AN INTRODUCTION TO METAL-WORKING

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PREFACE

My thanks are due, and are hereby tendered, to Mr Sidney Wells, Principal of the Battersea Polytechnic, for kindly reading the manuscript and making certain valuable suggestions; to Messrs J. C. Rawling and J. N. Davies (of the Liverpool Education Committee's Department) for revision of the proof-sheets and the provision of the photographs of operations, respectively; and to Mr J. H. Mathieson (Alex. Mathieson & Sons, Glasgow) for further revision of the proof-sheets and the loan of blocks for illustration of certain of the machine-tools.

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CHIPPING

When a piece of metal—a casting, for instance—needs to be reduced, cold, to given form and dimensions, the hand processes employed are *Chipping* and *Filing*.

Chipping is performed with cold chisels, driven by a succession of blows from a hand-hammer, and is for the purpose of roughing off the great bulk of surplus material, prior to filing to secure more minutely exact form and dimensions.

Chipping Chisels are forged out of hexagonal or octagonal steel, or from steel of this section.

They are about 8 in. long, the taper part being from 2 in. to 3 in.

'Flat' and 'Cross-cut' Chisels.—The two most commonly used forms are the *Flat* and *Cross-cut* chisels. The flat chisel (Fig. 1) has a width at the cutting-edge of from $\frac{3}{4}$ in. to 1 in., and is used for chipping flat and narrow surfaces. The cross-cut

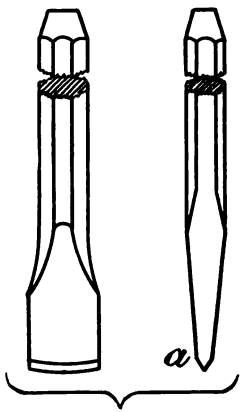


Fig. 1.

chisel (Fig. 2) has a width at the cutting-edge of about $\frac{1}{4}$ in. or $\frac{3}{8}$ in., and is used for such work as cutting out grooves and key-ways. In chipping a surface of large area this chisel would be used for cutting a series of parallel grooves across the surface (Fig. 3), to facilitate the chipping down of the whole; the grooves being slightly less in distance apart than the width of the flat chisel which would be used to chip the remaining high parts down.

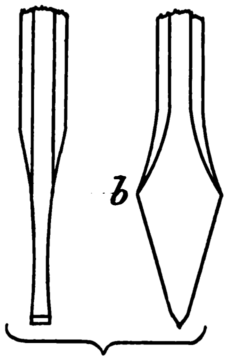


Fig. 2.

The width of a cross-cut chisel diminishes for an inch or so just above the cutting-edge, in order to give it freedom in the groove in which

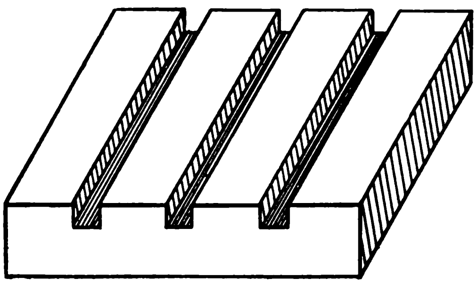


Fig. 3.

it works, and so that it can be moved sideways to govern the direction of the groove. It is strengthened at *b* (Fig. 2).

'Round-nosed' and 'Diamond-point' Chisels.—Two somewhat less commonly used forms of chipping chisels which should be noticed are the *Round-nosed* and the *Diamond-point.* The round-nosed chisel (Fig. 4) is of similar character in form to the cross-cut chisel, but the cutting-edge, lengthwise, forms a semicircle. It is used for cutting curved-bottom grooves.

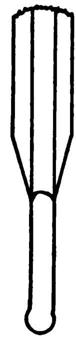


Fig. 4.

The diamond-point chisel (Fig. 5) is used for cutting small V-shaped grooves, and for squaring round holes. It has a single bevel, presenting the form of a diamond, and from this it receives its name.

Cutting-angles of Chisels.—Chisels for cutting metal are distinguished from chisels for cutting wood, in the former having much thicker edges, necessary on account of the greater resistance of the material on which they work. Further, the cutting-angle, *i.e.* the angles formed by the ground facets to one another (*a*, Fig. 1), again varies in accordance with the kind of metal to be chipped; for instance, the cutting-angle of a chisel for chipping cast iron is about twice as great as that of a chisel for chipping copper.

Fig. 5.

The following are the cutting-angles for chisels used on various metals:—

For *cast steel*	$=65°$	For *wrought iron* or *steel*	$=50°$
,, *cast iron or brass*	$=60°$	,, *gun-metal*	$=50°$
For *copper*	$=30°$ *		

* Some prefer that the cutting-angle of the chisel for copper should be equal to that for wrought iron.

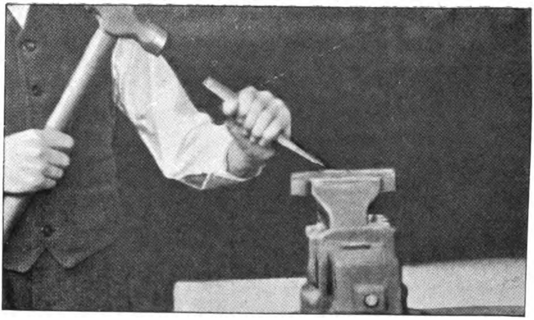
Rounded Chisel Edges.—The edges of flat and cross-cut chisels should be slightly rounded in the direction of their edge-length (*a*, Fig. 1); then, the chip not extending right across the width of the chisel, smooth chipping is ensured, because the corners of the chisel do not dig into and score the work; also, they are not themselves liable to be broken off.

'**Breaking-out.**'—A broader chisel is used for chipping cast iron and brass than for wrought iron and steel, because, in chipping the former the metal is liable to fracture in front of the chisel edge in the direction of the cut, the fracture perhaps extending below the level to be chipped down to; by using the broader chisel the force of the blow is distributed over a greater length of cutting edge, and the likelihood of fracture, or *breaking-out*, is correspondingly reduced. The hardness and toughness of wrought iron and steel render it that full force blows may be given on a narrow chisel without danger of breaking-out. In using cross-cut chisels lighter blows must be given when near the bottom of the groove, to prevent the metal breaking-out below this level; also, the groove should be worked from each end.

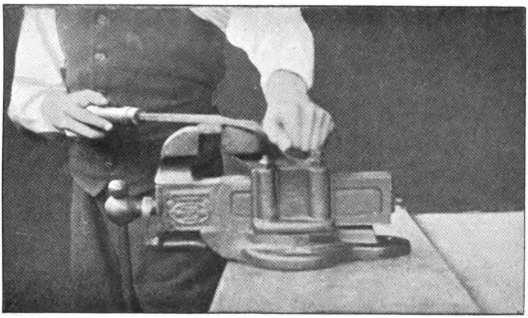
Lubrication.—In chipping wrought iron and copper the chisel should occasionally be dipped in oil or soapy water.

Weight of Hand-hammer. Freedom from Grease.—A $1\frac{3}{4}$ lb. hammer is of good average weight for chipping, and the face of the hammer and the end of the chisel must be kept free from grease.

The chisel should be held as close to the head as possible, to give steadiness.



Chipping.



Filing.

Draw-Filing.

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FILING

Distinguishing characteristics of Files.—Files are distinguished according to:

(*a*) *Length*, which is measured exclusive of the tang.

(*b*) *Cut*, which relates to the character and relative degree of coarseness of the teeth.

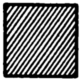
(*c*) *Sectional form*, which is in accordance with the form of, or which can best be admitted to, the work to be done.

The lengths of files vary from about 4 in. to 18 in. or 20 in.

'Cuts' of Files.—There are some half-dozen degrees of 'cuts' in files—*rough*, *coarse*, *bastard*, *second-cut*, *smooth*, and *dead-smooth*.

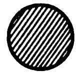
The teeth are formed by a series of parallel cuts at an angle of about 55° with the long axis of the file; 'single-cut' files, called also 'floats' or 'float-cuts,' have a single series of cuts all in the same direction, and 'double-cut' files have two series of cuts crossing each other at about equal angles to the axis of the file. The coarser cut files are used to remove a maximum quantity of material, and the finer cuts to produce a more smooth and true surface, and for draw-filing and polishing.

Sectional forms of Files.—Files are made in a variety of sectional forms, adapted for use on every possible form of work. The following are the most usual forms, each of which may be in several sizes :—



Square.

Flat.



Round (if tapered 'Rat-tail').

Half-round.

Double Half-round (or Fish-back).

3-square.

Knife-edge.

'Parallel' and 'Taper' Files.—Files may be *Parallel* or *Tapering*. Parallel files include all those which are of tolerably uniform width throughout, but the *thickness* may be somewhat greater near the centre than at either end. This is termed being 'bellied,' and is to enable the operator to bring his file to bear exactly upon any given spot on the work without danger of the file touching any other part.

'Safe' Edges.—Files of rectangular section sometimes have a *safe edge*—*i.e.* one edge without teeth—so that one side of an internal angle may be filed close up to the adjacent side without injury to the latter.

Use of Files on different Metals.—Some amount of discrimination has to be exercised in the selection of files for use on different metals. Files which have been worked on wrought iron or steel will not cut cast iron, brass, or copper, so that new files are generally kept for these metals, and can afterwards be used on wrought iron or steel with very little loss of cut.

Fixing Work in Vice.—In filing, under ordinary conditions, the work should be about level to the operator's elbow when he stands in position. The work should be fixed in the vice, as near down to the top of the vice-jaws as will allow of the required amount of metal being filed off without the file coming into contact with the jaws, and so that the level to which the work has to be filed down shall as nearly as possible be parallel with the top of the jaws. The jaws then serve as a rough guide to the operator.

Removal of Dirt and Scale.—The edge of the file should first be used to clean off any dirt or scale which may be on the material to be filed.

Cross-filing.—In *Cross-filing*—*i.e.* in filing in the direction of the length of the file—the beginner's chief difficulty will lie in the tendency of the file to rock in the direction of its length, and to produce a convex surface on the material instead of a flat one. Only continued practice will successfully overcome this, but a great deal may be done by a proper manner of holding the file. The end of the handle should butt against the hollow of the palm of the right hand—the handle resting along the fingers, with the thumb on the top side; the left hand should control the file at the point, the ball part of the thumb being on top and the fingers underneath.

The forward stroke only is the cutting stroke, the file merely sliding across the material on the return stroke. In making the forward stroke, downward pressure should be given with the left hand at the commencement, this pressure being gradually relieved from the left hand in the progress of the stroke, until it is greatest with the right hand at the finish.

In all cross-filing the file should be given a lateral as well as a forward stroke, principally from right to left; but a direction across this, occasionally (Fig. 6) will materially assist in rapidly reducing the material.

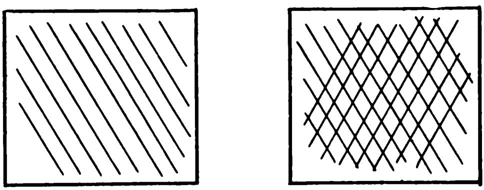


Fig. 6.

The hands should, as far as possible, be kept from touching the surface which is being filed, otherwise the file will not *bite* for several strokes, but will merely *slip* over the work. This, of course, equally applies to grease in any form touching the work.

Draw-filing.—When the work has been reduced by cross-filing to its approximate level and truth, it is subjected to the process known as *Draw-filing.* A smooth-cut file is grasped at each end (exclusive of the handle), and rubbed to and fro along the length of the work, the file being held at right angles to the length of the work. Care should be taken to keep the strokes exactly parallel with the direction of the length of the work, so that the grain of the material may be laid lengthwise.

Draw-filing is intended to take out the file marks produced by cross-filing. Also, it produces a smoother surface, but does not take off as much material in a given time as cross-filing, and should therefore not be resorted to until the utmost possible truth has been secured by cross-filing.

Pinning.—Both in cross-filing and draw-filing small points of metal cling in the teeth of the file, causing the latter to *slip* over the work, and scratch it. This is termed *pinning*.

These filings may be removed by brushing the file, laterally, with a 'file-card,' a kind of wire brush. In draw-filing, pinning may largely be prevented by chalking the file.

Polishing.—After draw-filing, the work can be still further polished by stretching a piece of emery-cloth tightly over the file, and using it in a similar manner to draw-filing. To produce a very high polish fine emery-cloth should succeed the coarser; and to prevent scratching oil should be used on the emery-cloth. Metals which are polished with oil withstand rust better than when the emery-cloth alone is used, although there may apparently be no oil on the work when it is finally cleaned up.

SCRAPING

The process of *Scraping* is employed in very particular work, to 'true' up surfaces more exactly plane than can be done even with the finest file, and is a necessary process where plane surfaces are required to fit perfectly to one another. It is also employed to give a 'frosted' appearance, without regard to the planeness of a surface.

Forms and Uses of Scrapers.—Figs. 7, 8, and 9 show common forms of Scrapers. That shown in Fig. 7 may be made from a small, worn-out flat file, and that in Fig. 9 from a three-square file.

Fig. 7.

The scrapers, Figs. 7 and 8, are used upon ordinary flat work; the three-square scraper is more suitable for hollow work and very small flat work.

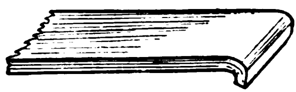


Fig. 8.

In scraping, short quick strokes are taken, the tool being pressed hard to the work in the cutting stroke, and lightly in the backward stroke. As the amount to be taken off becomes less, the cutting strokes need to be lighter.

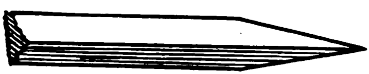
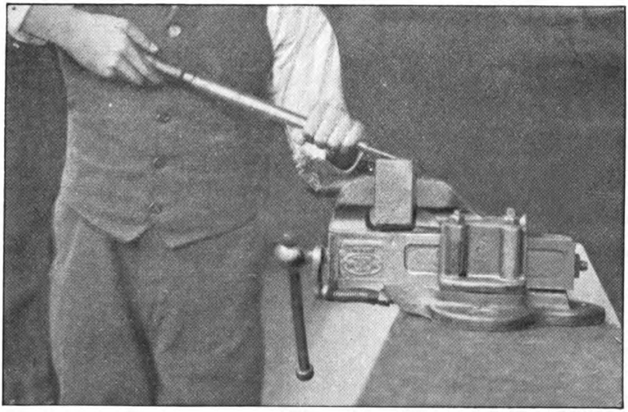
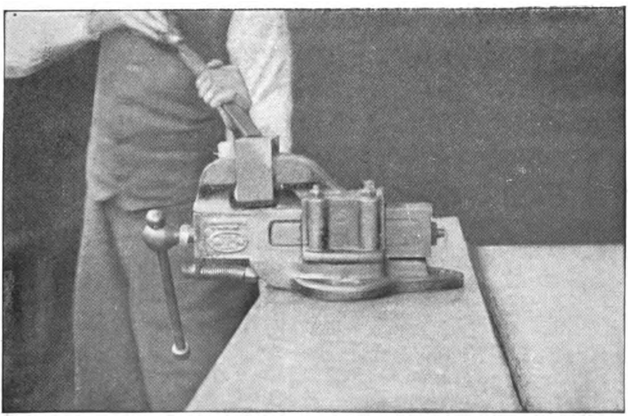


Fig. 9.

Testing Scraped Surfaces. The Surface-plate and Bar.—During scraping, the results are too fine to



Scraping.



Scraping.

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be tested by the ordinary straight-edge or try-square. A *Surface-plate* or *Planometer* is used.

The 'surface-plate' (Fig. 10) is a perfectly plane

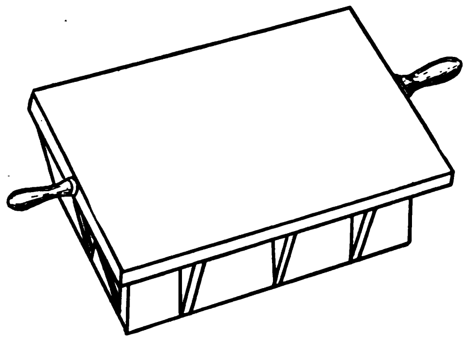


Fig. 10.

plate of cast iron, so constructed and supported that its plane surface always remains perfectly true. Sometimes a plate of glass, supported on a cast iron frame, is used as a surface-plate. This has the advantage of never rusting.

To test the truth of the surface that is being scraped, a little 'reddle'—a thin mixture of red ochre and oil, or red lead and oil—is rubbed with the hand evenly over the surface-plate; and then, after the work has been wiped clean, the surface-plate is rubbed backwards and forwards, and sideways, on the work; or, if the work is small, it can be taken out of the vice and rubbed over the surface-plate. The high parts on the work will be revealed by being smeared with the reddle. These should then be scraped down, and the surface-plate applied to the work again, followed by further scraping,—these operations being repeated until the whole of the scraped face of the work is shown to be in contact with the surface-plate, and therefore true, by the fact of the reddle evenly covering this face.

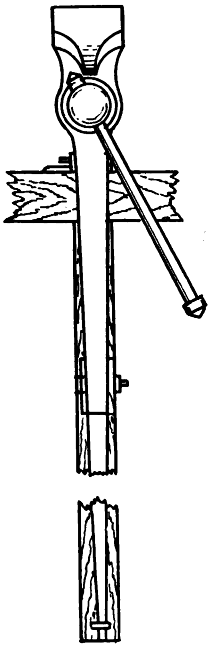


Fig. 11.

Sometimes a 'surface *Bar*'—a triangular bar having each face perfectly true—is more convenient for use on certain works than a surface-plate.

Scraped Surfaces not to be polished.—After the operator is satisfied with the truth of the work after scraping, no attempt should be made to polish it. It must be remembered that scraping is a very fine operation, and a 'face' produced by scraping is more than likely to be rendered untrue by polishing. The inspection of lathe-beds, for instance, will show to the observer the scraper-marks left on the surface.

VICES

The Leg Vice.—*The Leg Vice,* front and side views of which are given in Figs. 11 and 12 respectively, is the form of vice most generally found in smiths' and engineers' shops. It consists of two jaws or chaps, *a*, working on a hinge, *b*, and which are opened and closed by a screw working in the box, *d*. This vice has

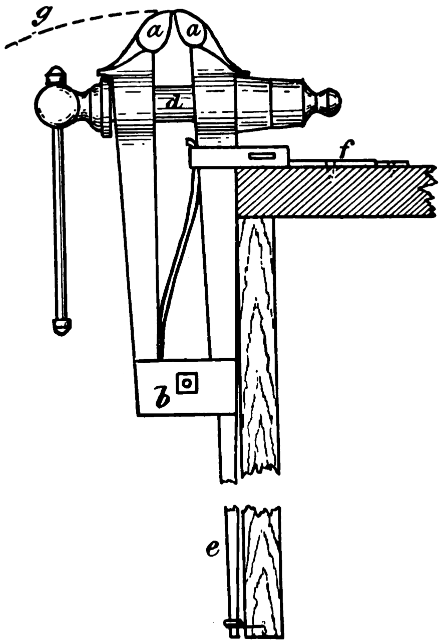


Fig. 12.

a leg or standard, *e*, which is fixed with a staple to the bench-leg, or to the floor; it also has a flat horn, *f*, which projects across the top of the bench, and is screwed down to it.

The leg vice grips tighter, and is better for very heavy chipping than, say, the parallel vice, but is open to this objection—which arises from the fact of it working on a centre or hinge—that while the jaws are quite closed they grip rather at the top than at the bottom; but, when widely opened, the fact that the outer jaw travels along the arc, *g*, renders it that the jaws grip the work only at the lower edges, and the top surface of the work is not in a plane parallel to the top surface of the bench. This interferes somewhat with the operator's judgment as to the truth of the surface he may be working upon.

The Parallel Vice.—*The Parallel Vice* is designed to obviate the objections referred to in the case of the leg vice. In the parallel vice the outer jaw forms part of a sliding box, so that the gripping surfaces of the jaws always retain their parallelism.

The following is a description of a very useful form of parallel vice—PARKINSON'S PATENT PERFECT VICE—which has the further advantage of instantaneous grip. (Fig. 13 gives a side view of this tool, and Fig. 14 a sectional view.)

The inside jaw (B, Fig. 13) forms part of the general body, H, of the vice, and is bolted to the base C, which is itself bolted to the bench. The outer jaw, D, forms part of the box E, which slides to and fro through H, carrying with it the jaw D, the face of which is constantly parallel with the face of the inner jaw B. J, Fig. 14, is a long, narrow plate, acted upon by the spring K, which controls the nut L. The spring keeps the nut in gear with the screw M. The screw and the box being relatively fixed, the turning of the screw secures the opening and closing of the outer jaw.

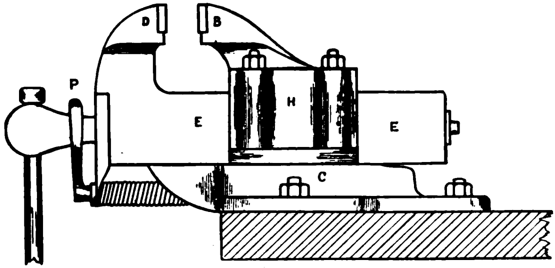


Fig. 13.

Instantaneous Grip—By pressing the handle, P, of the spring inwards towards the screw-spindle, the plate J is shifted downwards, disengaging the nut from

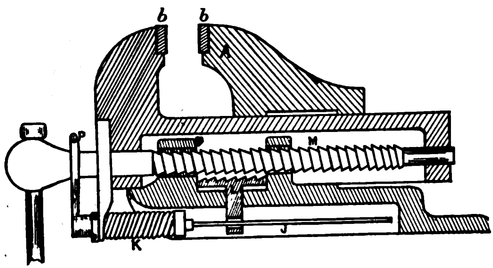


Fig. 14.

the screw. (Fig. 14 shows the nut disengaged from the screw.) Then with one hand the outer jaw can be slid in or out to any required distance, without turning the screw; and by releasing the spring it is secured in its position by the action of the spring on the plate throwing up the nut and engaging it with the screw. A single turn of the screw-handle secures absolute rigidity to the object gripped in the jaws.

This vice is fitted with a 'buttress-threaded' screw and nut, so that the nut follows up the wear between itself and the screw, thus preserving a good 'fit.'

It will be clear how great a time-saver the 'instantaneous-grip' vice is, and with how much greater nicety the work can be fixed in a parallel vice than in a leg vice.

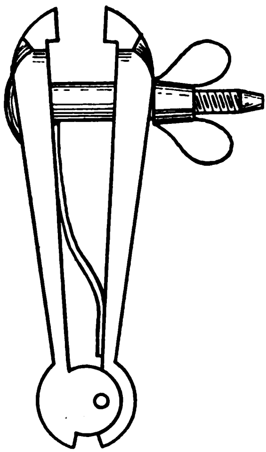


Fig. 15.

Height of Vice.—The height of a bench vice should be such as to allow the elbow to touch the top of the jaws when the arm of the operator is bent with the hand upwards, the operator standing upright. A good average height from the floor is about 44 inches.

The Hand Vice.—It often happens that very small objects require to be held in the hand, but that the fingers cannot grip them with sufficient firmness. In such cases the hand vice (Fig. 15) is used, which holds an object securely and allows it to be manipulated with almost as much freedom as if it were held in the hand itself. Reference to the figure will show that the hand vice is really a small type of leg vice. The jaws are manipulated and kept in position by a screw and winged nut.

VICE-CLAMPS AND FILING-BOARDS

Metal Clamps.—The jaws of vices are faced with hardened steel, cut like files, so as to grip securely; but delicate work, and work which is nearly finished, would be damaged by marking with the teeth of the jaws. Such work is protected by the use of *Vice-clamps* (Fig. 16), which are usually of brass, copper, or lead.

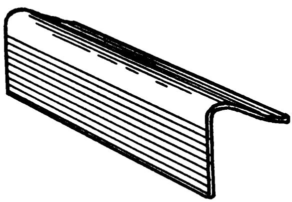


Fig. 16.

The clamps are made by taking two pieces of material of the length of the vice-jaws, and nearly as wide, and gripping them between the jaws; then one is hammered closely over the shoulder of each jaw, and, whilst readily removable when not required, retain their positions when not in use and when the work is removed from the vice.

Wooden Clamps.—Another simple but useful form of clamp may be improvised by taking two pieces of bay-wood and joining them with a leather hinge (Fig. 17).

Filing-boards.—Other devices have to be adopted for different forms of work, among

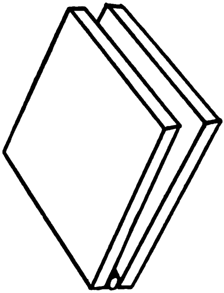


Fig. 17.

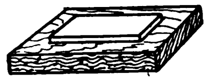


Fig. 18.

which is the *Filing-board* (Fig. 18). Sometimes a flat piece of work is too thin or too irregular to be gripped in the vice. In that case it would be laid upon the filing-board and held in position by small sprigs driven in close round it, and just below its top surface; the filing-board being gripped in the vice.

A variation of the filing-board is that shown in Fig.

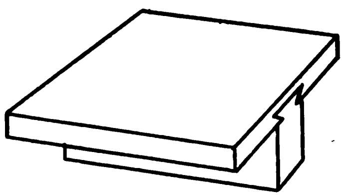


Fig. 19.

19. The vice holds the under piece, and the work can be fastened to the horizontal piece by a thumb-screw cramp.

Filing-block.—The *Filing-block* (Fig. 20) is a stout piece of wood, having a number of V-shaped channels of different sizes filed across it. These are for the purpose of resting small work in, which cannot well be held in the bench vice, and which may be more conveniently held and manipulated by the hand or hand vice. The filing-block is gripped in the bench vice; and if the material to be filed is rectangular, or otherwise angular, it is held still upon the filing-block, but if circular, it is worked to and fro in a rotary fashion whilst being filed, in order to preserve its circular shape.

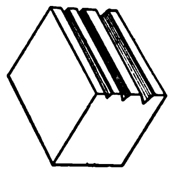


Fig. 20.

CALLIPERS; CENTRE-PUNCH; SCRIBING-BLOCKS; V-BLOCKS; TRY-SQUARE AND FOOT RULE

There are three forms of callipers—*Outside, Inside,* and *Jenny.*

'Outside' Callipers.—'Outside' callipers are used for taking the diameters of circular pieces, as in Fig. 21. The two usual shapes are shown in the figure, but that formed by the dotted lines is often preferred, because it will span a larger bar than the other.

'Inside' Callipers.—'Inside' callipers are used for such purposes as taking the inside diameters of tubes, as in Fig. 22.

'Jenny' Callipers. — 'Jenny' callipers have one straight leg, and the other curved at the end similarly

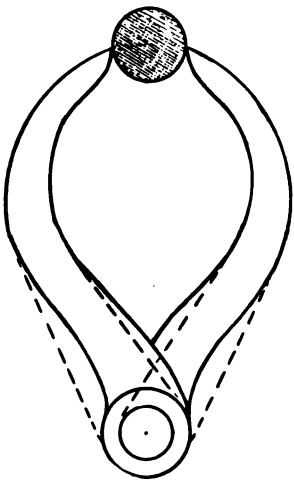


Fig. 21.

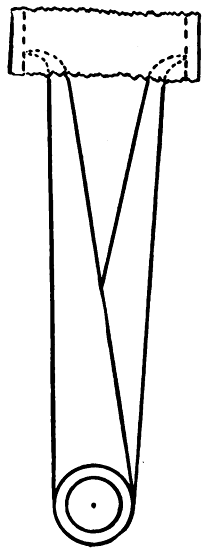


Fig. 22.

to inside callipers. They are used for such purposes as marking off distances on work in the lathe (Fig. 23), the curved leg serving as a guide against the end of the work, while the point of the straight leg pressed against the work—as at *a*, Fig. 23—scribes a line round it as it revolves. Jenny callipers are also used for scribing lines along plane pieces of work, the curved leg serving as a guide against one side while the point scribes a line on an adjacent side (Fig. 24).

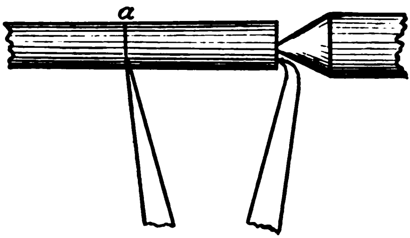


Fig. 23.

The Centre-punch.—The *Centre-punch* (Fig. 25) is used for 'centreing' pieces for turning—that is, for

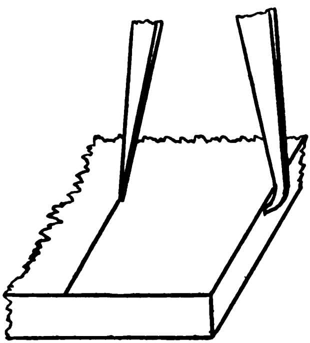


Fig. 24.

Fig. 25.

making a small conical hole in the sectional centre of each end of the piece to be turned, to receive the 'lathe-centres,'—and for giving a lead in the drilling of holes; also, for such purposes as the more clearly defining, by a series of centre-punch dots, scribed lines which are to be chipped or filed down to, as along the lines *a*, *b*, *c* (Fig. 26).

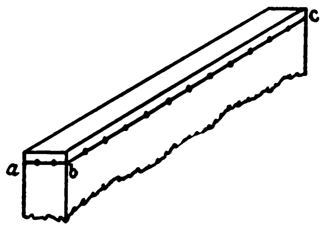


Fig. 26.

The Scribing-block.—The *Scribing-block* or *Surface Gauge* (Fig. 27) consists of a base, *a*, which is hollowed underneath (as shown by the dotted lines), so that, resting only on its outside strips, it can stand accurately level; a perpendicular shaft, *b*, screwed into the base; a sliding piece, *c*, which travels up and down the shaft, and may be fixed at any given place by the winged nut, *d*. The latter also holds a pointed steel bar, *e*, which can be shifted to and fro horizontally.

The scribing-block is used for such operations as scribing lines, or setting off points and centres on a piece of work, at any given distance from the surface-table upon which the scribing-block rests. The bed of a lathe often forms a convenient surface-table. It is also used as a gauge, by bringing the point of the curved end of the scriber down on to the piece at

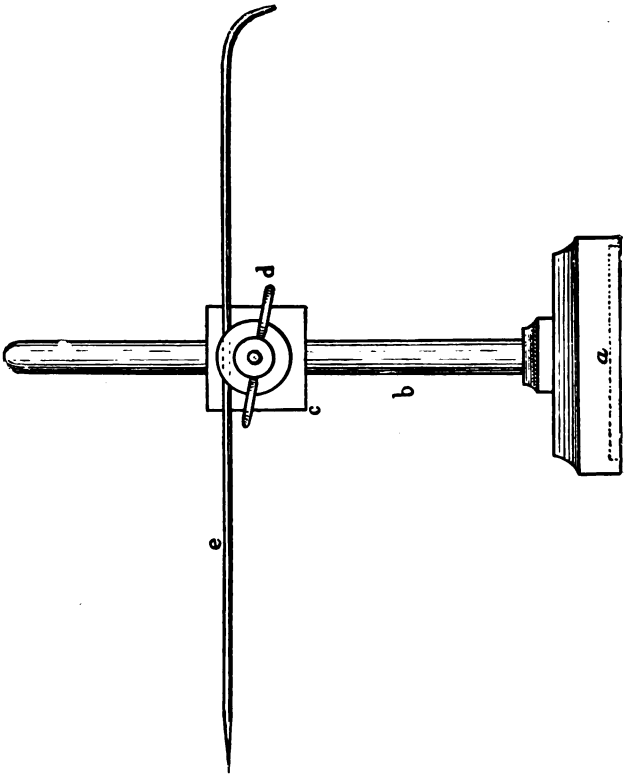


Fig. 27.

various points, for adjusting the horizontal position of a piece of work to the surface-table.

V-Blocks. — The *V-Block* (Fig. 28) is used as a rest for curved pieces of work during, for instance, such operations as drilling a hole perpendicularly through a round bar; or while the scribing-block is being used upon such pieces.

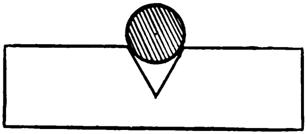


Fig. 28.

The Try-square and Foot Rule.—The metal-worker's *Try-square* and *Foot Rule,* which are both of steel, are shown in Figs. 28A and 28B. The latter should be graduated to sixteenths of an inch throughout, and over part of its length to thirty-seconds. The foot rule also forms a convenient straight-edge.

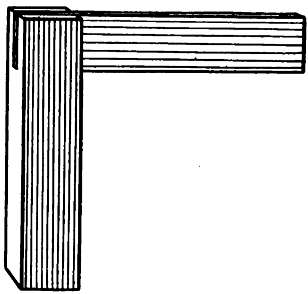


Fig. 28A.

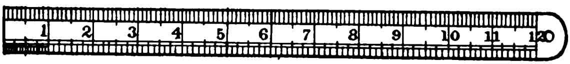
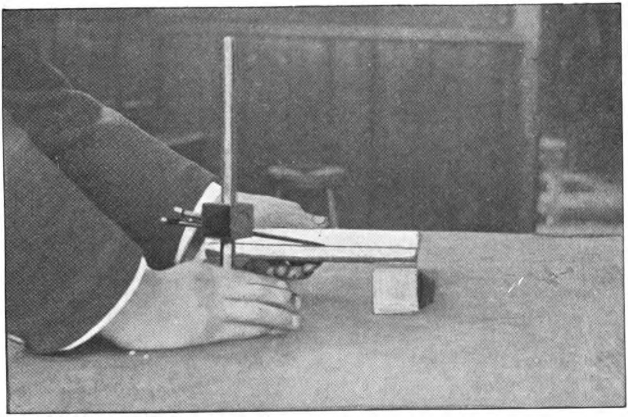
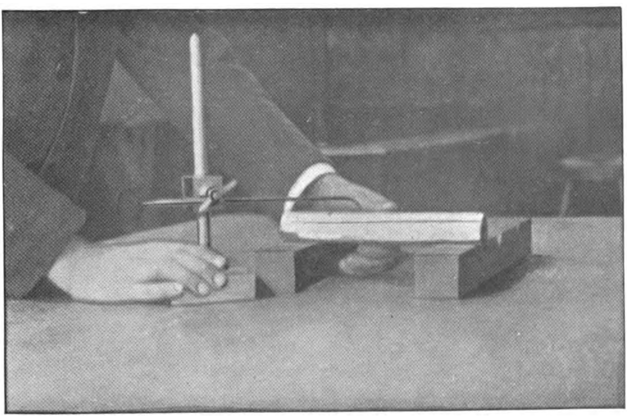


Fig. 28B.



Use of Scribing-Block.



Use of Scribing-Block.

[To face page 24.

SOLDERING

Soldering is the joining together of two pieces of metal by the application of molten alloys, and may be broadly divided into two classes of work—'*hard' soldering* (or *brazing*) and '*soft' soldering.*

'Hard' Solders.—*'Hard' solders* fuse only at a red heat, and are adaptable only to those metals which are not fusible at a red heat, or pieces of metal of sufficient substance to endure that heat.

Spelter-solder.—*Spelter-solder,* used for hard soldering, is an alloy of 4 parts of copper to 3 of zinc, fused together in a mortar, cast into ingots, and then pounded by being granulated in a mortar. Another method is for the spelter to be granulated while hot by being run through a very fine 'worm' (or spiral metallic tube) into water. Spelter-solder is used for soldering iron, copper, brass, gun-metal, etc., and the joints may be hammered, rolled, or bent at will.

'Soft' Solders.—*'Soft' solders,* according to their composition, are fusible at temperatures varying roughly from 200° F. to 400° F., and, whilst suitable for nearly all metals, are most commonly used for 'tinned' metals, and on articles which will not afterwards be subjected to great heat.

The soft solder mostly used is an alloy of 2 *parts tin to* 1 *part lead.* The addition of bismuth lowers the fusing-point. The following proportions of tin and lead are also freely used: 2 *parts tin to* 3 *parts lead,* for soldering *lead;* and 3 *parts tin to* 4 *parts lead,* for soldering *pewter.*

Soft solders do not make a malleable joint.

Fluxes.—It is important that the pieces which are to be joined by soldering should be clean and bright at the parts which are to be actually united. These parts must therefore be filed or scraped, and wiped, to free them from dirt, rust, grease, and metallic oxides, which might interpose between the solder and the metal. This cleaning of the edges, however, gives rise to another danger, for the affinity of the metals for oxygen is increased; they are, therefore, defended from the air by the application of a *flux,* which also destroys any portion of oxide which may be still remaining.

In hard soldering—that is, where red heat is employed—previous cleaning of the edges is not so necessary, for grease and other impurities are *burned* away; also, the borax which is used as a flux has the property of combining with nearly all the metallic oxides, and thereby cleansing the edges of the pieces.

The following is a list of fluxes, with the metals they are used on:—

For *Iron* or *Steel* . .	*Borax.*
„ *Copper, Gun-metal, and Brass* . . .	*Borax,* or *Chloride of Zinc.*
„ *Tinned Iron* . .	*Resin,* or *Chloride of Zinc.*
„ *Zinc*	*Chloride of Zinc.*
„ *Lead*	*Tallow and Resin.*
„ *Lead and Tin Pipes* .	*Resin,* or *Sweet Oil.*

In short, *Borax* is the usual flux for hard soldering, and *Chloride of Zinc* for soft soldering.

Preparation of 'Chloride of Zinc' Flux.—To prepare *Chloride of Zinc*—the general flux for soft soldering—pour some Muriatic Acid (otherwise known as Hydrochloric Acid or Spirits of Salts) into a shallow open glass or other similar vessel, and add some pieces of zinc; ebullition will be immediately set up, caused by the freeing of the hydrogen and the union of the chlorine and zinc. Let this stand for several hours, until the acid has ceased to act—which is shown by the cessation of the boiling—then pour the liquid off and bottle for future use. The sediment can be thrown away.

'Hard' Soldering or Brazing.—For *hard soldering*, a blacksmith's fire, or a candle or alcohol lamp and blow-pipe, may be used. If a blacksmith's fire be used, fresh coals are not suitable for fuel on account of the sulphur from them depositing itself on the pieces to be joined, and thus preventing their union. The best fuel is charcoal; but coke or cinders may also be used.

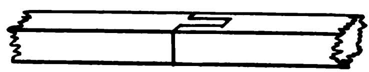


Fig. 29.

The pieces to be brazed should be fitted together in some convenient form (as, for instance, in Fig. 29), and firmly secured in position with fine binding wire. (The inspection of a brazed key-shaft will reveal this form of joint.) Sufficient spelter and borax are mixed in a vessel with a very little water, and spread along the joint with any convenient instrument, such as a strip of metal or a spoon. The work should then be held with the pliers or tongs, first at a little distance above the clear fire (or blow-pipe flame) to gradually evaporate the moisture, during which the borax will boil up with a frothy appearance. (At this stage the work must not be heated too hastily, or the solder may be displaced.) The heat is then increased, and when the metal becomes faintly red the borax fuses like glass; and, on being heated to a bright red, a small blue flame is seen—the result of the ignition of the zinc—and which indicates the fusion of the solder. Just at this stage a slight tapping of the work

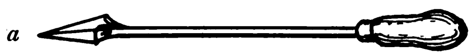


Fig. 30.

with the poker will assist the solder to run through the joint to the lower surface; but often it will 'flush,' that is, become absorbed in the joint, by itself. It is necessary to apply the heat as uniformly as possible, by moving the work about over the fire, so as when melting the solder to avoid injuring the object. As soon as the solder has 'flushed,' the work should be withdrawn from the fire, and when the solder has 'set' it may be cooled in water without danger to the joint.

'Soft' Soldering.—*'Soft' soldering*—for tinned iron, sheet zinc, and thin metal generally—is done with the *Copper-bit* (Fig. 30), or *Soldering-iron*, as it is usually termed, which suffices to convey all the heat required to melt the more fusible solders. This tool consists of a piece of copper (*a*, Fig. 30) of about three or four ounces in weight, and which is riveted to an iron shank fitted with a wooden handle.

The copper-bit is used for soldering *thin* metals only, because the two pieces of metal to be joined must be brought by the copper-bit to the same heat as is necessary for fusing the solder.

Before using, the copper-bit must be 'tinned'—that is, it must have a thin coating of the solder run on to it about the point, otherwise the solder for making the joint will not adhere to the 'bit.' To 'tin' the copper-bit it should be heated to a dull red, then filed to show a clean metallic surface, and wiped clean on a rag wet with chloride of zinc; if it then be rubbed upon a small portion of solder (which may conveniently be held upon a small piece of wood) it will become coated with solder, or 'tinned,' and after being again wiped clean, will be ready for use.

The pieces of metal to be soft soldered must be cleaned at the edges (as has been explained earlier, in connection with fluxes), and held together in position with the hand, or with binding-wire, as may be more convenient for the work, and the flux applied to the edges with a small brush or thin strip of wood. Then, the copper-bit having been heated sufficiently to pick up drops of solder, it is first used to heat the edges of the metal, and then to melt and evenly distribute the solder along the joint.

In soldering metals other than those which have tinned surfaces, such as brass, the edges must be separately tinned before being united with the solder.

The proper heating of the soldering-iron is an important matter, because, if it is not hot enough to raise the edges to be joined to the melting-point of the solder, the latter will not adhere; whilst, on the other hand, if the soldering-iron be overheated, the tinning will be burnt off and the solder will not follow along the joint.

Given a clean, well-tinned soldering-iron, and bright, clean edges to be joined, it will be found that the solder will follow the iron exactly where it is wanted.

The separate parts of all soldering work should be kept quite still relatively to each other while the operation of soldering is proceeding, as any movement of these parts during the transition of the solder from the fluid to the solid state disturbs its crystallisation, and prevents the proper union of the separate parts.

RIVETING (COLD-HAMMERED)

'Lap' and 'Butt' Joints.—In riveting two plates together, holes are drilled or punched in them, so that when the plates overlap, the holes in the two plates are opposite to one another. (*a*) and (*b*) Fig. 31, are examples of *Single* and *Double Riveted Lap Joints* respectively; and Fig. 32 shows a *Butt Joint and Strap*, A being the strap.

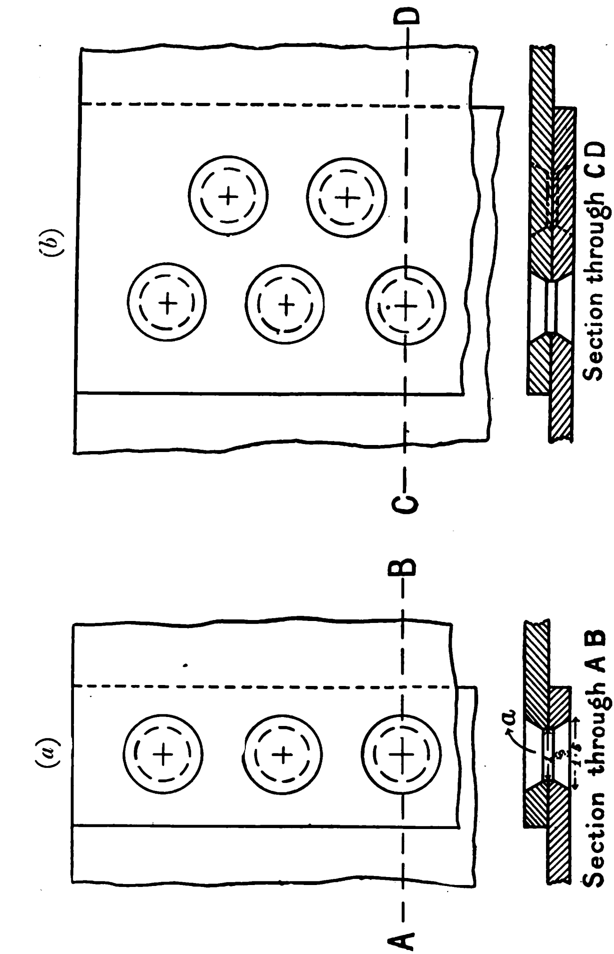


Fig. 31.

'Chain' and 'Zig-zag' Riveting.—(*a*) Fig. 31, and Fig. 32 are examples of *Chain Riveting;* and *b,* Fig. 31, of *Zig-zag Riveting.* The illustrations will explain how the names are applied.

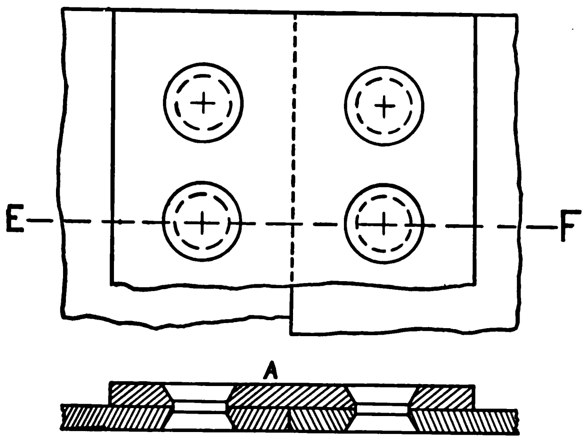


Fig. 32.

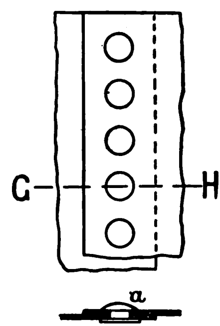
Countersinking.—In each of the foregoing examples the rivets are *countersunk,* that is, the head is formed within the body of the plate—a method suitable for plates of tolerable thickness, say $\frac{1}{4}$ in. or $\frac{1}{2}$ in. The rivets are made from the toughest and most ductile quality of round iron, so that the ends may be hammered down to form the heads without breaking-out. An advantage of countersinking is that the heads of the rivets are flush with the surface of the plate, while a disadvantage is that the plate is weakened by the loss of material taken up with the spread of the head.

The plates must first have holes, parallel throughout, drilled in them, and then be countersunk with a rose-bit to a depth of about three-quarters of the thickness of the plate. The countersinking should be at an angle of 60° with the surface of the plate, but this must of course be governed by the inclination of the 'bit.' The cylindrical pieces of iron for the rivets are then placed in the holes and hammered on an anvil, cold, at each end, until they spread out to closely fill the countersunk holes. The heads are then filed down flush with the surface of the plate.

Proportions of Rivets.—The diameters of rivets vary in accordance with the thickness of the plates, ranging from more than twice this thickness in thin (say $\frac{1}{4}''$ or $\frac{3}{8}''$) plates, down to 1·5 or even 1·1 in thick plates. A common formula is :—

If t = thickness of plate,
and d = diameter of rivet,
then $d = 1{\cdot}25\sqrt{t}$

For countersinking proportions :
If diameter of rivet . = 1
then depth of countersink = ·5
and outside diameter of
head . . . . . . = 1·5



Section through GH

Fig. 33.

Riveting Sheet Metal.—Fig. 33 gives an example of *Sheet Metal Riveting,* as in the production of light articles, such as stove-piping, corn-bins, etc., and in which the rivets are *snap-headed,* as at *a.* The rivets may be purchased in the form shown in Fig. 34.

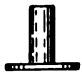


Fig. 34.

The pieces of sheet-metal to be joined are brought into position one over the other, and punched through together, during which operation they should be placed in some firm position, as on an anvil, with a thick piece of sheet-lead immediately under them, so that the punch may pass clear through the plates.

On the insertion of the rivet the plates will be found to fit irregularly round its shank. To remedy this a *drift* or *bolster* (Fig. 35) is placed over the rivet—the bore *a* fitting close over it—and is hammered to close the plates round the rivet and bring them firmly together. The top of the shank is then hammered down to the rough 'snap' form (*a,* Fig. 33), and neatly rounded off with a finishing tool called a *snap* (Fig. 36).

Fig. 35.

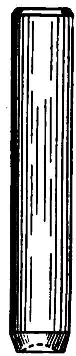


Fig. 36.

DRILLING

The operation of boring holes in metal is called *Drilling,* and may be performed in the lathe, by drilling machines, or by hand-drilling tools.

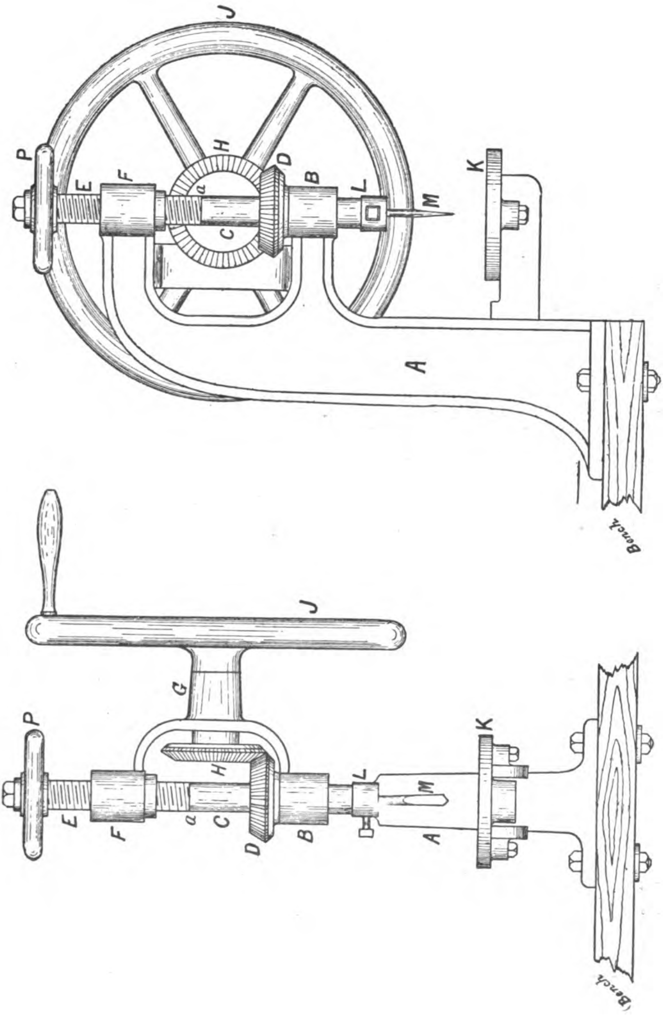
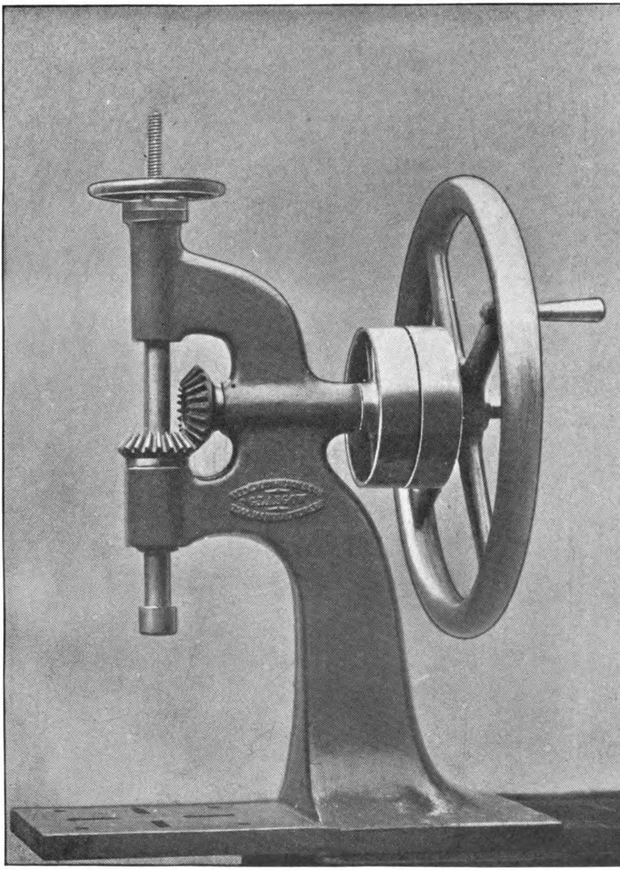


Fig. 37.

The Bench Drilling Machine.—Fig. 37 gives front and side views of a *Bench Drilling Machine* for handworking. A is *the frame,* B a bearing for *the spindle* C, to which is attached *the spur-wheel* D. On the inside of the spur-wheel is a 'feather,' which slides in a groove in the spindle, so that the latter revolves with the 'spur,' and at the same time allows the spindle (in the lower end of which the drill is inserted) to be raised or lowered to suit the work. Continuous with the spindle C, and above it, is *a screw-spindle* E. The two are connected by a pin-and-socket joint, so that the part C can revolve independently of the part E. A small set-screw passing through the socket-piece at *a,* and entering a horizontal groove which runs round the pin, secures the raising and lowering of the drill-holder when the screw-spindle is revolved. The screw-spindle works in *the screw-nut* F. G is a bearing, through which passes a horizontal spindle, having at one end the spur-wheel H, which engages with the spur-wheel D, and which is driven with the hand-wheel J. K is *the table,* upon which the piece to be drilled is clamped or bolted. At the lower end of the part C is *a socket* L, which holds *the drill* M.

The turning of the hand-wheel J revolves the drill, which is brought down to, or released from, the work by turning the screw-spindle from the hand-wheel P. By substituting a 'fast' and 'loose' pulley on the spindle at G in place of the hand-wheel, this machine can be driven by power.

The 'Breast' Drill-brace.—Fig. 38 is a *Breast*



Alex. Mathieson & Son, Glasgow.]

Bench Drilling Machine, for Hand or Power.

[*To face page* **36.**

Brace for small work—*i.e.*, for the drilling of holes of small diameter. From a comparison of this tool with the bench drilling machine it will be seen that the two are constructed on very similar mechanical principles. In the breast brace the part A is pressed against the breast or stomach of the worker, as may be convenient, and the tool is steadied by grasping the handle B. The drill is revolved by turning the handle C.

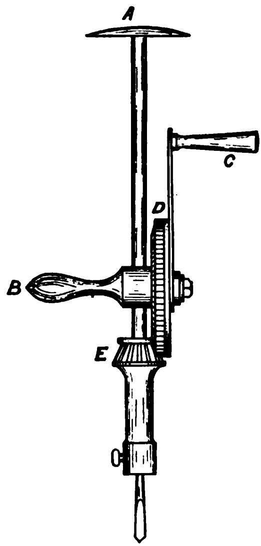


Fig. 38.

It will be noticed that in the gear-wheels the driver D is of much greater diameter than the driven wheel E (for one revolution of D, E makes five or six revolutions). The reason for this is that the machine, being used for small work only, and the pressure on the drill from the operator's body being slight compared with the pressure on the drill in the bench drilling machine, and there being consequently small 'feed,' the drill is required to revolve very fast in order to make reasonable progress with the work.

The Archimedean Drill Stock.—Fig. 39 shows an *Archimedean Drill Stock,* which is used for drilling *very* small holes. It consists of a *spiral spindle* A, which works loosely in a *stock* B, and the *bobbin* C, which contains a nut to engage with the spiral, and is moved rapidly up and down the spindle, causing the drill to spin in a rotary, to-and-fro motion. The drill is fixed in a small taper split 'chuck' at the end of the spindle, and which is 'threaded' on the outside to receive the winged nut D, for tightening the grip of the chuck on the drill.

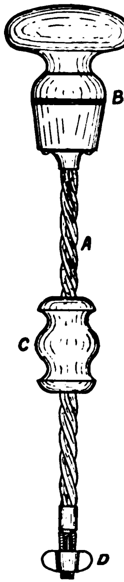


Fig. 39.

Although the breast brace and the archimedean stock are suitable for small work only, they are exceedingly useful, in that they are available for drilling holes other than in the perpendicular.

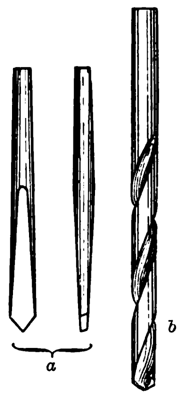
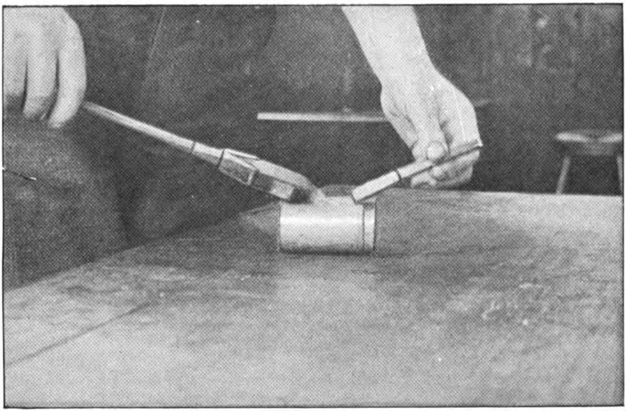
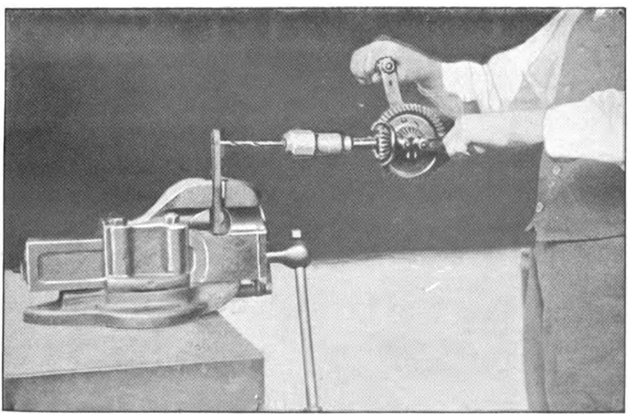


Fig. 40.

Drills.—Fig. 40, *a* and *b*, show the *Flat* and the *Twist Drill* respectively. The twist drill is much the more expensive, but the following are among its advantages, compared with the flat drill. It bores a perfectly regular and parallel hole, whereas the flat drill is inclined to 'wobble,' and so bore irregularly; the flat drill, especially when boring small holes, requires to be frequently removed from the hole in order that the



Soldering.



Using the Breast-Drill.

[To face page 38.

borings may be cleared out, but with the twist drill the borings automatically travel out along the flutings of the drill.

Drilling in the Lathe.—In addition to the use of drilling machines, drilling can be performed in the lathe. A drill-chuck, for holding the drill, is screwed on to the 'fast' headstock mandrel, and the work held between the drill and the poppet headstock. The work is kept up to the drill by screwing up the slide-spindle of the poppet headstock.

Points to observe in Drilling.—During the process of drilling there are a few points which require special attention on the part of the operator.

The work should be very accurately 'centred,' so that the drill may make a true start. After the point of the drill has entered the work a little distance it should be withdrawn, and the work examined, so that it may be seen that the bore has started true; and if it has not, the centre should be 'drawn over' with the centre-punch (see 'Centreing' in Turning).

The 'feed' to the drill should be even; that is, the drill should be advanced to the work, or the work to the drill, with perfect regularity, or the boring will not be smooth and regular. Also, if the 'cut' is less than the drill will take, time is being wasted; if a heavier cut than the drill will take should be attempted, the drill is liable to be broken, and the boring forced out of truth.

When boring wrought iron or steel the cutting-edge of the drill should be kept continually lubricated, otherwise it will become heated and softened, and will not cut until it has been re-tempered and ground.

SCREW-CUTTING

Stock-and-Dies.—The handiest general method of cutting screws is by *Stock-and-Dies.* Fig. 41 gives the usual form of stock, with cross-section at A B, for ordinary small work ; *a* is the *frame, b b* the *dies* (small blocks of steel with an internal screw-thread, and tempered to a degree of hardness for cutting), and *c* a *screw,* which presses the dies together and is a continuation of the handle *d.* The cross-section shows the arrangement by which the dies are held in the frame, *f f* being the frame and *g* a die. It will be seen that the die has V-shaped grooves, top and bottom, which fit corresponding V-shaped projections in the frame.

For large work a variation on this form of stock is used, as shown in Fig. 42. This stock is strengthened at *h,* to allow of a screw being inserted independently of the handle, for closing up the dies.

Method of using Stock-and-Dies.—In using the stock-and-dies, the blank bolt upon which it is required to cut a thread is firmly fixed at its head in a vice, the shank standing up. The dies are opened sufficiently, by turning the screw back, to just allow of their passing over the blank, and are then closed up so as to grip the latter, not too tightly, near the top. A rotary motion to the right given to the stock will cause it to travel down the blank, the dies tracing a light thread. The stock should then be run back to the top, where the dies are tightened up, and then run down again, this process being repeated until the thread is sufficiently deep, and sharp and clean at the edges.

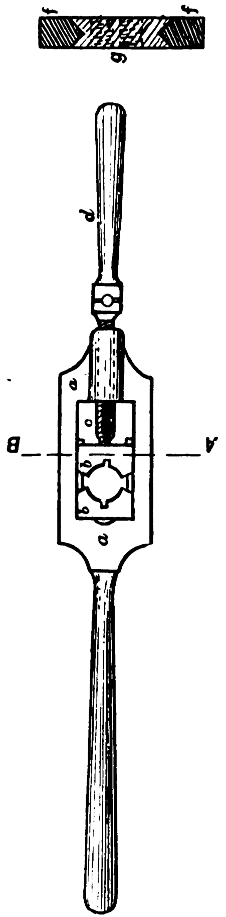


Fig. 41.

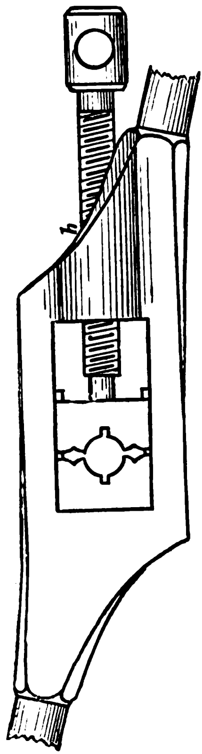


Fig. 42.

Dies are also made with the leading thread to cut backwards; they can then be tightened at the *bottom* of the blank, and will cut on the run back.

Sometimes it happens that the stock-and-dies will not at first travel down the blank, but cut horizontal parallel rings. In that case the dies should be loosened, and the stock placed slightly further down the blank, when it will probably be found to work all right.

The tightening up of the dies, for cutting the thread deeper, should take place only at the top or bottom of

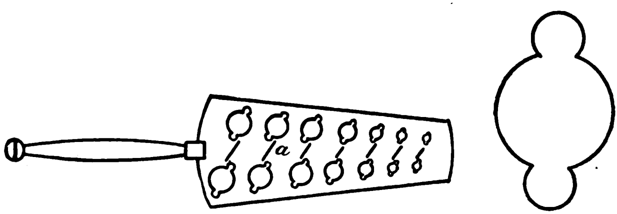


Fig. 43.

the thread, otherwise the diameter of the thread may vary at different points along the bolt.

The diameter of the blank upon which the thread is to be cut is that of the finished bolt, inclusive of the thread, and if the edge is slightly turned off at the end of the blank, the travel of the dies is facilitated.

When nearing the bottom of the thread the stock must be revolved gently, or, especially in the case of a screw of small diameter, the threaded part may be wrenched off when the stock runs against the shoulder of the plain cylindrical part below.

The Screw-plate.—The *Screw-plate* (Fig. 43) is used for cutting threads for very small screws. It consists of a thin plate of steel, with handle—the plate having a double row of tapped holes. Each of these holes has a much smaller hole drilled on either side, and intersecting it, for the purpose of providing cutting-edges to the latter, and as a clearance for the cuttings. An enlarged view of the tapped hole, with its pair of smaller holes, is shown in the figure.

The tapped holes are in pairs, each pair being indicated by the connecting line *a*. In each pair of holes one is the proper size for a given screw, and the other is a little larger.

In using the screw-plate, the blank should be turned or filed up to enter the larger hole; and, after being screwed through this, it should be passed through the smaller hole. Care should be taken to pass the blank exactly perpendicularly through the screw-plate, otherwise the thread will be out of its proper angle, and the head of the screw will not lie accurately in its proper place. The same remark applies to cutting screw threads with stock-and-dies.

Taps.—A *Tap* is a screw, tempered to a sufficient degree of hardness to cut metals, and having parts of its circumference fluted so as to give the alternate edges a cutting action. It is used to cut internal threads, as in a nut.

Taps are made in sets of three to each diameter-size, each set comprising *taper, intermediate,* and *plug* taps.

The 'Taper' Tap.—The *Taper Tap* (A, Fig. 44) is tapered almost throughout its threaded part, and so that at its extremity it is small enough to enter the blank hole which is to be threaded; the top end of the threaded part being as large as the bolt for which the nut is intended.

The 'Intermediate' Tap.—The *Intermediate Tap* (B, Fig. 44) is tapered at the extremity only, to allow of its ready insertion into the hole; the remainder of its length being parallel.

The 'Plug' Tap.—The *Plug Tap* (C, Fig. 44) is parallel throughout.

Tapping.—To tap, say a nut, a hole is first drilled through it, the diameter of this hole being equal to the diameter of the bolt, less the thread. (Drills are made to what are called 'tapping sizes' for this purpose.) The taper tap is then screwed through the blank hole. This being a 'through' or 'drop-through' hole—that is, a hole which goes right through the metal—the taper tap, only, needs to be used in cutting the thread.

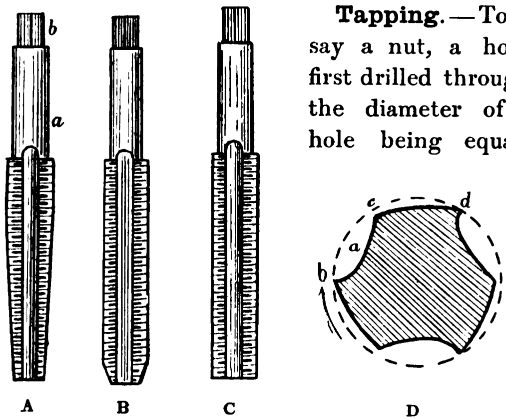
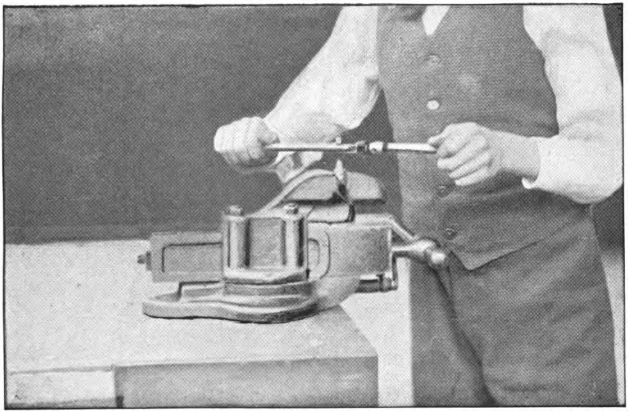
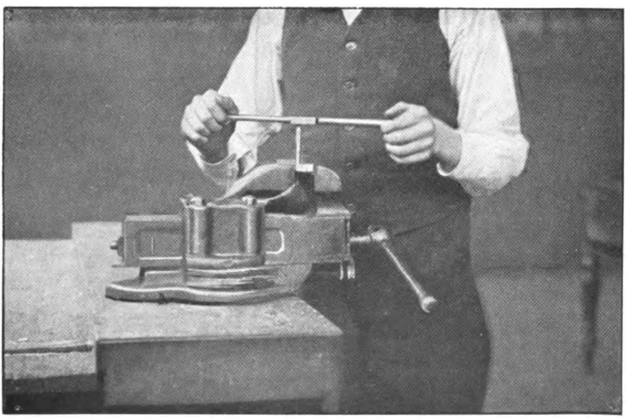


Fig. 44.



Screw-Cutting with Stock-and-Dies.



Tapping.

[To face page 44.

For tapping holes which do not pass right through the metal, the use of the taper tap must be supplemented by that of the intermediate and plug taps, successively.

Considerable force is required to screw the taps through the blank holes, and this is secured by using a *tap wrench* (Fig. 45). A square hole, *a*, in the wrench fits over the square head, *b* (Fig. 44), of the tap, and the wrench then serves as a lever for turning the tap.

It is impossible, the first time of going through the hole, to give a continuous forward movement to the tap, because of the resistance of the material which is being cut. The work has therefore to be 'humoured.' When the tap becomes 'jammed,' it should be turned back a quarter turn or so, and then screwed forward again, this process being repeated as often as may be necessary to cut through the obstruction.

The plain cylindrical part *a* (Fig. 44 A) and the square head, *b*, of the taps are sufficiently small to allow the latter to drop right through the hole, thus avoiding the necessity for winding the taps all the way back again when the whole of the threaded part has passed through.

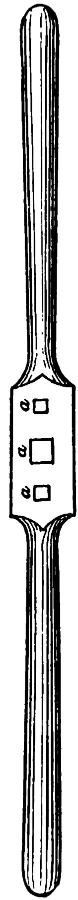


Fig. 45.

The Cutting-edges of Taps.—The

taps are *fluted*, to give cutting-edges to the threads and to allow the cuttings to fall away. Reference to the cross-section of a tap (D, Fig. 44) will explain this. The flutes *a* form, in cross-section, irregular curves, which give a sharper edge at *b* in each case than at *c*. The tap is screwed into the hole in the direction indicated by the arrow, and each thread is filed back as from *d* to *c*; thus the three edges, similar to *b*, of each thread only, constitute the cutting-edges. The dotted circle in the figure gives a comparison between the sectional form of a tap and a true circle.

Table of Whitworth Taps and Tapping Holes:—

Diameter of Tap. Inch.	No. of threads per inch.	Diameter of Tapping Hole. Inch.
$\frac{3}{16}$	24	$\frac{9}{64}$
$\frac{1}{4}$	20	$\frac{3}{16}$
$\frac{3}{8}$	16	$\frac{19}{64}$
$\frac{1}{2}$	12	$\frac{13}{32}$
$\frac{5}{8}$	11	$\frac{33}{64}$
$\frac{3}{4}$	10	$\frac{5}{8}$
$\frac{7}{8}$	9	$\frac{47}{64}$
1	8	$\frac{27}{32}$

THE SIMPLE LATHE

The parts of the Simple Lathe.—Fig. 46 gives the front view of a *simple Treadle-Lathe*. A is *the bed;* B, *the 'fast'* or *mandrel headstock;* C, *the 'loose' headstock* or *poppet head;* D, *the hand* or *tee-rest;* E, *the crank*, on which runs *the driving pulley* F; G, *the belt*, or *gut,* connecting the driving pulley and the mandrel pulley; H, *the treadle;* and J, *an endless chain* or *a hooked rod,* connecting the treadle and the crank;

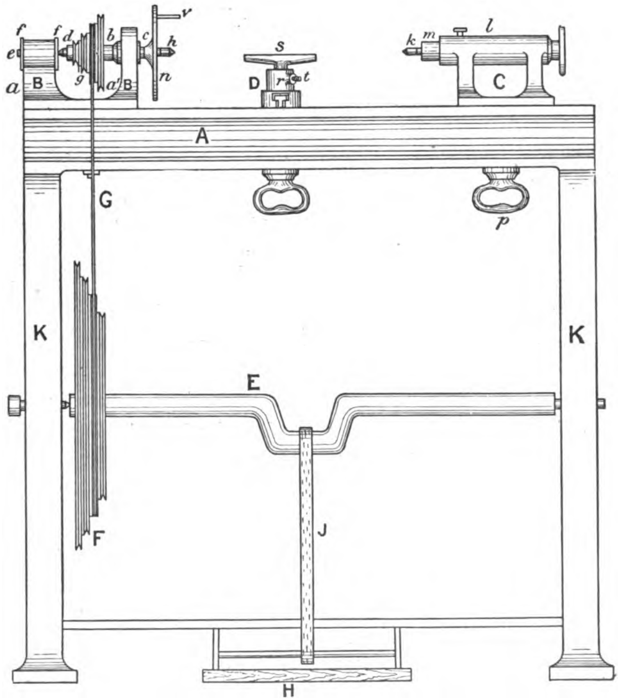


Fig. 46.

K K are *the standards,* or *legs,* supporting the bed; an end view of these would show them to be built, for steadiness, on the principle of the letter A.

The Mandrel Headstock.—The mandrel headstock comprises *two standards, a a′*, a *mandrel* (or *spindle*) *b*, which runs in the standard *a′*, and projects at *c* about a couple of inches towards the poppet head; the other end *d* of the mandrel terminates in a '*centre*,' or pointed cone, the point of which runs in a corresponding small hollow cone in the end of the screw *e*, which runs through the cylindrical top of the standard *a*; *f f* are two shallow circular nuts for tightening up the screw *e* towards the mandrel-centre *d*, when the small hollow cone becomes worn, and the mandrel, therefore, becomes loose and runs unsteadily. In some lathes the mandrel, instead of having a back 'centre,' as at *d*, is continued through both standards, and may be either conical or parallel at the bearings—that is, where it revolves in the standards; in such cases there is a projecting arm on the outside end of the standard *a*, which carries a screwed cylindrical piece in line with the mandrel, which resists the backward thrust of the latter, and is tightened up as necessary by nuts on either side of the arm.

The Mandrel Pulley.—The mandrel carries a stepped speed cone, *g*, called the *mandrel pulley*, which, in the lathe shown in Fig. 46, has four 'speeds,' which are provided with V-shaped rims to receive the driving gut.

The projecting part of the mandrel at *c* is threaded on the outside to receive a *face-plate* or a *chuck*, whichever may be necessary for any work in hand. This projecting portion is also hollow, to receive the 'centre' *h*.

Relation between Mandrel and Driving Pulleys.—Immediately below the mandrel pulley is the *Driving Pulley.* This corresponds to the mandrel pulley as to the number of 'speeds' and the width and form of the rims, but is of much larger diameter; and in the two pulleys the greatest 'speed' on each is opposite the smallest 'speed' on the other.

The greater diameter of the driving pulley over the mandrel pulley is necessary, because the former runs at the same speed as the treadle, and this would not be fast enough for the mandrel pulley, even in the slowest cases at which the work must usually revolve between the centres. The diameter of the 'speeds' of both pulleys must increase or decrease in the same ratio.

Rule for calculating Speed of Mandrel Pulley.—The following is a rule for calculating the speed of the mandrel pulley:—

Let x = *number of revolutions per minute made by driving pulley.*
y = *diameter of driving pulley.*
and z = *diameter of mandrel pulley.*

then $\dfrac{x \times y}{z}$ = *number of revolutions per minute made by mandrel pulley (or number of revolutions made by the work).*

In this formula, where the term 'pulley' is used, an individual 'speed' must obviously be taken.

Reference to the figure will show that the slowest and fastest rates obtainable are from a combination of the right-hand and left-hand 'speeds,' respectively. Further variations in the speed of the work is of course to be obtained by a slower or faster movement of the treadle by the operator.

Balance of the Driving Pulley.—The driving pulley is usually *weighted*—that is, a heavy block of iron is cast on to the inside of its rim over part of its circumference. The pulley is keyed on to the crank in such a relative position that when the pulley is at rest, and the weighted portion is therefore lowest, the bent portion of the crank stands out horizontally, and the treadle rests in the best position for the operator to start the lathe right off, without having to give an impetus to the driving pulley with the hand, and for the work to commence revolving *towards* the operator. Also, this weight gives additional steadiness to the lathe in running.

Lathe 'Centres.'—The 'centre' *h* (Fig. 46), which is of hardened steel, is shown separately in Fig. 47. It is slightly tapered at the end which fits into the mandrel, so as to secure accurate fitting, while the other end terminates in a pointed cone. There is a similar 'centre' at *k* (Fig. 46) in the poppet head. The centre in the mandrel headstock is known as the 'running' or 'live' centre, as it revolves with the mandrel and work. The centre in the poppet head remains still, and is called the 'dead' centre.

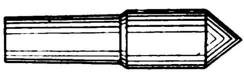


Fig. 47.

The Poppet or Back Headstock.—The sectional view of the *Poppet Head* (Fig. 48) will render plain the action of the screw and 'centre.' *a a* is a hollow cylinder (also shown at *l*, Fig. 46) and *b b* is another hollow cylinder (also shown at *m*, Fig. 46), sliding to and fro within the outer cylinder, and carrying, by the action of the screw *c*, the 'centre' with it.

The action of the screw and inner cylinder is as follows: The screw which forms a continuation of the shaft *d*, has a hand-wheel *e* keyed on to it, by which

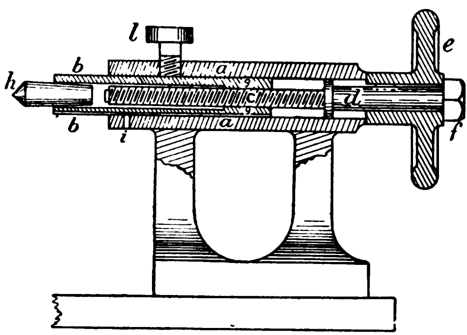


Fig. 48.

it is turned. The shaft and screw are prevented from travelling to and fro by the nut *f*. The inner cylinder is threaded internally at *g g*, and is geared into the screw, the whole length of which it traverses. The screw being stationary, longitudinally, and the screwed cylinder being 'free,' when the former revolves the latter travels along it, sliding in and out of the outer cylinder according to the direction given to the screw by the hand-wheel. A slot running longitudinally along the under side of the inner cylinder, and into which a small set-screw projects through the outer cylinder at *i*, prevents the inner cylinder revolving with the screw; and the inner cylinder (and therefore the 'centre') is fixed at any given position, laterally, by the set-screw *l*.

Connection of Headstocks to Lathe-bed.—The mandrel headstock is firmly screwed to the bed of the lathe, and always remains in the same position over the driving pulley; hence its second name, 'fast' headstock. The poppet or 'loose' headstock is movable over the remainder of the lathe-bed. It is provided with a T-headed bolt, the T of which fits into the base of the headstock, and the lower screwed end of this bolt is provided with a nut to bind the headstock tight down on to the bed after being run into position. The form of nut and handle shown at *p*, Fig. 46, is very convenient, as obviating the loss of time consequent on continually having to use a spanner for screwing up and unscrewing an ordinary hexagonal nut.

The Tee-rest.—The *Tee-rest*, D, Fig. 46, consists of a socket *r*, which is movable along the bed and is gripped in the same manner as the poppet head, and a 'T' piece, or tool-rest, which can be raised or lowered, and turned in the socket at any angle, to suit the work which is being turned; it is then held in position by a set-screw at *t*. Also, by loosening the nut underneath, the socket can be moved to and fro across the bed, to suit the diameter of the work.

Simple Power Lathe.—By displacing the treadle, crank, and driving pulley, and connecting the mandrel pulley by a belt with a driving pulley on shafting driven by power, the treadle lathe becomes a simple power lathe. In that case the mandrel pulley would require to have flat-rimmed steps to receive the belt, instead of the V-shaped rims as shown to receive the gut.

TURNING

Plain Cylindrical Turning. — For a general description of the operation of turning it will be sufficient if the turning of a plain solid cylinder be taken, as this is the most frequently recurring exercise in turned work.

A piece of round metal, slightly longer and of slightly greater diameter than the finished cylinder, should be selected, and the operator should first test it with the straight-edge to see whether it is perfectly true longitudinally. Should it be only slightly out of truth, a few blows with the hand-hammer — the work resting on some flat surface, as an anvil — will straighten it; but if it be much out of truth, it should be struck while resting on *two* bearing surfaces, such as the opened jaws of a vice.

Centreing.—The ends should then be filed square with the long axis, and the 'centres' struck with the centre-punch. A practised hand can strike a centre accurately from judgment alone, but the following method is safer and quicker for the beginner. Chalk the ends, and fix the work perpendicularly in a vice. (The chalking renders the subsequent marking clearer.)

Then, with jenny callipers—set at about the sectional radius of the piece—strike off four arcs, as on Fig. 49, the point of the bent leg of the callipers being held with the finger against the edge of the disc, successively at points *a*, *b*, *c*, and *d* on the figure. The centre of each end can thus easily be determined, and a small conical hole struck in each with the punch; but these holes should be very small at first, in case they prove, when the work is placed between the lathe centres, to be not quite true, and should require altering.

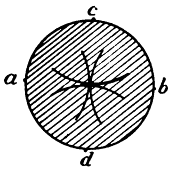


Fig. 49.

Proving the truth of the Centreing.—The work should then be placed between the lathe centres, but so as to run easily, and made to revolve by striking with the hand. The 'T'-rest then being brought into position near to, and parallel to, the work, a piece of chalk held quite still on the rest, and just touching the work, will determine whether the latter is centred truly or not by marking a continuous ring round it as it revolves, if it be true, or by only touching it at isolated places, if it be untrue.

If the centreing be untrue, the isolated chalk marks on the work will show which parts are farthest away from the long axis through the 'centre'-holes, and which require correction by the 'drawing-over' of the latter. The chalk test should be made at different points along the work, say at the middle and towards the two ends, so as to determine whether drawing-over is required at one of the ends or at both.

'Drawing-over.'—In *Drawing-over* the work is again fixed in the vice, and a fresh centre-hole struck within the first one, but towards that side of the work on which are the chalk marks. The new centre-hole should be driven deep enough to obliterate the effect of the original one. After this the work should again be tested between the lathe-centres, with chalk, and if still untrue the centre-holes should be still further corrected. It may be remarked that while the rough material may have been forged or cast slightly irregular, thus making it impossible for the work to run absolutely true between the centres before being turned, yet the greatest possible care should be taken in centreing, as both time and labour are thereby saved in turning, and the work more readily turned concentrically true.

Face-plate and Carriers.—For carrying work round in the lathe which is supported by the lathe-centres at both ends, a *Face-plate* and *Carrier* are generally employed. The face-plate, an edge view of which is seen at *n*, Fig. 46 (and an enlarged edge view of which is shown in Fig. 51), consists of a metal disc which is screwed on to the mandrel, and therefore revolves with it, and has a projecting driving-pin that forces the carrier round.

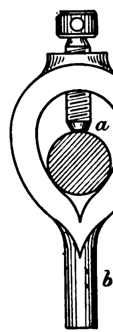


Fig. 50.

The 'Heart'-carrier.—Fig. 50 represents the *'Heart'-carrier*—the carrier most commonly used for cylindrical work—

which consists of a strong circular frame, in which the end of the work is placed and kept securely in position by the set-screw which binds it at *a*. The driving-pin of the face-plate runs up against the tail, *b*, of the carrier. Fig. 51 shows the work and carrier in position on the mandrel-centre. For finished work a small protector of brass should be inserted between the end of the set-screw and the work, to prevent abrasion of the latter.

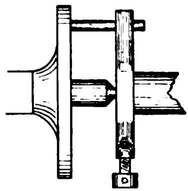


Fig. 51.

The carrier shown in Fig. 52 is used for holding work with angular ends.

Chucks.—Instead of carriers, *Chucks* are sometimes

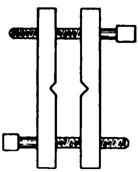


Fig. 52.

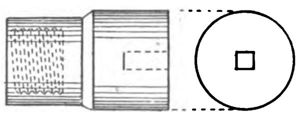
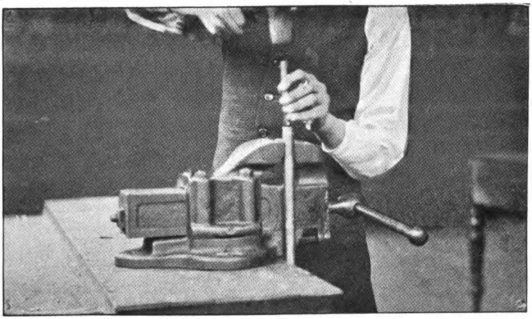
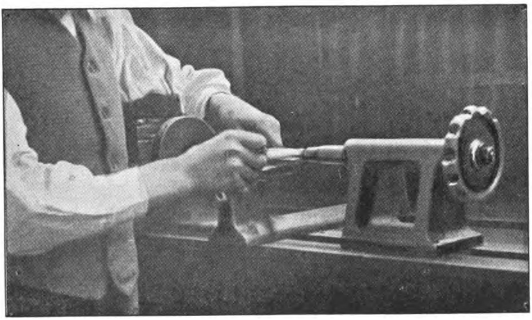


Fig. 53.

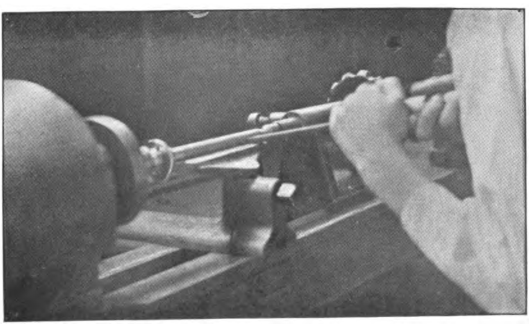
used for holding work in the lathe which is supported at the other end by the poppet 'centre.' Fig. 53 gives a form of chuck which is screwed on to the mandrel, and provided with a square hole in the centre to receive work which has a square tapered end, or on which a square tapered end may be filed for temporary purposes of 'chucking.'



Centreing.



Proving truth of Centreing



Hand-Turning.

[*To face page* 56.

Instead of a square hole this form of chuck is sometimes provided with a round *threaded* hole; the work also being provisionally threaded at one end for insertion in the chuck. This 'screw-hole' chuck gives a very firm grip to the work, and can also be used for work of small diameter and short length which is supported at one end only.

The Four-jaw Chuck.—*The Four-jaw Chuck,* Fig. 54, is used for holding work of considerable substance which can be supported at one end only. It screws on to the headstock mandrel at *a* (taking the place of the face-plate), and the jaws (three of which, marked *b*, appear in the elevation) grip the work, *c*, by closing in on it; they are moved radially, and independently of each other, by a screw-key applied to the nuts, as at *d*. The inner sides of the jaws are arranged in 'steps,' so as to take work of larger or smaller diameter, and they can be taken right out of the body of the chuck, reversed, and inserted with the steps outwards, for the purpose of holding hollow work on the inside. The accurate fixing of the work concentrically in the chuck can be tested with a piece of chalk in the same manner as has already been described in connection with the centreing of a cylindrical piece for turning.

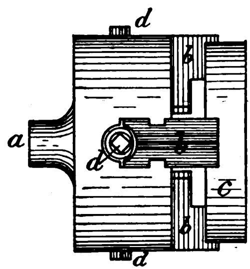


Fig. 54.

The Self-centreing Chuck.—*The Universal* or *Self-centreing Chuck* is similar in form to the four-jaw chuck, but all the jaws move radially together, thus facilitating the ready adjustment of the work.

The 'Bell' Chuck.—Another handy form of chuck which screws on to the mandrel is the *'Bell' Chuck.* This chuck is bell- (or cup-) shaped on the inside where the end of the work is fixed, and has set-screws passing through the rim of the cup to bind the work inserted in it.

Removal of Rough Casing before Turning.—Before commencing to use turning tools upon work, the hard black scales of forgings and the gritty exterior of castings should be removed with an old file while the work is revolving in the lathe.

Annealing Steel before Turning.—Steel requires to be *annealed,* or softened, before being turned (as also before being filed). This is effected by heating the work to redness, and then excluding the air while it is allowed to cool very gradually. A common method, after heating the work to redness, is to place it in the centre of the smithy fire, which is banked up all round, and then left until the whole is cold. The fire can be conveniently used for this at night, when other uses of the fire would not be interfered with, and time would not be lost in waiting for the steel to soften.

Turning Tools.—Figs. 55 give the most common and useful forms of hand-turning tools—viz., *a,* the *three-square tool; b,* the *graver; c,* the *flat tool; d,* the *round-nosed tool;* and *e,* the *parting tool.*

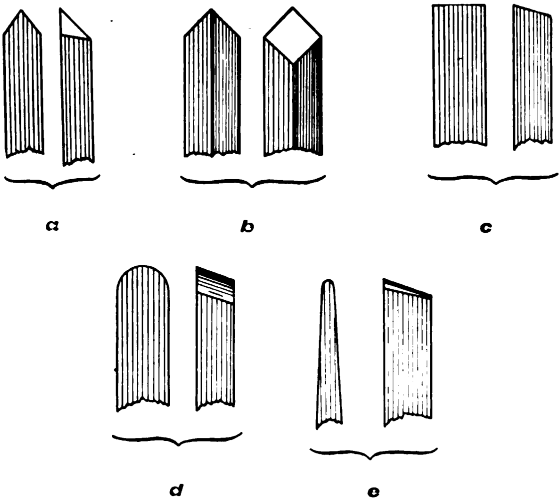


Fig. 55.

The Three-square Tool.—*The Three-square Tool* is used principally for 'roughing-out,' as in *a,* Figs. 56, which gives a plan view of the tool and work. It can also be used for more nearly finished work by using one of the cutting-edges lengthwise, as in *b,* or in 'facing' work at right-angles to the central axis, as in *c* and *d,* which give a plan and side view respectively of the one operation. The dotted arc in the latter figure shows the path of the point of the tool in travelling from the centre to the circumference of the work.

The Graver.—*The Graver*, or *four-square tool*, is used for roughing-out, finishing an outer surface, and for

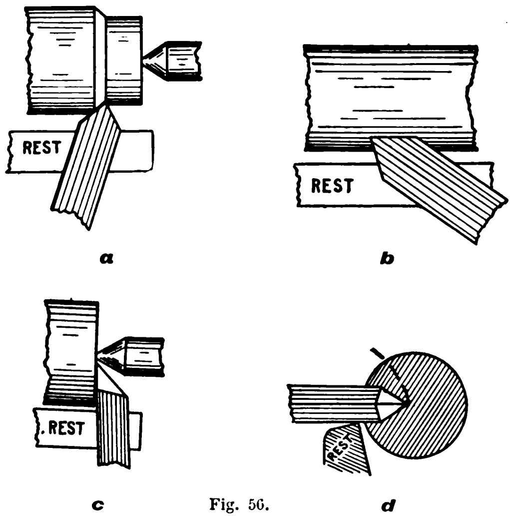
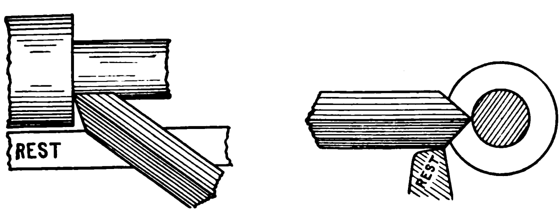


Fig. 56.

'facing.' It is a specially useful tool for finishing an angle, as in Figs. 57, *a* and *b*.



a Fig. 57. *b*

The Flat Tool.—*The Flat Tool,* which has a broad cutting-edge at right-angles to its length, is used for finishing work which has been turned approximately true with the roughing-out tools.

The Round-nosed Tool.—The use of *the Round-nosed Tool* is seen in Fig. 58.

Fig. 58.

The Parting Tool.—*The Parting Tool* is used for making deep, narrow cuts, for the purpose of dividing the work into parts.

All the foregoing tools should be about four inches long in the shaft, with handles of about the size of those of ordinary wood-working chisels or gouges; and it is convenient to have the first four kinds of tools in different sectional sizes, to suit large or small work.

Cutting-angles of Turning Tools.—The cutting-angles of hand-turning tools for metal vary from 60° to 90°, but 80° will be found to be a good general average for working in the various metals.

Sharpening.—The tools are sharpened by grinding, and are generally used straight from the grindstone; but for finishing work they may be 'set' on an oilstone at a slightly larger angle.

Management of the Tee-rest.—In using the turning tools particular attention must be paid to the position of the Tee-rest. If this is too far from the work, the leverage on the tools is so great that they cannot be held steady, and may perhaps be wrenched out of the hands altogether. If the rest is too high, the tool will not enter the work; and if too low, the point of the tool will get under the work and again be wrenched out of the hands, or, if the work be small, it will be lifted and bent, or otherwise thrown out of centre.

The proper position for the rest will vary slightly with different work, or with different tools, and can only be found by trial on each occasion; but with practice the operator, by judgment alone, will usually place the rest in the proper position at once.

Perhaps the only general rule which can be given is to place the rest as close to the work as possible, while allowing the shaft of the tool, clear of the cutting bevel, to lie firmly on it; and sufficiently high to allow the point, or the cutting-edge, of the tool to meet the work just above the axial line of the centres. Also, the rest should in general be parallel to that face of the work which is being turned; and to allow of this, as it has already been remarked, the rest can be turned horizontally in its socket to any angle.

Manner of Holding Turning Tools.—In holding a turning tool, the right hand should grip the handle somewhat in the same manner as was explained in connection with the manner of holding the file, while the fingers of the left hand should bend over the shaft of the tool, pressing it firmly down on to the rest—the right hand keeping the tool up to the work. The tool should not be run evenly along the rest, but that point of the rest upon which the tool lies at any given moment should act as a pivot for the tool to work on, so that a steady curved sweep maybe taken for each cut, and the tool then shifted along the work and rested upon another point on the rest as a fresh pivot for the next cut, and so on.

However carefully a new piece of work may be 'centred,' it probably will not at first run quite concentrically true at its outer surface because of certain inevitable irregularities of that surface; therefore the operator must hold his tool on the rest so firmly that it will not 'follow' the work—that is, will not move backwards and forwards with the inequalities of the work—otherwise the work will not be turned concentrically true. It will be found that until so much material is turned off as to reduce the work to concentric truth, the tool will take a heavier cut at some points of each revolution than at others.

Although the foregoing are general rules governing the position of the rest, the manner of holding the tools, and the contact of the tools with the work, the operator, with increased experience and skilfulness, will find that he must be continually adapting general methods to suit particular work. To be able readily to adapt and improvise methods to suit the circumstances of the moment forms an important part of the skilfulness required in the art of turning.

Testing Dimensions and Parallelism of Turned Work.—To turn work to the proper dimensions, and to maintain its parallelism with the central axis, requires that it should be frequently tested with the callipers. Where much work has to be turned down to the same diameter, it expedites matters to construct a permanent gauge in the form of a rectangular notch cut in the side of a piece of sheet-metal, the length of the notch being equal to the diameter of the finished work, and its depth a little more than half of this.

Speed of Work.—The rate of revolution of the work in metal-turning is much less than for wood-turning, and varies again for different kinds of metals; for instance, brass and gun-metal take a much faster speed than iron or steel. The rate of revolution should vary again according to the diameter of the work, it being clear that the outer surface of work of large diameter travels, for the same rate of revolution of the lathe, faster than the outer surface of work of small diameter.

The following is a table of approximate speeds for the several metals, the diameter of the work being 1 inch:—

	Number of feet per minute.*	Lathe revolutions per minute.
Wrought Iron .	35	133
Cast Iron . .	45	163
Brass . . .	100	382

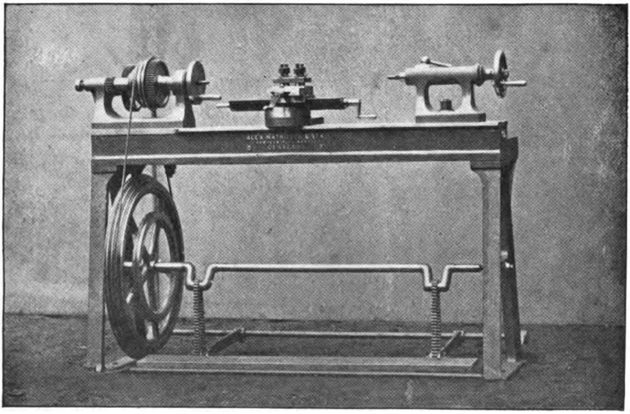
Softened steel may be taken to be about equal to wrought iron.

By 'feet per minute' is meant that any point on the outer surface of the work moves through that distance per minute.

If the work be run too fast there is risk of tearing the metal, of breaking the tool, or of over-heating—and therefore softening—it, and spoiling the temper of the cutting-edge.

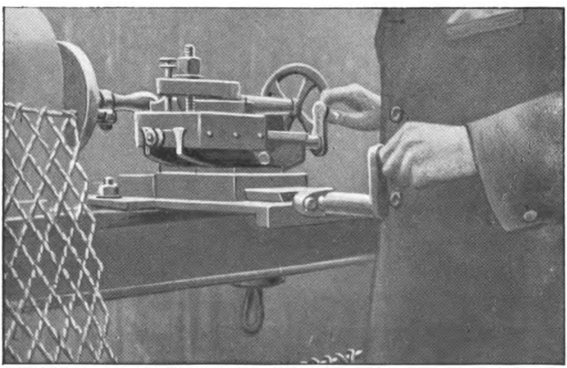
Lubrication.—In order to prevent the work being torn, and to otherwise secure smooth cutting, also to allay the heat resulting from the friction between the work and the tool, constant lubrication is necessary,

* 'Modern Machine Shop Practice.'—J. H. Rose.



Alex. Mathieson & Son, Glasgow.]

Simple Lathe, with Hand-Traversing Slide-Rest.



Double-Handed use of Slide-Rest.

[*To face page* **64.**

particularly in the roughing-out, where the cuts are naturally heaviest.

For wrought iron and steel, *water* is the lubricant; and besides the lubrication of the work, the tool itself should be frequently dipped in water, a small vessel of which should be kept standing near. *Oil*, or *soapy water*, is used with finishing-tools.

Cast iron and brass, in which the turnings break up and crumble away from the tool, are turned dry; that is, without lubrication.

The point of the 'dead' centre should be lubricated with oil occasionally, to prevent it becoming heated, or unduly wearing the centre-hole of the work.

Filing and Polishing Turned Work.—In order to take out the tool marks and to give a fine surface to turned work, it is filed with a smooth file while revolving in the lathe. The file strokes must be steady, and well distributed over the work, to preserve the parallelism of the latter. Also, they should cross and re-cross one another obliquely, to avoid leaving file marks. For the protection of 'collars' on work, the 'safe' edge—that is, the edge without teeth—of the file runs against these. A round file should be used for such curves as appear on the work shown on Fig. 58.

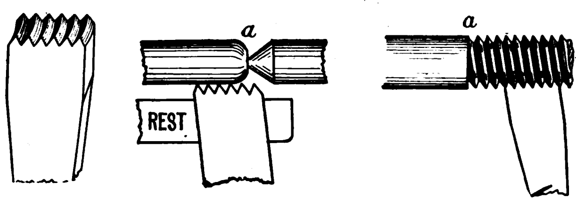
Next, the work should be gone over with a very fine file, the blade having been chalked; and then again with a piece of fine emery cloth, oiled, and stretched over the file. This leaves a very smooth, but somewhat dull, surface; to give a lustrous finish to the work, it may be finally gone over with a dry, well-worn piece of the finest emery cloth.

SCREW-CHASING

The art of *Screw-chasing,* or the *cutting by hand* of threads for screws, is one of the most delicate and interesting of all hand-turning processes.

Outside Chasing.—The Figs. 59 show the *Outside Chaser,* which is seen in contact with the work in B and C, and which is the converse of the screw-thread.

The work to be threaded is first turned to a blank cylinder of the diameter required for the screw, and the edge at the screw end rounded, as at *a* (B, Fig. 59).



A B C

Fig. 59.

Also, a ring is cut with the three-square tool round the blank, at that point where the thread is to terminate, as at *a* (C, Fig. 59).

Lubrication.—It is necessary that the chasing tool should slide along the 'T'-rest without the smallest interruption, and to ensure this the top of the rest should be smooth and slightly oiled. Also oil, or soap and water, should be used as a lubricant between the tool and the work.

Speed Relation of Tool and Work.—The relation in speed between the tool and the work is such that *the tool travels over the width of a thread during one revolution of the work.* If the tool travel either faster or slower than this it will cut a double thread; if the tool be interrupted, to ever so slight a degree, in its regular movement along the blank, the thread will have a sharp turn in it, and will be what is called 'drunken'; and if the tool stand still at any point the result will be, not a screw-thread, but a series of parallel rings round the blank.

Method of Using Chaser.—As can well be imagined there can be no certain calculation, on the part of the operator while at work, of the exact relation between the speed of the tool and of the work as given in the previous paragraph. In practice this is a matter of accurate 'feeling' more than of anything else. The operator should first press the tool lightly against the blank at the rounded end, and take it only a short distance along the blank—going over the same part two or three times, when a slight thread will have been cut sufficiently deep to control the tool. When this is successfully accomplished the most difficult part of the work is done. The operator should then, each time of going over the thread, take the tool a little further along the blank, gradually pressing a little harder, until the whole is threaded; he can then continue to run the tool along the whole thread until it is cut to the proper depth.

Each time the tool reaches the inside end of the thread, it must be promptly removed from the work so as not to damage the unthreaded portion of the blank.

Lessening Diameter of Screw-thread.—Should the diameter of the screw prove to be too large when the thread is complete, the latter may be turned down with the flat tool; sufficient of the thread will probably still be left to guide the chaser in the proper path of the thread for its re-cutting. If any attempt be made to lessen the diameter of the screw by a continuance of chasing, the thread will be damaged by its edges crumbling away under the friction of the tool.

Finishing-off of Thread.—After a thread has been chased to its proper depth and diameter, its edge should be just slightly taken off with a flat tool, and the free end turned slightly taper.

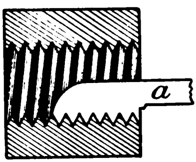


Fig. 60.

Inside Chasing.—In Fig. 60 an *Inside Chaser* is shown in contact with a completed thread.

Table of Screw-threads.—The following is a table of the number of threads per inch for screws of different diameters, and to correspond with which chasing tools are manufactured:—

Diameter of Screw. Inch.	No. of threads per inch.
$\frac{1}{8}$	24
$\frac{1}{4}$	20
$\frac{3}{8}$	16
$\frac{1}{2}$	12
$\frac{5}{8}$	11
$\frac{3}{4}$	10
$\frac{7}{8}$	9
1	8

THE SCREW-CUTTING LATHE

On first acquaintance, the screw-cutting lathe will appear to the beginner to be a somewhat complex machine; but by studying the various parts in the illustrations, in conjunction with observation of the actual machine, it will be found to be far from as difficult to understand as may at first appear.

In lathes by different makers, and sometimes in those by the same maker, differences in details of construction may be observed, even when the lathes are intended to perform exactly similar classes of work; but whatever minor differences there may be, in lathes intended for the same class of work the main features of their construction and operation will be similar.

Parts of the Screw-cutting Lathe.—In describing the screw-cutting lathe those details will be omitted which are similar to, and have already been described in connection with, the simple hand-turning lathe.

Figs. 61 and 62 give front and end views respectively of a *back-geared, slide-rest, screw-cutting, power-lathe,* of which the following are its parts:—

A (Fig. 61), is the *Mandrel headstock, with back-gear* (a plan of this is shown in Fig. 63).

B, the *Slide-rest.*

C, *Change-wheels* (these are shown on Fig. 62, at mandrel wheel *a*, mandrel wheel *b*, stud wheel, leading screw wheel, and U and V. A set of 22 change-wheels are supplied with each lathe, progressing in number of teeth, by fives, from 20 to 120).

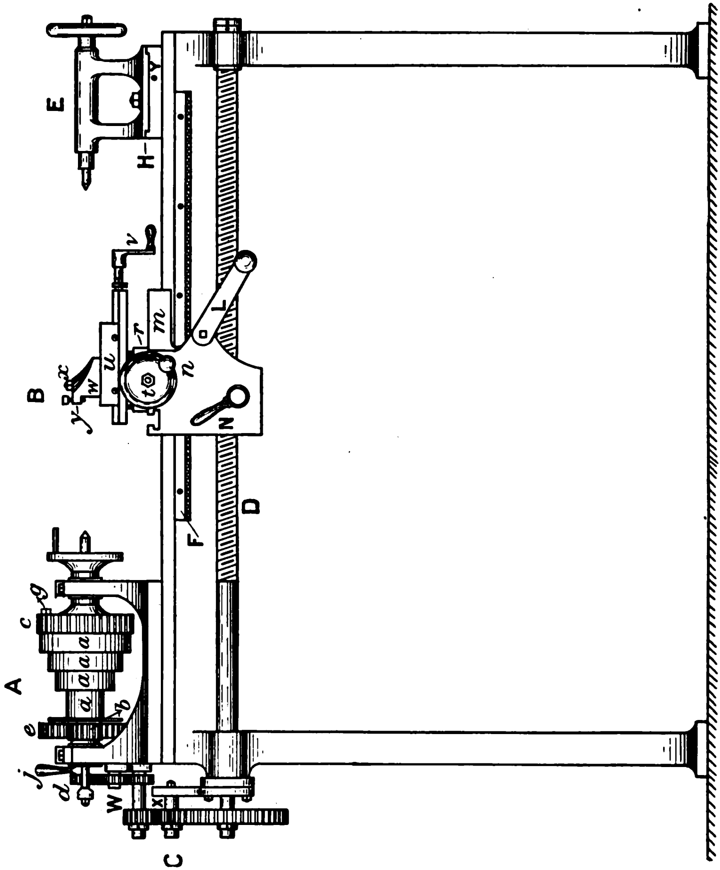


Fig. 61.

D, the *Leading screw.*
E, the *'Loose' headstock.*
F, the *Rack.*

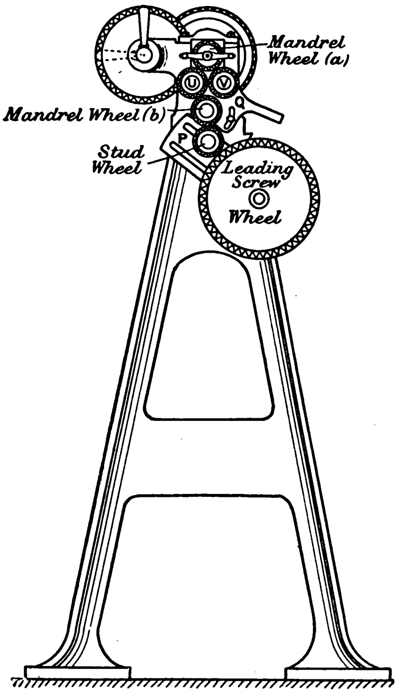


Fig. 62.

P (Fig. 62), the *Quadrant* (having longitudinal slots for carrying a stud; it works on an axis, and can be raised or lowered to suit the sizes of the change-wheels).

Q, the *Small Quadrant* (which adjusts the change-wheels U and V for cutting right- or left-hand screw-threads).

The Mandrel Pulley.—In the mandrel headstock, *a, a, a, a,* Figs. 61 and 63, are the four speeds of the mandrel pulley, to which is attached, so as to run with

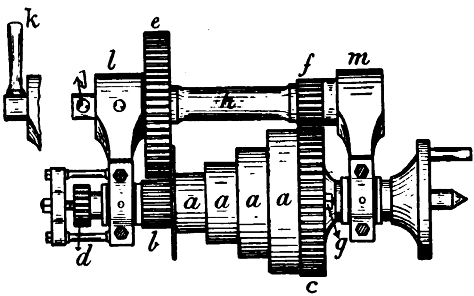


Fig. 63.

it, the small cogwheel or pinion, *b*. Both pinion and pulley are 'loose' on the mandrel—that is, they revolve independently of it.

c, Figs. 61 and 63, is a cogwheel, which is 'fast' on the mandrel, and at the opposite end of the mandrel, outside the standard, is a small cogwheel, *d,* also 'fast' to the mandrel, and which is termed the *mandrel change-wheel.*

Back-gear.—In the same illustrations is a cogwheel similar in size to *c*, but which is immediately behind *b*, and gears into it; and immediately behind *c*, and gearing into it, is another cogwheel, which is similar in size to *b*; (this latter wheel is not seen in Fig. 61, but is shown as *f* in Fig. 63). The gear-wheels *e* and *f*, together with the spindle *h*, inside the sleeve, and to which these wheels are 'fast,' constitute the *back-gear*.

Effect of Use of Back-gear.—For small diameter work, and light cuts with hand-tools, a quick mandrel speed may be employed; but for large work, and heavy cuts (with slide-rest tools), such as for cast iron and steel, the turning effort on the mandrel must be much greater, and therefore slow. This is effected by the back-gear, the action of which is as follows: The revolution of the mandrel pulley (driven by belting), to which the cogwheel *b* is attached, causes *e* to revolve, it being in gear with *b*; and *f*, which is 'fast' on the same spindle as *e*, revolves also. The latter, being in gear with *c*, this wheel is set in motion, causing the mandrel, and consequently the work, to revolve, but at a much reduced speed compared with that of the pulley.

Relative Speeds of Pulley and Work.—The reduction of speed depends upon the relative diameters of the cogwheels. Suppose *b* and *f* to be one-third the diameter of *e* and *c* respectively, *e* will revolve at one-third the rate of *b*; and *f*, which revolves at the same speed as *e*, and is one-third the diameter of *c*, will cause the latter to revolve at one-third the rate of itself (*f*), and *one-ninth* the rate of *b* and the pulley;

consequently the *mandrel* and *work* will also revolve at one-ninth the rate of the pulley.

Throwing Back-gear in and out of Gear.—The engagement and disengagement of the back-gear with the mandrel-gear is effected by an eccentric spindle which passes through the sleeve *h*, and carries the cogwheels *e* and *f*. A view of this spindle is shown in Fig. 64, where it will be seen that it has two axes, AB and CD, the former being the axis of the part *c* and the latter being the axis of the bearing parts *a* and *b*, which run in the bearings *l* and *m* (Fig. 63). The handle *j* (Fig. 63)—which is also shown as *k* in

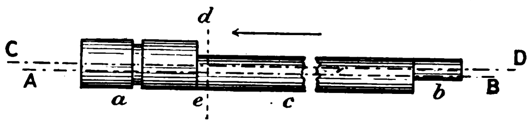


Fig. 64.

the supplementary plan view in the same figure—is attached to the bearing part *a* of the spindle (in Fig. 64 this handle cannot be seen, as in the position in which the spindle is shown the handle is resting horizontally on that side of the spindle which is away from the observer—the spindle itself being in the position it takes when the back-gear is 'out of gear' with the mandrel-gear).

Sectional views through *d e* of this spindle are shown at A and B, Fig. 65. If, from the position A—the 'in gear' position—the handle be moved through a quarter-circle to position B, the point *a* in A is brought to the position *a* in B, which position was previously occupied by the point *b* in A, and the part *c* (Fig. 64) of the spindle, which is shown by cross-hatching in Fig. 65, and which carries the gear-wheels, is thrown backward from the mandrel, and the back-gear consequently thrown 'out of gear' with the front-gear. The reverse action, of course, re-engages the back and front gears.

(Another common method of throwing the back-gear in and out of gear with the mandrel-gear, is for the back-gear to be shifted bodily to one side horizontally, to such a distance as to clear the back-gear cogwheels

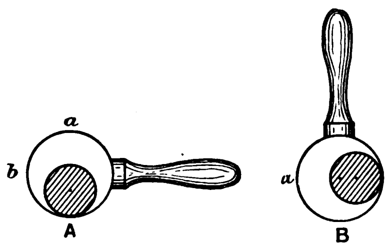


Fig. 65.

from those on the mandrel; a reverse movement brings the two parts into gear again.)

When the back-gear is thrown out, the work stops revolving, although the pulley may continue running.

Adaption of Back-gear Lathe as Simple Lathe.—The back-gear lathe may be used as a simple lathe, by throwing the back-gear out and connecting the pulley to the mandrel cogwheel, so that the whole may run as if 'fast' to the mandrel. At *g* (Figs. 61 and 63) is a nut which is on the end of a T-headed bolt, the T-head of which is inserted in a slot in the largest 'speed' of the pulley, and holds it fast to *c*. The driving of the pulley then drives the mandrel and work direct.

The Slide-rest.—B, Fig. 61, gives a front view of the *Slide-rest*, and Fig. 66 gives an enlarged end view of the same, looking from the direction of the mandrel

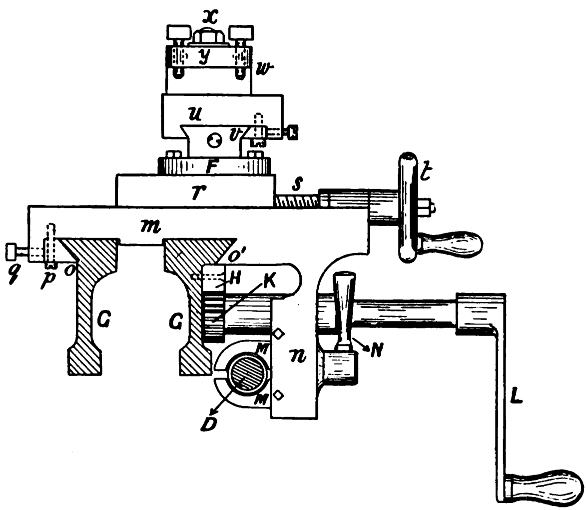
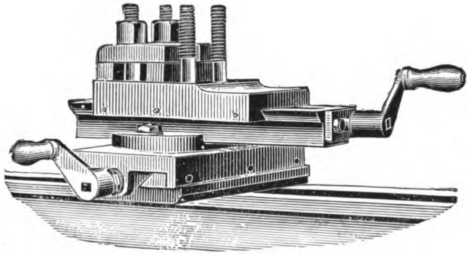


Fig. 66.

headstock. (Where the same reference-letters appear on the two illustrations, different views of the same detail are indicated.) *m* is the *saddle* and *n* the *apron*, these being cast in one solid piece; the saddle is accurately fitted to the lathe-bed (which is shown in



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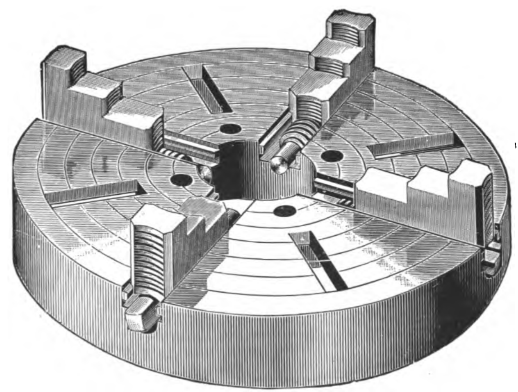
Compound Slide-Rest.



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Four-Jaw Chuck.

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section at G G), there being bevelled parts at *o* and *o*′ to ensure the smooth sliding of the saddle along the bed. At *o* there is an *adjusting strip*, which is held up by screws, *p*, which enter the saddle; the adjusting strip can be adjusted to the bed, as may be necessary after wearing, by the bolts *q* and *p*. *r* is the *bottom slide*, which travels to and fro across the saddle at right-angles to the bed, by the action of the screw *s*, worked from the hand-wheel *t*. *u* is the *top slide*, which is similar in construction to the bottom slide, but which travels to and fro in the direction of the length of the bed, being worked from the handle *v* (seen only on Fig. 61). *w* is the *tool-holder*, which is bolted down to the top slide, and which, therefore, travels with the latter, carrying the tool to and fro in the same direction. As the bottom slide carries all above it, the tool also receives from this its movement across the lathe-bed. Both the top and bottom slides have bevelled adjusting parts (as at *v*, Fig. 66), similar to those for adjusting the saddle to the lathe-bed.

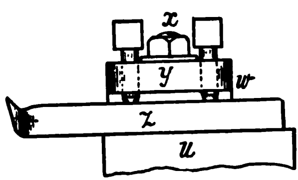


Fig. 67.

The Tool-holder.—A separate view of the *Tool-holder*, with the tool in position, is shown in Fig. 67. Tool-holders may be of various forms, but that in the figure fully illustrates their construction and use. *w* (see also Figs. 61 and 66) is a solid piece of cast iron, bolted down to the top slide *u* by the bolt *x*. This holder is furnished with a projecting piece, *y*, which has bolts passing through it on to the tool, *z*, binding the latter firmly down to the top slide.

Slide-rest Tools.—Figs. 68 show common forms of *Slide-rest Tools*: *a*, right and left hand *'roughing-out' tools*, for taking the first heavy cuts when roughly reducing the work to its approximate form and size; *b*, the *'finishing' tool*; *c*, right and left hand *'knife' tools*, for surfacing work at right angles to the long

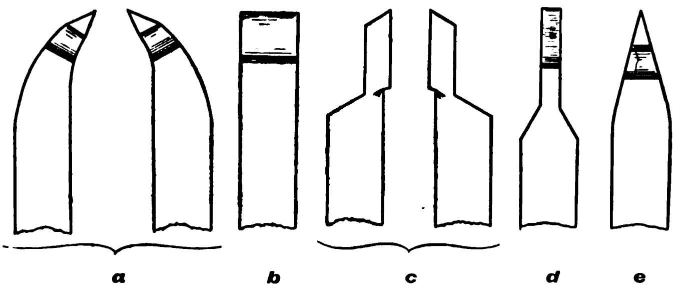


Fig. 68.

axis; *d* is a *'parting' tool*, and *e* an *outside screw-cutting tool.*

For work of even very moderate dimensions, these tools would be made out of inch square steel, and the cutting angles, though varying for different metals, usually exceed 60°.

The Leading Screw.—The slide-rest travels automatically along the bed of the lathe through the action of the *Leading Screw*, the long screw which runs parallel with the lathe-bed, and the revolution of which is effected from the mandrel by means of the train of change-wheel at C, Fig. 61 (and which will be explained a little later).

The motion of the leading screw is transmitted to the slide-rest in the following manner: The leading screw, D, Fig. 61 (a sectional view of which is shown at D, Fig. 66) is fitted with a divided nut, M, Fig. 66 (but covered by the apron of the slide-rest in Fig. 61), and which is shown as being *not* in gear at the moment with the leading screw. This nut is manipulated from the handle N, and throws the slide-rest in and out of gear with the leading screw. When the leading screw is in motion, by engaging the nut with it the slide-rest is carried along the lathe-bed; but by disengaging the nut the movement of the slide-rest is arrested, although the leading screw continues in motion.

Rack and Pinion.—The *Rack and Pinion* are for the purpose of traversing the slide-rest along the lathe-bed, independently of the leading screw.

The Rack, F, Fig. 61 (an end view of which is seen at H, Fig. 66) is a strip of iron which is screwed on to the front of the lathe-bed, and having teeth on its under side, into which a small cogwheel or pinion is geared (K, Fig. 66), and through the action of which, by the manipulation of the handle L, the movement of the slide-rest is effected.

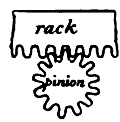


Fig. 69.

Fig. 69 shows the gearing of the rack and pinion.

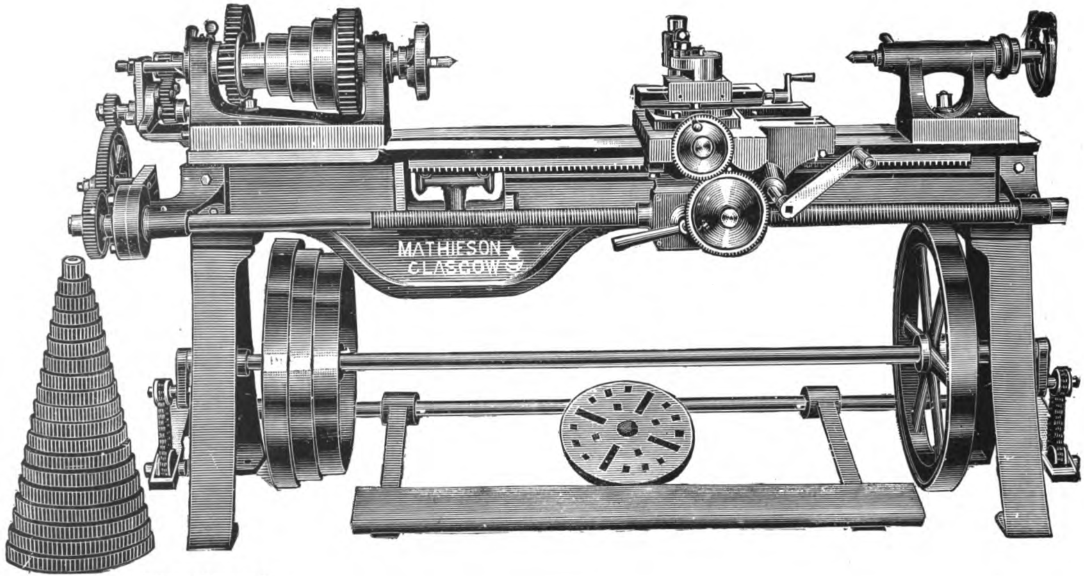
The Use of the Slide-rest.—When using the slide-rest as a self-acting tool the mode of procedure is as follows: Assuming the work to have been placed between the lathe-centres, and that a plain cylinder is about to be turned, the cutting tool is fixed in the tool-holder, as in Fig. 67, and the 'rest' is run by means of the rack and pinion back along to that end of the work which is towards the loose headstock, so as to take the point of the tool just clear, horizontally, of the work. The tool is then adjusted close to the work by means of the top slide, and so as to take a suitable depth of cut, by means of the bottom slide. Then, on engaging the nut with the leading screw, the tool travels at a steady, uniform rate along the work, turning it perfectly parallel, until arrested by the operator disengaging the nut from the leading screw.

If further cuts are required to be taken off the work, to reduce it to a given diameter, the slide-rest is run back to its first position at the 'poppet' end of the work, and the foregoing process repeated.

Hand-traversing Motion. — Sometimes the slide-rest is used with *hand*-traversing motion—that is, without the aid of the leading screw, for turning work

(*a*) Parallel to its longitudinal axis;
(*b*) At right-angles to this axis;
or (*c*) With a curved longitudinal outline.

In the first case—for turning parallel work—the tool is adjusted to the work in the same way as for using the slide-rest as a self-acting tool, but the leading screw nut remains disengaged. (It is then immaterial whether the leading screw be running or not.) If



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Compound Back-Geared, Slide-Rest, Screw-Cutting Lathe.

[To face page 80.

only a very short length of material requires to be turned, the cutting tool can be carried along it by traversing the top slide only. If a length of material longer than the limit of the top slide is to be turned, the tool is carried along the work by steadily running the whole slide-rest along by means of the rack and pinion.

In the second case—to face work at right-angles to the longitudinal axis—after the cutting tool has been adjusted, by means of the top slide, to the face that has to be turned, it is carried in its cut towards the central axis of the work, or away from it, by means of the bottom slide.

In the third case—in turning work with a curved longitudinal outline—both top and bottom slides must be manipulated at the same time, the proper relative movement of each to produce the desired curve being dependent entirely on the judgment and skill of the operator.

In all hand-traversing work with the slide-rest, and especially with very light work, very great care is required in taking the proper depth of cut, and in maintaining a uniform strength of cut throughout. Should the operator, by suddenly increasing the rate of traverse of the tool, exceed the maximum strength of cut which the cutting tool or the lathe will bear, the former is likely to be broken at the point, or the work thrown out of the centres.

SCREW-CUTTING

Relation between Leading Screw and 'Pitch' of Threaded Screw.—In *Screw-cutting*, the working of the lathe, so far as the traverse of the slide-rest is effected by its engagement with the leading screw, is similar to what has already been described in connection with the turning of a plain cylinder; but the cutting of the proper number of threads per inch upon the blank depends upon *the relation between the 'pitch' of the leading screw and the 'pitch' of the screw which is to be cut;* in other words, *upon the relation between the rate of revolution of the leading screw and of the blank.* (By 'pitch of screw' is meant the number of threads per inch, or the distance between the bottom of the V of one thread and of the next.)

Use of Change-wheels.—Suppose it is required to cut a screw with twelve threads to the inch, the pitch of the leading screw being four threads to the inch. Then the blank must make twelve revolutions, while the leading screw makes four, and the operator must know what change-wheels to use to secure these relative rates of revolution.

But before selecting the change-wheels which are necessary for cutting a screw of any desired pitch, he should understand—

First, how the change-wheels transmit the motion from the mandrel to the leading screw; and

Secondly, by what arrangement of change-wheels the leading screw is made to revolve *with* the mandrel, or *against* it, so that a right- or a left-hand thread may be cut.

Transmission of Motion from Change-wheels to Leading Screw.—First, as to how the change-wheels transmit the motion from the mandrel to the leading screw.

Fig. 70 shows a simple train of three change-wheels —the *mandrel wheel*, the *stud wheel*, and the *leading screw wheel*. The mandrel wheel is keyed on to the head-stock mandrel, and revolves with it; the leading screw wheel is keyed on to the leading screw, and drives it; the stud wheel revolves free about a stud bolted into the quadrant, P, Fig. 62 (and which is shown at X, Fig. 61), and is for the purpose of giving the proper direction to the revolution of the leading screw wheel. In Fig. 70 the arrow-heads indicate the directions in which the change-wheels are revolving, and it will be seen that the interposition of the stud wheel between the mandrel wheel and the leading screw wheel causes these two to revolve in the same direction.

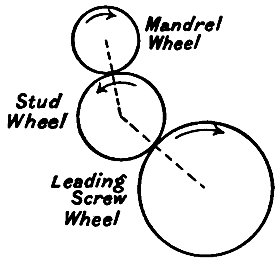


Fig. 70.

Use of Quadrant.—Reference to Fig. 62 will explain the use of the quadrant in enabling the stud wheel to gear into the two adjacent wheels. The quadrant is provided with slots, into either of which the stud can be bolted, and revolves free about the leading screw, so that it can be raised or lowered as may be necessary. These combined facilities for adjustment allow of varying sizes of stud wheels being geared in between the mandrel wheel and leading screw wheel.

Arrangement of Change-wheels for Cutting Right- or Left-hand Screw-threads.—Secondly, as to what arrangement of change-wheels causes the leading screw to revolve *with* the mandrel, or in an opposite direction.

This is illustrated in Fig. 71 (A and B), which are reproductions of the train of change-wheels shown in Fig. 62. In this train there is a second mandrel wheel —mandrel wheel (*b*) — keyed on to a supplementary

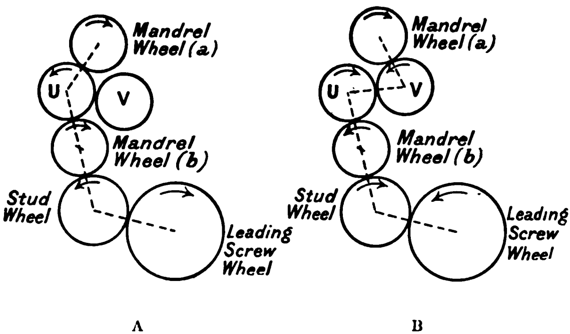


Fig. 71.

mandrel (seen at W, Fig. 61), and which is of the same size, and revolves at the same rate, as the mandrel wheel (*a*). The mandrel wheel (*b*), the stud wheel, and the leading screw wheel, form a simple train, similar to that shown in Fig. 70; and geared into this there is a combination formed by mandrel wheel (*a*) and wheel U, or mandrel wheel (*b*) and wheel V, which is a provision for giving reverse motions to the leading screw.

The combinations of wheels, from mandrel wheel (*a*) to mandrel wheel (*b*), operates as follows: The wheels U and V run on studs fixed in the small quadrant (see Q, Fig. 62), which can be adjusted so as to bring U into gear with mandrel wheels (*a*) and (*b*), as in A, Fig. 71 (when V runs free by the side of U), or bring V into gear with mandrel wheel (*a*) and with U, and the latter also into gear with mandrel wheel (*b*), as in B, Fig. 71.

The effects of these two gearing arrangements are:—

In the first case—that of A, Fig. 71—the movement of mandrel wheel (*a*) being transmitted to the leading screw wheel through the wheels connected by the dotted lines, and these wheels revolving severally in the directions indicated by the arrow-heads, the leading screw revolves in the same direction as the headstock mandrel—that is, in the same direction as the blank.

In the second case—that of B, Fig. 71—the direction of the dotted lines and of the arrow-heads will show the leading screw to revolve in an opposite direction to the headstock mandrel.

In the first case a right-handed thread will be cut upon the blank, and in the second case a left-handed thread.

Selection of Change-wheels for Screw Cutting.—The student, having learned how to arrange the change-wheels for cutting a right-hand and left-hand thread respectively, needs next to learn *how to select change-wheels for cutting a thread of any desired pitch.*

Each pair of change-wheels in gear with one another consists of a 'driver' and a 'follower,' and the latter runs faster or slower than the former, according to whether it has fewer teeth or more, and *the relative rate of revolution of the two is in direct proportion to the number of teeth on each.* For example, in Fig. 72, the 'driver' having 20 teeth and the 'follower' 60, the latter will run only one-third as fast as the former. Similarly, if the positions were reversed as to number of teeth, the 'follower' wheel would run three times as fast as the 'driver.' (If both wheels had the same number of teeth they would of course run at an equal rate.)

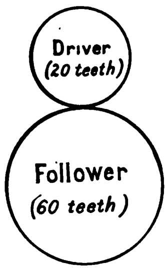


Fig. 72.

It has already been remarked that the cutting of a screw to any given pitch depends upon the rate of revolution of the work, compared with that of the leading screws. The relative rate of these depends upon the relative size, as to number of teeth, of the change-wheels on the mandrel (driver) and the leading screw (follower); in other words—

$$\frac{\text{Driver}}{\text{Follower}} = \text{Value of train.}$$

From this we get the formula—

$$\frac{\text{Pitch of leading screw}}{\text{Pitch of required screw}} = \frac{\text{Driver}}{\text{Follower}}$$

To take an example, suppose

Pitch of leading screw $= 4$

and „ required „ $= 12$

and that

the mandrel change-wheel has 20 teeth.

Then
$$\frac{4}{12} = \frac{20}{\text{Follower}}$$

that is, the leading screw change-wheel (follower) must have 60 teeth.

It will be seen, from Fig. 70, that the leading screw wheel is not engaged directly with the mandrel wheel, on account of the interposition of the stud wheel for the purpose of giving direction to the motion of the leading screw wheel. *Any* wheel of convenient size for gearing into the other two may be used on the stud, for the relative rate of revolution of the mandrel and leading screw wheels will not thereby be affected.

Compound Arrangement of Change-wheels. — Sometimes it happens that the proper rate of revolution cannot be given to the leading screw through a direct train of wheels, as shown in Fig. 70, and *two* stud wheels have to be used as in Fig. 73. Suppose it is required to run the leading screw at one-

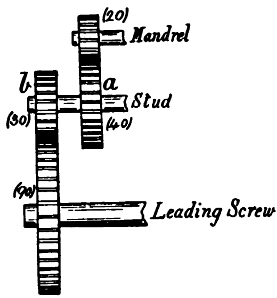


Fig. 73.

sixth the rate of the mandrel, and that these relative speeds cannot, for some reason or other, be secured by the direct train of wheels—viz., mandrel wheel—20 teeth, and leading screw wheel—120 teeth, with stud wheel at any convenient size for gearing. In such a case a compound arrangement could be made, as follows: Mandrel wheel—20 teeth (Fig. 73), geared into stud wheel *a*—40 teeth, which would give a rate of revolution to this wheel of half that of the mandrel wheel; another wheel, *b*—30 teeth, on the stud, would revolve at the same rate as the stud wheel *a*—that is, at one-half the rate of the mandrel wheel—and, being geared into the leading screw wheel—90 teeth, the latter would revolve at one-third the rate of the stud wheel *b*, and, consequently, at *one-sixth* the rate, as was required, of the mandrel wheel.

Recommencing Thread of Screw.—In cutting the thread of a screw, the work may be required to be gone over several times, a slightly deeper cut being taken each time; and the recommencement of the thread will probably present some degree of difficulty to the beginner.

In describing this feature of screw-cutting, screws may for the purpose be conveniently classed as:—

(1) Those in which the pitch of the thread to be cut is exactly divisible by the pitch of the leading screw; for instance:

When the pitch of the screw to be cut = 12,
and the pitch of the leading screw = 4;

and (2) Those in which the pitch of the thread to be cut leaves a remainder when divided by the pitch of the leading screw; for instance:

When the pitch of the screw to be cut = 10,
and the pitch of the leading screw = 4.

In the first case, on recommencing the thread, the slide-rest has simply to be run back to the beginning of the work, when, on being geared into the leading screw, the tool will travel exactly in the path of the thread.

In the second case—where the pitch of the leading screw, divided into the pitch of the screw to be cut, *leaves a remainder*—the exact positions which the large 'fast' cogwheel on the pulley mandrel and the leading screw wheel are in at the moment the slide-rest gears with the leading screw must be noted; and at each recommencement of the thread, *the slide-rest must be geared into the leading screw exactly when these two wheels are in the same relative positions.*

The manner of operation is as follows: After the work and tool are in position for the commencing the thread, the lathe should be slowly revolved (by forcing the mandrel pulley round by hand, at the same time pressing the divided nut down on to the leading screw, ready for gearing) until the slide-rest gears with the leading screw. Then a chalk-mark placed, say, at the top edge of the 'fast' mandrel cogwheel, and another at a corresponding point on the leading screw wheel (as viewed from the operator's position at the slide-rest), will serve to show the relative positions these two wheels must be in at each recommencement of the thread.

On recommencing the thread the tool must be run back to beyond the end of the work, and these two wheels watched until both chalk-marks appear at the top of the revolution together, when the divided nut must be immediately shut down; then the cutting of the thread will proceed regularly. Should the slide-rest be geared with the leading screw at any other moment than when the chalk-marks coincide, the tool will spoil the work by cutting a double thread.

Comparison of Screw-cutting with Plain Turning.—Plain turning with the slide-rest (when self-acting) is really a simple form of screw-cutting, except that the threads are so close to one another as to constitute a practically plain surface. In arranging the change-wheels, a very small one is used on the mandrel and a very large one on the leading screw, so that the revolution of the leading screw (or, in other words, the lateral movement of the tool) is at the slowest possible rate compared with the revolution of the work.

Taper Turning.—An additional operation which may be performed with screw-cutting lathes is that of *Taper Turning*. The lathe shown in Fig. 61 is fitted with double convenience for turning taper—

(1) By causing the tool to travel obliquely along the work; and,

(2) By setting the work obliquely to the long axis of the lathe 'centres,'—the tool travelling parallel to this axis, as usual.

In the first case, the slide-rest is fitted with a graduated disc (seen at F, Fig. 66), on which the top slide swivels. By setting the top slide at an angle from its normal position equal to the amount of taper required, the tool travels sufficiently obliquely to the long axis of the work, and so turns the latter to this degree taper. This is for hand-turning only.

In the second case, the loose headstock, E, Fig. 61, is jointed at H. By loosening the holding-down bolt, and turning the screw Y, the top part of this headstock (and therefore the back centre with it) can be shifted forwards across the lathe-bed, after which the holding-down bolt is tightened up again to hold the headstock in its new position. Then, suppose a piece of cylindrical stuff to be turned taper, as in Fig. 74; by shifting the back centre forwards across the lathe-bed to a distance equal to half the difference between the diameters *a* and *b*, the unturned cylinder will rest

Fig. 74.

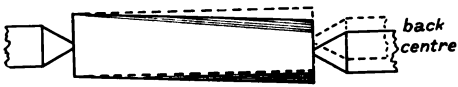


Fig. 75.

between the centres, in the position shown by the solid lines in Fig. 75, which gives a plan of the work and centres. The original position of the work and back-centre is shown by the dotted lines. The shaded portion is turned off all round the work by the tool travelling parallel to the centres' original axis.

FORGING

Forging is the shaping of iron, or the joining of separate pieces together, under the influence of heat.

In this department of working in metal there are few set rules for the guidance of the worker, but such rules as there are, are of almost unlimited application, depending upon the nature of the work in hand and the judgment of the worker. In this section it is proposed to enumerate the general apparatus and indicate the common operations only.

Hearths.—Fig. 76 shows a portable smith's hearth. A is the hearth, and B is a compartment, usually kept filled with water, for the reception and cooling of fire-irons and tongs. The bellows, which are fixed to the framework of the stand underneath the hearth, are worked from the handle C, while the blast of air passes through the pipe D and plays on the fire from the *tue-iron* or *tuyere*, E. A water-tank is often fitted at the back of the hearth against the tue-iron, around which the water circulates and prevents it from burning.

In the case of large hearths, necessitating very strong blasts, the bellows would be much larger, and would stand separate from the hearth; or, where engine-power is available, the blast might be produced by a revolving fan and conveyed through a

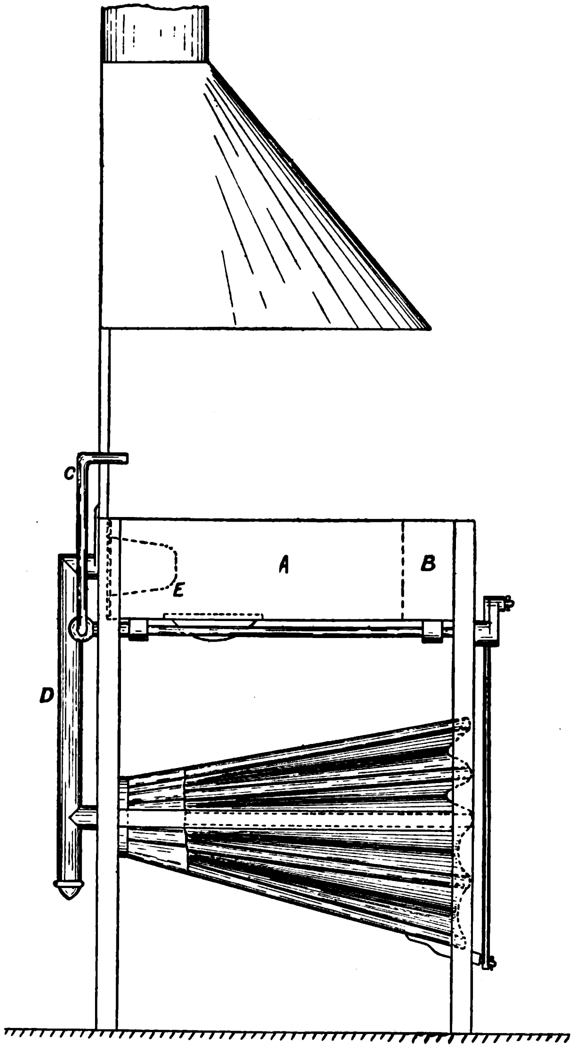


Fig. 76.

blast-pipe, having a branch to each of several fires, with facility for turning the blast on and off at each fire independently.

Fire Irons.—A, B, and C, Fig. 77, show the smith's fire irons—the *poker, slice* or *shovel*, and *rake*.

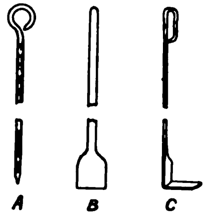
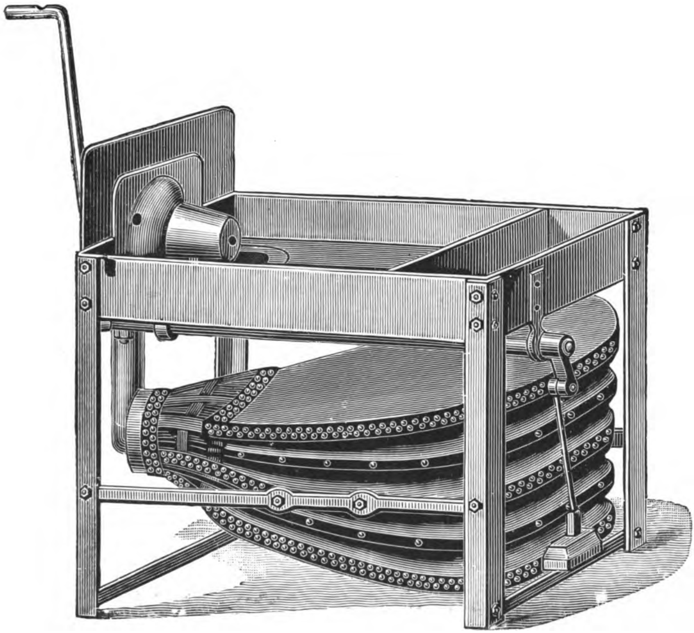


Fig. 77.

The Fire.—In starting a fire, turn the dead cinders back with the slice from the front of the tue-iron, and throw out the spent ashes, or 'dirt,' underneath; then place a handful of lighted shavings in front of the tue-iron, and blow them up until the flame is spent, and cover the glowing embers with small coal or coke, or a mixture of the two, still continuing the blast. At first there will be a dense volume of white smoke, followed by the bursting forth of a bright flame. The fire is then ready for use.

'Dirt' and Clinkers.—During working it will be found that the fire will now and then require 'cleaning.' 'Dirt' will accumulate in front of the tue-iron, and which, if not removed, will cling to the metal which is being heated; so the fire will require to be turned back and the dirt thrown out. Also, *clinkers*—fused masses.of fuel—will sometimes obstruct the blast, and will also require to be removed.

The Anvil.—Fig. 78 shows an Anvil, with cast-iron stand. A is the *anvil face*, and B the *beak-iron* or *horn*. The face is steel-cased, and is very slightly curved across its breadth; this allows that part of the work



Alex. Mathieson & Son, Glasgow.]

Smith's Hearth.

[*To face page* 94.

which is being struck with the hammer to rest plane upon the anvil.

Generally, the face of the anvil is used for plane work, the edges for angles, and the beak-iron for curved work; but this indicates only very generally the uses of the different parts of the anvil. For instance—as the worker will soon find in actual practice—there are forms of curved work which can

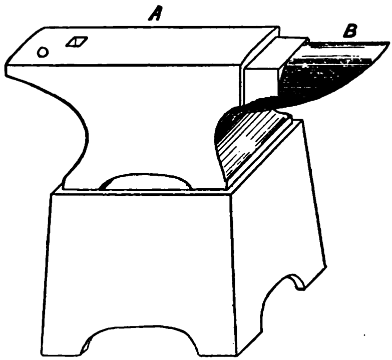


Fig. 78.

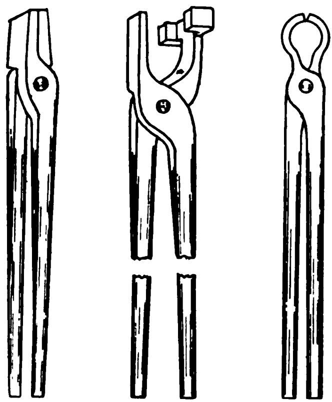
more readily be done on the face of the anvil than on the beak-iron.

Tongs.—Where a considerable length of iron bar is being used, it may serve of itself as a handle for holding the work, but for short work tongs are required.

The *Flat Tongs*, A, Fig. 79, are suitable for grasping small rectangular work. Tongs of somewhat similar general form, but grooved lengthwise on the inside of each lip, are for holding cylindrical work. At B, Fig.

79, are shown tongs for holding larger rectangular work; there are tangs on one of the lips which prevent the work slipping out sideways. C, Fig. 79, shows *Pincer Tongs*.

There are other forms of tongs for grasping different forms of work, but those mentioned above are most generally used.



A B C

Fig. 79.

After the work is grasped with the tongs, an iron ring, called a *collar*, is slid over the handles to hold the work tight and relieve the hand from the strain of gripping the tongs, which should be held lightly, and be easily balanced; then the work rests evenly on the anvil, and jarring from the impact of the hammer is avoided.

The Hand-hammer.—Fig. 80 shows the usual form of *Hand* (or *Pane*) hammer, which should be of about 2 lb. weight, and is used for light, single-handed work.

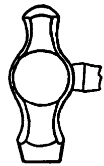


Fig. 80.

The Sledge Hammer.—The *Sledge Hammer*, Fig. 81, is of from 7 to 12 lb. weight, according to the strength of the user and the nature of the work to be done. It is wielded by an assistant to the smith, and who is called the *striker*, and is used when blows from the hand-hammer would not be sufficiently powerful, or would not accomplish sufficient work while the 'heat' lasts. The striker is directed where to strike, by the smith giving a slight tap with his hand-hammer on the work, just where he wishes the blow to fall; and by letting his hammer rattle on the anvil, he indicates to the striker to cease striking.

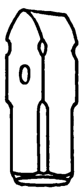
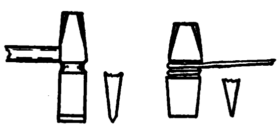


Fig. 81.

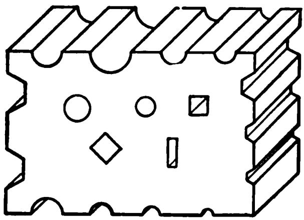
Sets.—Fig. 82, A and B, show a *Hot Set* and a *Cold Set*, respectively. The former is used for cutting off pieces from heated iron, and the latter from cold iron. A nick, deeper for hot than for cold metal, cut on opposite sides of the bar of iron, is usually sufficient to start a fracture, and the piece can then be broken off by striking it with the hammer while held over the edge of the anvil. The sets are held in position by the



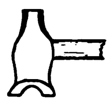
A Fig. 82. B

smith, and struck with the sledge hammer. The hot set has a wooden handle, while the cold set has a handle formed by a green withe, or a piece of rod iron of small diameter twisted about its neck, and projecting sufficiently to form a handle, in order to minimise the jar caused by the greater resistance of the cold iron.

Another and very handy form of set, called a *Hardie* (a corruption of 'hard-edge'), which is used for cutting small iron, is a chisel with a square tang which



A



B

Fig. 83.

fits into a corresponding hole in the anvil, leaving the cutting edge standing uppermost. The metal to be cut is laid across the hardie and struck with a hammer.

Whilst by far the greater proportion of forging is accomplished with the hammer and anvil alone, the smith is assisted in producing certain forms by tools of corresponding forms, among which are *Swages, Top* and *Bottom Fullers, Set Hammers* and *Flattening Hammers.*

The Swage Block.—The *Swage Block,* Fig. 83, A, is a cast-iron block with grooves of various forms and sizes running across its edges. In forging, say, a cylindrical or hexagonal shape, the smith would roughly shape them on the anvil, and then finish them in the corresponding grooves in the swage block.

The *Top Swage*, Fig. 83, B, is used, in conjunction with the swage block, for finishing off cylindrical work.

Set Hammers.—*Set Hammers*, Fig. 84, are used for 'drawing down,' or reducing, metal, or for setting work down to form a shoulder. The square-edged 'set' is used for producing sharp angles at the shoulder, and the round-edged one for less precise work.

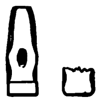
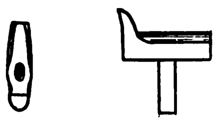


Fig. 84.

Fullers.—*Top* and *Bottom Fullers*, Figs. 85, A and B respectively, are for setting hollows in the upper or under side of work. The bottom fuller sits in the square hole in the anvil.



A B

Fig. 85.

The Flattening Hammer.—The *Flattening Hammer*, Fig. 86, is used for finishing off plane surfaces after they have been roughly shaped with the hand or sledge hammer.

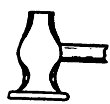


Fig. 86.

All the foregoing tools, with the exception of the swage block and bottom fuller, are held on the work and struck with the sledge hammer.

Primary Operations in Forging.—Primary operations in forging are—

Drawing-down: or reducing the sectional dimensions of the metal.

Upsetting (or *jumping up*): thickening the metal.

Welding: the joining together of two pieces of metal as one.

There may be unlimited varieties of shaping in accordance with the requirements of particular works in forging, but the foregoing operations are ever-recurring, and stand in somewhat similar relation to smith's work that, say, 'trueing up' does to woodworking; and when the student has mastered these, he will at the same time have learned how to manage his fire, and the value of different 'heats,' and will have acquired considerable skill in using the hammer and in the working of iron on the anvil.

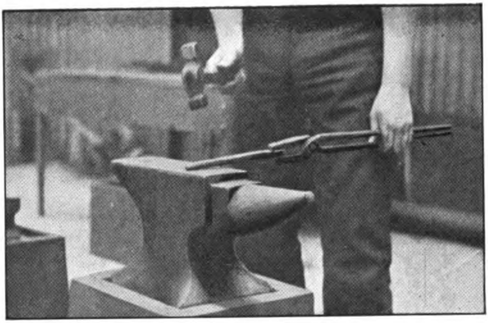
Heats.—The different stages of heat are known as follows:—

Low Red Heat: when the iron just shows red in ordinary daylight, and has dark scales, the result of oxidation.

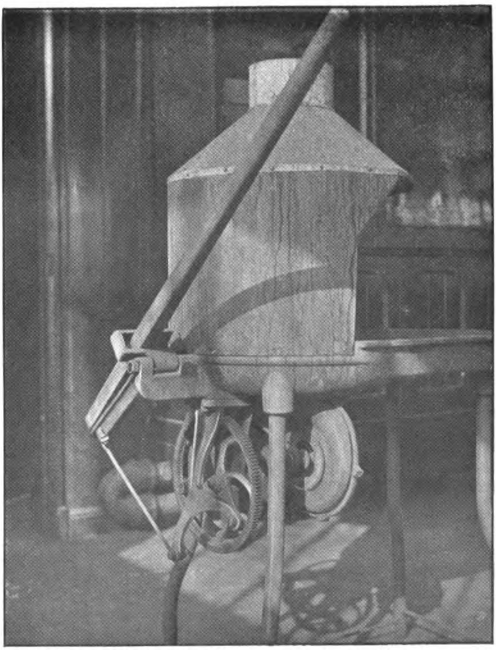
Bright Red Heat: when the iron is sufficiently red to give the scales on the outside a light greyish appearance.

White Heat: the stage immediately preceding welding heat, and when the iron has an almost completely white appearance.

Welding Heat: when the iron commences to lose its cohesion, and is assuming the fluid state. This is shown by the emission of bluish-white sparks.



Forging.



The 'Sturtevant' Hearth (with hood attachment).

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For merely shaping operations the white heat is that most usually used; but for finishing off—*i.e.*, to give a smooth, clean surface to the work—the bright red, or even low red, heat should be used. These latter heats should not be used while the iron is subject to heavy working—*i.e.* hammering—or it may split under the force of the blows.

If iron is left in the fire after the welding heat is reached, it will lose its cohesion altogether and crumble away; it is then said 'to burn.'

Drawing-down.—*Drawing-down* may be either the reducing of the material in section, but retaining the same sectional form, or to 'parallel' taper, 'spread' taper, or square or conical pointed form.

'**Upsetting,**' or **Jumping Up.**—When the end of a rod of iron is to be *upset*, or thickened at the end, a heat is taken, and the rod is then 'jumped,' or struck, at the heated end perpendicularly on the anvil; or it is held across the anvil and struck on the end with the hammer.

When the upsetting is to be other than at the end of the rod, on withdrawal of the rod from the fire the parts contiguous to the part to be thickened are cooled out in water to harden them, so that the force of the blows may take effect only on the part desired; the manner of striking is then the same as for upsetting at the end.

Welding.—In welding, a clean clear fire is of the first importance; and the student must, by practice, learn to judge exactly when the iron is at welding heat, and on drawing it from the fire be able to act with promptness and certainty, or his heat will be lost before he is able to complete the weld with the hammer and anvil.

In single-handed welding, as in the forging of a link, Fig. 87, the parts to be welded should, after the scarf has been brought closely in contact, be placed in the centre of the fire. (By 'centre of the fire' is meant the hottest part of the fire, the exact location of which may vary according to the direction of the blast.) When the iron is seen to be approaching welding heat, the top of the fire should be gently lifted to permit of more minute inspection of the 'heat,' or the iron may be gently withdrawn to be examined, and then replaced, meanwhile the blast being continued.

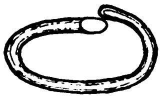

Fig. 87.

Burning.—The continuance of the blast during the withdrawal of the iron for inspection is important, as if the blast be discontinued and the fire allowed to cool ever so little, the iron will 'burn' on being replaced in the fire. (The student might experiment on this by first withdrawing the iron at welding heat, when he will see that white or bluish-white sparks are thrown off silently; on replacing the iron in the fire, after discontinuing the blast for a few moments, and blowing the fire up again, he will find, on again withdrawing the iron, that the sparks are red, and are thrown off with a fizzing sound. The iron is then burning, and is of no use for welding.)

Flux.—Just before welding heat is reached, a little fine sand should be sprinkled on the ends to be welded, or these dipped into it. The sand will fuse and spread as a thin glassy film over the iron, protecting it from the chemicals (chiefly sulphur) which may be given off from the fuel and prevent the parts from welding. At the moment that welding heat has been reached, the iron should be withdrawn from the fire, struck smartly over the anvil to throw off any scale, and then hammered to complete the weld.

Double-handed Welding.—In double-handed welding—that is, when two separate pieces are to be welded, as in Fig. 88—the smith will require an assistant to handle one of the pieces when they are finally with-

Fig. 88.

drawn from the fire. The two ends to be joined should first be heated and 'upset,' tapered off to form a scarf joint, and roughly notched to prevent them from slipping away from one another when they are laid together for hammering the weld. The 'upsetting' is for providing additional material for the inevitable waste and reduction in welding, and for the trimming up of the joint afterwards.

While the two pieces are being brought to welding heat they should be carefully watched, and their positions in the fire adjusted, to ensure that both reach welding heat at the same moment. On their reaching welding heat, they are drawn from the fire together (each worker taking a piece), the scale knocked off, and then laid together as they are to join. If the pieces have been properly heated they will bind immediately on touching one another, and the smith will simply require to hammer the weld firmly together all round, and trim the joint.

ANNEALING, HARDENING, TEMPERING

Annealing.—It often happens that metals, particularly steel, require to be softened, or *annealed,* before being worked upon with edge-tools or the file. Also, the brittleness produced by hammering, excessive vibration, strain, or sudden cooling may require to be removed. This is effected by heating the metal to redness, and then cooling it slowly. Where much annealing is required, the usual method is to heat the metal in a closed oven, with powdered charcoal, so as to exclude the air, and then allow the whole to remain until cool.

The use of the open fire is unsuitable, as, in the case of steel, the carbon of the steel unites with the oxygen of the air, thus reducing the quality of the steel; but, in the absence of better facility, the smithy fire may be made use of by, after heating the metal to redness, placing the latter in the centre of the fire, banking it up all round, and then leaving the whole to cool. The fire can be conveniently used for this purpose at night, when its other uses would not be interfered with.

Hardening.—If pure iron be heated to redness, and then cooled, it becomes softened. The rate of cooling matters very little, for if it be suddenly immersed in cold water the effect is still the same. But the presence of a small amount of carbon—anything from 0·2 per cent.—entirely reverses this result, for the sudden immersion of steel (or carbonised iron) into a cooling liquid produces extreme hardness and brittleness in the metal.

Tempering.—The simple hardening of steel tools would render them, on account of the accompanying brittleness, entirely unfit for use. They must also be rendered elastic, by what is known as *tempering*. This is effected by first hardening by the process indicated above, heating up again to a somewhat lower temperature, and then at a given heat cooling out.

Suppose a chipping chisel requires to be tempered. After forging, it is brought to a red heat in the fire, and then the lower portion dipped in water. This sudden immersion renders the lower portion very hard, but the heat retained in the upper portion is utilised in tempering the steel, that is, in reducing the extreme hardness of the cutting-edge, and giving it elasticity, to such a degree as will allow of it cutting metals without itself being fractured. After the immersion of the lower portion the conduction of the heat in the remainder towards the cutting-edge is observed by a parti-coloured band travelling down the tool. This band is led by straw-colour of varying shades, which is followed by purple and then by blue. When the straw-coloured portion reaches the cutting-edge, the chisel is quickly plunged into the water again and cooled outright. By shaking the chisel about in the water the cooling proceeds both more equally and more rapidly. If, after the first immersion of the lower portion, the flat sides of the chisel be rubbed with sandstone for a moment, the progress of the heat down the tool can be more clearly observed.

Different tools, requiring different degrees of hardness and elasticity, are cooled out at different stages of heat, which, while dependent upon the experience and judgment of the operator, are approximately recognised by the colour of the band. The following examples roughly indicate certain stages of heat required at the moment of cooling :—

Razors . .	*Somewhat light straw-colour.*
Knives . .	*Darker straw-colour.*
Chisels . .	*Still darker straw-colour.*
Plane Irons. .	*Brownish yellow.*
Watch Springs .	*Purple.*
Saws . . .	*Blue.*

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