of the box. The box being full of brine, which has flowed in through the check-valve at the bottom, the air pressure closes this valve and forces the liquid through the outlet pipe into the cooling and supply tank above. This latter tank, seen in the foreground of Fig. 36, is high enough so that the brine flows from it by gravity to the bottom of the tanks at the furnaces. The cooled brine entering at the bottom of these tanks rises and displaces the warmer fluid, which runs through an overflow at the top back to the reservoir again. In the cooling tank is a coil of pipe, through which water flows continuously from an artesian well sunk on the premises. This serves to keep the supply of brine cooled.

After the hardening there is a slight oxidation of the surface of the file, little more, however, than a stain; it could scarcely be called scale. To remove this the work is taken to the cleaning apparatus shown in the left background of Fig. 36. The sheet metal cases shown contain a quantity of water mixed with a fine clay. This clay is almost impalpable, with no perceptible grit that can be felt between the thumb and finger. A steam ejector draws the mingled water and clay from the bottom of the casing and directs it in a stream upward against the files, of which several at a time are grasped by the operator in a pair of long-jawed tongs. A few seconds' exposure to the blast, first on one side and then on the other, removes the stain from the cutting edges and leaves them bright and sharp. From here the files go to the packing department where they are inspected for hardness and accuracy of cutting, oiled, and wrapped in suitably labeled boxes ready for marketing.

Special Forms of Files

What we have said of the methods of manufacture followed relates to files with more or less regular outlines, which readily admit of being formed and cut by machinery. Great numbers of special shapes have to be made, however, in which the use of machinery is impossible. In the case of the various forms of rifflers, for instance, used by tool-makers and die-makers in working out otherwise inaccessible corners, the whole work of forging, stripping, cutting, etc., has to be done by hand, the surface being too irregular to admit of any other procedure. Other special forms of files are made here for various purposes. One interesting product is a form used in sharpening pins. It will be news to many mechanics, doubtless, to know that the points of pins are filed. The filing is done by square blocks of steel with single cut teeth formed in them, fastened to the sides of rapidly revolving disks. Large quantities of these are made here.

Swiss vs. American Files

The Swiss file is the outgrowth of the Swiss watch industry, which is nearly 200 years old. These watches have been and are now made quite largely by hand, so that the production of files of the very finest grade early became a vital necessity in that country. To this demand the high standard of the Swiss file may be traced. This excellence is due to the manual skill of the men who form the teeth, and the careful inspection which rejects all which are below the required standard of quality. As intimated, great skill is required to produce teeth of uniform depth and sharpness with the comparatively crude annealing methods used. The workman must be continually varying the force of his blow as he reaches spots of greater or less hardness. In cases where the variation is too great, the file has to be rejected. In a similar way, with the hardening process used, the inspection weeds out a considerable percentage of failures. This care, and the expertness of the help, accounts for both the excellence and the highness of the price of the European product.

The conditions which make it possible to compete with these makers are: the scientific method of annealing which reproduces the same conditions day after day, and year after year, giving a uniform product requiring the discarding of very few pieces; the use of machinery in cutting the teeth, made possible by this uniformity of annealing and making possible the cutting of good teeth at a not prohibitive cost; the ability to reproduce the same conditions in hardening day after day by careful attention to the uniformity of the steel, the temperature of the lead bath, and other qualities; and finally, the exercise of the same old-fashioned care and conscience that show themselves so plainly in the product of the standard Swiss manufacturers.

In making these files in America, it was decided that no improvement would be attempted, for the present at least, in the shapes and sizes of the blanks and the fineness of the teeth. These designs have been the result of filling the gradually developing needs of some of the most skilled hand workmen in the world, so it is not the task of a day or a year to devise anything better. For this reason, the product of this firm follows exactly in these particulars the product of the best Swiss makers.

No. 4. Reamers, Sockets, Drills and Milling Cutters.—Hand Reamers; Shell Reamers and Arbors; Pipe Reamers; Taper Pins and Reamers; Brown & Sharpe, Morse and Jarno Taper Sockets and Reamers; Drills; Wire Gages; Milling Cutters; Setting Angles for Milling Teeth in End Mills and Angular Cutters, etc.

No. 5. Spur Gearing.—Diametral and Circular Pitch; Dimensions of Spur Gears; Tables of Pitch Diameters; Odontograph Tables; Rolling Mill Gearing; Strength of Spur Gears; Horsepower Transmitted by Cast-iron and Rawhide Pinions; Design of Spur Gears; Weight of Cast-iron Gears; Epicyclic Gearing.

No. 6. Bevel, Spiral and Worm Gearing.—Rules and Formulas for Bevel Gears; Strength of Bevel Gears; Design of Bevel Gears; Rules and Formulas for Spiral Gearing; Tables Facilitating Calculations; Diagram for Cutters for Spiral Gears; Rules and Formulas for Worm Gearing, etc.

No. 7. Shafting, Keys and Keyways.—Horsepower of Shafting; Diagrams and Tables for the Strength of Shafting; Forcing, Driving, Shrinking and Running Fits; Woodruff Keys; United States Navy Standard Keys; Gib Keys; Milling Keyways; Duplex Keys.

No. 8. Bearings, Couplings, Clutches, Crane Chain and Hooks.—Pillow Blocks; Babbitted Bearings; Ball and Roller Bearings; Clamp Couplings; Plate Couplings; Flange Couplings; Tooth Clutches; Crab Couplings; Cone Clutches; Universal Joints; Crane Chain; Chain Friction; Crane Hooks; Drum Scores.

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