THE MECHANICIAN,

A TREATISE

ON THE

CONSTRUCTION AND MANIPULATION OF TOOLS,

FOR THE

USE AND INSTRUCTION OF YOUNG ENGINEERS AND SCIENTIFIC AMATEURS;

COMPRISING THE

ARTS OF BLACKSMITHING AND FORGING;

THE CONSTRUCTION AND MANUFACTURE OF HAND TOOLS, AND THE VARIOUS METHODS OF USING AND GRINDING THEM;

THE CONSTRUCTION OF MACHINE TOOLS AND HOW TO WORK THEM;

MACHINE FITTING AND ERECTION;

DESCRIPTION OF HAND AND MACHINE PROCESSES: TURNING AND SCREW CUTTING;

PRINCIPLES OF CONSTRUCTING AND DETAILS OF MAKING AND ERECTING STEAM ENGINES;

AND THE VARIOUS DETAILS OF SETTING OUT WORK INCIDENTAL TO THE MECHANICAL ENGINEER'S AND MACHINIST'S ART.

ILLUSTRATED BY 1147 ENGRAVINGS.

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PREFACE.

THE Mechanician is essentially a book of processes, including all operations by which the principal portions of engines are forged, planed, lined, turned, and otherwise treated. The author endeavours to perform two things—to explain to uninitiated students how engines are really made, together with the fundamental principles involved in making them, and also to produce a book which shall be useful to practical mechanics for reference in the difficult details of their business.

Of the six chapters constituting the work, the first is devoted to forging; in which the fundamental principles to be observed in making forged articles of every class are stated, giving the proper relative positions for the constituent fibres of each article, the modes of selecting proper quantities of material, the steam-hammer operations, the shaping-moulds, and the manipulations resorted to for shaping the component masses to the intended forms.

Engineers' tools and their construction are next treated, because they must be used during all subsequent operations described in the remaining chapters; the author thinking that the student should first acquire a knowledge of the apparatus which he is supposed to be using in the course of the processes given in Chapters 4, 5, and 6. In the fourth chapter, planing and lining are treated, because these are the elements of machine-making in general. The processes described in this chapter, are those on which all accuracy of fitting and finishing depend. The next chapter, which treats of shaping and slotting, the author endeavours to render comprehensive by giving the hand-shaping processes in addition to the machine-shaping.

In many cases, hand-shaping is indispensable, such as, sudden breakage, operations abroad, and on board ship, also for constructors having a limited number of machines. Turning and screw-cutting occupy the last chapter. In this, the operations for lining, centring, turning, and screw-forming are detailed, and their principles elucidated.

The Mechanician is the result of the author's experience in engine-making during twenty years; and he has concluded that, however retentive the memory of a machinist might be, it would be convenient for him to have a book of primary principles and processes to which he could refer with confidence. It is hoped that the descriptions given of the author's lining-tables, pillar-tables, gap straight-edges, slottil, valin, monto, and other instruments, may cause them to be more generally used by engineers, the author having proved them highly efficient during many years.

The Tables of dimensions relating to sizes of iron for forging, cylindrical gauges, screw-taps, and hobs, are also exactly in accordance with his practice; also his method of shaping tap-screws, hob-screws, dies, bolt-screws, and selecting screwing-wheels.

Erith, London, 1869.

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INTRODUCTION.

An attempt is now made to illustrate and explain the details of engine-making. The author knows by experience that there is no work in any language which enumerates a sufficient number of details concerning engine-construction. We have written instructions about everything connected with the subject, except concerning the actual manipulation of the tools and appliances employed for the purpose.

The subject, as considered in the Mechanician, is rather extensive, and, in order to give satisfaction both to mechanics and learners, it is necessary to treat each individual piece of machinery distinctly, to consider it as something that must be forged, previously to being shaped and put into its place. The forging of the article is often of much more importance and expense than any after-operation; and although all acknowledge that some practical instructions on the subject are needed, it is also acknowledged that none exist. The only one among us who has written anything reliable on forging is Holtzapffel. And even this industrious writer makes no mention of engine-work in its details. He commences his chapter on smith's work with a five-ton paddle-shaft; a subject which is rather sublime and overpowering, if not very comprehensible to a learner. The more rational and easy method of teaching forging, so that the instruction may be useful, is by first explaining the construction of those portions of a steam-engine which have simple forms only. When these are made tolerably familiar, is the time to introduce the compound ones.

This mode of dealing with the subject is adopted throughout the whole of the Mechanician to the end: consequently the plan of the work is quite original.

Probably it is impossible for any single writer to exhaust such a tedious and intricate matter; for this reason, the author considered it prudent, in order to admit a large amount of information on the subjects treated, to make the number of those subjects limited. And to make such a literary work new, in the proper sense of the term, we should endeavour to write about those branches of engine-making on which the least is written. These are forging, lining, planing, slotting, turning, and screw-cutting; a sufficient number for any one individual to manage properly.

The work comprehends three principal parts. The first part is devoted to forging, and a detailed description of engineers' tools and appliances. And, in addition to descriptions, sketches and detailed instructions are given in the several methods of making the tools that are mentioned.

The second part includes the application of the tools to the practice of engine-making.

The third part consists of details of mechanical processes which are not usually included in engine-making.

This arrangement is convenient to learners; because the names of tools and appliances must necessarily be frequently made use of in the second and third parts, and those who do not happen to know the particular form and method of making a certain tool, will refer to the first part for the desired information.

The details of the work commence with forging such simple articles as bolts and nuts, keys, straps, screw-keys, and similar articles. Several methods of making each article are mentioned, so that individual makers of small work may select the plan most suited to their requirements. The next treated are joint-pins, slide-valve rods, weigh-shafts, excentric-rods, piston-rods, connecting-rods, links, cross-heads, reversing-gear, paddle-shafts, crank-shafts, screw-shafts, propeller-shafts, and other shafts, small and large; the small being first introduced in order to make the work progressive and instructive to learners and to those who may not have previously studied engineering.

After the forging, the various modes of shaping and fitting are introduced. These include drilling, slotting, planing, turning, and screw-cutting; also drill-making, cutter-making, boring-tools, screwing-tools, lathe-tools, planing-tools, slotters, shapers, excavators, and other assistants in the necessary process of adapting pieces of machinery to each other, such as dies, screw-plates, die-nuts, and taps.

Skilful mechanics must kindly bear with details which may be particularly valuable to those who require them, and may be highly interesting to students and others who are commencing the business. And it will be acknowledged that details are absolutely necessary to make he work more or less useful to mechanics generally.

THE MECHANICIAN AND CONSTRUCTOR.

PART I.

CHAPTER I.

FORGING.

The importance of good forgings in engine-machinery cannot be properly estimated except by those who have been intimately connected with engine-making. All the working portions of an engine that are intended to sustain the greatest strain must be forged. A few years since, engineers used cast iron for such purposes, and, in order to obtain sufficient strength, made use of large masses of metal; thus ensuring a certain, or rather uncertain, amount of safety. However large a lever or shaft may be, there is always attending it some disagreeable apprehension of danger, if it is made of cast iron, and the suddenness of the break is almost certain; but, with forged iron, an instantaneous break, without some previous sign of approaching rupture, is extremely rare. Such a division may possibly occur if the shaft, lever, or rod is made too small; and there is also a small liability to such an occurrence with shafts that are too large. A well-proportioned forged shaft or lever may be so much injured by improper hammering as to render it liable to break with less than the ordinary wear and strain allotted to it. Good soft iron, of well-defined fibrous character, may, by hammering, be made crystalline, and will become as untrustworthy as the cast iron from which it was originally made.

The outside dimensions of a forging often convey an incorrect idea of its internal strength; and no engineer, however penetrating, can, by measuring a certain shaft or lever, ascertain whether it is strong enough for the engine of which it is a part; neither can he point out its weakest spot. The smith who made it should know much more about the strength of his forging than any other inspector; but smiths generally do not know. A good smith is a rare individual. He knows that the fibres of the iron must be so arranged as to be in proper position for sustaining the strain; and having succeeded in obtaining a proper arrangement of the fibres, he will not change them into crystals by improper hammering.

A smith is a much more important individual than a member of any other branch of engine-making. Planers, fitters, and turners are more dependent upon mechanical contrivances than smiths. An intelligent turner can very soon learn all that is needful for his business; but a good smith is more original and prescient than a member of any other branch. Much more time is required to make a good smith than to make a good planer or turner.

It is, however, proper to admit that the engine-smith of the present day is not generally so original or ingenious as the smith of olden time. An inferior smith can now produce good work in large quantities, in consequence of the great aid afforded him by various inventions for reducing the amount of labour, these inventions being the productions of studious mechanical men who are not necessarily smiths in the usual meaning of the term; but by placing a modern smith upon an equality with one of old, without recent inventions, we discover the amount of ingenuity in each.

Probably in a few years the forging process will become quite as mechanical as planing, slotting, or turning, at which time the present foresight, skill, and labour accompanying forging will be almost dispensed with; but, until forging machinery becomes general, the smith must continue to exercise his present amount of care, discretion, and skill.

The number of forging-machines is at the present moment very considerable, and some of them produce better work than can be made by any kind of mere hand-labour, unless an intolerably large amount of time is consumed during the process. We now have a variety of machines for producing forgings by compression, bolt-machines, nut-machines, a great number of rolling-machines, a variety of steam hammers, including the new patent steam striker and what is named the rotary hammer. All these are daily becoming more intimately associated with smith's work of all kinds, large and small. Even at the present time, all those forging machines that act by compression and cutting dies, can be adapted to produce all the necessary forgings for small engine-work, and we may reasonably expect to obtain machines each more and more varied in application than the preceding; and the works produced will be more and more the result of machinery, till the smith's hand-labour and intellectual energy now required for his work be reduced to a minimum. Probably, at the time the minimum of labour is reached, we shall reach the maximum of good quality. By referring to other branches of engine-making, such as turning or planing, we discover that every mechanical contrivance introduced to diminish labour, at the same time increases the good quality of the work produced. We may thus infer that similar things will occur in the noble art of forging.

The advantage of a tolerable knowledge of smith's work to engineers is hereby made apparent to readers generally; some remarks may therefore be submitted to students who wish to acquire some knowledge of the internal structure of the various pieces of machinery, and not merely how to shape their outsides.

Although we know that mechanical contrivances will become more and more extensively applied to forgings of all kinds, we do not anticipate any change in the circumstances that determine or control the production of good, sound work.

With relation to a good piece of smith's work, three principal circumstances require consideration. These are, the outside dimensions of the article when finished, the arrangement of its component fibres, and the amount of wear and tear to which the article will be subjected when in ordinary use.

The outside dimensions of a forging are ascertained by ordinary calculation, after it is decided to what purpose the engine, machine, or lathe is to be applied.

The position of the constituent fibres of separate forgings, and the several duties to be expected from them, shall now be considered.

This work is designed to be useful to those who are now actually working at the business, and also to those who intend to become practically acquainted with it. It is therefore proposed that all our younger readers first devote some careful attention to the forms and names of the forgings that are used in engine-making. A correct knowledge of names is very important to all beginners in engineering; consequently a number of outlines of forms are introduced immediately connected with their corresponding names. See Plates 1, 2, 3.

After examining a few of the figures of Plate 1, the student is directed to the technical phrases here introduced.

SIGNIFICATIONS OF TECHNICAL PHRASES.

To MAKE UP A STOCK.—The stock is that mass of coal or coke which is situated between the fire and the cast-iron plate through the opening in which the wind or blast is forced. The size and shape of the stock depend upon the dimensions and shape of the work to be produced. To make up a stock is to place the coal in proper position around the taper-ended rod, which is named a plug. The taper end of the plug is pushed into the opening from which comes the blast;

the other end of the plug is then laid across the hearth or fireplace, after which the wet small coal is thoroughly battered over the plug while it remains in the opening, and the coal piled up till the required height and width of the stock is reached; after which the plug is taken out and the fire made, the blast in the mean time freely traversing the opening made in the stock by the plug.

Fire-irons.—These consist of a poker with small hook at one end, a slice, and rake. The poker with small hook is used for clearing away the clinker from the blast-hole, also for holding small pieces of work in the fire. The slice is a small flat shovel or spade, and is used for battering the coal while making up a stock. The slice is also used for adding coal to the fire when only a small quantity is required at one time. The rake consists of a rod of iron or steel with a handle at one end, and at the other a right-angle bend of flat iron, and is used to adjust the coal or coke into proper position while the piece to be forged is in the fire.

A Rod.—This term is usually applied to a long slender piece of iron, whose section is circular.

A Bar.—Bar signifies a rod or length of iron whose section is square, or otherwise angular, instead of circular.

Plate.—This term is applied to any piece of iron whose length and breadth very much exceed its thickness. Thin plates of iron are termed sheets.

To take a Heat.—This signifies to allow the iron to remain in the fire until the required heat is obtained. To take a welding heat is to allow the iron to remain in the fire till hot enough to melt or partially melt.

To finish at one heat is to do all the required forging to the piece of work in hand by heating once only.

To draw down.—Drawing down signifies reducing a thick bar or rod of iron to any required diameter. There are several methods of drawing down: by a single hammer in the hand of one man; by a pair of hammers in the hands of two men; five or six hammers may be also used by five or six men. Drawing down is also effected by steam-hammers, air-hammers, and rolling-mills.

To draw away.—This term signifies the same as to draw down.

To upset.—This operation is the reverse of drawing down, and consists in making a thin bar or rod into a thick one; or it may consist in thickening a portion only, such as the middle or end, or both ends. The operation is performed by heating the iron to a yellow heat, or what is named a white heat, and placing one end upon the anvil, or upon the ground, and striking the other end with three or four hammers, as required. Iron may be also upset while in the horizontal position, by pendulum hammers and by the new patent steam-striker, which will deliver blows at any angle from horizontal to vertical.

Scarfing.—This operation includes two processes—upsetting and bevelling. Scarfing is resorted to for the purpose of properly welding or joining two pieces of iron together. When the two pieces are rods or bars, it is necessary to upset the two ends to be welded, so that the hammering which unites the pieces shall not reduce the iron below the required dimensions. After being upset, the two ends are bevelled by a fuller or by the hammer.

Butt-weld.—When a rod or bar is welded to another bar or plate, so that the joint shall be at right angles to the bar, it is termed a butt-weld.

A Tongue-joint.—This joint is made by cutting open the end of a bar to be welded to another, whose end is tapered to fit the opening, and then welding the two bars together.

To punch is to make a hole, either square or round, into a piece of iron by means of square or round taper tools, named punches, which are driven through the iron by hand-hammers or by steam-hammers.

To drift out is to enlarge a hole by means of a taper round or square tool, named a drift.

The Hammerman is the assistant to the smith, and uses the heavy hammer, named the sledge, when heavy blows are required.

The Tuyere, or The Tweer.—This is a pipe through which the blast of air proceeds to the stock, and thence to the fire. The nozzle of the tweer is the extreme end or portion of the tweer, which is inserted into the opening of the plate against which the stock is built.

SEPARATE FORGINGS.

By perusing the foregoing definitions, the learner will be enabled to understand the details given concerning individual forgings.

Round Keys without Heads.—Fig. 1, Plate 1, represents a simple kind of round key; and this, with other keys shown in a line with it, are proper objects for learners to attempt during their first essays at forging.

A round key is so simple that no forging is necessary to make it, unless the key is required to be about half or three-quarters of an inch in diameter. Small round keys are made immediately from the wire, which can be bought of iron or steel, of a suitable diameter, to avoid unnecessary labour. All small keys should be made of steel, whether they be round or square. If the steel is obtained small enough to obviate the necessity of forging, it should be cut to a convenient length for holding while being filed to fit its place, which is named the key-bed or key-way. Steel wire is easily divided by an edge of a file. After being cut to convenient lengths, the pieces should be made not more than red-hot, and allowed to cool gradually to soften them, remembering that such keys as we are considering should not be hardened. The advantage in making them of steel consists in two principal good qualities—their closeness of texture and their durability. A small pin or key of steel will sustain much more hammering in and out of the key-bed than an iron key of the same diameter and length. Small iron keys are liable to split while in use, through the number and shape of the fissures that steel does not possess.

But if the steel requires forging, it must be considered whether the pin or key is to be filed to fit the key-bed, or whether it is to be turned. A round key to be turned should be forged with a small portion drawn down from the largest end (Fig. 58), for the convenience of holding it while being turned in the lathe. Round keys are sometimes an inch and a half in diameter, and considerably taper; hence the convenience of the smaller portion at the larger end, allowing the key to be turned throughout its whole length without interruption.

If the key is to be filed to fit, instead of being turned, the smith must be careful to ascertain the proper angle or amount of taper required in the key, and also the finished dimensions. Attention to these particulars avoids unnecessary waste of time while fitting the key. Taper keys should be tried into their key-beds, before the forging of the key is finished. But when a great number of large ones are to be forged, a double-gap gauge (Fig. 57) should be made, one gap being for measuring the large end of the pin, and the other gap for measuring the small end, and both openings of the proper width to allow only a small amount of filing to the pins while being fitted.

The proportionate lengths and diameters of round keys depend upon whether they are intended for wheels, for levers and weigh-shafts, or for cranks. Fig. 1 shows the proportion suitable for the middle of a wheel, which is named the wheel-boss. Fig. 3 indicates a round key, of proportions suitable for a weigh-shaft or crank-lever, when the pin or key is inserted through the middle of the lever and spindle by means of a hole bored through the two (Fig. 59), instead of merely cutting a key-bed into the shaft, parallel to its length (Fig. 60). Fig. 3, being comparatively small in diameter, admits of a small hole in the shaft or spindle, instead of a large hole, which would needlessly weaken both lever and spindle.

The round pin or key is superior to the angular key for many kinds of work, such as wheels and crank-levers. This circular pin might be used oftener than it now is, because it can be quickly fitted by turning, and also because the curved key-bed is not so liable to break the wheel.

The manipulation of a round key upon the anvil consists in drawing down the end of a long rod, care being taken that the steel is never hammered too near the small end of the key. It is proper to commence the drawing or reducing at the large part of the key nearest the hand, and deliver each successive blow more and more towards the further end, and never contrariwise. For forging a small round key, no tools are required except the ordinary fire-irons and the hand-hammer, tongs, and anvil-chisel, in the anvil; shown by Figs. 61, 62, and 63. The forging a round pin is good and instructive practice for a beginner, to enable him to see the effect of his blows upon the piece of work. Sometimes he will strike the anvil instead of the key, and there is then a probability of the hammer bouncing up into his face. This will teach him to strike the key gently until he has acquired the method of holding his work upon the anvil, and also of striking upon the top of the key, instead of the side, which puts an ugly dent into the key that he intended to be round, and drives it sideways along the top of the anvil and down to the ground in a very unworkmanlike manner. But all such small difficulties are soon overcome by patient practice. He will soon discover that, if he holds his left hand too high, he will experience an indescribable tingling and jarring in the hand; and if he holds his left hand too low, he will feel a curious jerking of the left arm all the way to his shoulder. One remark concerning holding his work may be useful, and is, that if he is careful to keep two points of the key bearing upon the anvil at one time, and is careful to strike always between these two points, he will not undergo the tingling and jerking just referred to.

The pin should be forged to the proper diameter, and also the ragged piece cut off the small end, by means of the anvil-chisel, shown by Fig. 63, while the work is still attached to the rod of steel from which it is made. After having cut and rounded the small end, it is proper to cut the key from the rod of steel, allowing a short piece to be drawn down to make the holder, by which to hold it in the lathe. This holder is drawn down by the fuller, and afterwards by the hammer. The fuller is first applied to the spot that marks the required length of key; the fuller is then driven in by the hammerman to the required diameter of the holder, the bottom fuller being in the square hole of the anvil during the hammering process, and the work between the top and bottom fullers. During the hammering, the forger rotates the key, in order to make the gap of equal or uniform depth; the lump which remains is then drawn down by the hammers, or by the hand-hammer only, if a small pin is being made. If the pin is very small, it is more convenient to draw down the small lump by means of the set-hammer and the hammerman. The set-hammer is shown in Fig. 66; and the top and bottom fullers by Fig. 67.

The double or alternate hammering by forger and hammerman should at first be gently done, to avoid danger to the arm through not holding the work level on the anvil. The hammerman should first begin, and strike at the rate of one blow per second; after a few blows the smith, or intended smith, begins, and both hammer the work at times, and other times the anvil. The first attempt continues about a minute, after which the work receives a severe dent on one side, and is knocked off the anvil, and sometimes out of the tongs. After a short time occupied in collecting the various instruments, the operators begin again with renewed vigour.

Fig. 64 shows the top and bottom rounding-tools, for rounding large keys. These tools are necessary for large keys, but it is proper for the learner to make a small key without them. This he can do by rounding the work with his hand-hammer, and cutting off the pin by the anvil-chisel instead of the rod-chisel (Fig. 65). The rod-chisel is so named because the handle by which the chisel is held, is an ash-rod or stick (see Fig. 64). A rod-chisel is thin for cutting hot iron, and thick for cutting cold iron. Fig. 63 represents the anvil-chisel in the square hole of the anvil. By placing the steel while at a yellow heat upon the edge of the chisel, he can easily cut off a small key by a few blows of his hammer upon the top of the work.

Round Keys with Heads.—Fig. 4 represents this kind of key; the thickest part of it is termed the head, and the portion of the head at right angles to the small or thin part is named the shoulder; the thin part from the shoulder is the stem. Such keys are used for wheels or levers for spindles whose key-beds are parallel to the longitudinal axes of the shafts or spindles. In all cases where no objection exists to a key-head projecting beyond the wheel or lever, the head is admissible, because of its utility while driving out the key. When the stem of it is hidden by the wheel, the shoulder of the head receives the blows while driving out. The tools for unfixing keys are numerous, and will be treated in another place.

To forge a key with a head involves rather more labour than making a straight one. There are three principal modes of proceeding, which include drawing down with the fuller and hammer; also upsetting one end of the iron or steel; and doubling one end of a bar to form the head.

For proceeding by drawing down, a rod or bar of steel is required, whose diameter is equal to the thickness of the head required; consequently, large keys should not be made by drawing down unless steam-hammers can be used. Small keys should be drawn to size while attached to the bar from which they are made; the drawing is commenced by the fuller and set-hammer. Instead of placing the work upon the bottom fuller in the anvil, as shown for forging a key without a head, the steel is placed upon the face of the anvil, and the top fuller only is used, if the key required is large enough to need much hammering; but a very small key can be drawn down by dispensing with the top fuller and placing the bottom fuller in the hole, and placing the work upon the top, and then striking on one side only, instead of rotating the bar or rod by the hand. By holding the bar or rod in one position, the head is formed upon the under side of the bar; and by turning the work upside down, and drawing down the lump, the stem is produced. A learner should make a small key in this manner by his own hand-hammer only; and, having drawn the stem, he should cut off any unsound part at the end, and then cut off the key from the bar by the anvil-chisel; after which take out the anvil-chisel, and put in the bottom fuller, and draw down another key. When he has thus drawn and cut off a sufficient number, he can heat them again, and shape the heads. The set-hammer is useful to square the corner near the shoulders, and also to draw down the stems of very small keys, for which the drawing by the hand-hammer is not convenient, through the shortness of the stems.

But large round keys with heads require the top and bottom rounding-tools for adjusting the stems to their proper diameters. A double gap-gauge is also required, if a number of keys are required to be of similar diameters. This gauge is shown in Fig. 57; but this is not necessary for a few only. Instead of the gauge, two pairs of callipers are used, which may be opened or closed to any required width. Callipers are made of all sizes to suit the ordinary work. One pair of them is shown by Fig. 57. A pair of these callipers is adjusted to the required diameter of the small end of the forging, and another pair is adjusted to the required diameter of the large end, the callipers being riveted together sufficiently tight to prevent shifting of the two legs with relation to each other, while in fair use, but not tight enough to prevent them opening with the application of about twenty pounds of muscular force. The method of adjusting callipers is by closing the two legs by the two hands of the operator until the distance between the legs is about a sixteenth of an inch greater than the distance required; this sixteenth of space is then traversed by gently striking the edge of one leg against a soft piece of iron until the opening is of the distance required. Adjusting callipers by other machinery will be treated in another portion of this work.

If the work in progress is more than eight or ten inches in length, a straight-edge of iron or steel is required, to ascertain if the work is too much bent.

Large keys need a little management and attention, if being made of steel, to prevent overheating; it is also necessary to consider the proper amount of bar to be drawn down, to avoid waste by cutting off a large piece of the key after being drawn to the required diameter. Two important considerations belong to this subject, which are, the unnecessary consumption of time in drawing down more of the bar than is required, and the shape of the piece that is cut off, which is often in such a condition as to be only fit for the scrap-heap.

Previous to driving in the fuller at the commencement of the drawing down of the stem, it is necessary to determine the distance from the extremity of the bar or rod at which the shoulder of the key is to be formed, and the stem of the key to begin. The author's plan of determining this distance consists in comparing the amount of area of the key-stem required, with the amount of area of the rod of steel from which the key is to be forged. And in the process he uses this rule:—

As the mean sectional area of that portion of the bar to be reduced is to the mean sectional area of the key-stem required, so is the length of the key-stem required to the length of that portion of the bar which is to be reduced.

To apply this rule to the forging of a round key with head, such as we are now considering, it is only necessary to know distinctly the dimensions of the key-stem required, and the dimensions of the rod or bar from which the key is to be made. Both these things being determined, we will consider it stated that the key shall be made from a rod of steel whose diameter is three inches, and that the key-stem shall be eleven inches in length, and the shape of it conical, the largest diameter near the head to be two and one-eighth inches, and the diameter at the small end one and seven-eighths inches. The mean sectional diameter is therefore to be two inches. And the mean sectional area of the stem required is, consequently, three, and one hundred and forty-one thousandths of square inches. The diameter of the rod being three inches, its sectional area is seven, and sixty-eight thousandths of square inches. On paper the complete proposition is, therefore, thus indicated:—

$$7{\cdot}068 : 3{\cdot}141 :: 11 : 4{\cdot}889$$

The first of these terms represents the mean sectional area, in inches, of that portion of the rod which is to be forged into a key-stem. The second term denotes the mean sectional area of the required stem. The third term indicates the length, in inches, of the key-stem to be forged. And the fourth term points out the length of bar or rod required, to produce eleven inches of stem without requiring any portion to be cut off the stem when finished.

The proportions indicated by the symbols are not true; they are merely arithmetically correct to the extent of the fractions employed. But, practically, we find them valuable, because they inform us that four and nine-tenths inches of steel is sufficient for eleven inches of key-stem. This being known to the smith, he should put a small dent into the steel by means of the chisel for cold steel, at five and one-eighth inches from the end of the steel. This distance is more than that which is indicated by the symbols, because a small portion will be taken from the steel by heating, and the end of the stem will be unsound and may require welding or cutting off.

To ensure the necessary soundness at the end, it is curved, either by welding or by cutting off any ragged or hollow portions; and this must be done previous to any attempt to draw down by the fuller or steam-hammer; because, if the steel is hollow at the end, at the time of commencing to reduce it by the steam-hammer, and the steel too brittle to be welded, it will become worse under the hammer, which will in a short time break it to pieces.

This curving just mentioned is also important for iron keys, either large or small, and is always necessary in proportion to the amount of drawing the metal is to undergo, when it cannot be welded again after being made unsound.

The end being curved, or what is termed rounded, and the dent put into the steel at the proper place, by means of what is named the cold chisel, it is proper to commence drawing down by driving in the fuller, to produce the shoulder. When the fuller is driven to about half the depth that will be reached when finished, draw the lump which is to form the stem to a square; after which, drive in the fuller again at the shoulder, and make the gap deeper to admit of the stem being again drawn upon the anvil—remembering to make the key four-sided, and to commence the drawing down at the shoulder of the key, and draw the work towards you a short distance, after each blow from the hammer, until the extremity is reached; then commence the drawing again at the shoulder. The key-stem will, by such treatment, become compact, and, if the steel is good, rather improved, but not if hammered while it is much below the red heat. If the key is being made of iron, the openness of the grain is partly closed by hammering at a proper heat; and keys require a very close texture to prevent splitting when the strain of the lever or shaft is applied to the side. If the key should be made of layers of iron, welded together, instead of steel, the layers should be placed parallel to the side of the key-stem; in this position the strain upon the key-side will tend to close the key together; but if the layers of iron are parallel to the shaft, and the iron bad, there is a danger of the key being split into two, and one piece being carried round by the lever, while the other piece remains in the key-bed.

The four-sided shape of the key is now to be altered to eight-sided, by placing one corner upwards to receive the hammering, and afterwards the others, until a tolerable approach to eight-sided is attained; after which, round the key-stem by the ◊ top and bottom tools (Fig. 64).

and adjust the key to its proper diameters at each end, by the half-round top and bottom tools, at which time the double-gap gauge or the two pairs of callipers will be required to ascertain the size; and the straight-edge will be useful to ascertain if the stem requires straightening.

These remarks equally apply to small keys. The four-sided and octagonal forms are easily attained by the hand-hammer, and the learner will be pleased at the mechanical method just indicated.

The particular uses, and pieces of work, to which round keys should be applied shall be treated in another place. It is now necessary to mention the methods of upsetting to form the head; and the doubling of the iron to form the head.

Instead of commencing by making the stem, as in the drawing down, the head is first formed at the end of the bar by battering it, either in the horizontal position while lying on the anvil, or in the vertical position while standing on the anvil, or on a heavy cast-iron block, the top of which is level with the ground, if the work is too long to be stood upon the anvil. Till the present time, all the laborious upsetting, both of small work and large, has been done by manual labour of a tiresome character. Although our wonderful and valuable assistant, the steam-hammer, will upset a short piece of iron or steel, if it be only one or two feet in length, we cannot use our powerful friend to upset a long rod or bar without some means of making the steam-hammer strike the iron while in a horizontal position. This object is now conveniently accomplished by what is called Davies's patent steam-striker, which is an appropriate term, because the machine will deliver blows at any angle from horizontal to vertical, thus avoiding much of the troublesome upsetting by the hammerman. But if without such a contrivance, it is necessary to use the pendulum-hammer, if the bar is very long, or to cut off the piece to form the key, and upset it upon its end. The upsetting of iron generally should be done at the welding heat; the upsetting of steel, at the yellow heat, except in some kinds of good steel, that will allow the welding heat. And both iron and steel require cooling at the extremity, to prevent the hammer spreading the end without upsetting the portion next to it. If the head of the key is to be large, several heats and coolings must take place, which renders the process only applicable to small work. A small bar can be easily upset by heating to a white heat or welding heat, and cooling a quarter of an inch of the end; then immediately put the bar to the ground with the hot portion upwards, the bar leaning against the anvil, and held by the tongs (see Fig. 68). The end is then upset, and the extremity cooled again after being heated for another upsetting, and thus till the required diameter is attained. When a number of bars are to be upset in this manner, it is necessary to provide an iron box, into which to place the ends of the bars, instead of upon the soft ground or wood flooring, injury to the floor being thereby prevented.

When the key-head is sufficiently upset, the fuller and set hammer are necessary to make a proper shoulder, the stem is then drawn four-sided and rounded by the ◊ top and bottom tools. If the bar from which the key is being made is not large enough to allow being made four-sided, eight sides should be formed, which will tend to close the grain and make a good key.

The third method of making keys with heads is the quickest of the three, particularly for making keys by the steam-hammer. By its powerful aid, we are able to use a bar of iron an inch larger than the required stem, because it is necessary to have sufficient metal in order to allow hammering enough to make it close and hard, and also welding, if seamy. If the bar from which it is to be made is too large to be easily handled without the crane, the piece is cut from the bar at the first heat; and the length of the piece to be cut off is determined by aid of the rule given in page 8. But if the bar is small, it can be held up at any required height by the prop, shown in Fig. 69. While thus supported, the piece to be doubled to make the head is cut three-quarters of the distance through the iron, at a proper distance from the extremity. The piece is then bent in the direction tending to break it off; the uncut portion being of sufficient thickness to prevent it breaking, will allow the two to be placed together and welded in that relation. A hole may also be punched through the two, while at a welding heat, as shown by Fig. 70. The hole admits a pin or rivet of iron, which is driven into the opening, and the three welded together. This plan is resorted to for producing a strong head to the key without much welding; but for ordinary purposes it is much safer to weld the iron when doubled, without any rivet, if a sufficient number of heavy blows can be administered. At the time the head is welded, the shoulder should be tolerably squared by the set-hammer; and the part next to the shoulder is then fullered to about three-quarters of the distance to the diameter of stem required. In large work the fuller used for this purpose should be broad, as in Fig. 71. After the head is welded, and the portion next to it drawn down by the fuller, the piece of work is cut from the bar or rod, and the head is fixed in a pair of tongs similar to Fig. 72. Such tongs are useful for very small work, and are made of large size for heavy work. Tongs of this character are suited to both angular work and circular. They will grip either the head or the stem, as shown in the Figure. While held by the tongs, the thick lump of the stem that remains is welded, if necessary. Next draw the stem to its proper shape, and trim the head to whatever shape is required.

The Learner's Duties.—To give a large number of instructions to a learner before he begins to work involves a waste of time; because he cannot appreciate or understand everything that is told him until he has performed something. If he has tried to make an article and failed, he will probably perceive the cause of failure when pointed out to him. But these causes of failure are very little heeded by some individuals until they have really experienced the things mentioned to them. Hence arises the necessity of giving as many instructions to a learner as he can comprehend or make use of at the moment he receives them, but no more than the proper number, if that number can be ascertained.

When a learner has knocked about a few pieces of iron or steel upon the anvil, possibly made a few articles, and discovers that if he possessed a little more machinery he could make a few more, he is in a condition to attend to a few remarks about his tools. It is scarcely possible for him to begin forging by making his own tools, except to a very limited extent; but, as he progresses, he will become gradually able to make all he requires. At his present stage of progress he should consider his hammer and tongs, to ascertain if his hammer-handle is tightly fixed in the opening, or whether he has knocked out the wedge through striking the anvil too often instead of the work; also whether the rivets of his tongs are injured or broken by his own ill-treatment of them. He should not attempt any work that requires the sledge-hammer until he is provided with good tongs and rings to hold them tightly together; these will prevent the sledge-hammer driving out the work from the tongs into contact with some person's limbs. There are three kinds of tools that he can now make in a tolerable manner for his own use; these are straight-edges, squares, and callipers. Before commencing to make these necessary articles, he can make his handle tight, if it requires it, by making a wedge with ragged edges, either of ash or iron, remembering that the wedge must be of very gradual taper, as it is termed, signifying that the angle subtended by the two sides of the wedge should be five or six degrees. When the angle of the wedge is too great, there is danger of it soon tumbling out, and the hammer flying off to the injury of life or limb. As he advances in knowledge, he will learn how to make the opening of his hammer, so that the handle shall properly fit, and also how to make the hammer itself; but at present he must be content by making the wedge only. Having made his hammer safe, he can make a rivet for his tongs by fitting a pin to the two holes and allowing sufficient length of iron each side to form the two heads, at which time, while the tongs are apart, he can notice their form, which will probably teach him how to make a new pair. No tongs is required to hold the rivet or pin while he is making it, because he can provide a piece of iron or steel of sufficient length to hold in his hand.

He should now make, firstly, his callipers, two or three pairs; secondly, straight-edges, one or two; and, thirdly, a square, one or two.

The form of the callipers shown by Fig. 57 is merely of a simple character, easily constructed, and suitable for smiths, because a tolerable approach to precision in measuring is quite sufficient. The more scientifically made and valuable kinds of callipers suitable for fitters and turners, will be mentioned in due order.

The smith can make his callipers in his own ordinary mode of punching small holes. It is proper to punch the two holes for the joint-pin P, previous to filing or otherwise finishing the edges of the callipers. When the holes are punched, he can fix in a pin in a temporary manner, in order to hold them together a short time, while he grinds the edges to any required shape by the grindstone. But by careful shaping upon the beak of the anvil, he can avoid grinding the edges; and it will be only necessary to grind the ragged portions from the two sides that are to be put together while riveting in the joint-pin.

When the callipers are made, the operator can proceed to the straight-edge. This he can also make without proceeding to the erectory or turnery to borrow a straight-edge by which to make his own; and he can make an edge sufficiently near to a straight one, without resorting to two or three others, which is the custom if a near approach to precision is required. The mode, among others, resorted to by the author for producing in a remarkably short time a useful instrument, is thus indicated:—

If the tool required is to be twenty inches in length, procure a strip of thick white paper twenty-two inches by four inches wide, and drive two round pins through the ends of the strip of paper on the wall at about nineteen inches between the two pins, so that the line of distance between the two is nearly vertical; but a little to the left of the lower pin is the proper place of the upper one. Smooth the pins with a piece of emery cloth, and fasten a thread of black silk or black smooth cotton to the lower pin, and place the other portion of the thread over the upper pin, and allow the thread to hang with a weight attached, which will be on the left side of the apparatus, if the pin which is uppermost is to the left of the lower one. It is now necessary to drive into the wall, or board, if such is being used, a third smooth pin; the place of this pin is about half an inch above the lowest one, and half an inch to the right side of it. If all the pins are tight in the wall and the thread stretched tightly on the right-hand sides of the two upper pins, the affair is fit for use by applying an edge or side of any tool that requires some lumps to be taken off. This simple apparatus is capable of being adapted to straight-edges of any length less than twenty inches by driving in another pin at various distances from the upper pin, being careful to push the thread to the right hand while driving in the pin. By a little more contrivance, the thread could be made to subtend a near approach to an angle of ninety degrees to the plane of the horizon: the longitudinal axis of the thread would then be something like a geometer's idea of a straight-edge.

When the smith has ground or filed one edge of the straight-edge to the thread, he can make the opposite edge parallel by using his callipers.

In order to make a square, it is necessary for the smith to procure a piece of sheet iron, or some kind of flat smooth surface, about twelve or eighteen inches across. Describe a circle whose circumference shall reach nearly to the edges of the plate; and then, without any proper knowledge of how to form or construct a right angle, he can divide the circumference into four by his compasses; he can then mark lines across the middle of the circle to the four points, and the angles thus shown will enable him to adjust his square, which will be much nearer to correctness than his forging will at any time require. Fitters' squares are very different instruments, and require quite different treatment, which will be fully demonstrated at the proper time. Probably, the adjusting of a square is of little importance to the smith who is but a learner, when compared to the forging of a square, which is performed in several ways. The simplest method is that by which he should commence, and consists in welding the ends of two thin bars together, so that the one bar shall be at right angles to the other. The next method consists in cutting a slit into the end of a bar to form the thick part of the square, and then welding a thinner bar into the slit in order to form the blade or thin portion of the square.

The squares for fitters are forged of steel, and the blades are fullered down, processes that are included in the portion of this work concerning tool-making.

After the learner has actually forged a few tools, he is also in a condition to understand some remarks concerning the various qualities of iron; and he will, by experience, be enabled to select the particular kind of iron suitable to his particular piece of work in hand. Probably he will have noticed that some pieces of iron are very tough, and require more cutting than other pieces, in order to divide one piece into two, while cold. If this tough kind of iron is also tough while red hot, it is termed the very best kind of iron that can be produced. This kind is that with which the learner should make his tools that do not require to be made of steel. Another variety of iron will bear much twisting and hammering while hot, but very little while cold without breaking. This sort is not suitable for tools or machinery that require much moving or rough usage; but if, after being forged, such iron is to remain fixed, it is a very hard and durable metal. There is another class of iron which is the most troublesome variety with which the forger has to work. It is rather compact and tenacious while cold, but while hot it will split while being punched; it will break under the hammer; it will crack while being bent; and it is almost useless for welding. But even this kind of iron is useful in the hands of an experienced man who knows to what purposes it should be applied.

The varieties of iron may be thus noticed in a general manner; but the only true method of ascertaining whether an individual piece of iron is suitable for an individual piece of work is by forging a piece of the iron, and applying it to use. Then it is necessary to remember that the qualities of iron become altered during a course of time; the new or the foreign qualities and properties which the iron thus receives are the results of the agencies which have affected it. These agencies are conveniently termed mechanical, chemical, and improper. The mechanical agencies include a large number, such as those to which all pieces of moving machinery are subjected. The chemical agencies include the action of the atmosphere, water, and heat and cold. The improper agencies include ill-usage, such as hammering by careless workmen, improper hardening, and several others.

The quality of the coal influences the quality of the forging. The learner will be much discouraged by the unclean appearance of his work, and the trouble of welding, if he happens to be working with bad coals. He will be enabled to distinguish good from bad, by the ashes and coke which are found. Good coal produces a large quantity of coke, and but little white ashes. Bad coal produce but little coke or cinders, and a large amount of white ashes, which consist of lime and alumina and a few other earthy matters. Bad coal often contains much sulphur, which makes the iron brittle while hot, and prevents it from welding; and there is always a large quantity of clinkers formed by the fusion of the earthy matters which good coal does not contain. The manufacturer, whether large or small, may thus perceive that bad coal is much dearer than good, although the price is greater of the superior article. The name of the coal proper for forging is Tanfield Moor: this coal is remarkably friable, and may be broken by the hands.

It is also proper for the learner to keep his work well covered while in the fire. The work will thus become heated much sooner than if he allowed the heat to be blown up the chimney by the blast. Iron becomes oxidised by long exposure to the fire and air at the same time; consequently, by covering the work properly, coal, time, and metal will be economised.

Angular Keys.—Details of forging are now resumed. Angular keys are much more valuable, and more extensively used, than round ones, because, by proper forging, they may be made to fit their respective key-beds, so that, by a small amount of filing, the key may be reduced to enter the key-bed the whole distance required. The thinnest kind of angular keys is named flat, because the width of it is greater than its thickness, and not because it is very flat or true in any way, great numbers of them being used as they are forged, without any filing. Flat keys are made with heads, when the head will be required for unfixing the key. But when the head is not required, the keys can be made from a bar at a much quicker rate. Flat keys may be short and thick, or long and slender. They may have screws at the ends, or small pin-holes instead, as shown by No. 5, Plate 1. A flat key of this kind can be easily forged by a learner who has had a little practice; but the handling and forging of the round key is more instructive, because it compels the learner to strike carefully to prevent the disfigurement of his work. The smallest kind of flat keys are used for small joint-pins or ends of small bolts. A key-way is cut through, near the end of the joint-pin or bolt; and the small flat key is placed in the key-way so that the thin part of the key-stem is at right angles to the stem of the joint-pin or bolt. This allows great strength to the flat key, without making a large key-way to weaken the bolt. The key is fitted tight against the washer, or against the outside of the nut, as represented by Figs. 73 and 74.

To forge a key suitable for a joint shown by Fig. 73 or 74 but little labour is necessary, unless the steel or iron from which the key is made happens to be much larger at the commencement of the forging. This will often be the case with makers of small work, and private individuals, who are bound to make use of remnants of various dimensions, in an economical manner. In such circumstances, when a number of keys are required at one time of several sizes, it is usual to first draw down the steel to the largest size required, and make that number of keys required of the largest diameter, next draw down the steel to the second size, and afterwards draw to other dimensions required.

Split Keys.—Split keys are either flat or round, and are used to promote a feeling of confidence concerning the safety of a certain joint-pin or bolt and nut. After the split key is put into its key-way, the split part that protrudes beyond the side of the joint-pin or bolt is opened, and a safe fastening is effected; and ordinary wear or proper usage of the key will not have the effect of unfastening, which must be accomplished by straightening the key in order to draw it from its key-way. Round split pins are extensively used, and for several years the wire for making such has been made by the manufacturers into a semicircular shape, so that by doubling the wire the split pin is formed. The split key is shown in Fig. 75; the split pin, by Fig. 76.

A split pin is also a split key, because both are used to lock or fasten pieces of machinery together. But the term split pin is properly applied to the circular variety, in order to make some approach to a distinction of technical terms and names. To make names definite, it is necessary that one name should not be used for more than one form.

The method of making the half-round wire into a split pin, fit for use, belongs to the portion of this work devoted to fitting; because no forging is required. But the split keys are sometimes made of large sizes, and, being forged in large numbers, demand some attention.

Small split keys are easily made by doubling the iron, and welding the two together at one end. After being welded, the solid part, which is to be formed into the head, may be held by the tongs while the stem is reduced to its dimensions. Although the stem is split, at the time of being drawn down, it will bear a large amount of hammering without breaking, if the heat of the key while on the anvil is not allowed to fall much below dull red. If the key is to have a head, and the amount of iron used not very important, the piece may be cut from the stem, in order to avoid drawing down.

Split keys, eight or ten inches in length, should be made from one bar, instead of welding together two bars. A solid bar can be easily divided at one end to form the split, by means of the rod-chisel or trimming-chisel. The chisel is driven half way through that part of the bar which is to be the edge, or small side of the key-stem; when it is cut half through, turn the key upside down, and drive the chisel through the uncut portion. When the opening is first made, it is ragged; and it is necessary to cut off all the ragged pieces previous to smoothing the two insides; because if the loose or semi-detached pieces are flattened with the key, it will be far from solid; and if the key should be afterwards very much drawn down, some part of it would break.

The method of smoothing the two insides is by a thick wedge being placed in the opening, and the key being drawn while the wedge is in. After being smoothed, the wedge is taken out and the key drawn without the wedge. The operation is shown by Fig. 77. It is proper to make the wedge of steel, because it will be useful for split keys of various sizes.

In addition to machinery for making half-round pin-wire, we have machinery for making split keys and other kinds of keys, at a quick rate, both of steel and iron. Large firms, who may require large numbers of the articles, can avail themselves of the opportunity, when the machinery shall have become adapted to produce the kind and size required by different individuals. And even at the present time, if those who require them will be careful to order the keys, so that, when received, they will be a little too large, instead of a little too small, the small amount of fitting necessary will not be of great consideration.

But these considerations have but little relation to the private learner's advancement in the art of forging. He will discover the great value of practice in key-making, because of his experience in the several different processes. And it is necessary for him to commence forging simple articles, that he may become skilful when forging compound ones.

When it is necessary to forge a number of flat keys with heads, and the keys are required to be of similar length, breadth, and thickness, the method consists in making a long bar of the required thickness of the keys, the width of the bar being a little greater than the required width of the key-heads.

The bar must be thoroughly welded and drawn down by the steam-hammer, being careful not to injure the bar by unnecessary hammering, or by making it too thin. Next to cutting off the ragged part that may be produced at the end of the bar, the end of it must be carefully squared, and then properly mark the size and shape of the keys upon the bar by means of a pencil. The marking thus produced is shown by Fig. 78.

This method is only available with proper care to make the bar the proper width and thickness, previously to commencing to cut. If each key is cut a little larger than it is required to be when finished, the process will economise time and metal. The correct way of marking consists in making a thin piece of sheet iron to the shape of the key-side. This piece of iron, when properly filed to the dimensions, is termed a gauge: the size of it should always be a little larger than the side of the key required.

The gauge is placed upon the bar, and a slate-pencil with a small end is used to mark the shape; after which drive the chisel for cold iron into the middles of the pencil-marks. Both sides of the bar are to be marked, the operator being careful to make the marks opposite to each other, that he may avoid the danger of spoiling the keys. This disaster he can prevent by marking and cutting out a few, and then marking and cutting out a few more. To mark a great number before cutting out one is allowable, if the bar is marked upon one side only. The length and width of a gauge for keys ten inches long and four inches wide should not be more than one-sixteenth greater than the required keys.

Square Keys.—These are very much used for engine-making, and require to be made very compact by proper steam-hammering. If the iron should be too small to admit of being welded and hammered sufficient to destroy the appearances of any plates or layers that may be in it, these plates should always be parallel to the two sides of the key that sustain the strain while in use.

The term, square key, is applied to any four-sided key whose width is nearly the same dimension as its thickness: the geometer's idea of a square is not signified; but the idea of something resembling a rectangle is that which is implied when speaking of a square key.

While drawing a rectangular key upon the anvil, it is necessary to watch the form that is produced by presenting each side to the hammer. If the key is improperly placed, the form of a rhombus will be produced; and if the width of the iron or key greatly exceeds its thickness, a rhomboid will result. Both these forms result from the blows being delivered at the wrong angle to the side of the work, either by the hand-hammer or steam-hammer. To produce again the proper form is always easy, by presenting the longest diameter of the rhomboid or rhombus to the direction of the hammer's blow, which may be either vertical or horizontal; consequently, under the vertical steam-hammer, the proper position in which to place the longest diameter of the piece of work in hand is vertical, as shown by Fig. 81. By placing the work in this position, the two prominent corners or projections are battered in by the hammer, after which the work is drawn down by hammering the four sides that are required.

All kinds of rectangular keys are flattened by a flatter, shown by Fig. 79, or by a short thick set-hammer (Fig. 80). By careful flattening, keys may be nicely reduced to the finished width and thickness, when it may be necessary to avoid the planing process. The amount of time saved by a careful use of the flatter and several pairs of callipers is very great. Previous to adjusting the callipers, the finished width and thickness of the keys required are ascertained by measuring the key-beds or key-ways, and not by referring to any kind of sketch or drawing, which would be useless in such cases. The callipers are adjusted to allow only sufficient to fit the key to its place by filing; and when convenient, the key is also put into its key-way a few times, previous to being finished by the flatter. During the final reducing by the flatter, the square is used to ascertain if the work is rectangular and straight.

Gibs.—A gib is also a kind of angular key, because it is used to prevent the two arms of the strap (Fig. 25) from opening while in use.

The simplest method of making gibs is by cutting out a piece from a bar which is the width and thickness of the gib required. The bar is supported by a screw-prop, while the shape of the piece to be cut out is marked upon both sides of the bar by means of a pencil and straight-edge, and the chisel for cold iron is driven into the middles of the pencil-marks, after which the piece is cut out, while at a yellow heat. It is necessary to cut the piece small enough to allow the gib to be afterwards flattened by the flatter to the required dimensions.

This mode of making gibs is available is cases of emergency or break-down; but the economical method is by the fuller, and the application of the rule given in page 8. When the length of iron or steel required is ascertained by this means, two dents are put into the edge of the bar while cold; the distance between these two marks is the length of bar required to produce the required length of the opening or gap in the gib. After being marked, it is heated and fullered at the two marks by driving in a fuller, as shown by Fig. 82. The top fuller only is required; after which, reduce the middle portion to the required width and thickness by hammering, and the gap in the gib will then be of proper length.

Strap Keys.—A key for a strap is termed a cotter; and if the name were not used for any other kind of key, the term would be significant; but it is also used for piston-rod keys, crank-pin keys, and keys in the ends of bolts; by such usage the name cotter is more confusing than definite. The better plan would be to apply the term only to those keys which have rows of small holes bored in the small ends for the admission of split-pins. The name cotter would be suited to such keys, because they are neither split-keys nor gibs.

A key intended for a strap is thoroughly welded to allow the pin-holes to be bored into solid metal; and strap-keys that require frequent fixing and unfixing may be made of soft steel. Small strap-keys, being without heads, are quickly and conveniently made by tapering the end of a long bar, and cutting off each key, when reduced to its dimensions, by means of the anvil-chisel and stop, which is placed upon the anvil-measure, as in Fig. 85. When a large number of taper keys are required, the author's rule mentioned in page 8 is useful, in order to ascertain the precise quantity of iron or steel necessary to produce the required length of key.

Screw Keys.—Some kinds of taper keys have screwed ends, for the convenience of having a nut to prevent the key slipping back from its place while in use. The longitudinal axis of the portion intended for the screw is sometimes in the same line with the longitudinal axis of the taper part of the key; it is always necessary for the smith to know the required position, that he may not leave a larger quantity of iron for turning than is sufficient when the part to be screwed is in its proper position.

After the extremity is carefully welded and curved, the reducing to form the stem is commenced by top and bottom fullers. These are driven in at the spot intended to be the termination of the taper portion, and the commencement of the screw part. This screw part or stem is first made eight-sided by reducing with the hammer, and then rounded by means of angular gap tools, which thoroughly close together the fibres of the iron; if this is not done, a good screw cannot be produced on the key-stem. If the extremity of this stem is hollow or concave, instead of being properly curved, there is a liability of the stem becoming split in some part, although the outside may appear solid. The split could be remedied by welding, but in some cases the stem would then be too small. One kind of split-stem is shown by Fig. 83.

Bolts.—Bolts are made in such immense numbers, that a variety of machinery exists for producing small bolts by compression of the iron while hot into dies. But the machinery is not yet adapted to forge good bolts of large size, such as are daily required for general engine-making. Good bolts of large diameters can now be made by steam-hammers at a quick rate; and small bolts of good quality are made in an economical and expeditious manner by means of instruments named bolt-headers. There is a variety of these tools in use, and some are valuable to small manufacturers because of being easily made, and incurring but little expense. The use of a bolt-header consists in upsetting a portion of a straight piece of iron to form the bolt-head, instead of drawing down or reducing a larger piece to form the bolt-stem, which is a much longer process; consequently, the bolt-header is valuable in proportion to its capability of upsetting bolt-heads of various sizes for bolts of different diameters and lengths.

The simplest kind of heading-tool is held upon the anvil by the left hand of the smith, while the piece to be formed into a head is hammered into a recess in the tool, the shape of the intended head. Three or four recesses may be drilled into the same tool, to admit three or four sizes of bolt-heads. Such a tool is represented by Fig. 86; and is made either entirely of steel, or with a steel face, in which are bored the recesses of different shapes and sizes.

The pieces of iron to be formed into bolts are named bolt-pieces. When these pieces are of small diameter or thickness, they are cut to a proper length while cold by means of a concave anvil-chisel and stop, shown by Fig. 87, or by a large shearing-machine, if one be on the premises. One end of each piece is then slightly tapered while cold by the hand-hammer or a top-tool. This short bevel or taper portion allows the bolt to be driven in and out of the heading-tool several times without making sufficient ragged edge to stop the bolt in the hole while being driven out. Those ends that are not bevelled are then heated to about welding heat, and upset upon the anvil or upon a cast-iron block, on, or level with the ground. This upsetting is continued until the smaller parts or stems will remain at a proper distance through the tool; after which, each head is shaped by being hammered into the recess. During the shaping process, the stem of the bolt protrudes through the square hole in the anvil, as indicated by the Figure (86).

This method is the cheapest that can be adopted by a maker of small numbers of bolts, because no expensive machinery is necessary. Bolts with conical heads, represented by Fig. 6, when of small size, are easily made by means of the heading-tool just referred to. The recesses in the tool are carefully and smoothly bored to the depths and diameters of the bolt-heads. And if a stop is to be forged solid with the bolt-head, such as Fig. 6 indicates, a straight groove is filed into one side of the recess with a small round file, the shape of the groove being the shape of the intended stop. This method of forging a stop in one piece with the bolt-head is very simple; the stop being formed by the same hammering and at the same time as the head itself. For several kinds of work such conical heads do not require to be fitted by being turned in a lathe; in such cases a large amount of time is economised that would be occupied in fitting separate stops to the heads.

But when a large number of small bolts are required in a short time, a larger kind of heading-tool is made use of, which is named bolt-header. One of these, indicated by Fig. 89, is a jointed bolt-header. Another, of simpler character, is shown by Fig. 90. The actual height of these headers depends upon the length of bolts to be made, because the pieces of which the bolts are formed are cut of a suitable length to make the bolts the proper length after the heads are upset; consequently, bolt-headers are made two or three feet in height, that they may be generally useful.

The header represented by Fig. 89 contains a movable block B, upon which rests one end of a bolt-piece to be upset; it is therefore necessary to raise or lower the block to suit various lengths of bolts. In the header shown by Fig. 90 the movable block is not needed; the bolt-pieces being supported by various lengths of iron, differing in length according to the different lengths of the intended bolts. The pieces that are below the bolt are prop-pieces; two or three of them are sometimes necessary to maintain the bolt-pieces at the exact height. In the top of the header is a circular steel die, D, through the opening in which the bolt-piece is put, in order to be upset. The dies are of various sizes, and each die is tightly fixed into a die-block. The outside of every block, being of the same size and shape, each one fits the opening in the top of the header, which may be six-sided or circular. All the die-blocks are taper, to admit of being easily placed in or taken out of the header. The dies are smoothly bored, and the upper edges of the holes are carefully curved previous to hardening. This smooth curve prevents the die cutting the iron while being driven down to form the bolt-head. In the figure the bolt is shown on the die after the head is upset. Under the head are dots to indicate the bolt-stem and the prop-pieces below, which maintain the bolt-pieces at the height desired; consequently, if the pieces were previously cut to a suitable length, the bolts when forged are of correct length, and their heads of the proper thickness.

After the head is upset, the bolt is driven out of the die. This is effected by the hammerman striking the short lever L, at the bottom of the apparatus. The outside end of this lever being struck by the sledge-hammer, the inside end is raised, and the prop-pieces also, which drive out the bolt, while the smith holds the bolt-head with the tongs. To prevent the die-block being driven out at the same time, a key is fitted across the side of the block, pointed out in the figure by K. But in the jointed bolt-header two half-dies are used, which are opened sideways by a treadle, to allow the bolt to be taken out, instead of being driven out by a sledge-hammer.

Small bolts sometimes require square holders, by which the bolts are held while being turned in a lathe, or while being ground after being hardened. The holder is similar to that shown in Fig. 59. In small bolts the holder is drawn down from the head; for larger bolts the holder is reduced from the stems, to avoid the longer process of reducing from the heads.

The ordinary vertical steam-hammer is very efficient for bolt-making. By its powerful aid, bolts are quickly made by reducing the iron to form the stems, instead of upsetting iron of smaller diameter to form the heads. Large bolts for engines of all kinds demand extra care, because of their important uses; and also because much time is needlessly consumed in the lathe process with bolts that are badly made or forged too large. The tough Low Moor iron is exceedingly good, and should be used for all bolts of importance, such as connecting-rod bolts, main-shaft bolts, and coupling bolts.

Large numbers of small bolts are forged to a gauge, that they may be screwed easily by dies, the bolt being neither too large nor too small. A bolt to be screwed by dies need not be forged larger than the finished diameter of the screw; but frequently it is necessary to forge it smaller. The precise amount smaller depends upon the kind of screwing-dies used at the time, which will be demonstrated in its place. The safe method of proceeding is by carefully rounding one or two bolts and screwing them, previous to forging the total number necessary. These are rounded to the diameter of the one that was found to be correct, a gauge being made thereto. If all dies were so constructed as to cut equally and similar to each other, it would be convenient to make standard gauges by which to round the bolt-ends, and the result would be good screws without the bolts being too large.

All bolts, large and small, that are to be turned in a lathe require the two extremities to be at right angles to the length of the bolt, to avoid waste of time in centring previous to the turning process; and connecting-rod bolts, and main-shaft bolts require softening, which makes them less liable to break in a sudden manner; and it is important to remember that hammering a bolt while cold will make it brittle and unsafe, although the bolt may contain more iron than would be sufficient if the bolt were soft. Great solidity in a bolt is only necessary in that portion of it which is to be formed into a screw. The bolt is less liable to break if all the other parts are fibrous, and the lengths of the fibres are parallel to the bolt's length. But in the screw, more solidity is necessary, to prevent breaking off while the bolt is being screwed, or while in use. However good the iron may be, the bolt is useless if the screw is unsound; and it is well to apply a pair of angular-gap tools (Fig. 64) to the bolt-end while at welding heat.

When Bessemer iron or steel is selected for bolts, it is particularly necessary to reject all the brittle varieties, of which there is a large number. It is much safer to reject Bessemer product altogether for bolt-making, until the process shall have become more capable of producing a tough, reliable metal, sufficiently tenacious to resist the vibration and straining to which all bolts are subjected. Although Bessemer product will sustain a greater tensile strain than Low Moor iron, it would be highly improper to use such product for bolts unless it would bear the same amount of bending, twisting, or vibration as Low Moor iron. We know by experience that this iron, generally, is far superior to any kind of Bessemer product for bolts ; consequently, we must continue to use Low Moor iron until the Bessemer process can supply our requirements at a cheap rate.

Small connecting-bolts, not more than two or three inches in diameter, are made in an economical manner by drawing down the stems by a steam-hammer. Those who have not a steam-hammer will find it convenient to make a collar (Fig. 91) to be welded on a stem, in order to form a head, as shown by Fig. 92. After being welded, the head may be made circular or hexagonal, as required. The tools for shaping hexagonal heads are indicated by Fig. 93, and also by Fig. 94, which is the more convenient of the two. Such an apparatus may be adapted to a number of different sizes by fixing the sliding part of the tool at any required place along the top of the block, in order to shape heads of several different diameters. The movable or sliding block is denoted in the figure by S.

Fig. 8 represents a bolt with circular head and stop. This kind of bolt is used principally for piston-rods and connecting-rods, and requires proper fitting by being turned in lathes, and the stops are not forged solid with the heads, but are tightly fitted in the holes or slots, which are made for the purpose after the bolts are turned; consequently, the smith forges the bolts as if no stops were intended.

Small bolts with six-sided heads (Fig. 9) may be quickly made by means of a small heading-tool similar to Fig. 86, if the recess for shaping the heads is slightly tapered to allow the bolts to be driven out easily from the tool. Large bolts with six-sided heads are made of two pieces; one to be formed into the head, and the other piece the stem. The piece for the head, previous to being welded to the stem, is named a collar. By referring to Fig. 92, it may be observed that the collar is short enough to form a gap or opening between the two ends, after being wrapped tightly round the bolt-stem. By this means the collar, when welded by a pair of angular-gap tools, is both closed together and united to the bolt-stem at the same hammering; and if the collar is of a suitable thickness previous to welding, the bolt-head, when produced, will be of the desired dimensions.

To make a bolt-head by such means, it is not necessary that the bolt should be at welding heat to the centre; it is sufficient if the outside of the bolt-stem is at welding heat at the time the collar is in similar condition. To promote an easy weld, the iron of which the collar is formed should be of the same tendency to fusibility as the iron for the stem, both pieces being of tough Low Moor iron. The collar will thus arrive at welding heat about the same moment as the outside of the bolt-stem. Low Moor iron requires a very great heat for welding; and if attempt should be made to weld a collar of impure fusible iron to a bolt of fibrous Low Moor iron, the collar would fuse and burn to clinker before a welding heat could be obtained in the superior metal.

But there exists no absolute necessity for welding a head to the bolt; for many kinds of work it is sufficient if the two ends of the collar are welded to each other. The bolt-head is permanently fixed by upsetting about an eighth of an inch of the bolt-stem at the outside end of the collar. Previous to welding, the bolt-stem is allowed to protrude only an eighth of an inch beyond the collar; and during the welding, the eighth of an inch is upset or riveted, and the shape of that part of the bolt within the head becomes conical, and the larger diameter of the cone is outwards, so that the strain upon the bolt-head while in use tends to tighten instead of loosen it, the head being hindered from slipping off by the conical shape of the bolt-stem, although the one may not be, and frequently is not, welded to the other.

Key-Head Bolts.—Fig. 10 represents a key-head bolt, with a slot for a key, which is driven into the slot or key-way after the bolt is put into its place; such bolts being used in circumstances that do not allow room for an ordinary bolt-head. In many cases a careful smith can cut the key-ways by punching, thus avoiding the drilling process. The punching is performed by thin oblong punches instead of round ones. If a key-way of considerable length is required, the bolt is placed into a half-round bottom tool, and a small hole or slit is first punched at each end of the place of the intended key-way; the middle portion is next punched out in small pieces by the same punch. By driving the punch half way through the bolt from both sides of it, instead of from one side only, the key-way is made tolerably central. If a short key-way only is desired, the punching is performed with a punch whose end fits the intended key-way.

After being punched, a steel taper drift is driven into the opening, which becomes gradually smoother and larger, till the required dimensions are attained. The angle subtended by any two sides of these drifts should not exceed one degree; for this reason the lengths of the drifts require to be three or four times the thickness of the bolt to be punched or drifted. The extremities of the drifts are curved, to avoid trouble in driving them into and out of the key-ways.

During the use of the drifts and punches, a slot-bolster is between the work and the anvil, to permit the small end of the punch or drift to project into the slot. The dimensions of the slot are greater than of the required key-way in the bolt; and the height or width of the bolster from the anvil is sufficient to prevent the point or extremity of the drift touching the anvil while being driven into the key-way.

The drift being of taper character, renders the key-way also taper. By driving the drift to an equal distance from both sides of the bolt, the key-way becomes larger at the two mouths than at the centre of the bolt. Parallelism of the key-way is attained by means of a parallel filler. This filler is made of steel, and to the exact dimensions of the intended key-way. While the filler is in, the bolt is rounded by rounding-tools, which produces the required cylindrical form for the bolt, and at the same time the desired parallelism in the key-way. If the bolt becomes nearly cold while the filler remains in the key-way, it is necessary to re-heat the part, that the filler may be easily driven out by a soft iron punch or drift.

Flange Bolts.—Fig. 11 represents a collar bolt or flange bolt. Such bolts are much used in engine-making, large and small. The quickest method of forging small bolts of this character is by drawing down or reducing the two stems from a rod or bar which is rather larger in diameter than the collar required. In the Figure the two stems are indicated by A and B. The reducing by fullers and ordinary hammers is a quicker process for small and short work than the method of making separate collars and afterwards welding them to their places. Collar bolts of great length are made by welding on separate collars, to avoid the lengthy process of reducing a piece of iron of large diameter. In a collar bolt, the strain upon the bolt while in use affects the collar in a small degree only; the principal strain is that of the nut below at the moment the bolt is fixed to its place, after which the working strain upon the upper stem of the bolt removes the strain exerted upon the collar by the nut below. Consequently, if the flange is not thoroughly welded, no great harm will result from that circumstance. But in all cases that require a clean, solid appearance to the bolts after the lathe process, great care in welding is necessary to promote the desired result.

If the smith who makes them receives proper instructions, he will observe that a screw is to be formed at each end of the bolt, and he will be careful to weld each end to ensure the necessary solidity in the screw. After the collar is welded, a square is needed to ascertain whether the sides of the collar are at right angles to the two stems, or whether too thick or irregular in one or more places; if so, a set-hammer is used to rectify the irregularities; and if the collar is too thick, a trimming or paring chisel is preferable to cut off the ragged projections while hot; much time is thereby saved from the lathe process. The larger the bolt, the greater is the importance of the collar being at right angles and of suitable dimensions previous to the bolt being turned and screwed by a lathe.

Instead of bolts with circular flanges, bolts with four-sided flanges are sometimes used. The methods of making these consist either in drawing down the stems from a square bar, or in welding a collar to a circular bolt in the ordinary manner, and squaring the collar while at a welding heat by applying large angular gap-tools.

Nut-head Bolts.—These are indicated by Fig. 12. Small bolts of this character are termed studs, when one end of the bolt is to be permanently fixed by being screwed tight into a hole, instead of a separate nut being used. When a nut is required for each end, the bolt is named a nut-head bolt. These are made use of when it is necessary to put the bolt into its place without disarrangement of machinery. Such bolts are also frequently used as holdfast bolts for framing, also for securing or holding down cylinders and condensers. Small studs or bolts of this kind are sometimes forged to a diameter suitable for screwing by dies, instead of being turned and screwed in a lathe by change-wheels. During the rounding and reducing of the bolts to the precise diameter required, gap-gauges or callipers are necessary to measure the bolts in a convenient and correct manner.

Bolts of all kinds, large and small, are injured by the iron being overheated, which makes it rotten and hard, and renders it necessary to cut off the burnt portion, if the bolt is large enough; if not, a new one should be made in place of the burnt one.

Long bolts that require the lathe process are carefully straightened. This is conveniently effected by means of a strong lathe, which is placed in the smithy for the purpose. Long bolts are also straightened in the smithy by means of a long straight-edge, which is applied to the bolt-stem to indicate the hollow or concave side of the stem. This concave side is that which is placed next to the anvil-top, and the upper side of the bolt is then driven down by applying a curved top-tool and striking with a sledge-hammer. This mode is only available with bolts not exceeding two or three inches diameter and of length convenient for the anvil, because in some cases bolts require straightening or rectifying in two or more places along the stems. If a bolt six feet in length is bent one foot from one end, the bent portion is placed upon an anvil, while the longer portion is supported by a crane, and a top-tool is applied to the convex part. The raising of the bolt-end to any required height is effected by rotating a screw which raises a pulley, upon which is an endless chain; the work being supported by the chain, both chain and work are raised at one time. It is necessary to adjust the work to the proper height while being straightened; if not, the hammering will produce but little good effect. The amount of straightening necessary depends upon the diameters to which the bolts are forged, and also upon their near approach to parallelism. A small bolt not exceeding one and a half inches in diameter need not be forged more than a tenth of an inch larger than the finished diameter; a bolt about two inches diameter, only an eighth larger; and for bolts four or five inches in diameter and four or five feet in length, a quarter of an inch for turning is sufficient, if the bolts are properly straightened and in tolerable shape. This straightening and shaping of an ordinary bolt is easily accomplished while hot, by the method just mentioned; other straightening processes, for work of more complicated character, will be given as we proceed.

After the bolts are made sufficiently near to straightness by a top-tool, the softening is effected by a treatment similar to that adopted for softening steel, which consists in heating the bolts to redness and burying them in coke or cinders till cold. A little care is necessary while heating the bolts to prevent them being bent by the blast. To avoid this result, the blast is gently administered and the bolt frequently rotated and moved about in the fire.

Nuts.—The simplest method of making small nuts is by punching with a small punch that is held in the left hand; this punch is driven through a bar near one end of it, which is placed upon a bolster on the anvil, while the other end of the bar is supported by a screw-prop. This mode is adapted to a small maker whose means may be very limited. By supporting the bar or nuts in this manner, it is possible for a smith to work without a hammerman. A bar of soft Low Moor iron is provided, and the quantity of iron that is required for each nut is marked along the bar by means of a pencil, and a chisel is driven into the bar at the pencil-marks while the bar is cold. A punch is then driven through while the iron is at a white heat. Each nut is then cut from the bar by an anvil-chisel, and afterwards finished separately while on a nut-mandril. The bar on the bolster is shown by Fig. 95, and a nut-mandril for finishing is indicated by Fig. 96.

A more economical method, suitable for a smith who has a hammerman, is by punching with a rod-punch, which is driven through by a sledge-hammer. By this means several nuts are punched at one heating of the bar, and also cut from the bar at the same heat. A good durable nut is that in which the hole is made at right angles to the layers or plates of which the nut is composed. Some kinds of good nut iron are condemned because of these plates, which separate when a punch is driven between them instead of through them. By punching through the plates at right angles to the faces of the intended nuts, the iron is not opened or separated, and scarfing is avoided. Nuts that have a scarf-end in the hole require boring, that the hole may be rendered fit for screwing; but nuts that are properly punched may be finished upon a nut-mandril to a suitable diameter for the screw required. Nuts for bolts not exceeding two and a half or three inches diameter can be forged with the openings or holes of proper diameter for screwing by a tap. The precise diameter is necessary in such cases, and is attained by the smith finishing each nut upon a nut-mandril of steel, which is carefully turned to its shape and diameter by a lathe. The mandril is taper and curved at the end, to allow the nut to fall easily from the mandril while being driven off. Such nut-mandrils become smaller by use, and it is well to keep a standard gauge of some kind by which to measure the nuts after being forged. The best kind of nut-mandril is made of one piece of steel, instead of welding a collar of steel to a bar of iron, which is sometimes done.

One punch and one nut-mandril are sufficient for nuts of small dimensions, but large ones require drifting after being punched and previous to being placed upon a nut-mandril. The drifting is continued until the hole is of the same diameter as the mandril upon which the nut is to be finished. The nut is then placed on, and the hole is adjusted to the mandril without driving the mandril into the nut, which would involve a small amount of wear and tear that may be avoided. A good steel nut-mandril, with careful usage, will continue serviceable, without repair, for several thousands of nuts.

The holes of all nuts require to be at right angles to the two sides named faces; one of these faces is brought into contact and bears upon the work while the nut is being fixed; consequently, it is necessary to devote considerable attention to the forging, that the turning and shaping processes may be as much as possible facilitated. If the two faces of the nut are tolerably near to a right angle with the hole, and the other sides of the nut parallel to the hole, the nut may be forged much nearer to the finished dimensions than if it were roughly made or malformed.

To rectify a nut whose faces are not perpendicular to the opening, the two prominent corners or angles are placed upon an anvil to receive the hammer, as indicated in Fig. 97. By placing a nut while at a yellow heat in this position, the two corners are changed to two flats, and the faces become at the same time perpendicular to the opening; the nut is then reduced to the dimensions desired. If the nut is too long, and the sides of it are parallel to the opening, the better plan is to cut the prominences from the two faces by means of a trimming-chisel (Fig. 84), instead of rectifying the nut by hammering. Cutting off scrap-pieces while hot with a properly-shaped chisel of this kind, is a much quicker process than cutting off in a lathe.

Hexagonal Nuts.—The most useful kind of nut at the present time is of hexagonal form, and is indicated by Fig. 13. Such nuts, if small, are made at a quick rate by being compressed and punched in steel dies, which are fitted to machinery specially made for the purpose. But we have no machinery for making large nuts so efficient as the steam-hammer. Large nuts are easily punched and drifted by a steam-hammer while the nuts are attached to the bars from which they are made. The drifts for steam-hammers are short and comparatively thick, and the bolsters underneath the nuts are of similar proportions. When a sufficient number of nuts are punched, drifted, and cut from the bars, the shaping of the six sides is effected by placing and hammering each nut in a three-sided tool, or anvil block. The nut is held in this shaping-tool by means of a drift or mandril, having a long handle. This handle enables the smith to rotate the nut during the hammering, in order to produce the hexagonal form desired. The nuts are placed in a large forge fire or furnace, and heated to welding heat; one nut is taken out when sufficiently heated, and the slag that may be in the opening is quickly scraped out, and the mandril or drift is then put in; the hammering upon the outside will then form the six sides without affecting the cylindrical form of the opening in the nut.

Flange Nuts.—Fig. 14 indicates a six-sided flange nut. These are useful to obtain a large bearing for the nut's face, without using a heavy nut. And if contact with angles or corners is to be avoided, the flange is curved as in Fig. 17, which denotes a handsome nut, well adapted to bear upon brass or gun metal, or other soft metal, without wearing or tearing the surfaces in contact. The forging of flange nuts is performed by forcing the iron while at a welding heat into top and bottom tools, which are made to the required shape. Each nut is punched and cut from the bar and afterwards heated to welding, and then compressed to shape by striking the top-tool while the nut is on a mandril held by the workman. The mandrils for welding and shaping the outsides of nuts need not to be turned by a lathe, because the opening in each nut is afterwards shaped and finished by a finishing mandril specially made for the purpose (Fig. 96).

Stop-Ring Nuts.—Fig. 15 points out an ordinary hexagonal nut for a stop-ring, which is indicated by Fig. 16. This kind of nut is much used by engineers, who consider it a sort of safety nut, by reason of the set-screw in the ring having some tendency to prevent the nut unscrewing through straining or vibration of the machinery while at work.

Nuts of this character are made by cutting partly through a bar and doubling or trebling the bar, and thoroughly welding the layers while in that relation. While the lump is still attached to the bar, the opening is made by a punch driven through at right angles to the layers, and the opening is then drifted to any required diameter; after which the nut is cut from the bar, and another doubling and welding is effected to produce another nut. When the desired number is obtained, the outside of each nut is shaped while at a welding heat.

The short cylindrical portion named the stem is formed sometimes by cutting off the six corners or apices by turning-tools, and at other times by cutting off the pieces while hot upon the anvil, which is a much quicker process. The nuts are marked while cold by means of a chisel, which is driven in at the spot which marks the required forged length of the stem; they are then heated to a light yellow heat, and the pieces are cut from the stems with a trimming-chisel and light hammer. Each nut is placed upon a mandril, and while supported by an angular-gap tool in the square opening of an old-fashioned anvil, the chisel is driven in at the marks to the distance required; after which the nut is taken from the mandril and placed with the face-side upwards upon the anvil; while the nut is in this position and gripped by a tongs with large jaws, the chisel is driven down to meet the extremities of the six incisions previously made, and the scrap-pieces are thus cut from the stem in an easy manner.

Nut Rings.—These are indicated by Fig. 16, and are forged by two methods. One mode consists in marking the lengths required for the rings along a bar of iron or steel, and piercing the bar midway between every two marks that denote the amount of iron required for one ring. The openings are made by circular punches, or by circular punches which are both circular and elliptical. Above the elliptical portion the punch gradually increases in diameter, and the shape becomes circular; consequently, it is a circulo-elliptic punch. This kind of punch cuts out but a small piece of metal, and at the same time makes a comparatively large hole, the precise diameter of which depends upon the amount of the punch that is driven through the iron.

The circular form for the outside circumference of the ring is partly developed by cutting off the corners while the ring is still attached to the bar; after being thus trimmed with a chisel, the ring is cut from the bar and shaped while on a mandril. Each ring is heated to welding, and the rounding is performed with top and bottom tools. If it is necessary to enlarge the opening, a taper mandril is used, and the ring is drawn or stretched by hammering the edge of it while tight on the mandril. During this stretching, the mandril and ring are rotated by the smith to produce an equal thickness throughout.

The economical mode of making large rings consists in forming them from a straight bar which is of a suitable width and thickness. The bar is cut into pieces, each being of the length required for one ring. The pieces are thickened at each end, scarfed on opposite sides, then bent to a circular form, and the scarfs welded together.

Previous to cutting off the pieces, the bar is reduced to that thickness which will allow not more than sufficient iron for boring and turning the rings to their finished width and thickness. If the opening of the ring is to be bored in a lathe to $5\frac{3}{4}$ inches diameter, and the thickness of the ring's face-side to be $\frac{5}{8}$ of an inch when finished, the forged thickness of the ring should not exceed $\frac{7}{8}$ of an inch; and this is the thickness to which the bar is to be reduced previous to cutting off the piece or pieces.

If the bar is reduced to the required thickness, the length of each piece should equal the length of the middle circumference of the ring's face. The face-side of a ring is the side which is placed next to the plummer-block cap, or to the connecting-rod cap; and if the required forged thickness of the ring is $\frac{7}{8}$, and the required diameter of the opening or hole when forged $5\frac{1}{2}$ inches, the outer diameter is $7\frac{1}{4}$ inches. The length of the mid-circumference is therefore 20 inches, because its diameter is $6\frac{3}{8}$ inches. The length of bar required for one ring is consequently 20 inches: nothing being allowed for scarfing, because, during the scarfing, nothing is cut off, the scarf being drawn by a fuller while the piece is straight. After 20 inches of the bar $\frac{7}{8}$ thick is scarfed, formed to a circle, welded and flattened; the diameter of the opening is $5\frac{1}{2}$ inches, and the outer diameter is $7\frac{1}{4}$ inches; which will allow rather more metal than an ordinary turner requires, to produce a ring $\frac{5}{8}$ thick, and whose opening is to be finished to $5\frac{3}{4}$ inches as desired.

The precise amount required for boring and turning depends upon the smoothness or roughness of the work; and also upon its form being, or not being, nearly circular. This is attained by rectifying each ring after measuring it with callipers, both inside and outside. After discovering by the callipers which is the longest diameter of the ring's opening, it is rectified by placing the ring upon the anvil with the longest diameter vertical, and striking it by hammer and top-tool.

It is always advantageous to make the bar or piece the proper thickness previous to making the ring; although it is not absolutely necessary, because the ring may be stretched by hammering, after being welded. Previous to welding, the piece may be thicker than the finished forged thickness, but not in any case thinner. Whatever may be the precise thickness of the bar previous to making the rings, the author's rule here given is always applicable:

As the thickness of the bar from which the ring is to be made is to the required forged thickness of the ring, so is the length of the middle circumference of the ring's face-side to the length of bar required for the ring.

The length of the middle circumference is discovered by referring to ordinary tables, or by multiplying the diameter by 3·1416. The diameter of the opening of the ring when forged being $5\frac{1}{2}$ inches, and the forged thickness to be $\frac{7}{8}$; the outer diameter must be $7\frac{1}{4}$, and the mean between $5\frac{1}{2}$ and $7\frac{1}{4}$ must be $6\frac{3}{8}$, which is the diameter of the middle circumference required. Multiplying $6\frac{3}{8}$ by 3·1416 produces 20 and a fraction, too small for us to notice in this case, consequently 20 inches of bar is sufficient to make one ring, if the bar is $\frac{7}{8}$ thick.

But if it should be necessary to use iron which is an inch thick, a shorter length of bar would be sufficient. This is demonstrated by applying the rule and making a ring of a piece of bar which is the length indicated. For example:

$$1 : \cdot875 :: 20\cdot02 : 17\cdot52;$$

the first term denoting the thickness in inches of bar used, the second indicating the required forged thickness of the ring desired, the third term representing the length of its mid-circumference, and the fourth term pointing to the length of inch bar required. This length is $2\frac{1}{2}$ inches shorter than the proper length of bar, which is $\frac{7}{8}$ thick. If bar $\frac{7}{8}$ thick is used, the complete proposition is thus represented:

$$\cdot875 : \cdot875 :: 20\cdot02 : 20\cdot02;$$

twenty inches of $\frac{7}{8}$ bar being used will obviate the necessity of drawing or stretching the ring, either before or after being welded together.

French symbols of dimensions also are given, because of their great utility and simplicity. Seven-eighths of an inch equals 22·2 millimetres, and 20 inches equal 508 millimetres, consequently the proposition appears thus:

$$22\cdot2 : 22\cdot2 :: 508 : 508.$$

In forging a ring we do not require to measure the two-tenths of a millimetre, and the result would meet the requirement if 22 were stated instead of 22·2. But in the case of bar an inch thick being used it would be necessary to state 25·4 instead of 25 ; twenty-five millimetres being about half a millimetre less than one inch. In millimetres, the proposition relating to bar one inch thick is thus written :

25·4 : 22·2 :: 508 : 444.

To ascertain the number of millimetres contained in any mentioned number of inches or parts of inches, it is only necessary to divide the mentioned number by ·03937, always indicating the fractions by decimal symbols; and the quotient or result will indicate the number of millimetres and parts.

And to ascertain the number of inches and parts of inches contained in any mentioned number of millimetres, it is only necessary to multiply the mentioned number by ·03937, and the product or result will indicate the number required. For example, 500 millimetres equal half a metre; and $500 \times {\cdot}03937$ of an inch $= 19{\cdot}685$ inches. And twice this amount of inches is a complete metre of 39·37 inches. A nearer approach to precision is attained by using the fraction indicated by ·0393708, instead of ·03937.

A few dimensions of rings are indicated by the Tables, as examples of lengths of iron required for the different diameters.

Table 1 contains only the diameters and circumferences of the mean or middle circles of the face-sides, the lengths of bar required being the same as the lengths of the circumferences. These dimensions are only available when the thickness of the bar is the same as that of the ring when forged, whatever the required thickness may be. If a ring is to be 11·5 centimetres in diameter at the mean or mid-circle of the face, the necessary length of bar is 36·12 centimetres, which is pointed to in the Table at line 14. The thickness of the bar may be 1, 2, or 3 centimetres, being the same as that of the ring itself.

But if it is necessary to use remnants of bar which are thicker than the rings intended, the necessary length of bar for making a ring of the mentioned diameter may be seen in Table 2; if not in this Table, the length may at any time be ascertained by applying the rule just given.

By reference to line 109 of Table 2 it will be perceived that $9\frac{1}{2}$ inches of bar $\frac{7}{8}$ thick is sufficient for a ring whose mid-circle diameter is to be $4\frac{1}{4}$ inches, and forged thickness to be $\frac{5}{8}$. And if remnants of $\frac{7}{8}$ bar are to be used, it may be known what lengths of remnants are required for drawing down to $\frac{5}{8}$ thick. Also by referring to line 135 in the same Table, it will be perceived that $49\frac{1}{2}$ inches of bar one inch thick may be drawn down or reduced in order to make a ring which is required to be $\frac{3}{4}$ thick, and whose mid-circle diameter is to be 21 inches.

When cutting the lengths of bar, it is not necessary to add any for scarfing, because whatever amount of iron may be upset will be afterwards drawn down in welding; but if the iron is to be heated a number of times, an eighth of an inch should be added for that which may be burnt or taken from the iron by the fire.

The width of a ring is sometimes named its height. No mention is here made of the widths or heights of rings, because their widths are the same as the widths of the bars of which the rings are made; consequently, the widths of rings are independent of the dimensions here given and referred to.

TABLE 1.

Line.	Diameters of mean-circles of face-sides of rings, in centimetres.	Lengths of circumferences of mean-circles of face-sides of rings, in centimetres.	Line.	Diameters of mean-circles of face-sides of rings, in centimetres.	Lengths of circumferences of mean-circles of face-sides of rings, in centimetres.	Line.	Diameters of mean-circles of face-sides of rings, in centimetres.	Lengths of circumferences of mean-circles of face-sides of rings, in centimetres.
1 . . .	5	15·7	21 . . .	15	47·12	41 . . .	25	78·54
2 . . .	5·5	17·27	22 . . .	15·5	48·69	42 . . .	25·5	80·1
3 . . .	6	18·84	23 . . .	16	50·26	43 . . .	26	81·68
4 . . .	6·5	20·42	24 . . .	16·5	51·83	44 . . .	26·5	83·25
5 . . .	7	21·99	25 . . .	17	53·4	45 . . .	27	84·82
6 . . .	7·5	23·56	26 . . .	17·5	54·97	46 . . .	27·5	86·39
7 . . .	8	25·13	27 . . .	18	56·54	47 . . .	28	87·96
8 . . .	8·5	26·7	28 . . .	18·5	58·11	48 . . .	28·5	89·53
9 . . .	9	28·27	29 . . .	19	59·69	49 . . .	29	91·1
10 . . .	9·5	29·84	30 . . .	19·5	61·26	50 . . .	29·5	92·67
11 . . .	10	31·41	31 . . .	20	62·83	51 . . .	30	94·24
12 . . .	10·5	32·98	32 . . .	20·5	64·4	52 . . .	30·5	95·81
13 . . .	11	34·55	33 . . .	21	65·97	53 . . .	31	97·38
14 . . .	11·5	36·12	34 . . .	21·5	67·54	54 . . .	31·5	98·96
15 . . .	12	37·69	35 . . .	22	69·11	55 . . .	32	100·53
16 . . .	12·5	39·27	36 . . .	22·5	70·68	56 . . .	32·5	102·1
17 . . .	13	40·84	37 . . .	23	72·25	57 . . .	33	103·67
18 . . .	13·5	42·41	38 . . .	23·5	73·82	58 . . .	33·5	105·24
19 . . .	14	43·98	39 . . .	24	75·39			
20 . . .	14·5	45·55	40 . . .	24·5	76·96			

TABLE 2.

Line.	Required forged thickness of rings' face-sides; or distances from the inner circumferences to the outer.	Diameters of mean-circles of rings' face-sides.	Lengths of circumferences of the mean-circles of rings' face-sides.	Lengths of bar required.	Thickness of bar from which the rings are made	Line.	Required forged thickness of rings' face-sides; or distances from the inner circumferences to the outer.	Diameters of mean-circles of rings' face-sides.	Lengths of circumferences of the mean-circles of rings' face-sides.	Lengths of bar required.	Thickness of bar from which the rings are made.
	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	Inches.
1 . . .	$\frac{1}{4}$	1	$3\frac{1}{8}$	$3\frac{1}{8}$	$\frac{1}{4}$	23 . . .	$\frac{3}{8}$	$3\frac{3}{8}$	$10\frac{9}{16}$	$10\frac{9}{16}$	$\frac{3}{8}$
2 . . .	$\frac{1}{4}$	$1\frac{1}{8}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{1}{4}$	24 . . .	$\frac{3}{8}$	$3\frac{1}{2}$	11	11	$\frac{3}{8}$
3 . . .	$\frac{1}{4}$	$1\frac{1}{4}$	$3\frac{15}{16}$	$3\frac{15}{16}$	$\frac{1}{4}$	25 . . .	$\frac{3}{8}$	$3\frac{5}{8}$	$11\frac{3}{8}$	$11\frac{3}{8}$	$\frac{3}{8}$
4 . . .	$\frac{1}{4}$	$1\frac{3}{8}$	$4\frac{5}{16}$	$4\frac{5}{16}$	$\frac{1}{4}$	26 . . .	$\frac{3}{8}$	$3\frac{3}{4}$	$11\frac{3}{4}$	$11\frac{3}{4}$	$\frac{3}{8}$
5 . . .	$\frac{1}{4}$	$1\frac{1}{2}$	$4\frac{11}{16}$	$4\frac{11}{16}$	$\frac{1}{4}$	27 . . .	$\frac{3}{8}$	$3\frac{7}{8}$	$12\frac{3}{16}$	$12\frac{3}{16}$	$\frac{3}{8}$
6 . . .	$\frac{1}{4}$	$1\frac{5}{8}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$\frac{1}{4}$	28 . . .	$\frac{3}{8}$	4	$12\frac{9}{16}$	$12\frac{9}{16}$	$\frac{3}{8}$
7 . . .	$\frac{1}{4}$	$1\frac{3}{4}$	$5\frac{1}{2}$	$5\frac{1}{2}$	$\frac{1}{4}$	29 . . .	$\frac{3}{8}$	$4\frac{1}{8}$	$12\frac{15}{16}$	$12\frac{15}{16}$	$\frac{3}{8}$
8 . . .	$\frac{1}{4}$	$1\frac{7}{8}$	$5\frac{7}{8}$	$5\frac{7}{8}$	$\frac{1}{4}$	30 . . .	$\frac{3}{8}$	$4\frac{1}{4}$	$13\frac{3}{8}$	$13\frac{3}{8}$	$\frac{3}{8}$
9 . . .	$\frac{1}{4}$	2	$6\frac{5}{16}$	$6\frac{5}{16}$	$\frac{1}{4}$	31 . . .	$\frac{3}{8}$	$4\frac{3}{8}$	$13\frac{3}{4}$	$13\frac{3}{4}$	$\frac{3}{8}$
10 . . .	$\frac{1}{4}$	$2\frac{1}{8}$	$6\frac{11}{16}$	$6\frac{11}{16}$	$\frac{1}{4}$	32 . . .	$\frac{3}{8}$	$4\frac{1}{2}$	$14\frac{1}{8}$	$14\frac{1}{8}$	$\frac{3}{8}$
11 . . .	$\frac{1}{4}$	$2\frac{1}{4}$	7	7	$\frac{1}{4}$	33 . . .	$\frac{3}{8}$	$4\frac{5}{8}$	$14\frac{1}{2}$	$14\frac{1}{2}$	$\frac{3}{8}$
12 . . .	$\frac{1}{4}$	$2\frac{3}{8}$	$7\frac{7}{16}$	$7\frac{7}{16}$	$\frac{1}{4}$	34 . . .	$\frac{3}{8}$	$4\frac{3}{4}$	$14\frac{15}{16}$	$14\frac{15}{16}$	$\frac{3}{8}$
13 . . .	$\frac{1}{4}$	$2\frac{1}{2}$	$7\frac{7}{8}$	$7\frac{7}{8}$	$\frac{1}{4}$	35 . . .	$\frac{3}{8}$	$4\frac{7}{8}$	$15\frac{5}{16}$	$15\frac{5}{16}$	$\frac{3}{8}$
14 . . .	$\frac{1}{4}$	$2\frac{5}{8}$	$8\frac{1}{4}$	$8\frac{1}{4}$	$\frac{1}{4}$	36 . . .	$\frac{3}{8}$	5	$15\frac{11}{16}$	$15\frac{11}{16}$	$\frac{3}{8}$
15 . . .	$\frac{1}{4}$	$2\frac{3}{4}$	$8\frac{5}{8}$	$8\frac{5}{8}$	$\frac{1}{4}$	37 . . .	$\frac{3}{8}$	$5\frac{1}{8}$	$16\frac{1}{16}$	$16\frac{1}{16}$	$\frac{3}{8}$
16 . . .	$\frac{1}{4}$	$2\frac{7}{8}$	9	9	$\frac{1}{4}$	38 . . .	$\frac{3}{8}$	$5\frac{1}{4}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$\frac{3}{8}$
17 . . .	$\frac{1}{4}$	3	$9\frac{7}{16}$	$9\frac{7}{16}$	$\frac{1}{4}$	39 . . .	$\frac{3}{8}$	$5\frac{3}{8}$	$16\frac{7}{8}$	$16\frac{7}{8}$	$\frac{3}{8}$
18 . . .	$\frac{1}{4}$	$3\frac{1}{8}$	$9\frac{13}{16}$	$9\frac{13}{16}$	$\frac{1}{4}$	40 . . .	$\frac{3}{8}$	$5\frac{1}{2}$	$17\frac{1}{4}$	$17\frac{1}{4}$	$\frac{3}{8}$
19 . . .	$\frac{1}{4}$	$3\frac{1}{4}$	$10\frac{1}{4}$	$10\frac{1}{4}$	$\frac{1}{4}$	41 . . .	$\frac{3}{8}$	$5\frac{5}{8}$	$17\frac{11}{16}$	$17\frac{11}{16}$	$\frac{3}{8}$
20 . . .	$\frac{3}{8}$	3	$9\frac{7}{16}$	$9\frac{7}{16}$	$\frac{3}{8}$	42 . . .	$\frac{3}{8}$	$5\frac{3}{4}$	18	18	$\frac{3}{8}$
21 . . .	$\frac{3}{8}$	$3\frac{1}{8}$	$9\frac{13}{16}$	$9\frac{13}{16}$	$\frac{3}{8}$	43 . . .	$\frac{3}{8}$	$5\frac{7}{8}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$\frac{3}{8}$
22 . . .	$\frac{3}{8}$	$3\frac{1}{4}$	$10\frac{1}{4}$	$10\frac{1}{4}$	$\frac{3}{8}$	44 . . .	$\frac{3}{8}$	6	$18\frac{13}{16}$	$18\frac{13}{16}$	$\frac{3}{8}$

TABLE 2—*continued.*

Line.	Required forged thickness of rings' face-sides; or distances from the inner circumferences to the outer.	Diameters of mean-circles of rings' face-sides.	Lengths of circumferences of the mean-circles of rings' face-sides.	Lengths of bar required.	Thickness of bar from which the rings are made.	Line.	Required forged thickness of rings' face-sides; or distances from the inner circumferences to the outer.	Diameters of mean-circles of rings' face-sides.	Lengths of circumferences of the mean-circles of rings' face-sides.	Lengths of bar required.	Thickness of bar from which the rings are made.
	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	Inches.
45 . . .	$\frac{3}{8}$	$6\frac{1}{8}$	$19\frac{1}{4}$	$19\frac{1}{4}$	$\frac{3}{8}$	97 . .	$\frac{5}{8}$	$3\frac{1}{2}$	11	11	$\frac{5}{8}$
46 . . .	$\frac{3}{8}$	$6\frac{1}{4}$	$19\frac{5}{8}$	$19\frac{5}{8}$	$\frac{3}{8}$	98 . .	$\frac{5}{8}$	$3\frac{3}{4}$	$11\frac{3}{4}$	$11\frac{3}{4}$	$\frac{5}{8}$
47 . . .	$\frac{3}{8}$	$6\frac{3}{8}$	20	20	$\frac{3}{8}$	99 . .	$\frac{5}{8}$	4	$12\frac{9}{16}$	$12\frac{9}{16}$	$\frac{5}{8}$
48 . . .	$\frac{1}{2}$	3	$9\frac{7}{16}$	$9\frac{7}{16}$	$\frac{1}{2}$	100 . .	$\frac{5}{8}$	$4\frac{1}{4}$	$13\frac{3}{8}$	$13\frac{3}{8}$	$\frac{5}{8}$
49 . . .	$\frac{1}{2}$	$3\frac{1}{8}$	$9\frac{13}{16}$	$9\frac{13}{16}$	$\frac{1}{2}$	101 . .	$\frac{5}{8}$	$4\frac{1}{2}$	$14\frac{1}{8}$	$14\frac{1}{8}$	$\frac{5}{8}$
50 . . .	$\frac{1}{2}$	$3\frac{1}{4}$	$10\frac{1}{4}$	$10\frac{1}{4}$	$\frac{1}{2}$	102 . .	$\frac{5}{8}$	$4\frac{3}{4}$	$14\frac{15}{16}$	$14\frac{15}{16}$	$\frac{5}{8}$
51 . . .	$\frac{1}{2}$	$3\frac{3}{8}$	$10\frac{9}{16}$	$10\frac{9}{16}$	$\frac{1}{2}$	103 . .	$\frac{5}{8}$	5	$15\frac{11}{16}$	$15\frac{11}{16}$	$\frac{5}{8}$
52 . . .	$\frac{1}{2}$	$3\frac{1}{2}$	11	11	$\frac{1}{2}$	104 . .	$\frac{5}{8}$	$5\frac{1}{4}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$\frac{5}{8}$
53 . . .	$\frac{1}{2}$	$3\frac{5}{8}$	$11\frac{3}{8}$	$11\frac{3}{8}$	$\frac{1}{2}$	105 . .	$\frac{5}{8}$	$5\frac{1}{2}$	$17\frac{1}{4}$	$17\frac{1}{4}$	$\frac{5}{8}$
54 . . .	$\frac{1}{2}$	$3\frac{3}{4}$	$11\frac{3}{4}$	$11\frac{3}{4}$	$\frac{1}{2}$	106 . .	$\frac{5}{8}$	$5\frac{3}{4}$	18	18	$\frac{5}{8}$
55 . . .	$\frac{1}{2}$	$3\frac{7}{8}$	$12\frac{3}{16}$	$12\frac{3}{16}$	$\frac{1}{2}$	107 . .	$\frac{5}{8}$	6	$18\frac{13}{16}$	$18\frac{13}{16}$	$\frac{5}{8}$
56 . . .	$\frac{1}{2}$	4	$12\frac{9}{16}$	$12\frac{9}{16}$	$\frac{1}{2}$	108 . .	$\frac{5}{8}$	4	$12\frac{9}{16}$	$8\frac{15}{16}$	$\frac{7}{8}$
57 . . .	$\frac{1}{2}$	$4\frac{1}{8}$	$12\frac{15}{16}$	$12\frac{15}{16}$	$\frac{1}{2}$	109 . .	$\frac{5}{8}$	$4\frac{1}{4}$	$13\frac{3}{8}$	$9\frac{1}{2}$	$\frac{7}{8}$
58 . . .	$\frac{1}{2}$	$4\frac{1}{4}$	$13\frac{3}{8}$	$13\frac{3}{8}$	$\frac{1}{2}$	110 . .	$\frac{5}{8}$	$4\frac{1}{2}$	$14\frac{1}{8}$	$10\frac{1}{16}$	$\frac{7}{8}$
59 . . .	$\frac{1}{2}$	$4\frac{3}{8}$	$13\frac{3}{4}$	$13\frac{3}{4}$	$\frac{1}{2}$	111 . .	$\frac{5}{8}$	$4\frac{3}{4}$	$14\frac{15}{16}$	$10\frac{9}{16}$	$\frac{7}{8}$
60 . . .	$\frac{1}{2}$	$4\frac{1}{2}$	$14\frac{1}{8}$	$14\frac{1}{8}$	$\frac{1}{2}$	112 . .	$\frac{5}{8}$	$6\frac{1}{4}$	$19\frac{5}{8}$	$19\frac{5}{8}$	$\frac{5}{8}$
61 . . .	$\frac{1}{2}$	$4\frac{5}{8}$	$14\frac{1}{2}$	$14\frac{1}{2}$	$\frac{1}{2}$	113 . .	$\frac{5}{8}$	$6\frac{1}{2}$	$20\frac{7}{16}$	$20\frac{7}{16}$	$\frac{5}{8}$
62 . . .	$\frac{1}{2}$	$4\frac{3}{4}$	$14\frac{15}{16}$	$14\frac{15}{16}$	$\frac{1}{2}$	114 . .	$\frac{5}{8}$	$6\frac{3}{4}$	$21\frac{3}{16}$	$21\frac{3}{16}$	$\frac{5}{8}$
63 . . .	$\frac{1}{2}$	$4\frac{7}{8}$	$15\frac{5}{16}$	$15\frac{5}{16}$	$\frac{1}{2}$	115 . .	$\frac{5}{8}$	7	22	22	$\frac{5}{8}$
64 . . .	$\frac{1}{2}$	5	$15\frac{11}{16}$	$15\frac{11}{16}$	$\frac{1}{2}$	116 . .	$\frac{5}{8}$	8	$25\frac{1}{8}$	$25\frac{1}{8}$	$\frac{5}{8}$
65 . . .	$\frac{1}{2}$	$5\frac{1}{8}$	$16\frac{1}{16}$	$16\frac{1}{16}$	$\frac{1}{2}$	117 . .	$\frac{5}{8}$	9	$28\frac{1}{4}$	$28\frac{1}{4}$	$\frac{5}{8}$
66 . . .	$\frac{1}{2}$	$5\frac{1}{4}$	$16\frac{1}{2}$	$16\frac{1}{2}$	$\frac{1}{2}$	118 . .	$\frac{5}{8}$	10	$31\frac{7}{16}$	$31\frac{7}{16}$	$\frac{5}{8}$
67 . . .	$\frac{1}{2}$	$5\frac{3}{8}$	$16\frac{7}{8}$	$16\frac{7}{8}$	$\frac{1}{2}$	119 . .	$\frac{5}{8}$	11	$34\frac{9}{16}$	$34\frac{9}{16}$	$\frac{5}{8}$
68 . . .	$\frac{1}{2}$	$5\frac{1}{2}$	$17\frac{1}{4}$	$17\frac{1}{4}$	$\frac{1}{2}$	120 . .	$\frac{5}{8}$	12	$37\frac{11}{16}$	$37\frac{11}{16}$	$\frac{5}{8}$
69 . . .	$\frac{1}{2}$	$5\frac{5}{8}$	$17\frac{11}{16}$	$17\frac{11}{16}$	$\frac{1}{2}$	121 . .	$\frac{3}{4}$	$7\frac{1}{2}$	$23\frac{9}{16}$	$23\frac{9}{16}$	$\frac{3}{4}$
70 . . .	$\frac{1}{2}$	$5\frac{3}{4}$	18	18	$\frac{1}{2}$	122 . .	$\frac{3}{4}$	$8\frac{1}{2}$	$26\frac{11}{16}$	$26\frac{11}{16}$	$\frac{3}{4}$
71 . . .	$\frac{1}{2}$	$5\frac{7}{8}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$\frac{1}{2}$	123 . .	$\frac{3}{4}$	$9\frac{1}{2}$	$29\frac{7}{8}$	$29\frac{7}{8}$	$\frac{3}{4}$
72 . . .	$\frac{1}{2}$	6	$18\frac{13}{16}$	$18\frac{13}{16}$	$\frac{1}{2}$	124 . .	$\frac{3}{4}$	$10\frac{1}{2}$	33	33	$\frac{3}{4}$
73 . . .	$\frac{1}{2}$	$6\frac{1}{8}$	$19\frac{1}{4}$	$19\frac{1}{4}$	$\frac{1}{2}$	125 . .	$\frac{3}{4}$	$11\frac{1}{2}$	$36\frac{1}{8}$	$36\frac{1}{8}$	$\frac{3}{4}$
74 . . .	$\frac{1}{2}$	$6\frac{1}{4}$	$19\frac{5}{8}$	$19\frac{5}{8}$	$\frac{1}{2}$	126 . .	$\frac{3}{4}$	$12\frac{1}{2}$	$39\frac{1}{4}$	$39\frac{1}{4}$	$\frac{3}{4}$
75 . . .	$\frac{1}{2}$	$6\frac{5}{8}$	20	20	$\frac{1}{2}$	127 . .	$\frac{3}{4}$	$13\frac{1}{2}$	$42\frac{7}{16}$	$42\frac{7}{16}$	$\frac{3}{4}$
76 . . .	$\frac{1}{2}$	$6\frac{1}{2}$	$20\frac{7}{16}$	$20\frac{7}{16}$	$\frac{1}{2}$	128 . .	$\frac{3}{4}$	$14\frac{1}{2}$	$45\frac{9}{16}$	$45\frac{9}{16}$	$\frac{3}{4}$
77 . . .	$\frac{1}{2}$	$6\frac{5}{8}$	$20\frac{13}{16}$	$20\frac{13}{16}$	$\frac{1}{2}$	129 . .	$\frac{3}{4}$	$15\frac{1}{2}$	$48\frac{11}{16}$	$48\frac{11}{16}$	$\frac{3}{4}$
78 . . .	$\frac{1}{2}$	$6\frac{3}{4}$	$21\frac{3}{16}$	$21\frac{3}{16}$	$\frac{1}{2}$	130 . .	$\frac{3}{4}$	$16\frac{1}{2}$	$51\frac{13}{16}$	$51\frac{13}{16}$	$\frac{3}{4}$
79 . . .	$\frac{1}{2}$	$6\frac{7}{8}$	$21\frac{9}{16}$	$21\frac{9}{16}$	$\frac{1}{2}$	131 . .	$\frac{3}{4}$	$17\frac{1}{2}$	55	55	$\frac{3}{4}$
80 . . .	$\frac{1}{2}$	7	22	22	$\frac{1}{2}$	132 . .	$\frac{3}{4}$	$18\frac{1}{2}$	$58\frac{1}{8}$	$58\frac{1}{8}$	$\frac{3}{4}$
81 . . .	$\frac{1}{2}$	$7\frac{1}{8}$	$22\frac{3}{8}$	$22\frac{5}{8}$	$\frac{1}{2}$	133 . .	$\frac{3}{4}$	$19\frac{1}{2}$	$61\frac{1}{4}$	$61\frac{1}{4}$	$\frac{3}{4}$
82 . . .	$\frac{1}{2}$	$7\frac{1}{4}$	$22\frac{3}{4}$	$22\frac{3}{4}$	$\frac{1}{2}$	134 . .	$\frac{3}{4}$	20	$62\frac{13}{16}$	$47\frac{1}{8}$	1·0
83 . . .	$\frac{1}{2}$	$7\frac{3}{8}$	$23\frac{3}{16}$	$23\frac{3}{16}$	$\frac{1}{2}$	135 . .	$\frac{3}{4}$	21	66	$49\frac{1}{2}$	1·0
84 . . .	$\frac{1}{2}$	$7\frac{1}{2}$	$23\frac{9}{16}$	$23\frac{9}{16}$	$\frac{1}{2}$	136 . .	$\frac{3}{4}$	22	$69\frac{1}{8}$	$51\frac{13}{16}$	1·0
85 . . .	$\frac{1}{2}$	$7\frac{5}{8}$	$23\frac{15}{16}$	$23\frac{15}{16}$	$\frac{1}{2}$	137 . .	$\frac{3}{4}$	23	$72\frac{1}{4}$	$54\frac{3}{16}$	1·0
86 . . .	$\frac{1}{2}$	$7\frac{3}{4}$	$24\frac{3}{8}$	$24\frac{3}{8}$	$\frac{1}{2}$	138 . .	$\frac{3}{4}$	24	$75\frac{3}{8}$	$56\frac{9}{16}$	1·0
87 . . .	$\frac{1}{2}$	$7\frac{7}{8}$	$24\frac{3}{4}$	$24\frac{3}{4}$	$\frac{1}{2}$	139 . .	$\frac{3}{4}$	25	$78\frac{9}{16}$	$78\frac{9}{16}$	$\frac{3}{4}$
88 . . .	$\frac{1}{2}$	8	$25\frac{1}{8}$	$25\frac{1}{8}$	$\frac{1}{2}$	140 . .	$\frac{3}{4}$	26	$81\frac{11}{16}$	$81\frac{11}{16}$	$\frac{3}{4}$
89 . . .	$\frac{1}{2}$	$8\frac{1}{8}$	$25\frac{1}{2}$	$25\frac{1}{2}$	$\frac{1}{2}$	141 . .	$\frac{3}{4}$	27	$84\frac{13}{16}$	$84\frac{13}{16}$	$\frac{3}{4}$
90 . . .	$\frac{1}{2}$	$8\frac{1}{4}$	$25\frac{15}{16}$	$25\frac{15}{16}$	$\frac{1}{2}$	142 . .	$\frac{3}{4}$	28	$87\frac{15}{16}$	$87\frac{15}{16}$	$\frac{3}{4}$
91 . . .	$\frac{1}{2}$	$8\frac{3}{8}$	$26\frac{5}{16}$	$26\frac{5}{16}$	$\frac{1}{2}$	143 . .	$\frac{3}{4}$	29	$91\frac{1}{16}$	$91\frac{1}{16}$	$\frac{3}{4}$
92 . . .	$\frac{1}{2}$	$8\frac{1}{2}$	$26\frac{11}{16}$	$26\frac{11}{16}$	$\frac{1}{2}$	144 . .	$\frac{7}{8}$	30	$94\frac{1}{4}$	$94\frac{1}{4}$	$\frac{7}{8}$
93 . . .	$\frac{1}{2}$	$8\frac{5}{8}$	27	27	$\frac{1}{2}$	145 . .	$\frac{7}{8}$	31	$97\frac{3}{8}$	$97\frac{3}{8}$	$\frac{7}{8}$
94 . . .	$\frac{1}{2}$	$8\frac{3}{4}$	$27\frac{1}{2}$	$27\frac{1}{2}$	$\frac{1}{2}$	146 . .	$\frac{7}{8}$	32	$100\frac{1}{2}$	$100\frac{1}{2}$	$\frac{7}{8}$
95 . . .	$\frac{1}{2}$	$8\frac{7}{8}$	$27\frac{7}{8}$	$27\frac{7}{8}$	$\frac{1}{2}$	147 . .	$\frac{7}{8}$	33	$103\frac{11}{16}$	$103\frac{11}{16}$	$\frac{7}{8}$
96 . . .	$\frac{1}{2}$	9	$28\frac{1}{4}$	$28\frac{1}{4}$	$\frac{1}{2}$	148 . .	$\frac{7}{8}$	34	$106\frac{13}{16}$	$106\frac{13}{16}$	$\frac{7}{8}$

To prevent burning of the rings, and to promote an easy welding, sand, loam, or powdered glass is applied to the iron at the time it commences to melt. The sand is placed upon the iron, while it is in the fire, by means of a ladle or spoon having a long handle; the blast being gently administered at the moment. Large rings require a fire which is open in front, but closely built on the opposite side, and having a strong, thick arch, to cause the flame to whirl around the joint instead of being blown upon one side only. While the rings are being curved upon the beak of the anvil, or while being welded, stretched, flattened, or smoothed, a tongs, represented by Fig. 98, is required, by which to grip the rings in a convenient and safe manner.

When it is necessary to weld together the two scarfs of a ring so that the joint may be almost as solid and strong as any other part of the ring, great care must be exercised in selecting a tough, fibrous iron, and in having a weld free from burnt iron, slag, or other foreign matter. To prevent the slag adhering to the joint, a large supply of sand is given, and, by the sand becoming liquid while upon the surface of the iron, whatever slag may be formed upon the joint is washed off. This slag is produced by the fusion of the impurities in the coal or iron, and constitutes part of the clinker which accumulates at the bottom of the fire.

Circular Nuts.—When it is necessary to insert a nut into a circular recess, and to fill, or partly fill it, a circular nut is used, having holes bored into the outside face of the nut for fixing or unfixing it.

Circular nuts are also used for ornament, and to prevent contact with corners. Fig. 18 represents one of this class, having a flange, and holes bored around in which to place the end of a steel lever, named a tommy, by which the nut is fixed or unfixed.

The forging of circular nuts with flanges consists in drawing down or reducing a bar or rod which is of the same diameter as the intended flange of the nut. After being partly reduced to the finished diameter, the smaller part is made as solid as possible, by welding and hammering, to give the necessary strength to the nut while being punched. After it is welded, the proper quantity of iron to make the nut is cut from the bar and punched, and the hole then drifted to the required diameter. The rounding of the outsides is accomplished by rounding-tools, while the nut is upon a nut-mandril.

This method is economical if the proper length of iron is reduced, to avoid cutting off large scrap-pieces; and is always available with good, soft, fibrous metal, that will bear punching without splitting. The tongs for gripping the nuts while being punched is shown by Fig. 99.

Steel Nuts.—Several classes of nuts require to be frequently fixed and unfixed, involving much wear and tear. All such are forged, either of steel, or of iron sufficiently solid and welded to allow the nuts to be hardened after being screwed, turned, and shaped.

A soft steel nut is the most durable and efficient of all varieties with which we are acquainted. Several obstacles, which have prevented the free use of such nuts, are now removed by the manufacture of Bessemer steel. Soft Bessemer steel, being only half the price of charcoal-steel, is preferable for nuts, because Bessemer nuts are about as durable as those made of the costly variety. The screwing or tapping and the turning and shaping processes are troublesome and lengthy with the superior sorts of charcoal steel; consequently, the soft Bessemer steel is eminently useful and applicable to nut-making. Such nuts are, in all cases, thoroughly softened, and all slag or scale thoroughly cleaned off by chisels and old files previous to being screwed, to avoid injury to the taps, and also to facilitate the whole of the shaping processes to which all nuts are subjected.

Disconnecting Levers.—Such levers are used to lift the excentric-rod from the gap-pin; by this disconnexion, motion of the slide-valve and engine is immediately arrested. The forging of one, which is shown by Fig. 19, is performed with a straight bar of soft steel that is drawn to its width and thickness, and then partly curved by bending, and partly by a trimming chisel. By careful trimming, the precise dimensions of the gothic arch, and the necessary distance between the two intended joint-pin-holes, can be easily attained,—these holes being, in all cases, bored by careful drilling.

Excentric-Rod Guards.—When the excentric-rod is disconnected from the gap-pin, the guard, which is fixed by screws to the underside of the excentric-rod, forms a parallel path, in which is the gap-pin, instead of being in the excentric-rod gap. Very little abrasion attaches to the guard, consequently, it is forged either of iron or of steel that is very fibrous. The guard, with the two screws for fixing, are shown by Fig. 20.

The guards are made of thin bars of suitable width and thickness, which are then bent to the shape desired. This bending is named cranking. There are several ingenious modes of cranking adopted by smiths; of these methods it is necessary, in this place, to mention only one, which is suitable for a thin, flat bar, and consists in first forming the two outside bends which are nearest to the two ends of the guard, and afterwards making the two inner bends or curves.

The two outer bends are effected by heating the iron or steel to a bright yellow, and cooling to an equal distance on each side of the spot intended to be the centre or middle of the intended curve, named the corner; the cool end is then placed into a slot in a heavy block, and the work bent while therein.

The length of iron placed into the slot is the length of the end required; and while one end is in the slot, the opposite end is in a tongs, shown by Fig. 100. The tongs, and the work to be bent, together constitute the lever by which the smith bends the iron to a right angle; after which, the corner is shaped by applying a flatter or a set-hammer. If a long curve is desired, instead of a sharp angular corner, the end of the piece to be bent is put into a slot having curved edges, instead of into a slot with angular edges, which is necessary to produce a sharp or square corner. There is also a difference in the length of iron which remains heated after being cooled to the proper distance. For a small corner, the length of the heated part is only sufficient to allow the bar to be bent without the risk of cracking. For a longer curve, or curve of longer radius, the length of the heated portion is about the same as the length of the curve required; if not, the iron will require to be re-heated, and cooled to proper distances from the corner, in order to make the curve to the correct length.

When one end of the work is thus bent to a right angle, the bent part is fixed in tongs resembling Fig. 101, and the opposite end of the piece is bent in a similar manner, so that the two bent portions, or arms, will be on the same side of the work. The two inner bends are next effected by placing the work, while heated, between two studs or pins loosely situated in two slots or holes in the heavy cast-iron block. In some cases, the two studs constitute one solid tool, having a square stem to fit the square hole in the anvil.

The two inner bends are produced by similar careful heating and cooling, to make the curves of the correct length; and by bending in the opposite direction to that of the two previous operations, the two cranks in the work are made.

Studs.—A stud is a permanently fixed bolt without a head, and is fixed either by a conical portion in the middle or at one end. Studs intended for joint-pins or pivots are screwed at one end; and screwed at both ends if intended for connexions for cylinder lids, slide-jackets, and similar work.

Pivot-studs are made of tough, fibrous iron or steel, to resist the side strains continually imposed during use. A pivot-stud is shown by Fig. 21. That part of a stud intended for a joint-pin or pivot of any kind requires good welding and closing by the angular-gap rounding-tools, which facilitates the production of a smooth surface for friction. A close texture is necessary for those parts of studs or pins intended for wear, whether soft, hard, or case-hardened. The conical part of a stud may be more fibrous than the parallel portion, which will be subjected to continual abrasion while in use. The screw part, also, must be welded to a depth which is rather greater than the depth of the intended screw-thread. Studs, which are represented by Fig. 21, frequently need drilling and screwing at the centre to admit a small bolt for fixing a washer. The place of the washer is indicated in the Figure by W. Much trouble will arise in drilling and screwing the hole if the metal is not welded in that part; consequently, the smith obtains the requisite solidity by upsetting and rounding the work while at a welding heat.

The screw-pin or screw-pivot, shown by Fig. 22, is quickly forged by reducing, with a fuller and steam-hammer, a bar or rod which is the diameter of the intended pin-head. A portion of the stem of the pin is parallel, and a part is conical. This conical part is that which holds the pin in its place while in use, and should be soft and fibrous.

Iron and steel studs, of all classes, are in condition to wear properly, with but little friction, if hardened. For this reason, attention to the forging and quality of the iron or steel from which they are made is necessary to ensure a good friction surface. The careful labour of the turners and grinders will be of little service if the metal contains cracks, small openings, or other defects arising from careless forging. Such blemishes seldom appear till the work is turned by the lathe nearly to the desired diameters, so that much time is consumed in the turning of articles that are discovered to be unfit for their uses. Such errors in forging arise from the smith considering merely the simple appearance of the article he is about to make, and not, at the same time, reflecting or inquiring concerning the particular uses to which his work will be applied. Many forgings of importance are entrusted to unskilful men, because the outside appearance of the forging is of simple character, and the result, in many cases, involves a consumption of twice the amount of time that should be employed. A good smith is also a man of experience in general mechanical affairs; without such experience he cannot produce good work, however skilful he may be, except he happens to be working under a man who is able to tell him what to do, and also able to tell him how to do it. The smith must know, at the time of commencing to forge the article, the amount and character of the wear and strain to which his work will be subjected, and whether the work will be exposed to destructive chemical action in addition to friction, side strains, and abrasion.

It is only by such foreknowledge that a smith becomes a really valuable man—one who is able to produce solid work, and to select the class of metal adapted to the requirements. Such a man will not cut a piece from a straight bar of iron or steel and name it a forging, merely because the outside shape of the piece cut off corresponds to the outside shape of the forging desired. The internal structure may be different to the structure necessary; and is often discovered after several hours of lining, centring, planing, turning, and screw-cutting. Every operation may progress favourably till the screw is being made, which is often the last process; and if the portion intended to be formed into a screw is not welded, it will tumble off while being screwed, and the elegant piece of turning and screw-cutting becomes fit for the scrap-heap.

Rods.—When speaking of engine-making, the name rod signifies a transmitter of motion or force from an active agent to a passive object. And in all cases where practicable, the sectional area of the rod is greatest midway between the two ends; because, when the rod is parallel, the centre or mid-portion of it is weakest.

The variety of rod indicated by Fig. 23 is sometimes made by upsetting each end to form the circular portions termed bosses. This mode is tedious, and requires much welding if the iron should not be very soft and tenacious; consequently, upsetting is seldom adopted except for small work, or for work which is short and thick.

A very efficient mode for general work consists in preparing a bar to the suitable diameter for producing the bosses by a small amount of upsetting, and a small amount of reducing to form the intermediate portion. If the boss portions are upset, curved, and welded, a circular arrangement of the fibres is obtained, which ensures the necessary solidity for the boss after the holes are bored.

After the boss is upset, while at welding heat, and the extremity put into a circular form by hammering, and by large curved rounding-tools, top and bottom fullers are driven in to form the inner extremity of the boss, shown in the figure by A. By this means the whole of the fibres in the boss are put into a circular arrangement, which is a desideratum. The intermediate portion of the rod is then reduced to its proper diameter and shape, and the length increased to the length desired.

This method of making such rods is very economical, and produces a solid kind of work without waste of metal, if the piece was originally cut to a suitable length, ascertained by application of the rule in page 8.

Another mode of proceeding is by making separately each boss with a short stem; these stems are then scarfed, and welded to the intermediate portion, which may be of the diameter required, to avoid reducing. When this plan is adopted for long heavy rods, a tongue-joint is made, instead of a scarf-joint.

To produce a good tongue-joint, the two ends to be welded are upset, either by Davies's patent striker or by a pendulum-hammer. The length of the upset part is about equal to the length of the rod's diameter previous to upsetting; after being upset, the diameter is one-third longer than previous. After the two ends are upset, the taper part, named the tongue, is drawn down from one of the pieces, by first driving in a broad fuller, at a short distance from the extremity, and from two opposite sides of the rod or bar. The fuller is driven to a short distance only, and the lump that remains is conveniently tapered by the patent striker, which is adjusted to deliver its blows at an angle of 45° or 60°, as desired. During the tapering, the work may be placed along the top of an anvil, or the anvil may be shifted to suit the position of the striker, and the work laid across the anvil.

The opening, or orifice in which the taper end is fitted, is named the mouth; and is produced by cutting open the end with a chisel, and afterwards enlarging by driving in a wedge. The use of the wedge produces a large mouth without the necessity of cutting out a large piece of the iron, which may be needed during the heavy blows when welding and rounding is being performed. The depth or length of the mouth from the extremity of the rod should not be more than twice the length of the rod's diameter, to prevent the joint-edges becoming too thin while being reduced or rounded after being welded.

The next operation is shaping those portions of the mouthpiece which will receive the hammering during the welding. These portions are curved, either by hammering or by a trimming-chisel; this curving prevents the hammer from spreading out the outside of the mouthpiece and making a series of thin ragged edges. And if the hammers or rounding-tools are thus made to strike a curved lump, instead of an angular projection, the iron is closed in towards the centre of the rod, instead of being spread out at the circumference.

After the mouth and tongue are properly prepared, the stock near the tweer is mended, or made anew if necessary, and the two pieces are laid together in their proper positions in the fire or fireplace. And if the work is long and heavy, each piece is supported by a crane at each side of the forge; the endless chains around the work allowing it to be rotated to expose the entire circumference to the action of the blast, that one portion may not become heated previous to another. In order further to promote a proper distribution of the heat, the fire is of the two-stock character: one stock being opposite the other stock near the tweer. Both stocks as built gradually taper upwards to four or five inches above the work. The stocks are well hammered and battered together; and a thick arch is built, which is supported by each stock, and prevents the heat escaping. A good arch is made after the work is laid in the fire, by laying sticks of wood around the top of the work, and piling to five or six inches thick. Pieces of coke and coal are then placed upon the wood, and among it; and wet small coal is then put into all the cracks and piled up, and battered closely together. After the wood is consumed, the arch remains, and the only escape for the flame is by the two openings at the sides of the fire. These two openings are also partially closed, when necessary, by placing pieces of coke that are heavy enough to withstand the force of the blast.

When the welding heat is nearly attained, the blast is moderated, and while gently blowing, a large supply of sand is administered through the two openings or outlets for the flame. The ladle having a long handle is used for applying the sand, which causes much of the slag which is formed around the joint to slip off the work into the fire, instead of being welded into the joint.

When the welding heat is reached, the joint is welded while in the fire, by striking the end or ends of the work with a pendulum-hammer. These blows are very effectual for welding the joint to the extreme depth of the mouth, if the iron is properly heated to the centre, which cannot be done by hasty urging of the blast. The outside will in all cases become a few degrees hotter than the middle; but, with ordinary care, the difference is not sufficient to prevent a good weld and a good joint. After being welded by a pendulum-hammer, or as it is sometimes termed, an oscillating-hammer, the work is taken from the fire by swinging out the two cranes to place the joint upon an anvil; or the work is conveyed by a truck and railroad, if necessary. The welding of the joint is then completed by hammering, or by large angular-gap tools, which are effectual for closing the iron and welding a greater part of the circumference at one blow than could be welded by one blow of the hammer only. For steam-hammer work, the angular-gap tools are very thick and strong, to avoid liability to break while in use. Large tools of this character are not used for ordinary sledge-hammers, because the blow given by such a hammer would have no visible effect upon the work beneath, the force of the blow being absorbed by the metal which constitutes the tool.

Whether it is more economical to punch and drift the eyes or holes in the bosses, or to leave them solid to be entirely bored by a boring or drilling machine, cannot be decided in any general manner. If a man possesses a number of good boring machines, he may prefer to cut out the lumps by boring-bars and cutters, because he may not have much forging machinery. In most cases, it is both quicker and cheaper to drift the eyes to a proper diameter, leaving only sufficient metal to bore out to the dimension required. If, by punching and drifting, a large hole is made, a large boring-bar can be immediately inserted; but if a little hole only is made, it is almost as useful as none, because an extra boring-tool must be used to admit a large boring-bar of suitable diameter.

And in addition to an economy of time and metal by drifting, there is the advantage of securing an approach to a concentric disposition of the fibres in the boss. This disposition is attained by the metal being swelled out by the drift, and by being well hammered and stretched while the drift is in the opening.

The making of large holes or eyes will be again treated in the portion devoted to crank-lever forging.

Levers.—A lever which is represented by Fig. 24, if small, is easily made by drawing down the two ends from a bar which is large enough to be formed into the fulcrum boss of the lever, which is situated near the middle, or, in some cases, near one extremity. Short levers are quickly made by this method, and the work produced is of close, solid character; but for long levers the bosses are separately forged with short stems, and afterwards welded to the smaller portions which are termed the arms. A considerable amount of drawing down is thus avoided, which is often of great importance to a maker with only a small amount of machinery.

In levers of all classes, the fulcrum boss is that which sustains the largest share of the whole strain that is applied to the lever while in use; consequently, this boss is the strongest part. And the lengths of the fibres of the iron or steel in the boss should constitute a series of concentric rings, whose centre is the centre of the boss.

This form is produced by two or three methods; one of which is by selecting a soft fibrous bar, and punching a small hole into that part intended to be the boss, and then drifting the hole to any required diameter while the iron is at a bright yellow heat, or, if the iron is large enough, at a welding heat. The fibres are thus curved, and will have some resemblance to the arrangement desired.

The next method of making a boss consists in using a large bar and placing it between a pair of top and bottom fullers, to reduce the metal on each side of the intended boss. This mode of drawing down produces the required circular arrangement of the fibres without punching and drifting, if the metal at the commencement were large enough, but is a more lengthy mode of proceeding because of the greater quantity of metal to reduce.

One other plan of making a lever boss consists in laying and welding three pieces together, the middle piece constituting the lever itself, and the other two the boss. The two pieces for the boss are of sufficient length to be welded a considerable distance into the arm of the lever.

Upsetting also will produce a lever boss, and is sometimes resorted to in small work. To produce a good boss by upsetting, an excellent tenacious iron or steel is necessary, to avoid risk of splitting.

Those two parts of a boss which project from the two sides of a lever are named the boss-ends. The producing and forming of these ends is effected by driving in fullers and set-hammer; and afterwards by top and bottom die-tools of the required shape, and also by trimming with a trimming-chisel. The shaping by these die-tools or bossing-tools is the cheapest in cases of large numbers of bosses being required. If large bosses are needed, these tools are made in pairs, jointed together, and strong enough for a steam-hammer. For small work the bottom tool fits the square hole of an old-fashioned anvil, the top tool being supported by an ordinary ash or hazel handle in the hand of the smith. Such bossing-tools are not difficult or expensive to make; the simplest variety are not made with guides and jointed together, but are distinct, and are easily bored by a lathe or boring-machine to any desired diameter and depth, according to the length of the intended boss. While making these tools, it is important to smoothly bore the holes, and to make each hole larger in diameter at the entrance than at the innermost end; the hole, being made of regular conic form, will allow the bosses to be driven in and out of the tools with rapidity. The metal around the holes of these tools must be thick, to prevent the tendency to split during a severe hammering.

The use of bossing-tools greatly facilitates the processes of turning and shaping by the boring-machine; and in many classes of small levers the entire shaping can be done upon an anvil.

In those cases that require levers to be finished without turning or boring, the joint-pin holes or connecting-pin holes are punched and drifted to the finished diameter; and a square is used to ascertain if the hole is at right angles to the length of the lever. A drift is driven tight into the hole, and, while in, a square is applied to both sides of the two arms of the lever; or to both sides of one arm, if the boss under treatment is at the extremity of the lever. And if the drift is not parallel to the blade of the square, the hole is not at right angles to the lever, and must therefore be altered, until a near approach to the desired position is attained.

The adjusting consists in bending one arm, or both arms; and sometimes a twist is needed. Twisting is effected in small work by tightening one arm of the lever in a vice, and twisting the other arm by applying a twisting-lever (Fig. 102). If a vice is not near, two of these twisting-levers are used, one upon each arm of the lever that is to be adjusted; while the smith holds one twister, the hammerman holds the other, and each man pulls in opposite directions, by which the adjustment is easily effected if the work is sufficiently heated. To twist a large lever it is only necessary to place the boss or one arm upon a steam-hammer anvil, and to gently let down the hammer to the arm or boss, and there to fix it by the steam. While thus fixed, twisting-levers are applied to one arm, or to both arms if necessary.

Another kind of adjustment is needed when the two faces of the boss or bosses are not parallel to each other, or not parallel to the lever-arms, or not at right angles to the sides of the lever boss. In such cases the hole is first adjusted to a right angle with the arms, the boss is then pared by a chisel to produce the necessary parallelism with the hole; after which, the two prominent projections are trimmed off the two faces.

The lengths of the fibres in the lever-arms require to be parallel to the length of the lever itself, to avoid sudden breaks. For many varieties of small levers Bessemer steel is used, and, if of soft fibrous character, is very advantageous for the production of smooth friction surfaces for the joint-pin holes. Levers that are made of steel are drawn down from a piece which is sufficiently large to produce the fulcrum boss of the lever; and by applying the author's rule, no steel need be wasted, through not knowing the length of metal necessary, previous to drawing down.

Straps.—The variety of strap denoted by Fig. 25 is used for connecting crank-pins with connecting-rods; also beam gudgeons with side-rods and connecting-rods.

The proper arrangement of the constituent fibres is obtained by bending the straps from straight bars which were previously welded and reduced to a suitable width and thickness.

Those portions of the arms which are indicated in the Figure by A are thicker than the adjoining portions, because the key and gib-way detracts from the strength of the arms.

The thicker portions of the arms are made by doubling the piece at each end, and welding by good steam-hammering; after being welded, and while being reduced to the thickness, the part intended for the semicircular portion is allowed to remain a little thicker, to compensate for waste while being heated several times for bending, and also for stretching.

The bending or curving is effected by heating the intermediate portion to a length which is equal to the entire length of the curve required in the strap. It is then bent by placing one end into a slot in a heavy block, and pulling down the opposite end; after which, the two arms of the strap are flattened and smoothed by placing a filler into the mouth or opening, and hammering the outsides.

Straps of great weight and dimensions are bent by long and strong levers, which have gaps or openings at the ends, one end of the strap being gripped by the lever while the bending is effected. Several heatings are necessary, the precise number of which depends upon the thickness of the work, the quality of the implements employed, and the promptness with which the power is applied.

The fillers for shaping the curved parts are made of cast iron, and of various dimensions to suit various sizes of straps. Each filler has a wrought-iron handle, which is fixed by the iron being poured around one end of the handle, at the time of casting the filler. Another class of filler also is used for shaping, and consists of a piece of cylindrical iron or steel, which is supported at each end by two heavy cast-iron blocks. On the upper side of the blocks are two angular gaps, into which the two ends of the cylindrical filler are placed. The distance between the two blocks is only sufficient to allow the two arms of the strap to hang freely while the curved part is supported by the piece of round iron, the ends of which are in the two angular gaps (Fig. 142).

Round iron of any suitable diameter may be selected as a bearing for the strap; and, while thus supported, either of the two arms may be gripped by tongs, and any part of the bent portion may be stretched, flattened, smoothed, or adjusted.

Weigh-Shafts.—Fig. 26 indicates a weigh-shaft with the three levers, that are usually connected, by which motion is transmitted from one to the other. The levers are distinct from the shaft, and are keyed to it, sometimes near each other, and at other times near the two extremities of the shaft; the whole arrangement depending upon the length of the shaft or spindle, and the width and class of engines for which the levers are designed.

That lever which is indicated by L B in the Figure, transmits all its moving power to the shaft and the other two levers; consequently, the lever L B is one class of prime mover of the weigh-shaft. When this lever is fixed midway between the other two levers, instead of being at one end of the shaft, the arrangement is suitable for some classes of land engines, and tends to an equal distribution of the friction, and consequent equal wear of the bearing surfaces.

Soft steel is suitable for weigh-shafts, by reason of the closeness of its texture, which facilitates the production of good friction surfaces, and because of the superior strength of steel as manifested in its resistance to torsion.

Weigh-Shaft Levers.—Weigh-shaft levers are usually forged of tenacious iron to facilitate the fitting of them to their shafts. In some cases the levers are tightly fixed by making them hot and shrinking them while in their precise situations on the shaft. In such cases, the contraction of the boss would have a greater tendency to tear it asunder, if made of steel, than if made of iron.

The necessary strength of the boss is obtained either by adopting a long boss of short diameter, or by a short boss of long diameter; these bosses are made by doubling or trebling a bar at one end, and thoroughly welding the layers together, and then punching and drifting the opening or orifice to the required diameter, which produces the desired circular disposition of the fibres in the boss. After which a welding heat is again given to the boss, and it is shaped by a sledge-hammering equally administered around the boss, while it is upon a cylindrical filler, similar to that mentioned for strap-shaping. This hammering is needed to produce a tough fibrous boss. After the boss is thus made at the end of the work, broad fullers are driven in to reduce that portion next to the boss; the adjoining part is then reduced to the shape of the lever arm, and a piece is allowed to remain, which is of sufficient dimensions to be formed into the smaller boss at the other end of the lever. The next operation is cutting the work from the bar, and making the smaller boss, either by doubling or trebling if necessary. When both the holes are made and drifted, and the outsides of the bosses well hammered, they may still be too large; if so, a trimming-chisel is used to trim the bosses to their respective dimensions. The bosses are finally flattened, and also smoothed with curved rounding-tools, whose gaps are of suitable width.

Weigh-shaft levers are also made by reducing the ends of two bars, and welding the reduced portions together. By this method, all doubling or trebling to make the bosses is avoided. But, after being punched, they require the same welding, drifting, and hammering as other bosses, for producing the circular arrangement of the fibres. This mode of drawing down to produce half the lever arm from each boss is economical for all kinds of short levers, because only a small amount of reducing is necessary to attain to the length desired; but for long levers, whether large or small, the plan is not adopted without making two joints for each lever. By this means, a piece which is of the finished forged width and thickness is welded into the two stems which were reduced from the bosses.

Slide-Valve Rods.—Several varieties of slide-rods are used; a few of which are represented by the Figures in Plates 1 and 2. Steel is useful for slide-rods, because it is less liable to wear by the friction of the packing in the packing-box. When slide-rods are of iron, they require the fibres of the metal to be well closed by angular-gap rounding tools; when this is well done, the durability of the rod is much greater than with iron of open texture, which collects grit and other foreign matters. Iron of close texture is also necessary to ensure a smooth surface to the rod after being hardened, which is sometimes done.

When steel is used for slide-rods, it must be of very fibrous character, and be thoroughly softened by heating and gradual cooling in coke or charcoal. Such treatment will tend to prevent sudden breaks down, which will occur with hard steel of all kinds.

When the old-fashioned D slide-valve is employed, a rod similar to that shown by Fig. 27 is made use of to connect the two D portions; and two valves are thus formed, connected by one rod. The intermediate portion of this rod is therefore in the steam space of the slide-box; and, to protect the iron from the ravages of the steam, the rod is coated with gun-metal throughout the length of the intermediate part, including the two flanges or collars denoted by C.C.

The diameter of the iron hidden by the gun-metal should not exceed the diameter of the screw at each end of the rod; and, being of this dimension, the cheapest method of forging the rod is by welding a collar to each end, at a proper distance from the extremity. By this plan, the two portions intended for the screws require upsetting or thickening to admit of a good weld, and also hammering to obtain the requisite solidity for the screws.

The lower D valve is fastened to the rod by one or two nuts; the upper D valve is secured by a joint-nut, which is denoted by Figs. 28 and 29. Into the joint-gap of the nut is placed the square boss of the upper or gland slide-rod shown by Fig. 30. The connexion is effected by a square pin or bolt being fastened in the joint-nut after the boss of the upper slide-rod is put into the gap.

The forging of the joint-nut consists in thoroughly welding and hammering a square bar of iron, and cutting off a solid piece which is long enough to make the nut; the gap in which is afterwards made by drilling and slotting.

The upper slide-rod may be made of soft fibrous steel, for the advantage of having a good sliding surface for contact with the packing in the packing-box. If the rod is made of steel that cannot be welded, it is sometimes necessary to make the whole of the sliding part and screw portion by reducing it from a bar whose width and thickness are about two-thirds the width and thickness of the intended square boss. The sliding part may be produced at the end of the bar;

or may be reduced while a lump is allowed to remain at the extremity, for the convenience, if necessary, of upsetting to form the boss. By upsetting, a part of the drawing may be avoided. In either case, the length of bar required is ascertained by applying the rule in p. 8, and substituting slide-rod stem for key stem.

These upper slide-rods are also made of iron which is well hammered by a steam-hammer, and also well closed by a pair of angular-gap tools. Very little reducing is sufficient when iron is employed. The square boss is formed by doubling and welding a lump at the end of a bar or rod, which is equal in diameter to the diameter of the required sliding part. The diameter of the iron made use of is only sufficient to admit a good welding and closing, to reduce it to the desired diameter of the slide-rod when forged.

Ring Slide-Rods.—The class of slide-rods shown by Fig. 32 is forged of three pieces. One of the three constitutes the intermediate part of the rod, indicated in the Figure by B B; the second piece is formed into the circular portion, denoted by C C; and the third piece becomes the friction portion and the screw part, represented by A.

The intermediate piece is first made, by punching a hole into and cutting open the end of a bar whose diameter is about 1½ times the diameter of the intended sliding part. The two ends thus produced are carefully separated while at a bright yellow heat, and shaped into the form of a T. The length of the three arms of the T-piece are sufficient to allow the other two pieces to be conveniently welded to it. The proper length and thickness of the two smaller arms are attained by driving in a fuller at the two curved parts, B B, and afterwards reducing the remaining lumps to the dimensions desired; a thick portion being allowed to remain at the ends of the two thin arms, for being formed into a scarf. The larger arm is next reduced by a fuller to the forged diameter required; a lump remaining for a scarf, as for the two thin arms. By this mode, all upsetting of the T-piece is avoided.

After the T-piece is made, the length of bar necessary for the circular portion may be ascertained by subtracting the lengths of the two thin arms of the T-piece from the entire length of the ring's mid-circle circumference, and that which remains indicates the length of the ring-piece required, if the thickness of the bar previous to being welded is equal to the thickness of the ring after being finished to the forged dimension. It is always convenient to use a rather shorter length of bar than the symbols indicate; and also to select bar which is rather thicker than the finished forged thickness, because the ring can be stretched or lengthened after being welded, but it cannot be upset or shortened without trouble.

Previous to joining the ring-piece to the T-piece, the two thin arms are curved to their proper form; and the bending or curving of the ring-piece is also partly effected previous to welding it to the T-piece.

After being scarfed while straight, the ring is formed across the anvil beak until nearly circular, to avoid contact with that arm of the T-piece which is not to become part of the joint first made; and after the first joint is made, the ring is properly curved to its circular form, and to fit the scarf of the other thin arm; and while in this relation, the second joint is made by welding; after which the ring is stretched, if necessary, while on a piece of large round iron which is placed upon the blocks having angular gaps. Another mode of lengthening is performed by aid of a long cast-iron conical filler, slightly tapered to suit rings of various diameters.

After the two ring-joints are effectually made by using a large supply of sand and a rapid hammering, the lump at the end of the thick arm of the T-piece is scarfed, and a piece of iron is prepared for the parallel portions of the slide-rod. The diameter of this piece is only equal to the forged diameter of the sliding or friction part of the rod; and the length of the piece is sufficient for the sliding portions and the screw part.

A slide-rod which is indicated by Fig. 33 requires but little more forging than welding and closing the fibres of a bar of good iron or fibrous steel, and then cutting the rod to a proper length, and squaring or curving the extremities to facilitate the centring process, previous to turning. In that part of the rod's parallel portion which is to be outside the packing-gland, two flats are made for the convenience of rotating the rod while in its place. A spanner which fits the two flats is employed to rotate the rod, whereby the position of the slide-valve is altered at pleasure. These flats being very shallow, no attention need be given them by the smith, who makes the rod sufficiently solid throughout its whole length.

Fig. 34 represents a slide-rod whose small end is fixed in the slide-valve by nuts on each screw, the valve being between. An opening, which is four-sided instead of circular, contains the block and pin by which motion is given to the valve-rod. In the figure this opening is indicated by F; and when of small size, the whole of the rod may be forged of one piece which is large enough to produce the boss by being flattened and spread out by a steam-hammer, the four-sided opening being afterwards made by drilling and slotting.

A more convenient mode of making large rods of this character consists in using a shorter piece of iron, which is only sufficient to make the boss and two short stems. These stems are reduced from the lump by fullers and hammering, and produced to a convenient length for welding to two other pieces, which are to be formed into the friction parts, indicated by A and B. These two pieces are of a suitable diameter, to admit only a small amount of reducing and hammering to attain to the forged diameter, and to ensure sufficient solidity for the screws.

Rods that are to have large frames in the middles, to fit the outsides of slide-valves, require a different method of forging. Instead of forging a solid boss and leaving it to be drilled and slotted, the square frame itself is forged upon the anvil. In such cases, six pieces are necessary to make one rod. Of these six, two are formed into T-pieces, whose thin arms constitute portions of the intended square frame, and whose thick arms are scarfed for welding to the two cylindrical friction parts of the intended rod. After the T-pieces are made, two thin bars are bent to the forms of crotchets or brackets, thus ⊏, and the thin arms of the two T-pieces are welded to the two crotchet-pieces. When the square or rectangular frame is thus complete, it is welded to the two cylindrical ends of the rod, by which the forging is finished.

In many cases the friction portions of the slide-rod are keyed or screwed into the bosses of the valve-frame; such a frame may be made of four pieces only, as indicated in Fig. 134.

Connecting-Rods with Inside Screws.—Fig. 31 indicates a rod having an inside screw, which is occasionally used to connect the upper end, or what is sometimes the outer end, of a slide-rod. Six or eight sides are formed upon the boss for the convenience of rotating the rod with a spanner. It is not necessary to forge any opening or orifice whatever in the rod, because drilling or boring such small holes is a preferable process. It is generally most convenient to forge such rods of one piece, which is welded and made solid with hammering, to produce the larger boss in which a screw is to be made. The intermediate portion is next reduced by fullers and hammering, and a lump is allowed to remain for the smaller boss, in which is placed the joint-pin. Rods of this character must be welded to a proper distance from the outside; if not, the screw will be unsolid and liable to break.

Rods with inside screws are also used, which are of great length. In such cases, the larger boss is forged with a short stem only, which is afterwards welded to the intermediate portion of the rod that is of a suitable diameter to avoid reducing. Another smaller boss, or sometimes a joint-piece, is also made, and welded to the intermediate piece to complete the rod.

Links.—Links are of two principal varieties—slotted and solid. The forging of that which is termed a solid link is about equal to the forging of a slotted one, because both are forged without the slot.

The simplest class of links, and the easiest to forge, is that named solid, and having no bosses whatever in any part of the link. Such a link is almost as easy to make as a straight bar, until the curving commences, which may be carefully managed to leave only a small amount of iron or steel for finishing the link, or may be so carelessly done as to require a greater amount of shaping than should be administered. Consequently, at the time of reducing the bar, the smith leaves more or less metal for shaping, according to the amount of care he intends to bestow upon the curving.

Soft fibrous steel is exceedingly good for links of all varieties, and especially for those of the solid class. Such links may be produced by flattening a bar of steel until the required width and thickness is attained, after which the curving is effected by a series of heatings and hammerings while across a cylindrical shaper, which is supported by the blocks having angular gaps.

Two arcs are necessary for adjusting the link, and to ascertain if any needs cutting off with a trimming-chisel. These two arcs are marked upon a flat surface-table of large dimensions, which will allow the links to be laid conveniently to the arcs to detect any irregularity in the forging. A light radius-rod is used to construct the arcs, which are marked upon the surface-table through a layer of soft chalk or whiting that is spread evenly on the surface. The distance between the two arcs is an eighth of an inch greater than that distance across the link which is the width of it when forged; and when the link is placed midway between the two arcs, each one will be a sixteenth of an inch distant from the link, which will enable the smith to see clearly which part of it needs rectifying.

Heating the link for bending commences by heating a few inches at one end, and a small amount only of hammering will effect the small curve desired in that part. After a few blows are administered, the link is put between the two arcs to ascertain if more hammering is needed. As soon as the first few inches of the link-end is bent to a corresponding number of inches of the arcs, the adjoining portions are successively heated and bent in a similar manner. A succession of heatings are thus conducted until the curving is completed.

Links with Bosses.—Links are also forged with bosses—either one, two, or three—as represented by Fig. 35. The slot of such a link is easily made while cold, and properly shaped by a machine for the purpose; consequently, it is not necessary to forge any slot in the link, except the maker is compelled to do so through want of slotting machinery.

When a link is to have one, two, or three bosses, the mode of procedure consists in making a link which is equal in width to the total width of the link, the bosses included. After such a link is reduced to the necessary width and thickness, and also curved, the bosses are produced by cutting off the superfluous iron or steel that surrounds the intended bosses.

The link is marked upon both sides of it while cold, and a chisel for cold metal is driven into the marks, and the superfluous metal is afterwards cut off while at a yellow heat, and thus the bosses are produced.

Another mode of making link-bosses consists in forging each boss separately, and afterwards welding them to the link. The boss-pieces are made by driving in fullers at each end of a thick piece, thus forming a boss between two stems that are welded to the link. A boss thus formed possesses a concentric arrangement of the layers and fibres, and, consequently, is very durable.

But the strongest sort of link results from forging it of one piece, and producing the bosses by driving in a fuller at the extremities of each intended boss, and afterwards reducing the intermediate portions of the link to its proper width.

This mode requires a little arithmetic, to ascertain the precise length of metal necessary previous to drawing down or reducing by a fuller to form the bosses.

Previous to driving in a fuller, the link is reduced to its total forged width and thickness: the length of metal required is then discovered by applying the author's rule in this form:

As the mean width of the link previous to forming the bosses is to the required mean width afterwards, so is the required mean length of the link to the mean length previous to forming the bosses.

The mean width of the link is ascertained by adding the width across the link at one of the bosses to the width across the link at that part which is without a boss. The sum of both dimensions is then divided by 2, and the quotient is the mean width required.

For forging purposes, it is sufficient to consider the link's mean or mid-curve to be an arc of a circle's circumference, and the length of this arc is the required mean length of the link when forged, supposing that no bosses were necessary. In such cases, the length of straight iron required would equal the length of the mean or mid-curve. But, bosses being intended, it is necessary to add the lengths of the semicircular parts of the bosses, and subtract the lengths of those parts of the link which will be occupied by the bases of the bosses.

The length of the link's mid-arc is ascertained by multiplying the number of its degrees by ·017453, and multiplying the product by the length of the arc's radius.

The rule applies especially to small work, of iron. Steel links require the same length of metal as the mean length of the link after forging. Driving a fuller into the edge of a steel one produces a burr instead of lengthening the work, and a trimming-chisel is needed to cut off the burr to prevent it being hammered into the link.

Thick links are lengthened by fullers and ordinary hammering on an anvil, but thin ones require to be placed edge upwards in a groove, for the convenience of holding or maintaining the work in an upright position during the hammering upon the edges.

Link-Slots.—Cutting a link-slot while on the anvil is managed by first carefully marking the two arcs which determine the width of the slot. To mark properly, the link is laid upon a table, and a radius-rod having a steel scriber is made use of. This steel scriber is that which marks the two arcs upon the link, while the other end of the radius-rod is fixed in a centre-punch cavity in the surface-table upon which the link rests. After the two arcs are delineated, and the two ends of the slot also indicated, a chisel is driven in at the marks, and the link is then turned upside-down, and a similar pair of arcs are made upon the other side. Cutting out is then commenced while at a bright yellow heat by punching holes at each end of the intended slot. The punch for making these holes is a circular one, the diameter of which is only one-third the forged width of the slot. With this punch two holes are made at each end of the slot, leaving between each two holes a piece of metal which is one-third the width of the slot. After the ends are thus treated, a row of holes is made along the middle of the slot, and the portions which still remain around the holes are then easily cut out with a trimming-chisel.

Excentric-Rods.—In an excentric-rod, represented by Fig. 36, the mouth or orifice indicated by O is usually cut while cold by slotting, the rod being forged solid at both ends, although a gap is shown in the Figure, which should be the case with any sketch or drawing by which the smith may be working. He will then exercise sufficient care to arrange the fibres, that they may be in a suitable shape and position after the mouth or gap is cut.

The two ends of such a rod are first forged separately, each piece having a stem with a good scarf for welding to the intermediate portion of the rod. To form the gap end or fork end, a thick bar is doubled at one end and welded together. The length of the doubled part is sufficient to extend a considerable distance into the stem that is to be scarfed, to prevent cracks being formed at the inner curves of the boss.

Another method of making a good fork-end consists in welding and reducing a bar to the outer dimensions of the fork or fork-piece, and then driving in a fuller at the inner extremity of the solid or boss part of the intended fork. After the boss is thus produced by a fuller, the adjoining stem is reduced to its width and thickness and increased to a convenient length for welding to the intermediate piece, a lump being allowed to remain to avoid upsetting for scarfing.

In a fork-piece thus made, the orifice may, if necessary, be formed by first punching a round hole at the inner extremity of the intended opening, and afterwards cutting out with a chisel. The chisel is driven from both sides half way through the work, and every semi-detached piece is cut out previously to smoothing the inside, which is performed by placing a filler into the opening and hammering the outside. The filler is made of soft steel and to the shape of the opening desired. While this kind of filler is in use, the outer end is in a gap-stop, to avoid being shaken out by the hammering. A gap-stop in the square hole of an anvil is shown by Fig. 77.

After the fork-piece is made, the T-piece is formed for the opposite end of the rod, which is similar to that indicated by A in Fig. 37. A good arrangement of the fibres in the T-piece is obtained by punching a large hole into a bar of good soft iron or steel, and afterwards splitting open the end by cutting a slit to meet the round hole, the hole being at a proper distance from the extremity. When the two ends thus produced are separated and properly bent to a right angle with the bar, the lengths of the fibres will be at right angles to the bar, and, consequently, at right angles to the stem, which is to be welded to the intermediate portion of the intended rod; and this disposition of the layers and fibres is that which is necessary for strength in the T-piece.

After the T-piece is tolerably shaped, it is cut from the bar with sufficient length to be formed into a stem and scarf; and when cut off, the stem is produced and the scarf formed for welding.

The intermediate part is then made of a suitable width and length to complete the forging of the rod. The width and thickness of the intermediate piece is rather greater than the required forged width and thickness, for the convenience of stretching or drawing the rod to its exact length at the conclusion of the forging; consequently, the length of the piece is shorter than the finished length. After the three pieces are welded together, the rod is hammered to the precise length, which is measured from the centre of the fork-eye, or hole, to the centre of the T-piece, or its extremity.

While lengthening the rod to its exact length, a simple variety of gauge is made use of to ascertain the precise amount of stretching which is necessary. Such a gauge is made of a thin bar of $\frac{1}{4}$-inch iron, the width of which is at least 1 or $1\frac{1}{2}$ inches. Ten or twelve inches at each end of the bar are tapered, and afterwards bent edgeways to the bar and at right angles to it, which produces the form of a bracket, thus: ; the distance between the two extremities being the length of the excentric rod. These two pointed ends are filed to a circular form, and to half a millimetre in diameter, which is much too large for other work, but small enough for forging an excentric-rod. The mode of adjusting the gauge to its exact length consists in opening or closing the two legs of the gauge until the distance between the centres of the two circular extremities is the distance desired.

Fig. 38 represents an excentric-rod for oscillating and other classes of paddle-engines. In the Figure, the gap is indicated by G, which is intended for the gap-pin. In one particular, the forging of such a rod is similar to the forging of other excentric-rods; the rod being forged of three pieces, which are welded together at the first forging, or afterwards, when the engines are in the ship, as circumstances may require.

The forging of the T-piece is similar to that mentioned for Figs. 36 and 37. The forging of the gap-piece is performed with a piece whose width and thickness are sufficient to make a solid lump for the gap-boss. A fuller is driven in at each extremity of the intended boss, and the two straight stems are then reduced to a suitable width and thickness for the intermediate portion; a larger piece remaining at the extremity of the boss-piece for scarfing. If the stem of the gap-piece is to be turned in a lathe, a lump is allowed to remain at the taper end, instead of reducing the whole of it to the thickness when finished. Both of the extremities of the gap-piece stems are made square and solid, to conveniently admit the centring process previous to turning. No cutting or punching of the gap-piece is necessary, because it is afterwards bored while cold.

Steel Gap-Liners.—These are indicated by Fig. 40, and are dovetailed in the gap of Fig. 38. After these liners are worn too thin, or the openings too wide, a new steel liner is put into the rod, without interfering with its gap.

Forging a small liner of this class requires two principal tools—a bottom fuller, to place in the anvil for shaping the inside, and a top-tool for shaping the outside of the liner while it is supported by the bottom fuller in the anvil.

The only part of such a liner which is subject to wear, is the curved or half-round portion, consequently this should be the thickest. If the liner is not required to have sharp corners at the entrance to the gap, the forging of it is performed with a bar of flat steel which is the thickness of the thickest part of the intended liner.

After this bar is reduced on both sides of the thickest part of the intended liner, one of the two outside arms is bent, by heating to a bright yellow heat, and placing the end into a slot in the heavy block, or by placing the end a proper distance beyond the anvil edge, and driving down the projecting end with a hammer, while another much heavier hammer is held on the part that remains on the anvil. When one arm is thus produced, the entire work is cut from the bar; the piece cut off being of sufficient length for the entire liner. To ascertain the length necessary, the lengths of the parallel sides of the gap are added to the length of the semicircumference which constitutes the bottom, or, as it may be termed, the top, of the gap. These lengths, added to the length of the other arm, denote the length of bar necessary

After the piece is cut off, the length of the gap boundary is properly marked upon the work to indicate the commencement of the other arm. Marking the place for bending is performed by a centre-punch, having a broad conical end instead of a narrow one. A punch with a broad end will make a hole that can be seen, without making it too deep, which would injure the work. The situation of the mark also is of consequence. When a large hole is made in a careless manner with a sharp punch, into the side of a thin bar, and the bar is bent where that deep cavity is situated, the cavity becomes a long rent, of dimensions too great to be obliterated without spoiling the work; but if the cavity is made into an edge, or both edges of the bar, and with a blunt punch instead of a sharp one, the work when bent will not be disfigured, and, if necessary, the dot or cavity can be easily erased.

After two dots are thus made into the two edges of the work, the other arm is produced from the same side of the bar as at the first bending. The two arms will then be extended from the same side of the bar, and parallel to each other.

The gap-curve is next formed by placing the work upon a bottom fuller, which is of a suitable height to prevent the work touching the anvil, and of sufficient thickness to form the gap desired. At the first heating for this curve, the liner is placed upon the fuller with the two arms of the work upwards, and while the fuller is precisely midway between the two arms, a broad half-round top-tool is employed to force down the gap sides; and when the top-tool will not force the metal further without thinning the top of the work, a smaller top-tool is applied, and the curving is completed by hammering, and also stretching, to lengthen the gap to the proper dimensions.

Another method of making these liners consists in forging them from a bar of steel which is three or four times the thickness of the intended work. A boss is formed upon one side of the bar by driving in a fuller at two places, the boss being between. Two small or thin ends are then made, which extend from both sides of the boss to a short distance. A hole is next punched into the boss with a punch of elliptic section; or, as a substitute, an ordinary circular punch. The hole is made at a short distance from the edge of the work; after which, the thin piece is cut out by a chisel, and the gap is thus partly formed. The gap-sides are next lengthened by hammering, while on a narrow bottom fuller, on the anvil, and also while on a fuller having a long handle, which is held by the smith. Lengthening the gap is also performed by driving a top fuller into the gap while it is in a half-round bottom-tool in the anvil.

By this method, all upsetting, to produce what are named square corners, is avoided. As soon as the hole is punched, and the thin piece adjoining cut out with a chisel, the angular corners or entrances to the gaps are produced, and so continue till the forging is complete.

Stud Rivets.—These are occasionally used for beams or other work when it is necessary to penetrate entirely through and effect a fastening at the other side. The shortest method of forging one, which is denoted by Fig. 39, consists in making a collar or flange, and welding it to the stud, at a proper distance from the extremity. Such studs must be made of soft iron, for the convenience of riveting; and if it is necessary to frequently fix or unfix them, a screw and nut are used instead of a rivet.

Plunger Joints.—Such joints are applied to what are named hollow plungers, or trunk-plungers, and consist of two principal parts—the connecting-rod and the joint-head bolt. At the end of this bolt is a screw for a gun-metal nut, by which the bolt is secured to the plunger.

By referring to Fig. 42, it will be observed that the boss B of the connecting-rod is about equal in dimensions to the rectangular portion or boss at the other end; and the smith will thus perceive that the shortest and most economical method of forging is by steam-hammering a bar to the dimensions of the two ends of the connecting-rod, and then by reducing the intermediate part till the desired length is attained. And to do this in a scientific manner instead of by a series of random hammerings and cutting pieces off, he will learn precisely how much metal is necessary to produce the rod to the proper length by applying the rule stated in page 8.

When the bar is reduced by sufficient welding and hammering to the dimensions of the two larger portions of the rod, the sectional area may be stated, the rule applied, and the length of bar necessary will be ascertained. If the sectional area of the lump which is being forged is $12\frac{1}{2}$ inches, and the required sectional area of the intermediate to be 7 inches, and the required length of the intermediate between the two bosses to be 20 inches, the proposition appears thus:

$$12\tfrac{1}{2} : 7 :: 20 : 11\tfrac{3}{16}, \text{ nearly}:$$

11·2 is the true amount. And although this is but little more than half the length of 20 inches, the smith may drive in a fuller at each extremity of the indicated distance, allowing only an eighth or a quarter of an inch for heating and burning the iron, and also for the metal being closed into a smaller space by hammering.

The forging of the joint-head bolt which is attached to the connecting-rod consists in making a bolt with a large solid head, the fibres in which are circularly arranged. This arrangement is obtained by heating a thick end to welding heat and placing it into a large half-round bottom-tool, which is on the floor if the work is too long to be stood lengthways upon an anvil. The cold end of the work is then struck by hammers until sufficiently upset, after which, the stem or screw end of the bolt is produced, either while the bolt is attached to the bar, or after being cut from the bar and held by the bolt-head.

The amount of iron necessary to produce the stem to its proper length is ascertained by the same method as for the connecting-rod, and the length of bar may then be cut off; but it is generally more convenient to reduce the bolt-stem to the diameter desired previous to cutting it from the bar.

Small Crank-Shafts.—While speaking of crank-shafts, the three names, shaft, spindle, and axle, are synonymous, of which three "axle" is correct. The arm of a crank is a lever, and if a crank has two arms, it is a two-lever or double-lever crank. That part of the lever at which the power is applied is a handle, and in a crank is named a crank-pin. The two arms, together with the crank-pin, are termed the crank, and also the throw.

Fig. 43 represents a two-arm crank, and Fig. 44 indicates a one-arm crank. In both these Figures the letters L signify lever, and the letters P signify crank-pin. S denotes the portion named the axle or spindle, and B shows the bearing surfaces.

Small crank-axles are sometimes forged with cranks of circular section, which are named round-throw cranks. These are used for small machinery, such as foot-lathes, small pumping-engines, steam-cranes, and similar work.

Small round crank-axles are made by two principal methods. The one consists in bending a straight rod of iron or steel on an anvil, or anvil-beak, until the cranks are produced; and the other method is by forcing the work into cast-iron shapers or dies, which are of suitable dimensions to produce the throws to the necessary length, width, and shape.

To forge a small two-arm crank-shaft of round iron or steel, and without dies, it is usual to proceed by selecting a soft, tenacious metal which may be upset without opening or splitting. The diameter of the iron selected is that which is required when the crank is forged. If the entire crank-axle is to be of great length, the crank part is forged separately, and afterwards welded to the other part of the spindle; but if only a short axle is wanted, the entire length of metal necessary is ascertained, when the length is cut from a bar or rod, and the crank-axle made of one piece. The first requisite is to determine the position of the intended crank-pin. This is done by adding the length of the intended arm to the length of one end of the axle. These two lengths added together indicate the commencement of the crank-pin, and from this spot to a short distance beyond the other end of the crank-pin is the part of the work which is to be first upset. This portion is heated to a welding heat and upset till the rod's diameter is about a fourth greater than its previous diameter. The next step is to upset two other portions of the work, and the situations of these two portions are equidistant from the portion that was upset for the crank-pin. A dot is put into the work at an equal distance from either end of the crank-pin to indicate the length of the lever, because both levers must be of the same length. The work is then heated and upset at the place indicated by one of the dots, and the diameter increased to about the same as that of the crank-pin. Another upsetting is next performed at the place marked by the dot showing the length of the other lever. (See Fig. 135.)

After the three portions are upset, the first bending is effected at one end of the intended crank-pin. The next bend will be at the other end of the pin, but if the crank-pin is to be very short, instead of two bendings, one is sufficient.

When this portion of the crank is made, the two ends of the intended shaft are parallel to each other, and the distance between the two centres should be the same as the length of the crank-pin, if measured from the centres of the lever ends. If the length of the heated part previous to bending were too short or too near the centre of the crank-pin, the bent part must be re-heated and adjusted, or stretched and lengthened by fullers of proper thickness; and if the heated part were too long, the crank-pin is also too long; in such cases it is shortened by re-heating and cooling to the right place and closing the two ends of the work together.

During forging, the diameter of the crank-pin is not so important a consideration as the length of it. If the pin is upset beyond the finished diameter, and the pin too long to admit of being stretched, it is afterwards reduced to the right diameter by the lathe process.

When the crank-pin is formed, the throw is then produced by bending back the two ends of the shaft while the pin is cool enough to prevent any alteration of it during the bending which produces the levers. The cooling is effected by placing the bent portion already made into the water until a proper amount of the intended two arms is cooled, while the remainder is still hot enough for bending. It is then placed between two studs of a suitable length and width on a heavy block, and bent by forcing the end back with levers or tongs which are fixed at the end of the work.

The length of the heated portion at the time of bending should be the length of the curve desired; consequently, the iron is cooled until the punch-mark is exactly midway between the two extremities of the curve intended. If the curve is not made in the right place, the throw will be either too long or too short; the work is then re-heated and cooled to lengthen or shorten the throw to its proper length. During this lengthening or shortening, top and bottom tools and fullers are also needed to produce the necessary curved outline of the work.

Adjusting the crank and shaft is next performed by making the two levers parallel to each other, and in the same plane with the crank-pin and crank-axle. Another sort of adjustment also is performed by the aid of a long straight-edge. This is applied to the axle of the work to indicate whether the longitudinal axis of one end is nearly in line with the longitudinal axis of the other end. If the work is not properly adjusted at the first forging, it must be adjusted at some other time previous to being turned, and also at a needless expense.

Cutting the extremities to a suitable length is next performed. The precise length will depend upon whether or not the axle-ends are to be steeled. Steel ends may or may not be necessary, according to the intended use of the axle. Such ends are often used for lathe crank-axles when each end is to be supported by a screw whose end fits the end of the axle.

If steel ends are needed, their attachment is effected by driving in a small punch and making a hole in line with the axis of the axle, and then welding in a piece of steel, the length of which is according to whether the end of the axle is to be tapered or whether the parallel portion is to be continued to the extremity. If an inch or two of steel is necessary, the pieces are scarfed, or a tongue-joint made in the usual manner.

Crank-shafts of round iron are also made by first forming the two outer curves of the crank instead of first making the two curves at the end of the crank-pin. A long crank-pin is easier formed after the two outer curves are made, and a short crank-pin may be produced at one bending, which is conveniently done at the commencement of the forging.

Those who make small crank-shafts in large numbers require the dies or moulds, into which the iron is pressed and hammered to the shape desired.

These moulds consist of cast or wrought-iron blocks, which are sufficiently thick and heavy to bear much hammering without breaking. They may be so shaped as to produce crank-axles of either round iron or square, and effect a large economy of time and labour.

The lower die or block is that which receives the piece of straight iron that is to be cranked, and the upper block is that by which the work is forced into the die; and both blocks, when together without the work between, form a cavity which is the shape, or, in some cases, nearly the shape, of the crank required. Each pair of shapers is jointed together, or guided together with guide-rods, that both dies may be in their exact relations to each other when brought together by hammering.

But to make a small crank with square corners a different method is adopted. Cranks with angular corners are used for small land-engines, or small pumping-engines, and are of different forms, according to their intended destinations and positions. They are made with but one arm, having the crank-pin outside, as in Fig. 44, or, as in Fig. 43, with two-arm cranks having the axle-bearings at a distance, depending upon the amount of room desired between the main framing.

The crank-pin represented in Fig. 44 is distinct from the crank-arm, being secured to the arm by a nut, to avoid weakening the pin by cutting a key-way into it. The lever and axle constitute one piece, and the forging of this piece consists in either upsetting the axle and bending it to a right angle, or in cutting a slit into the end of the shaft and welding in the end of the lever.

The strongest work is produced by bending, and the upsetting previous to this bending must be well done; or a larger bar is selected and reduced on each side of the intended apex or corner until the dimensions of the intended lever and axle are attained. This reducing of a bar which is too large is as effectual as upsetting a bar which is about the diameter of the shaft. But whichever plan is adopted, it is necessary to form a thick lump at the place of the intended corner. The inner side of this thick part is then reduced by a broad fuller and hammering, which makes the bending comparatively easy, prevents the inner edges being squeezed up during the bending, and renders the bending process altogether less difficult, while the thick portion outside remains to be formed into the sharp or square corner desired.

The bending or angling is commenced by driving a fuller, which is held on the axle while it is lying across an opening in a large heavy bottom-tool, or some other convenient gap. After being thus partly formed, the angling is continued on an anvil edge, while heavy hammers are held on the work; or the work is put upon a steam-hammer anvil, the hammer of which is fixed upon the work by the steam. While thus fixed, the sledge-hammering is administered sideways to the work.

The final squaring of the corner is accomplished by upsetting it while at a bright yellow heat. During this upsetting, the blows are given both to the cold end of the lever, and to the cold end of the axle. By such treatment, if necessary, a well-defined corner will be produced, without cutting a gap into the corner, and welding in a piece which is named, for some funny reason, a sticking-piece.

The mode now to be mentioned, of making a small one-arm crank-axle, obviates much upsetting, or large amount of reducing; and is also a quicker method of proceeding than by angling, but care is necessary to ensure good work.

The plan consists in welding the lever to the axle; and requires a large opening or gap to be made in the end, into which is fitted a stem that is tapered down from the lever. The depth to which this gap should extend from the extremity is $1\frac{1}{2}$ times the finished diameter of the axle. Such a depth of gap admits a stem of great strength; and to allow as much strength as possible to the axle, the bottom of the gap is in the shape either of a long curve or of an angular > form.

If the end of the lever is then spread out and tapered or fullered down to fit the gap, a tolerable joint may be effected with about three welding heats; consequently, every provision must be made to secure sufficient iron for a large amount of welding and hammering. If such a joint happens to be thoroughly welded in all its parts, the work is equal to a shaft made of one piece; and for many classes of small work such a joint can be made.

The forging of a small two-arm crank-shaft, represented by Fig. 43, includes two or three methods; the particular plan selected depending upon the dimensions of the work and upon the resources of the maker. A simple mode consists in welding and preparing a bar whose width equals the total width of the crank, measured from the outer extremity of the crank-axle to the outer extremity of the crank-lever. When such a bar is made, the crank is formed by cutting out three large pieces: the cutting out of one piece produces the gap which adjoins the crank-pin, and the cutting out of the other two pieces forms the spaces at the outsides of the two levers. After carefully marking upon both sides of the work while cold, the cutting out is commenced at a yellow heat by punching a round hole at each spot which marks the forged width of the lever, and also marks the forged thickness of the crank-axle. Two chisel-cuts are then made at right angles to each other, and whose vertex is the inner extremity of one of the holes. By these two cuts, one of the larger superfluous pieces is cut out; and the other similar piece is then cut out by similar means.

The gap-piece is next cut out by first punching a row of holes which is parallel to the length of the crank-pin, and at the bottom of the intended gap. Two other rows of holes are then made at right angles to the first row, and to meet it; the gap-piece is then separated by a chisel which is driven half way through from both sides. A crank-piece of this character is shown by Fig. 136.

Crank-axles made by this mode require the iron to be very close and welded in the lever portion; if not, the crank will certainly break while in use, although it may be of twice the ordinary necessary dimensions of a good crank for the same engine. And the rupture will occur because the lengths of the fibres in the levers are at right angles to the proper position. This position is parallel to the length of the lever, and not at right angles to it.

One other method to be mentioned of making a small two-arm crank-shaft consists in making a solid crank, or solid throw, and leaving the superfluous gap-piece to be cut out by drilling and slotting.

The forging of such a crank commences by welding and reducing a bar until the width of it equals the total length of the crank-lever, and then drawing down a portion of the bar each side of the intended crank.

The length necessary for each end of the axle is discovered by applying the appropriate rule in the ordinary manner; after which a fuller is driven in at the intended commencement of each axle-piece, and the ends are lengthened by ordinary hammering. If the axle-pieces are too short to be reduced while attached to the bar, it is necessary to cut off the work, and grip it with angular-gap tongs of suitable dimensions.

The making of large crank-axles will be mentioned in due order.

Hoop Excentric-Rods.—These are also named band excentric-rods, and are indicated by Figs. 45 and 115. The forked or hoop portion is of one piece with the remainder of the rod; although it is first forged distinct from the straight part, the two being afterwards welded together.

The hoop portion is formed by spreading out the end of a thick piece which is of sufficient length to be conveniently handled by means of tongs, or by a bar named a porter, which is welded to the work at the commencement of the forging. A round hole is made at the inner extremity of the intended gap, or concave portion of the hoop, and a slit is cut from the hole to the extremity of the work. After being thus divided, the two ends are reduced to a proper width and thickness, and increased to a suitable length, care being exercised to leave a thick piece at each end to be formed into bosses for the connecting-bolts.

After the semicircular portion is formed, a stem is made of the thick part of the work, which is produced to a convenient length for welding to the straight part of the excentric-rod. This straight part is then made of proper length, width, and thickness, and welded to the hoop-piece for completing the rod.

Large hoop excentric-rods for marine engines are made of several pieces, which are then welded together. One piece constitutes the boss part which is bolted to the link; another piece is made into the intermediate parts of the rod; the next piece is formed into the fork junction, being that which connects the intermediate piece with the fork-ends; and these two fork-ends are the portions required for completing the rod.

After the whole number are welded together, such large rods need careful adjusting to place the band portion at right angles to the straight part of the rod. To effect this adjustment, a straight line is marked upon a large surface-table, the length of the line being a few inches greater than the total length of the rod. At one extremity of the line another is made at right angles to the first, and across it, the length of the second line being equal to the total breadth across the gap and the bosses included. From the centre of this line two concentric circles are described, the distance between their two circumferences being an eighth of an inch greater than the distance between the two curves of the hoop-forks. Next mark the shape of the intermediate part of the rod, by drawing a line on each side of the first one made, and making the distance between the two outer lines an eighth of an inch greater than the width across the rod.

By placing the rod between these lines on a surface-table, any irregularity in the band or straight part of the work will be easily observed, and corrected accordingly.

Semi-Hoops.—The forging of the separate semicircular bands of excentric rods consists in preparing and curving a straight bar which is of proper length, width, and thickness. (See Fig. 140.) If the bar is first well hammered and reduced while straight, after the band is curved to its form, the fibres will be in a suitable position for sustaining the strain while in ordinary use. After the piece is reduced to its width and thickness, the length of bar necessary for the band is equal to the lengths of the two bosses added to the length of the band's mid-semicircumference; and the length of the semicircumference is known by being half the length of the entire circumference of the band's mid-circle.

The bending or curving of the straight piece to a semicircle is accomplished by first heating a few inches of one end, and bending it to a few inches of the curves that are marked on the surface-table. The adjoining portions are afterwards successively heated and bent to the same lines, until a near approach to circularity is obtained.

For large bands it is necessary to provide thick cast-iron rings, to hang on the cylindrical pieces in the angular gaps. The bands are heated to a suitable heat, and then placed upon rings of suitable diameter, and bent by large top-tools, or by hammering.

A substitute for these rings consists of the conical filler that was mentioned for stretching slide-rod rings. While the filler is lying in a horizontal position, in a convenient place, the band or bands are held on that portion which is nearest to the diameter desired. While on the filler, the bands may be curved, and lengthened by hammering if necessary.

Connecting-Rods with Screw-ends.—A rod of this class is shown by Fig. 46. When such rods are to be short, the forging is accomplished with two pieces, which are welded together at the conclusion of the forging, the joint being in the middle of the rod.

The fork-piece or boss-piece may be forged either solid or with a gap. If forged solid, the gap or opening may be afterwards formed by drilling and slotting. To forge a solid fork-piece for a small rod, the smith commences by selecting or making a bar whose width and thickness are about twice that of the intended piece. The work is welded and reduced by a steam-hammer to the outer forged dimensions of the boss. After which, top and bottom fullers are driven into the work at the inner extremity of the boss, which is denoted in the Figure by C. The fullers reduce the metal in order to produce the inner curves by which the boss-piece is terminated and the intermediate part of the rod commenced. After two hollows or concave recesses which are parallel to each other are thus formed by the fullers, the work is placed at right angles to its former position, and two new hollows are formed. By such reducing with fullers, the fibres are curved and arranged into a graceful position and relation to the boss, and to the intermediate part of the rod; and the required shape of the boss-piece is obtained. The outer extremity of the work is then curved by a half-round top-tool, or by holding the work with the hot end in a half-round bottom-tool, and upsetting by sledge-hammering the upper cold end. When the boss is tolerably shaped by fullers, top-tools, or upsetting, the boss-stem is reduced to its proper diameter, and increased to its desired length to become the intermediate part of the rod.

For making the screw-end of the rod but little forging is needed, if the iron which is selected were properly prepared by rolling; if not, it is thoroughly welded and steam-hammered, for two reasons—to obtain a tenacious iron in which the lengths of the fibres are parallel to the length of the rod, and to obtain sufficient solidity in that part which is to be formed into the screw.

When rendered sufficiently hard and close by hammering, the two pieces are united by a tongue-joint, or by a scarf-joint, if the rod is not more than $1\frac{1}{2}$ inches in diameter.

Small connecting-rods of this class are sometimes used for imparting motion to the slide-valves of land-engines, and are attached to slide-rods similar to Fig. 47.

Piston-Rods with T-ends.—The brittle character of steel generally, does not prevent piston-rods, small and large, being made of it, for several reasons; among which are their comparative lightness and favourable arrangement of the constituent particles, and their greater capability of resisting the destructive abrasion resulting from the friction of the packing in the packing-box; also because the amount of power absorbed and wasted by friction is small, the area of the rod's friction surface being comparatively small; and because manufacturers are now commencing to make a strong tenacious steel that meets the requirements.

Small piston-rods may be forged with T-ends large enough to constitute guide-blocks, so that the rod, crosshead, and guide-blocks together constitute one forging only. To make a small rod of this character, a bar of iron or steel is selected, or drawn down until its width is about the same dimension as the length of the intended crosshead or T-part. A pair of fullers is then driven in at the junction of the crosshead and cylindrical part of the intended rod. The thick lump that remains is then reduced by hammering until the forged diameter is attained; or two pieces may be cut off, leaving the rod between, if the economy of metal is not at that time being considered.

Large piston-rods with T-ends need a more economical method. To avoid the lengthy process of reducing, or the wasteful method of cutting off, the T-part is formed by splitting open the end of a bar and upsetting it until the necessary right-angular form is obtained.

At the place intended to be the outer extremity of the T-piece a round hole is punched. A slit is next made from the hole to the extremity of the bar by driving chisels half way through from both sides, the length of the slit being equal to the distance of the hole from the extremity. A thick wedge in a handle is next driven into the slit to partly open it, and the two ends thus produced are afterwards opened to the necessary distance by sledge-hammering sideways while the work is across the anvil.

Upsetting is next performed to produce the flat bottom or bearing of the T-piece. For small work this upsetting is done by two methods, one of which consists in putting the work into a heading-tool and flattening the head by hammering; and the other plan is to place the T-part upon the anvil and shape the work by striking the upper cold end. When the rod is too long for the anvil, the upsetting-block, whose top is level with the ground, is preferable to the anvil. Upsetting the T-piece of a large rod is performed by striking or battering the end with a pendulum-hammer.

During these upsetting processes the iron is at welding heat; if steel is being used, the heat is as great as the character of the particular piece of metal will allow.

After the head or T-part is sufficiently upset, and its proper length, width, and thickness attained, the part of the rod next adjoining is reduced by fullers to the desired forged diameter; tongs are then fixed to the T-part, and the lump for the cylindrical portion is welded, reduced to proper dimensions, and well closed by angular-gap tools, the smoothing of the work being effected by half-round tools.

The final process is straightening the round part with half-round top-tool and sledge-hammer, or steam-hammer, and adjusting the T-end to a right angle with the length of the rod. For this purpose a long straight-edge and a square are needed. The straight-edge is applied to several sides of the round part of the rod to discover the hollow places; these places are put next the anvil-top while the upper sides of the rod are driven down by hammering. After the round or cylindrical portion is sufficiently near to straightness, the T-part is adjusted to a right angle by being struck with a pendulum-hammer, or by a sledge-hammer if the work is not too large.

CROSSHEADS FOR ONE PISTON-ROD.—In crossheads of this character the lengths of the constituent fibres should be at right angles to the length of the corresponding piston-rod, and therefore parallel to the length of the crosshead itself. To obtain this arrangement it is necessary to draw down a bar of tenacious iron until its width and thickness equal the thickness and width of the largest part of the intended crosshead, which is the boss or mid-portion.

A small crosshead is easily forged at the end of a long bar, and may be completed previous to cutting off. A pair of fullers are driven in at two places in the mid-portion of the piece intended for the crosshead; the boss is then produced in the middle as required. After the boss is thus formed, the lumps adjoining are reduced by sledge-hammering to the suitable width and thickness. A crosshead-piece is shown by Fig. 143.

By this treatment the fibres are properly arranged throughout the length of the crosshead, the fibres of the boss being circularly disposed by driving in the fullers; and the fibres of the adjoining portions are retained in a position which is parallel to the length of the work, being the arrangement desired.

For a large crosshead a similar arrangement is necessary; but a difference of manipulation is resorted to, by reason of the greater weight of iron requiring to be handled. For portability, it is advantageous for the workman to know what length of metal is necessary to be drawn down to any length of crosshead that may be desired, if the forging is to be of one piece only. The engine-smith can then select a bar from a shingler who is appointed to build up the bars from pieces, or from any other forgeman whose duty it is to prepare the bars. If the smith has thus a suitable bar at command, he can commence forging by driving in the steam-hammer fullers to produce the boss; but if the bar is too long, the necessary length may be ascertained by the appropriate rule (page 8), and that which is not needed is cut from the bar at the first heat. The fullers are then applied, and the adjoining parts reduced by steam-hammering, the work being supported by endless chain and a crane during the whole of the forging.

It is not usual to forge any hole whatever in a crosshead-boss, the entire boring being done in suitable boring-machines.

SIDE-RODS.—These, like crossheads, are used of all lengths and diameters, and for engines of all classes. When used for small high-pressure land-engines, side-rods are at the same time connecting-rods, being connected at one end to the main crank-shaft, and the other end of the rod being attached to one end of the piston-rod crosshead.

However small the side-rod may be, it is advantageous to punch a hole into the eye or boss-part. The punching is not needed to avoid drilling, but to produce the necessary circular disposition of the fibres in the boss. For this purpose the punching is very effectual, if performed at about welding heat; after which a six-sided or eight-sided drift may be driven into the eye to shape it for the brasses when it is desirable to avoid shaping by other machinery.

After the boss and eye-part is forged, the adjoining portion of the rod is reduced by thorough hammering while at about welding heat, to produce a tough intermediate portion for the rod. The whole of a small side-rod may be forged at one end of a bar of convenient length to hold without tongs, the work being cut off at the conclusion.

Large side-rods need a more careful management to ascertain the length of metal necessary for the rod. By first distinctly stating the respective sectional areas of the iron to be used, and the rod to be made, only a sufficient length of metal need be handled, which is advantageous both for convenience of portability and economy of metal.

Side-rods are also made by another method, which consists in making two separate pieces and afterwards welding them together, the joint being in the middle of the rod. The length of iron required may be discovered in the appropriate manner, after which the eye is punched and drifted, at nearly welding heat, to any desired diameter and shape; the proper shape of the eyes in large side-rods being circular. When the two pieces are reduced to their proper diameter and increased to a correct length, the two are strongly united by a tongue-joint (Fig. 133).

The Learner.—A learner who is commencing the business, and has attended to the foregoing instructions, may now be able to make a few more tools, and to understand a few remarks on welding.

The easiest joint for a learner to make is that of two small flat bars united by a scarf-joint, shown by Fig. 132. To weld such a joint either of two methods may be adopted, according to circumstances. The first-mentioned plan is suitable for a smith who may be without a hammerman. In such cases the workman places a screw-prop at that side of the anvil which is usually occupied by the hammerman. The distance of the prop from the anvil depends upon the length of the work; the prop, being portable, may be in any desired situation for supporting one of the bars to be welded; the fork is then screwed up or down to suit the thickness of the work, and to make the scarf touch the anvil while the remainder of the bar is an eighth or a quarter of an inch above the anvil.

After the prop is put into its proper situation and position, the two scarfs are placed into the fire side by side, with the two extremities of the scarfs upwards, that they may not be burnt off, and that the heat may be driven upon the entire surfaces that are to be welded together, instead of upon the edges only.

When the welding heat is attained, a supply of sand is given to the two scarfs to cleanse the slag or other impurities from the iron. When the scarfs are thoroughly cleansed, the workman brings out both pieces at one time, one in each hand. The piece in his right hand he puts upon the prop with the scarf end a quarter of an inch beyond that edge of the anvil which is nearest to him. The piece in his left hand he then places upon the top of the other piece, and with the scarf end of the upper piece a quarter of an inch nearer to the further end of the work than the joint will be when welded. He then delivers a few blows with his hammer, which drive the upper bar down to its proper position, which is in line with the other bar. These few blows also stick the scarfs together; and while the scarfs are still at welding heat the whole work is turned upside down by the operator carefully twisting the part on the prop with his right hand at the same moment that he twists the other part with his left hand. After being reversed, the scarf end that was underneath is still at welding heat, because it was a short distance beyond the anvil-edge. The welding is then completed by hammering the sides and edges of the work until sufficiently solid for the purpose intended.

The second mode of making a scarf-joint, is managed by instructing the hammerman to take out one of the pieces from the fire, and causing him to supersede the screw-prop.

It may be also necessary to advise the learner not to draw down his work with a steam-hammer until he has acquired the method of holding his work in a correct position on an old-fashioned anvil. Serious effects to the arms will result if the work is held too high or too low, the danger being in proportion to the force that may be imparted to the hammer at the moment.

If the learner should be making any rings according to the instructions that were given on the subject, he may refer to Fig. 139, in which he will see the mid-circle of the ring's face marked by M. And if he should meet any difficulty in finding any Figure that may be referred to, he can avoid trouble by remembering that if the greatest number at the bottom of any Plate he may be looking at, is one or two less than the number of the Figure he desires, he will know that the required Figure is in the next Plate following, although the number of the Plate may not be mentioned. Also, if the smallest number at the top of any Plate he may be examining is one or two greater than the number he desires, he will know that the required Figure is in the next Plate previous. The terms "Plate 10," "Plate 12," and similar phrases, are often omitted for brevity and to avoid repetition; the simple sentence, "Fig. 122," being more isolated and easily remembered.

Connecting-Rods with T-ends and Fork-ends.—Connecting-rods are of three principal varieties, the simplest form of these being the rod with two T-ends; the next class having hollow or curved ends for circular brasses; and the third variety having a T at one end, and at the other a fork.

Plate 13 represents the several classes of rods in their respective shapes during forging. In this Plate, Fig. 144 represents a small connecting-rod in process of forging from one straight bar. Fig. 145 indicates a connecting-rod with two T-ends, also in one bar. Fig. 146 shows a similar sort of rod, but made of two pieces. Fig. 147 points out a connecting-rod intended to have hollow ends for circular brasses. Fig. 148 denotes a rod having a fork at one end, and at the other a T-end, which is at right angles to the fork; or, in lengthy language, at right angles to a line through the centres of the two fork-eyes that are intended to contain the connecting-pin, gudgeon, or gudgeon-crosshead.

Small connecting-rods with fork-ends are sometimes made without a T-portion at the other end. Instead of a T-end, a screw is used, or key inserted. For such a rod the bar of which the work is to be made requires to be split open at one end only, to produce the fork. To make a rod with both fork-end and T-end, the bar is split at both ends; then opened and shaped to the desired form. By these considerations it may be inferred that a tough tenacious iron is necessary, if only the forging of the rod be considered. If brittle Bessemer iron be selected, it is troublesome to make either a T or a fork, without great risk of cracking and spoiling the work during its forging. The smith will therefore select the iron with due regard to its capability of being forged, and to its durability afterwards.

The convenient mode of forging a small rod, shown by Fig. 144, consists in making the T-end first, because of the upsetting which is needed. If a very small rod, a slit is cut at one end of a bar whose length is convenient for handling, and the two ends thus formed are opened until the T-piece is produced. A welding heat and upsetting is then necessary to thoroughly flatten the extremity, and to erase the appearance of the split. Larger rods may need a hole to be punched, previous to cutting the slit; the hole allowing the ends to be easily spread out and flattened to a right angle. After the T-end is thus shaped, the necessary length of iron is ascertained, when the work is cut from the bar and the fork-end produced.

The manner of splitting the bar for the fork depends upon the thickness. A small bar is divided by a chisel-cut only; a larger bar needs a hole to be punched, and a slit cut from the hole to the extremity; a still larger bar may require two chisel-slits from the hole, so that a piece may be cut entirely out, to shorten the after process of thinning the fork-ends, after the slit or opening is made.

After the opening is made, the curving and shaping of the intended fork is effected by first hammering the work while on a round filler of suitable diameter, which is across a pair of blocks as shown by Fig. 142. The fork being very small, a piece of round iron half an inch in diameter may be large enough.

A pair of small fullers are next driven in to form the hollows that adjoin the circular portions, in the middle of which are the holes or eyes for the gudgeon, or gudgeon crosshead.

The final flattening of the fork-gap is effected by hammering the fork-ends while on the edge of a flat bar, which is in the gaps of the blocks that previously supported a round bar.

In those cases that require a large number of such small fork-ends to be finished on the anvil, it is necessary to make a steel filler which is just the thickness of the intended gap; one side of the filler, or what is named one edge of it, being curved to shape the bottom of the gap. This filler is held in the fork-gap by a gap-stop, while the outsides are hammered to make the insides of correct dimensions. A gap-stop in the square hole of an anvil is shown by Fig. 77.

When the fork-end and T-end are made, the intermediate part of the rod is drawn down and the length increased to the length desired.

Figure 145 indicates a connecting-rod bar which is split at each end, and also fullered at the inner sides of the intended T-portions. To make a T-end rod in such a manner of one piece, the bar at the commencement of the forging may be equal in diameter to about two-thirds of the entire length of the intended T-end. A short slit, S, is first cut to allow the ends of the bar to be spread to the desired length of the T-part. Fullers are next driven in to produce the hollows or recesses indicated by H. The thick lump in the middle is then reduced by steam-hammering to the desired diameter and length.

Rods with two T-ends are also made of two pieces, as shown by Figure 146; this mode being adopted for portability, or for the purpose of using two short pieces of iron when one piece of sufficient length is not comatable.

Reference to the Figure (146) will show that each piece has a slit at one end, corresponding to the two slits in Fig. 145. The utility of these openings is rendered apparent, by considering the economy of iron resulting from opening the end, instead of reducing the rod from a bar which is as thick as the length of the intended T or head; also by considering the proper disposition or arrangement of the fibres in the T-pieces. At all times when circumstances permit, the forging should be so managed as to place the lengths of the fibres in the two heads at right angles to the length of the rod itself.

To obtain this arrangement, it is only necessary to cut open the ends and upset the work as indicated by the Figures—the ordinary method of upsetting heavy work being by the pendulum-hammer; and, in a few cases, with a steam-hammer. Although it is not convenient to upset work of great length by a steam-hammer, it may be conveniently used for a short piece which has a base or bottom of sufficient dimension to maintain the work in an upright position during the hammering. Pieces not exceeding two or three feet in height may be managed with an ordinary steam-hammer by driving a fuller into the middle of a short piece, as shown by Fig. 149, after which the two prominent portions are driven down by the hammer and at the same time spread out to form the head, or what is named the T. For this purpose, a hammer should be used whose face is concave, and not flat.

A short piece of this character may also have a slit cut into one end, instead of a hollow made with a fuller. If a slit is made, it is necessary to drive a thick wedge into the opening to make it several inches in width, previous to upsetting; if the gap is not well opened with a wedge, or by sledge-hammering while across an anvil, the blows of the hammer will shorten the work, without producing the head or T-form that is desired.

Another method of making a large T-end consists in laying and welding two bars together as in Fig. 150. The bars are thoroughly welded in the intermediate portion, but not at the two ends; these are opened, and one pair formed into a T, and the other two ends are shaped for becoming part of a tongue-joint, by which the T-portion is welded to the remainder of the rod.

Either of these methods for making T-ends may be adopted, according to the resources of the maker; whether he has small iron or large at command, and whether he has a number of small remnants he may desire to forge.

When it is intended to forge the entire rod of one bar or piece, the necessary length of iron is discovered at the commencement of the forging, by applying, in a modified manner, the rule in page 8. Whether the original piece be four-sided or circular is of no consequence, if it is of good quality and of sufficient sectional area. When the intermediate part of the intended rod is to be of circular section, or what is commonly named round, a square bar is a very convenient one to commence with.

If we consider it stated that the intermediate part is to be circular, and its forged diameter to be 150 millimetres, the first step is to select a bar whose sectional area is about double or treble that of the intended mid-portion. The dimensions of the bar selected depends upon the intended length of the work. If the length of the intermediate is to be 1524 millimetres, the original piece selected may be 230 millimetres square.

The next step is to ascertain the length of iron required for the circular intermediate part; then discover the length required for the two T-portions, and add all together to indicate the total length requisite.

The bar selected being 230 millimetres square, its sectional area, 52900 millimetres, constitutes the first term of the proposition. And if the mean diameter of the intermediate part is to be

150 millimetres, its sectional area, 17671 millimetres, constitutes the second term of the proposition. The length of this part, 1524 millimetres, is the third term. The three terms, with the result, appear thus:

$$52900 : 17671 :: 1524 : 510,$$

the fourth term denoting the length, in millimetres, of iron necessary; this result being obtained by multiplying the second and third terms together, and dividing by the first term, in the usual manner, avoiding minute fractions as of no use in this affair. The proper length of metal for the intermediate is thus found to be 510 millimetres, if the bar is 230 millimetres square, and therefore contains 52900 square millimetres in a sectional area.

The two T-parts next demand attention. These portions are sometimes short and thick; in such cases the amount of upsetting required is but small; but, whether little or much is needed, the requisite length of metal may be known by a little measurement. If it should be necessary to make the length of the T-part three times the length of the rod's diameter, the end may be either opened, spread out, and upset to 450 millimetres, or it may be spread out in an easier manner to the desired length, without upsetting; in which case the fibres of the head will be parallel to the rod's length, instead of at right angles to it, which is the preferable position.

To ascertain the length of bar that will be needed for the head or T-part, the rule is applied in a similar manner to that for the intermediate. If it is decided that the length of one head shall be 450 millimetres, and its sectional area 20000 millimetres, the necessary length of the original bar appears in the fourth term of the complete proposition, thus:

$$52900 : 20000 :: 450 : 171.$$

171 millimetres of the bar being sufficient for one head or T-piece, 342 millimetres are sufficient for both; this length is therefore added to 510 millimetres for the intermediate, which result determines the total length of bar needed for one connecting-rod, to be 852 millimetres, if its sectional area previous to forging contains 52900 square millimetres.

Through the necessity of heating the iron a number of times, a portion will be taken from the lump by the fire, for which a few millimetres should be allowed, so that the length of bar actually required and used is about 900 millimetres.

After a lump of these dimensions is selected, the first step is to either spread out or upset both the T-parts; and when the desired shape of these ends is attained, the intermediate lump is reduced to its intended diameter.

This reducing is facilitated by the two hollows at the inner extremity of each head. The forged thickness of the head indicates the places for these hollows, shown in the Figure by H. Steam-hammer fullers are driven in to an equal distance from both sides, after which the work is lengthened and drawn down to its proper diameter.

To forge a connecting-rod in the manner indicated by Fig. 146, the proper quantity of iron necessary for each of the two pieces may be ascertained, and each piece separately forged to the required dimensions, and welded together at the conclusion.

Each of the pieces shown in the Figure is handled by a porter, marked P. These porters are round at that part which is supported by the endless chains, for the convenience of being easily rotated by the workmen. Fastened to a porter is seen a rotator, R, which is gripped by the men for the purpose of reversing or rotating the work.

The two pieces represented by Fig. 147 are nearly the shape of those in Fig. 146. The difference consists in the heads or T-parts being of greater relative dimensions because of more iron being required to surround the brasses. These brasses being circular, their recesses in the rods' ends may be formed by boring holes into the ends of the rods that are forged solid with the cap C, without any hole whatever.

To make a small rod of this class, it is not necessary to produce a solid head; the semicircular recess for the brass may be easily formed in the ends of the rod by broad fullers; and the rod-cap also, may be conveniently and separately forged with its recess for the other brass.

When it is needful to forge the rod in one piece solid with the two caps, a lump of iron is required for each head or end, and another piece for the intermediate, three pieces in all; two welds are therefore made in the mid-portion.

By selecting a piece for the middle, and welding it to the two heads in this manner, the drawing down of a large mass of metal is avoided; an important consideration with makers who may have small steam-hammers instead of large ones.

But if the rod is to be short, two pieces, instead of three, are sufficient; the drawing down for a short rod being comparatively small. The width and thickness of the lumps or bars selected for a short rod being about the same as the thickness and width of the intended heads, upsetting will be avoided; and by this method only one joint is required, which will be near the middle of the rod.

In Fig. 148 a connecting-rod is represented having a solid fork-piece, which is intended to be bored to produce the fork-gap, instead of forging it upon the anvil.

To make the fork-end, one piece of iron is used that is equal in width and thickness to the greatest thickness and width of the fork-end when forged. A porter is welded to the end intended for the intermediate part of the rod; and the forging commences by forming the two hollows or recesses shown by R. These are made by broad top and bottom steam-hammer fullers being driven from two opposite sides. The next reduction consists in drawing down a portion of the intermediate until its thickness is about the same as the thickness of the work at the bottom of the two hollows first made.

After a part of the mid-portion is thus reduced, the work is placed at right angles to its former position, and fullers are again driven in, to form two other hollows shown in the Figure by J J, which indicate the junction of the fork-end with the intermediate.

The fullers, being thus repeatedly driven into the work while in two positions at right angles to each other, produce the desired shape of the fork-end, and also the two curves J J. The thick lump remaining for the intermediate is then reduced to its intended thickness.

Another mode of making a solid fork-end consists in placing and welding two bars together as in Fig. 152, a convenient method for using small bars. Each of these pieces is first attached to a porter, then separately heated to welding, and welded by a steam-hammer or by angular-gap tools. During the welding, care is necessary to thoroughly weld the work at the part intended to be the junction with the fork; to weld the whole of the fork-end is not needful, because of the intention to cut out the piece from the middle.

After being thus welded, one of the two porters is cut off, one being sufficient. By this one the work is handled during the shaping, which is effected by fullers being driven into the work while in two positions, at right angles to each other, as previously described.

A very strong sort of fork-end is made also by bending a straight bar and welding the two ends together; the two ends, after being welded, constituting a part of the intermediate. Such a fork-end is represented by Fig. 151.

To forge the T-piece of the rod shown by Fig. 148, two bars may be welded together, as for the fork-end; or the T-end may be made of one piece, either by drawing down a part of a large bar or by upsetting a portion of a smaller bar, as in Fig. 176. When both T-end and fork-end are forged, the two are united by means of a tongue-joint. During the preparation of the joint for welding, the tongue-piece is flattened or tapered on the two proper sides to cause the T-end to be nearly at right angles to the fork-end, when the work is welded together.

The rod being thus completed by welding, it is adjusted on a surface-table. The adjusting consists in twisting the mid-portion of the rod in order to make the T-end at right angles to the fork. The rod may be heated to redness, then fastened at one end to the table with bolts and plates, while the opposite end of the work receives a few sledge-hammer blows that drive down the end to its proper position. The convenient method is by fastening the fork-end tight to the table, and supporting the T-end by placing a few blocks under the intermediate part next the T. This T-part is then struck a few blows to make it parallel to the table. A rod of this character may be adjusted also by fixing with the steam on a steam-hammer anvil, and twisting the work with levers or hammering until adjustment is effected.

Thrust-Shafts.—All thrust-shafts are forged without the grooves in the thrust portion, so that the smith makes it equal in diameter to the outer forged diameter of the intended thrust.

A small thrust crank-shaft may be forged of one piece solid with the crank-pin, as shown in Fig. 106. When it is not intended to place the constituent fibres in their proper positions, the crank-shaft may be made of a bar whose width equals the entire length of the intended crank-arm or lever. At one end of the bar a piece is cut out adjoining the crank-pin. Another piece is cut from the opposite side, leaving the lever between. Welding heats are next given to reduce the intended shaft or axle and also the crank-pin to their circular form, and to obtain solid metal for the thrust part. A lump is also allowed to remain at the end, to be made into the disc D, or, in some cases the disc is produced by upsetting.

A preferable mode of making a small thrust crank-shaft consists in forging it of two or three pieces; one piece being for the disc and part of the axle, and the other pieces for the thrust and crank.

By this method, the iron for the disc-end at the beginning of the forging is about the diameter of the intended disc; and the short axle-piece adjoining is produced by driving in fullers at a place which is the same distance from the extremity as the thickness of the intended disc. The adjoining lump is next drawn down by hammering to the desired diameter of the axle.

To form the crank and thrust-piece so that it shall be without a joint, and also to place the fibres in their proper positions, it is necessary to provide a piece of iron whose sectional area is about twice that of the intended shaft.

When the iron is selected, it is first necessary to ascertain the place of the intended corner or junction of the crank-arm with the shaft. Fullers are driven in at each side of this corner, to about the thickness of the crank-arm at one side and to the diameter of the axle at the other side, leaving the thick lump between to be afterwards made into a sharp corner. The corner is next produced by bending, upsetting, and welding; after which, the mid-portion of the lever is drawn down to its forged dimensions, leaving a lump at the end to be made into the crank-pin. The crank-pin is then drawn from the lump at the side of the lever by driving in a fuller, or, if the work is very small, a set-hammer.

Large crank-shafts of this class are made of several pieces. To make one of four pieces, the disc-end and part of the axle constitute one piece; the remaining axle part and the thrust portion are the second piece; the lever becomes the third piece; and the crank-pin the fourth piece.

Both the disc-end and the thrust-piece may be made of the same bar, or of two pieces of the same sectional area, the area being about that of the disc when forged; or if upsetting of the disc is to be entirely avoided, the area of the iron at the beginning is rather greater, to admit of welding and rounding.

The short axle-piece attached to the disc is produced by fullers and drawing down to the desired diameter; after which the thrust-piece is prepared by careful welding and reducing, that there may not be any unsolid parts in the thrust after being turned. To one end of this thrust-piece the lever is to be welded; a gap is therefore cut, in which to place one end of the lever. At the other end of the lever, another gap or opening is made, in which to weld the crank-pin.

Shafts of great length require one or two other pieces, in addition to those four that become the principal components.

A very ordinary sort of thrust-shaft, without any crank, is shown by Fig. 107, and is made of three pieces by reducing the axle-parts adjoining the two discs, from two pieces whose area is equal to that of the discs, and welding a piece into the middle to the two ends. The diameter of the middle piece is of the intended forged diameter, that no reducing may be needed after the welding together.

In all thrust-shafts, the strain while in use principally affects the bottoms or junctions of the circular ridges with the shaft. The smith, therefore, thoroughly welds and closes the iron in the thrust part with angular-gap tools. This thrust portion needs also a sufficient hammering and rounding to make it rather harder and more crystalline than the remainder of the shaft, the wearing qualities being thereby improved; and if the thrust is reduced from a larger straight bar or rod, the fibres are in their proper position to resist the strains on the sides while in use.

INTERMEDIATE SHAFTS.—The length of these shafts is sometimes twenty-five times the length of their diameters, so that it is convenient to make them of several pieces. Two or three pieces may constitute the intermediate, and be of the finished forged diameter, thus avoiding drawing down; but the two disc-ends should be made of lumps that are large enough to become the discs without upsetting.

Such shafts may be made, also, by welding the two discs to the shaft-ends. In these cases, the discs are made of flat cakes, having holes punched in their middles and drifted to the diameter of the shaft. From the hole to one edge a piece is cut out previous to placing the disc upon the shaft, that the opening may be closed at the time of welding. The holes in the discs are conical, and the larger part of the hole is outwards when on the shaft; and during the welding the shaft-end is sufficiently upset to fill the hole, by which the disc is riveted to the shaft. The straight piece of iron selected for the shaft itself is of the required forged diameter; all drawing down of this portion is therefore avoided.

But it is frequently advisable to make such an intermediate shaft of only one piece; the sectional area of the piece selected being equal to, or greater than, the sectional area of the intended disc. If the lump is greater in diameter than the disc required, the proper amount of reducing is given until the diameter of the disc is attained. After which, the necessary length of iron selected to produce the required length of intermediate, is ascertained by applying the appropriate rule in this form:

As the mean sectional area of the lump, is to the mean sectional area of the intermediate part of the shaft; so is the length of the intermediate required, to the necessary length of the lump to be reduced.

If the smith desires to make a shaft whose length of intermediate is 4500 millimetres, and whose forged diameter is 180 millimetres, he may select a lump whose diameter is 450 millimetres. Omitting small fractions, the sectional area of the lump to be operated upon is therefore 159043 square millimetres, and the first term of the proposition. The second term is represented by 25447, being the number of square millimetres in a sectional area of the intended intermediate. The length of this portion, 4500 millimetres, becomes the third term; and the fourth term that indicates the requisite length of iron is seen in the complete proposition thus:

$$159043 : 25447 :: 4500 : 720.$$

To this length of 720 millimetres for the intermediate, the thickness of the two discs is to be added. If the thickness of each intended disc is 90 millimetres, 180 millimetres are added to 720; and their sum denotes the total length of bar or lump to make one complete shaft, to be 900 millimetres. To this length 100 millimetres should be added for that which will be burnt or wasted during the several heatings. The precise amount requisite for the burnt portion principally depends upon the number of times the work is heated; and this again depends upon the length of iron heated at one heat, and also upon the capability and power of the particular steam-hammer employed at the time.

Intermediate shafts and other screw-shafts of great length need considerable care in straightening. For this purpose, a large surface-table should be provided in the smithy, that the shaft may be laid upon it and straightened with a half-round top tool. In addition to the table, a thick, smooth cord should be used. The mode of applying the cord consists in making a straight-edge of it by stretching it along the shaft-sides. A man may stand at each end of the shaft and stretch the cord while it is at an equal distance from the shaft at both ends; the cord being as near to the work as the heat will allow, but always applied to the sides of the work, and never above or beneath it. Another man may then observe any irregularities along the shaft by comparing them with the cord straight-edge, after which the work is rectified with hammer and top-tool. Such straightening processes as these may be resorted to when it is not convenient to put the work into a lathe.

Propeller-Shafts.—An ordinary sort of propeller-shaft for a small screw steamer is shown by Fig. 109. The number of pieces made use of in forging the shaft is about three; but if the shaft is small, two are sufficient. One of these two becomes the shaft proper, and the other piece the disc, which is welded to one end in the manner described for an intermediate screw-shaft.

The diameter of the piece selected may be only equal to the forged diameter, if the iron is soft and fibrous; if not, the piece should be larger, that it may admit a welding and steam-hammering to produce a tenacious metal. The smith will observe whether a screw is to be formed at the propeller end; if so, he will be careful to make that part sufficiently solid.

Propeller-shafts may be made also by the drawing down of a lump whose sectional area is the same as that of the disc; the stem thus produced being intended for part of the shaft or axle. To this short portion two or three other pieces are welded to complete the work.

The two parts represented by G are linings of gun-metal, placed upon the shaft to receive the friction. When these linings are made by the metal being poured around in a liquid state, the shaft at those places needs no lathe-turning, being roughly forged to the finished diameter by the smith. After the gun-metal is poured, the shaft becomes bent, and is afterwards straightened in a lathe, either in the smithy or elsewhere.

The smith effects the straightening by heating the shaft and afterwards rotating it in a lathe, and marking the prominent sides at those places which rotated truly previous to the casting. These projecting sides are then put downwards, a few blocks are put upon the lathe-bed and beneath the bent portion of the shaft; wedges are then driven in between the blocks and the shaft, by which it is forced up and straightened while a few blows are given to the upper side. The amount of hammering needed is but small, if the shaft were heated to redness. During the whole of such straightening the work should be well supported with chains; it is also necessary that the centre recesses be large, and that the lathe poppet-screw be frequently screwed in, to fill the gap made by the continual shortening of the work while in the lathe.

Piston-Rods with Conical Ends.—These are of various lengths and diameters, according to the lengths of cylinders and class of engines for which the rods are made. A few are indicated by the Figures, No. 111 representing one for an engine having two piston-rods attached to the crosshead, No. 112.

Such rods may be made of fibrous steel, when metal of that quality is accessible. Previous to forging the rod, a piece of the steel should be subjected to a severe steam-hammering and reducing while at a bright red heat, and be drawn down to a four-sided bar about half or a quarter of an inch square. This small piece may then be further thinned on the anvil-beak, and made round instead of square. The stretching on the anvil-beak should be performed at about a foot from one end. If this thin part can be drawn to about a sixteenth without cracking, the steel is good enough for a piston-rod.

Another mode of discovering the quality is by subjecting a piece of the cold steel to a gradual tensile strain. If the steel breaks suddenly without stretching, it is not fit for a piston-rod, or any other engine-work of consequence, however great the strain may be that breaks it; but if, previous to breaking, it will stretch to a diameter which is about three-quarters of its original diameter, the metal is about as tenacious as can be expected, and may be used with confidence and advantage if it possesses the hardening properties.

If such steel is to be used for a piston-rod having a conical end, the cone may be formed by upsetting a rod whose sectional area is equal to that of the rod when forged. Steel rods should be forged so that not more than three-sixteenths is allowed for lathe-turning; they should, therefore, be carefully smoothed and straightened with rounding tools while on a surface-table, or by means of a lathe, as previously described.

Fig. 113 denotes a piston-rod having a holder at the conical end, for the convenience of holding the work while in a lathe. The holder may be made in the lathe by turning a short portion of the rod to the desired diameter, or the holder may be forged on the anvil by fullers and reducing, this being the shorter method.

Piston-rods of this character, also, may be made of fibrous steel, for the benefit of its superior wearing qualities or non-wearing qualities. The conical end is commenced by first tapering down a short portion of the end to about a fourth of its diameter. This part, being intended for the holder, is cooled after the rod is again heated for the upsetting of the cone; and after repeated coolings and upsettings, and when the cone is increased to its proper dimensions, a few pieces are cut from around the intended holder, so that drawing or stretching it may be commenced. The holder is next reduced, by fullers and hammering, till its desired form is produced. The work is next cut to its length, and finally smoothed and straightened, the proper quantity of metal being allowed for the lathe process.

Crank-Pins.—A crank-pin, having a screw for a nut, is shown by Fig. 114, and another class of pins, for use without nuts, is indicated in Plate 4.

The forging of a crank-pin principally consists in well closing the metal in those places intended for the friction part and the screw, if a screw is to be used. All the other parts of a crank-pin should be fibrous.

The angle subtended by the two sides of a crank-pin cone should be less than that of a piston-rod cone; so that a crank-pin requires no upsetting, the iron or steel selected being large enough for the largest end of the cone.

For a pin whose largest end of the cone is to be outwards, a holder is sometimes made resembling that in Fig. 113, for the convenience of holding while being turned.

Crossheads for two Piston-Rods.—The forging of a two-piston-rod crosshead is performed by several methods, the plan selected depending upon the resources of the maker. A convenient mode to avoid bending consists in making it of three pieces. The thickest or mid-portion of the crosshead is made of one piece; and the other two constitute the two ends for the piston-rods. These three portions are shown in Fig. 163.

To make the middle part, a lump is selected whose sectional area is rather greater than that of the largest part of the intended piece. A porter is attached to one end, and the circular part is shaped to its intended form. The length of this part is next marked by a chisel being driven in at two places, and the work is reduced from the larger mid-portion to form the two square or four-sided ends.

The two ends or stems thus produced, are next prepared for a tongue-joint, by making a gap in each end, to which the other two pieces will be welded; and, by allowing thick lumps to remain at the ends during the drawing down of the stems, upsetting for the joint will be avoided.

The other two pieces are next prepared, or may have been in progress at another furnace during the forging of the middle part. Straight pieces are used for these two parts, with porters attached, as for the middle part. After the bosses of these two pieces are formed, the projecting stems are cut to a proper length and shaped to fit the openings in the stems of the middle piece, and when the suitable length to admit a stretching after welding is attained, the three are welded together.

After being welded together, the four-sided parts, or arms, of the work are drawn until the proper distances between the centre of the crosshead and the centres of the intended holes are attained. The superfluous iron that then remains must be either cut off with chisels or allowed to remain for planing and shaping. During the hammering for welding, and also during the trimming with chisels, two protuberances should be allowed to remain for centring purposes. In these projections the recesses are made, by means of which the circular portion in the middle is turned. These centre-pieces are shown in Fig. 112 by dots and the two letters C C.

Two piston-rod crossheads are made also of one piece; the troublesome joint-making being thereby avoided.

By this mode a lump of rather greater sectional area than the middle of the crosshead is made use of; and the length of the iron required for one of the four-sided ends is ascertained with proper measurement, and by the rule. This length is marked upon one end of the piece, at a proper distance from the extremity; fullers are next driven in, and the work reduced on both sides of the intended mid-portion; or, for portability, the entire length necessary for the crosshead may be cut from the lump, if it is desirable to handle only the smallest quantity of metal that is sufficient. During the drawing down, a lump is allowed to remain at each end of the work, which is amply sufficient for the circular boss that is to contain the end of the piston-rod. Two small projections also, are allowed to remain for the centre-pieces, C C.

When the work is lengthened nearly to its intended length, the bending or curving is accomplished.

A short length of the four-sided part on both sides of the circular portion is in line with its centre, so that it is necessary to prevent these two parts being bent or put out of position during the angling or bending of the adjoining ends. Consequently, whether the work is to be angled or curved, as in the Figure (112), the iron, after being heated to nearly welding, is cooled to the intended commencement of the bent part. The bending is then effected either by a steam-hammer or by affixing a lever and bending the work while on a surface-table.

A crosshead of only a few inches thick can be bent by a few men at one end of a strong lever whose other end is attached to the work. The crosshead is fixed to the table by bolts, plates, and studs being fixed to that end of the work not in course of bending. A strong lever is then bolted to the outer end, and the work gradually bent by means of several heats and sledge-hammerings at the time the power by the lever is applied.

When the crosshead is being forged with a porter attached, the diameter of this porter at the end which is welded to the work should be nearly equal to the diameter of the crosshead end. The porter will then be strong enough to be more conveniently used as a lever than a separate one that needs to be attached.

The bending of a large crosshead is readily effected without a porter. To commence the bend, the work is placed beneath a steam-hammer and across a bottom tool or hollow anvil-block. The upper side of the crosshead is that intended to be the hollow side after the work is bent. While in this position, a few blows are administered to the work, by which it is partly curved or angled, according to the shape of the top and bottom tools, or hammer and anvil-block.

After being thus slightly bent, the work is again heated and cooled to the proper distance, and a tongs is attached to the middle of the crosshead, which is then placed end upwards under a steam-hammer of sufficient height, the lower end being tightly fixed in a recessed tool or anvil-block. A few blows are then struck to complete the necessary angling; or if a great length of metal were heated at the time of bending, it will be curved instead of angled.

One end of the work being thus managed, the other end is treated in a similar manner.

The bosses for the piston-rods are next shaped, the centre-pieces put into position, and the arms lengthened and trimmed to the form desired, which is either curved or angular.

A substitute for these processes of shaping the arms consists in making a straight crosshead whose thickness or sectional area is about a sixth greater than that of the circular mid-portion when forged. The angular form is then produced by partly cutting and trimming on the anvil, and afterwards by the planing process.

Link Connexions.—A simple and also an old mode of connecting a link to its lifting or reversing rod consists in fastening the eye-part or boss of the rod to the link stud-plate, the stud-plate itself being bolted with small bolts to the link-side.

The forging of such a stud-plate is effected by drawing down the stud at one end of a bar or rod, and then cutting off the stud with a slice of metal attached to it, which is to be spread out and welded to two other thin ends, in order to complete the stud-plate. The stud with the two plate-pieces are shown in Fig. 153.

A stud-plate of this class may be also made of one piece. By cutting open one end of a bar and spreading out the ends, as indicated in Fig. 137, sufficient iron can be obtained for spreading out to the entire distance across the link-side, which is the length of the stud-plate.

A stud-plate shown in Fig. 116 requires rather more iron than the stud-plate last mentioned, through the connexion being effected with bolts in the edge of the link, instead of its side. The forging is therefore managed with three pieces, as shown in Fig. 154; except the stud-plate is very small, in which case it is easily made of one piece, in the manner described. The eye part or boss of the reversing rod, R, is fastened to the link-stud with a screw-bolt and washer, or with a split pin and washer.

The connexion represented in link 117 has the disadvantage of not affording any stay to the mid-portion of the link, which is its weakest part. In other respects the rod with fork-end is very efficient.

Link No. 120 is made of two separate pieces or sides, and connected together partly with the two bolts at the ends, and partly with the bolts of the excentric-rods. The circular and sliding block, B, is made either of gun-metal, iron, or steel; and is sometimes in one piece and at other times of several pieces, having wearing strips, that may be rejected when too much worn, and new ones put into their places.

Sliding Sectors.—These sectors for oscillating engines need not be forged in one piece, as indicated in the sketch No. 119; for the convenience of the turning and shaping processes, the guide-rod may be keyed or screwed into the stud-boss of the sector, instead of being solid with it.

When the rod is a distinct piece, it is often circular throughout its whole length, so that but little forging is needed if the metal of which it is to be made is not too large in diameter. Either steel or iron is suitable, by reason of the very small strain imparted to such rods.

The sector with its boss for containing the lower end of the guide-rod is shown in Fig. 155. Such a piece is easily drawn down from a bar whose width equals the total width of the intended sector, boss included. The ends shown by B (Fig. 119) are then thinned to their dimensions for receiving the bearing brasses, and the boss is shaped to a circular form.

When a sector is thus made of one piece, the slot is drilled and shaped by a suitable machine, instead of making any slot while on the anvil. Such a sector without a rod may be made also of two straight pieces, as shown in Fig. 156. These pieces are scarfed, or a tongue-joint made at the place indicated in the Figure.

To forge a sector entirely of one piece solid with the guide-rod, it is necessary to weld the rod to the boss part of the sector, which is made either of one piece or two.

The boss, or that projecting part which is to be welded to the rod, should be midway between the two ends of the intended sector-slot; and any alteration of situation that may be needed should be done previous to welding it to the rod. To discover the proper place for the boss, the length and place of the slot is marked upon the work; a pair of compasses is then used to ascertain the middle or centre of the slot. This centre is also the centre of the intended boss or lower part of the rod; so that if the boss-portion is not in its proper place, it can be put right. When the boss is large enough, a piece or pieces may be cut from one side to make the boss central; but if not large enough to admit cutting, it is heated to nearly welding, and driven to its proper situation by a few blows with a set-hammer

To avoid trouble with the boss, it is preferable to shape it before trimming the ends of the sector to the finished length. For this purpose one foot of the compasses is placed at the centre of the boss, or centre of intended slot, and the other foot is used to mark the half-length of the work; the two ends are then shaped, and finally cut to an equal length.

After all the joints are welded, the work needs adjustment, to produce the required curve in the sector proper, and to place the rod at a right angle with the remainder of the work.

This adjustment is readily effected by making a few lines on a surface-table to indicate a full-dimensioned outline of one side of the sector with its rod. The sector is then placed between the lines, and any irregularity in the curve, or in the situation and position of the rod, is detected and corrected accordingly.

Templates also, are much used in the adjustment of heavy work. These templates, being made of thin sheet iron, are very portable; also easily constructed, and applicable to either links, band excentric-rods, or sectors.

A sheet-iron template is used also in those cases in which the sector is forged, slotted, and shaped while distinct from its rod; the rod also being turned previous to welding it to the sector-boss.

To make a sector template, a sheet of thin iron is provided and flattened. A straight line is marked with a steel scriber along the length of the sheet. This line represents the centre of the guide-rod of the intended sector; and if one sheet of iron is not of sufficient length, part of another sheet or a whole sheet is riveted to the first one. While the sheet is lying on a table or block, the two arcs that denote the extreme forged width of the sector are marked upon the iron with compasses, and to an equal distance from both sides of the centre line; one foot or leg being in some part of the centre line, while the other leg is sufficiently extended to mark the arcs desired. When the template is large, it may be necessary to put one point of the compasses in some part of the table, instead of the sheet; in these cases, the iron is fixed to the table or block with a few weights around the edges, while the centre line is continued to any desired distance along the table. Any point in this line may then be selected as a centre from which to mark the arcs. The width or diameter of the guide-rod is also denoted by two other straight lines, one at each side of the centre line.

When the shape of the sector ends also are marked, cutting out the template is next effected with a chisel and hand-hammer; or if the work is too large for a hand chisel, with a rod-chisel and small sledge-hammer. Any additional corner pieces that may be required are then riveted to the template, and the shape completed by careful filing to the lines, and flattening on the table or block.

The use of such a template or gauge to the smith, results from the extreme lightness and portability allowing it to be put upon the top of the work at any moment during the forging; also the convenience of referring to the gauge at any future time when a new sector is to be made, or an old one mended.

Cranked Levers.—Fig. 118 represents a lever for an ordinary oscillating engine having two slide-valves. The making of such a lever is conveniently managed, and good work produced, by forging it of one piece.

The thickness of the lump selected is rather greater than the length of the gudgeon-boss, G. Fullers are first driven in at each side of the intended boss; the adjoining lumps are next reduced to a proper width and thickness, allowing a thick lump at each end, which is amply sufficient to be formed into the two smaller bosses without upsetting.

During the thinning of the two arms or ends the work remains straight; so that it is needful to know the necessary length of straight iron to be formed into the required cranked arm.

The readiest mode of ascertaining the length of this arm is by making use of the full-dimensioned outline of the bent or cranked side of the lever, this outline being that to which the smith is working. A wheel measure is held in one hand, and driven along the middle of the arm or arms on the table; and the distance thus indicated by the instrument is the length of the required cranked arm, and also the length of straight iron necessary, if the straight arm at the time is reduced to its finished forged width and thickness. But the proper mode is to bend the arm while it is rather thicker and shorter than required to be when forged; so that, after being bent, it can be thinned and stretched to its proper length.

Bending or cranking commences by first making that bend which is to be nearest to the gudgeon-boss. During the first bending the lever is laid a few times to the sketch on the table, to discover if sufficiently bent or angled, or if the work were heated in the proper place.

After being heated and bent a sufficient number of times to place the angle or curve into its desired shape and situation, the work is cooled, or allowed to cool, and heated at the place for the next curve, being careful to keep the whole of the lever cold except the part in course of bending.

When all the cranking is completed, the three bosses are shaped by welding and trimming, until the three lines passing through the centres of the bosses are parallel to each other. This parallelism is known by the sides of the bosses being parallel to the boss lines when the lever is put to the sketch on the table.

Cranked levers of this class are made also by welding together three pieces. By this mode the middle boss is separately prepared with the short arms or ends for welding to two other pieces intended to complete the lever. By adopting this method, little or no bending is incurred after the work is welded together. The necessary angling is easier accomplished previous to making the joints. A cranked lever in three pieces is shown by Fig. 157.

The bosses of all such cranked levers as we are now considering are forged solid, so that no punching by the smith is necessary.

Crank-Shaft Levers (L, Fig. 122).—The precise mode of forging one of these depends upon the weight of the intended lever, also upon the relative proportions of any one lever; whether the mid-portion is to be long or short, and whether the bosses are to be comparatively large or small.

All crank-shaft levers should be made of soft, tenacious, new, puddled bar-iron, without any mixture with old scrap; although new, puddled scraps may be admitted, if they be first made into the form of bars.

Whether the lever is to be a very small one, or one of great weight, it is desirable to forge it so that the lengths of the fibres in the arm shall be parallel to the length of it; and that the lengths of the fibres in the boss shall constitute a number of rings, whose centre is the centre of the hole in the boss, and named the eye.

This arrangement is easily produced in the forging of a lever whose weight is a few pounds by doubling two straight bars, and welding the four ends together, the weld being made in the middle of the lever or arm. The width of one of these two bars is equal to the length of one of the bosses, and the width of the other bar is equal to the length of the other boss. The thickness of both bars may be about $1\frac{1}{2}$ times the thickness of the intended metal around the shaft or crank-pin.

When two such bars are curved to the forged diameter of the required bosses, the holes in the bosses thus formed will be small enough to admit of boring to the finished diameters. In some cases it is more convenient for boring to fill up this hole that remains, which is done by roughly welding in a plug to make the boss appear as if solid. In other cases the small hole which is formed by bending is useful for fixing, and is therefore allowed to remain.

The first welding, after the boss is roughly formed, is performed at the boss itself, and is managed by placing the work between a pair of fullers and thoroughly closing the metal while at welding heat. This welding being very near the extremity of the work in progress, the small hole may become so flattened as not to be seen; if so, the work is probably sound at the weld, and the hole may be again punched and drifted if necessary.

Another good weld is then given to the adjoining part intended for the arm, and the straight ends may then be made into part of a tongue-joint or scarf-joint.

By thus making the two bosses with half the lever to each boss, both pieces may be easily welded together while the thickness is rather greater than the required forged thickness; and, after being united, the lever can be lengthened to its desired length. A lever made by this method is shown by Fig. 158.

Another mode of making a small crank-lever is commenced by selecting a piece whose sectional area is about $1\frac{1}{2}$ times the mean sectional area of the lever arm required. One end of this piece is first tapered or curved on two opposite sides, and next upset, while at welding heat, by striking the work while in an upright position. This produces the desired shape for the outer extremity of the boss. The inner curved extremity or boundary of the boss, is next formed by top and bottom fullers while the work is between.

When one boss is thus roughly shaped, the work is cut to a proper length, and the other boss is produced in a similar manner: the lump in the middle for the arm is then reduced to the requisite width, thickness, and length. (See Fig. 159.)

Small crank-levers are also made of two pieces without resorting to curving or upsetting, as in Fig. 160. According to this mode, the upsetting of the bosses is avoided by using iron of the requisite sectional area to make a solid boss, and from the boss half the lever is produced by drawing with fullers and hammering while the boss is being formed at the end of the bar. The boss and part of the arm being thus formed, the work is cut from the bar, and another boss-piece is formed of the same bar, if necessary.

This plan is the shortest that can be adopted for making a crank-lever of two pieces. The only existing objection to the method is that the constituent fibres at the outer extremity of the boss are parallel to the length of the lever, because they were parallel to the bar previous to forging, and no alteration of relative position has since been effected.

A partial remedy for this consists in punching a hole into the boss, and giving a few welding heats and hammerings to it while a drift or mandril of some sort is in the hole. When it is intended to adopt the welding for this purpose, sufficient iron is allowed for the boss being burnt by the several heatings.

Small levers having bosses of great length are made also by bending and piling. For this purpose three or four bars are selected whose thickness is about equal to the intended thickness of the metal around the boss-eye or hole. The bars are bent to a circular form which is smaller in diameter than the desired boss, and a sufficient number are employed and piled together to produce a boss about $1\frac{1}{2}$ times the length of the finished boss. This pile is then heated to welding, and upset, by which the boss is shortened in length and increased in diameter to that which is necessary. Such piles are represented in Fig. 161.

The loose straight ends of the bars are next welded together for producing the arm of the lever. To this another boss-piece is welded to complete the lever.

Fig. 162 represents a crank made by closing together a ring, and welding the middle to become the arm.

For large crank-levers several pieces are needed, both for portability and to produce the desired arrangement of fibres without a difficult bending of thick bars.

Lever-bosses for large crank-levers may be conveniently made of several thin bars, which are separately curved and then welded together. The thinner the bars for this purpose, the easier will be the bending, and the greater is the number that will be required. The width of the bars is about the length of the intended boss, and their length should be only sufficient to extend round the work and allow the ends of the bars to be welded together, or to a straight bar that may be between.

The manner of bending consists in heating a bar to about welding heat in the mid-part, or in that part which is to be bent. The bar is then put between a set of bending-rolls, or under a steam-hammer, and across a bottom-tool or anvil-block having a deep curved gap. A cylindrical filler or piece of round iron is next put upon the bar and driven down by a few blows with the hammer, the hammer being of sufficient length to reach and strike the filler without coming into contact with the two ends of the bar which are being forced up by the filler being driven down.

When partly curved, the next bar is treated in a similar manner; or if only one bar is in progress, the filler is taken off and the bending continued at the next heat by striking the ends of the bar until both are near enough together to fit the middle bar, and a small hole remains representing the boss-eye. A welding heat is next given, and a pair of fullers are applied to thoroughly weld that part of the work immediately adjoining the hole, being careful not to close or flatten the curved part at the extremity. The straight ends are next soundly welded to the middle bar, and the work becomes a sort of nucleus for the reception of other bars. (Fig. 165.)

One bar being thus bent and welded to the primary or middle bar, another is bent in a similar manner, but with a larger filler, which is about equal in diameter to the diameter of the boss in its present condition. This second bar is next welded to the work, and fullers again employed to thoroughly weld that part near the hole. (Fig. 166.)

If the second boss-piece is not sufficient to increase the boss to its desired diameter, a third piece is bent and welded to the work in a similar manner.

When all the welding that may be required by the fullers is completed, but not till then, that end of the primary bar that protrudes into the boss-eye may be punched out; and the welding of the boss may then be completed while on a filler or mandril in the boss-eye.

To conveniently weld the boss, a short porter is attached to the arm or lever portion of the work, and the boss is heated to welding in a furnace which is large enough to heat the entire boss at one heat. During the time of heating, the filler or mandril is put beneath the hammer and supported at each end, allowing sufficient space for the lever-boss to be raised or lowered by the chain which is attached to the porter, so that the boss may be partly rotated on the filler during the hammering for welding.

The work is next put beneath the hammer while the mandril is being put into the hole, and the welding of the boss is effected with two or three heats.

The next operation, after welding the boss, is to determine which is to be the centre line of the lever, also what point in this line is to be the centre of the boss-face, or, as it may be termed, the boss-end. A piece of wood is fixed for a short time in the hole at that end of the boss which is to be the end projecting from the lever-side when finished. The centre of the boss-face is then determined, and a circle marked with compasses; the diameter of this circle being the diameter of the boss when forged. A chisel with thick cutting edge is then driven in at the circle, and the work heated to produce the required boss-end that is to extend from one side of the lever.

This projection is formed by driving a top-fuller into the lever at the circular chisel mark. When a gap is thus made, the remaining thick lump of the arm is reduced by hammering to the necessary width and thickness.

Bosses thus made with half the lever are welded together by means of a tongue-joint about the middle, so that if the ends attached to the bosses are too long, they are cut to length and trimmed to shape while preparing the joint-ends for welding.

By reference to the Figure 168 it may be observed that the joint is of great length in order to secure a sound weld and thereby a good lever. The welding of the joint is effected by placing the two pieces together in one fire or furnace that is open at two opposite sides, and welding while in the fire with a pendulum-hammer. If a convenient furnace of this character is not accessible, the two pieces of work are separately heated in two fires, and put together, end upwards, under a steam-hammer, and welded by upsetting. Another welding-heat or two is afterwards given to complete the welding of the sides and edges, and to drive in the prominent scarf-ends.

Shaping and trimming the lever is next performed; after which the two bosses are trimmed with chisels and smoothed to their forged dimensions. The lever is finally made red-hot from one end to the other, all scale and clinker scraped off, and the work allowed to gradually cool.

Crank-levers made by this mode have a hole in each boss, so that a great amount of boring is avoided, in addition to the advantage of securing a strong lever.

To avoid the bending processes, crank-levers having bosses of great length are made by piling and welding several bars together until the desired length of boss is attained; the bosses thus made being without any hole to the end of the forging. A pile of this character is represented by Fig. 169.

After a few short bars are thus soundly welded together with several heats, the extremity is tapered on two sides; this taper or curved part being on those two sides of the work that are intended to be the boss-sides, and not the boss-ends. The taper part is next heated to welding and put beneath a hammer with the cool end of the work upwards, and the end at welding heat in a bottom tool having a sharp curved gap. While in this tool, the work is upset with a few heavy blows, to produce an approach to the desired circular arrangement for the boss-fibres. Two or three such upsettings are administered, after which the fullers are driven in at the place intended for the junction of the boss with the lever; and thus the circular form for the boss is obtained The boss-piece then appears as in Fig. 170.

The bosses made by this process have stems or arms that may be of sufficient length to be made into the lever, and also the boss at the other end of the work; or another solid boss may be made, and the two stems or arms welded together to complete the lever. (Fig. 171.)

Paddle-Axles.—To produce a good paddle-axle, the smith commences by referring to the sketch by which he is to work, and discovers the places of the bearings in the shaft he is about to make. If no information is given in the sketch about the bearings, he should apply, or take a walk to the individual who ought to have put it in; and when the smith has learnt something about the intended use of the work, he can commence.

A paddle-shaft has two bearings, one in the paddle-box and the other near the crank-lever by which the shaft is driven. Both these bearings being near the ends of the work, the smith will measure the iron he selects, or the iron he is compelled to use, and endeavour to manage so that what joints may be necessary shall be in some part of the mid-portion.

The whole of the bars selected should be of new puddled iron; and the first pile made use of, a sufficient length to extend beyond one of the intended bearings of the shaft. Consequently this first pile may be three feet in length and bound together with soft iron binders at both ends, and having a porter or porter-tongs attached to one end. A sufficient length of the pile is then heated to welding so that about two-thirds of the length may be welded at one heat; or if the furnace is large enough, the whole pile may be welded.

If the shaft is to be twelve feet in length, three such piles will be sufficient for the work, and the two necessary joints will be in the intermediate part, and not in any portion of a bearing.

The convenient sort of joint for such a shaft is a tongue-joint. All such joints require upsetting at the commencement of the welding, that the pieces may be firmly united previous to the second welding or hammering, which closes the iron at the outside of the shaft, but does nothing towards welding the inner parts of the joint.

After the preliminary upsetting with a pendulum-hammer, this second welding is administered to the shaft while in the ordinary horizontal position on an anvil.

The best sort of paddle-shafts are made of one thick lump, that is drawn down to the diameter and increased to the length of the desired shaft; the work being handled or rotated with a porter during the forging.

If the original piece is soundly made of good iron previous to the forging of the shaft, the work will be as good as iron can make it; having no tongue-joint in any part; neither requiring upsetting in any place, so that the mode is also economical, if the good piece to commence with can be obtained. A component piece of this character with a porter attached, is shown by Fig. 172.

The particular shape of the piece is of no consequence. If it should be a two or three feet cube, the smith proceeds by making it into a bar of four sides, and increasing the length to about double. He next places one of the corners to the hammer and makes the work six-sided, and by afterwards half rotating the bar it is made eight-sided.

The length of bar that can be drawn at one heat depends upon the capacity of the furnace for heating, and upon the sort of crane in use. The better the crane, and the greater its capability of moving the work forwards and backwards, the greater is the economy of time in working the several heats. However large the furnace or the hammer, however great the length of iron that is heated, the metal must become too cool to work, if a greater length of iron is heated than can be managed at one heat with the crane.

Drawing down is facilitated by first heating that portion which is nearest to the porter; this part is reduced until the metal requires another heating, which is given to the adjoining lump to reduce it to the dimension of the part already drawn. The largest part is again heated and drawn down, to make the whole length of the bar about the same diameter; by such a series of heatings and drawings, the unreduced lump is always at that end of the work furthest from the smith or smiths, which is its proper place, both for convenience of reducing, and to prevent cracks or unsolid parts being formed at the shaft-end, which often happens when the end is much drawn previous to thinning the middle.

By thus drawing the shaft so that the unreduced lump is always at that end which is furthest from the porter, the work is made sound, and the fibres are put into the desired condition of parallelism with the length of the axle. Towards the conclusion of the drawing or stretching, angular gap-tools of suitable dimensions should be applied to the metal at welding heat, and with especial care to well close the parts intended for bearings. The only portions of a shaft that require a granular or crystalline form for the constituent particles are the bearings. For this reason the smith may give an extra hammering with angular-gap tools, and also with curved gap tools, to these parts, and while the iron is below redness, about 600° Fahrenheit.

When the shaft is reduced to its dimensions, smoothed, and also straightened by means of a long straight-edge or cord, as previously described, the work is cut out from the two ragged lumps at the ends of the shaft, one being the porter-lump and the other the unreduced lump. This piece is that which is first cut off; and the work is next heated at the porter-end, and a tongs fixed to the finished end of the shaft. The ragged porter-piece is then cut off, and a sound shaft is the result. A straight shaft of this sort is represented by Fig. 175; which is an ordinary shape at the conclusion of forging.

Large paddle-shafts are sometimes taper, and are forged taper; the shoulders of the bearings also are formed during forging, by either reducing the adjoining parts, or welding collars to the shaft at the ends of each bearing. Such collars for bearings are welded to the shaft, after the cylindrical or taper character is produced; the making of the original piece is therefore nearly the same for shafts of all sizes, whether taper or cylindrical. A taper paddle-shaft is shown in Fig. 177.

To avoid the upsetting that was stated to be necessary for welding tongue-joints, another kind of joint-making is adopted, by means of which welding is accomplished by ordinary drawing with a hammer.

With this intention, all the necessary components of the shaft are united during the original piling together of the constituent bars; and the shapes of the joint ends are those of long forks. Such a fork is obtained by welding together two bars at the middle only; and when the loose portions not welded are opened, a piece having two fork-prongs at each end is the result. Any required number of these original constituents may be employed, according to their thickness and the desired dimensions of the shaft to be produced. When only two or three such forked pieces are to be used, and welded together end to end, they may be fixed in position by closing the four ends with hammering, previous to placing them in a furnace for a welding heat. But when five, six, eight, ten, or any greater number of such pieces require piling and welding upon top of each other, or side by side, instead of being united at their ends only, the pieces are bound together with binders, which are attached whenever fresh piles are added. Fork-joint piles are shown by Figs. 179 and 180.

This method of interlaying and piling is applicable to paddle-axles, or any other axles of similar shape, and also to the cylindrical portions of crank-axles, whether small or large. By thus uniting the forked constituents, welding them together and forming a square bar, a cylindrical shaft of good quality can be afterwards produced, without any upsetting of tongue-joints.

Middle Shafts (Fig. 178).—A middle shaft, or middle axle, is that which is between the two paddle-shafts, and also in the middle of the ship. The simplest class have no crank forged solid with the shaft, but are of cylindrical forms resembling paddle-shafts. Two crank-levers are keyed to a middle shaft, one at each extremity; instead of only one at one extremity, as on a paddle-shaft.

At each end is a bearing, adjoining or a few inches from each crank-lever; the forging of such a shaft is therefore similar to that for a paddle-shaft, the smith exercising the necessary care to make the joints in their proper places, and to well close the bearing-parts, although it is not necessary to hammer the work sufficient to harden the metal at the centre; this portion may be fibrous throughout the total length of the work.

The mode of procedure resembles that for a paddle-shaft, and much depends upon the shape of the iron at the disposal of the workmen. The quality of the metal is the same as that of all other engine-axles, where iron is employed, and should consist of new puddled bars.

When convenient, these bars are made into a pile and welded by steam-hammering the mass into a shape of a short thick bar, or into the form of a cubic lump. In these cases, the porter which is used for reversing or rotating the work is welded to the middle bar of the pile; and thus remains solid with the work until the shaft is forged. But when a cubic lump is selected from a piler or shingler, the engine-smith welds one of his own porters to the piece selected.

A convenient and safe mode of attaching the porter consists in making a gap with a steam-hammer fuller into one end of the piece, and placing into the gap a porter whose extremity is rather thicker than the part next adjoining; the gap is next closed, and becomes what is termed a dovetail joint. This class of porter attachments is shown in Fig. 172; when thus prepared, a welding heat is given to the joint, and the work is fit for drawing down to the required dimensions of any cylindrical shaft that is desired.

While finally reducing a middle shaft or any other shaft of similar character, gauge-blocks may be conveniently used. These blocks are on the anvil, and packed up to a height from the anvil which is equal to the required diameter of the work. The shaft is then slid along between the blocks, and reduced until the hammer strikes the gauge-blocks at the same moment as the work; by which the proper diameter is attained without making any part of the shaft too small, the rotator being used for reversing the work in the ordinary manner. By this mode of finishing, the amount of smoothing required with half-round tools is very small, the circular shape of the shaft resulting from its rotation by the workmen.

The larger the shaft, the greater is the necessity for clean orderly cuts at the conclusion of the forging, to make the extremities of the work at right angles to its length. A few of the methods for attaining this end shall be described.

One mode for producing a right-angular cut consists in using a straight chisel which fits a steam-hammer, and also a broad arched anvil-chisel which fits an anvil-block, so fixed that, when the two chisels are put together, both cutting-edges are opposite each other. By then placing the shaft into the horizontal position upon the anvil-chisel, and striking with the hammer-chisel, two cuts are commenced around the work; and if both the cutters are properly fitted, the incisions will be opposite each other, and, by slowly rotating the work during the cutting, each cut will be continued until both meet, forming a cavity or incision around the shaft which is at right angles to its length, as desired. After this, the cutting off is completed by the hammer-chisel only, the bottom anvil-chisel being taken away.

A right-angular cut is produced also by fixing a pair of half-round bands or clips to the shaft, so that the distance between the extremities or faces of the bands and the intended cut shall be equal to the breadth of the half-round anvil-block on which the work is to rest while cutting off is effected. While putting the shaft into the horizontal position for cutting, the chain that suspends the work is wound out, or what is called payed out, towards the centre of the hammer, so that the clips shall bear tight against the anvil-block while the shaft is being rotated by the men, and also while the hammer-chisel is being driven through the work. The shaft being thus prevented from moving forwards or backwards, and the chisel being fixed in the hammer-head, causes a square cut to result, however thick the shaft may be, and however quickly the chisel may be driven through, or the work rotated.

A third method of cutting off is managed with a chisel having a long handle held by a workman, or two or three workmen; so that one part is kept close to the side of the bottom tool, while the other part of the chisel is driven through the work with the hammer, the shaft being rotated by the men in the usual way.

While measuring for the final cutting to length of any large shaft, it is proper that the work be as nearly cold from one end to the other as circumstances permit. The work may then be cut much nearer to the finished length than by allowing a large quantity for lathe-turning, or for shortening of the work while cooling.

Beam Gudgeons.—The shorter the projecting end or ends of any gudgeon, the greater is its capability of resisting the strains imposed during use; these are always at right angles to the length of the gudgeon; wrought iron or tough fibrous steel is therefore the suitable material for making the gudgeon.

To make a gudgeon shown by Fig. 123, the smith provides, if possible, one thick lump similar to that for a paddle or middle shaft; but if two pieces are to be used, the joint is made in the middle.

To make a gudgeon shown by Fig. 124, a little more care is requisite to make each extremity of the work of solid close metal, by reason of the intention to bore and screw a hole at the centre of each end. Much trouble of plugging up cracks is avoided by proper attention at the first forging.

The thickest parts of the gudgeon are fixed tight in the sides of the condenser, and should be fibrous; but the bearings adjoining may be hardened with a final hammering, similar to that given to other bearings.

Beam Slabs.—These slabs are rolled to any required thickness, according to the desired width across the middle of the intended beam; the thinner the slab, the wider or higher is the beam.

For small slabs, a bar may be rolled to a sufficient length to make several slabs, the bar being afterwards cut with shears into the desired number of pieces.

Large slabs are conveniently made singly, the width of each one being the width of the widest part of the slab when finished. After the component piece is rolled to a proper thickness, the desired shape is next marked upon the side, and the superfluous pieces cut off with a broad steam-hammer chisel. During the trimming of a beam slab, or other similar piece of work, a thick plate of copper or soft iron is fixed to the anvil face, to prevent the chisel edge touching the anvil. The mode of fixing or shaping the fender-plate to a small anvil or anvil-block consists in heating the plate to redness and fixing it between the hammer and anvil; and, while fixed, the portions that extend from the anvil are driven down with sledge-hammers. For such fender-plates, a thick iron plate is preferable to copper, although copper is much used.

Columns.—The simplest class of columns are made cylindrical, and of three pieces. Of these, one is the column itself, and the two other pieces are the collars or bearings. Each of these two is separately forged, and afterwards fixed to the straight piece which may be called the column proper. Such a method obviates the necessity for the drawing down of a thick piece which is the diameter of the required collars.

Cylindrical columns of this simple form are much used for oscillating engines and some classes of land engines; and when short columns are required, they may be forged also by making the collars solid with the remainder of the work. With this object, two pieces, whose diameters are equal to those of the collars, are drawn down to the desired diameter and length, and so welded together that the joint may be about the middle of the column when finished.

The class of columns represented by Fig. 130 are used also as stays, and in the horizontal position; they are in such cases named stretchers, and should be forged as nearly as possible to the intended form, by which a large amount of reducing during the lathe process will be avoided. Small stays of this shape are easily forged to the required form, and the two collars welded to the work at the conclusion. Large ones, also, are made of three pieces; the screw end and the adjoining collar are one piece, and the opposite end and collar constitute another piece. These two are the pieces first made, when a large column is required, and are produced by drawing down the ends of thick pieces whose diameters are about equal to those of the collars required. After the proper length and shape of these two portions are attained, the third component piece is forged to its shape and dimensions, and welded between the other two, to become the middle or intermediate part of the stay or column.

Large columns may be made also by forging the collars separately, and afterwards fixing them to the column by either welding, or shrinking the collars to the column during the lathe process.

Crank-shafts.—The bearings of axles of all classes demand much attention from the smith during forging, and the greater the dimensions of the work in progress, the greater is the responsibility of the workman who happens to be managing the particular forging being made. No one but himself knows the quality of the metal employed, the relative position of the components, or the treatment the work receives during the several processes.

Crank-axles involve an additional consideration to that of the bearings. The levers are equally important, many of them being improperly made, either of unsuitable metal or of good metal whose component plates or fibres are at right angles to the proper position. It is an almost unknown occurrence for a smith to receive any instructions concerning these matters; he therefore depends upon what ingenuity or practical knowledge he may possess, and proceeds accordingly. A good smith will therefore be careful to ascertain the quality of the bars he is to use; and, when circumstances permit, he will superintend the shingling, and thus become intimately acquainted with the metal with which he is supplied. The material selected for crank-shafts should be of hard, close-grained, tenacious character; and the suitable degree of hardness for the axle portions is attained with hammering, as previously described for other shafts.

A class of simply formed crank-axles is that having one-arm cranks; such axles have their crank-pins extended or produced from the outer sides of the arms or levers. Of this class of cranks, those that are made of two pieces are first described.

Crank-shafts in Two Pieces.—To forge one of this variety intended to have a separate crank-pin, only two components are necessary, one for the lever and the other for the axle proper. The forging of the axle-piece commences by either drawing down a piece whose sectional area is greater than that of the axle desired, or upsetting a smaller piece at that end which is to be welded to the lever, the object being to form a thick lump at the intended joint, to admit two or three welding heats.

The preparation of the shaft end for welding to the lever consists in either punching a hole into the upset part, or cutting a slit and forming a gap of the slit, for the purpose of fitting in the end of the lever. When a hole is punched, it is drifted with an oval or oblong drift, thus making the greatest width of the hole to be in line with the length of the shaft. The greatest width of the hole should be about $1\frac{1}{2}$ times the diameter of the shaft, and the shortest width about equal to the shaft's diameter.

The shaft end being thus prepared, the lever is selected or drawn down of a straight bar, until the sectional area and shape is that of the lever required. One end is next shaped to fit the hole or gap in the shaft; this shaping consists in drawing down and spreading out a stem at the lever end, the shape and dimensions of the stem being the same as those of the hole. At the junction of the stem with the thick part of the lever, a concave shoulder is formed, instead of a flat one. The hollow shoulder or bearing is made by driving in a fuller at each side of the stem; to do this conveniently, the thick end of the lever is put to the ground, and the fuller driven in at the two corners while the stem is upwards.

By thus hollowing the shoulder, it is made to partly resemble the circular form of the shaft; and when the two are welded together, a firm bearing and joint will be the result. When the lever and axle are fitted sufficiently near to each other for welding, the two components appear as in Fig. 181.

The method of welding consists in placing the two together in the furnace with the lever end upwards; and when welding heat is obtained, the work is carefully swung out from the fire to the hammer, and, while still in the same relative position, the work is placed with the lower heated portion in an anvil-block having a half-round gap of suitable width. A few blows are then given to the upper end of the lever, which firmly weld the shoulder to the shaft. The work is next partly rotated by the rotator, and a few blows given to one side of the joint; after which it is partly rotated back again to present the opposite side of the joint to the hammer, and the welding is then continued. When thus partly united, another welding heat is given, and the joint finished by upsetting the shaft end with a pendulum-hammer, and with another upsetting of the lever and hammering of the joint sides, if necessary.

After the joint is made sufficiently solid and the boss part reduced to a suitable thickness and width, the superfluous metal is cut off, and the lever-boss is shaped with fullers and hammering to the desired form.

Crank-shafts of Three Pieces.—One-arm crank-shafts are sometimes made solid with the crank-pin; in these cases, three principal components are required, instead of only two.

To make a shaft of this sort, an opening may be made into the shaft end by punching; or, instead of this, the lever end may be split open and the two ends bent together around the shaft; and the other end of the lever requires similar treatment for being welded to the crank-pin. By this method the pin is first fitted to the lever. and the other end of the lever is next adapted to the shaft. When both joints are prepared, the first joint welded is that of the pin with the small end of the lever, after which the other end of the lever is welded to the shaft. The three components together are represented by Fig. 182.

Of the three components, the first prepared is the crank-pin. This is reduced to its finished forged diameter, and a thick part allowed to remain at one end for the joint, and is shaped for either a tongue-joint, or for an oblong hole in the lever, or for a gap similar to that shown in the Figure (182). The small end of the lever is next prepared, and the crank-pin joint then welded and finished, after which the shaft end of the lever can be cut and prepared so that the lever shall be about the proper length when welded to the shaft. The welding of the lever to the shaft is next performed, and the lever adjusted to its required length.

From the centre of the shaft to the centre of the crank-pin is the length of the lever's throw; and, after deciding which shall be the centre of pin and which the centre of the shaft, the smith lengthens or shortens the lever to that which is desired. Adjusting to length is effected by heating the lever to a yellow heat in the mid-portion and upsetting it, if too long; or by laying it upon one side and drawing it, if too short.

When the proper length is attained, the superfluous metal is cut from the lever and from the bosses, and the work is shaped with fullers and rounding-tools until the necessary curves for the bosses are produced.

Two-arm Cranks of one Bar.—A class of simply formed two-arm crank-axles is represented by the intermediate axle in Fig. 122. Short axles of this sort, having the bearings at a great distance from the keyed crank-levers, are best when made of one piece; and an intermediate axle of great length, whose bearings are to be close to the keyed levers, is conveniently made of three pieces, the axle-pieces being made of proper length to cause the two joints to be made between the middle crank and the bearings at the axle ends.

To make a short axle in one piece, the lump is selected, or a sufficient number of bars are piled and welded together until a lump of the required dimensions is obtained, the amount of metal in the piece being amply sufficient for the whole of the intended two-arm crank and the two axle ends included. The shape of this component piece should be that of a bar having a thick lump on one side and midway between each extremity, similar to that indicated in Fig. 183. The thickness of the two axle parts is nearly double that of the finished thickness, and are, therefore, much shorter than the finished length; and the thickness and width of the thick lump in the middle are about equal to the thickness and width of the crank required. This thick portion may be formed upon one side, as desired, by piling and welding short bars upon only one side of the primary axle-piece; or by another process the lump can be made, which consists in reducing a thick short bar at each end of the intended lump, allowing it to remain between. When drawing down is adopted, the thick portion is made to project from one side of the bar by means of drawing down, without turning the work upside down, the lump, by such treatment, being produced from the upper side.

Cranking.—After the work is suitably shaped, the thick part is formed into the crank, partly with bending and partly with chisels.

The first heating for bending is given to the lump, and also to portions of the axle ends; the work is then put beneath a hammer and across a gap which is a few inches wider than the width of the intended crank measured from one axle end across the crank to the other axle end.

The two upper corners or entrances to the gap are curved, to promote an easy bending; and, while the work is lying across the opening, with the thick lump downwards, a fuller-hammer is driven into the place of the intended crank-gap.

At the commencement of cranking, the length of the protruding fuller portion of the hammer employed need not exceed four or five inches; consequently, when the fuller has been driven in to the distance of four or five inches, the broad shoulder of the hammer will strike the two axle ends at the same time that the thin fuller portion strikes the bottom of the newly made gap, at which time the hammer will tend to straighten the work, which has become bent with driving in the fuller. The fuller is next taken out, the axle ends further straightened, if necessary, and another fuller put in, which is about eight inches in length. The fullering is resumed, the axle ends straightened as before, and another longer fuller is driven in, if necessary.

During these gap-making processes, that part of the lump intended for the crank-pin should be as nearly cold as the adjoining heated portions of the crank will allow, because it is necessary that the two arms and their junctions with the axle ends should be at nearly welding heat. It is also necessary to remember that each successive heating should be further and further from the crank-pin, and nearer and nearer to the ends of the axles, for the purpose of lengthening the throw of the crank without injuriously stretching the two lever-arms.

By such a series of fullerings, a crank of short throw, suitable for an intermediate axle, is formed in a few heats, if the thickness of axle does not exceed seven or eight inches; and for throws of any length, or metal of any thickness, the same method may be adopted, if the hammers and anvil-blocks are of sufficient dimensions.

When a crank is thus roughly formed, the crank-pin portion may be lengthened by drawing, or, if necessary, shortened by upsetting with a pendulum; any superfluous metal may be also cut off, and the two crank-arms shaped to the proper form.

The crank being finished, the drawing down of the axle ends to their diameters is next completed, the bearing parts well closed, the work cut to length, and allowed to cool slowly.

Of a crank forged in this manner two uses can be made. It may remain in its condition of a two-arm crank, or it may be divided and become a one-arm crank, having the crank-pin outside and solid with the lever. A crank made in this manner is shown in Fig. 185.

When it is intended to divide the work, the cut is made through that arm which is not required to be part of the crank. The place of the cut is in line with the edge of the thick crank-pin portion; and when the superfluous lever is cut off, the crank-pin remains already produced from the lever as intended. The place of the cut is indicated in the Figure (185) by C.

The making of an intermediate crank-axle of three pieces consists in forming, by the method described, a crank having two short axle ends, and welding them to two other pieces of any required length and shape.

Several other processes are resorted to for producing two-arm cranks; of these methods the principal shall be described.

Solid Cranks.—An easy mode of making a crank consists in piling and welding a number of bars until the width and thickness of the mass is equal to or rather greater than the thickness and width of the intended crank. When such a piece is closely welded and finished to suitable dimensions, the two extremities of the crank are marked upon the work to indicate the junctions of the crank with the two intended axle portions. At these two marks the drawing down is commenced by driving in fullers, and afterwards continued with hammering in the usual manner. All further forging of the work is performed upon the two thick portions remaining for the axle ends, the solid crank part having been finished previous to driving in fullers at the two axle junctions. The length of the component bar, and therefore the length of the two axle ends, depends upon the length of the shaft required.

To make a crank by this plan of piling, and without cranking, the work may be of any required convenient length, because no bending is intended, for producing the crank part; consequently, no inconvenience will result through the irregular form that is produced during cranking. And if, for portability, a crank having two short axle ends be first made, any additional length of axle may be welded to the primary crank-piece, that the axle ends may be produced to the length required. A bar fullered in two places to produce a solid crank is shown by Fig. 188.

Crank-axles with Discs.—To make an axle represented in Fig. 121, having a disc at each end, it is necessary to use about three principal components, if the shaft is to be only three or four inches in diameter; but for axles of larger dimensions five, six, or eight components are required.

When only three pieces are to be used, one becomes the crank, which may be either solid or having a short fullered gap, as indicated in Fig. 189. The two other components become the discs, having a portion of the axle solid with each disc. These two are first forged together of one rod, as denoted by Fig. 190; after which the work is divided into two at the middle, and the required disc ends produced.

If the lump selected for the discs is cylindrical, its diameter is equal to the forged diameter of the required discs; but if the shape is four-sided, eight-sided, or any other shape except cylindrical, the shortest diameter of the lump must be equal to or greater than the disc's diameter. This shortest diameter is the distance between those two opposite sides of the lump that are nearest to each other; and the only proper mode of measuring this distance is by means of callipers of suitable dimensions. If the shortest diameter is thus found to be equal to the disc's diameter, no upsetting is needed; but, on the contrary, a small amount of reducing and rounding is admissible, by which the work is made circular and to the diameter of either of the intended discs.

When the piece is thus reduced to proper shape and diameter, the thicknesses of each disc are added together and marked upon the mid part of the work. If the forged thickness of each disc is to be four inches, the marking is effected by putting two indentations into the work with a fuller, the distance between the two dents being eight inches, the length required for both discs.

Being thus marked, the work is heated to nearly welding, and a pair of fullers fixed, one into the hammer-head and the other into the anvil-block, the fuller ends or extremities being, as nearly as possible, opposite each other; a pair of side guides also are fixed at the sides; and when the work is sufficiently heated, it is put as nearly as convenient into the horizontal position, and upon the bottom fuller. While thus lying, the chain is adjusted until one of the two dents is brought exactly beneath the hammer fuller, which is then driven in three or four inches, and the worked turned downside up; after which, the fuller is again driven in a few inches, and the work is next adjusted to be fullered while at right angles to its former position. This is effected by placing the two newly made gaps opposite the pair of side guides, and, when adjusted, the fuller is again driven in, and the work put upside down, as at the first fullering. After the four recesses are thus made into the work from opposite sides, the four corners produced in the gap are next driven down with the fullers, and a circular gap or recess around the work is the result; and when the gap is once regularly made, it may be further deepened without trouble.

After one gap is thus made, the other gap is formed in a similar manner, and eight inches distant, as required, being made at the other dent, which indicates the extremity of the other disc. When both the circular recesses are formed, the work appears as in the Figure (190).

Well-formed gaps of this character may be made also by means of semicircular concave fullers, both top and bottom; side guides not being necessary in such cases.

Drawing down the two ends to the diameter of the axle is next performed; after which, the work is cut into two pieces, the division being made in the middle of the lump. This cutting is effected with the concave bottom chisel, as used for other similar work, when a clean right-angular cut is necessary. During such cutting off of large work the chisels are prevented becoming too hot, through cooling the hammer-chisel by means of a ladleful of water, and cooling the anvil-chisel by applying a mopful of water.

When the two components are thus made by cutting the work into two, each disc is trimmed, flattened, and finished to its forged dimensions. The axle ends projecting from the discs are next cut to a suitable length, and shaped for welding to the two short axle ends of the crank-piece. And after the three components are united, and either stretched or upset to the precise length required, the forging is complete.

A two-disc crank-axle, of ten or twelve inches diameter, may, in some cases, be conveniently made of six or seven pieces, as shown in Fig. 191.

The seven components include the middle piece for the solid crank, the two axle-pieces to be welded to the crank-piece, also two other axle-pieces to lengthen the axle ends to the desired lengths, and the two portions for the discs.

The forging of all the components may be conducted at one time, at different furnaces and hammers; by which the work is completed in about a quarter of the time that would be required for forging at one furnace only.

To make the crank part, a pile of bars are welded and cranked, or allowed to remain solid in the ordinary manner. The straight axle-pieces, also, are produced by either piling or drawing down a thick lump, and the two discs are made of flat cakes or circular slices. The mode of making and attaching discs is described in the section on intermediate screw-shafts. When a crank-shaft is being made in this manner of several pieces, the attachment of the discs should be the joints last made.

Crank-bars.—An easy and common mode of crank-making is that by which the entire crank, with its two axle ends, is cut from a straight flat bar. The length of this bar is equal to the total length of the crank-axle when forged. The width of the bar is equal to the total length of the crank-arm; and the thickness is equal to the distance through the crank-gap, or through the solid metal at the place of the intended gap.

After the piece is piled, welded, drawn down, and flattened to these dimensions, the crank is formed by one of four methods—by either cutting with steam-hammer chisels, punching rows of holes, sawing with saws, or drilling rows of holes with a drilling-machine. The bar reduced to its dimensions, and ready for cutting, is denoted by Fig. 192.

After the crank part is produced by either of these cutting processes, the axle portions are reduced to the circular form, and the superfluous metal cut off to complete the forging. Crank-axles made by this plan are objectionable, because the lengths of all the fibres are parallel to the axis of the axle.

Crank-shafts of Four Pieces.—To place the fibres into their proper positions, a method may be adopted by which the two levers may be separately made, the axle and crank-pin also separately made, and the four pieces welded together.

All the pieces may be separately forged at different fires, as for other large forgings, each component being trimmed to shape and cut to length while adapting them to each other. The two parts for the levers are made by reducing them of one straight bar of sufficient length for both levers; or of two shorter bars, each of sufficient length for one lever. When both levers are drawn down until their thickness and width are about equal to the required forged thickness and width, the ends are cut open by first punching a hole, and next cutting a slit, as described for other work. The gaps thus made are further enlarged and shaped to fit the two ends of the crank-pin, and also to fit the axle-piece; so that each lever has one of its forked parts shaped to fit one end of the crank-pin, and the other forked part shaped to fit some part of the axle. The length of this axle-piece may, therefore, be about three times the width of the crank between the two axle junctions. For short axles, the length of the axle-piece may be equal to the entire forged length, to avoid lengthening by welding pieces to it. The length of the crank-pin piece is only a few inches longer than the finished length, to allow the crank-pin ends to be riveted with upsetting, if considered necessary, during the welding of the pin to the levers. The four components appear in Fig. 193.

The joints first made are those of the levers with the axle. By referring to the Figure, it may be observed that the ends of the levers are of sufficient length to project beyond the axle, and allow them to be closed towards each other previous to welding, by which the components are retained in position until welding is effected.

The hammering for welding commences by first placing the work with the axle upwards;

the axle is then driven down with a narrow hammer to thoroughly weld the bottoms of the lever-gaps; after which, the work is put down with one side next the anvil-face, and the lever ends closed towards each other. After this the welding is completed at one or two other heatings, with additional upsetting and welding of the lever sides, if necessary.

If it is intended to weld both levers to the axle at one welding, the thickness of the two levers together should equal the total width of the crank, which is the distance between the two axle junctions. The levers may then be put close together on the axle, having the lever ends closed together sufficiently to maintain them in proper position until welded. By thus welding the levers close together, the crank is made as if solid, although a slit remains which is the centre of the gap intended; and the same amount of boring and slotting will result as if the crank were a single solid piece. But when it is necessary to avoid this boring, each of the levers may be forged nearer to its desired dimensions, and welded to the axle, so that the distance between the two levers shall be equal to the forged width of the required gap. This arrangement is denoted in Fig. 196.

After the levers are united to the axle, the opposite forked ends are adapted to contain the crank-pin; and the joint parts of the pin are trimmed or thinned at one side to fit the gaps in the levers. The pin is next put in and tightened sufficiently to allow the work to be carried about, and, after heating, the welding is performed in a manner similar to that for the axle. The crank is afterwards completed by cutting off the superfluous metal at the projecting fork ends, and joining other axle-pieces to the primary one, if not already of sufficient length.

Crank forging by means of forked levers is specially applicable to all crank-axles intended to have levers of comparatively great length, or whose levers are long when compared with the axles. For short levers the next mentioned methods are more suitable.

Cranks of Two Bars.—Cranks are made also of two bars welded together, so that the width and thickness, when welded, shall be about equal to the thickness and width of the crank required. By this mode, the primary axle-piece may be of any convenient length, and is fitted to the intended crank in a manner similar to that described for forked levers. The difference consists in not making a separate crank-pin; this pin being part of the two bars of which the crank is made.

It is necessary that the bars be soundly welded in the parts intended for the levers and crank-pin; but the opposite ends may remain open, and will require cutting open, if the two become united during the welding. After a thorough welding, the quantity required for the crank is cut off, and the ends not welded are heated and placed upwards beneath a hammer. A narrow fuller is next driven in between the two ends, and afterwards a broader fuller is driven in, also a wedge or thick chisel, until a gap is produced similar to that in Fig. 194. The axle is then fitted to its place, and there welded to complete the crank-shaft. The axle and crank are represented by Fig. 198.

Instead of thus making a crank of two bars, one may be used, if circumstances permit. When a piece of metal large enough to be formed into the entire crank, and a steam-hammer chisel big enough to make the opening, are accessible, it is advisable to use one solid piece for the crank, because in such a piece the metal for the crank-pin will be compact, and not so likely to show any joint. The shape of the axle gap in a single piece is similar to the gap in a crank made of two pieces; the crank and axle are therefore united together in a similar manner. A solid crank-piece without a joint is shown by Fig. 195 Whether one bar or two be used for such a crank, the lengths of the crank-pin fibres are at right angles to the proper position; therefore this is an objection to the method, which should be partly remedied by making the crank-pin part as solid as possible.

By a method similar to the one last described, two cranks may be made of one bar, or of two bars welded together in the middle. In such cases, a lump is selected or reduced to proper width and thickness, and a sufficient length to make two cranks. The work is next cut into two at about midway between the ends, and the axle gaps are made with chisels and fullers, as for other cranks. When two bars are welded together for the purpose of obtaining one bar of sufficient thickness, the axle gaps may be formed by omitting to weld the work at the ends. The bar for making two cranks then appears as in Fig. 197.

GAP-MAKING.—To avoid drilling and a part of the slotting, crank-gaps should be formed while on the anvil. For this purpose three lines may be marked upon the solid crank part to indicate the place of the gap when forged; and a chisel or small fuller is driven in at the marks to a sufficient depth to allow the indents to be plainly seen when the work is heated. The crank is next heated to about a yellow heat, and two cuts are made into the work at the two marks that are parallel to the length of the levers. These cuts are conveniently made by driving a chisel to an equal distance from both sides, but only a few inches into the place of the gap from the entrance of it. After two short cuts are thus made, a gouge chisel, whose cutting end is the width of the gap, is driven from both sides, and a portion of the superfluous gap-piece is cut out. The straight chisel is afterwards again driven in, to extend the side cuts, and the gouge again employed to deepen the gap.

TWO-CRANK AXLES.—Two-throw crank-shafts are made by first forging two separate cranks, either with gaps or without, and afterwards welding two of the axle ends together; the joint being between the two cranks. Whether the cranks are to have curved extremities or angular, the desired shape is produced previous to the final joint-making.

One of the two cranks is placed at right angles to the other by means of the joint; this is made to fit and coincide while the two cranks are at right angles to each other, and welded in that relation. The particular relative position of the joint ends with the cranks is of no consequence, because the joint is thoroughly welded by upsetting while in the furnace; but the situation of the joint may be at any convenient distance from either crank. To make a good joint a large mass of metal is provided, to admit two or three welding heats; after which the joint part is reduced to the forged diameter of the axle. By this treatment the extreme ends of the original joint become extended to a great distance along the axle, and are so amalgamated with each other that the men who made the joint cannot tell either its situation or position.

Two-throw crank-shafts are made also by piling up the cranks on the sides of a primary axle-piece. This piling is of sufficient height and in the required places to form the cranks to the length desired, and also at the required distance from each other. Each of the piles being at right angles to the other, the cranks are produced in the required relative positions, and without much twisting of the axle or making a joint between the two cranks. At the conclusion of forging, a small amount only of twisting is necessary, to adjust the cranks to a right angle with each other. Cranks thus forged are shown in Fig. 199.

TWO-CRANK AXLES OF ONE BAR.—A two-throw crank-shaft may be made also of one flat bar. The length of this bar is equal to the total length of the axle; the width equals the total length of one lever or arm; and the thickness equals the distance through the crank-gap when formed. When reduced to thickness, the work is carefully trimmed and flattened throughout one small side, usually termed one edge. The work is then ready for marking.

The bar being thus prepared, it is laid upon some convenient table, and the thickness of the intended axle is marked along the bar and at a proper distance from the flattened side, this distance being equal to the forged diameter of the axle. The middles of the two intended cranks are next marked by making two lines across the bar at right angles to the length of the axle. From these two centre lines the forged dimensions of the two cranks are marked, after which a chisel is driven in at each line.

When thus marked, the bar is ready to be formed into a two-crank axle, which is effected by either drilling or sawing. When sawing is adopted, two rows of holes must be drilled at the bottoms of the crank-gaps, each row being parallel to the length of the adjoining crank-pin part; the formation of the cranks is completed when the five superfluous pieces are cut out, at which time the two cranks are extended on the same side of the axle instead of at right angles to each other, as required.

AXLE-TWISTING.—Twisting the axle is resorted to for placing the cranks into their proper positions. For small axles, this operation is conveniently performed at a bright yellow heat while the work is in a furnace or other fire. The portion of the axle heated is that between the two cranks. The first heat is given to that part which adjoins one of the cranks, and the length of axle heated should be about two feet, if the fire will permit. By heating a great length of axle, the twist will be equally distributed along the work; but, if the fire is not large enough for this purpose, a greater number of heatings and twistings should take place. The extent of twist first given may be about thirty degrees; the adjoining portion of the axle is next heated, and the angular distance between the two cranks is increased with twisting to about sixty degrees; after which another portion of the axle is heated, and the distance increased to ninety degrees as required.

The modes of applying the power for twisting are various; and the method selected is that most suitable to the dimensions of the work. An axle of only four or five inches diameter can be twisted while in the fire, by bolting one of the cranks to a table or to a pedestal fixed in the ground. When one crank is thus tightly fixed, the other crank is conveniently made use of for attachment. A lever is fastened to this crank, and the axle is twisted by a few men at the end of the lever.

When a bearing or pedestal is specially made for such purposes, it is preferable to fix the work by means of caps or clamp-plates across the axle, instead of attaching the plates to one of the cranks. If the axle is thus gripped, instead of a crank, the fixing-bolts and plates may be quickly unfastened and refastened during the process. To facilitate the twisting, a few sledge-hammer blows are struck at the moment the power by the lever is applied. Screws also are used to gradually bring the cranks into proper position, instead of applying the power by the lever only; but a few men at the end of a lever which is fastened to a crank or some part of the axle is the quickest mode of twisting all kinds of small axles.

Large axles are twisted under a steam-hammer, instead of in a furnace, and, if convenient, the twist is equally distributed along all that portion of the axle between the two cranks. The axle requires supporting at two places, one bearing being placed to each of the axle ends. One of the bearing-blocks is therefore near the anvil, or, if a large anvil, the bearing may be on the anvil; the other bearing-block is at any convenient place along the axle end. For convenience of handling the work during twisting, the axle ends are rounded previous to attaching the fastenings to the bearing-blocks.

After two or three feet of the axle is heated to a bright yellow, the work is put upon the bearings, and, with one crank beneath the hammer, the work is so adjusted that the crank-pin portion shall receive the blows for twisting; and during the twisting a space is allowed beneath the crank; all superfluous anvil-blocks are therefore removed from the anvil.

Fixing the opposite end of the axle during twisting is effected by attaching a lever to the crank, or to some part of the axle, and fastening the power end of the lever to a pair of blocks and tackle of sufficient strength. By this means the lever can be shifted during the successive hammerings, that the work may be retained in position to receive the blows. A substitute for a lever of great weight and dimensions consists of a pair of grips having angular gaps for attachment to one end of the axle, the axle end being made four-sided to fit the gaps in the grips. Around the rim of the grip are several holes large enough to contain the end of a strong fixing-pin; and, during the hammering for twisting, the work is retained in position through the fixing-pin being tight in one of the pin-holes in the grip, at the time the pin is also tight in a block or iron post fixed for the purpose.

Another means of facilitating the holding of the work in position may be briefly mentioned, which consists in hooking a number of weights to the lever and crank. The greater the weight thus applied, the more effectual will be the blows of the hammer. Whatever particular method may be adopted for fixing, it is advisable to make the cap or clamp-plates for gripping the work, of thick wrought iron, and with great gripping or bearing surfaces, that the work may be easily tightened in any desired position at any moment while on the anvil.

Gap-blocks.—Two-crank-axles made of straight bars, or made by any other mode, may be twisted also by a method which obviates the use of levers and all their necessary attachments.

This plan is applicable to an axle of one inch diameter, or to another of twenty inches, and is accomplished by supporting one crank in a gap-block or pedestal, while the other crank is on an anvil and beneath a hammer of any size to suit the dimensions of the work. The gap-block may consist of any desired number of tons of metal, and be of the needful dimensions for the usual work. In the upper part of the block, and in the vertical position, is the gap or opening for containing the cranks; and across the gap, at the top of the block, is a cap-plate to prevent the work being much shaken with hammering. The precise width of the gap is of no consequence, but it is necessary to make the opening a few inches wider than the thickness of the thickest crank to be put within, in order to allow the crank to be inclined about ten or fifteen degrees while adjusting it for twisting. When a small crank is in the gap, any required number of packing-plates can be inserted to fill the openings that remain.

After a great length of the axle is heated, the work is put upon the anvil and into the gap, and, while suspended with the crane, the shaft is adjusted until the crank-pin part is beneath the hammer, at which time the fixing-cap is tightened and the hammering for twisting commenced.

When a sufficient length of axle is heated at the first heat, the entire twisting can be performed at one heat; but if only a short length is heated, the process of reheating should be adopted. A two-crank axle supported by a gap-block is shown in Fig. 201.

After the cranks are thus put nearly at right angles to each other by some of the methods described, and the outsides of the cranks tapered, or sometimes smoothed, by being hammered into moulds, the work is cut to length and adjusted.

Crank Adjustments.—The final adjustment of all sorts of crank-shafts includes straightening the axles, and placing the centres of the two crank-pins at right angles to each other. The entire adjustment can be effected while the shaft is either entirely supported by the anvil, or partly supported by the anvil at one end, while the other end is in the gap that was used for twisting. To ascertain the amount of adjustment necessary, an iron template is made, having two arms at right angles to each other, representing the two cranks. This template or gauge fits the intermediate portion of the axle, and, being portable, is easily applied.

To rectify a shaft without such a gauge, it is necessary to put the shaft upon a table of sufficient length; and in many cases such a table is not accessible; hence the convenience of a portable gauge.

To straighten the axle, the anvil having the largest face that the framing will admit should be put into position; and the face of the anvil should be concave to the extent of about half an inch or an inch at the middle. To indicate the part of the work which needs a blow, a wooden iron gap-straight-edge, or straight-edge of wood only, is supported at different sides of the axle by three or four men while the smith walks along and observes the distances between the straight-edge and shaft at several places throughout its length. He then measures the distances with inside callipers having a long handle, if the work is hot enough to require it. And when the differences of the distances between the straight-edge and shaft are thus discovered, the concave parts or hollow parts of the axle are also discovered; these parts are then put next the anvil-face and a few blows given; after which the straight-edge is again supported and applied to the work by the men, to ascertain if the axle has been improved with the hammering, and which part is next to receive a few blows.

By means of a long gap-straight-edge thus handled, or by means of a large surface-table, the crank-shaft can be adjusted while it is still hot at the conclusion of forging, and previous to putting it into a lathe. The gaps in the straight-edge are to admit the fulcrum ends of the cranks that extend beyond the axle sides; the gaps should therefore be five or six inches deep; by this means the straight-edge can be put close to, or near to, the axle throughout its total length.

When it is considered inconvenient to make a long gap-straight-edge, the axle must be put into a lathe to ascertain the places of the bent portions, because short straight-edges are of little use for work of great length. During the application of the straight-edge to a shaft of great length, the work requires supporting at several places to prevent it bending through its own weight.

STEEL CRANK-SHAFTS.—All crank-shafts are best when made of a hard metal that will admit beautifully polished surfaces for the crank-pins and axle-bearings. For this reason, a hard, highly tenacious steel, which will resist strains of vibration without being very liable to break, is pre-eminently the very best material of which crank-shafts can be made. And the reason why large crank-axles are not made of it is because it is an exceedingly rare product; and, when it is comatable, great difficulty is encountered in forging it into a large crank-shaft without spoiling it, or placing the lengths of the fibres into the wrong positions. But the great advance lately made in steel-making by the Bessemer process enables us to hope that a steel which will be tough, hard, and also easily forged, may be produced at a not very distant time.

SUMMARY.—From the foregoing remarks and details of processes given in the previous sections of this chapter, an attentive student will learn that, however good the iron or steel may be which is used for forging, it is always desirable to devote some attention to the relative positions in which the several forging components are to be welded to each other, and the positions of the fibres in the work after being forged. From the details of processes already given, these six general rules may be deduced:

1. That all piston-rods should be so made, as to place the longitudinal axes of the constituent fibres parallel to the lengths of the piston-rods.
2. That the straight portions of all levers should be so forged, as to arrange the longitudinal axes of the fibres into a position of parallelism with the lengths of the levers.
3. That the lengths of the fibres in any curved junction of a fork-end or T-head with its respective rod should be parallel to or concentric with the curve itself.
4. Also that the lengths of the fibres in all lever bosses and fork-end bosses should constitute portions of rings whose centres are the centres of the holes in the bosses.
5. Also that the fibres in the arms of all crossheads should be disposed into a position of parallelism with the lengths of the crossheads.
6. And that all axles should be so made, as to put the lengths of the fibres into a position of parallelism with the lengths of the axles.

These general deductions relate to the principal portions of engine work, and may be reduced to this comprehensive general statement:

That the lengths of the fibres in all piston-rods, connecting-rods, and other rods generally, should be parallel to the line or direction of the motive force applied while in use; and that the lengths of the fibres in all levers, crank-pins, and axles generally should be at right angles to the direction of the force applied while in use.

To enable a beginner to appreciate these deductions and statements, it will be necessary for him to refer to the opening sections of this chapter, and to devote some attention to the sketches in Plates 1, 2, 3, and 4, that he may obtain a general idea of the shapes of the forgings he is considering.

The character, formation, and uniting together of forging components having been thus for the first time generally described, a description of the appliances and implements for facilitating the various processes is now added.

SHAPING IMPLEMENTS.

During the making or using of these implements, the fundamental principles of forging stated in the first sections of this chapter should be remembered in all cases that require good work; by no other means can good forgings be produced when ordinary bars or rods are used, whether they be Lowmoor, Bessemer, or any other product; therefore every tool, shaper, mould, or other implement that can be used or made to facilitate the forging by the first principles should be eagerly employed; but all those implements or machines that put the metal into the outside shape without properly arranging the fibres should be avoided when circumstances permit.

Shaping moulds for forging purposes are more applicable to Bessemer ingots than to laminous bars, and especially when a Bessemer product nearly free from phosphorus and sulphur is accessible.

The principle involved in forging with moulds consists in shaping the metal to the required form by adopting the shortest method, entirely disregarding the internal arrangement of fibres; for this reason, tenacious Bessemer metal is very suitable for forging in moulds of all classes, small and large. Such metal can be upset without splitting; and, when newly cast, Bessemer product is devoid of an orderly side-by-side arrangement of fibres. While in this condition, it may be shaped, pressed, bent, or upset in any direction, if the metal itself is good.

It may be stated generally, that bending and pressing are the two principal operations in these shaping processes, and that the tools and shapers employed are of cast iron or of Bessemer metal; also that the great economy of time resulting from the use of shaping moulds requires that they should be employed by every manufacturer who has regularly to perform or conduct any kind of smiths' work, whether it be very small or, on the contrary, very large. Such shaping tools are equally applicable to work of all dimensions, whenever many articles are required to be of the same or similar shape.

The bending and shaping tools, and appliances for small work, shall be first described.

Top Tools.—Plate 20 contains a number of sketches of shapers for small work; in this Plate, Fig. 202 denotes a top rounding tool that may be used in the usual manner with another bottom rounding tool, for rounding small work to a cylindrical form; or the top tool may be separately used for producing work of semicircular section, usually named half-round. When such a form is required, the work is put upon an anvil or some other convenient flat surface, instead of into an ordinary bottom rounding tool; the top tool is then applied with hammering, to produce the required half-round shape.

Top tools are used also for curving those two sides of a flat key which are named the edges, when keys of this form are required.

Such top tools are very durable when made of Bessemer steel, and can be easily formed by splitting open one end of a piece, with punching a small hole at a short distance from the extremity, in the usual manner, and afterwards shaping the two ends thus produced, until the desired concave form is obtained. The required curve is effected with hammering the work while it is on a piece of round iron or steel, whose diameter is suitable for producing the desired curve in the tools being made. During the shaping of the curve, the round iron or steel is supported in any convenient gap, or in a pair of angular gaps similar to those in the two blocks shown in Fig. 142.

Another mode of making top rounding tools consists in forming the curved or fork portion of steel, and welding a piece of iron of any desired length to the steel fork part. The straight soft iron portion is therefore that which receives the hammer; and when any of the thin pieces become detached from the top of the tool during the usual hammering, the mischief resulting through the pieces being driven about is not so likely to be as extensive as when the entire tool is made of one piece of brittle steel. But now that a soft Bessemer steel is attainable, the complete tool can be made without any joint.

The upper extremities of all top rounding tools should be curved; and, in all other tools, rods, or bolts that are intended to sustain a severe hammering, the extremities that receive the hammer should be also curved, by which the desired shape is retained a greater length of time. The curved outlines of such extremities are clearly shown in the larger sketches of this class of tools in Plate 7.

The smoothing of the gaps of rounding tools is done with half-round or round files; the tool is next hardened and tempered to that degree which the particular piece of steel requires, to prevent it breaking with the ordinary hammering. The upper ends of such tools do not require any hardening process.

Fullers.—Fullers are used in all cases that require recesses with curved bottoms to be made into any piece of work during its forging; and according to the width of the recess required, so is the width of the particular fuller employed. Fullers are used also for scarfing, in which case the end to be scarfed is put upon an anvil, or a bottom rounding tool, and the fuller is driven into that side of the work which is intended to be bevelled. Fullers are useful also for the drawing down or otherwise thinning of work that is too small for the ordinary set-hammer.

The forging of a fuller is properly done when the entire tool is made of one piece of steel, which is easily tapered, or upset at one end, until the required curve and thickness of fuller is obtained.

The mode of holding a fuller, or other similar top tool, during its use, is by means of either a straight ash handle or a tough rod, which is twisted around the outside of the tool, and tightly fixed with two iron clips. The straight handle allows the tool to be kept firmly upright, and should be used when good hammermen are comatable, who are not so liable to hit the handle instead of the tool-head; but the twisted handle is preferable when it is likely to receive a severe blow, which would break the handle without injuring the arm of the man who holds it.

Those tools that are intended to have straight handles should have the handle-holes punched and drifted, instead of being drilled, because the drifting spreads out the metal around the hole and strengthens the tool, the eye part being the weakest portion.

The final shaping of a fuller end is effected by hammering the tool while its lower end is heated and in a gap of a bottom rounding tool, the curve of the gap being that which is required for the fuller. Such shaping drives out a few ragged edges, named burrs, which are produced at the angular extremities of the fuller; these burrs are not hammered in, but filed off, and the curve of the fuller itself is also smoothed with filing; after which the fuller part of the tool is hardened, and is then ready for its handle.

Carriers.—These are of various shapes and dimensions, to suit both small work and large; and are used to grip the various pieces of work while being carried about from a fire to a hammer or to a shaping implement. Carriers are represented by Figs. 204, 205, and 206.

The cranked carrier shown by Fig. 204 is a very safe instrument to prevent the hot piece of metal slipping away from the middle of the carrier while being carried about. A carrier of this class is made of a straight piece of round iron or steel; and the cranking is effected on an anvil-beak, or on a block in which are studs or pins to hold the work while being cranked. Such studs for bending purposes may be placed also in some of the slots in a table shown at the bottom of the Plate (20).

The hook carrier, denoted by Fig. 205, is useful to a hammerman for carrying about small rods or bars of great length. While the smith carries one end of the work, the other hot end is suspended with the hook, and carried by the hammerman. Such carriers are useful also for twisting and bending small work.

Fig. 206 indicates a class of carriers for carrying long bars or plates, the work being gripped by one of the gaps in the cranked part. Either one, two, or three such carriers are employed by one or more hammermen, according to the dimensions of the work to be moved about.

To make such a carrier, two components are necessary; one of these is a straight bar for the cranked portion, and the other piece is a rod of iron of sufficient length to make any length of handle that is required. The bending of the bar to the shape of the crank is effected in a manner similar to that for making other cranks, which is by means of studs on some convenient block or table. After the gaps are made to the width desired, the crank part is welded to its handle, and the carrier is complete.

Bolsters.—Bolsters are used to support a piece of work at a proper distance above an anvil, while being punched or drifted; consequently the greater the length of drift that protrudes beyond the work being drifted, the greater is the height or thickness of the bolster. Some sorts of bolsters consist of thick circular rings having holes of various diameters; other bolsters are slotted, or may have a long narrow gap, as in Fig. 207. The forging of one of this class consists in bending one end of a long bar and closing the work together until the gap is of the proper width. After the bolster is finished, it is cut from the bar which was used as a handle during the forging.

Angular Shapers.—To shape angular extremities, it is often convenient to hammer the work while at yellow heat, or sometimes at welding heat, while the heated portion is in an angular gap. The angle of the gap-sides is that of the work required to be shaped. An angular shaper is shown by Fig. 208; and when the gap-sides subtend an angle of sixty degrees, the tool is sometimes used for shaping the outsides of six-sided nuts of several sizes.

The material used for making such blocks should be Bessemer steel, cast into sand moulds that were shaped by wood patterns whose shapes resemble the shapes of the required blocks.

When it may be necessary to forge such a block, instead of casting it, the square stem is first produced at one end of a bar, fullers being used to commence the drawing down, in the usual way; and when the stem is reduced to nearly its finished dimensions, it is placed in some convenient hole or slot, with the thick part of the work upwards; while thus fixed, chisels and wedges are driven in at the place of the intended gap, until its required dimensions are attained.

Collar Shapers.—Several classes of small bolts and studs have collars or flanges near one end, or near the middle. For such studs, a shaping-block denoted by Fig. 209 is employed, together with another top tool having a recess similar to that in the bottom block.

The use of such blocks obviates the necessity of welding separate collars to the bolts, because the stud or bolt may be made of one single piece, which, in diameter, is equal to the diameter of the collar desired. When such a piece is used, it is first fullered in two places to produce the required collar between the two fullered recesses. After being thus roughly formed, it is again heated to about welding, and put between the top and bottom collar shapers; and, while between, a rapid hammering produces the shape required.

These collar shapers are used also for welding and shaping flange bolts when made of two pieces instead of only one, the collar being bent around the bolt as previously shown (Plate 8). In such cases, the collar is welded to the bolt by means of the usual hammering, while the work is between the shaping tools.

Cast iron or steel being used for these shapers, it is easy to shape the gaps to any form of flange that is required. If needful, the gaps may be made to produce four-sided flanges, and also four-sided bolts, instead of circular ones; but, whatever form of bolt is required, it is desirable to make the bottoms of the recesses smaller than the mouths or entrances, to prevent the bolt sticking in the block after being hammered into it. If the bottom of any such gap should be larger than the entrance, instead of smaller, or if any irregular hollows or holes in the block should exist, when newly cast, at the sides of the gap, the work after being hammered into it will remain in, securely dovetailed, until drilled out piece by piece.

Drifts.—It is often necessary to punch small keyways, or other slots of similar shape, into small pins and bolts, to avoid drilling; and, after punching, thin drifts of various lengths and thicknesses are driven into the slots to enlarge them to the required dimensions. A thin drift, having curved extremities to resist the hammering, is shown by Fig. 210.

Drifts are made also of circular, oval, rectangular, hexagonal, and octagonal transverse sections; and are used for drifting nuts, joint-pin holes, small connecting-rod eyes, lever-bosses, fork-joints, spanners, machine-handles, and several other articles, when the object is to economise the time that would be occupied in shaping with more expensive machinery.

Whatever may be the particular shape of the drift, it should be of excellent steel, very smooth, and as near to straightness as can be made. For general work, it may be stated that the angle subtended by any two opposite sides of a finishing drift should not exceed one or two degrees, which is termed very slightly taper.

Drifts for enlarging the holes in large work during forging should be very taper, the angle subtended by the sides being about fifteen degrees.

Slotted Bottom Tools.—A slotted bottom tool having a half-round gap is very convenient for supporting a bolt or pin, or other cylindrical piece, while being punched or drifted. The tool may be of sufficient length to extend beyond the anvil-edge, to allow the end of the drift to clear the anvil while in the slot or key-way. In other cases a shorter bottom tool may be used, having the slot directly above the anvil-face; in either case the slot in the tool is formed entirely through it, to allow the punched pieces to be easily cleared away.

When such tools are made of cast iron or cast steel, the slots can be formed at the time of casting, and are afterwards finished with filing. If the tool should be made of wrought iron or wrought steel, the slot may be punched, or, if too small for punching, it may be drilled and afterwards finished with filing. A slotted bottom tool is indicated by Fig. 211.

Punches.—The usual shapes of all punches are conical, and the angle subtended by two opposite sides should be about six or seven degrees. The outlines of the transverse sections of punches do not differ so much from each other as the sections of drifts, the only two general forms for punches being circular and rectangular, termed round and square. Round ones are used for piercing holes into nuts, joint-bosses, rings that are to be forged without a joint, spanners, and many other classes of ordinary work; also for making flat-bottomed recesses into iron or steel previous to punching smaller holes at the centres of the flat-bottomed recesses, the shapes of the smaller holes being either round or square. Square punches are required for square bolt-holes, key-ways, also rectangular gaps in the ends of rods or bars. In this case, the square hole is first punched at a proper distance from the extremity, and the superfluous piece afterwards cut out with chiselling. Square punches are useful also for making many other rectangular openings in thin bars and plates.

Four-sided punches for making small holes are made ten or twelve inches long, for the convenience of holding the punch with one hand while the other hand is employed to drive the punch through or partly through the work. Large punches that require a sledge or steam-hammer are made of the shortest possible length that is sufficient, that the hammering may not bend the punch to any considerable extent. A short square punch is represented in Fig. 212. Whether the punch is round or square, a short one requires an iron-wire handle, twisted around the punch, instead of a wood handle; an iron handle, being thin, will allow a great length of the punch to be driven into the hole during the hammering for punching.

Punches small or large, long or short, require to be made of the best tough, hard, cast steel. When such metal is accessible, the only hardening that the tool requires is given when it has been driven into the work and become nearly or quite red-hot; at such times, the punch is put into water in a bucket provided for the purpose.

Key-shapers.—To facilitate the forging of keys of various shapes and dimensions, a number of blocks are cast having recesses and grooves of different shapes corresponding to the shapes of the keys required. For round keys, half-round taper recesses are formed; for square and other kinds of rectangular keys, the recesses are about the same depth as the thickness or width of the intended keys, some of the gaps being used for shaping the keys while their small sides are upwards, and other recesses being used for shaping the keys while their broad sides are upwards. The bottoms of the gaps may be either flat or curved, according to the required shapes of the key-sides.

Keys having heads are shaped by hammering them into gaps that are shaped to receive the heads in addition to the stems of the keys. The gaps for the heads may be open at the front end of the shaping-block near the workman, or the recess for the head may be made nearer to the middle of the block-face; the recess will then be surrounded with metal, except at the place for containing the key-stem. This situation for the heading recess is necessary for shaping great numbers of headed keys, that they may be firmly retained in their respective recesses instead of being pushed out with the hammering.

The tools that are required while hammering the metal into the shapers are half-round top tools and flatters, or, in some cases, the hammer only. The half-round top tools are used for round keys and the small sides of taper flat keys, also one of the small sides of a gib. Flatters are necessary for all sorts of rectangular keys; and when considerable numbers are wanted of similar width and thickness, the required dimensions are obtained by hammering each key into two gaps, one gap being just the width of the required keys, and the other gap being just the thickness. When two such gaps are provided, they are termed gauge-gaps;

and while the key is in either of these openings, it is flattened with a flatter until the flatter strikes the face of the block at the same time that it strikes the key, at which time the work is of the required dimensions, measuring with callipers not being necessary in such cases.

Many classes of keys can be shaped and reduced to the finished dimensions at only one heating and hammering; for such keys only one gauge-gap is requisite for each size of keys.

The material used for such shapers should be cast Bessemer steel, the proper care being exercised to slightly taper the gaps that the work may be easily separated from the shapers. A key-shaper is shown by Fig. 213.

Rounding Blocks.—Instead of a separate bottom rounding tool being used for each different diameter of bolts or pins, a block having three or four gaps is often used, all the gaps being of different sizes, to suit various diameters of bolts and rods.

The making of such a block consists in either casting it of Bessemer steel or forging it of wrought iron; sometimes adding a steel face for the gap part, in other cases making the block entirely of iron.

The forging is commenced by producing the square stem by drawing down one end of a bar or other component piece, and, when the stem is squared, a sufficient quantity of metal is allowed for the block, and the entire work cut from the bar or lump. The intended face side is next flattened or welded, if not solid, and the half-round gaps are formed with fullers. For this purpose, the places of the gaps are marked with a chisel, and the work is heated to nearly welding and put across a convenient opening to permit the square stem to hang between; or, if the steel is sufficiently reduced, it can be put into the square hole of an anvil. While thus situated, fullers of proper width are driven in at the marks, and with two or three heatings the gaps are roughly formed. The shaping of the gaps is next continued by hammering cold pieces of round iron or steel into the gaps, first at near welding heat, and afterwards at a dull red heat; each of the pieces used for shaping being of a proper diameter to form the opening desired. After all the shaping with fullers and pieces of round iron is completed, the burrs spread out at the angular extremities are filed off, and the smoothing of the gaps is effected with half-round or round files.

When the blocks are cast instead of being forged, the needful shaping and smoothing is effected with files only, because the gaps are cast nearly to the finished dimensions. A rounding-block is represented by Fig. 214.

Bolt-head Shapers.—When great packing numbers of bolts having cylindrical heads are wanted, it is advisable to use an implement which will reduce the bolt-head to its proper diameter, also reduce the bolt-stem to its diameter, and make the bolt-head concentric with the bolt-stem, the three objects being effected at only one hammering. The lower block of such an apparatus is shown by Fig. 215. The upper shaper consists of a top tool having a recess, which is of the same shape as that in the bottom tool. After a bolt is drawn down and roughly shaped, it is put between the two tools and adjusted to the desired shape and dimensions at one or two heats.

Shapers of this sort will not adjust a bolt-head to any particular length; it is therefore necessary to make the recesses for the heads longer than the length of the longest bolt-head to be put within. The easiest method of making such shapers is by casting, the recesses being formed at that time.

Another plan consists in casting or forging the top and bottom blocks separately and without any recess. The next step is to carefully flatten the two faces that are to come together; after this the two tools are firmly bolted together in their intended relative positions during use. While thus fixed, the bolt-holes and head-recesses are bored with suitable apparatus.

Tongs Shapers.—The principal parts of a pair of tongs are the joint portions; and all the joints of tongs for small work are made about the same shape, consequently it is convenient to make recesses for forming such pieces without trouble. Any additional portions for the grips may be afterwards welded to the joint pieces, if the work in progress is large enough; but for small tongs, the joint portion may be shaped at a proper distance from one extremity of a bar, and a thick lump be allowed to remain at the end, beyond the joint part. This thick portion may then be shaped or cut to any desired form, to become the grip, instead of welding an additional piece to the joint part, as for larger tongs.

The only top tools that are required for use with tongs shapers are ordinary hammers, flatters, and set-hammers.

The shaping recesses in the block may be formed of a sufficient depth to contain the whole of the piece being shaped, or may be shallow, so that a portion of the metal may project above the face of the block when thick joint pieces are being made.

Through the irregular forms of the recesses in tongs shapers, it is necessary to carefully form and polish the wood patterns to the proper shape, that no further shaping may be necessary, after the blocks are cast. A tongs shaper is indicated by Fig. 216.

Tables.—A great number of small tools and shaping implements are used on some sort of block or surface-table. Every smithy should contain one or more of these tables; and the greater the dimensions of the usual work of the shop, the greater should be the table or tables. The length of large blocks or tables of this class should be about five or six times the width, that the men may make use of nearly the whole surface, instead of working at the edges only. For the convenience of fixing various pieces of work to the table, it should be cast with a large recess for the under side; and also contain a number of slots in various parts of the upper side or surface, and also around the other sides next the workmen. These slots are useful to contain the ends of studs, pins, hooks, poppets, bolt-heads, and other instruments employed for fixing and shaping various classes of forgings. In addition to slots, the table may have several straight lines marked along the surface, and a few other shorter lines marked across at right angles to the long ones. While the table is in use, it is in any convenient part of the shop, and supported with a few wood blocks to raise it to any particular height that may be desired. When the table is required at some other unusual place, a few wood or iron rollers are put beneath, and it is rolled to its intended destination.

If an instrument of this character is accessible, the straightening, flattening, and adjusting of rods and shafts of all sorts will be greatly facilitated. The lines, being of great length, will admit several men to work at one time in several places along the table; the lines being also at right angles to each other, will allow work of all sizes, and in all stages of forging, to be put to the lines for adjustment; and when a curve of any particular radius, or diagram of other variety is desired, it may be delineated on the surface with chalk or compass point, and becomes for a time the workman's gauge or standard. Any of the places of intersections of the lines with each other may be selected for centres from which to excribe the necessary arcs or other curves that may be needed, for the adjustment of links, sectors, connecting-rods, eccentric-rods, slide-rods, rings, cranked levers, straight levers, and other varieties of work that are in progress.

One or two of the lines near the edges of the table should be divided into mètres, decimètres, centimètres, and millimètres; such an arrangement would tend to abolish the old mode of measuring by inches and parts.

A thick heavy table of this class may also be adapted to a steam-hammer, instead of using it as a portable table in various places. The steam-hammer thus supplied may then be specially reserved for straightening, flattening, adjusting, and cutting to length a variety of rods, axles, and other forgings.

The material of which such tables should be made, is Bessemer metal, or a hard cast iron which is not too hard to admit the planing process; such metal will be durable, and if the intended top or face of the table is downwards at the time of casting, a good surface will be the result. The preparation of the table for use commences with reducing the upper side to a plane by means of a planing machine; after planing, the same machine is the means of marking the long lines on the table, and also the short lines, if the machine is suitable; if not, a steel scriber and straight-edge are employed to mark the short lines, when the planing-machine is not capable of being adapted to the purpose. The method of correctly marking the cross lines consists in bisecting the long lines, or portions of them, in all those places intended for the intersections of the short lines with the long ones. By this means, the marking tool may be afterwards used to enlarge the marks, and the desired right angular positions of the lines are obtained. This class of tables, having a few lines marked on the surfaces, is represented in Fig. 217.

Angling Blocks.—The slots and square holes in a portable table may often be conveniently used for holding the square stems of rounding tools, bending tools, and other shaping implements represented in Plates 20 and 21; instead of placing the stems into the square holes of ordinary anvils. In Plate 21, two bending tools for bending ends of bars, as shown by Figs. 218 and 219. The number of slits or narrow gaps in each tool may be three or four, if the tools are large enough; and the angles of the gaps with the faces of the tools differ according to the desired angle of the work when angled. For the convenience of shaping curved work, the entrances of the gaps may be curved, as in Fig. 219.

When such a tool is in use, it is fixed by its stem in some convenient hole, and the bar to be angled is heated to a proper softness and upset, if necessary, to obtain a thick portion at the intended corner; after this, the iron or steel is again heated and angled by placing the end of the bar into the gap, to such a distance that the middle of the heated portion shall be in contact with the bearing or projecting edge at the mouth of the gap. When the work is thus fixed, it is ready for angling, which is effected by one or two men pulling down the end of the bar until it is brought to the desired position. After being thus roughly bent, the work is properly shaped by hammering and flattening that part of the iron which is on the angling block.

The angling block shown by Fig. 219 is useful for shaping work which is to be very strong at the corner, having a curve inside and an angle outside. To make such a corner, the iron is heated to welding and driven into the gap with flatters or set hammers.

Gap-blocks for angling and corner-making are made by first preparing a solid block having a square stem, but no gap. The material used may be either Bessemer metal or inferior homogeneous iron; and the cutting of the gap is performed while cold. For this purpose, the place of the required gap or gaps is marked upon the face and two sides of the block, by means of a scriber and straight-edge; after which the opening is made with drilling about half way through from two opposite sides of the block, and not with drilling from the face of the block. After being drilled with drills of proper sizes, the gap is completed with chiselling and filing.

Large gaps, two or three inches wide, and six or eight inches in length or depth, are formed at the time of casting; the wood patterns being shaped to draw easily from the sand in a direction which is parallel to the length of the gap, and not in a direction which is at right angles to the block face; consequently the block is cast with one side at the bottom of the mould, instead of the block-face being in that situation.

Gap blocks or other implements of similar character, having wide gaps, are made to suit thin bars, by putting packing plates of various thicknesses into the gaps by the side of the work to be angled.

Screw-Clamps (Fig. 220).—Screw-clamps are used to fix two or more bars or plates together, or to a block or table; the object being to tightly fasten the pieces in any required relative position during a short time while marking with a scriber or other instrument. Clamps are used also for lifting heavy plates, and for attaching various pieces of work to each other. Screw-clamps are made of all sizes from half a pound weight to fifty pounds; and the form is nearly the same for all dimensions, being similar to that shown in Fig. 220.

When clamps are used for fixing a long straight-edge upon a piece of work, two or three clamps are necessary, and are placed in two or three places along the sides of the straight-edge and the work while in their required positions; pieces of soft iron are then put upon the straight-edge to receive the points of the clamp-screws, and all the screws are tightened with a tommy, by which the straight-edge is securely fixed. During the final fixing, the work is adjusted to its exact intended relative position by giving a few knocks to either the straight-edge or the work to which the straight-edge is fastened, using a tin hammer for this purpose, or, for some work, a copper drift.

For lifting purposes one clamp is often dangerously used, the clamp being suspended with the chain-hook, and the bar or plate which is being lifted being wholly dependent on the bite of the screw-point to prevent the work falling and doing mischief; consequently, for safety, the clamp-screw point should be screwed into the metal sufficient to make an indentation about a sixteenth deep.

A good clamp is that which presents a large bearing surface to the work after being fixed, thus preventing the clamp and work from altering their relative positions. With this object a clamp should be made so that its two arms are nearer to each other at the extremities than at a few inches towards the bottom of the gap, or mouth, as it is termed. Such a clamp, when in ordinary use with the work between, should be screwed tight until both arms are parallel to each other; any further screwing after this will further separate the arms and tend to make the work less secure. During a long usage, the arms of clamps become too wide apart by the frequent screwing; a clamp in this condition should be rectified by heating the thick curved part, and closing the arms to a proper distance.

The metal for clamps should be Bessemer iron or steel; the screw-points also must be of steel, that they may be forced into the work or packing which is being fixed, when such a bite is necessary. These packing-pieces should be hollow at those sides that are to be next the work to be fixed; and the bearing of the clamp also, shown in the Figure by B, should be hollowed by filing a shallow narrow groove along the middle.

The forging of a clamp, when small, consists in making it of one straight piece, which is reduced to a suitable thinness at each end, and the boss for the screw also made at one end, both operations being completed previous to bending the clamp at the middle. Large clamps are conveniently made of two pieces when bending tools are not accessible; in this case, the joint is made at the thick curved part.

Cup Tools.—A cup tool consists of a top tool which is held on the work by means of a handle in a hole punched into the tool for the purpose, or held by an iron wire or wood handle twisted around the outside. The outline of the lower extremity of a cup tool is circular, and in the midst is a plano-convex recess whose plane coincides with the flat bottom of the tool, also named the tool-face. The straight part of the tool is often much smaller in diameter than the cup-portion, for the purpose of making the tool as light as possible; one of this character is shown in Fig. 221.

The tools may be of several sizes, some having recesses of half an inch diameter, and others having recesses three inches diameter; the tools are thus adapted for chamfering nuts, shaping plano-convex bolt-heads, convexing extremities of pins and bolt stems, and also for general riveting purposes. If the object is to chamfer nuts, the cup tool is applied to the nut and struck with a sledge hammer, after the work is reduced to proper dimensions and shaped to the desired form, whether square or hexagonal. For bolt-heading, the cup tool is applied after the bolt is put into the header and roughly upset with hammering. If a cup tool is required for convexing extremities of long bolts or pins, the tool is held to the work and struck with a sledge hammer while the bolt is in the horizontal position on an anvil. A short bolt is stood upright upon the anvil, or upon an upsetting block, and the cup tool applied in a vertical position. For riveting purposes, cup tools are very small, having recesses only three-quarters of an inch, and for some work only three-eighths in diameter. Such tools are parallel, having their straight parts about as large in diameter as their cup-portions.

Cup tools are often forged of two pieces, one piece of iron for the stem, and the other piece being of steel for the cup part; the two being welded together. A preferable mode consists in forging the tool entirely of Bessemer steel, and the implement used for shaping the recess is a punch shown by Fig. 222. This punch is partly shaped with hammering, and afterwards filed and smoothed with emery cloth until the convex part is of the desired shape; it is next hardened and fixed to a handle, and becomes fit for use. The mode of applying the punch consists in driving it into the solid metal at the place of the intended recess, the intended cup part being heated to about the softness of cold lead. The blows first given are with a sledge hammer, which is used till the recess is about the depth desired; and after one or two heatings, the finishing of the hollow is effected with a few blows of a light hammer, the work being a little cooler than red heat. In addition to this smoothing of the hollow with the punch, the cup may be further hollowed by lathe-turning; but in most cases such a troublesome process should be avoided, and the entire smoothing done with a properly shaped punch.

A cup tool may be also made in the form of a steam-hammer shaping block, in which case the recess may be formed by either casting or by punching with punches of proper sizes.

Tube-Measures.—Such measures are made of pieces of plate iron that are bent to a tubular form, to fit loosely on the bolt, pin, or rod to be measured. They are made also of thin iron pipe which is sawn into pieces of the required lengths. If necessary, two or three tube-measures may be used at one time on one bolt or pin, the measures being placed end to end, and extending along the bolt to the length desired.

Measures of this sort are used to indicate the commencements of keyways in the ends of bolts that require punching instead of drilling. After a measure of proper length is selected or made, it is put upon a bolt or pin while at a proper heat for punching; the portion of the bolt projecting beyond the measure is next put into the gap of a bottom tool, and the punch is held on the bolt-end and tight against the measure; while the punch is thus situated, it is driven half way through the work from both sides, the tube is next taken off, and the keyway finished with further punching and drifting.

These measures are useful also for indicating the intended junctions of bolt-screws with the adjoining portions of the bolts, when it is necessary to reduce the end for the screw to a diameter which is shorter than the diameter of the adjoining part. A tube-measure may be also used for a pin, bolt, or rod when screwing is not intended. For such purposes the tube is put upon the work, and the rounding tool, set hammer, fuller, or other tool to be used is put close to the measure, and the drawing down commenced while the set hammer is tight against the measure, so described for key-way punching.

Another use for such measures consists in applying one to a great number of bolts that require to be forged to one length; in these cases the cutting-off chisel is put close to the end of a measure while it is on a bolt, and a correct length is thus ensured. A measure for this purpose on a bolt is represented by Fig. 223.

A usual mode of measuring lengths in bolts or other work without a tube, consists in marking the length with chalk upon a straight-edge of convenient length, to be held to the work by the hammerman; and while he holds one end of the straight-edge tight against the shoulder of the bolt-head, the smith puts the reducing tool or chisel to the bolt and also opposite the chalk mark on the measure; while the smith thus holds the tool, the hammerman takes away the measure and drives in the tool with his hammer.

The mode of making tube-measures, and also other work of similar shape, consists in bending the pieces of plate while at a suitable heat. If several are to be made at one performance, all the pieces may be first cut and prepared previous to bending, and all may be cut small enough to form spaces between the extremities after being bent to a tubular form. Such a space is shown in the tube on the bolt shown by the Figure (223), and the advantage of such an opening consists in its allowing the plate to be bent in an easy manner. The length of the tube is the distance along the bolt to which the tube will extend when finished, and the piece of plate is cut a trifle longer to admit a little filing or adjusting to a proper length. After a sufficient number of pieces are prepared, they are curved while heated by driving a piece of round iron or steel on to the plates while lying across some convenient gap. For such bending, the gaps of half-round bottom tools are suitable, and after the round iron shaper is driven in to a proper distance, the curving of the tube is completed with a couple of top and bottom tools of a suitable size, while the round iron is in the hole and held by the workman as an ordinary nut mandril. After the tubes are made, the two bearing extremities of each one are adjusted to a precise length, and made parallel to each other; this is effected by placing the tube with one end upwards on an anvil and flattening with a flatter, and afterwards with filing, if necessary.

Arched Fullers.—Fullers whose shaping parts are arched or concave, resembling Fig. 224, may be used in pairs or singly; when used in pairs, they become both fullers and gauges, because the work which is being reduced between the two fullers cannot be reduced after the two tools are brought together by hammering, without applying other tools having smaller gaps.

Such fullers are made by first preparing the shaping parts with thin ends that are about the same thickness as when finished, but having straight bottoms instead of curved ones. The forming of the arches is commenced by cutting out the superfluous pieces with a punch, or with a gouge-chisel, indicated by Fig. 226; after being thus hollowed, the shaping is completed by driving each fuller while heated into a grooved shaper, the groove being the shape of the required fuller-end. For this purpose a groove is made around a piece of round steel by means of a lathe, until the groove is of proper depth and width. If necessary, several grooves may be made into one shaper, and each groove formed for one particular work. A grooved shaper of this class is shown by Fig. 225.

After the intended fullers are cut with punching or gouging, the grooved shaper may be held with tongs between a pair of the fullers at a suitable heat, and the two tools shaped by sledge-hammering the top tool; or, the fullers may be shaped separately, by putting them into the groove, and hammering the square stems which are upwards. During such hammering, the grooved shaper is held in some convenient gap or gaps to keep it in position. The finishing of the arches consists in filing off the burrs that were produced by the shaping processes, and afterwards filing the extremities to the required dimensions.

Handle Shapers.—Shapers for machine handles are in pairs when intended for handles of circular transverse section, so that when both top and bottom shapers are put together in their proper positions, a hole is formed which is the shape of the handle required. Handles of rectangular section require but the bottom tool, which is used as other bottom tools—the handle being pressed into the shaping implement by means of an ordinary hammering, or by means of a flatter.

Fig. 227 represents the bottom tool of a couple of shapers for circular handles; the top tool may be attached to the bottom one by means of guides to guide the top tool to its required relative position; or the top tool may consist of a light shaper, not too heavy to be held by means of a wood handle, similar to that for other top tools.

The convenient mode of making handle shapers is by casting, at which time the gaps must be formed so that little or no smoothing after casting shall be necessary. The small amount of finishing which is required is performed with small chisels, gouges, punches, and scrapers; the cutting parts of the scrapers being semicircular, rectangular, and triangular.

Bossing Tools.—Bossing tools are adapted to shape bosses of levers or rods that are either round or flat. A bottom bossing tool for round rods is shown by Fig. 228; a tool of this class is useful for shaping several varieties of joint bosses. Fig. 229 denotes a bottom shaper for eccentric-rod bosses that are forged without gaps; also for shaping a large class of lever bosses, including weigh-shaft-levers, lifting-levers, reversing-levers, crank-levers, and others of similar shape. A flat rod or lever having one or more bosses extending from only one side of the lever, instead of from two opposite sides, may be shaped by being hammered into the bottom tool, a top bossing tool not being required. Such a bottom tool will shape also lever bosses that extend from two opposite sides of the lever, if both bosses are to be of one diameter, and are to extend to an equal distance on both sides. But to shape a boss which is larger in diameter at one end than at the other, or is not of the same length at one side of the lever as at the other, two tools are required, top and bottom; and when a number of bosses are wanted at one time, the tools should be guided or jointed together.

The diameter of the metal selected for making a lever boss may be sufficient to allow the boss to be formed without any previous upsetting. Such a piece will need therefore a reducing, to produce the arm or lever which is to extend from the boss. This reducing is effected at the beginning of the forging; after which the boss part is roughly formed with fullers and chisels, and the work finished with the bossing tools.

Such shaping implements will also form bosses that are made by piling; being piled up on one side or on two sides of a lever; this lever portion being of the forged dimensions previous to attaching the bosses, that the bossing tools may not be required to shape anything more than the bosses.

To make a boss at one end of the lever, the iron may be cut partly through in several places and doubled and welded together until a lump of sufficient thickness is obtained. When enough metal is accumulated by this method, the boss lump is heated to welding and shaped by the tools at one or two heatings.

When these methods of piling and doubling are adopted for making bosses in large numbers, it may be necessary to cut the component pieces to a proper length, previous to commencing the formation of the bosses. For this purpose, the smith can ascertain the sectional area of the boss required, and also its length; and having also discovered the sectional area of the bar or rod which he is to make into the boss, he may know the length of bar necessary to be piled or doubled for one boss, by applying the appropriate rule (page 8). This rule is equally applicable whether the original piece is larger than the intended work, or whether iron of smaller diameter is to be used, and upset or doubled to the needful dimensions. After thus discovering the exact amount required for one boss, the proper amount may be added for welding and burning during the several heatings.

Cranking Tools.—Gap-liners of steel or iron, or any other forgings of similar shape, are easily cranked by means of a couple of appropriate tools. Both the shaping tools may be used together as top and bottom tools, or the bottom tool may be the only one employed; in this case the bar to be cranked is driven into the shaping gap with ordinary fullers. A cranking implement of this class is shown by Fig. 230; such a tool may be used for small work that is to be cranked with hand fullers; or for large work, the tool may be fitted to a steam-hammer, and a steam-hammer fuller employed, instead of a hand fuller.

In this class of shaping implements, a broad gap is made across the shaper, for the convenience of using pieces of round iron for the purpose of cranking, when fullers of proper shape are not accessible. This gap for containing such pieces of round iron is shown in the Figure by I.

The piece of bar which is to be cranked with such an implement requires the intended cranked part to be equally heated, and that part of the work intended for the centre of the crank should be placed exactly opposite the centre of the gap in the cranking tool, that the straight ends of the work may be of proper length after being cranked; but when the bar to be cranked is several inches longer than necessary, the precise situation of the bar on the cranking tool is not important, the straight ends being cut to length after cranking.

These implements may be made having cranking gaps or grooves of various shapes, to suit many classes of work; and to avoid casting a number of blocks, several cranking gaps may be made in one tool.

T-Head Shapers.—After a short slit is cut at one end of a small bar or rod, for the purpose of forming a T-piece, the workman puts one of the two branches thus produced into a hole in a block, or into some convenient slot, and while the branch is thus fixed, he pulls down the other end of the work until the branch in the hole is at about right angles to the bar; after one branch is thus bent, the work is again heated and the other branch is put into the hole, and bent by the same sort of pulling by the workman. T-pieces of small bars or rods are easily commenced by such means, and the further shaping required is effected with welding heats and upsetting while the T-piece is still attached to the bar, if the work is very small; but if two or three inches thick, it is better to cut the T-piece from the bar after being slit and the branches roughly separated. The T-piece thus partly made is next attached to a porter of some kind and heated to welding, and put into a T-head or T-piece shaper, shown by Fig. 231. This implement has a hole in the middle for containing the rod part of the T-piece, and the upper edges at the entrance of the hole are curved, to shape the required curved junction of the head with its rod part. This short rod portion of the T-piece may be of any convenient length for handling while forming the work, and also of sufficient length for welding to the other component piece which is to be the intermediate portion of the connecting-rod, eccentric-rod, or whatever rod is being made.

The T-end shaping tool may be fixed across any convenient opening when in use, the opening being deep enough to allow the rod part of the T-end to project below, while the T-head is being hammered into the shaping gap with sledge hammers.

When a T-end shaper is fitted across a gap in a steam-hammer anvil, the lump which is intended for the T-end requires no slit to be made with cutting, but merely a sufficient reducing to allow the rod part to pass easily through the hole in the shaping tool, and a tapering of the head. After the rod part is thus prepared, and the intended head spread out with hammering, it is heated to nearly welding and put into the shaper. The thin part, which was previously spread out with hammering, will then stand up considerably above the shaper, and this part is immediately battered into the shaper, by which the head and also the curved junction is formed, almost at one heating and hammering. To complete the T-piece, it is only necessary to cut off all the superfluous metal, which will be in only two places; these are at the two ends of the head that was lying in the shaping gap. Short T-ends may thus be conveniently made with such an implement, and afterwards welded to rods of any length, by which the handling of long pieces is avoided.

T-pieces may be made also without shaping-moulds, by drawing down. This mode is indicated by Fig. 200. By this method, a lump is employed which is thick enough to spread out to the length of the head required, or the piece may be thick enough to form the head without spreading out; consequently, the rod part of the T-piece is produced by drawing down the thick mass of metal, which is large enough for the T-head. Although this mode involves a large quantity of reducing to make the rod portion, the plan is applicable to the forging of T-ends of various dimensions, when only one T-piece is to be of one size; therefore gap-gauges or callipers must be carefully used, as indicated in the Figure, to adjust each T-end to the length, width, and thickness.

Joint Welders.—The scarf joints of bolts, rods, and bars of two or three inches thickness can be easily welded together with steam-hammering; the only manual labour involved in the process being that of placing the two scarfs into a proper situation beneath the steam hammer, and into a bottom tool resembling either Fig. 232 or Fig. 233. One of these tools is fixed to the anvil either by means of a key at the side of the bottom tool, or by means of a square stem which constitutes part of the tool; bottom tools having square stems being employed, if the anvil contains a suitable hole to receive them.

A bottom tool for welding round iron is shown by Fig. 232, and another for welding bars is denoted by Fig. 233. In the one for round iron, the gap is wider and deeper at the middle than at either end, this form being that which is suitable for producing rods that are to be thicker at the joint; and also highly advantageous for welding, reducing, and smoothing a joint at only one hammering. The corresponding top tool has a gap of similar shape, and should be so guided to the bottom tool that when both are together the widest part of one gap shall be opposite the widest part of the other gap. For this purpose, the guide-rods may be two or four in number; the tool shown by the Figure having four. Around each guide-rod is a coiled spring to raise the top tool.

While preparing the scarfs for welding by this method, it is advisable to so shape the ends as to obtain an oblong section, making the greatest length of the oblong to be in a vertical position while the scarfs are under the hammer ready to be welded. After the scarfs are shaped and heated to welding, the two pieces are conveyed to the hammer, and put into the shaping or welding tools from opposite sides, each piece being held or guided by one or two men at opposite sides of the welding tools; consequently, the two scarfs are pushed towards each other in opposite directions, until one is on the other in the required position, at which time the man who works the hammer drives down the top tool and the welding is commenced, the springs between the two tools pushing up the top tool at each blow, to permit the work to be rotated or partly rotated when necessary.

To weld a bar joint in a tool shown by Fig. 233, the two pieces are put together in a similar manner, but no top tool is required except an ordinary flat-faced hammer, the desired shape of the joint part being obtained by making the gap in the tool of a suitable width and depth.

Springy Shapers.—Fig. 234 indicates a couple of tools in their relative positions during use, having guide studs with springs around and between the two faces of the tools. The recesses or gaps in such shapers may be, in some cases, specially made for merely finishing a great number of bolts, rods, or bars to one diameter or thickness; and each pair of shapers may contain several gaps of different sizes. In other cases, the blocks are strong and thick enough to press a rude lump at welding heat into the form of a smoothly finished headed bolt, handle, boss, or lever.

The guides of such shapers may be studs, whose lower ends are screwed tight into the bottom block; or, instead of studs, bolts having heads at the under side of the shaper may be employed if it contains sufficient metal.

In order that the gaps or recesses in any pair of shapers may properly correspond and be opposite each other, it is necessary, during the making of the wood patterns, to carefully mark the face sides of the blocks to indicate the places of the intended gaps, and also recesses, when required. To obtain a correct delineation of the outlines of each recess, the two face sides of the blocks that are to be close to each other should be made rectangular, and of exactly the same length and width. When the edges of the two faces are thus squared and the surfaces smoothly planed, the place of one recess is determined, and the centre of it also ascertained in one of the block-faces. The distance of this centre or point from any one edge of the block-face is next ascertained by means of compasses, callipers, or scribing-gauge; and while the gauge is adjusted to the distance of the centre from the selected edge of the face, the gauge is held close to the corresponding edge of the other block-face which is not yet marked; while thus held, the marking-point of the gauge is drawn along the surface, and a short scratch made. The next step is to select one of the two edges or boundaries that are at right angles to the edge first used for marking; and the gauge point is then adjusted to the distance of the centre from the edge, and the gauge again drawn along the corresponding edge of the block that needs marking, and another short scratch is made across the first one, and the two will be at right angles to each other. The point of intersection of these two short lines is the centre of the desired gap or recess which is being marked, and from this centre the outline can be exscribed to indicate the form of the intended recess; consequently, if the outline is to be curved, compasses are used, and if rectangular, a square and straight-edge are needed.

A pair of outlines delineated by such means will coincide with each other when both faces are put together; and any other pairs of outlines may be marked, by similar means, upon any other part of the block-faces; after which, the carving, to form the recesses or gaps, is effected with proper tools, a chisel being first driven in at each line to prevent the wood being split in wrong directions.

After the patterns are made and the shapers cast, each recess will require a little trimming with files, and, in some cases, with chisels and scrapers, to make each pair of recesses fit a pattern rod, lever, or boss, which is being used for placing into the recess several times, until the pattern or gauge will slip easily to the bottom.

The coiled springs for raising the top tool are made of round steel wire or of small bar steel, and the coiling is effected by making a loop at one end of the wire, fixing the loop to an upright post, and coiling the steel around the post.

The post for the purpose, and also for making other coiled springs for larger work, may consist of a piece of round iron of any suitable diameter, which is fixed with a small pedestal of some kind into the ground. In the post, and at about four feet from the ground, is fixed a pin or hook for holding the loop or hook which is at the end of the wire to be coiled. After the wire is looped and ten or twelve inches of the steel heated, the loop is attached to the pin in the post, and the other end in the man's hand, or, in a tongs, is stretched out as tightly as possible, and at the same time coiled around the post by the man walking around until the heated portion of the steel is coiled; after which, the adjoining part is heated and the coiling continued until a sufficient length is coiled. When the coiling is completed, the spring is made red hot throughout its total length, and pulled out until a sufficient travel of the spring is obtained. The work is next cut to length, fitted, and hardened in oil, or, in some cases, in water, and afterwards tempered to a proper softness. When hardened in oil, no tempering is necessary for some sorts of steel; but whether or not oil or water should be selected for the hardening, must be decided by considering the quality of the particular piece of steel to be hardened.

Small springs can be made also while cold, and the coiling effected in a lathe. For this purpose, a proper spindle with apparatus is put into the lathe, and after attaching one end of the steel, the lathe is put to work and coiling performed.

Another class of springy shapers is represented by Fig. 235, for use on steam-hammer anvils. The spring of these shapers is bolted at one end to the top shaper, and the other end of the spring is loosely fitted in a recess in the bottom tool. Two or four guide studs may be used, the number depending on the dimensions and shape of the blocks. A pair of shapers having such a spring are more troublesome to use than the shapers shown by Fig. 234, although the long spring being bolted to the top tool allows the same spring to be attached to different tools, if necessary.

Fork-end Shapers.—Solid fork-ends, small and large, are easily shaped by means of a mould, like Fig. 236. An implement of this shape may be used as a bottom tool without a corresponding top tool; or a pair of tools may be made having recesses of the same shape in each tool; and both tools may be adapted to a steam hammer and anvil, the top shaper being keyed in the dovetail gap of the hammer, and the bottom shaper being keyed in the dovetail gap in the anvil. When the bottom tool only is employed, the lump to be shaped is driven into the recess with ordinary fullers and rounding tools; and when one half is thus shaped, the work is put upside down, and the rounding tools again employed to drive the fork-end into the shaper. Fullers and rounding tools are thus employed as substitutes for a top shaper; but when the shaper is in two pieces, the fork-end may be entirely formed at one or two heatings, while between the shapers, no other tools being required.

If a great number of fork-ends are to be formed in such implements, it is necessary to ascertain the exact quantity of metal required for each fork-end, to avoid the necessity of taking the work from the shapers during forging and cutting off the superfluous pieces with chisels. The proper quantity of metal for each one, and also for burning and welding, is known by entirely finishing one or two, previous to preparing or drawing down the metal for the total number of fork-ends required.

The making of fork-ends, and all other forgings that are pressed into moulds, is greatly facilitated by forcing into the shapers only that quantity of metal which is sufficient, by which the danger of injuring the moulds is also avoided.

Strikers.—Striker is a name given to a hammerman; also to substitutes and superseders of hammermen, such as air-hammers and steam-hammers, whether vertical or horizontal. A class of patent strikers invented by Mr. Davies, of Crumlin, is represented by Fig. 237. These strikers are of different arrangements to suit individual requirements, but the principle involved in them all is the same, and consists in the strikers being capable of delivering blows at any angle between vertical and horizontal, and also in being easily swung around their main pivots, in the same manner as cranes are swung, so that one striker may be made to work on three or four anvils.

Such strikers are made to work by either steam power or water power; and may be actuated with one foot of the smith, who treads upon a pedal near the anvil at which he is working. This pedal is attached to a rod that is connected with the valves, by which the motive power is controlled and the hammer made to strike.

Strikers of this class are well adapted to the making of all sorts of small forgings that are shaped in moulds and springy shapers denoted by Fig. 234; and when the striker is made to strike in or near the horizontal position, it is useful for angling ends of bars, rods, and plates, and for upsetting forgings that cannot be upset in the vertical position.

Bar Gauges.—Bar gauges are used while adjusting several classes of smiths' work to a stated length or width; for this purpose, two dots are put into two places of a rod or bar, and the work is afterwards lengthened or shortened until the distance between the centres of the two dots is the length required. This desired length is the distance between the two centres of the two-pointed extremities of the gauge represented by Fig. 238. Such a gauge is quickly made, in cases of emergency, by bending any piece of wire or small rod which is near; but the suitable material is a broad thin bar, that the gauge may be easily carried about, and not liable to bend in the mid portion, which renders it an uncertain measure.

A bar gauge which is made by bending the iron or steel edgeways is good enough for many purposes; and if the ends are thinned to a taper form, the gauge is much lightened without impairing its efficiency. A gauge of this shape is tapered, and the ends bent, also the small points made and smoothly filed, previous to adjusting the gauge points to that distance from each other which is required. This adjustment is effected by means of a hammer, and one of the divided lines on the surface of a table similar to that described in the section on Tables. After applying the two gauge points to the stated length on the measure, the gauge points are separated from each other, if too near; and put nearer to each other, if too far apart. When discovered to be too far apart, the curved junctions of the arms with the remainder of the gauge are heated, and the arms are driven towards each other with a few blows; but if only a small amount of alteration is needed, it is given while cold, by placing the gauge on some hollow place, with the inner edge of the gauge upwards, and giving a few light blows with a hammer. When the gauge points are found to be too near each other, they are separated by hammering the outside edge of the gauge, instead of the inner edge; but if much lengthening is required, the gauge is heated in the mid part and stretched with hammering.

Gap Gauges.—Gap gauges are used for measuring diameters or thicknesses; and are made of thin plate iron or steel. One gauge may contain several gaps, if all the gaps are to greatly differ from each other in width, that no mistake may occur through measuring with the wrong gap; but when the gaps are very nearly alike, only two or three should be made in one gauge.

Fig. 239 indicates a gauge whose handle is smaller than the remainder, to admit an easy handling; and whatever may be the widths of the gaps required, the handles of all such gauges should be made large enough to be comfortably used; therefore, in many gauges the handles are larger than the end which contains the gaps; and in other gauges the gap-ends are of the same widths as the handle-ends. When a number of gaps are necessary, some of them should be at each end of the gauge, as denoted by Fig. 240, instead of all the gaps being at one end.

If gauges of this class are to be used for heavy work which is being reduced or flattened to a precise dimension with a steam hammer, it is necessary to make the gauges of sufficient length to prevent the workman who holds them being scorched with the heat from the work; and each gauge may have a hole, that it may be hung in a place secure from injury; also around each gap should be written the name of the particular work for which the gap was made.

During a long usage, the gaps in such gauges become worn too wide; the remedy for this is to heat the gap-sides and hammer them to make the openings of less width; after which, the gaps are enlarged to the exact width required, with a little filing.

Radius Gauges.—A light radius gauge, denoted by Fig. 242, is used for measuring distances between any two places on a measure, and also for adjusting a forging to the desired length or width; a radius gauge is therefore a substitute for the bar gauge shown by Fig. 238; a radius gauge is also a superseder of a simple bar gauge, because the points or scribers are capable of adjustment at any distance between each other within the limits of the instrument. Another important use for such a gauge is that of exscribing arcs or circumferences of various radii; the required length of radius being obtained by shifting the scriber-holders to the proper places on the bar, and fixing the scriber-holders with the fixing screws, F, and F.

To produce a good gauge of this class, the radius bar itself should be of steel, and carefully smoothed throughout its length; and the scriber-holders also, denoted by H, and H, should be of steel or of close-grained iron. The slots in the holders are carefully fitted to the bar, after the bar is smoothed to the proper width and thickness. Whether the holders fit tightly or loosely on the bar is of little consequence; but it is necessary that the whole of the slot surfaces be smoothed and polished, that the holders may be easily moved along the bar without being liable to stick. The scribers are of hardened steel wire, and fixed to the holders by making a screw upon one end of each scriber and screwing it into a screwed hole in the bottom of each scriber-holder. Another mode of attaching the scriber consists in making a taper hole into the bottom of the holder, instead of making a screwed hole; and into the taper hole the scriber end is smoothly fitted, so that it will admit of being gently driven in, to properly fix it, and also easily pulled out when it requires hardening and grinding.

Callipers.—Callipers for large forgings possess handles, and are denoted by Figs. 243, 244, and 245. The tool shown by Fig. 243 has a hole at one end to allow the tool to be hung in a safe place, after being adjusted, and when not required for immediate use. The handle may consist of iron, and be distinct from the callipers, that are of steel; or the handle may be an extension or continuation of one of the calliper legs, in which case the entire tool is of steel.

Fig. 244 indicates a couple of outside callipers attached to one connecting-rod. This rod is long enough to allow the workman to measure the work without being scorched; and one of the callipers should be smaller than the other, because when both callipers are adjusted to two different dimensions, the smaller callipers should be for the smaller dimension; consequently, the workman will not be so liable to put the small callipers to the work when he ought to put the large one; such a mistake causes him to reduce the work more than necessary, and obliges him to afterwards upset it to the proper size.

By thus adjusting two pairs of callipers, or, properly speaking, two callipers, two dimensions of a forging are easily reserved by keeping the callipers adjusted until the forging is reduced to the two dimensions. Such callipers are useful for measuring the large and small ends of cones, the large and small parts of bolts and rods, also the lengths and widths of T-ends. A connecting-rod callipers in use for T-ends is represented by Fig. 200.

Fig. 245 denotes two callipers of another class, named inside callipers, which are for measuring two holes of different diameters, or for measuring one hole of two different diameters. Inside callipers measure also the large end and the small end of a conical hole; also all such openings as slots, gaps, grooves, and keyways.

The joint-pins of all such callipers should be tightly riveted until the legs cannot be shifted without a considerable strain being applied; this tightness being necessary to prevent the legs shifting when not desired. During the adjustment of such callipers, it is proper to separate or close the legs until the points are about an eighth of an inch further from each other than required to be when adjusted. After this, the feet or points are closed to the proper distance with a few blows of a hammer. To do this conveniently, the callipers are put upon some convenient piece of soft iron or other metal, with the edges of the legs upwards, and one edge resting on the iron; while in this position, the point or toe of the upper foot is gently hammered with a smooth-faced hammer, or a copper hammer, until the feet or points are at a proper distance from each other. After one callipers are thus adjusted, the other callipers at the opposite end of the rod are adjusted by similar means. This mode of adjusting, by hammering the callipers, instead of using the callipers as a hammer, prevents the adjusted callipers being shifted while the other callipers are being adjusted.

Chisels.—In a rod chisel for cutting hot metal, the angle of the long taper portion should be ten or twelve degrees, and the angle of the short bevelled part for cutting about forty or fifty degrees. Chisels for cold iron require the angle of the long taper part to be about thirty degrees, and the short bevel for cutting about eighty degrees.

All rod chisels are best when made entirely of a tough hard steel, without any iron being added to make the head. Such a chisel will sustain a severe hammering without much injury to the head and cutting part, if only about half an inch is hardened, and the head made as soft as possible. After the cutting end is become too thick with hammering during ordinary use, or is become otherways damaged, the lower part of the taper portion is thinned to a proper shape, and only a short length of the chisel hardened as at the first making. Every time a chisel is repaired by such thinning, it is advisable to cut off about a quarter of an inch of the thin ragged end, because this portion becomes burnt during heating, and also contains several cracks that are not visible to an unassisted eye.

An ordinary method of preventing a rod chisel being driven through its handle during the hammering consists in making a few ragged notches into that part of the chisel which is to be encircled by the handle; the sharp projections thus made stick into the wood handle at the time it is twisted around the tool, and it is thus firmly gripped until the wood is broken with repeated hammering. Another mode of fastening the tool consists in making around the chisel a groove having a half-round bottom, the width of the groove being about equal to the diameter of the chisel-rod, or wire handle, which is to be twisted around. Such grooves are made with a couple of top and bottom fullers, that may be narrow to suit a wire handle, or broad to fit a wood handle.

In chisels for steam hammers, the angles of the taper parts are about the same as those of small chisels; but the cutting parts are thicker, and of greater length. A very useful class of chisels is that named trimmers; these are represented by Fig. 246. A trimmer is used for cutting all sorts of thin bars, rods, and plates; also for cutting off all superfluous metal that may be attached to any forging which is being shaped to the finished dimensions. To permit the free use of a trimming chisel, its cutting edge is convex, because this form enables the smith to slide the chisel easily along a cut which may be of great length, although not very deep. A trimmer may have an iron handle as shown in the Figure (246), or a wood handle similar to that in Fig. 247. A wood handle is preferable for a heavy chisel, to obtain a proper amount of holding power, that the workman may keep the chisel as nearly upright as possible.

In addition to trimming chisels, another sort of hand chisels is employed, named arched or concave chisels. In such chisels, the cutting edges are concave, instead of straight or convex. Concave chisels are useful for making a square cut through an axle or shaft, while it is being rotated on a gap bearing-block, which maintains the shaft in a proper situation for cutting.

The concave chisel shown by Fig. 248 is a tool for two handles, that are welded to the two short ends extending from the chisel, and indicated in the Figure. These two ends are named tangs, and may in some cases be made for two wood handles that are fixed in the manner shown in Fig. 247; or, in other cases, the tangs may be bent to about forty-five degrees with the remainder of the chisel, and the wood handles fixed so that they also shall be at an angle of forty-five degrees with the broad side of the chisel. A concave chisel having two handles thus fixed is supported on a shaft beneath a hammer by means of two men, one at each handle; consequently one man is at each side of the shaft, and the shaft is between the two men. While the chisel is thus held, it is driven through, or partly through, the shaft to the depth required, while being rotated in the usual way.

To avoid the necessity of holding a chisel on the work, the chisel may be keyed to the hammer; and if the bottom chisel also is to be used, it may be keyed to the anvil-block. A couple of keyed chisels are shown by Fig. 249; the upper one being keyed to a hammer-block, and the lower arched chisel being keyed to an anvil-block. When the hammer chisel is to be used without the bottom one, the shaft to be cut is supported on a proper number of bearing blocks, and also prevented from moving forwards or backwards by means of half-round clips or bands of some kind. By thus holding the shaft, it can only move in a direction of rotation around its own axis; and this is the only movement required for rotating the shaft with the rotators to make a cut entirely around the work, which shall be at right angles to its length.

When both hammer-chisel and anvil-chisel are used at one time, no bands or clips are required to keep the shaft in its place; it is only necessary that the concave part of the bottom chisel be of greater curve than the curve of the shaft, and that the depth of the concave be nearly equal to half the shaft's diameter. Such a form will allow the work to be rotated without sticking on the chisel-edge, until a cut is made to a short depth entirely around the work. After the cut is thus commenced, the anvil-chisel and its block is taken away, and, if necessary, the work is again heated and the cutting off completed with the hammer-chisel only, the work being supported with the bearing blocks, but without the concave chisel.

While cutting any large shaft or axle, the suspension of the work with the cranes must be properly managed; and the supporting blocks also demand attention. The greater the length of the work to be cut, the greater should be the number of suspending chains. If the anvil is too small, which is often the fact, three or four chains are required for suspension, so that the piece to be cut off may not get out of position and break a chisel, or do other damage by falling; and that the work itself may be kept as nearly as convenient in the horizontal position. But if the anvil is long enough, four or five gap bearing-blocks, or supporters, as they are termed, may be used, because they are preferable to a number of suspending chains. Two of these supporters should be put as near as possible to the chisel, so that the cut may be between each supporter. Another supporter may be put near one end of the superfluous piece to be cut off, and a fourth supporter is required for supporting the opposite end of the shaft or axle. This outer supporter, being at a great distance from the chisel, may in many cases be on a gap pedestal similar to that in Fig. 201. In this Figure, it may be observed that supporters are used also for axle-twisting. For this purpose, two supporters are required, so that one may be at each side of the crank which is being hammered for twisting the axle.

The forging of chisels for keying to hammer-blocks and anvil-blocks consists in making them entirely of steel; and several of them should be made, and also fitted to each block, so that if a chisel breaks during the cutting of a shaft, another chisel can be immediately put in, and several hours of reheating the work will thus be avoided.

Shaper-Fastenings.—In many cases, the shaping blocks and other bottom tools for large work are kept in their places by the square stems of the blocks being in a square hole in the anvil; so that one shaper may be taken out, and another put in, without any key-driving. When keys are used, they are so fitted that their lengths shall be in a convenient position for driving the keys into and out of the keyways. If square stems are attached, they should be as large as convenient, to prevent them being broken off, and the junctions of the stems with the blocks should be curved; consequently, the entrances to the square holes are curved to fit the stems.

For the convenience of lifting shaping blocks and other tools while being taken to, or away from, their places, several holes are made around the sides of the blocks to contain the ends of levers that are held by the men while carrying the blocks; or the holes may be required for the ends of the hooks, when the shapers are lifted by means of a crane.

After the shaping implements are lifted to their places, they are usually fastened with keys, represented in Fig. 250, if the blocks are without square stems; and the keys are driven in either at the sides of the dovetail gaps or at the bottoms. When the key is fixed at the side, the block is made to bear tight against the opposite side of the gap; and when the key is driven in at the bottom of the gap, the block is made to bear against both sides of the dovetail; and during the hammering, the key sustains the force of the blows. A shaper fixed with a key at the bottom is denoted by Fig. 251. A key in this situation requires to be almost parallel, and is therefore troublesome to drive in and out; but a key at one side, through not sustaining any of the force of the hammer, may be considerably taper, which renders it preferable to a key at the bottom. Bottom keys are only suitable for blocks that do not require frequent fixing and unfixing.

All keys for shapers require to be of steel, and very smooth; also possessing curved extremities or boundaries, to resist injury through hammering into and out of their places. The two keys in Fig. 250 are fitted with a taper of about one or two degrees, if not intended to be often unfixed; but to allow an easy driving, the taper may be five or six degrees, and the key prevented from slipping back by means of a split key in the small end of the shaper key. The split key has a handle, to permit its being easily pulled out and put in when necessary.

Hexagon Shapers.—The top and bottom shapers, indicated in Fig. 250, are in their positions during use, which is that of shaping hexagonal nuts and bolt-heads. The gaps in such implements are of various sizes to produce hexagons of the required dimensions, so that each pair of shapers produce a hexagon of one size; and either pair may be selected and keyed to the hammer and anvil at any time when required.

The method of using such implements consists in placing a nut, while on a mandril, between the shapers, and hammering the work until the two faces, marked with F, strike each other, at which time the nut is of correct diameter; after which it is cut to a proper length with chiselling, if necessary.

To shape a bolt-head or other hexagonal boss in the mid-part of a piece of work, the component pieces may be piled together, or a collar wrapped around the bolt, to produce a lump of sufficient thickness; after which, a welding heat is given to the lump, and the hexagonal form produced with two or three blows while in the shaping gaps. The head or boss being thus partly formed, it is next completed by trimming the shoulders with a set hammer and with a chisel, that the head may be of proper length.

When two such hexagon shapers are employed for bolt-making, two or three blows are first given to the collar for the head, or pile, if a pile is used instead of a collar, and it is thus thoroughly welded to the bolt-stem; this stem is next put into a heading tool to square the shoulder, and also the upper extremity of the head; and the bolt-head is afterwards finally reduced with a few blows in the shaping gaps. To make a number of bolts by such means, all the component pieces are cut to the exact dimensions, to avoid cutting off superfluous pieces during forging. The precise quantity of metal required is known by ordinary measurement, and by finishing one or two previous to the entire number.

Cranking Blocks.—The shaping implement indicated by Fig. 252, may be used as a top tool or as a bottom tool, and the corresponding tool possesses a groove which is of the same outline as the groove in the block shown by the Figure (252). These grooves are half round, and their width equals the diameter of the iron or steel to be cranked. The height of the hump in the mid-part of the tool is sufficient to make the throw of the crank to the desired length. Such blocks are, therefore, especially adapted to bend straight pieces of round iron or steel, so that the crank-arms and crank-pins shall be of a well-defined outline throughout.

Crank Moulds.—Crank moulds are used principally for what are termed solid cranks, which are forged without gaps. If necessary, crank moulds may be made to shape the largest cranks that are made, and are useful to thoroughly condense the metal in any solid crank, whether it is made by piling up the cranks of small pieces, whether the levers are forged and welded to the axles, or whether the crank is a solid piece, which is made by drawing down the two axle-ends, and thus forming the crank between.

Crank moulds for large work must be very strong, because, to shape a solid crank properly, a superabundance of metal must be provided, which is cut off during the forging. All such moulds may be used as bottom tools without any top shaper, except ordinary hammers and top-rounding tools; but to make a number of cranks of one size, it is proper to make a top shaper to shape the half of the axle and the short part of the crank that projects above the mould.

One great advantage in using these moulds, and others of similar character, consists in the facility and speed with which the desired contour of any forging is indicated by the shapers. Although the entire shape may not be obtained at one or two hammerings, through too much metal being in the mass to be shaped, the desired form is attained at all parts except between the faces of the two shapers. This space is named the fin-way; and into this place all the superabundant metal is squeezed. This portion is the fin, and in large work it may be a projecting ridge of fifty or sixty pounds, and another fin may be formed at the opposite side of the axle; if so, the work is well and equally condensed, but if only one fin is formed, it signifies that the mass was not properly piled up previous to being driven down. This piling consists in laying the crank, or whatever is being forged, upon its side, and hammering it to make it taper, and of a sufficient length to stand up above the remainder of the crank when it is put into the mould. By thus making a taper pile or projection which is exactly in the middle of the upper side of the crank or other lump to be shaped, the projecting portion will be battered into the middle of the mould, instead of being spread out into one side of the fin-way and not into the other.

During the forging of cranks that are being made of square iron or of round iron, shaping-moulds, whether with top shapers or without them, will greatly facilitate the work; consequently, crank moulds are much used. A few crank moulds are represented by Figs. 253, 254, and 255.

Fig. 253 represents a mould for shaping a crank intended to have the circular axle-ends, the arms, and the crank-pin all of one thickness. Fig. 254 indicates a mould for producing cranks with square axle-ends. The mould denoted by Fig. 255 is shaped to forge a large and ordinary class of cranks whose levers or arms are to extend from the axles in four directions. While looking at a crank which is in its mould being shaped, these four directions are upwards, downwards, to the right, and to the left.

Lever Moulds.—The simplest sort of lever mould is that which will form only one of the lever's bosses, so that two moulds are required to shape one lever, each mould having a recess of proper size to form the particular boss which is to be put into the mould. A mould of this class, having one boss cavity, is denoted in Fig. 256. At the further side of the mould is a sort of groove, indicated by H, which is to receive the superfluous metal that will be squeezed from the boss during hammering. This portion becomes a handle or holder, and is useful to the smith, and sometimes also for fixing purposes during turning or other shaping; the holder is therefore allowed to remain after the forging is complete, if necessary.

A very useful class of levers is that in which the boss is formed in the mid-part of the lever, so that the boss is between two arms of equal dimensions. To shape a lever boss of this sort, the mould shown by Fig. 257 is suitable. Levers having arms on both sides of the boss are forged by reducing a thick bar to form two arms with a thick part between; this part is next heated to welding and put into the mould, and the boss with both the short arms are shaped at one or two heats.

An ordinary crank-lever having both its bosses projecting from one side of the lever is easily forged of a straight bar and two piles; the bar being intended for the lever, and the two piles for the two bosses. Each boss-pile may consist of only one piece of metal, if a small boss is required; or for a large boss, the pile may consist of three or four pieces. After the bosses are roughly welded to the lever, and in their proper places, both bosses may be heated to welding at one heating, at which time the entire lever may be put into a mould resembling Fig. 258, and partly shaped. Another heat is next given to the work, and the superfluous metal squeezed into the two openings for the handles, shown by H and H; and, if necessary, the superabundant material is cut off during the making.

Moulds of this character (Fig. 258) will also shape levers made by any other mode, whether of one piece drawn down in the middle, or of one bar which is doubled or trebled at each end, or whether the lever is made of two pieces and joined at the middle of the arm.

Branchers.—Branchers consist of moulds having recesses that resemble the branches to be produced. By means of a brancher, the curves that may be required in the junctions of the branches are easily formed without a tedious cutting, or welding bars together to produce the necessary arms or branches.

Branchers are useful also for shaping the branches of connecting-rods, which are termed fork-ends; also for link connexions, eccentric-rod forks, and other forks; also for shaping the T-ends of rods that are too long to be shaped in the vertical position.

A brancher for forming four arms that are at right angles to each other is indicated by Fig. 259. Either one or two principal components may be used for producing a piece having four such arms; and the component may be either one thick lump or two flat bars. If one thick piece is selected, a porter is attached to one end, and into the lump four slits are cut; these slits are short, and made first with a punch and afterwards with a chisel, so that the slits shall be at right angles to each other, or, rather, in the form of a cross. These short slits cause the lump to be formed into a sort of irregular cross, having four short, thick arms. One of these arms is attached to the porter; consequently, the slits must be at an angle of forty-five degrees with the porter. Into the four slits wedges are next driven, and the four arms, or branches, are thus roughly separated, and made to enter the cross-shaped recess in the branching-block. Being thus roughly prepared, the entire piece is heated to welding, and shaped with hammering while in the brancher. By this means the four thick arms are lengthened to the length desired.

To make a cross of two bars it is necessary to heat both bars to welding, and put one bar into the shaper, so that the portion at welding heat shall be in the centre of the cross; while thus situated, the other bar is put upon top of the first one, and across it, so that the two parts at welding heat shall be in contact. When properly placed, the top bar is immediately hammered down to weld it to the lower bar; and with one or two heatings the cross is shaped, without any trouble, to form the curved junctions of the four arms with their centre-piece, which is named the nave and also the boss.

To form a T-piece by means of a brancher, denoted by Fig. 260, one thick cubic lump may be attached to a porter, as described for a cross; but the easiest mode of forming a T-end is by welding two bars together in a manner which is somewhat similar to the method of making a cross with two bars, and described in the adjoining paragraph, but with the difference of heating one of the bars at one end instead of in the middle. By means of a brancher for T-pieces, rods of great length having T-ends are easily forged without upsetting, and also without drawing down a large quantity of metal to produce the rod part. To make a T-end with a branching tool, a hole may be punched through the intended head, and the rod welded in the hole; or the rod may be slit at one end, and two fork-prongs, or branches, made, and the intended head welded between the two branches.

Branchers of this form (Fig. 260) are useful also for shaping T-pieces that are made by cutting open ends of bars, and bending the two branches to a right angle with the bars, as described in previous sections of this chapter. When a T-end is being forged by such means, the two ends produced by cutting are bent back, and the head upset, until the T-end will enter, or nearly enter, the T-brancher. The work is then heated, and finally shaped at one or two hammerings; and the curved junctions are thus formed without trouble, because the gaps in the brancher are suitably shaped.

Small connecting-rods, having branch ends, are easily shaped in branching tools, whether the branches are circular or rectangular. A brancher for connecting-rod fork-ends of circular section is indicated by Fig. 261; and a brancher for rectangular branches is shown by Fig. 262.

Porter-tongs.—Porter-tongs are used when an ordinary straight porter cannot be welded to a forging which is in progress; also after a porter is cut off for the purpose of finishing the end to which the porter was welded. Porter-tongs usually consist of a few bars and plates that are bolted at one end to the forging, by means of screw-bolts and nuts; and at the other end is bolted a straight piece of round iron, which may be a porter that has been welded to other forgings. This straight piece is used for piloting the work, in the same manner as if the porter, or handle, were welded to the work, instead of being merely bolted to it.

Fig. 263 represents a porter-tongs that may be made to fit the ends of several shafts, or bars, of different thicknesses. This is effected by the tongs being capable of opening or closing while attached to the porter. The porter consists of a straight rod of round iron, or steel, having a T-head at one end, which is forged solid with the porter, or, properly speaking, the handle. The two arms of this T-head may be of square section or of circular; and each arm fits a hole in one of the tong-pieces, named jaws. This hole, being through the jaw, allows the jaw to be moved along one arm of the T-head, and fixed at various places, according to the thickness of the pieces to be gripped with the jaws. The other arm of the T-head also holds the other jaw, and this jaw slides along the arm with the same facility as the opposite one. Through this freedom in bringing the tongs together, or pulling them apart, forgings of several sizes and shapes may be put between the jaws; and the porter may at all times be in line with the axis of any shaft, rod, or axle that is being forged while attached to the porter-tongs.

Attachments.—The mode of fastening the tongs to a forging consists in lifting them to the work by means of any crane that may be near; and while suspended with two or three chains, the two jaws are brought close to the part of the forging to be gripped; while the tongs are thus posited to the work, screw-bolts of proper length are put through the two holes in each jaw that bites the work, and a bolt is put also through the holes in the other end of the tongs, and through the porter between; the two jaw-bolts are then tightened, and the tongs are firmly attached. After the tongs are fixed, the porter is raised or lowered, or otherways shifted, until it is in line with the axis of the work; packing-blocks are next put in, to fill the spaces between the porter and tongs, and the porter-bolt is tightened to firmly fix the porter to the tongs, after which the apparatus is in working order. The spaces for the packing-blocks, or, in some cases, washers, are shown in the Figure (263) by W and W.

The fastening bolts for porter-tongs may be made having screws of several inches in length, to avoid using several bolts of different lengths, to suit forgings of various thicknesses; or, instead of long screws for the bolts, short screws and washers may be used, and injury to the screws will thus be avoided. To economise time, porter-tongs are often fixed to one end of a forging, while the opposite end is in a furnace, being heated; it is therefore convenient to lift the tongs to the work, when it is in a furnace; but if tongs are being fixed while the forging is on the table, or supported by supporters, the porter-tongs also may be thus supported, and the bolts put in, while in the horizontal position. The tongs represented by the Figure are suitable for holding T-ends, fork-ends, short rods and bars, and short axles. Tongs for shafts of twelve or thirteen feet in length require to be made with jaws of great gripping surface, and having holes for four gripping bolts instead of only two.

During the use of a porter-tongs or of an ordinary straight porter, the endless chain, by means of which the work is rotated or turned upside down, is sometimes in immediate contact with the circular part of the porter, and at other times in contact with some part of the rod or shaft which is being forged; and if the shaft is of great length, the endless chain will be several feet from the porter; and it is necessary for the chain to be thus situated, to avoid using a porter of an inconvenient great length, for the purpose of obtaining the leverage which is necessary for an easy manipulation of the work.

Rotators.—The rotator shown by R in Fig. 146 may be fixed at any required place on any porter, and be handled by three or four men; and another rotator may be fixed to some other part of the same porter, when the work is heavy; consequently, two sets of men can handle two rotators, instead of crowding too many men together at one rotator. The men at the extreme end of the porter do not handle either of the rotators, but steer the work to its required situation for undergoing the various processes.

When it is inconvenient to use rotators having arms of great length, windlass rotators are employed. These consist of pairs of semicircular grips that are bolted to various parts of the porter, and sometimes to the shaft or axle which is being made. Around the rims of the grips are holes for containing ends of levers, named handspikes. These levers are made of ash, and when the work needs moving around its axis, a few men place the thick ends of their handspikes into some of the holes in the rotators, and adjust the work to the position desired.

Supporters.—One of the supporters which are several times mentioned in this chapter is represented on the anvil and beneath the axle in Fig. 201. For long shafts several supporters are required during the forging, and two are required during the twisting of an axle, that the axle may be supported at both sides of the crank. Many supporters are flat-bottomed, and some have square stems; these are used when it is necessary to maintain a shaft in one precise situation, and the square stem is therefore put into some convenient hole. Some supporters have angular gaps instead of half-round ones, that the gaps may fit a number of shafts of various sizes.

For the advantage of having a hard, smooth surface for the gaps of supporters, to allow a rough shaft to be easily moved while in contact with the gap-sides, it is advisable to make supporting blocks of either Bessemer steel or hard cast iron.

Upsetting-blocks.—Blocks for upsetting or thickening small work are placed on the ground in some convenient place, and are capable of being easily moved about. Blocks for upsetting large work that is short are adapted to steam-hammer anvils.

Upsetting-blocks are useful for shaping ends of keys, gibs, bolts, bosses of connecting-rods, lever-bosses, joint-bosses, T-ends, and cones. The simplest class of such blocks consist of thick heavy cubic lumps of iron or steel, having flat tops, resembling Fig. 264. These are moved about to various places, or fixed in the earth, so that the upper sides shall be level with the floor, or a foot above it; and, for some purposes, a foot below the floor, the particular height depending on the length of the work to be upset.

To upset a short rod, or bar, by means of a flat-face block, shown by Fig. 264, the work may be placed with one end upwards and the other end on the block; and while thus held with tongs, or porter, a few sledge-hammers are used by two or three men, who hammer the upper end; but when the piece is too long to be thus hammered, the hammers are superseded by the piece of work which is to be upset, because it is made to hammer itself. This is effected by standing the work upright upon the block, lifting the work up and letting it fall. To do this conveniently, the work is heated to nearly welding, and stood upon the block; three or four men then stand around, with the work in the midst, and each man grips a part of the work, and all lift at the same time, until the lower extremity of the piece is a foot or two above the block, at which time all the men let the work fall, and as nearly as convenient in the vertical direction. After one blow given in this manner, the work is again lifted up, and let down as before; and the process is continued until the metal is too cold for further thickening, or until the piece is thick enough, which may be at the first upsetting.

Upsetting by this means is named jumping, and the plan is more suited to thick rods or bars than to thin ones; rods five inches thick are easily thickened by such means, when a band having one or two handles is bolted to the work. Such handles admit a number of men to lift, without hindering each other through being too close together. By jumping, a joint boss can be formed in the mid part of a rod or lever, or near one end; and the boss may be solid or with a hole. If a round hole is wanted, a narrow slit, or slot, may be punched at the place of the intended round hole, and the opening is afterwards made circular by jumping.

When it happens that a great number of pieces are to be upset in this manner, a guide is fixed near the middle of the block face, to maintain the work in the vertical position while being lifted and let fall.

Several sorts of work require to be upset after the extremities are smoothly finished. For work of this character the upseting blocks are made of lead, or, if of iron, a recess is formed into the top of the block that it may hold a thick block of lead, upon which the work is stood instead of iron. After this lead block is become too much damaged by use, it is taken out and melted, with more lead added to the old block; it is next poured into the recess, and is again used for upsetting as before.

Recessed Blocks.—Upsetting-blocks that are required to form the extremities of rods or levers to particular shapes are made with recesses and gaps in the upper sides. Fig. 265 represents a block of this class, having a few recesses for shaping convex extremities of rods and bolts; also for forming joint bosses at the ends of levers and solid fork-ends. A rectangular recess also is shown for shaping T-heads by upsetting. Such blocks may also have recesses for angling bars and plates, and recesses of any forms that are suitable to produce the particular forgings desired.

When an upsetting-block or any other shaping-implement is intended to shape a great number of forgings, it is advisable to make the implement of Bessemer steel or of hard cast iron. Bessemer steel is more suitable than soft wrought iron which is case-hardened, because the hard Bessemer product does not need any additional hardening process; also because, when soft iron is case-hardened, the soft portion which is beneath the hard part allows the hard thin crust to be hammered out of its proper shape.

The Learner.—It is now necessary to conclude this treatise on forging with a few remarks to beginners who may not have had patience to read the brief details given concerning the various processes. A knowledge of forging is more useful to any beginner in engineering than a knowledge of moulding and casting without forging; because a number of the parts of small engines may be forged instead of cast, when casting is inconvenient; also because, when casting is convenient, a large number of engine components cannot be, or ought not to be, made by casting. Guides, slides, plummer-blocks, supporters, pedestals, cams, and wheels may be either cast or wrought; but rods, axles, and levers must be in all cases made of wrought iron or steel, that the homogeneous character imparted by the original casting may be destroyed, and tough fibrous rods and axles thereby produced. A beginner may thus perceive that forging is the first thing to practise or commence with, whether or not it may be absolutely necessary to him. And whatever branch of engineering he intends to enter, whether as designer, draughtsman, or constructor, he will be liable to commit many mistakes without a knowledge of forging and casting.

Every beginner in engineering should first learn the names, forms, and definitions relating to that particular branch which he intends to study. To attempt to study the whole of engineering would result in acquiring merely a variety of confused ideas of drawings, mathematics, and the vast crowd of inventions in actual use at the present moment. Therefore, because the branch of engineering treated in the "Mechanician" is engine-making, a learner is directed to learn the definitions concerning those things of which and with which engines are made. And even with this, his alphabet, properly so named, he must not be overburdened at any one particular stage of his progress, but should refer, at one time and at another time, to any definition or description that he may require as he gradually advances in his work, and develops to practice the verbal knowledge he has acquired. By thus frequently adding to his knowledge of a subject at one time and at another time, instead of learning too much at once, he will be enabled to retain that which he has found to be true, and to neglect and endeavour to unlearn any false notions he may have imbibed. And this remark applies not only to progress in engineering, but also to the gradual acquisition of every other art and method now in existence or which will be developed at a future day.

CHAPTER II.

TOOLS.

WHILE speaking of engine-making or other machine-making, the name "tools" includes every implement and machine, small and large, simple and complicated, which is used to produce or operate upon the pieces of machinery in course of progress. Through the name being used in such a general manner, a hammer in the hand of a smith is a tool, and a twenty-ton steam-hammer also is a tool. A centre-punch in a turner's pocket is a tool, and the lathe before him is a tool.

The tools now to be treated are indispensable to all engine and machine makers, whether producers of small work or large. Although a maker of small machinery may work for several years without resorting to moulding, casting, and forging, he will find it impossible to do without the machinery described in this chapter, if he is to profit in any monetary way whatever by engine or machine making. Very few of the tools now introduced are used for bending and pressing as in the forging processes, because nearly the whole of the implements to be mentioned are adapted to operate upon and alter the external forms of cold metals, without altering their internal shapes. When the internal arrangement of fibres is changed, the operation belongs to forging, strictly speaking, although the metal may be cold while the inside is being bent or otherwise modified.

To produce an orderly description of these instruments is difficult; therefore to effect an approach to a progressive and intelligible array of details that shall not be monotonous, but shall manifest as much variety of expression as the subject will admit, the tools are arranged into classes, and the tools of each class are separately described. The first division contains descriptions and processes belonging to marking, lining, and measuring tools; and the second division is devoted chiefly to implements and machinery for purposes of cutting. The intricacy and variety connected with the processes belonging to tools and tool-making requires a preliminary understanding of terms and names; because no reader can comprehend an author's description of a method or process, unless the author first tells what meanings he intends by the terms he uses. The terms employed in engineers' factories resemble the terms in all other factories in containing numerous words that do not convey a correct idea of the tools and processes to which the terms belong. Many tools of quite different appearances and uses have but one name given to them by workmen who know nothing more than their own routine of work. Numbers of technical names now in use were thus invented or applied by ignorant men, and are now freely used by scientific writers, to describe various things and processes, because shop and factory terms are familiar to those who use them. But these phrases are of little use and often perplexing to a careful student of names and definitions, because he has nothing definite to use as a key to the descriptions and details of processes which he reads. And because the "Mechanician" abounds with processes that are known only to engineers and other mechanicians, and also to enable the author to make himself understood, it is necessary that a few definitions be now introduced.

SIGNIFICATIONS OF TECHNICAL PHRASES.

It will be noticed that the primary significations of each phrase are placed first, because they are the meanings which belonged to the terms before they were applied to engineering purposes; and, by comparing the primary meanings with those that follow, a student will be enabled to distinguish the appropriate phrases from those that are not so expressive as they should be.

To ANNEAL.—To soften materials by means of slow baking. To soften iron and steel by making them red hot, and afterwards gradually cooling in cinders or charcoal. Also to soften copper and brass by heating and immediately cooling in water.

AN ARBOR.—A piece of timber that was used as an axle in a machine. A piece of iron used for the same purpose is therefore termed an arbor, or arbre; and, in a rather inappropriate manner, arbor is the name given by watch-makers and lathe-makers to small spindles used in their work, although such spindles may be only a millimètre in diameter.

AN APPARATUS.—A collection of implements or furniture that are in a condition of being ready for use. A finished tool. A finished machine. Also a number of machines that are complete and in order.

AN APPLIANCE.—A means. An act of applying an implement or apparatus to use, but not the apparatus itself. A method of performing an operation, but not the tools that are employed.

AN ARC.—Any portion of a circle's circumference.

AN ARM.—In a piece of machinery, the arm is the thinner part which extends from the thicker. The arm of a crank-lever is the portion between the two bosses. Arms of machinery are both straight and crooked.

AN AXIS.—A distance across an object. A diameter. Any line in any rod, lever, or shaft may be considered as an axis; and the principal axes are the mean major and the mean minor. The mean major axis of a shaft is a straight line through the centre of the shaft, and equal to its length; and the mean minor axis is the mean diameter of that across section of the shaft which is at right angles to the major axis, and also divides it into two equal lengths. Consequently, if the shaft is cylindrical, all its minor axes are of equal length; but, in a rectangular or rhomboidal shaft or bar, the minor axes are of different lengths, and the longest one is the length of the longest diagonal of the across section. In a crosshead, the major axis is the total length of the crosshead through the centre; and one of the minor axes is the length of the hole in the middle of the crosshead. The major axis of a wheel is usually termed the wheel's diameter; and the minor axis is the length of the wheel-boss; therefore, a wheel on a shaft rotates around the wheel's minor axis, while the shaft rotates around its major axis. The terms major and minor are preferred to longitudinal and transverse, because the transverse axis of a rod or shaft is merely the thickness of it, but the transverse axis of an ellipse is the greatest length of it.

AN AXIS OF ROTATION.—That line which remains at rest in an axle while the axle rotates; whether the axle rotates around one of its longitudinal axes or around one of its minor axes. An excentric cam on a shaft rotates around one of the cam's minor axes, and this axis is the straight line through the hole in the cam. A crank-lever on a shaft rotates around that minor axis of the lever which is a line through the centre of the hole in the boss.

AN AXLE.—A piece of machinery which is intended to be itself rotated, or intended for something to be revolved on the axle.

Back-Lash.—In machinery, back-lash is an amount of space which allows one piece of a machine to be moved forward and backwards a short distance, without moving the piece with which it works. In two cog-wheels in gear with each other, the back-space is the distance that one wheel may be rotated without moving the other. The back-space or back-lash of a screw and its nut is the distance which the nut may be moved forwards or backwards without rotating either the screw or the nut.

A Bearing.—The bearing of an axle or joint-pin is that portion which is in immediate or direct contact with the bearing-brass or other bearer. The principal bearing of a piston-rod is the portion that is in contact with the packing in the packing-box; and a thrust bearing includes all its ridges and all the necks between.

A Bearer.—Bearers in machinery include brasses for axle-bearings, bushes, blocks, slides, guides, and many others; and are used in a variety of positions.

A Bed.—The bed of a lathe is part of it, being that which sustains the entire movable portion of the apparatus, including the mandril-frame, wheels, poppet-head, carriage, slide-rest, screwing gear, and traverse gear; but the foundation on which the lathe rests is a bed of timber, stone, or some other material distinct from the lathe. The bed of a steam-hammer's framing is its foundation.

A Belt.—In machinery, a belt is an endless band of leather or other material in contact with the rims of two wheels for the purpose of communicating motion from one wheel to the other.

A Bevel.—The bevel of a chisel is its cutting part. The bevel of a valve is the part which bears on the valve-seat. To bevel is to make a bevel on a piece of machinery by means of filing, forging, or some other method.

A Blow.—A knock. An amount of knocking or percussive force imparted from one body to another.

A Bolt.—A stick, rod, or bar, intended to move in the direction of its length. In machinery bolts are used for fixing pieces of work to each other; and may be either key-bolts or screw-bolts. To bolt is to fasten by means of a bolt, whether it has a screw or not.

To Bore.—To make a hole by means of a rotatory motion, which is applied either to the object to be bored or to the boring tool. A bore, is a general term applied to any tubular opening. To bore a wheel is to make a hole, or enlarge a hole, into the wheel by means of boring; and while the hole is being made, the wheel is bored, but not the hole.

A Boss.—A boss of a rod, lever, or shaft, is a thick portion adjoining a thinner, or between two thinner portions. The fulcrum boss of a lever is always the strongest when compared with any other bosses of the lever. A boss may be globular, cylindrical, hexagonal, and of many other shapes, and may be with or without a hole.

A Brass.—A bearer or covering made of brass or gun-metal, placed to some part of an axle or rod to sustain its friction. A couple of brasses are named a pair, when the two brasses are so shaped that both are required for one axle-bearing; consequently, each of the two brasses possesses a semi-cylindrical gap, if intended for a cylindrical bearing; and if for a bearing of any other form, the gaps are shaped to correspond.

Brittleness.—A hardness belonging to a metal or other material, which allows or admits of its being easily broken by strains of percussion or vibration.

A Bur.—The bur of a piece of work is a jagged projection or number of projections; these are formed along the edges and sides of the work while being turned, planed, or otherwise cut. Burs are produced also by hammering a piece of work; and by two pieces knocking together during use.

A Bush.—A bush is a piece of furniture made to fit a hole, whether the hole is cylindrical or of any other form. When bushes are required for sustaining friction, they are of gun-metal, steel, or wood. These furnishers or garnishers are used also for levers of various sorts, when it is necessary to make one lever fit spindles of different sizes; in such cases, the garnishers may be square or hexagonal. To bush a joint-hole is to adapt a bush to the hole; and to bush a joint-pin or bolt is to adapt a bush to the bolt instead of the hole.

A Cam.—A class of bosses that extend from one side of levers and axles, instead of both sides. An excentric cam is a wheel having a hole which is not in the middle. A lever-cam is a projection on one side of a lever-boss. A solid cam is one which is solid with the axle or lever, instead of being keyed or bolted to it.

A Calliper.—An instrument for measuring the bore of a gun. Callipers are used to measure lengths, widths, and thicknesses, and each calliper consists of two legs jointed together by means of a pin, which is fixed in the thick ends of both legs. Legs of callipers are both straight and arched. To calliper is a useful verb, signifying, to measure with a calliper. One calliper is often named a pair, because its two legs are of the same shape.

To Cast.—To pour melted metal or other material into sand moulds or other moulds. Cast steel is that which is poured after being made into steel.

To Calk.—To calk a boiler consists in thickening the overlying portions of the plates, after they are riveted together; this calking is performed with hammers and punches. The calking of joints in engine-work is effected by driving cements of various sorts into narrow openings provided for the purpose.

A Centre.—A middle point. A centre is also any important place in an object, whether in the middle or elsewhere. The centre of magnitude or extension in or belonging to any object is a point which is at a mean distance from the object's pourtour, or entire external surface. The centre of mean diameters, or axial centre, in or belonging to any body, is the point of intersection of the mean major axis with the mean minor axis; consequently, in a crank-shaft lever, which is forty inches in extreme length, the axial centre is twenty inches from either extreme end, although one of the lever-bosses is much larger than the other. To centre, is to find and indicate the middle points in various sides of pieces that need such processes. Lathe centres are cones, or conical pivots, on which an axle rotates while being turned.

To Chase.—To make a screw with a hand-tool upon a piece of work while it rotates in a lathe.

To Chip.—To cut with a chisel in two hands. Also to cut with a chisel in one hand while the chisel is driven with a hammer in the other hand.

To Chuck.—To chuck a piece of work is to fix it tight upon a chuck; these chucks are tables, plates, or boxes to which the work is bolted, or fastened by cement. Chucks are of many sizes and shapes, and belong to lathes, planing-machines, drilling-machines, slotting-machines, and others.

A Clamp.—A plate or other instrument which grips and tightly holds one piece of work to another, or to a table or platten. To clamp is to fix something with a clamp.

A Clearance.—An amount of space allowed between the extremity of a piston's travel and the cylinder-lid. Also the space between a bolt and the boundary of the hole in which the bolt is placed.

To Cog.—To cog a wheel is to put teeth into it, which are named cogs. A cog-wheel may be one having teeth solid with the wheel, or one having distinct teeth that are made of wood and fixed to their places.

A Collar.—The collar of a bolt, bar, or axle is a ring of metal that may either be slidden loosely along the axle or forged solid with it. Collars are usually circular; but some are square, hexagonal, octagonal, and oval.

To Cone.—To cone a pin, or rod, is to make a frustum in some part of the rod; to cone a hole is to make the boundary of a hole to the form of a frustum, or cone, by means of boring tools or punching tools.

A Cotter.—A key having pin-holes at the small end for holding a split key.

A Coupling.—A joining together of two articles so that they may be easily separated. A coupling for joining two shafts end to end consists of a thick tube, or socket, that fits a few inches of both the shaft-ends that are to adjoin; and when the two shaft-ends are put into the coupling, both shafts are in one straight line. A preferable mode of coupling consists in using flange-couplings. A flange-coupling is a thick socket, having a broad flange at right angles to the length of the hole for the shaft; around the flange are a few holes for connecting bolts, which are put in and out when coupling and uncoupling is necessary. Two of these couplings are keyed to the two shaft-ends, so that both the flanges are outwards; and when the two faces of the flanges are put together, the bolts are put in and fastened, and the coupling is effected.

A Cover.—A cylinder-lid is a cover for one end of a cylinder. A lid of a slide-jacket is a cover for the face to which the lid is bolted.

A Crank, or Crankle.—A crankle is the bent or zig-zag part of a rod or bar. An engine crank consists of only one lever when it is situated at one end of an axle, and includes two levers and the crank-pin when the crank is near the middle of an axle.

A Diagram.—A figure or writing on a surface. Diagrams for workmen consist of figures on paper, and also of figures of chalk on boards, sheet iron, and tables. An inscription made with a steel point into a table is also named a diagram.

A Diameter.—A distance across or through an object, whether it be the length of the object, or the width of it, or its thickness. The three terms, diameter, axis, and thickness, are synonymous, if not specially defined.

Dies.—Dies are moulds of various forms for shaping forgings and other work, and are made of chilled cast iron or of steel. Dies for making screws on bolts consist of hard steel grips having inside screws on the gripping sufaces that are to bite the portion of the bolt to be screwed.

A Draught.—The draught of a piston-rod key-way is a space which allows the end of the rod to be drawn to its place while the key is being driven into the key-way. The draught of a crank-pin cone is the distance which the extremity of the cone projects beyond the place it will occupy after being heated and fixed.

A Drum.—An instrument resembling a cylinder, or, in some cases, a disc. A wheel having a broad rim, which is used for transmitting motion with bands. Drums are fastened to long shafts, and also to short axles, of lathes and other machines; and one drum is sometimes made with a rim broad enough for several bands.

An Edge.—The outer extremity of a ridge, whether the edge is thick or thin. That projecting part of a surface which is formed at the junction of two planes that are inclined to each other; or of two curved surfaces inclined to each other. An edge is also a relative term to denote a small side of an object. The edge of a disk is its rim, or one of its boundaries.

An End.—The end of a rod is a portion near its extremity. Frequently, for convenience of reference, a rod is said to consist of three parts, or lengths, one length being the mid portion and the two others are the ends. Short rods and levers consist of two equal lengths, termed ends, each end being half the total length of the lever.

An Eye.—The eye of a hammer is the hole for the handle. The eye of a boss is the hole for containing the end or some other part of the pin belonging to the boss. An eye-bolt is one having a loop at one end, or having the end punched to make a hole for a pin. Consequently, all such eyes are holes in sockets and rings of various shapes. The shaft-eye of a crank-lever is the shaft-hole.

A Face.—A term to denote that side of a piece of work which is to be in close contact with another piece during use. To face, signifies to make a plane surface on a piece of work. To face a slide-valve is to flatten the bearing surfaces with filing and scraping.

A Feather.—A feather is a ledge, and consists of a key of steel which is sometimes fitted into a shaft or axle previous to putting the axle into the hole in the wheel; and at other times the ledge is fitted to the wheel instead of the axle. Feathers are fitted into shallow recesses, instead of key-ways, that are cut through a shaft or axle; two or three feathers are sometimes required for one wheel, or one boss, and may, in a few cases, be solid with the shaft. A short feather is named a stop.

A Figure.—The form of the upper, front, and side surfaces or sides of an object which appear to an observer at one view. A figure is also a mark or number of marks on a surface for explaining an idea, or representing an object. A figure for a workman, is a figure on paper or on sheet iron, which represents to him a side, or two or three sides, of the object he is to work upon.

To Fit.—To properly adapt two pieces of work to each other.

A Fitter.—A man who can properly adapt pieces of work to each other; whether he is a filer, turner, planer, driller, slotter, or any other sort of shaper.

A Filler.—A piece of metal which is put beneath a brass, or fastened to a brass, in order to raise it after being worn. A filler is also a piece of iron driven into a hole to fill it, when it is required for drilling, shaping, hardening, and other purposes.

A Flange.—A ridge, or a ledge. The difference between a flange and a collar consists in the collar being either loose or fixed, and the flange being always solid with the metal adjoining. Pipe-flanges are the projecting ridges which contain the holes for the joint bolts; cylinder-flanges contain holes for connecting the lids, slide-jackets and valve-boxes. The flanges of engine-work and cast-iron pipes are cast solid with the remainder of the work; the flanges of wrought iron or steel work are welded and rolled; the flanges of copper steam-pipes are soldered to the pipes, and fixed at various angles to the lengths of the pipes.

A Flute.—A flute in a piece of machinery is a long narrow groove having a boundary at one end, and being open at the opposite end. Some flutes have a boundary at both ends; when of this form, the flute is a long shallow recess.

A Fork.—A bar or rod having two or more branches at one end, or at both ends. A fork end of a connecting-rod may have two or four branches. Branches, arms, and prongs belonging to any bar or rod may be bent and separated in any direction until they are at right angles to the length of the rod; and if further bent to bring the extremities nearer to the rod, the branches become hooks.

A Gap.—Any space or opening having a wide mouth, if bounded at the bottom and two opposite sides only. The opening between the two branches or prongs of a fork-end rod is a gap; also the space between two teeth of a wheel.

A Gauge.—An instrument for discovering qualities, shapes, and dimensions of various materials. In engine-work, gauges are principally used for dimensions; and, if to be much used, are of hard steel. A couple of cylindrical gauges consist of a steel ring and plug; the plug is a small piece of round steel having a convenient handle at one end, and at the other end a part which fits the hole in the ring or collar. To gauge, signifies to measure with a measuring tool of any shape or dimensions.

Gear.—A collective name for several pieces of machinery when considered as a collection. Two pieces of a machine are said to be in gear, or engaged, when the two pieces are in position for moving or acting in some way upon each other; and are out of gear, or disengaged, when one piece is shifted so that neither can move the other. When one cog-wheel is driving another cog-wheel, both are in gear; and when one wheel is shifted a short distance, to prevent it driving the other wheel, both are out of gear. Two wheels may be put into and out of gear also by means of bolts and keys, so that the relative situation of the wheels need not be altered.

A Gland.—Glands of piston-rods, air-pump rods, slide-rods, propeller-shafts, and other shafts, are made of gun-metal, and consist of rings which are pressed tight against the india-rubber packing to squeeze it close to the rod or shaft. Forcing the gland on the packing, is effected with screws that are applied in various ways.

To Grind.—To rub little pieces from an object through applying hard powder or stone of some sort. Also to separate pieces of two surfaces by rubbing the surfaces together. The substances used for grinding engine-work, are emery and sand, which are applied with oil and water.

A Groove.—A long narrow gap. A long, narrow, curved or angular indentation intended to guide or fix some piece of machinery. An endless groove is that which is formed through the surface of some object, and entirely encircles the object, whether it is a lathe-wheel, pulley, lever, rod, or bar. A groove may be either zig-zag or serpentine in its length, and have curved or flat bottoms. A short groove is termed a gap, and the difference between the two consists in a gap being included in three sides of an object, and a groove being sometimes extended across or into five or six sides, or entirely around the object.

A Guide.—Any piece of machinery which tends to force or maintain another piece in a desired path or motion. In an engine, all the moving parts are guided by those that are in direct contact and do not move. The principal guides of an ordinary steam engine are those for the piston-rod, to keep it in a straight line with the cylinder.

A Hole.—An equal-sided or circular opening which extends entirely through an object from one of its surfaces to some other surface. If the opening is not circular, square, octagonal, or of similar form, but oblong, it is a slot. When a hole or slot is covered or closed at one of the entrances, it becomes a recess; and when closed at both entrances, it is a cavity.

A Holder or Handle.—A projecting piece of metal which is cast solid with the work to afford a means of fixing it during planing, turning, and other operations. A holder may be also forged solid with a rod, bar, or key that requires planing, the holder being cut off after the key is fitted.

An Index.—A steel instrument which is finely pointed and polished to indicate a point, and denote minutes and seconds of angles and arcs.

To Jam.—To fasten two nuts together on one bolt. Of two nuts thus fixed, the one put on last is termed a lock nut; and the greater the thickness of this nut, the greater is the friction surface of the screw; consequently the thicker the lock nut, the less is its liability to rotate on the bolt, and separate from the other nut.

A Lid.—The lid of a slide-jacket is bolted to the flange of the jacket. The lid of a valve-box is bolted to the box after the valve or valves are put within.

A Line.—A line in a piece of work, is any stated distance into it, through the work, or across one side of the work. A line on one side of a lever or rod is denoted by a scratch or indentation.

To Line.—To mark a line or several lines into various sides of a piece of work, to discover centres, and to enable men to work to the lines.

A Machine.—An instrument consisting of several moving parts. Any instrument which contains a lever and axle; or which contains several levers without an axle.

To Mark a Line.—To mark a line upon a lever, is to draw a steel point along some part of the lever and plough up a portion of the lever, or plough a furrow into the layer of whiting that may be on the surface.

A Neck.—The neck of a bar is an intermediate part between two thick portions. The neck of a bearing, is the portion between two shoulders of the bearing; therefore if a bearing has two shoulders, it has one neck; and a thrust bearing having ten shoulders, has five necks.

To Oscillate.—To move gently to and fro, and traverse arcs while moving. To swing backwards and forwards a rod or rope which is sustained at one end. To swing a cylinder on its trunnions.

A Pinion.—In machinery, a pinion is a relative term to denote the smaller of two cog-wheels that work together, whether the pinion drives the wheel, or the wheel drives the pinion.

A Pulley.—A relative name to distinguish between two wheels or drums that are connected with a driving band; the driving wheel being that which gives motion to the band, and the pulley being that which is pulled and rotated by the band.

To Scribe.—To write with a steel instrument, named a scriber. To mark a line with chalk or with slate-pencil upon a piece of work, or upon a table. To scribe a line, signifies merely to write the line, without regarding its position to any other line.

A Scriber.—A scriber for marking diagrams on tables or plattens, is a piece of steel wire which is hardened and pointed at one end, to give it a capability of cutting the surfaces of iron, steel, and other metals. Scribers are of various lengths, according to whether they are required to be held in one hand while scribing, or fixed in legs of compasses and other scribing instruments.

A Shoulder.—The shoulders of bolt-heads, are the surfaces that press against the work to be bolted together. The shoulders of an axle-bearing, are the surfaces that sustain any strains which are imparted to the axle in the direction of its length.

A Slit.—A cut. A split. An opening or space extending through a piece of work, if the opening is made by means of a hand-chisel, chopper, steam-hammer chisel, or similar tool.

A Slot.—A regularly formed oblong opening, which extends entirely through a plate, rod, or bar; consequently, a slot resembles another hole in being closed except at two places, which are the entrances or mouths of the slot. Slots may be oval, rectangular, serpentine, or arched; and may be made by punching and drifting; also by drilling-machines and slotting-machines.

A Socket.—A short tube intended to contain one end of a smaller tube, or to contain one end of a shaft, axle, rod, or bar.

A Stroke.—The stroke of a slide-valve is the length of the path along which the valve moves. The stroke of a piston is the length of its travel or path.

To Temper.—To moderate. To mix cements. To soften a tool to the proper degree of hardness, after the tool is hardened by cooling it in water, or is hardened by some other means.

A Vibratory Strain.—When a rod or bar of steel is quivered by hammering, or other means, the fibres are either bent or broken; if the fibres of the bar are short in the direction of the bar's length, the quivering drags some of the particles across those in contact, and this cross motion from one side of the bar to the opposite breaks some of the fibres; and if the quivering is continued, the bar will be divided at the place where the breakage of the fibres commenced; but if the fibres are of considerable length, and parallel to the length of the bar, the quivering merely bends it, and must be continued a long time before it is broken.

The general significations given with the foregoing phrases are sufficient for many of the processes in the "Mechanician;" but, through the custom of making one word signify several different things, it will be necessary, as we proceed, to specially define ambiguous terms.

MARKING-TOOLS.

Marking-tools include all implements for indicating lines and centres in various pieces of work, and consist of scribers, straight-edges, squares, gauges, dividers, and a few others; and it will be observed that several marking-tools are sometimes used for measuring.

Scribers.—The simplest sort of scriber is a piece of straight steel wire pointed at one end, and six or seven inches in length; this is held in one hand, in the same manner as a pen is held; and, while thus held, the scriber is put to one side of a straight-edge which is on the work to be marked, and a straight line is made, by drawing along the scriber while in contact with the straight-edge, and with sufficient pressure to make the mark desired, whether thick or thin. Scribers are both straight and angled, resembling Figs. 266, 267, and 268; the angled ones being necessary for marking the places of holes and slots where there is not sufficient room to admit a straight scriber. Bent scribers are used in a horizontal position, consequently it is convenient to either fix the scriber in a wood handle, similar to that in Fig. 268, or to provide a bow handle, like the one shown in Fig. 267. The short marking end of a bent scriber is as short as convenient, that it may not tremble while in use.

Centre Punches.—Centre punches consist of two principal classes, named dotting punches and coning punches. Dotting punches are made of small steel wire, not exceeding a quarter of an inch in thickness, and are used for making dots to indicate the places of centres in sides and ends of various pieces of work; they are used also for making dotted lines to indicate the place of a line or other mark which is liable to be rubbed out or filed out. All dotting punches or dotters require to be sharply pointed and applied with a small hammer, because the dot which is formed should be only large enough to be seen whenever it is necessary to refer to it. A dotter is shown by Fig. 269, the angle of the dotting part being about forty degrees.

Coning punches are of various sizes from half an inch to one inch in thickness, some being held in one hand while in use, and others being attached to handles, if the punches are driven into the work by means of heavy blows. Coning punches are represented by Figs. 270 and 271, and are required to make or enlarge conical recesses in work which is to be lathe-turned. For this purpose, the piece of work to be turned is properly lined, and small holes are drilled at the centres of the intended conical recesses; after this, the recess is formed by widening the mouth of the small hole with a larger drill, or sometimes with a chisel; and when roughly shaped, the coning punch is hammered into the recess, to make it smooth, and give it the proper conical form.

Fiddling Drills.—Fiddling drills are represented by Figs. 272 and 273, and are rotated by means of a bow, shown by Fig. 274. A fiddling drill is fixed tight in a wood pulley, and is used with a plate termed a breast-plate, which is fastened to the workman's waist. In this plate is a small recess to contain one end of the drill while it is in use. Fiddling drills are used in a horizontal position; consequently, the work to be drilled is supported in various ways, sometimes on a lathe, at other times on a few packing-blocks, and frequently in a vice; while the work remains fixed by some means, the bow-string is wound around the pulley of the drill, and the cutting part is put to the work, while the opposite end of the drill is put into a recess in the breast-plate which is fastened to the workman's waist; he then raises, lowers, or otherwise shifts the drill until it is in a right line with the work, at which time the drilling is commenced; this is effected by moving the bow to and fro, and gently pushing the drill, if it is only about a sixteenth in diameter at the cutting part; but if it should be a quarter of an inch, the pressure necessary for drilling is about as much as the operator can administer by such means. Sometimes two operators are required, one to move the bow, while another one pushes the drill into the work. Fiddling drills are useful for all sorts of work that require short holes to be drilled, also for drilling small holes into large work that cannot be quickly moved about. Such drills are useful also for drilling the centre recesses in rods and axles that require lathe-turning.

Centre Gouges.—Centre gouges consist of small chisels having curved cutting edges, and are of different sizes, according to their intended uses. Gouges of this character, to be held in one hand, are represented by Fig. 275; a tool of this sort is used for cutting away the metal at the mouth of a recess that has been drilled with a small drill and requires coning; after sufficient metal is cut away by the gouge, a coning punch is hammered into the recess until the desired form is obtained. Gouge chisels are used also for centring and channelling; when employed for centring, a gouge is the tool for enlarging a conical recess at only one side, by which means the centre or middle of the recess is put into another place; gouges for channelling are made from a sixteenth to a quarter of an inch wide at the cutting part, and are required to cut or form grooves into the sides of centre recesses to admit oil for lubrication.

Coners.—The class of coners with which we now have to do, is represented by the cutting tool attached to the breast-brace or hand-brace, shown in Fig. 276; such a coner consists of a semi-conical cutter, which is rotated by the brace, and cuts away the metal at the mouth of a recess until it is formed to the depth and width required. Coners of this class are used to shape the centre recesses in the ends of rods and axles when a coning punch is not adapted to form the recess to the necessary dimensions; through the taper form of such a cutter, it will shape recesses of various sizes, according to the dimensions of the work to be coned, and a coning punch may be afterwards hammered into the recess to smooth the sides, if necessary. Coning with such a cutter is easily effected in iron or gun-metal; but to form a conical recess into steel, it is advisable to first cut away the metal with a gouge (Fig. 275), and next hammer a coning punch into the recess to smoothly form it to the required shape.

Scriber-Blocks.—A scriber-block is an instrument consisting of two principal parts; these are the movable scriber, and the block to which the scriber is attached; the other smaller pieces are the fastenings by which the scriber is fixed to its block after the scriber-point is raised or lowered to any particular height which is necessary. That portion of the tool termed the block, is a small pedestal, which may be of wood, steel, or any other metal, the principal requirement being lightness combined with stability. Scriber-blocks are principally used to mark straight lines upon engine-work of all classes, large and small, and all scriber-blocks are used on plane surfaces, named surface-plates. The process of scribing consists in laying the piece of work upon the surface-plate, or upon a few packing-blocks that may be on the plate, and moving along the scriber-block with one hand or two hands while the scriber-point is in close contact with the piece of work to be marked, and the base of the block touches the surface-plate; consequently, all lines made with a scriber-block thus used, are straight, and also parallel to the plane on which the block is moved. If a scribing instrument of this character is properly made, and the surface on which the block is moved, is clean, all lines made with the scriber-point as much resemble straight lines as that portion of the surface on which the block moves resembles a plane. Scriber-blocks will mark any number of straight lines upon a piece of work, or upon several pieces of work, so that the lines may be of the same or of different lengths, also at various angles to each other, and at the same time parallel with the plane; also, several lines may be marked upon one piece of work so that all the lines shall be parallel to each other; and this is effected by raising, or lowering, and fixing the scriber-point to the various heights that the lines are required to be above the surface-plate. This property of marking parallel lines is the most important quality of the instrument, and renders it applicable to the scribing of work of all sizes and conditions; scriber-blocks are therefore made of various heights, from one inch to several feet, and the height of the particular block selected for use depends on the distance to which the piece of work extends above the table or surface-plate.

Scriber-blocks are represented by Figs. 277, 278, and 279. By referring to these Figures, it may be observed that each scriber is bent at one end; this bent part being used for making lines upon the top of a piece of work, and the straight end being for the lines that are required on those surfaces of the work which are at right angles to the plane on which the block moves. The block shown by Fig. 277 is of wood, and the two other blocks are of iron or other metal. Fig. 279 denotes a tall block which becomes an el-square by taking off the scriber.

Vee-Blocks.—Vee-blocks consist of cast-iron pieces having gaps which are angular, similar to those in Fig. 280. When two such blocks are of the same shape and dimensions, they are named a pair, and are used to support a piece of work at a proper height above a surface-plate or table. A couple of vee-blocks are often used to support a rod or lever while being scribed; for this purpose, the two blocks are put upon the table, and the piece of work is put into the gaps of both blocks, a scriber-block is then put to the work, and the scriber-point is adjusted to the desired height for the object of marking the lines required. The gap sides in vee-blocks are at an angle of about ninety degrees with each other, and are made wide enough to allow one pair of blocks to be used for a variety of work of different sizes; consequently, a thick lever or rod will fit the mouths of the blocks, and a smaller rod or other piece of work will fit some other portions of the gaps at a distance from the mouths or entrances. In Fig. 281, a pair of vee-blocks are shown on a surface-plate or table, this being the manner in which the blocks are generally used. The uses of scriber-blocks, vee-blocks, and tables, are closely connected, the three tools being necessary to scribe one piece of work.

Compasses.—The compasses represented by Fig. 282 possesses jointed legs, to admit two pointed pieces which are of the same length and shape, and also one leg having a thick conical foot; when this foot is fixed for use, the instrument appears as in the Figure. Such a foot is used when it is necessary to scribe arcs or circumferences by placing one foot of the compasses into a mouth of a hole or recess, in which case a thin compass-leg cannot be used without fixing something in the mouth of the hole; a conical foot is therefore useful to fit a number of holes of different sizes, if the legs are fixed at a proper distance in their sockets in order to scribe the arcs in an easy manner. Compasses, fitted with such a conical foot, will mark circumferences if the cone is in a hole which is either round, square, hexagonal, or of any other section. When it is necessary to use the instrument without the cone, it is taken out, and the thin pointed leg put into the socket; and, while thus fitted, the compasses are in order for scribing curves or circumferences upon gun-metal, iron, or steel, the points being properly hardened to cut into the metal whenever it may be necessary to do so.

Dividers.—The divider to be now considered consists of a pair of legs connected with a spring, and is therefore named a springy divider: such an instrument is denoted by Fig. 283. Whenever it is needful to perform a great quantity of scribing arcs, or measuring, without any great care or precision being necessary, an ordinary compass is the proper instrument for the work, because compass-legs can be separated or closed together in less time than is required for the shifting of divider-legs; but to easily and precisely measure a length, or mark a length, and to properly scribe arcs and circumferences, springy dividers, having fine points, are indispensable. A spring divider is a very useful instrument for scribing and measuring, if properly hardened and pointed, to maintain the necessary sharpness while the tool is in use on hard surfaces. The mode of adjusting a divider to a length on a rule, or other measure, consists in rotating the thumb-nut until the two divider-points are nearly the required distance from each other; and this is effected by putting the points near to the rule, but not touching it; after this, the final adjustment is performed by softly placing one point upon or into one of the marks on the rule, and while one point is held in the mark with one hand, the other leg is screwed in or out by gently working the nut until both points are felt to be in the marks, or seen to be on the marks, according to the particular rule in use while the adjustment is effected. To avoid wearing the divider-screw and nut to a needless extent when the legs require shifting a great distance, the two legs should be squeezed towards each other in one hand, while the other hand is used to rotate the thumb-nut during the time it is not in contact with the divider-leg.

MEASURING TOOLS.

In this place measuring tools are considered to include such implements as divided measures, rulers, and callipers, and also tools for ascertaining qualities and conditions of various pieces of work: to this class of tools belong straight-edges, squares, gauges of several sorts, and surface-plates.

Straight-edges.—A straight-edge is generally a steel or wood right-angled parallelopiped, whose length is twenty or thirty times its width, and two or three hundred times the thickness. The two broadest surfaces which extend along the length of the instrument are termed its sides, and the two smaller surfaces that extend along the length are named the edges, and these consist of two planes that are parallel to each other. These two edges are the only portions of the implement that can be referred to when applying the tool to use; consequently it is named a straight-edge, and sometimes a ruler. Such tools are made of all lengths, from three inches, to fit a waistcoat-pocket, to several feet or yards. Straight-edges are much used to mark straight lines upon work, and also to ascertain if some portion of a surface is a plane, or how near it resembles a plane. The primary use of the tool is to indicate straight lines and lengths, and these are the elements of precision in measurements; therefore a straight-edge is the first tool to be made by a beginner, when he has so far advanced in his work that precision is his object. The simplest sort of straight-edge is that indicated by Fig. 284, being without a divided measure, but having curved ends to admit a free handling, and to render it fit for carrying in a pocket, if necessary. Fig. 285 denotes a ruler whose length is sixteen centimètres, each centimètre being marked on one of the broad surfaces of the ruler. Fig. 286 represents a ruler whose length is shown to be sixteen centimètres, and which is also shown to be one hundred and sixty millimètres in length, this length being the same as sixteen centimètres, because one centimètre equals ten millimètres. From the left-hand extremity of the ruler to number 10 is the length of one decimètre, or, which is the same length, ten centimètres, as indicated on the straight-edge; and if the instrument were ten times the length of ten centimètres, it would be one mètre in length, and therefore would contain one thousand millimètres, because one hundred millimètres equal one decimètre. During the application of any straight-edge to a piece of work, it is necessary to so place the tool that its two broad sides shall be at right angles to the surface to which the straight-edge is put; if not, one of the corners of the tool will touch the work, at which time the tool will bend through its own weight, and its utility is, for the moment, destroyed.

Squares.—The tool named a square is a right angle, and consists of a steel tool whose broad side or surface is bounded by two right angles which are parallel to each other. We may say also that the simplest sort of right angle or square is that which is formed by bending a straight-edge at one place only until the two arms extending from the bend are at right angles to each other; consequently, the straight-edge or parallelopiped is more like a square previous to being bent than it is afterwards; and at the present time a square may be termed a ninety, and other angular gauges may be named sixties, forty-fives, or some other number, to denote the quantity of degrees in their angles, until a circle's circumference shall be considered to have one hundred degrees, or some other number than three hundred and sixty. A square having its two arms of equal width and thickness is denoted by Fig. 287; such a square is said to have no back, or, properly speaking, no pedestal, and the tool is used for scribing right angles; for this purpose it is laid with its broad side in contact with the work to be scribed, and held or fixed in position, and, while securely held, a scriber is moved along the edges of the square, and at the same time in contact with the work which is being scribed. A square having legs or arms of equal thickness is also sometimes used for adjusting pieces of work; when thus used, the square is preferred merely for its lightness and portability. The two squares shown by Figs. 287 and 288 are termed el-squares, through resembling a letter L; and the one denoted by Fig. 288 is also a pedestal square, because one of its arms is thicker than the other; and the thinner arm extending from the pedestal is the blade. The pedestal of a square is also its handle, being that which is held in the hand while applying the tool to a piece of work. A good pedestal-square is distinguished by means of a plane surface, which is placed in a horizontal position in some convenient situation for reference. On to this plane is put the square so that its pedestal shall rest on the surface and the blade extend upwards; and while thus resting the blade should be at right angles to the plane, whether viewed on the broad side, edge, or corners of the blade; if not, the blade is bent, or some other defect exists in the tool and requires adjustment. Pedestal-squares are used for adjusting surfaces of a piece of work to a right angle with each other, also for fixing one piece of work at right angles to another piece, or to a table of a machine.

Tee-Squares.—The implement denoted by Fig. 289 is a tee-square, and consists of a pedestal having a blade at right angles to the pedestal, but situated midway from each end instead of at one extremity, as in an el-square. Such a tool is sometimes employed for work that requires a square to be applied to the outer surfaces, but a tee-square cannot be applied to an inner corner; the tool is therefore specially adapted to measure and discover conditions of holes in levers, wheels, bosses, and other work having openings through or partly through. Tee-squares are useful while forming rectangular holes, and for marking the places of intended key-ways in circular holes; also for marking slots and key-ways in ends of bolts, rods, and axles. The tee-square shown by Fig. 290 is a bisector or centre-finder. The instrument consists of a tee-square whose pedestal is furnished with two projecting pins so adjusted that a straight line connecting their centres is at right angles to the length of the blade; both pins are also equally distant from the blade, so that the centre length of the blade is exactly midway between the centres of the two pins. A square of this sort is applied to use by placing its blade across an end of a rod, bar, or shaft that requires its centre to be found; and at the time the blade is put across the two pins are put in contact with one side of the work; while in this position two lines are marked with a scriber across the end of the work, one line being at each edge of the blade; after two lines are thus scribed upon the shaft-end, the centre line required is marked midway between the two by means of a divider and straight-edge. When one centre line is found by such means, the square may be again applied to the work so that the blade shall be at right angles to its former position; and while it is thus held two other lines are scribed across the two first made, and the centre discovered as before. Bi-secting by means of such an instrument may be further simplified by so placing the two pins that one edge of the blade shall be midway between the two pin-centres, instead of the centre length of the blade being in this situation; by this arrangement only one line is marked instead of three, this one line being the centre line required.

Cross-Squares.—Cross-squares are represented by Fig. 291. Such a tool is made of two principal pieces, one of which is the thin blade that slides through a slot which is formed in the middle of the pedestal or shoulder-piece. This slot is of great length, because it is necessary to prevent the blade wearing and getting out of its position at right angles to the shoulder-piece. A small screw having a milled head is also shown in the Figure, for fixing the blade at any required length from the shoulder, indicated by S. On the blade are marked inches and parts, or millimètres, according to the intended use of the tool. A cross-square is used for the same purposes as tee-squares, and also for measuring depth of holes, recesses, slots, key-ways, and similar openings. Cross-squares are never used to accurately adjust surfaces to right angles with each other, because the blades cannot be adjusted to right angles with their shoulder-pieces so as to remain in such condition for any great length of time.

Angle Gauges.—An angle gauge is a tool consisting of two arms which are at any desired angle to each other; consequently, the name of any particular gauge is the number of degrees of arc in the angle of the gauge. The gauge denoted by Fig. 292 is a hundred and twenty, because this is the quantity of degrees in the angle between the two arms. The tool denoted by the Figure is made of one piece, but, by making the two arms of distinct pieces, an instrument may be formed which is capable of adjustment to any angle. This is effected by connecting the two arms with a bolt, nut, and washer; if thus fitted, the arms of the gauge may be made to subtend any angle by adjusting the arms to the angle-measurer shown by Fig. 293. During this adjustment the nut and bolt should be screwed tight, so that the arms cannot be shifted by any amount of proper handling; and while in this condition, the gauge is opened or closed by means of a wood hammer, or some other soft hammer. An angle gauge having adjustable arms should have one thick arm, corresponding to the pedestal of a square; and into one end of the thick arm a gap is formed for containing one end of the other thin arm of the gauge, termed the blade; and the two pieces are therefore united together by means of the joint bolt through both arms at the place of the joint-gap. A gauge thus made requires the thick arm to be put to the straight-edge of the angle measurer (Fig. 293) whenever it is necessary to adjust the arms to subtend the angle desired.

Cylindrical Gauges.—Gauges for measuring solid cylinders and cylindrical holes are denoted by Fig. 294. Such tools are made of all sizes, and consist of plugs and rings of steel, the plugs being used as standards for measuring cylinders or while making them, and the rings being employed as standards for cylindrical holes. Any plug and ring which fit each other so that the plug requires a little pushing with the hand through the hole in the ring, are termed a pair. When such a pair are selected for use, the plug represents the rod or spindle which is being lathe-turned, and the ring represents the wheel, lever, boss, or other article which is intended to fit the spindle. One mode of making the spindle fit the wheel or lever consists in carefully measuring the gauge-plug with an outside calliper, and making the spindle fit the calliper; and also measuring the gauge-ring with an inside calliper, and enlarging the hole in the wheel until it fits the inside calliper. Another method consists in giving the plug to the workman who is making the hole, and giving the ring to the one who is turning the spindle; by this plan, each man requires to measure with two callipers—an inside calliper and an outside one. A third mode of using rings and plugs consists in avoiding the use of callipers, both inside and outside; in this case, the operator who makes the hole requires the plug, and he who turns the spindle uses the ring; and to avoid taking the spindle from the lathe to receive the ring, the ring is suspended on the poppet cylinder, and is therefore pushed on to the spindle whenever necessary, and without removing the work from the lathe.

Surface-Plates.—Surface-tables or plattens consist of cast iron or Bessemer steel blocks resembling Fig. 295, and a few others adjoining. Such tools are made of various sizes, from an inch across to several feet, and each platten has at least one plane surface. One principal use of a surface-plate consists in applying a piece of work to the plane for the purpose of ascertaining how near the surface of the work resembles the plane of the table; consequently, plattens are standards of reference during the formation of plane surfaces, and are used whenever a plane is being produced upon any piece of work that may be in progress. Surface-plates are also planes from which to exscribe straight lines upon pieces of work by the aid of scriber-blocks. The smallest sort of platten is held in one hand, and applied to the work, instead of the work being moved to the platten; and small surface-plates of this class may be only a few ounces in weight. A good platten is that which is made of hard iron or steel smoothly finished to a plane, and which will maintain its plane character while being used; therefore any surface-plate, small or large, must contain a proper amount of metal which is so distributed as to prevent the platten bending through its own weight. For some purposes a surface-table is fixed in one place, instead of being portable; when thus placed, with its plane boundary upwards, and in a horizontal position, the metal should be as thick as the space allotted to the table will permit, and the base of the table should rest on as unyielding a body or cement as can be obtained. The number of bearing points or touching points of contact of the base with its support should include all the points in the base, so that no portion of the surface-table's base shall be without a prop which is directly underneath; and after the table is permanently fixed the plane surface is finally smoothed while in its position for use, if the fixing process has rendered such final finishing necessary. Some plattens are suspended above a piece of work which is being filed or scraped, so that the platten can be let down to try the work when it is necessary to do so, and also easily raised up to allow the surface to be further smoothed or scraped after being tried with the platten. Tables for such purposes are provided with lifting studs; these are screwed into holes that are formed into various sides of the surface-plates; implements of this character are represented by Figs. 296 and 298. Fig. 297 indicates a wood cover which is put over a plate's surface when not in use, or, in some cases, the plate is put into the cover; if so, its bottom is covered with soft clean cloth. Such covers may be made also of sheet iron.

The surface-table shown in Fig. 299 is supporting four additional surface-tables or blocks; the two blocks on the right-hand end of the table are similar to each other in shape and dimensions, and are termed a pair; and the other two blocks on the left end of the table are named a couple of odd blocks, through being of different sizes. The corners of all these movable blocks require to be curved, that they may be put to or moved about the surface-table without injuring it. All the four blocks are useful for trying pieces of work while being adjusted to right angles, or being made parallel; such blocks are useful also for trying el-squares, tee-squares, rulers, and other gauges. A table thus employed with blocks thereon requires to be fixed in a quiet place which has a good supply of equally diffused reflected light, and but little dust; and the surface of the table ought to be high enough to enable an observer to look across and see the light between the blocks without an inconvenient stooping; and to facilitate the observation, white paper may be placed, either near the blocks, or at a distance behind the table.

Radius Gauges.—The radius gauge shown by Fig. 300 consists of a steel bar on which slides two scriber-holders; the small wires, which are the scribers, being fastened in their places with little screws having teeth around the rims of the heads. One of the scriber-holders may be moved along to any desired place on the bar, but the other holder can be moved only about an inch. This one is shown at the right-hand end of the Figure, and is connected with a short screw, denoted by A, having a head with teeth on its rim, for the purpose of easily rotating it with a finger and thumb, or, if necessary, with the palm of the hand. The use of the gauge consists in scribing arcs and circumferences of long radii which are too long for compasses; and when the instrument is required for use, the scriber-holder at the left end of the bar is slid along until the distance between the two scriber-points is about a sixteenth greater or less than the distance when adjusted; after this, the adjusting screw A is rotated slowly, and moves the holder which is nearest to it until the two scriber-points are at the exact distance from each other which is required.

Callipers.—The simplest sort of calliper is made of a piece of straight wire, which is first bent to produce a short arm at each end, and afterwards bent in the middle, to make the tool resemble an arch, similar to Fig. 301; in this form the tool is an outside calliper for measuring rods, axles, and other work; and in the form shown by Fig. 302 it is an inside calliper for measuring holes. Fig. 303 denotes an outside calliper of two legs, which are connected with two friction plates and one rivet, the two plates being termed washers. Fig. 304 indicates a springy calliper, whose action is similar to that of a springy divider. Springy callipers are very useful for small work that does not require the calliper's legs to be separated more than seven or eight inches; but for large work callipers resembling Fig 303 are more frequently used, and are made large enough to measure three or four feet. Next to the springy calliper is shown an inside calliper, whose feet may be, if necessary, only an eighth of an inch in length, by which means the tool is capable of measuring a hole which is only a quarter of an inch in diameter. Fig. 306 represents an inside calliper which is shaped to resemble legs, merely for ornament. It may here be mentioned that all inside callipers may be, if necessary, used as outside callipers, and this is effected in cases of emergency by sliding one calliper leg across the other, so that the toes of the feet are put nearest to each other, instead of the two heels being nearest each other, which is the usual position. By adopting similar means, outside callipers also are made to serve as inside ones. Fig. 307 represents an awkward, inconvenient class of callipers, which are never used by engineers; the tool has four legs, two for measuring holes, and two for rods and other work that needs outside measurement. When such a tool is newly adjusted, the distance between the points of the inside legs is the same as the distance between the points of the outside legs, but after a short time the wear of the points makes the distance between the outside legs too long, and the distance between the inside legs too short; it is therefore necessary to hammer the ends and re-file them, so that the tool is only fit for those who do not understand the use of proper gauges.

Hobs.—A hob is a fluted screw, having several narrow flutes, which are generally parallel to the length of the hob, the number of flutes in a hob two inches in diameter being usually thirteen or fifteen. A hob may be termed a steel plug, having at one end a screw in which several cutting edges are formed by means of fluted grooves, and having at the other end a square head. This head is that which is held while the hob is in use, whether by means of a spanner, or by the hob being rotated in a lathe. Hobs are, at the present time, a class of standards from which several other instruments for screwing are made, such as comb screw tools, one-point screw tools, dies, screwed plates, and taps. Sometimes a lot of hobs, consisting of about twenty, are kept as standards for reference and measurement, but no other use is permitted them, for fear of injuring or reducing them below their respective dimensions. A hob which is intended for die-making is sometimes held in a vice, the square head being gripped and the screw part extending upwards; while thus fixed, the die-making is effected by revolving the dies around the hob. The two most useful shapes for hobs are indicated by Figs. 308 and 313.

Taps.—A tap is a fluted steel screw for forming screws into nuts and other work which needs inside screws. The proper number of flutes in a tap is only three, and, in a few special cases, five, the length of each flute being parallel to the length of the tap. Taps are denoted by a few of the figures in Plate 27, and that smaller part of a tap which extends from the screw is the stem, and of this portion the square part is the head. If the taps are only about an eighth or a quarter of an inch in diameter, they are formed with square heads, which are as thick as the screw parts, and resemble Figs. 309, 310, 311, and 312. The three taps that are shown to be each of the same length constitute a set, because the three tools are used to form one screw into the boundary of one hole or recess, and this operation is termed tapping the hole. The tap shown by Fig. 309 is named number one, and is the one first used when tapping is being performed; this tap is screwed into the recess to be tapped until the point of the tap touches the bottom, and this screwing is effected with a two-handled tap spanner, having a square hole which fits the head of the tap. After the first tap has partly formed the screw, the tap named number two, shown by Fig. 310, is screwed into the hole, or recess, the point of the second tap being larger than the point of tap number one. Number three tap is next employed for completing the hole; this tap is shown by Fig. 311, and its screw is not taper like the two previously used, but parallel, and is termed a plug tap, or parallel tap. When a nut is to be screwed, or other piece of work having the hole entirely through, three taps are not necessary, only one is sufficient, and this one is shown by Fig. 312. This tap is longer than the others, and the thickest part is of the same thickness as the parallel tap shown by Fig. 311, so that by screwing the entire screw of the long taper tap through the nut which is tapped, a parallel screw is formed into the nut, and the screw is of the same size as if three taps had been used.

Taps which are from half an inch in thickness to three inches, are made with heads that are only as thick as the other portions of the stem adjoining; such taps are denoted by Figs. 314, 315, 316, and 317. The fluted screw portions of these tools are shaped to the same forms as the corresponding parts of smaller taps, and are made in sets or lots of three each, so that they may be used in the same manner. There is, however, one advantage connected with taps having small heads, which allows them to be put entirely through a nut during a tapping process, instead of merely screwing to the end of the screw and then screwing backwards or unscrewing, to release the tap from the nut, which process is unavoidable with large-headed taps. Fig. 317 indicates a long taper tap which does the same quantity of work as the three hand taps adjoining, the long taper tap being always used in preference to the three shorter ones, whenever there is sufficient room for the taper end to project beyond the work which is being tapped. This long tap is also employed to screw nuts in a screwing machine; and it may be noticed that the long taps contain three flutes of a shape somewhat resembling the three flutes in the shorter taps.

PLANING TOOLS.

Hammers.—Engineers' hammers are of two principal varieties, one class being named ball hammers, and the other class being termed pane hammers. A ball hammer is one which has a ball at one end, and at the other end a flat extremity named a face. A pane hammer is a wedge-ended hammer, the wedge-shaped part being the pane. Ball hammers are represented by Figs. 318 and 320, and are used for riveting and ordinary hammering; if employed to rivet, the ball of the hammer is first hammered into the centre of the rivet's end, in order to thicken the rivet in addition to merely spreading the extremity, and this thickening is effected by making the convex surface of the ball form a hollow in the rivet end, after which the riveting is completed with the flat face of the hammer instead of the ball. Wedge-ended hammers are denoted by Fig. 319, and these are useful for hammering in a gap or other opening which is not large enough to admit a broad face, also for bending and straightening, and for thinning extremities of bars and plates, also for riveting small rivets. That which is termed the flat face of a hammer is always convex to the extent of about an eighth of an inch at the centre, such a form being necessary for ordinary hammering, to prevent the edges of the hammer face damaging the work which is hammered.

Chisels.—The chisels indicated by Figs. 321, 322, and 323, are chipping chisels, and are used with the hammer denoted by Fig. 320, which is termed a chipping hammer. Chisels of this class are employed to cut iron, steel, and gun-metal, and while a chisel is in use it is held in one hand so that the chisel is at an angle of about forty degrees with the surface which is to be chipped, and while thus held, the chisel is struck with repeated blows of a hammer until the surface is chipped. The chisel shown by Fig. 321 is a planing or smoothing chisel, and is used alone for chipping small surfaces which are to be planes; but for a large surface, the channeler or groover shown by Fig. 322 is first driven across the surface to make a number of grooves at a short distance from each other, and also at right angles to each other; after this, a planing chisel is driven across the surface to cut off the prominences which were left by the channeler. Channeling chisels are used also for cutting key-ways into wheel bosses, also for key-ways in bolts, rods, and axles. Fig. 323 indicates a pointed chisel which is used for making angular grooves, and for driving out hard pieces from a piece of work which is to be planed or lathe-turned, also for clearing inner corners of angular holes.

Files.—Files are planing implements for making plane surfaces upon pieces of work which have been roughly planed with a planing machine. The rough square file denoted by Fig. 324 is a quicker cutter when compared with the flat file shown by Fig. 325, because a smaller amount of cutting surface is applied with a square file than with a flat one, but a flat file is conveniently used after a square one, if the surface being filed is large enough, because the surface is easier planed with a large amount of cutting surface acting at one time than with a small amount. For some work, files are used upon a surface after it has been chipped with chisels; for such work, a square file is always the preferable one to commence with, after which, a flat one is effectual for taking off the ridges formed by the square file. The weight of any particular rough file selected for use should be according to the power of the operator, whether a boy or a man, whether a strong man or a weak one; and to make all files as light as possible, a side of a thick square file is made to possess about half the cutting surface of a thin flat file whose weight equals that of a square one. Any file which has one of its sides without teeth, is termed a safe-side file; such a file is used when it is necessary to put it into contact with a surface that must not be filed, or which has been filed and must not be further reduced. The safe-side of a file is that which is rubbed along in contact with a surface which requires protection, while another surface at right angles to the protected one is being reduced by the filing. In cases of emergency it is often necessary to make a safe-side to a file that does not possess one, and this is done by grinding off all the teeth from the intended safe-side by means of a grindstone.

To file slide-valve faces, cylinder faces, surface-tables, and other faces whose distance across is much greater than the length of a file, an appropriate method must be adopted for holding the files; for such work, holders and cranked files are used. Holders are of two principal shapes, that are indicated by Figs. 326 and 327; in Fig. 326 a dovetail groove is shown, into which the small end of the file named the tang is tightly fitted; this holder may be attached to the tang while straight, and the holder used with a wood handle of the ordinary shape. The holder shown in Fig. 327 is much simpler and more effectual, but requires the tang to be bent, to raise it a convenient distance from the surface which is to be filed. Another mode of raising the handle is shown by Fig. 328, and consists in cranking the tang, by which means no other handle is required than the ordinary wood handle.

Fig. 329 represents a file which is bent to a curve; this bending may be performed on any flat file whether rough or smooth, and is effected by heating the file to redness throughout the entire length of the part which is to be curved; while thus heated, it is laid across a wood block having a hollow of proper width and depth, and a wood hammer is applied with a number of gentle blows which are given to the entire length of the portion to be bent. If a number of files are to be curved, a broad wood fuller should be made, and a corresponding bottom block, the fuller and block being curved to suit the files. Bent files are necessary for filing concave surfaces, and the curve to which the file is bent is always much less than that of the surface to be filed, to permit a comfortable handling of the tool. Bent files are consequently useful for the inner boundaries of steam-cylinders, air-pumps, packing-rings, lids having dishes, brasses, and guides.

Scrapers.—A scraper is the next tool to be used on a surface after it is smoothly filed with the object of forming a plane; after it is thus filed, a scraper will make it still smoother, and after a smoothly polished scraper has been employed, the jagged projections made with the scraper must be smoothed by grinding and polishing. A scraper for making plane surfaces is denoted by Fig. 330; a tool of this class has only one cutting edge if the extremity is at about forty degrees with the length of the scraper, and has two cutting edges when the extremity is at right angles to the scraper's length. Fig. 331 indicates a scraper which is made of a three-sided file that has been used for sharpening saw-teeth and become too much worn for this purpose. When made into a scraper, the scraping part may be made to any precise shape the work may require, or the scraping part may be sharpened while still maintaining its three-cornered character. A three-cornered scraper is used for finishing curved holes, round holes, inner corners of a number of openings of various shapes, mouths of holes, and small plane surfaces. The scraper shown by Fig. 332 is adapted for large curved surfaces; the cutting part of the tool is somewhat similar to a semi-cone, and is provided with a blunt curved point or end, and two cutting edges which are useful for scraping the curved surfaces of brasses, also bearers of other metals, whether of steel or of Babbitt's metal; scrapers of this form will scrape also the inner surfaces of lever bosses, wheel bosses, joint bosses, steam-cocks, and water-cocks. For the advantage of a free handling, scrapers are made of small files, or of other small steel which is only large enough for the purpose.

Drifts.—The particular class of drifts represented by Fig. 333 and others adjoining, are cutting drifts, and consists of angular tools having cutting teeth extending from the sides or faces; such tools are employed for enlarging holes, such as key-ways, and joint-pin holes, this being effected by driving the drift through the work with hammering. Cutting drifts for making parallel holes are thickest at a short distance from the extremity which is first put into the work, and by hammering a drift until its thickest part has cut its way entirely through the length of a hole, the hole is made parallel without a tedious filing. When it is requisite to enlarge a hole by cutting on all its four sides, a drift is used having teeth on all the four faces, resembling Fig. 333 or 334; but if it is necessary to enlarge a hole at only one side, or end, a drift having teeth on only one side is employed for the purpose; a tool of this kind is indicated by Fig. 335. Cutter drifts that are taper, similar to Fig. 336, are useful for making taper square holes. One important use for cutter drifts, whether for parallel holes or taper ones, is that of making a large number of holes to one shape and thickness, this being effected for parallel holes by merely driving the drift through the hole or holes which were previously roughly formed by drilling and chiselling. To make a number of taper holes to one size, the drift is hammered to a certain distance which is indicated by a mark on the drift.

Punches.—The punch shown by Fig. 337 is a sort of drift having a short bearing with a small number of cutting edges, or with only one cutting part, which is the outer extremity of the thickest part of the tool. The thinner portion of the tool is its handle, and a part of this extends into the hole which is being drifted, but does not touch anything, consequently the friction while driving the tool is confined to the cutting edges and a short portion of the thick part, and this allows the tool to be driven through a piece of work quicker and easier than a drift having a longer bearing and a greater number of teeth, resembling Fig. 333 or 334; but a drift having only a short bearing is not so advantageous for making long straight holes; consequently, a drift having one cutting edge and a short bearing is suitable for finishing short holes, and a drift with a long bearing is proper for finishing long holes. With this object, a drift with a short bearing may be first hammered through the work in progress, which is afterwards finished with a drift having a longer bearing.

The punch shown by Fig. 338 is a cutting tool whose extremity is bounded by a circle, and is made to form round holes into plates of various metals by being held in one hand while the other hand hammers the punch through the plate. To make holes in this manner, the punch is used with a die or bolster, and this a thick steel ring or block having a round hole which is rather larger than the cutting end of the punch, this hole being intended to receive the cutting end of the punch after it is hammered through the plate. When punching is to be performed, the plate is first marked with a dotting punch, compasses, or some other means, to indicate the places of the intended holes, and the punching is begun without the bolster, by putting the plate across a larger hole, and hammering the punch a short distance into the plate; by this means a bump is formed upon the under side of the plate, and this projection is next slid along, or the bolster is moved along, until the bump slips into the bolster-hole; after which, the punch end is hammered through the plate, and the piece which is cut from the work falls into the bolster-hole. Circular punches are useful also for smoothing bottoms of recesses in various pieces of work. Fig. 339 represents a punch having a half round cutting end instead of a round one; Fig. 340 indicates a punch with a rectangular end, and both these tools are used with bolsters in a manner resembling that described for round punches.

SPANNERS, BROACHES, AND BRACES.

Spanners.—A spanner is a tool for gripping or spanning nuts and bolt-heads for the purpose of screwing and unscrewing them. Spanners are used also for rotating plugs of water-cocks, steam-cocks, and valve-spindles, also for twisting metals, and holding tools while boring with a lathe. The simplest sort of spanner has but one gap, which is formed in cases of emergency by heating one end of a straight bar of iron and bending it to make a gap of the width required.

A simple class of spanners in general use is represented by Fig. 341, having but one gap end attached to a straight lever named the handle. With the object of making one spanner suitable for nuts or bolt-heads of two sizes, the tool is provided with two gaps, one at each end; such a spanner is indicated by Fig. 342. The most convenient spanners for use are those which are thick at the gap parts, but not broad; most of the gap spanners in use being too thin and too broad, which prevents them being used in corners where there is not much room. The gap-sides of spanners are smoothly polished and made to fit the nuts with only sufficient room to allow a spanner to be quickly put to a nut and taken away from it during use. When it is needful to use a spanner for nuts that are too small for the spanner's gap, the mode of making them fit each other consists in placing a packing plate or filler between the side of the nut and the gap-side; and, if necessary, two or three such pieces may be used for one nut, by which means a spanner whose gap is half an inch too large may be used with a filler which is half an inch thick. A number of these pieces should be made, each about two and a half inches long, and of various thicknesses, so that they may be kept ready for use. To prevent injury to polished iron nuts, and to gun-metal nuts, it is necessary to make the fillers of sheet brass, and to polish them.

When it is requisite to use a spanner for a nut or head which is below a floor, or a foot plate, or beyond a wall, a socket spanner is used. Such a spanner may have a short bent handle for small nuts or heads that are only a short distance from the operator, and the tool is indicated by Fig. 343. Fig. 344 denotes a socket spanner having a straight handle with a hole in its end to hold a lever which is put into the hole when the spanner is on the head ready to be rotated; such a tool is therefore convenient when the object to be fastened or unfastened is in a corner or near a wall. Fig. 347 denotes a tee-handle spanner, the entire tool being in one piece, and used in places where there is sufficient room for the handle to rotate. The claw spanner shown by Fig. 348 is employed for nuts or heads that are situated in corners, gaps, slots, and similar places. The spanners represented by Figs. 345 and 346 are a class of strong spanners with only a small thickness of metal, but these can only be used where there is sufficient room for the spanner to entirely encircle the nut.

A very useful class of spanners is that named screw spanners, which may be made to fit nuts and heads of several different diameters; these tools are represented by Figs. 349 and 350. The gap of the variable spanner shown by Fig. 349 is made to open or close to the desired width by rotating the screw shown by S with a thumb and finger; consequently, this tool is not so easily handled as the one shown by Fig. 350, which is adapted to nuts of various sizes by rotating the handle, and this may be done while the spanner is around a nut, so that both hands of the operator may be used for rotating the spanner-handle.

Broaches.—Broaches are cutting tools for enlarging holes by rotating either the broach or the piece of work to be broached. A broach is a straight piece of steel that cuts by edges which are formed along its sides, but does not cut at the end in the manner of a drill. A broach is used to enlarge a hole, or smooth it, after it has been formed by drilling; and it is rotated by either a wood handle, a spanner, or a brace. Both parallel holes and taper ones may be made by broaches, and for small holes, not exceeding an eighth of an inch in diameter, a broach may be fixed in an ordinary file handle shown in Fig. 351. When it is desired to make a hole smooth and parallel, a broach is used which is thickest at about a quarter of its length from the point, and it is rotated until the thickest portion has passed entirely throughout the length of the hole, by which means the hole is made parallel, and also straight, if the broach did not bend while in use. To avoid as much as possible the tendency to bend, it is necessary to make the broach only that length which is sufficient for the work; and when a long one is requisite, it is rotated with only a gentle pressure while finishing a hole. Broaches for taper holes are denoted by Figs. 351, 352, 353, and 354. The three-cornered broach shown by Fig. 351 is a quick cutter for small holes; and the five-cornered one shown by Fig. 352 is used for larger holes, and rotated with a spanner or brace. A superior cutter for taper holes is a half round taper tool shown by Fig. 353; and for smooth and straight taper holes, a broach having one flute is employed; this is denoted by Fig. 354. A good tool for parallel holes is shown by Fig. 355; this has three fluted grooves and also a short taper part at the point, to allow the tool to be easily entered into the work to be broached. Another excellent tool for making parallel straight holes is indicated by Fig. 356; this one possesses five grooves, and also a short taper portion for introducing the thick part of the tool to the work.

Fig. 357 represents a broach which may be used for both parallel holes and taper ones. The tool consists of a cylindrical piece of steel into which two grooves are planed, each groove being opposite the other; in one groove is tightly fitted a steel cutter, which is shown by C; this cutter is forced out to any desired distance by means of the four small screws shown by S, and the cutter is made to produce either parallel holes or taper ones, according to the amount of inclination of the cutter to the cylindrical part of the tool. To ensure a good hole, it is necessary that the cutting edge of the cutter should not extend more than an eighth of an inch from the groove, and that the edges of the opposite groove in which are the adjusting screws should be smoothly curved.

The heads of broaches may be either square or round, and adapted to be used with a spanner having two handles, while the work to be broached is in a vice, or the heads of the broaches may be fitted to lathes and drilling-machines, and thereby rotated instead of being used by hand. When it is necessary to broach a hole so that it shall be larger in diameter than the broach, a smooth piece of sheet brass or copper is put to one side of the tool, and both the copper and broach are together rotated and passed through the hole.

Wrenches.—A wrench is a spanner having two or more handles, and usually consists of a straight tool having a thicker portion in the middle, in which is a square hole, or in some spanners, two or three holes of different sizes; these holes are made to fit the heads of taps and broaches, and are used when the work to be operated upon is held by a vice. Wrenches are represented by Figs. 358, 361, 362, and 364. If a wrench is only about two feet in length, it is used by only one man, but long wrenches, for tapping large nuts when they cannot be conveniently tapped in a machine, are used with three or four men, each wrench having three or four handles. A tap spanner for small work is denoted by Fig. 358, having but one hole; and another one, having three holes of different sizes, is shown by Fig. 362. In some cases, taps and broaches are employed in holes which are in corners, or near walls, while in such places the taps are rotated by a spanner having only one handle; a tool of this form is indicated by Fig. 361. A large capstan spanner for tapping large nuts is shown by Fig. 364; this is employed for large nuts that are fixed in a vice or other grip of suitable dimensions which is conveniently situated to allow the long handles of the spanner to revolve. A spanner of this class may be used also for rotating the boring bar of a portable boring machine.

Any hole in any tap spanner may be adapted to the head of a tap or broach, although the head may be too small for the hole, and the adaptation consists in either putting a garnisher into the hole, or placing one on to the tap-head. The garnisher consists of a piece of iron or steel which fits the space between the sides of the tap-head and the sides of the hole in the wrench, and is shown by Fig. 359. This garnisher, or filler, is made by bending a piece of metal which is only as thick as the space around the tap-head when it is in the wrench-hole; consequently, if the hole in the wrench is seven-eighths square, and the tap-head only three-quarters of an inch square, the piece for the intended filler is a sixteenth thick. After such a piece is cut to length and heated, it is angled by laying it across a hollow, and hammering a piece of square iron into the work, the piece of iron which is used being equal in thickness to that of the tap-head. After the filler is formed, it is put into its hole, and riveted a little at each end, to prevent its falling out; and while in its place it is filed until the head of the tap will slip easily into and out of the hole, at which time the tool is ready for use.

Braces.—The two principal classes of braces are named crank braces and swing braces. A crank brace is used to rotate broaches and to drill small holes with drills; a brace of this sort is shown by Fig. 360. When a hole is to be drilled in a corner, there is not sufficient room for a cranked brace to revolve, therefore a swing brace is used; one of these is indicated by Fig. 363, which swings to and fro only a third, or sometimes only a quarter, of a revolution of the handle. Swing braces are named also ratchet braces, because they are worked my means of toothed wheels, named ratchets. While a ratchet brace is in use, the lever, or handle, is pulled forwards and backwards, instead of being entirely revolved in the manner of a cranked brace. To make this alternate motion capable of rotating that portion of the brace which holds the drill, a pawl is fixed to the lever so that one end of the pawl shall be held in a gap between two ratchet-teeth while the drill is rotated forwards for cutting, and shall slip over the tops of the ratchet-teeth while the handle is moved backwards during the time the drill is not cutting. By this means the lever is pushed backwards without moving the drill; this remains stationary until the pawl is again engaged with the ratchet to advance the drill another portion of a revolution. This gradual process of making holes is well adapted to large holes that cannot be made with a cranked brace, which has but little power when compared with the long handle of a swing brace; but little power can be exerted with a cranked brace, through the shortness of its levers, but a swing brace may have a handle of any length which is not too long for the strength of the instrument; such tools being made of all sizes, and capable of making holes from an eighth of an inch in diameter to three inches.

TOOLS FOR SCREWING.

Screwed Plates.—A screw is a rod of metal, either short or long, having a helical ridge around the outside, the ridge being solid with the remainder of the screw. The ridge of a screw is named the thread, and the helical space which adjoins the thread is the thread-groove. The distance across the thread-groove, measured from the centres of two contiguous summits of the thread, is the pitch or step of the thread; and the distance from any summit to the cylindrical part of the screw is the depth of the thread. That portion of the thread which is the termination of it, and also the commencement of the cylindrical part of the screw, is the bottom of the thread, named also the thread-junction. To make a screw is to form a piece of metal into a screw by cutting or otherwise making a thread-groove into the piece to be screwed. The simplest mode of screw-making which is generally adopted for small work consists in screwing a hard steel screwed plate on to the piece to be made into a screw; a plate of this sort is shown by Fig. 366. Screwed plates are therefore screw formers for rods, wire, small bolts, or any other work not exceeding half an inch in thickness; but for larger work screwed plates are not suitable, except for rough, unimportant work. Small pieces, not exceeding a quarter of an inch in thickness, can be screwed by only one screwing on of the plate, but larger work requires two or three screwings, and in such cases three holes in the plate are used, each of a different size, the smallest one being that which is the diameter of the intended screw. By reference to the Figure 366 it may be noticed that each screwed hole is provided with three gaps, to admit the shavings which are formed during the process of screwing. One screwed plate has frequently sixteen or eighteen holes of different sizes to suit various screws. The taps which are used in connexion with small plates are rotated with an ordinary file handle; for this purpose each tap is provided with a taper tang, resembling a file tang, instead of a square head for an ordinary tap spanner. A small tap in a handle is denoted by Fig. 365.

Dies.—Dies are employed for screwing rods and bolts, and are made in couples, termed pairs. Each pair of dies are required to make one class of screws, and a pair consists of two steel grips, having teeth on the gripping surfaces. The shapes and dimensions of these teeth are the same as of the required thread on the work, consequently the grips are formed with teeth of various thicknesses, to make small screws and large ones. Each pair of dies are held while in use by means of a die-holder, or die-frame. A light class of die-frames are shown by Fig. 367, which indicates a pair of dies in their frame ready for use. One of the handles of this frame has a short screw, and also a hole; this hole admits one end of a short lever to work the screw in or out, by which the dies are closed together or separated to make the piece which is being screwed to a proper diameter. To allow the egress of shavings, dies are formed with gaps somewhat resembling the gaps in screwed plates; but the action of dies while in use is different to that of a screwed plate, because one hole in a plate will form screws of only one diameter, but one pair of dies will make screws of several different diameters, the precise diameter depending on the distance between the two dies while in use. This distance is shortened or lengthened to a minute degree by the dies being in their frame and adjusted by the adjusting screw which constitutes part of the handle. The point of this screw is in contact either with a packing block, or with the die which is nearest the screw point, and this die is the one which is pushed by the screw towards the other die that remains fixed at the bottom of the slot in the die-frame.

The die-frame denoted by Fig. 368 has a distinct screw for adjusting the dies; this arrangement being preferable for all large frames, in order that the adjusting screw may not be large, which is unavoidable with large handles having adjusting screws at their ends. Fig. 369 indicates another class of frames for large dies, having two adjusting screws; in this frame the dies are held by two thin plates that are attached with six small screws; these screws are partly unscrewed whenever it is necessary to take out one pair of dies and put another pair into the die-frame. The slots in the frames shown by Figs. 367 and 368 are shaped to fit the angular gaps in the dies shown by Figs. 370 and 371; and the dies shown by Fig. 372 are shaped to one of the forms that are used for the frame 369. The six holes in the two plates of frame 369 are shaped to the outline of the figure 8, the smaller end of the hole being for the stems of the fixing screws, and the larger part being large enough to allow the heads of the screws to pass through; by such means the two plates are slid along until the holes are opposite the screw-heads, and lifted off with merely loosening the screws about half a rotation.

The die-frame shown by Fig. 375 has but one plate for holding the dies; this plate is a little tapered, and also dovetailed in shape, which permits the plate to be gently driven into and out of its place whenever it is necessary to put in other dies. The plate or lid is shown by L, and is between the two guides, which are attached by six screws; these guide-plates are made distinct from the remainder of the frame, and fastened with screws, after which they remain fixtures. Fig. 376 denotes a frame which is fitted with a lid similar to that of Fig. 375, but has but one handle; such a die-frame is especially adapted to hold dies for screwing by means of a lathe, and for holding die-nuts, that are denoted by Figs. 373 and 374. Fig. 377 shows a frame whose plate swings on a joint-pin when it is needful to take out a pair of dies and put another pair into their place. The two pairs of dies shown by Figs. 378 and 379 are in the shapes that are suitable for either of the frames indicated in Figs. 369, 375, 376, and 377.

The teeth on the gripping surfaces of dies are formed by hobs and master-taps, and afterwards by making the gaps for the shavings. A master-tap is a class of hob which is larger in diameter than the screws that will be made by the dies when screwed; and by using both a hob and master-tap for screwing one pair of dies, one die is made with a larger curve in the gap than is given to the curve in the gap of the other die, by which means the die having the larger curve is made to act as a bearing while the other die is cutting. When it is convenient, the hob or master-tap is screwed into the dies to form the thread, instead of the dies and frame being revolved around the hob, which sometimes injures the thread. Dies are often screwed with a hob having straight grooves; one of this class is denoted by Fig. 380; and a die-screwer, which is rather taper instead of being parallel, is indicated by Fig. 381. In some hobs for die-making the grooves are not straight, but in the shape of screws; a tool of this class is denoted by Fig. 382.

Die-Nuts.—A die-nut is a screwed block with or without a handle; die-nuts without handles are represented by Figs. 373 and 374, and are used for finishing a number of screws to one diameter without the need of measurement during the process. For this purpose all the screws are first screwed with either a screwed plate or with a pair of dies until the screws are but little larger than the screw in the die-nut, after which the screws are finished by screwing the nut upon each one by means of a spanner. By such usage die-nuts are not much injured through the small amount of metal taken off during use; and such nuts may be made to finish screws of two or three inches in diameter. For convenience while finishing a large number of screws, each nut may have a handle, or the nut may be held in a frame resembling Fig. 376, such a frame being especially useful if the nut is to be used for a screw which is being made in a lathe. Die-nuts are always useful when the object is to make a number of screws similar to each other, but gauge-nuts are especially useful for long screws, because the greater the length of the screw the greater is the trouble of making it parallel and forming the entire thread to the proper shape, if a pair of dies are employed for the purpose. If the screw to be finished with a nut is in a vertical position, a spanner may be used to rotate the nut upon the screw, but if the screw in progress is in a horizontal position, a nut in a frame, or solid with a handle, may be used, because the weight of the frame is not so likely to injure one side of a thread while the screw is in a horizontal position as when the screw is in a vertical position.

Benches.—Benches for drilling, screwing, tapping, lining, and filing are represented in Plate 31. In this Plate, Fig. 383 indicates a man who is lining a cylindrical piece of work in order to mark the centre at each end. For this purpose the work is put upon a pair of vee-blocks that rest on the lining table at which the operator is at work, and while the work is supported in the two vee-gaps, a scriber-block is placed upon the flat smooth surface of the lining table, and the point of the scriber is raised or lowered to about the centre of the work, and the workman then moves the block a short distance to mark a line upon the end; after this he rotates the work with his left hand about a quarter of a complete rotation; he then again moves the scriber and makes another short line; he next rotates the work another quarter of a rotation and makes another line; when he has thus made three short marks, he again moves the work to complete its rotation, and then marks a fourth line; these four lines enclose a small space, in the midst of which is the centre required. This centre is easily marked with a small dotting-punch, and is near enough to the exact centre for a great number of different sorts of work. After the operator has thus marked one end of the work, he puts the scriber-block to the other end and marks four other lines in a similar manner to indicate the other centre. If the piece of work thus marked is straight, the four lines made will indicate the centre of that extremity of the work which is near the scriber; but if not straight, the centre indicated merely denotes the axis of that portion of the work which touches the vee-gap during the process of scribing.

The lining table on which the scribing is being performed is of hard cast iron, or of Bessemer steel; it may be cast with a large recess at the under side, and in only one casting, or it may be made in two parts, consisting of the flat slab which is smoothly planed, and the lower framework which supports the slab. On the surface of the slab are marked several lines at right angles to each other, and two or three of them are divided into centimètres and millimètres, and also inches and parts, that the measures may be ready for the use of the workmen while lining or adjusting their work. Such a table seldom requires to be moved from its place, but if it is necessary to make it portable for use in various places, the making of the top slab distinct from the lower frame is advisable for heavy tables.

A bench for screwing, filing, and drilling is shown near the lining table. This bench may be made of either wood or plate iron riveted, and may be fixed or portable, so that it can be placed in the midst of an open space to allow several men to work at all its four sides. At one of the vices, Fig. 385 represents a man filing a broad side of a straight-edge, which is supported on a long block of wood about the length of the straight-edge. The wood is gripped in the vice at one end, and supported with a screw-prop at the other end; and the straight-edge is fastened to the wood block with two screw-clamps; these clamps are moved to various places according to the part of the work being filed, so that the filing may be always performed on that portion of the work between the two clamps. Fig. 386 indicates a man working at a parallel vice; this is a vice which is without the usual straight leg reaching to the ground, the vice being entirely supported by the bench. A parallel vice forms a space between the two jaws, which is always parallel, whether a small space or a large one; this is effected by making one of the jaws solid with the nut which contains the screw of the vice. By the jaw being thus solid with the nut, both move the same distance in the same time, and the desired parallel space is the result. Fig. 387 denotes a man scraping a piece of work which is edge upwards in the slit of a wood block supported on the lining table. Thin bars and straight-edges may be thus held during a final scraping for the convenience of having the work near a plane surface, to which the work is applied to denote which part needs adjustment.

A convenient mode of drilling by hand is indicated by Fig. 391. The drilling apparatus consists of a strong pillar which is bolted to the bench, and on the pillar is an arm to sustain the pressure of the drill while in use; this arm may be swung around the pillar to any required place, and when a heavy piece of work is to be drilled, the arm may be placed over the work while it is on the floor, to avoid lifting it to the bench. In the arm of the drilling apparatus is a slot for attaching a hard steel plate having a few small conical recesses to hold the point of the screw in the drill-brace. This plate slides along the slot in the arm to the exact place required to suit the work to be drilled. An ordinary cranked brace is shown at work, but for large holes a ratchet-brace may be used having a long lever for exerting the necessary power.

TOOLS FOR SMALL LATHES.

Heel Tools.—A heel tool is used for roughly turning iron and steel, and is a tool having a curved cutting edge. The tool is held in a wood handle, and moved to the right and to the left by the workman while in use. This movement is a sort of swinging motion on the tool bottom, which is termed the heel; this heel is smaller than the cutting part, and is a pivot which sticks tight in some part of the tool supporter, which is of soft steel, to allow the heel, which is hard, to cut a hollow into the supporter named a tee-piece. Heel tools are represented by Fig. 392, and are the tools first used when a large amount of reducing by hand-turning is necessary.

Gravers.—A graver is a tool with a rhomboidal extremity, and is shown by Fig. 393; such a tool is used for smoothing iron and steel, and also for roughly reducing them, if only a small quantity is to be cut off. The cutting capabilities of gravers are very inferior to heel tools, but for smoothing cylindrical work and also flat surfaces, gravers are necessary, and are sometimes required for squaring inner corners.

End Tools.—An end tool for hand use is made of a three-cornered file, and the cutting part also is of a three-cornered form, being ground to such a shape when intended for lathe-turning. A tool of this class is employed for bevelling work, and also for turning the ends of pieces of work, and for making short cones. Such tools are never required for the cylindrical sides of any rod or bolt, but are always employed for squaring, bevelling, or other shaping of ends. Tools of this class are denoted by Fig. 394.

Corner Tools.—One of these is employed for squaring inner corners, and for such purposes is superior to a graver, because the acute angle of the graver's end renders it more liable to break, while in a corner, than a proper corner tool. The angle of a corner tool is nearly a right angle with the length of the tool; such a form belongs to the tool shown by Fig. 395. Corner tools are not adapted to cut quickly or in large quantities, but are specially suited to finish the corners of work which has been properly reduced with other tools.

Groovers.—Groovers possess curved ends of various widths according to the widths of the groovers required in the work, and every groover is narrower than the groove to be made by the tool, in order that the tool may not cut both sides of the groove at one time, and the larger the tool the greater is the necessity of preventing it cutting in this manner. The groover shown by Fig. 396 is a tool for finishing broad grooves after they are roughly formed with another tool, or with a narrower groover shown by Fig. 397. This narrow tool is also useful to reduce general brass and gun-metal work when a considerable quantity is to be turned off.

Parters.—A parter is a thin groover, and is employed to separate a piece of work into two lengths by means of a narrow groove which is formed around the work with the parter. Fig. 398 represents a tool of this class having a thin cutting end that will cut a piece into two lengths without much waste, the waste being unavoidable if the cutting end is too thick. Parters are useful also for making small grooves around various sorts of work during progress.

Planishers.—Planishers are tools for flattening ends of brass work, and also for smoothing the sides, which are the cylindrical portions. This class of smoothing tools is denoted by Fig. 399, and they are occasionally employed to smooth iron and steel, in addition to general brass work.

Drills.—A drill is a tool for making holes, or enlarging holes. Drills do not cut at any place along their sides, but at their ends. A drill for making holes where none exist, and which is easily made, and suitable for both iron and brass, is shown by Fig. 400. This drill is made of square steel, and the end, which is square and tapered, is suitable for a lathe, crank-brace, or ratchet-brace. The drill shown by Fig. 401 is made of round steel, and is fastened to its place by means of a small flat-bottomed gap in the conical portion. The square ends and conical ends of drills are their heads; these heads are the portions by which the drills are held in the drill-chucks. A drill-chuck is a drill-holder that is attached to the lathe when drilling is to be performed, and drills with cutting parts of various shapes and sizes have heads which are all alike, so that all may fit the holder.

Fig. 402 denotes a screw-drill. This tool is advantageous for drilling long holes, and is so formed that the diameter of the screw part is nearly equal to the diameter of the short straight portion at the end. A drill thus shaped is well guided by the screw without much friction, and the shavings are allowed free egress along the length of the thread-groove. The short straight end and the screw part adjoining are of a flat bar shape, the screw being made by twisting. Another screw-drill is denoted by Fig. 403, which has a longer screw and longer bearing; this drill is suitable for long holes, and may have either a square taper end, or a taper round end, for holding the drill in its holder. A good drill for making straight smooth holes is a cylindrical drill denoted by Fig. 404; this tool has a short flat portion at the cutting end, which is convenient to allow the tool to be several times ground without reducing the adjoining cylindrical part. Another good cylindrical drill is indicated by Fig. 405; this one has a few teeth for cutting, instead of a flat portion. The number of teeth in such a tool should be three, for drills not exceeding an inch in diameter, and for larger sizes the numbers of teeth may be five, seven, and nine. Both the screw-drills shown by Figs. 402 and 403 are adapted to make holes where none existed, but the cylindrical drills shown by Figs. 404 and 405 are only available for enlarging or finishing holes that were made with other drills. A half cylindrical drill is indicated by Fig. 406, and is very different in shape to the cylindrical ones, but the uses of both classes are the same, either tool being very efficient for making straight parallel holes, if the holes were commenced with another tool. In the Figures of the cylindrical drills, the letters G denote fluted grooves extending along the sides; such grooves are not for cutting, but merely to admit oil and water, and to allow room for shavings.

When it is intended to make a hole so that its boundaries shall be straight, smooth, and parallel, and no hole exists at the place of the intended hole, the drilling commences with a simple pointed drill shown by Fig. 400, or 401 or 402; such a drill is first passed through the work to be drilled, and if only a small hole is to be made, the first drill may be large enough to leave only a sixteenth of an inch to be bored out for making the hole to the finished diameter; this sixteenth is next taken out with the finishing drill, which may be either a half cylindrical, or a cylindrical one. When a hole two or three inches in diameter is to be made by means of a small lathe, and no hole exists in the work, it is necessary to employ three or four drills previous to the finishing tool, in order that only a small amount shall be taken out during the final smoothing.

Screw Tools.—The class of screw-forming tools to be here mentioned are hand tools, and named combs, through having a resemblance to hair combers. An outside comber for making a screw upon the outside of a bolt-end, rod, spindle, or any other cylindrical piece while in the lathe, consists of a tool in a wood handle, and is denoted by Fig. 407 or 408. Fig. 407 shows the form for a tool that is to be repaired after being worn, by merely flattening the end and making fresh teeth, without any forging. The tool shown by Fig. 408 is shaped for lightness, and when the screwing part is worn away, the tool must be upset or rejected for another one. While an outside screw tool is in use, it is held by the workman so that the length of the tool shall be at right angles to the length of the lathe, and therefore at right angles to the length of the spindle or bolt to be screwed. The preparation of a bolt for screwing consists in smoothly turning it to a cylindrical shape, by means of slide-rest tools, heel tools, or gravers; and when ready for the screw, the screwing is commenced with a graver's point. For this purpose, a graver is held to the part to be screwed so that the graver point shall be in contact with the work and make a small groove into it during its rotation in the lathe. While the workman thus holds the graver, he gives a twisting movement to the tool handle, and makes the tool point travel quickly across the work, if he desires a large thread for the screw; but, for a small thread he moves the graver slowly, the precise speed of movement depending on the pitch of the intended thread. The direction in which the graver's point travels, depends on the character of the intended screw; for a right-hand screw, the graver point moves to the left hand, and for a left-hand screw, the graver point moves to the right hand. After the screw is commenced with a graver, a comb is applied, and if a small screw is being made, no other tool is needed for beginning and completing the work.

The making of large screws is greatly facilitated by the use of vee-groovers. An outside groover is shown by Fig. 410, which is a quick and easy cutter for purposes of screwing. Such a tool is applied to screws having threads an eighth or a quarter of an inch thick, for the purpose of deepening the thread-groove in an easy manner, the comb being a slow cutter when compared with a vee-groover. A tool of this sort should not be used at the beginning of a screw-making process, but after a comb tool has begun the screw, a groover is applied until the thread-groove is exactly the depth which it is required to be when the screw is finished; after this, a comb tool is again used to finish the work. The angle of a groover for screw forming should be less than the angle of the thread to be made; consequently, a groover cuts at its point until the thread-groove is of a proper depth, and leaves the thread thicker than the finished thickness; while in this condition the comb finishes the thread by travelling along its entire length and cutting the whole of it to a proper thickness. This finishing process does not in any way deepen the thread-groove, because the proper depth of this groove is attained by the vee-groover. If a comb tool is thus properly used, its teeth do not wear at their points, and a great quantity of grinding for sharpening the tool is avoided. The groover indicated by Fig. 411 is a tool for inside screws, which is employed to deepen thread-grooves of inside threads instead of outside ones. This groover is supported while in use by the short end of the hook tool shown by Fig. 412.

For making screws into the boundaries of holes an inside comber is employed, which is denoted by Fig. 409. Such a tool is held in the hole so that the length of the tool is parallel to the length of the lathe, and screws are made with inside tools much easier than with tools for outside screwing, through the inside tool sustaining but little friction while sliding along the tool supporter, and also through the tool being wedged into its place by the forward motion of the work which is being screwed.

Holders.—A holder is a tool for gripping a rod, axle, or other piece of work while it is being turned, the holder being fastened at one end of the work, and constituting the means whereby the rotatory motion of the lathe-spindle is imparted to the piece to be cut or otherwise modified. Holders are also named carriers, and are represented by Figs. 413, 414, 415. A general form of such tools is indicated by Fig. 413, which has a hole in the mid portion to receive work of various thicknesses, and one fixing screw, which is of sufficient length to allow the point to be screwed in to fix pieces of work whose thicknesses may be only about half the diameter of the hole in the holder. The holder shown by Fig. 414 consists of four pieces; of these, two are the grips that bite the work, and the other two portions are the fixing screws. Each of the grips has an angular gap, and these two gaps are important features of the instrument; being thus provided, the holder is capable of gripping a large number of pieces that are of different thicknesses, the two fixing screws being made of any desired length to make the holder suitable for its particular work. Fig. 415 denotes a strong class of holders having two levers by which the instrument is rotated; in the Figure these levers are shown by L. Through the tool being thus provided, its use is greatly extended, and may be used for other purposes in addition to the purposes of ordinary holders. The gripping power of the two holders shown by Figs. 414 and 415 is greatly superior to that of Fig. 413; but all such grips that are fixed by means of two screws require care while tightening the fixing bolts; during such fixing, while the work is between, both grips should be parallel to each other, if not, a severe tightening will not tend to secure the work. but to injure and in a short time to break the bolts.

Tommies.—A tommy is a short lever having conical ends to enter holes in heads of bolts for screwing and unscrewing. The one shown by Fig. 416 is a simply formed tool having a loop at one end, which is a handle and a means for hanging the tool in its place. An arched tommy which is used for small lathes is denoted by Fig. 417; a tool of this shape can be used in many places and positions in which a straight tommy is useless. Tommies are indispensable for a large number of operations, such as fixing slide-rest screws, screw making with dies, drilling holes with crank-braces and ratchet-braces, and fixing carriers.

Screw-Drivers.—The screw-driver denoted by Fig. 418 is a tool for fixing and unfixing small bolts having square heads or hexagonal ones. The tool is fixed in an ordinary handle, and has a boss at one end in which is a recess that fits the heads of the bolts to be fixed. A screw-driver of this form may be made of a sufficient length to enter a deep recess or other opening which is not accessible to arms and other tools. A powerful screw-driver for bolts having grooved heads is shown by Fig. 419; this is a convenient tool for entering narrow openings in which a tee-screw-driver cannot be used, and is specially adapted to large screw-heads that are provided with deep grooves to receive the ends of the screw-driver. Each one of the thin ends that enters the screw-heads is at right angles to the other end, for the convenience of rotating screws in places where there is but little space for the handle of the screw-driver to revolve. The tee-screw-driver denoted by Fig. 420 is a powerful tool which is much used, but must be employed directly over the screw, and in a position which is in a straight line with the screw to be rotated.

Parallel Callipers.—A parallel calliper is also named a jaws, and consists of a sort of el-square, on the blade of which slides one of the jaws of the instrument. On the blade are two or three rows of centimètres and millimètres, and also inches and parts; and by means of the measures the jaws are put near each other, or separated to any distance that can be indicated by the tool. The sliding jaw is provided with a small fixing screw to tighten it at any desired place along the blade. A jaws is indicated by Fig. 421, and the tool is useful to directly measure the thickness of any object which is between the jaws, such thickness being known by inspecting the measure, and without reference to any other standard. Measuring by such an instrument is sufficiently near to correctness for a great variety of work, both for lathes and vices; consequently the tool is preferable to callipers having curved legs when such measuring is desirable, because the thickness of any piece of work is indicated by one tool instead of two. The tool shown by Fig. 422 resembles a parallel calliper which is deficient of the sliding jaw. This instrument is a butt measure, or a stop measure, and consists of a straight-edge which is accurately marked with centimètres and millimètres, and having at one end a stop which is at right angles to the length of the straight-edge. While the tool is in use, the work to be measured is put to the instrument, so that one extremity shall touch the inner side of the stop, and while thus held the measurement can be accurately performed, without any need of looking to see if the extremity of the work coincides with the extremity of the measure.

Hollow Drifts.—A hollow drift is a cylindrical tool of soft iron, or of copper, in one end of which is a recess of a cylindrical shape and about an inch deep. The tool is employed for protecting the centre recesses while driving out studs, pins, bolts, and other pieces of work that may be tightly fitted. An implement of this class is denoted by Fig. 423, and while in use it is held in one hand, with the recessed end of the tool in contact with one end of the pin to be driven out; the other end of the drift is then hammered with a small hammer or with a large one, according to the dimensions of the work in progress. A hollow drift may be of any convenient length for holding in one hand, when intended for small work; but for large work the drift may be short and attached to an iron wire or wood handle, to allow a sledge-hammering. When a bolt or pin is so situated in a hole that one extremity of the pin is at a distance from the mouth of the hole, it is necessary to use a drift which is of proper length to extend into the hole a sufficient distance to strike the end of the pin which needs driving out.

Tin Hammers.—A tin hammer is used to hammer all classes of gun-metal, iron, and steel work which is smoothly finished and must not be bruised or disfigured with hammering, which would be the result if ordinary hammers were used. A tin hammer supersedes the use of a hollow drift, if the end of the pin to be hammered protrudes a sufficient distance to receive the blows; if not, a drift is necessary to reach the pin, which is then dislodged with hammering the drift. Tin hammers are of various sizes to suit all classes of work, and are provided with ordinary ash handles similar to those for other hammers. Fig. 424 indicates an ordinary shape for tin hammers, the whole class being useful while fitting and dislodging pins, bolts, keys, slides, guides, rods, levers, and a large quantity of other engine and machine work of all descriptions. Another class of hammers for similar purposes are those made of copper; these are only available for hammering iron and steel, copper being too hard for gun-metal. Brass, which is much softer than gun-metal, must be hammered with wood hammers or with ash-wood drifts. For a great variety of small work, an iron drift having a thick leather face attached to one end is very useful.

Universal Drills.—A universal drill is one which is suitable for making holes into iron, steel, brass, gun-metal, a number of other metals, and a large number of woods. The tool consists of a cylindrical piece of steel in which are cut two thread-grooves, these grooves being channels along which the shavings travel after being detached from the work with the cutting end of the drill. Fig. 425 denotes a tool of this character, which is adapted to originate holes in places where none exist, and also to enlarge holes that are made with other tools. Such a drill may be used in crank-braces, swing-braces, lathes, and vertical drilling-machines; but the tool is specially adapted for lathes, because the cuttings from the work easily travel along the thread-grooves while the drill is in a horizontal position. Drills of this form never need any forging to repair them, all the mending which is necessary through the proper wear of the tool being effected by ordinary grinding; and because the drill is parallel, all the holes made with it are of the same diameter, although the cutting part may have been shortened an inch or two inches with repeated breaking and grinding.

Slot Drills.—A slot drill is one with a concave extremity, instead of a conical point. Slot drills are represented by Fig. 426, and are used in slot-drilling machines, the concave form of the cutting part being necessary to permit the traversing motion which produces the desired slot in the work. The straight part of the tool being of a cylindrical shape, it is very strong and adapted to its special uses.

SLIDE-REST TOOLS.

A slide-rest tool is bolted or fastened by some other means to the lathe, and is thus used instead of being held to the work by the hands of the workman. There are several classes of such tools, which are named respectively roughing tools, end tools, borers, corner tools, screwing tools, and springy tools. Roughing tools or side tools are instruments for commencing plane surfaces, and also the cylindrical sides of rods and bolts of all descriptions; roughing tools are therefore broadside tools. End tools are required for both roughing and smoothing, and include all those that operate upon the ends of various work while being lathe-turned, but are not used for the broadsides. Borers are for making holes into wheel-bosses, levers, and similar work. Corner tools are either left handed or right handed, and are required to shape grooves, shoulders, ends, and ridges. The class termed screwing tools include several different shapes, and springy tools are made to serve as roughing tools, smoothing tools, corner tools, and screwing tools, also to make grooves, corners, curves, and ridges.

Roughing Tools.—A slide-rest roughing tool for brass and gun-metal is nearly straight and slightly tapered, and the cutting end may be either in a straight line with the remainder of the tool or the end may be cranked, for the convenience of making it cut in corners. A straight tool of this class is shown by Fig. 427, and a cranked one is denoted by Fig. 428. A roughing tool for iron and steel has a thinner cutting part than that of one for brass, and instead of being nearly straight it is either curved or angled to form a hollow in its upper side. A straight roughing tool and a cranked one, for the broadsides of iron and steel, are denoted by Figs. 429 and 430.

Corner Tools.—Corner tools for brass and gun-metal have flat tops; the cutting ends of some are bent to the right hand, and of others to the left hand, that the tools may cut in the corners for which they are adapted. A corner tool is termed a left-hand tool if its cutting end is bent towards the left of the operator while he stands at the front of the lathe with his face to the work, but if bent to the right hand it is termed a right-hand tool; consequently a right-hand one will cut or operate upon all shoulders of the work which are on the right of the turner, and a left-hand one will operate upon shoulders that are on the left of the workman. Fig. 431 denotes a left-hand corner tool for brass and gun-metal, and Fig. 432 shows a right-hand one. Left and right hand corner tools for iron are denoted by Figs. 433 and 434.

Borers.—Corner tools, both for brass and iron, are often used for boring holes of large diameter; but for making and enlarging small holes a proper boring tool is necessary. A tool of this sort is so shaped that its cutting end extends only about a quarter of an inch from the side of the tool, when it may be necessary to make a hole only about half an inch in diameter. Such a boring tool for brass is shown by Fig. 435, and its straight taper end is only of that length which is sufficient for the usual work allotted to the tool; the shorter the taper part, the greater is its steadiness while in use. Another borer, for iron, is shown by Fig. 436.

Groovers.—A groover for a slide-rest has a flat upper side, whether the tool is intended for iron or brass. The extremity of the cutting part may be either curved or angular, the particular form being suitable to produce grooves which have either curved bottoms, flat bottoms, or those of a vee-shape. A thin groover having its cutting edge at an angle with the length of the tool is employed as a parter to separate a piece of work into two lengths; a tool for this purpose is shown by Fig. 437, and a groover with a curved extremity is shown by Fig. 438. One having a cutting edge which is at right angles to the length of the tool is denoted by Fig. 439; such a form is suitable for flat-bottomed grooves, square corners, and shoulders.

Screwing Tools.—Slide-rest screwing tools include those for outside threads, and those that are necessary for inside threads. The implements for outside screwing are these: one-tooth vee-tools, one-tooth tools having straight cutting edges instead of vees; also vee-tools having two or three teeth, and springy tools having two or three teeth. For inside threads a tool is used which has a single tooth that is solid with the remainder of the tool; a small tool having one tooth which is distinct from the holder is also used for inside threads, this tool being keyed to its holder when necessary. Another class of small instruments for inside threads are those which have two or three teeth, and are keyed to their holders in the same manner as the one-tooth tools. A straight tool having a vee-tooth for outside threads is denoted by Fig. 440, and one with a similar tooth, but cranked, is shown by Fig. 441, the crank being necessary for corners which will not admit a straight tool. Screw tools having two teeth are denoted by Fig. 442; one of this shape is employed after a one-tooth tool has cut out about five-sixths of the thread-groove; and after a straight tool with two or three teeth has smoothed and nearly finished the thread, a springy tool is used for a final polishing; one of this class is indicated by Fig. 443.

Inside threads are made with tools shown by Figs. 444, 445, 446, 447, and 448. The tool shown by Fig. 444 has a tooth extending from one side and solid with the remainder of the implement; this is only used for small holes that will not admit a stronger tool. The small tools named dents, are indicated by Figs. 445, 446, and 447; these are effectual for screwing all holes that are large enough to admit the dent while fastened in its holder; one of these holders is shown by Fig. 448, having a slot in which the dent is keyed ready for use. A dent whose cutting part is made to extend beyond the extremity of the holder is a cranked one, and denoted by Fig. 446; a tool of this shape is required when it is necessary to screw a hole having a bottom. A cranked dent-holder, which is so shaped to make it suitable for some sorts of slide-rests, is represented by Fig. 449.

Springy Tools.—Springy tools are provided with arched ends named springs, and each spring has a cutting end which is in a particular shape to suit its intended work. These instruments are represented by Figs. 450, 451, 452, 453, and 454. The spring of a tool for roughing is much thicker than that of one for smoothing, a greater resistance being necessary for making a thick shaving than for a thin one. A narrow tool for roughing is shown by Fig. 450, and a broader one for smoothing is indicated by Fig. 451; this tool has a nearly straight cutting edge, that a broad surface may be presented to the work at the time of cutting. A right-hand springy tool for shaping curved inner corners is shown by Fig. 452, and a left-hand tool for similar corners is seen in Fig. 453. A tool for convex or outer corners contains a gap, and the curve of the gap is rather greater than the curve of the corner required to be made with the tool. A tool which will shape both inner corners and outer ones is indicated by Fig. 454.

Oilstones.—A small piece of stone for sharpening slide-rest tools may be occasionally held in one hand and applied to the tool without unfixing it from its tool-holder. Several classes of small tools can be thus sharpened, although the stone may not be fixed in a frame or holder of any sort; but for large tools, it is convenient to fix the stone at one end of a wood holder, instead of near the middle. An oilstone thus fixed is shown by Fig. 455, and the outer end of the stone is made to extend about an inch or half an inch beyond the extremity of the holder, which allows the workman to use the stone while vertical, horizontal, or in any other position suitable for the tool to be sharpened, and the holder can be gripped with both hands of the operator instead of only one.

CHUCKS.

Cutter-Bars.—Two classes of cutter-bars are represented by Figs. 456 and 457, one class being cylindrical boring-bars or rods; these are used in lathes by being rotated while on the conical pivots termed lathe centres. The other class of cutter-bars consists of square bars that are similar to other slide-rest tools, and are bolted to slide-rests in a similar manner. A cylindrical boring-rod has two or three slots, termed cutter-holes, for tightly holding the cutters while in use. In the Figure a cutter is shown to be keyed in its place ready for use, the cutter being denoted by C. A boring-tool of this class is used to bore wheel-bosses, lever-bosses, tubes, garnishers, and many other pieces of work that are too long to be bored on a chuck.

The slide-rest tool shown by Fig. 457 also has a cutter, denoted by C, but this tool is employed for making grooves, key-ways, and similar openings into wheel-bosses and lever-bosses after they are bored to their finished diameters, the key-ways being made with the cutter-bar while the piece of work is still bolted to the lathe chuck. The method of using this bar consists in tightly bolting it to the slide-rest and moving the rest to and fro; by such means the cutter is made to traverse the entire length of the hole in the wheel or lever that requires the key-way, and cuts out a portion of the metal every time the cutter enters the boss. In small lathes, the rest to which the cutter bar is fastened is moved to and fro with the ordinary handle; but rests and carriages that are too heavy to be thus handled are moved with the aid of the lathe-screw and a few wheels.

Coned Plates.—A coned plate is a circular plate having several conical holes of various sizes; this plate is fastened to a pedestal or standard by means of a fixing bolt which is put through the middle of the plate, and the standard is fastened to the lathe-bed when the apparatus is required for use. A coned plate is required for boring ends of rods, bars, axles, and other work, and the piece to be bored is supported in a lathe at one end by means of the conical pivot near the chuck, and at the other end by means of the coned plate. That hole in the plate, which is of suitable diameter for the end of the piece, is selected to support it, and the standard belonging to the plate is bolted to any place along the lathe-bed according to the length of the piece to be bored. While the work is thus held, it is rotated by means of a gripper, and the centre of the rod or axle is centred, bored, or, if necessary, screwed to the desired shape. A coned plate is represented in Fig. 458, which denotes a pedestal or standard, having the circular plate attached in the manner described. Fig. 459 denotes a standard with a joint, shown by J, for the convenience of shifting the coned plate when it is necessary to take out one piece of work from the lathe and put another piece into its place. A standard of this sort is useful when a large number of rods or axles are to be bored, to avoid unfixing and fixing the apparatus to the lathe-bed every time a fresh piece of work is put into the lathe.

Poppets.—A poppet consists of two principal pieces, one of which is a stud fastened to the table of the machine, or to a chuck of a lathe, and the other piece is a screw-bolt that fits one or two holes in the poppet, the head of the bolt being generally square or six sided. A general shape for poppets, whether small or large, is denoted by Fig. 460, and such tools are used to tightly fix pieces of work to engineers' machines of all kinds. When required for a lathe, three or four poppets are employed to fix one piece of work, and each poppet is fastened in one of the holes or slots in a disc chuck belonging to the lathe. While in their places, poppets are at right angles to the chuck; and after the poppets are tightly fixed, the work is put to the chuck and fastened by screwing the poppet-screws tight against the work.

Poppet-Chucks.—Chucks that consist of cup-shaped holders having screws for holding the work are named poppet-chucks, or cup-chucks. Two or three such chucks of different sizes are made to fit one lathe, and are useful for drilling, boring, and screwing rings, nuts, lever-bosses, wheel-bosses, bushes, and other work that requires internal screwing and turning. A chuck of this kind is shown by Fig. 461, which has four fixing screws, and another cup-chuck with six screws is denoted by Fig. 462, this one being necessary for work that is too long to be held in a short chuck with four screws.

For several sorts of work that require boring, it is necessary to use chucks that are fixed to the carriage, instead of to the disc chuck. Poppet-chucks or boring-chucks to be thus fastened are shown by Figs. 463 and 464, both chucks being required to hold one tube or other piece of work which is to be bored. While in use, both chucks are at a proper distance from each other, and bolted to the carriage, the work to be bored being fixed in the chucks by means of the six screw-bolts. Each chuck consists of two half-round portions that are connected together with a joint and the bolt shown by B; and when a piece of work has been bored and is to be taken from the lathe, the bolts shown by B and B are taken out, and the upper halves of the chucks are raised to allow the work to be lifted out.

Wood Chucks.—Wood chucks for engineers' lathes consist of strong elm, teak, or beech discs and rings, which are of various sizes to suit various work. A wood chuck while in use is bolted to one of the disc chucks belonging to the lathe; consequently, three or four holes are made through the wood chuck to admit three or four fixing bolts. A wood chuck, in the form of a disc, is denoted by Fig. 465, which is applicable to hold very small articles, because the chuck is without a hole in the middle, and will therefore admit a small hole if necessary. Wood chucks are made to hold pieces of work in two ways, either by gripping the outside of the piece to be fixed, or by gripping its inside. If the chuck is in the form of a disc, it may be either turned until a portion of it is small enough to fit the inner surface of a ring, or a hole may be made into the middle of the chuck to fit the outer circumference of the ring. A wood chuck in the shape of a disc is indicated by Fig. 465, and another in the form of a ring is denoted by Fig. 466; Fig. 467 shows one having a stem extending from the middle, and a chuck having a conical stem suitable for holding ends of tubes of various diameters is shown by Fig. 468.

LATHES AND SHAPING-MACHINES.

Small Lathes.—An engineer's lathe is a machine which is principally used to produce circular boundaries on various pieces of work, and the machine consists of a long, heavy portion, named the bed, and three other principal portions, which are supported by the bed; these three are named, respectively, the spindle-frame or mandril-frame, the carriage, and the poppet-head. The mandril-frame is that in which the lathe spindle rotates to communicate its rotary motion to the work which is being turned. The various sizes of lathes are distinguished by the heights of their lathe spindles above the upper surfaces of the lathe beds; if the centre of the spindle is six inches above the bed, it is termed a six-inch lathe. In Plates 35 and 36 a few small lathes are shown, the sizes of which are about nine to eleven inches. In Plate 35 two lathes are represented, and a shaping-machine, which is situated between the two lathes. All the three machines are worked by means of the driving shaft above, which is fixed near the wall. This shaft is driven by either wind, water, steam, or any other agent that may be selected for the purpose. The wheels on this shaft are driving wheels, and communicate their rotary motion to the wheels of the lathes by means of the leather or india-rubber bands that are seen in the Figures, the direction of motion being indicated by the arrows which are seen in several places. In order to allow the lathe to be put to work and stopped without interfering with the motion of the driving shaft, an auxiliary shaft and its wheels are introduced between the driving shaft and the lathe, these wheels being properly arranged for the purpose. In the lathe at the right hand, the principal portions are named, and these names are the same in all other lathes, small and large. This lathe is one for ordinary turning, but not for screw-cutting. In this lathe the driving apparatus consists of one keyed wheel on the driving shaft and three wheels on the auxiliary shaft below; one of these three is termed a step drum, and is keyed tight at one end of the shaft; the other two wheels are termed pulleys; these are close together, and one of them is keyed tight on the shaft, but the other pulley is loose, and rotates without moving the shaft; this loose pulley is that which is rotated by the driving-shaft band when the lathe is not required to work; and to cause the band to rotate the auxiliary shaft, it is only necessary to move the band from the loose pulley to the tight one; when this is done, the step drum is also rotated, and because this is keyed tight to the shaft, the drum moves the lathe band, and the lathe spindle is made to work.

The starting and stopping machinery for moving the driving-shaft band consists of a fork having two prongs, which are in contact with the band's edges, also a straight rod in a vertical position at the farther side of the lathe, near the wall, and a starting handle at the lathe front, which is handled by the turner; these articles also are denoted in the Figure by two names and the letter F for fork.

When the lathe is at work both the carriage and the poppet-head are sometimes in use, this head being fastened at any desired place to suit the length of the work to be turned, and the carriage being moved along to carry the slide-rest denoted by S R, in which is fixed the cutting tool. In order to make the lathe itself move the carriage, a long rod or bar is employed, which is as long as the lathe; this is the traverse bar, and is situated at the side of the lathe farthest from the workman, termed the back of the lathe. This traverse rod is made to rotate by means of a teeth pinion, which is keyed to the small end of the lathe spindle; this pinion drives another teeth-wheel, to the spindle of which is attached a small step drum, and a leather band from this drum drives another drum below, which is connected with the wheels that drive the traverse rod. On the traverse bar slides a worm pinion that drives a teeth-wheel, and this wheel is attached to a spindle in the carriage; consequently the carriage is moved slowly along the lathe bed by rotating the worm.

Lathes for Screw-making.—A lathe for screw-making, which is represented in the left of Plate 35, has, in addition to the ordinary traversing apparatus, a few other attachments, named, respectively, the principal lathe-screw, the screwing-wheels, apron, and backward band. In the Figure the screw is fixed at the front near the workman, and is made to move the carriage and tool-rest along the bed when a screw is to be made, instead of moving the tool by means of the ordinary traverse bar and worm. Teeth-wheels are required to rotate the lathe-screw, which are termed screwing wheels, and the apron is that which is attached to the carriage, and contains the screw-nut, which fits the thread of the lathe-screw. By this arrangement the teeth-wheels rotate the screw, and the screw-thread pulls the apron and carriage along, because the screw-nut is fixed to the apron.

In the Figure the backward band is shown, which is actuated by the same drum-wheel that drives the forwarding band, and the backward band is crossed, to produce a backward movement of the lathe spindle, which is necessary during the process of making a screw. In order to make this backward motion quicker than the forward one, the wheels on the auxiliary shaft, which are rotated by the backward band, are smaller than the wheels which are rotated by the forward band; and by referring to the Figure it may be observed that three wheels are required for each band, and that each three are situated close to each other. By means of these six wheels, or pulleys, as they are termed, the two bands are allowed to either travel around the driving shaft without moving the auxiliary shaft, or to work the auxiliary shaft and lathe forwards, or to work the lathe backwards when screwing is being effected. Of the six wheels two are keyed tight on the shaft, and four are loose, one tight wheel belonging to the forward band, and the other tight wheel belonging to the backward band. In the arrangement shown in the Figure, the two tight wheels are close together, and the four loose ones are outside. A two-prong fork is shown for each band, and both bands are moved at one time by the workman moving both forks at one time. The principal situations of the bands on the pulleys are three in number, one for the forward movement, the second for the entire stoppage of the lathe, and the third for the backward movement. The particular situation selected for the Figure is the first mentioned, by which the forward band is shown to be on its tight wheel, and the backward band is seen to be on one of its loose wheels; while in this condition the lathe spindle rotates forwards until the turner desires to alter the direction of motion or to stop the lathe, at which time he shifts the two bands at one time, and causes them to travel around the two loose wheels immediately adjoining the two tight ones; each of these two loose wheels is the middle one of each three, and while the two bands are on these two middle wheels, the entire motion of the lathe is stopped; consequently, when the workman wishes to stop all motion, he moves the two bands only sufficient to place them upon the two middle wheels, and fixes the starting handle in a suitable notch, to prevent movement; but if he desires to make the lathe spindle rotate backwards, he continues shifting the bands until the backward band is put upon its tight wheel, and the forward band is put upon its outside loose wheel; while thus arranged, the backward motion continues until the operator desires to stop the process or alter the direction of movement, which he effects by shifting the two bands to their former situations.

Shaping-Machines.—A simple class of shapers to be here described are those which work with a to-and-fro movement which causes the cutting tool of the machine to move in the same manner, while the work which is fixed to the machine may be said to remain stationary. In the middle of Plate 35 such a machine is shown, and the principal portions are named agreeably to the plan for naming the lathes. Such a shaper will produce both flat surfaces and circular ones, but the instrument is specially adapted to small flat surfaces whose areas do not exceed one or two feet. The various sizes of shaping-machines are distinguished by the extreme lengths or distances that can be traversed during one effort or stroke of the cutting tool. If the extreme distance is ten inches, the machine is said to have a ten-inch stroke; and to make the tool travel ten inches, the crank-pin, which is situated at one end of the connecting-rod shown by C R, is fastened at five inches from the centre of the slot-wheel. This crank-pin or adjustable stud is denoted by P, and may be fastened at any desired place along the slot or recess in which one end of the stud is fixed; the stud being fastened with a spanner either near the centre of the slot-wheel, or near its rim, the precise place depending on the length or width of the surface to be shaped. For the purpose of moving the table and thereby the work which is fixed thereon, a traverse screw is provided which is as long as the machine, and in the Figure the screw is shown by T S; on the outer end of this screw is keyed a teeth-wheel which rotates the screw and moves the table. Engaged with this wheel's teeth is a pawl which is moved to and fro by means of the small levers and rods attached to the traverse plate, denoted by T P. Another screw shown is the head-screw, and is required to move the carriage and head along the machine. In order to raise and lower the table to which the piece of work is fixed for shaping, a screw and wheel are provided at the front of the machine near the workman. At the front of the machine is a worm pinion or screw pinion which works between the teeth of the segment rack, the spindle of the worm being indicated by W, and rotated either by a handle or by the machine itself by means of light rods attached to the moving head of the machine. Both hollow surfaces and convex ones are formed with the aid of this worm and rack; and when ordinary plane surfaces are being made, the worm is not rotated, but is only the means of adjusting the tool-holder to any particular angle that may be necessary for the work. A backward band is not required for a shaping-machine of this sort; only the usual forward band, with its tight pulley, and a loose one, are necessary, which are represented in the Figure. The particular method shown in the Figure for starting and stopping consists in the use of a vertical rod fastened near the wall, similar to the mode for the lathes; to this rod, a bar, levers, and a handle are connected, the starting handle being in front of the machine and indicated by the name.

In Plate 36 the back of a lathe is represented in order to show the traverse bar and worm. The traverse bar may be either round or square; if square, no key is necessary for the worm pinion, the hole in which is also square and just large enough to let the worm slide easily along the entire length of the bar; if the bar is circular, it is necessary to make a key-way along the entire length, and to provide the hole of the worm with a ledge to fit the key-way. The entire traversing apparatus is worked by means of the traverse band named in the Figure, and the band may be crossed when it is necessary to reverse the direction of the traverse. To avoid this crossing, additional cog-wheels are provided in some lathes, and situated near the driving pinion. Those lathes that are merely capable of moving the carriage along the bed are single traverse lathes, and those that are capable of moving the carriage along the length of the bed, and also capable of moving the slide-rest across the bed, are double traverse lathes. The movement along the length of the bed is termed the long traverse, and the movement across the bed is termed the across traverse. Some lathes have only the longitudinal traverse, and, for these, only one teeth-wheel is required to engage with the worm; but a double traverse requires two wheels and a pinion, because two spindles are provided in the carriage. Both these spindles are at right angles to the length of the bed, and one of them has a screw formed in the mid-portion; this spindle is the one for the across traverse, and works in a screw-nut which is fastened to the pedestal of the slide-rest, and by the rotation of this screw the tool is made to travel across the lathe, so that the length of this across traverse depends on the length of the screw employed for the purpose. The other spindle is for the long traverse, and has no screw, but has a cog-wheel keyed at one end to work in a long row of teeth which extends along the entire length of the lathe bed; this row of teeth is termed a rack, and may be either on the front of the lathe bed, on the back, or situated in the long narrow space in the lathe bed. In order to arrange both spindles so that either one may be conveniently worked without the other, both the spindle wheels must either have room to slide into and out of gear with the worm, or one wheel must be capable of being loosened while on its spindle, so that it may rotate freely without effecting any traverse.

Those lathes that are not provided with a proper traverse bar are worked by means of the lathe-screw and some of its wheels, and the carriage is made to move at a proper slow rate by using four or five wheels between the lathe-mandril and the lathe-screw. This method may be also adopted if the lathe has a traverse bar, but only in special cases; for ordinary traversing, the traverse by screw wheels is awkward, and involves needless labour, and also an unnecessary wearing of the lathe-screw.

When a lathe is fixed near a wall, as shown in Plates 35 and 36, the wall may be conveniently used for hanging up grippers, gauges, callipers, spanners, and plates; also for fixing shelves to hold cutting tools of all sorts, rings, blocks, poppets, scriber-blocks, dotting punches, straight-edges, and measures. A series of shelves may also be fixed for the screwing wheels, so that each wheel is kept apart from the others, and can be immediately lifted and put into the lathe without interfering with any other wheel that may be near it. Another easy mode of arranging the wheels is to hang each one separately on a round iron pin tightly driven into the wall, the pins being arranged in one or two rows, and each pin kept for its own wheel. If any wall should be injured by thus using it, the fact would merely prove that the wall was not strong enough for its use. When iron walls are adopted, a proper fixing of shelves, stays, hooks, and pins strengthen the structure. It may be here mentioned that only such tools as are in daily use by the workman may be thus publicly exposed: all others are to be taken to the tool-keepers, whose duty it is to collect, distribute, and keep in their places the various portable implements that are used by nearly all the men in a factory. If every workman could be made to properly use and manage his tools, and also those which he borrows from his companions, every small tool in the factory might be kept in sight, because this is the only proper means of finding a tool at the moment it is required; but in the present circumstances it is necessary to appoint men to take care of all small implements, and frequently to lock them up, so that much time is lost while obtaining a tool when it is wanted.

In Plate 36 is also shown a drilling arm which is attached to a wall by means of a davit or post belonging to the arm; at each end of the post is a circular pivot which is gripped by a pair of grips having half-round gaps; of these grips, those two that are fastened to the wall are long enough to effect a firm fastening, and may extend one or two feet along the wall, but the front grips are only long enough to admit the fixing bolts which hold the post in its pivot bearings. The pivots being circular, allows the arm to be swung around to any desired place, and to be there fixed by tightening the fixing bolts with a spanner. Another kind of adjustment is effected by means of a slot in the outer end of the arm; in this slot slides a block which constitutes a screw-nut in which a screw-pin is represented; this slot is of sufficient length to allow the block to be placed at the extremity of the arm, or at several inches nearer to the post. To tighten the block at any desired place to suit the work being drilled, a nut is provided, which is tightened with a spanner. The screwed hole in the block is of sufficient diameter to admit a screw a foot in length, when it may be necessary; when a long screw is not required, a short one is used, and the lower end of each screw contains a recessed portion which is hardened, the shape of the recess being conical. Into the recess is put the point of the drill brace when in use, and swing-braces and crank-braces may be thus used although they may not have any screw, because the long screw in the arm can be screwed down by means of its handle to advance the drill into the work during the drilling.

Vices.—The two general classes of vices are taper ones and those named parallel. A taper vice opens by one jaw or leg being swung on a pivot-bolt at the lower part of the instrument; consequently, the space between the two jaws is taper, and therefore not so efficient for gripping a parallel piece of work as if the space were parallel. The space is always parallel between the jaws of a parallel vice, because one jaw is connected with a slide which slides along a parallel groove in the bed of the instrument, this bed being that which is bolted to the vice-bench. Fig. 471 denotes a parallel vice having a leg or pedestal somewhat like the leg of a taper vice;

this leg is attached to the front jaw of the vice and also to its bed, and while the vice is in use, the leg, front jaw, and bed remain stationary, while the back jaw is moved backwards or forwards to grip pieces of work of various thicknesses; this movement is therefore contrary to that of a taper vice, of which the back jaw remains stationary. To the back jaw is attached the slide which slides in the bed, and to the slide is attached the cylindrical box which contains the screw-nut belonging to the vice-screw. The box is large enough to contain a strong nut, about three inches in length, which is tightly fixed in the box. In the back jaw is a hole to admit the vice-screw, and this hole is of sufficient diameter to also admit a thin tube that covers the front end of the screw, by which it is protected from injury through filings, chips, and other substances falling upon it; the screw is therefore not seen, being hidden by the tube, and this tube is kept in its place by a small ledge which acts as a key. When it is necessary to oil the screw, the tube is pulled forwards a short distance to release the key, and then half rotated to place upwards that side which was underneath; when this is done, an oil-channel is seen; the oil is next put in, and the screw rotated, after which the oil-channel is again put underneath to prevent anything falling into it. If it is desirable to keep the oil-hole upwards, a plug or lid may be attached. A parallel vice of this sort is efficient for chipping, through having a leg which reaches the floor, and through being heavy enough to resist the hammering.

The taper vice, denoted by Fig. 470, is also of a strong character, to render it suitable for chipping small work. The two arms are as long as convenient, to cause the space between to be nearly parallel; and the back arm or leg is tightly fitted in a gap which is formed in the edge of the bench, whether the bench is of iron or of wood.

Both parallel vices and taper ones are often used with vice-clamps; these are protectors which are placed between the gripping surfaces of the jaws and the work which is gripped. Vice-clamps are made in pairs, and a pair consists of two plates of metal that are made to fit the upper surfaces of the vice-jaws. For gripping rough iron and steel, the clamps should be made of soft sheet or plate iron, or of copper; for gripping brass, gun-metal, and polished iron and steel, the clamps are made of lead, tin, and also of plate iron to which are riveted a couple of thick strips of leather, to be in immediate contact with the work to be gripped.

CHAPTER III.

TOOL-MAKING.

The entire excellence of the engines and other machines made at the present time is the result of the superior tools which are used to accomplish the work; and because good tools are available for makers of steam-engines and all other classes of machinery, it is necessary that the tool-making processes be introduced to the student, by which all those who wish or may be obliged to make their tools themselves will be enabled to produce such instruments as are necessary for their own peculiar work.

In the second chapter a number of names, forms, and definitions of tools are given, which are sufficient for the purpose, and require perusal in order to avoid the introduction of explanations into the processes to be now considered.

CONSTRUCTION OF MARKING TOOLS AND TOOLS FOR CENTRING.

Scribers.—A straight scriber is made by sharpening and hardening one end of a piece of steel wire, and bending the other end to a form of a loop, that the tool may be hung up. To produce a twisted mid-portion in a scriber, for the convenience of preventing it slipping from the fingers while in use, a piece of square steel is selected, and the mid-part twisted while red hot. This is effected by holding one end in a vice, and gripping the other end with a tongs and twisting to the shape desired. A small scriber may be made by heating in a gas-flame near a vice, reducing the point nearly to its size previous to hardening; after which, it is tempered to a light-brown colour.

Dotting Punches.—Steel about a quarter of an inch thick is suitable for a dotting punch, and a piece of convenient length to hold is selected, and one end is ground to nearly the finished size of the intended point; it is next hardened and tempered to a light-brown colour, after which it is sharpened to the proper angle, and a proper length for the punch is cut off with a file; the filed extremity is then curved with a grindstone, and the tool becomes fit for use with a hammer about a quarter of a pound in weight.

Coners.—A coner is intended to resist a severe hammering, and should be made of the best steel. A coner to be held in one hand is about half an inch thick at the mid-part, and for large work it is often necessary to make the coner an inch thick. To produce a six-sided shape in the middle, for holding the tool, it is forged of a round or square piece of convenient length, and cut off at the conclusion of forging. If the punch is to be lathe-turned, a holder may be provided; and if the punch is to be only filed, a holder will facilitate the operation. In such cases the handle is forged square, to be firmly gripped in the vice. For a small punch only half an inch thick, the conical portion is easily formed by filing, grinding, or turning; but a large punch may require the cone to be reduced while forging; in this case it is necessary to commence the drawing down with fullers to avoid too much hammering at the extremity of the cone, which often spoils the end by forming cracks and hollows.

Coners for use in wire or wood handles are short and thick, to sustain a sledge-hammering; and all coners, small and large, should be hardened only at the conical end, which prevents the punch breaking while in use, and thereby doing mischief to those around; and after being hardened, the tempering is continued until a dark brown appears. The hardening and tempering of coners, dotters, and scribers is effected by cooling only that length of the end which is to be hard, and allowing the heat which still remains in the adjoining part to temper the hard part to its proper colour. Every coner is improved by curving the extremity that receives the blows, and this should be done several times after the tool has been in use, in order to prevent the end burring over and causing pieces to break off and be scattered around during hammering.

Centre Gouges.—A small gouge chisel for cutting small channels and small centre recesses requires a cutting end only about an eighth of an inch thick; a small gouge of this sort is easily made by grinding and hardening one end of a piece of round wire about a quarter of an inch thick. Centre gouges for gun-metal and iron are tempered to a dark brown, and gouges for steel require the angle of the cutting part to be rather greater than that for iron, but the tool is hardened and tempered to about the same colour.

Fiddling Drills.—A fiddling drill that is to be made of square steel and rotated by means of a drill-bow is about a foot in length, the spindle which fits the hole in the drill-pulley and the drill itself being of only one piece of steel. Such a piece is thinned at one end by a partial reducing on an anvil-beak, and afterwards reduced and smoothed with filing. When the end for drilling is shaped to the form of Fig. 472, and also hardened, it is tempered to a dark brown, the tempering being done with the heat in that portion of the drill which adjoins the part made hard at the first cooling. The other end of the tool is next ground to form the pivot-cone, and this is also hardened, but not tempered. Being thus shaped and hardened, the final operations are sharpening the cutting end and polishing the pivot end to prevent it wearing the breast-plate or other recessed plate that may be used to push the drill into the work.

Another mode of producing fiddling drills consists in making the drill distinct from the remainder of the tool named the holder. By this plan the drill is only about three inches long, and made of round steel wire, the end that fits the holder being made into a half-cylindrical form. A drill end of this shape is denoted by Fig. 473, and one in its holder is shown by Fig. 474. To make such a spindle a piece of steel is selected which is as thick as the boss, this being the thickest part of the tool. The smaller portion adjoining the boss is formed by reducing on an anvil until near the finished dimensions, allowing a sufficient quantity for lathe-turning. The boss needs no forging, unless it were too large in diameter, because its shaping is effected while cold. After forging, the work is centred and smoothly turned to its finished dimensions; after this it is supported in a small coned plate, and the hole for the drill's end is made and slightly tapered with broaching; when thus far advanced, the gap in the boss is made with an edge of a file, being careful to make the depth of the gap about equal to half the diameter of the boss. The end of the drill is next fitted to its place, and the pivot end of the spindle shaped and hardened. Drill-holders of this character are economical, because several drills may be made to fit one holder. No screw is required in the boss, and when a drill is to be taken out it is pushed from its place by gently driving a small wedge between the extremity of the drill and the side of the gap nearest to it. In the Fig. 474, the place for the wedge is shown by W.

Breast-plates.—A breast-plate for drilling is made of thin sheet iron or steel, and is bent to a curved form that it may fit the operator's hand or chest. If a large amount of drilling is to be performed by such means, two holes may be made into the plate to contain ends of strings by which the tool may be tied to the workman's waist. The bearing portion of the plate, which sustains all the friction of the conical drill-pivot, consists of a plate of steel about a quarter of an inch thick; this is smoothly recessed in five or six places, and a couple of holes are bored by which to rivet or screw it to the thin plate. After being properly smoothed, the bearing-plate is hardened, but not tempered; it is next attached to its breast-plate, and the tool is then ready for use. A breast-plate made by such means is shown by Fig. 475.

DRILL-BOWS.—The cheapest sort of drill-bow is that which is made of an ash or hazel stick, which has a thin ferrule tightly fitted to each end, and a couple of holes bored through to contain the ends of the thong or string by which the drill's pulley is rotated. A superior sort of drill-bow is made of a thin piece of sheet steel, in which a hole is bored at each end to hold two hooks for attaching the thong; or the thong may be fastened to the steel without any hook. The thong or band of the drill-bow is an engineer's ordinary band-lace, and should not be twisted, but applied flat to the pulley and occasionally chalked.

BREAST-BRACES.—A light crank-brace for drilling small centre holes and enlarging conical holes in work to be lathe-turned is made of three principal pieces: one piece consists of the circular plate which is to be in contact with the operator's hand, breast, or thigh; another piece is the crank part; and the other portion is the boss that will contain the end of the drill to be rotated with the brace. The boss portion is forged of a piece from the side of which an end is fullered and reduced until small enough to be welded to the crank piece. This crank is forged of straight iron, and the plate is riveted to a couple of small arms, or to a thin flange that belongs to the pivot-bearing, this bearing being that which sustains the pressure while the tool is in use.

The cone-driller shown in the brace denoted by Fig. 276 is provided with either a square taper end or with a conical end to fit the boss. The forging of such a coner is effected with a piece of round steel about as thick as the thickest part of the intended tool, and after being tapered for the hole in the brace, and reduced in the mid-part, the tool is lathe-turned and coned, and also lined to indicate the place for the cutting edge; at this stage the implement appears as in Fig. 476, and to produce the semi-conical form it is reduced until a cutting edge is formed at the centre of the tool's rotation; this edge is shown in the Figure by the dotted lines. The hardening and tempering of a cone-driller is somewhat similar to that for a dotting punch or a drill, and consists in heating the cone, and also nearly the whole of the other portion of the tool, to redness, and moving about in the water until cold that portion which is to be hard; when hard, the cutting end is cleaned to show the colours. For a cone-driller the tempering is effected with the heat in the tool until a dark brown is seen, at which moment the entire tool is cooled in the water to prevent the end becoming too hot, and thereby too soft.

SCRIBER-BLOCKS.—Scriber-blocks, whether of wood or of iron, are made in a great variety of forms, the precise shape adopted depending on the taste and skill of the designer. To make one that consists of a circular or rectangular base plate, and a vertical standard to be fixed to the plate, it is usual to screw a hole in the plate, and to screw one end of the standard to fit the hole. A block of this class is shown by Fig. 477, the pillar or standard being shown distinct from its plate. In the upper part is seen a slot to hold the fixing bolt that tightens the scriber while being adjusted; this slot is made by drilling and filing, and the arrangement for causing the bolt to grip the scriber is shown in Fig. 478. A tall block, which is in the form of an el-square, is very firm on its base if the long blade is of wood and the pedestal of iron or other metal; a wood blade several feet in height may be thus used without causing the block to be unsteady. To avoid inconvenience through the wood blade getting loose in its joint gap, it is necessary to bore a hole through the pedestal and blade, and tighten them together with a small screw-bolt.

VEE-BLOCKS.—The most durable vee-blocks are those of steel, the second quality being those of iron. A couple of vee-blocks that are not required to be very firm on their bases, and may need much handling, may be made light by making them of cast iron or steel, and forming a hollow at each end at the time of casting. Blocks of this form are denoted by Fig. 479. The simplest mode of making vee-blocks consists in forging them to very near their finished dimensions. To do this, the vee-gaps are made while the work is hot on the anvil, and the cutting commences by first punching a hole at the intended bottom of the gap; after this the superfluous piece is cut out with chiselling. When roughly prepared, a paring chisel is required to shape the gap sides and other sides of the work, and the tool is completed by smoothing in a small planing-machine or shaper. Vee-blocks that are smoothly forged or cast need no planing for many sorts of work, the small amount of finishing which is necessary being effected with chipping and filing. When a couple of vee-blocks are required to be very smooth and similar to each other, both are planed together on the table of the machine.

Straight-edges.—The cheapest straight-edge is that made of a piece of hoop iron which is flattened with a tin hammer, and next straightened along its edges with filing; or, if the tool is several feet in length, it is straightened with planing. Those who may be obliged to make a long straight-edge without another for reference, and also without a planing-machine, can use the thread straight-edge shown by Fig. 480. The thin thread of such an instrument is a simple and efficacious standard of reference, and the apparatus may be made of any length to suit the particular straight-edge which is being formed. An iron or steel straight-edge is not liable to rust, if the thin scaly coating on its broadsides is allowed to remain, which presents a better appearance than a rough grinding and filing. In order not to disfigure the scaly sides, it is gripped with leather or wood clamps during the filing of the edges.

Straight-edges that are made with a planing-machine may be produced by forming two at one time by using a strip or plate of steel which is more than twice the width of one of the intended tools. Such a piece is bolted to a few blocks which rest on the table, or on to a couple of long packing-strips that are as long as the steel, the broad side of the steel being upwards. The packing-strips are put near the edges, and thus a clear space is allowed between the table and the straight-edges and along their entire length. When the steel is bolted in this situation, a roughing tool having a vee-point is used to make a cut along the length and in the midst of the steel, and two or three cuts will divide the work into two if it is only about a tenth of an inch thick; but if thicker, a narrow parter is employed to effect the division. When thus cut into two, both pieces are still held with the holding-plates, and in this condition the two contiguous edges are straightened with a sharp springy tool or with a pointed corner tool. During the last cuts, water or soapsuds are applied to the work to produce smooth surfaces. After the two edges are thus prepared, the two tools are released from their plates, and both tools are put close to each other with their broadsides in contact, while the two planed edges are made to rest on the planing-table. The tools are also fixed so that their broadsides shall be at right angles to the table, and this is effected by fastening them to a holder or chuck which has a surface at right angles to the table; to this surface the straight-edges are fixed, and the mode of fixing is by applying poppet screws along the broadsides, and by fastening each end with a holding-plate. While properly fixed, a few light cuts are given to the upper rough edges, which are then made straight, and both tools are made to one width. The next step is to cut the tools into shorter lengths, if short ones are required, and to again divide them along their mid-lengths, if small straight-edges are to be made. After all the planing is done, they are next smoothly filed, and also scraped to make each edge coincide with a surface table of suitable length. During the trial of an edge on a table, a thin layer of oil and soot or lampblack is put on the places which are to serve as standards for the edges being adjusted, and this oily mixture is strained and kept free from filings, dust, scrapings, and other substances moving about. The final adjustment of straight-edges should consist of grinding, and this may be effected by placing two tools together, with their edges in contact with each other and with their broadsides in contact with a table; while thus situated, they are gently pushed together and a few rubs given by moving the tools while in contact. During this rubbing a mixture of the finest emery and oil is applied to the surfaces.

Twist-Finders.—Two straight-edges which are of similar dimensions are named a pair, and if they are also right-angled parallelopipeds, and are thick enough to stand on their small long sides as bases, the two tools are twist-finders. Two such tools are used to ascertain if one surface is inclined towards another, or inclined to some other part of the same surface to which the twist-finders are put. This angular inclination is termed the twist, and to discover it the two finders are stood with their edges in contact with the surfaces that are supposed to have a twisted relation to each other; and while the finders remain in position, an observer stands a few feet from the work and looks across the upper edges of the two tools. If the surfaces that are being tried are either parallel to each other or in the same plane, the upper edges of both tools will appear to be parallel to each other; but if one surface is inclined to the other it is detected by one end of one straight-edge being seen to be too high, and by the opposite end of the same straight-edge appearing too low. This observation is facilitated by whitening the two inner broadsides of the straight-edges, these sides being those that are nearest to each other during the observation. The material for such whitening may be either white paper stuck to the tools, paint, soft whiting, or other white substance which is near.

Twist-finders differ from other straight-edges in being much thicker, and therefore too heavy for general use; but the planing and finishing are managed in a manner similar to that for other straight-edges. When it may be necessary to use two thin ones as twist-finders, they are made to stand with packing-blocks that are narrower than the straight-edges, in order that the observation may not be obstructed by the blocks being too high. The blocks are put close to the broadsides of the tools, to make them stand without other fastenings.

Straight-edges that are to be made into measures by marking lines upon their broadsides, are smoothly polished, and the marking is effected either with a straight-line dividing-machine, a machine having a fine micrometer screw, or by means of some other ordinary screw. Machinists who may be obliged to make a few measures instead of buying them, effect the marking with the screw of an ordinary lathe for screw cutting. With this object, the broadsides are first marked with three or four lines along the entire lengths of the tools, the lines being at different distances from each other to distinguish the shorter divisions from the longer ones. These long lines are made with a planing-machine and a sharp pointed springy tool; after which the straight-edge is fastened to a table of sufficient length attached to the side of the lathe farthest from the operator. The table being connected to the carriage allows the lathe-screw to move the straight-edge along the lathe. After the tool to be marked is properly adjusted to place the edge parallel to the length of the lathe, a sharp vee-tool, or other scriber is attached to a small tool-holder that may be connected for working by the lathe, or the tool-holder may be merely the usual upper slide of the rest that may be moved to and fro by the operator's hand. The screwing wheels for moving the tool may be only two—one having eighty teeth to be put on the lathe screw, and a small one having twenty teeth for a stud in the slot; these wheels being suitable for a screw having a half-inch step. It is not necessary to connect the wheels with the lathe spindle, the small wheel being rotated by an assistant during the process. If sixteenths are required on the tool, the small wheel is moved half a complete rotation at each mark, which advances the straight-edge a sixteenth of an inch; and if thirty second parts are desired, the pinion is moved only a quarter of a revolution each time. In order to cause the pinion to advance the proper number of teeth, a stop is put to the space between the two proper teeth, which are plainly marked at the commencement. If nicety is required in the marking, it is necessary to select a lathe whose screw is accurate, and with a screw-nut of great length, also having screwing wheels with teeth properly made. After all the marking is performed, the measure is adjusted by filing the extremities to the marks, if it is desirable to thus place the marks at the edges; if not, any required length is allowed to remain beyond the marks which constitute the measure.

CONSTRUCTION OF SQUARES AND PLATTENS.

EL-SQUARES.—An el-square having arms of equal thickness and width, is made of a piece of sheet steel; this is marked to show the place of the intended square, and afterwards heated to redness a few times to be cut out with chiselling. A pedestal square requires to be made with fullers, if both arms of the tool are to be of one piece, but if of two pieces, the only forging which is necessary is the reducing and cutting to length of the blade and pedestal as two straight pieces, these being afterwards made into a right angle by means of drilling, filing, and riveting; and if forged too large, planing also is necessary. To forge a square of only one piece, a piece of steel is selected which is amply large enough for both blade and pedestal, and in most cases it is convenient to forge the square at one end of a square bar, and when partly made, to cut off the tool to be separately finished. After this the smith reduces and shapes another square of the same bar, if more than one are wanted. The fullering commences at a short distance from one end, a pair of top and bottom fullers being applied to make two hollows opposite each other, as in Fig. 481; the work is next bent at the hollows, and with bending, portions are squeezed up opposite the hollows, this place being the intended inner corner of the square. During the angling, the squeezed-up parts are chiselled off to promote an easy bending, and the work is made to resemble Fig. 482; when sufficiently angled to produce the right angular form, the short end is upset to make the outer sharp corner; fullers are next driven from both sides of the blade, and the work appears as in Fig. 483; after this the lump for the blade is thinned and cut to its intended length.

Another mode of making a pedestal square of one piece, consists in first bending the bar without fullering, to make it resemble Fig. 484; it is then upset by hammering the short end, in order to square the outer corner; this operation makes it resemble Fig. 485, and at this stage fullers are driven in to commence the reduction of the lump for the intended blade; this fullering is shown by Fig. 486; after which, the tool is completed by lengthening the blade to its proper length and trimming off the superfluous metal.

To avoid a lengthy reducing of metal when a large square is to be made, soft steel which will partly weld may be used; of such metal a thin piece for the blade is selected, and a thicker piece for the pedestal, both pieces being of the intended finished dimensions of the square. At one end of the pedestal a gap is made with chiselling, and punching, if necessary, and into the gap the blade is put; a square rivet-hole is next made through both pieces, and a rivet put in. When thus prepared, the joint is heated in a clear fire to welding, and the welding is effected with a few light blows. A joint thus made will not be solid, but if the mouths of the hole are coned, and a rivet made to fit, the blade will be securely fixed, which is the principal consideration.

An el-square which is to be made of two pieces without forging, is united by means of a joint-gap that is drilled and filed. The blade is securely fixed to its pedestal either by means of a square rivet-hole and rivet, or by means of three small wire rivets. The holes in the pedestal are deeply coned at the mouths, and the rivets are of soft steel; these are properly riveted by hammering the centres of the ends first with a ball face, and finishing with a flat face, and when all the conical recesses are filled, a good joint is the result. To shape the square after forging, it is planed and filed, or filed only, if but little metal is to be taken off. A square thus made is denoted by Fig. 487.

Tee-squares.—A tee-square which is made of two pieces, consists of the blade and its pedestal, and in this pedestal a gap is made in the mid-part to contain one end of the blade; such a gap is shown in Fig 488, and the blade is denoted by Fig. 489. The two pieces are first securely riveted together, previous to adjusting the tool, as in the making of other squares; and if the blade of a tee-square is straight and parallel, and the gap exactly at right angles to the length of the pedestal, both blade and pedestal may be reduced to very near their finished dimensions previous to riveting together.

To forge a solid tee-square of one piece, a piece of steel is provided which is twice as thick as the intended pedestal; the steel is first fullered and reduced at both ends to form a lump in the mid-portion, at which time the piece resembles Fig. 490; the lump in the middle is next fullered either at both sides or one side, to commence the reduction to form the blade; if fullered at both sides to cause the blade to extend from the middle of the pedestal, instead of from one side, the work appears as in Fig. 491, but if the blade is to be in the same plane with one side of the pedestal, the lump is fullered at only one side. After this operation, the fuller is also driven in at right angles to its former position, in order to make two other hollows at right angles to the two or one first made; and when thus hollowed, the piece for the blade appears to be united to the pedestal with a square neck, as seen in Fig. 492; while in this condition the thinning and lengthening of the lump is commenced, and when partly reduced to the required size, the fullers are again driven in a short distance, after which the thinning of the blade is again resumed, and by such reducing the blade is made of a sufficient length.

A tee-square may be forged also by using a thick bar and forming a stem at one end, as seen in Fig. 493. After this stem for the blade is produced, the entire piece for the square is cut from the bar, and the thicker part is spread and lengthened at each side of the stem first made to form the two arms of the pedestal, this lengthening being effected with hammering on the anvil, and also by hammering the pedestal while the blade extends through the hole in a heading-tool having a square hole. By these means the pedestal is first formed; after which the stem for the blade is fullered and then lengthened to its dimensions.

A centre finder, which consists of a tee-square having two pins extending from one side of the pedestal, is made of either one or two pieces; and when roughly made into a square, the two pins are fixed by screwing them tight into two screwed holes made entirely through the pedestal. The screw-parts of these pins are larger in diameter than the straight-ends which are to project outside, and the holes are also tapered to allow the screws to be riveted after being screwed into their places. In order to place the pins at right angles to the length of the blade, and in their proper places, an arc is marked upon one side of the pedestal. When the centres of the pins are to be equi-distant from the centre length of the blade, an arc is exscribed from the centre shown by C, in Fig. 494; and when the centres of the pins are to be equi-distant from one side of the blade an arc is exscribed from the point denoted by P, in Fig. 495. In both these Figures the two places in the mid-line of the pedestal that are intersected by the arcs are the places for the holes, and indicated by H and H. These places are marked with a dotting punch, and from the dot a small circle is marked which is about a sixteenth larger in diameter than the hole to be drilled. This small circular line is a guide or sort of indicator during the entrance of the drill's point, and if the workman observes that the drill is nearer to one extremity of the circle than to the opposite extremity, he takes out the drill when it has entered only a short distance, and endeavours to put the drill point into its proper place. This is effected with a gouge chisel, which the operator drives in at that side of the recess towards which the drill's point should be brought; by this means the chisel cuts out sufficient metal to make the drilled recess concentric with the small circular line, at which time the drilling is resumed and watched, and, if necessary, the gouge is again applied as before. By this method the holes are made very near to their required places, and when drilled, screwed, and the pins are tightly riveted in, the entire tool is smoothed and adjusted to make the length of the blade exactly at right angles to a line which connects the centres of the two pins. This final adjustment is effected with filing and scraping both the pins, and also the blade and pedestal; for this reason the two pins are thicker when put into their places than they will be when finished, in order to avoid taking a large quantity from the blade or pedestal.

Cross-squares.—A cross-square is made by forging two separate pieces, one being the blade and the other being the thick shoulder-piece, or pedestal; this portion is forged solid, and with a flat-sided lump in the middle, in which the small slot is to be made for the blade. A piece of this form is shown by Fig. 496, and through the lump having a flat side instead of a curved one, the piece can be firmly placed while drilling the slot. The drilling is effected by advancing the drill to about half way through from both entrances; and after the drilling and filing is performed, the lump is curved to a semicircular form, and the blade is tightly fitted to its plate. While the blade is thus fixed, both pedestal and blade are adjusted to place them at right angles with each other, and also to make the length of the pedestal at right angles to the slot; consequently, the slot and blade are finished previous to finishing the shoulder of the pedestal.

Adjustment of Squares.—The adjustment of squares of various classes is effected with scraping and by reference to right-angular blocks, to lines, and to other squares which are used as standards. To try an el-square by means of a surface-table and blocks, the tool is stood on its pedestal, with the blade in contact with a side of a right-angular block that rests on the table; a square in this situation is seen in Fig. 497; and if no light can be seen between the blade and the block, the outer boundary of the square is right angular. To try the inner boundary, the tool is suspended by its pedestal on a block, as shown in Fig. 498; and by placing two blocks near each other, with the blade between and in contact, it is known whether the inner and outer edges of the blade are parallel to each other, and also which of the two edges may need adjustment to make both edges at right angles to the pedestal; this arrangement is shown in Fig. 499. To discover if the two broad sides of the blade are parallel to each other, straight, and also at right angles to the pedestal, the pedestal is tightly held on one block while the blade depends between two other blocks that almost touch; a square in this position is denoted by Fig. 500.

Tee-squares are adjusted with a pair of blocks that are of similar shape and dimensions; these are stood near together, and the tee-square is put with its pedestal on both blocks and its blade hanging between; while thus situated, either one of the edges of the blade may be tried, and it may be known whether both edges are parallel to each other, and also at right angles to the pedestal. A tee-square being tried in this manner is indicated by Fig. 501. It is also necessary to ascertain if the broad side of the blade is square with the pedestal; for this purpose the tool is put with the entire length of its pedestal bearing on one block, with the blade extending downwards, and the broad side at a short distance from the block; while in this condition it appears as in Fig. 502. In order to discover whether the outer side of the pedestal is at right angles with the length of the blade, the tool is stood on the table with the blade extending upwards, and one arm of the pedestal extending into a gap in a block which is put into close contact with the blade's edge; this block is shown in Fig. 503 with the square's blade in contact.

The adjustment of squares by means of lines is effected on surface tables. A table is selected having a surface about two or three feet across, on which are marked several gauge lines at right angles to each other and to the edges of the table's surface; these marks are very narrow, but deep, and are made with a scriber having a hard thin point. If all the four small sides, termed edges, of the table are at right angles, any one edge may be selected from which to exscribe lines that shall extend across the surface and be at right angles to the selected edge; but if all are not at right angles, the surface is not rectangular, and one edge, or small side, is selected for the marking. This edge is specially smoothed, planed with scraping, and also made at right angles to the table's surface, which is the face. This edge is that to which the pedestals of squares and other tools will be put when they are to be tried. When the lines are to be marked, the planed edge, which is the true edge, is used as a sort of standard, or base, from which to exscribe the gauge lines, and the principal gauge line is one which is at right angles to the true edge, and extends across the table's face somewhere about the middle. This one line is represented in Fig. 504; this Figure denotes a platten, or table, whose gauge line is marked by merely placing a large square to the true edge, and scribing a line along the edge of the blade on the table's face. Several other lines may be marked parallel to each other, and by means of the same square, if necessary. This mode of making gauge lines is effectual with a good square, but to place the line at right angles to the true edge, when a large square is not comatable, a scriber-block and straight-edge are necessary.

To mark the line or lines at right angles to each other and to the true edge, by means of a scriber-block only, it is necessary that the true edge of the platten be at right angles to one of the edges that adjoin; if the platten were thus right-angled when it was made, the marking is quickly effected by placing the platten to be marked upon another platten, or table, and scribing with a scriber-block. This is performed by placing the work edgeways upon the table, and scribing a line along at about the middle; after this, the table being marked is stood upon its end which is square to the side that was first lying on the table, and while standing the across line is marked with the same scriber-block, or with another taller one, if required. While the platten to be marked is in these two positions, several lines parallel to each other may be scribed by raising or lowering the scriber's point to various heights above the table used for scribing. The scriber-block for such purposes requires a firm, heavy bottom, in which is cut a shallow recess about a sixteenth deep, to prevent the block canting and rocking while being moved along.

If only one small side or edge of the platten is true, the scriber-block is only useful to mark a line or lines parallel to the true edge; all other lines at right angles are marked with compasses and straight-edges. This marking is commenced by placing the true edge in contact with a table's face, and using a scriber-block to mark a line along the face to be marked, and near the middle; this line is the primary from which others are exscribed, and is denoted by No. 1 in Fig. 505. To mark a line at right angles to the primary one, and across the middle of the face, it is only necessary to make with a dotting-punch a dot at each end of the primary near the edges of the surface, and scribe a perpendicular to the primary by means of the dots as centres; this is done by using a sharp compasses, or large divider, and placing one point into one dot, and scribing an arc near the middle of the face; one compass point is next put into the other dot, and another arc is scribed to intersect the first one in two places; these two places are points in a straight line which is at right angles to the primary, and to mark the line a straight-edge is put to both intersections, and a scriber is moved along in contact. When this line is shown, it becomes a sort of standard to which the blades of squares are put while their pedestals are in contact with the true edge of the table. The dots, arcs, and straight lines should be allowed to remain in the table's face, in order to indicate at any future time whether each arc and line is correctly scribed; and the numerical order in which the dots and lines are scribed is denoted by their numbers, the first one being the primary, and the sixth one being the primary's perpendicular. If several other lines are required to be made across the primary, they are marked by exscribing arcs from any other dots that may be made in any other places along the first line. Fig. 505 denotes the appearance of the table, but Fig. 506 indicates merely the table's face and the actual relative positions of the lines.

A square may be tried also without any standard right-angular lines whatever, and also without marking any line on a table's surface. With this object a strip of thick white paper may be stuck to a table's face with thin white lead, boiled oil, or paint, and on to the paper the blade of a square is put while its pedestal is in contact with the true edge of the table; while thus held a line is marked on the paper with ink, or with a fine pencil point, along one edge of the blade; the square is then put upside-down, and with the same edge of the blade touching the line just made; while in this situation the observer looks to the blade's edge and to the ink line, and if both coincide while the square's pedestal is held tight to the table's edge, the edge of the blade is square to the pedestal. In order to try the other edge of the blade, a line is marked along it as for the other edge, and the square is put upside-down, with the same edge near the line, similar to the first marking. If the tool is far from correctness, it is necessary to mark a second ink line upon the paper, and this is done by placing the square's pedestal to the table and the blade to the line on the paper, so that one point in the blade's edge just coincides with one point in the line, and when fixed a second line is marked along the edge of the blade, and the second line will coincide with the first only in one point, while the greatest distance between the two lines indicates twice the amount of adjustment necessary for the tool.

A bisector which consists of a tee-square having pins projecting from its pedestal is tried by placing the pins into contact with the true edge of a table and marking lines along the blade's edges, similar to the mode for trying other squares. It is also necessary to try the bisector by placing its blade across rings, and the ends of cylinders, or pieces of round iron of several sizes, and to adjust the pins with filing, so that they may be both of one shape and circular. To try the edges of the blade and pedestal, the bisector is put upon right-angular blocks, and the light is observed between, as in the method for trying other squares.

During the scraping for adjusting squares and other angular gauges, it is necessary to properly prepare the inner corners; these are the junctions of the blades with their pedestals, and require to be hollowed, which facilitates the final adjustment. Such a hollow is very small, and is made by gently driving a sharp chisel edge into the corner, and then scraping off the burs which are raised up by the light hammering. The chisel for this purpose has a small cutting end only about as wide as the small side of the blade termed the edge. When a square needs much scraping near this inner corner, the small indentation becomes lost, and in such cases the chisel is again required to make another small hollow.

Angle-Gauges.—The two classes of angle-gauges now mentioned are those which are made of only one piece of steel, and those which are jointed and consist of two or three pieces for each gauge. To make one of a single piece of steel, the tool may be formed either by bending or by cutting the gauge from a piece of sheet steel. If it is to be made by bending, the piece selected is a small bar which is thicker than the intended arms of the gauge, and bent while thick; it is next reduced in order to thin and lengthen the arms to the proper length. When the gauge is to be made of a piece of sheet steel, the metal is marked while cold, and next heated to redness a few times to be cut out with chiselling on an iron block.

The angle-gauges termed hexagon gauges subtend an angle of one hundred and twenty degrees, and to adjust the arms of a gauge to this angle a circumference should be scribed and intersected in three places. A circle's circumference for this purpose is indicated by Fig. 507. In order to indicate the required angle, a circumference is scribed upon a plane surface, and with the same radius the circular line is cut in three places, which may be those shown in the Figure; a straight-edge is next put near to the point P and to the next place of intersection and a straight line marked, after which the adjoining straight line is marked by placing the straight-edge to the next point of intersection; these two lines are made of any length to suit the work and subtend the required angle of one hundred and twenty degrees.

Those gauges that are jointed are represented by Fig. 508, and are made with a thick shoulder-piece or pedestal, in one end of which is a joint-gap containing one end of a thin piece, which is the blade. The joint-gap is made with drilling and filing, the drilling being commenced at that place which is to be the bottom of the gap. The joint-pin for attaching the blade to its place may be either a rivet which is riveted tight enough to prevent unintentional shifting of the blade, or a small bolt, nut, and washer, the nut being a thumb-nut, that it may be easily worked with a finger and thumb. Of these two fastenings the rivet is most effective and simple, although not ornamental. The rivet-holes in such a gauge should both be coned, and the rivet while in its place should extend an eighth of an inch from each side of the pedestal; such a length will allow the blade to be tightened at a future time after becoming loose, and allow the burs made with riveting to be filed off. The only adjustment which jointed gauges require consists in making the blades and pedestals straight and rectangular, and filing the gap-sides parallel to the pedestal; if this is done, the broad sides of the blade will be parallel to the broad sides of the pedestal when both are riveted together.

Angle - Measurers. — An angle - measurer which consists of a semicircular tool having degrees of arc marked on it, is made of either sheet brass or sheet steel. If to be of brass, Muntz metal is suitable, which is cut while cold, a piece about a sixteenth thick being selected for an instrument about three or four inches in length. The marking to indicate the shape of the tool is commenced by scribing a straight line along one side of the piece, and at about an eighth of an inch from the edge; this line is made to serve as a base for a semicircle, which is scribed by means of a centre dot situated about the middle of the line, the dot being marked by C in Fig. 509. The radius with which the first semicircle is scribed is about a sixteenth longer than the radius when the tool is finished; consequently, if cut at this line, ample metal is allowed for filing. Previous to cutting, another semicircular arc is scribed to denote the smaller or inner boundary which will surround the space in the middle of the tool; the length of this arc is rather less than that of the finished length, and the base or chord of the arc is a line parallel to the line first made, the distance between these two straight lines being the width of the straight part of the tool. This portion is termed the straight-edge, and the outer straight side is termed the true edge or base of the implement. After the shape is marked, the sheet is put upon a soft iron block and fastened with one or two screw-clamps to hold it while being cut, the cutting being effected with a sharp chisel and hammer; the piece in the middle is first cut out, and afterwards the superfluous pieces which surround the intended tool, except the superfluous eighth of an inch which adjoins the intended true edge. In addition to this piece, another small piece may be allowed to remain at the opposite side, such pieces being useful as holders or handles while marking and finishing the broad sides of the instrument.

To make large tools of this class it is necessary to cast them in sand moulds, which are shaped by wood patterns that are very nearly of the finished dimensions and shapes of the required implements. Two or three holders are provided, as for smaller work; but large ones are planed on a machine, after which the straight lines are marked to indicate the portion termed the straight-edge, and the semicircular lines are scribed to the desired length. While in this condition the edges are shaped and the angle-measurer is made ready for the marking of the degrees.

A steel measurer of this shape is made of a piece of sheet steel, which is marked, while cold, in the same manner as for making one of sheet brass; and, when marked, the steel is heated and chiseled to its proper form, being careful to drive the chisel about halfway through at all the marks previous to cutting any part entirely through. When it is entirely forged and trimmed it is softened by slow baking, and next ground on a grindstone, which prepares the tool for filing and smoothing.

A large angle-measurer, intended to be about three or four feet long, may be made of two pieces of a hard tough iron. The metal selected consists of a bar or bars about as wide as the straight-edge portion of the intended tool. Two pieces are required, and are welded together, one of which is long enough to be curved to form the half-round portion, and the other piece being sufficient for the straight portion. This straight piece is upset for scarfing at each end, and also upset along its length; by this means it is made shorter than its finished length; the curved piece also is upset, and both are welded together by two joints which are situated at the two corners of the implement. When the joints are finished, it is stretched to its shape and dimensions by hammering and with a flatter. During this shaping, the work is put to a diagram on a table; this diagram is a full-dimensioned outline of the tool's broad side, being about an eighth of an inch longer and wider than the work when finished.

In order to tightly hold thin tools of this class and other work of similar shape while filing their broad sides, they are held by means of screw-clamps on a wood or iron table, pieces of plate iron and leather being put under the screw-points to prevent injury to the work. Marking the degrees of arc is not done till the broad sides are smoothed, if not polished. To mark an angle-measurer without a machine, only a divider, straight-edge, and scriber are necessary, and the marking commences by making a small centre dot, termed the primary centre, in the middle of the outer straight line. From this dot two or three semicircular arcs are exscribed to distinguish the longer from the shorter divisions to be marked. At each place where one of the semicircular arcs intersects the outer straight line, another dot is made, and into one of these a divider-point is put and the legs adjusted to a radius which will scribe a short arc at a short distance beyond the ninetieth degree; another short arc is next marked with the same radius by putting one point into the dot at the other place of intersection and scribing across the arc first made; at the point where the two short arcs intersect is the ninetieth degree, and to this point and the primary centre the straight-edge is put to scribe a straight line across the instrument. The divider is next closed to the same radius which scribed the semicircle, and while thus adjusted the entire semicircular line is divided into six equal lengths, which represent thirty degrees each. These portions are next divided into three parts of ten degrees each, and afterwards each of these is bisected to make each division represent five degrees. One more bisecting process will produce marks for each two and a half degrees, which is about as small a quantity as can be marked by these operations. Such dividing processes are in daily use among engine-makers, but the accurate marking of degrees is always effected in proper arc-dividing machines.

Ring and Plug Gauges.—Cylindrical gauges of this character are made of good iron which is hardened, or of steel which is not hardened. To make them of steel without hardening is the cheapest plan; such a course avoids the tedious grinding and filing after the gauges are swelled or injured in some other manner during the usual hardening processes. When it is intended to make them of iron, the metal selected should be a hard crystalline iron, which has been thoroughly welded and hammered to erase all appearances of cracks, sandy streaks, limy and other earthy accumulations, these rendering the metal unsolid and unsuitable for such gauges, although it might be of excellent quality. The proper metal being selected, the forging of the plugs commences by heating in a clean fire and steam-hammering a rod or bar and welding it with rounding tools having angular gaps, in order to close the particles. After the iron is thus prepared the plugs are roughly shaped while attached to the bar, each one being made singly and cut off to be afterwards separately trimmed to the proper form. A plug thus shaped and ready to be cut off is shown at one end of a piece denoted by Fig. 510. Previous to forging, it is often necessary to consider the sizes and conveniences of the lathes that are to be used for the turning; in small four or six inch lathes one plug is easily turned without any additional handle, but if a large lathe is to be used for small plugs they are forged with handles which are solid with the work, and so remain until of no further use, when they are cut off in the lathe. For some lathes two plugs may be forged with their handles solid together, as shown by Fig. 511; these are turned while together, the cutting apart being the final process. The convenient method to suit most lathes is to forge the holder at the cylindrical end of the plug, as indicated in Fig. 512; by this arrangement the necessity for gripping the cylindrical end of the gauge is avoided. Steel plugs are forged with similar holders, if required, a cheap close-grained cast steel being selected for the purpose.

The forging of the rings is effected by two principal processes, whether the metal used is iron or steel. One process is suited to all small rings not exceeding two inches at their outer diameters; these are forged by cutting slices from a rod of solid close-grained metal, and afterwards cutting off the rugged portions near the centres of the intended rings. The other process should be resorted to for making the larger sizes; these are produced from slices or properly welded cakes, that have holes made in their middles, and are finished separately on a mandril which is of the same diameter as that of the intended hole when forged. In such a ring the hole is first made with a punch, and afterwards enlarged with taper drifts. If the ring being made is of iron, a welding heat is given to the work after a hole is made, and the ring is welded with a hammering given to its entire surface, by which it is rendered solid, and any injury that may have resulted from punching is remedied. To punch steel, a round punch having an oval cutting-end is used, that the punch may gradually enlarge the hole from its original form of a slit, indicated in Fig. 513, to the desired circular shape. After punching, the hole is drifted until of sufficient diameter to admit the mandril's end which is to hold the ring while being hammered for stretching or welding. The final forging of the ring consists in cutting off superfluous pieces, and curving the outer circumference termed the edge, and this is done with half-round top and bottom tools; after which the ring is softened for turning, by allowing it to cool slowly in cinders.

Plug-turning.—The lathe-turning of the rings and plugs is effected by several methods, the mode selected depending on the quantity in progress and their dimensions. Plugs that are about a quarter or half an inch in thickness are turned of steel wire, without any forging being necessary. For such plugs the wire is cut into lengths, and their extremities are flattened to admit the centring process; this is effected by the aid of a couple of vee-blocks and a scriber-block, which are used on a table, as shown by Fig. 383. When the intended plugs are centred and drilled, they are separately turned with a small lathe and slide-rest in which is a vee-point tool. All the plugs are thus roughly turned to nearly their finished diameters, and are next smoothed to their proper dimensions with a springy tool and soapsuds. These diameters are not the finished diameters, but are larger, each plug being turned to fit a special gauge-hole, which is of a suitable diameter to allow a proper quantity of filing and grinding the plug to finish it.

Plugs about an inch or two inches in thickness, that are to be finally hardened, are also hardened at the commencement of the turning, after about a sixteenth of an inch has been turned off the entire surfaces of the plugs. After this hardening, they are again softened by gradual cooling, and next turned to their proper diameters for grinding. To turn a large number of plugs expeditiously, they are roughed in one lathe, smoothed with a springy tool in another lathe, and ground to the finished thickness in a third lathe. Cutter-rings also are useful to roughly adjust a number of plugs to one diameter. A cutter-ring or cutter-socket is a piece of steel which resembles an ordinary six-sided nut, having a number of cutting edges formed in the boundary of the hole. This hole is rather taper, and the cutting teeth are made by rifling, which consists in making coarse-thread grooves into the boundary of the hole while the ring is fixed to a chuck of a screw-cutting lathe. After the teeth are sharpened and hardened, the tool is used by slowly forcing it on to a plug or other piece of work which has been turned to allow only a small quantity for the ring to cut off. The cutting is effected by rotating the work in a lathe, and slowly advancing the ring along without allowing it to rotate; consequently it is held with a spanner, or some other kind of frame which may be fixed to, and made to traverse along with, the lathe-carriage. A cutter-ring of this class resembling a nut, is denoted by Fig. 516.

Plugs and other short pieces of work of similar character may be conveniently turned with a double lathe, similar to that represented by Fig. 528. Such a machine resembles two lathes having short beds which are together in one casting. On the bed are two mandril frames and two poppet-heads, each lathe-spindle being actuated by a driving band and starting apparatus which is distinct from that belonging to the other spindle. Each half of the machine has also its slide-rest and traverse gear, so that one can be worked quicker or slower than or without the other. When a piece of work of great length is to be turned, the two middle heads are taken from the bed, and the two traverse gears made to serve as one; by this means the entire length of the bed is always in use, and the affair is therefore economical for a great quantity of small work when only a few lathes are accessible.

Plugs whose diameters are three or four inches require holes to lighten the tools without impairing their efficiency. These holes are bored to about the lengths of the cylindrical parts, and the boring is partly done at the commencement, after the outer surface is roughly turned. The boring or drilling is effected either with a coned plate on a lathe or with a drilling-machine. All the large plugs are easily bored roughly in a vertical driller, and, after being bored by some means, the hardening is the next process to the first boring. When hardened, the plug is next softened, and again bored smoothly, and this time to the finished dimensions. The diameter of this hole is about half the plug's diameter, and is useful for turning the outside of the plug, which is done either by driving a spindle tight into the hole and fixing a gripper to the plug, or by allowing the edge of the hole to rotate on a large conical pivot.

Ring-turning.—Making small gauge-rings about an inch or two inches in diameter is performed by boring holes into well-forged cakes of steel while attached to a lathe-chuck. The chuck is a dog-chuck or grip-chuck, consisting of a disc-chuck having a pair of angular grips connected with one screw. This screw is a spindle on one half of which is a right-hand screw for working one of the grips, and having on the other half a left-hand screw for moving the other grip; such a screw is fitted to the disc-chuck, and rotated for fixing and unfixing the work by means of a spanner which fits both ends of the screw. Such a screw by being rotated will move both the dogs in opposite directions at the same time, so that when a piece of work is between the dogs, it is fixed or unfixed by merely placing the spanner to only one end of the screw and rotating it. Chucks worked with right and left screws, are of several sizes, and have dogs of various shapes. One class of these are denoted in Fig. 540, in which a right and left-screw chuck is shown, that is suitable for boring gauge-rings and a large number of rings for other purposes. When used for gauge-rings, each ring is first bored while in the chuck to a diameter which is smaller than the finished diameter; they are next turned on an arbor in some other lathe to reduce them to the proper thickness and outer diameter; after this they are again fixed to the same lathe-chuck, or to some other lathe, and the holes are finally bored with a slide-rest tool and water.

The turning of gauge-rings about four or six inches in diameter is performed in a manner somewhat resembling that for smaller ones; and if to be hardened, it is done next to the first boring and turning of the entire surfaces. After being softened for the second turning, the outer sides are finished while on an arbor; consequently, while fixing each ring to the chuck to be finally bored, the outside of the ring is made to rotate exactly concentric with the lathe-spindle or with the outer edge of the chuck. This concentricity is termed truth; and when a certain edge, rim, side, or other portion of a piece of work rotates concentric with the lathe-spindle, the particular edge or rim runs truly. If a right and left-screw chuck is used for boring large rings, a couple of fastening-plates and bolts are required to hold the work, in addition to the two dogs. While thus held, the hole is finally bored with a slide-rest tool, and also, in some cases, finally ground to the finished diameter while still in the dogs.

In order to avoid much of the lathe-boring with slide-rest tools, it is proper to enlarge the holes in the rings by means of a drilling-machine when a large quantity of metal is to be taken out. The drill used for this purpose is usually a cylindrical one having a few cutting teeth at the end; such a drill is termed a rosebit, and is represented by Fig. 517. This tool is specially adapted to vertical drilling-machines, but is also sometimes used in a lathe, to avoid taking out several cuts from a ring or boss, and also to roughly adjust a number of holes to one diameter without the need of measuring. A rosebit in use in a lathe is shown in Fig. 540, being supported at one end with the poppet-pivot. A rosebit is not used until the hole is truly bored by some other means; and when a proper quantity has been taken out, the rosebit is used to avoid boring with a slide-rest tool, or to finish the hole to the diameter desired. If a rosebit is employed to bore a steel gauge-ring, a plentiful supply of oil is given to the tool while the work rotates; the oil at such times is poured into one of the oil-channels of the rosebit, by which means the oil travels to the cutting teeth of the tool. During the rotation of the work, the rosebit is held by a spanner which fits the square head of the tool next to the poppet-pivot. In the Figure the long end of the spanner is shown in contact with the carriage, and to advance the tool into the work the operator rotates the poppet-wheel, which advances the poppet-cylinder, and, consequently, the rosebit in contact.

Grinding Rings.—The final adjustment of the hole in a ring, whether soft or hard, must be effected by grinding. When a ring is to be ground with the same lathe in which it was bored, the ring is allowed to remain in the same condition fixed to the chuck, and the grinding-tool is fixed to the slide-rest in the same manner as a boring-tool. The grinder for rings is a long slide-rest tool having a lead or wood boss attached to one end, this end being put into contact with the surface to be ground while the other end is tightly fastened in the slide-rest tool-holders. The grinder is quickly moved to and fro in the hole by means of the lathe-traverse, and is made to bear either tight against the work or gently, by working the slide-rest screw. While moving to and fro, a mixture of emery and oil is applied to the grinder, and only the smaller sizes of emery are used. For each size of emery a separate grinder is required, which is one means of preventing irregular scratches in the work. The smallest emery, termed flour emery, is not necessary for adjusting to the required dimensions, but merely for a final polishing; the larger sizes of emery are therefore useful to quickly adjust the work, and the flour emery to smoothe it.

While adjusting a ring to its finished dimensions a standard gauge is necessary, and this is not the plug which is to be used with the ring, but another of the same diameter, and to this plug all the rings of one size are ground. By such means a number of rings may be made of one diameter, and all will be of the required diameter if the standard is right; but when each ring is made to fit merely its own plug, all are of different diameters, and all may be either too large or too small. The standard plugs used for such measuring should be hard, to avoid much of the tendency to wear, although steel ones that are not hardened may be employed and used for several years, if in the hands of proper workmen.

Grinding Plugs.—By means of springy tools and soapy water, also a smooth filing, a plug, whether a small one or a large one, may be nicely smoothed to fit the proper hole which allows the necessary quantity for grinding the plug to its final diameter. Only by care in the turning can the grinding be effected with some degree of comfort, and without a great consumption of time. To facilitate the making of a large number of plugs, it is usual to perform the grinding with a lathe specially adapted to the purpose. Such a lathe requires no gear for slow movements, nor any delicately finished machinery that would be injured by the emery falling about. The tools that belong to such a lathe consist of cans or boxes having lids to contain emery of two or three sizes—a reservoir of oil and emery, which is suspended so that the mixture may run easily to the work—and a few grinders. A grinder for plugs and other cylindrical work consists of a pair of grips made of lead or wood; these are of various sizes to suit work of various diameters, and each pair of grips are jointed together at the end for grinding, and are held together at the other end with a bolt through a hole in each arm or handle of the tool, Wood grinders of this shape may have two or three grinding gaps, similar to those shown in Fig. 529, and a gap which is too large for the particular work in hand is made to suit the work by placing pieces of sheet lead between the wood and the surface to be ground. The grinding surfaces of all the gaps should be hollowed, to form recesses in which the emery and oil will collect, instead of being quickly rubbed off with the edges of the grips. The process of grinding by such means consists in rotating the plug in the lathe while a pair of grips is fixed tight to the surface to be ground, and while in contact a traversing motion which is parallel to the length of the lathe is imparted to the grinder, by which a smooth circular form is given to the work being ground, and without this movement, together with the rotary motion, a cylindrical form cannot be produced; if the traverse of the grinder ceases only a few seconds, the work is disfigured with circular grooves around the surface, and is in danger of being spoiled. In order, therefore, to continually move the grinder, it is moved to and fro with the hands of the operator, or by means of the lathe-traverse. This traverse is termed coarse, because the wheels are of proper sizes to produce a much quicker movement along the lathe than would be required for turning. The length of the hole in a grinder is about equal to the thickness of the work to be ground, if it is about three or four inches in thickness; but for work about one or two inches thick the length of the hole is about twice the diameter of the work. During the grinding, emery and oil is applied either by a pipe from the reservoir, or applied with a brush by the operator, and the traversing motion is continued to and fro along the entire length of the work, if it is parallel and needs an equal reducing; but if one portion is too thick, while other parts are of the required thickness, the grinder is moved only along the thick portion until sufficiently reduced.

The grinder-frame shown by Fig. 530 is bolted to the saddle or carriage of the lathe, and is provided with a jointed cap in one end of which is a screw-bolt for applying the pressure necessary for grinding. The grinding grips which belong to the frame are of lead, and of various sizes and thicknesses to suit various work, and the emery and oil or diamond-dust are applied to the work through a hole in the middle of the cap. This hole is large enough to hold the end of a pipe belonging to a feed-cup which is put on to the cap when grinding is to be effected. A frame of this class is suitable when a large quantity of reducing is to be effected, which occurs when a plug has been distorted with hardening and requires three or four days' grinding. In order to accommodate the frame to the work when it does not rotate truly, the frame is loosely bolted to the saddle to permit a small movement which effects the accommodation required. A grinder frame which is provided with a joint in the middle may be tightly bolted to the saddle, instead of loosely, which is necessary for a frame without an accommodating joint.

Standards.—A standard measure is any measure that may be adopted as a standard by any individual, whether he makes it himself or purchases it from those whose business it is to make standards. The particular standard rings and plugs selected by any one maker are those which suit his particular work. The standards that he selects to be used for measuring general work, are those of his own make, and several plugs and rings of one size are required in order that they all may be in use at one time when a great number of pieces of work of the same dimensions are in progress. Such gauges are made to resemble the standard which he adopts as his authority, and in England the Whitworth gauges are the standards in use at the present time. These are hard, and therefore not liable to wear with proper usage. Each one has a name that indicates the number of inches and parts in the diameter of its cylindrical portion, and the difference of diameter is the sixteenth, eighth, tenth, and other portions of an inch, as they are usually named. The most useful and universal dimensions for plugs and rings are those differing by millimètres, and of these two Tables are now given. Table 3 denotes the dimensions of the plugs, and in the first column are seen all the names of the plugs, each name denoting the diameter of the gauge; in the second column are seen the total length for each different diameter; the lengths of the cylindrical portions are given in the third column, and the lengths of the handles in the fourth column. In Table 4 are given the dimensions for each ring, the first column indicating the diameters of the holes, the second column showing their heighths or widths, and third column denoting the extreme diameter of each ring.

TABLE 3.				TABLE 4.		
DIMENSIONS OF PLUGS.				DIMENSIONS OF RINGS.		
Diameters of cylindrical portions.	Total lengths.	Lengths of cylindrical portions.	Lengths of handles.	Diameters of holes.	Heights or widths.	Extreme diameters.
Millimètres.	Millimètres.	Millimètres.	Millimètres.	Millimètres.	Millimètres.	Millimètres.
1	20	7	13	1	4	15
2	25	10	15	2	5	18
3	30	13	17	3	6	20
4	35	16	19	4	7	22
5	38	17	21	5	8	24
6	40	17	23	6	9	26
7	45	20	25	7	10	28
8	50	21	29	8	11	29
9	58	25	33	9	12	30
10	64	27	37	10	13	31
11	70	28	42	11	14	32
12	75	30	45	12	15	34
13	80	32	48	13	16	37
14	83	34	49	14	17	41
15	86	36	50	15	18	43
16	90	38	52	16	19	45
17	94	40	54	17	20	48
18	96	42	54	18	21	51
19	99	44	55	19	22	52
20	102	46	56	20	23	56
25	110	50	60	25	28	68
30	120	54	66	30	33	78
35	130	57	73	35	38	88
40	139	60	79	40	43	98
45	148	65	83	45	48	110
50	155	69	86	50	53	122
55	162	75	87	55	58	132
60	170	82	88	60	63	140
65	178	89	89	65	65	148
70	184	94	90	70	67	156
75	186	95	91	75	69	164
80	188	96	92	80	70	170
85	190	96	94	85	71	176
90	194	98	96	90	72	182
95	196	98	98	95	73	192
100	198	98	100	100	74	200

The smaller sizes of plugs have broad thin handles, which are larger than the cylindrical portions, for convenience of holding with a finger and thumb; their rings also are comparatively large; such are represented by Fig. 518. Plugs about thirty or forty millimètres thick have handles about as thick as the cylindrical portions; these are denoted by Fig. 519. The heavy gauges require holes through their handles to hold a lever for moving the plugs and for lifting them; the handles of large plugs are smaller than the parallel portions, and are denoted by Fig. 520.

In order to allow the rings to be easily and quickly tried upon the work which is in progress, the entrances to the holes are curved and smoothly polished; both ends of the hole are thus treated to permit the ring to be placed either way first on the work being tried. Each plug is also curved at the end, for effecting an easy entrance into the gauge ring, and for entering any other hole for which the plug may be used as a standard. To properly use ring and plug gauges it is necessary to make the surface of the work to be measured as smooth as possible previous to trying in the plug or trying on the ring; if the work is not smooth, it cannot be measured with any gauge whatever. Those who are particular in the management of cylindrical gauges keep them oiled with good oil, and in a box free from dust; and every time a plug or ring is to be put to a piece of work, both the work and gauge are first cleaned with a clean cloth, and then oiled with clean oil.

Surface-plates.—A small surface-plate about three or four inches across is easily made of steel, and forged instead of cast. After the steel is cut to its length, it is trimmed with a chisel, to prevent the rugged pieces being hammered into the work; and after a smoothing with a flatter and a softening with slow cooling, the plate is ready for planing.

Where a steam-hammer large enough is on the premises, it is advisable to forge the larger plates also, and the material used should be a cheap cast steel, which is now attainable. By forging a large surface-plate all risk of making a spongy casting is avoided. When a plate is to be made by forging, the steel should be cast in a mould about the same shape as the intended forging when finished, but it should be larger, to admit a steam-hammering; this hammering is given as soon after the pouring as convenient, to avoid the reheating in a furnace. Surface-plates require a granular or crystalline form for the particles; so that only a small amount of hammering is given to the work, the amount being sufficient to condense the mass without producing fibres.

Surface-plates and tables of several feet in length and width are cast to their intended shapes, some having a number of slots and holes in various sides, to render the tables suitable for their special work. A surface-plate termed a bench-plate is one used near vices, and is kept on or near a vice-bench. Such a plate is frequently moved from place to place, and two handles are provided to screw into holes in the plate's edges when it is necessary to carry it about. To avoid the plate's tendency to bend with its own weight, a hollow is formed at the time of casting in the back of the plate; this recess is at the middle, which is the portion furthest from the plate's edges, and therefore needs to be made as light as possible, because while in use it is without any prop or support, except the adjoining metal. Large tables, which are made by casting without any forging, are made strong and light by means of recesses and ribs that are formed at the time of pouring; and if only one side of the table is to be specially planed, this one side is at the bottom of the mould, the bottom of the work being the most solid portion.

A cheap class of plates are those formed of the superfluous cakes or slices which are cut off a shaft while in a lathe. A surface-plate made by such means is lathe-turned on both sides while still attached to the shaft, but partly cut off with a parter; after being smoothed with turning to as near the centre of the shaft as possible, the piece is broken off, and the rugged portions which remain at the middle are planed off with a shaping-machine or planing-machine. By this means a small quantity is taken off both sides of the plate, in addition to cutting off the rough pieces at the middle.

Pillar-tables are those which consist of pillars that have one end specially smoothed and planed. One of these implements is stood in some convenient place, with its plane extremity upwards, and at a proper height for its special use. These tables are of different heights and diameters, and the simplest sort consists of either a short bar or rod of iron which is lathe-turned at one end and smoothed with scraping to produce the required surface. Pillar-tables are not liable to distortion in their plane surfaces while being moved about, or through their own weight; so that such a tool is specially useful when a particularly good surface is required. Such a table, if cast, may easily be made ornamental by carefully designing the shapes of the wood patterns. A simple class of such implements are denoted by Fig. 514, and are made of either wrought iron or cast steel. Another class which may be made of cast steel or cast iron are indicated by Fig. 515. Pillar-tables may be tightly fixed in the ground if not intended to be portable, and loosely stood on any floor when they are to be capable of being moved about.

The methods for planing surface-plates after being cast or forged, include grinding on a grindstone, chipping with hand chisels, turning, planing on a planing-machine, filing, and scraping. A small steel or cast-iron plate, that is only a few pounds in weight, is first ground by gripping it in tongs and holding it to a grindstone well supplied with water. After all the outer hard skin is thus taken off, the work is next turned with a lathe, or flattened with a planing-machine, until the plane surface or surfaces are produced. Small plates should be forged or cast of a proper size, to avoid all reducing, except by means of a grindstone and filing; such a course is especially necessary for a maker who is not furnished with planing-machines. When it is necessary to reduce a surface with chipping-chisels, the edges are first bevelled, and a number of grooves, or channels, are next made across the surface with a grooving chisel, having a cutting part about a quarter of an inch wide; after which the ridges thus formed are cut off with a planing or smoothing chisel. A plate grooved by this mode is denoted by Fig. 521. Lathe-turning is a convenient process for reducing a surface-plate which is circular. To-and-fro shaping-machines are used for planing small plates which are rectangular, and all large surface-plates or tables of several feet in length are reduced to their proper dimensions with large planing-machines.

When any one of these processes is in operation, the roughing of the entire work should be finished before the smoothing of any part is commenced. During the chipping, turning, or planing of any surface-plate, it is necessary to take off the outer hard skin of every side of the work which is to be reduced, and also to reduce the entire piece of work to very near its finished dimensions, previous to completing the planing or turning of any one side. By this method the work is put upside down and otherwise shifted several times during progress, because each side which is to be reduced is fixed twice to the lathe-chuck, or other machine-table employed for the purpose. By such modes of reducing, the work is not bent nor any of its smooth sides bulged after being smoothed, which will happen if a rough side is reduced after a smooth one is finished. This bulging is caused by the metal being harder and more elastic on one side than at some other side or place in the work, and also by the friction of the tool heating the work and expanding it, and through one side of a casting being cooled too soon; also through hammering one side of the plate more than the opposite side while finishing the forging, and other causes. Previous to each fixing, the work may be tumbled about, stood on its corners, and hammered in several places, which further tends to promote a sort of permanent relation of the particles, which will not be liable to disarrangement by the future usage of the table. After the work is properly reduced on all sides, the final cuts given are very thin; and during the finishing cut of any side the work is but lightly held with only a gentle pressure of the fixing bolts, every bolt or other fastening being loosened after all the rough cuts.

In the course of planing or other reducing of a surface-plate, the work may be condemned through the appearance of spongy portions. If these are not numerous, the defects are remedied by plugging. To fill up a spongy place, the proper materials are gun-metal, iron, and steel. If a hole about half an inch in diameter is situated near the middle of a surface, the hole is put into a proper shape with chiselling and filing, the bottom of the hole being made a little larger than the mouth, and the edges around the mouth being thickened and smoothed. When the hole is ready, a plug of red-hot iron or steel of proper length is hammered into the hole until the outer extremity of the plug is about an eighth of an inch above the surface; about a sixteenth of this eighth is next chiselled off, and the plug allowed to cool. When cold, a final hammering is given to make the plug fill the entire recess; after this final riveting, the plug must not be chiselled or hammered in any way, but is reduced with planing and filing until level with the surface. To fill a hole situated near one edge of a surface, a small portion may be chiselled out to enlarge the opening until shaped to a dovetail form; after which, a piece of metal is tightly fitted into the opening, and also riveted a little to fill up all interstices. When several sponge-holes are discovered near together and near an edge, all of them are enlarged to form one large opening, which is next dovetailed and a piece fitted to the opening in the mode described.

Finishing of Surface-plates.—Filing is performed upon all surface-plates, whether they have been prepared with a planing-machine, chipping, or turning. Small plates are filed while in a vice, and those that are too large for a vice are put flat upon a vice-bench or other bench, and the broad sides filed while the work is fixed with its own weight. To file the narrow sides termed edges, the plate is gripped in a vice, or stood on the floor edgeways and held with packing-blocks if the work is not heavy enough to stand alone. The first step after the planing or turning of a surface-plate is the filing with rough and smooth files having cranked holders, until the machine-tool marks are only just erased; the plate's surface is then put upon the surface of another table, which is a secondary standard of reference; while on this surface, the plate in progress is moved to and fro a few times to be marked with a black oily mixture which is thinly spread over the entire face of the standard. The marks thus made indicate the prominent portions which are to be filed off with short smooth files, in order that the hollow places may not be touched. At this first trial of a plate, only the marks in the middle of the surface should be filed off; and although marks may be seen around the edges, no attention need be given them at the first few trials, because any plate which is convex will exhibit marks of contact on its entire surface merely through the rocking motion given to the work while rubbing it on the standard. In order, therefore, to destroy all convexity on the surface in hand, it must be filed only in the middle after each trial, if any marks are seen in the middle, whether or not they appear near the edges; but as soon as the middle is sufficiently reduced to prevent the marking matter or tange adhering to it, the surrounding parts are reduced, and the reduction of these portions may be safely continued until the middle again exhibits the marks of contact, at which time it must be reduced to produce a hollow form rather than a convex one. While a slight concavity exists at the middle, the surface is favourably progressing; but if only a small degree of convexity exists, the evil will probably increase after each trial, if the entire surface is reduced merely because the marks seem to indicate such a course. By thus duly recognising the possible existence of a convexity, the surface is gradually and surely filed; and, after filing, the scraping is conducted by observing the same order of reducing, first the middle, next the surrounding portions, and lastly the edges.

The secondary standard surface on which the trials are made is that which sustains the greater portion of the rubbing, and therefore also the small amount of wear that results from the attendant friction; all secondary or tertiary standards are therefore more or less liable to defect, and near the conclusion of a scraping process the work is put upon a sort of primary standard, on which only about three rubs is allowed for fear of injuring its surface.

The processes just mentioned are effectual for producing good surfaces whenever the necessary standards are accessible; if not, straight-edges must be used as standards, and the work itself is also made a standard; this is effected by making three or four plates, and finishing them at one operation, so that all the surfaces are scraped at one time, rubbed together and finished about the same time. When two or three plates are being tried by thus referring them to each other instead of to a finished standard, it is necessary to frequently apply the straight-edge, because one surface which is convex will fit another which is concave, and cause both to appear flat. The management of such surfaces therefore consists in making them as much like planes as possible by means of the straight-edge and referring them to each other. After the surfaces are thus adjusted with smooth filing, the next step is to grind three or four of them together successively with emery and oil until all coincide with each other when put together and appear to be flat. Grinding any two of the surfaces together generally makes the upper one convex and the lower one concave, through the lower one sustaining the weight of the upper one; consequently, if four surfaces are in progress, all of similar metal, and all equally flattened to the straight-edge at the commencement of the grinding, two pairs of convex and concave surfaces will be produced, the two hollow ones differing from a plane just as much as the two convex ones. At this stage the two hollow ones are selected and rubbed together with the marking matter on one of them instead of emery, and the marks thus made indicate the surrounding portions which are to be filed off with smooth files, or rough ones if necessary. Another grinding with emery and oil is next given, with emery which is smaller than that first used, in order to indicate distinctly the hollow places, and distinguish them from the prominent edges that are being taken off with grinding.

By means of such grinding and filing, very tolerable surfaces are produced without the aid of a standard plate, but not without a standard straight-edge; therefore, if it happens that the straight-edge in use is defective, an opportunity occurs for improving the tool. This is effected by referring it to both the surfaces which were made by grinding the two hollow ones together; and, to do this effectually, the straight-edge is rubbed on the plate in various directions. To avoid being deceived with any slight rocking that may arise through a small convexity that may exist on the surface, the straight-edge should be held by holding it at the middle with one hand, and with the other hand at one end, instead of with one hand at each end. By being thus held, it is put into contact and made to touch at least two places in both the straight-edge and the surface-plate; these two places are easily discovered by the light being obstructed at the points of contact. If the work is high enough for convenient observation, the operator will discover which of the two surfaces is convex, and whether the straight-edge is convex. If the tool is held in the mode directed, and no light is seen along the entire length of the straight-edge, the two surfaces in contact are either both straight, or one happens to be as much concave as the other is convex. To ascertain if both are straight, put the straight-edge upon the other surface which was ground with its companion, and if no light is seen at this trial, all the three implements are straight, including the straight-edge and both the plates. When the implements do not thus coincide, the faulty ones are distinguished by the situation of the points of contact. If the straight-edge is held in the proper manner, and each end of it touches each end of the plate, but not at the middle, one of the two tools is hollow; and to discover which one, the straight-edge is put upon the other companion plate, and if the light appears at the middle as before, the straight-edge is hollow, because the two plates which were ground together cannot both be hollow, through having been in close contact with grinding. If one plate is hollow, light will be seen under the middle of the straight-edge while it is on the hollow plate; but while on the convex-plate, light will be seen only at one end, and will be obstructed at the middle and the other end of the straight-edge. The next test is to find the convexity of the straight-edge, if it possesses any, and this is detected by its rocking on both the surface-plates; it is also detected by holding the straight-edge with one hand at one end, as directed, and observing the light; if the light appears under that end of the straight-edge which is not held, while it is situated on either plate, the straight-edge is convex, and can, therefore, be adjusted with filing and scraping until it is nearer to straightness than either of the plates, at which time it is a better standard than before; consequently the two plates can be further improved, if necessary.

By a due consideration of the processes just mentioned, it may be noticed that bad tools are the means whereby good ones are produced, and this is the secret of all good tool-makers' operations. In the hands of a careless man, a defective straight-edge becomes worse; but if in the possession of a tool-maker, its defects are discovered and removed. All surface-plates and straight-edges were thus gradually improved forty years ago, and similar tools are now adjusted in the same way, because we have no planing-machine which will plane a surface-plate so that it does not need any further adjustment. This adjustment is always effected with scraping, grinding, and by referring the surface which is in progress to another surface that is being made at the same time, or to another surface made by similar means on some previous occasion.

Those who may be obliged to make straight-edges and surface-plates without any primary implements as standards may proceed in the order thus indicated. First provide two straight-edges, each about three feet long, two inches wide, and a quarter thick, and file one edge of each tool to a thread straight-edge, shown by Fig. 480. The two opposite unfiled edges are to be next filed until parallel to the two first adjusted by the thread. This parallelism is attained by adjusting a tightly riveted calliper to the desired width of the straight-edges, and then gradually filing the entire length of the tools until the calliper will fit any width along their lengths. After this, the four edges are further straightened by applying them to the thread, and their parallelism is also improved by again using the calliper. The next step is to grind all the four edges together; this would be done on a plane surface, if one were accessible; and instead thereof, the two tools are put on the ground, on the floor, or on to some board nearly flat, with the broad sides of the two tools in contact with the board, and two of the edges in contact with each other. In this situation the four edges are ground with emery by rubbing to and fro, putting the tools upside down, and placing all the edges successively together several times during the process. This treatment is continued until all the four edges appear to coincide with each other, at which time all the emery is cleaned off, and tange is applied to discover which of the four edges are the two hollow ones; these two may be discovered also by putting the edges together and observing the light between. The two hollow edges are next ground until they coincide, at which time they are straight enough to serve as standards while scraping or smooth-filing the two inferior edges; after which, the two concave edges are again detected, if possible, and ground together as in the previous grinding; but if no concave edges can be found, the tools are near enough to be used for making surface-plates. These plates are made in pairs as previously described, and adjusted to the straight-edges, and also with grinding the two concave surfaces together. At this time another adjustment can be given to the two straight-edges, which could not be given before; this consists in grinding the straight-edges together on the surface-plates. This grinding includes two processes; one of which is the grinding while the broad sides are in contact with the plate's surface, and the other process is the grinding to make both the straight-edges of one width. By these successive grindings of the implements with each other, good plates and straight-edges are made with very ordinary tools; and if the straight-edges are each a quarter thick as directed, they will serve as twist-finders.

In addition to the trial processes and grinding processes now described for adjusting surface-plates, a few other means should be adopted while making plates or tables that are specially intended to be standards of reference. A couple of tables of this class are finished by placing the two surfaces together and rubbing them as in other processes, but in a vertical position, instead of horizontal. The two plates or tables are stood together edgeways on a block or table which is convex, to cause a rocking motion while moving the work to and fro for grinding, and the plates are stood on all their edges successively, to give a sort of equality to the operation. Makers of plates, who have any fear of a surface being injured with its own weight, should use the pillar-table that was mentioned; the surface of a table of this class is about the same in any position, whether vertical or horizontal, so that while a surface-plate is in progress, or may require a trial, t should be rubbed to the pillar-surface while in a vertical position, and also while in a horizontal position, and if the tange presents the same appearance in both cases, it may be inferred that the plate is strong enough to sustain its own weight without apparent distortion.

It is also necessary to consider the small sides or edges. Every good surface-plate should have the edges at right angles to the principal surface; and the nearer it is to precision in this particular, the greater will be the future usefulness of the implement. The boundaries of the principal surface should also be as nearly as possible rectangular.

Surface-blocks.—The steel parallelopipeds termed surface-blocks are from two or three inches across to ten or twelve inches, but seldom any larger, through the great consumption of time necessary to make the larger sizes. An ordinary surface-plate has only one or two plane sides; but a surface-block has six planes, and each one must subtend a right angle with each of the four planes adjoining. Such blocks should be made of steel which is forged only sufficiently to condense the particles and to avoid stretching the metal in any direction. The particular method by which they are forged depends on their thicknesses. If the thickness is not to exceed about two inches, a slab may be forged about two inches thick, and amply large enough for four blocks, which are partly or entirely divided into four by means of a planing-machine parting-tool. While forging a piece of this character, it is necessary to provide ample superfluous metal at each end of the slab, or to reduce each end and form a couple of handles or holders, in order that such portions may be gripped with the holding plates to avoid gripping the intended blocks while being planed. A slab thus made is denoted by Fig. 522; such a piece is first planed on both the broad sides while held with the holders, and the two broad sides are thus made plane and parallel to each other. The work is next put with one narrow side or edge in contact with the planing-table, and with the broad sides in a vertical position; these sides are carefully adjusted to a right angle with the table's face, by means of wedges driven between the lower rough edge of the slab and the face of the table, and also by the aid of an el-square. After the work is adjusted and fixed by attaching holding plates to the holders as before, the upper side is planed, and is thus made square with the two broad sides; the slab is next put upside-down, and the opposite edge is also made square to the broad sides, by which time four of the slab's sides are flattened. The dimensions of the four intended surface-blocks are next marked on one of the broad sides, by scribing very thin lines on the surface, and exactly at right angles to the two planed edges; the slab is then ready to be again fixed for being divided into four pieces, and at this fixing the work is carefully adjusted by the lines so that the cuts shall produce the required right-angular shape on the blocks. If it is intended to entirely cut the work into distinct pieces, the slab must be put upon parallel packing-blocks, instead of in immediate contact with the planing-table; but if to be cut only partly through, the slab rests in contact with the table, no packing-blocks being required. When the slab is finally adjusted to the lines, eight fastenings are required, the two holders being then of but little use; two of these fastenings are necessary for each intended block, one fastening at each end; by this means, all the places for the intended cuts are exposed to the parting-tool, and each block is securely held until all are separated from each other. In the Figure 522, the five cuts necessary to produce the four blocks are indicated by the letters C.

Surface-blocks which are eight or ten inches thick are not easily divided with parting-tools; it is therefore convenient to forge them separate, each block having two holders, as indicated by Fig. 523. If a pair of these blocks are wanted, two are fixed near each other and planed together on the table of the planing-machine; both are reversed and finished at the same time, so that both are of similar shape and dimensions. When a pair of large blocks are to be made of one single piece, they are partly divided with a chisel during forging, to avoid the use of heavy parting-tools. A piece for this purpose, partly divided, is denoted by Fig. 524. The two holders shown are to hold the work while the broad and narrow sides are planed; after which the fastenings are taken from the holders, and the two intended blocks are carefully lined to indicate their dimensions; when thus prepared, the work is again fixed by the lines, and each block is held with plates and bolts while being divided with parting-tools or corner-tools.

Surface-blocks that are not required to be solid may be provided with screwed holes, which greatly facilitate the planing, and also the lathe-turning, when the blocks are prepared with a lathe instead of a planing-machine. The holes in such blocks are bored and screwed entirely through, and cross each other at the centre of each block; such are denoted by Fig. 525, and when so made, they are planed or lathe-turned without any stems for holding being required. Blocks of this sort are held, while planing, with screw-bolts, which are placed through the machine-table near one edge, the screw of the bolt being screwed into the hole of the block. Several blocks may be thus tightly held in a line with each other, and one side of all the blocks planed at one time; after which, all the blocks are shifted and the fixing bolts are put into other holes, or opposite ends of the same holes, to hold the blocks for planing another side of each block. During these fixings, great care is necessary to fix the planed sides at right angles to the surface of the planing-table; if not, a large quantity of unnecessary finishing after planing will be the result. Such blocks are also easily lathe-turned by bolting three or four to a disc-chuck, and exercising the same care in fixing the turned surfaces to a right angle with the chuck, that was bestowed upon blocks prepared on a planing-machine.

Finishing of Surface-blocks.—Although sharp tools and water may be used, and great care may be exercised while planing or turning surface-blocks, every one must be afterwards filed and scraped. Those that require the greatest attention are the pairs, because, if one of a pair is reduced below its intended dimensions in order to make it right-angular, the other one needs a similar reduction to make them alike. If only a single block is being made, it is made right-angular by means of an el-square; but if a pair are in progress, both may be adjusted by means of a surface-plate and a straight-edge. The adjustment of all surface-blocks, whether single or in pairs, commences by first making one of the broad sides a plane; the opposite broad side is next adjusted to make it as nearly as possible parallel to the side first smoothed, and this parallelism is obtained by repeated measuring the thickness with a gap-gauge or with a tight calliper. The two long narrow sides are next adjusted to make them square with the broad sides, and the two smallest surfaces, usually termed ends, are lastly adjusted to make them square with all the other four surfaces.

All large surface-blocks should have curved corners, to allow them to be easily used without burring the surfaces while being handled and put into contact with each other; these curves may be formed previous to the final scraping of each block, and the form for such corners is denoted in Fig. 526. The final trials of a pair of surface-blocks consist in placing the two blocks close together on a surface-table at a convenient height for observation; and if any selected surface of one block will coincide with any selected surface of the other block while both remain together on the table, both blocks are right-angular. If any two surfaces thus put together do not coincide, the faulty one of the two is discovered by applying an el-square to the table and to the two blocks; and if both are faulty, both are rectified.

Small blocks are easily tried without placing any marking mixture to one of the surfaces, because the light is distinctly seen between the surfaces, if they contain only a few inches of area; but for trying two large surfaces, one of them must be thinly covered with the mixture to indicate the places of contact. In addition to ascertaining whether the surfaces are right-angular, it is necessary to know if the two blocks are of the same length, width, and thickness; this is known by placing them together on the table and applying a straight-edge to the upper surfaces; while thus situated, light will be observed between the straight-edge and that block whose upper surface is the lowest.

MAKING OF GAUGES, CALLIPERS, AND TAPS.

Radius Gauges.—The long bar or rod of a radius gauge for scribing and lining, is made of wood, if a light gauge easy to make is desired, and a couple of movable scribers are attached with small bolts having thumb-nuts. These bolts are moved along and carry the scribers along to any required part of the bar by means of a long slot which is nearly as long as the instrument. A wood gauge of this class is shown by Fig. 527, in which the scribers consist of straight wire that fits a hole in each bolt-head, so that by tightening the thumb-nuts the scribers are fixed. The mode of accurately adjusting the two points to any required distance from each other consists in first tightening the scribers with the nuts, and next gently hammering one of the scriber-heads until the point is gradually adjusted to its proper place. In the Figure, each scriber-head is denoted by H.

Callipers.—Callipers are made of sheet steel and of small bar steel. To make an outside calliper of a short piece of bar steel, the two legs are forged together in one piece, the two thighs or joint portions being in the middle. Two legs being thus made are shown by Fig. 531, the legs being only partly bent to the curve desired. In order to effect an easy bending, the work is bent edgeways while on the anvil-beak, previous to the legs being thinned to the intended thickness; after being partly thinned, a small amount of curving is given, and after a further thinning the work is curved a little more, the final thinning being done after the legs are curved to the intended shape. The work is next cut into two, and the joint portions trimmed to a circular form.

Outside calliper-legs are also made singly, each leg being made at one end of a thin bar, and curved while still attached to the bar; a leg being thus made is shown by Fig. 534. In this Figure the end lump is shown; this unreduced lump is always thicker than the adjoining portion while the work is being thinned, in order to avoid cracks being made during the reducing, whether two legs are being forged solid together, or whether only one leg is being made at an end of a bar. The method of making each leg singly, or a pair of legs together, at one end of a bar, is always preferable if the bar can be obtained, because the long part of the bar is a much better handle for the work than a tongs, however good the tongs may be.

Calliper-legs that are made of sheet steel are cut from the sheet or plate while red hot, after the shapes of the intended legs are marked, and a hand-chisel driven in at the marks, while the metal is cold. A plate thus marked is shown by Fig 532 ; such a piece is held by the smith on an anvil with an iron fender-plate between the work and the anvil, and in this situation the legs are cut out with a rod-chisel which is struck by a hammerman. The making of inside calliper-legs is effected by the same means as for outside ones, either thin bars or sheet steel being employed, according to the arrangements of the maker. Those who make large quantities of callipers should always make the legs of sheet metal, and provide punches and dies that are the shapes of the intended legs, so that each leg can be cut out at one stroke or effort of the punching-machine.

The circular washers with which the legs are riveted together are also of steel, and should be forged separately of a thin bar. The bar is heated to redness at one end, and a few holes made with a round punch, the holes being at a proper distance apart for each washer. In order to allow each hole to be afterwards enlarged by broaching, the hole is punched smaller than the finished diameter, and after punching, each washer is cut off, and the corners also are cut off, each one being finally rounded with top and bottom tools. To make such washers in large numbers, each should be cu⁺ out and punched at one blow with a machine while the metal is red hot, similar to the mode for pui.ching the legs.

The smoothing of the broad sides of the legs consists in first grinding them on a grindstone, and next filing each one separately while held with a thumb-vice on a piece of wood or plate iron which is gripped in a bench-vice. A leg in such a situation is shown by Fig. 535 ; it is not necessary to finish the broad sides previous to filing the edges; it is sufficient to grind or file off the rough portions, so that a pair of legs can have a hole drilled in each, and be fixed together in a temporary manner, in order to file the edges to the desired form. Two legs thus fixed are shown by Fig. 533, and are held by means of a rivet which is about an eighth of an inch longer than the thickness of both legs together; this temporary rivet is very slightly hammered—only sufficient to hold the work together, and while fixed, the desired shape for both legs is easily obtained with filing. Both outside calliper-legs and inside ones can be thus held, and the entire edges roughly filed to shape, except about half an inch at the small end of every leg which is intended for an outside callper ; this short portion is allowed to remain thick, to be made into a broad end, if such an end is required. A pair of these broad ends are shown by Fig. 541, and are useful for callipers that are to measure screws, thin edges, and pointed extremities. Broad calliper-ends are made by heating the end to redness, and spreading it out with a small hammer. If the leg is a small one of only three or four inches in length, it is heated in a gas-flame and hammered on a small anvil near a vice ; but large legs require heating in a forge fire, and spreading while on an anvil-beak. Another class of calliper-ends are shown by Fig. 542, which are useful for measuring the bottoms of narrow grooves, such as screw-grooves. Ends of this shape are formed with mere filing, without any spreading being required. Fig. 543 indicates a pair of pointed ends; such ends are only made to small callipers, and are shaped and smoothly polished on an oilstone after the callipers are riveted together and finished. The shapes for ends of inside callipers are shown by Figs. 544 and 545 ; those denoted by Fig. 544 are for ordinary measurement of holes and openings of various sizes and shapes, and the pointed ends indicated by Fig. 545 are useful for measuring inside screws.

After the broad sides are filed, the joint holes drilled, and the edges filed, the two washers are turned, and the thighs are prepared for a final riveting together. This preparation consists in properly broaching the holes and smoothly polishing the broad sides of the thighs, also the two sides of the washers which are to be in contact. All these six surfaces should be as smooth and as nearly plane as possible, by which means chips, file-dust, and other substances will be kept out from the joint while the tool is in use. The broaching consists in using a slightly taper half-round, or fluted broach ; this is put through all the four pieces, including the two washers and the two thighs, and while the broach is in a few turns round are given while the four pieces are held in a vice, or held over a hole, and clamped with two plates. The holes in the washers are coned with a cone-driller of proper shape, to produce a deep cone instead of a shallow one, and after all the burs made upon the edges of the holes with filing and broaching are rubbed off with smooth emery-cloth, the work is ready for riveting together with a steel rivet; this rivet is smoothly polished to provide a good bearing surface for the joint, and each end is allowed to project sufficient to be filed to a convex form, resembling that of the rivet in Fig. 546. A rivet having such extremities is easily riveted at a future time when necessary, but a flat end which is level with a flat washer cannot be riveted without indenting the rivet and requiring the entire side of the washer to be filed. When a rivet is hammered too much at any time, and the joint thereby made too tight, it is loosened by heating it in a gas-flame, or on a piece of hot iron, and allowing the joint to gradually cool.

Springy callipers are of two sorts, inside and outside. The making of a calliper belonging to either class is managed by forging it of one piece for both legs, and curving the mid portion to about a semi-circular form, to produce the required spring. This curving is effected on a steel filler of proper shape; and, after curving, the legs are filed and drilled to receive the adjusting screw. One end of this screw has a round hole drilled in, and swings on a pivot-pin which is tight in one calliper-leg, while the remainder of the screw extends through an oval hole in the other leg. In Fig. 547 a springy calliper's adjusting screw is shown by S, one end of the pivot-pin on which the screw swings is denoted by P, and the oval hole, to permit the swinging movement of the screw, is indicated by H.

The feet or points of all small callipers require hardening; this is effected by heating them to redness in a gas-flame and cooling them in oil, and allowing them to remain without any future tempering, or by cooling them in water, and afterwards tempering them to a blue colour. When cooled in water, the tempering is effected by polishing the point with emery-cloth, and holding the mid portion of the leg in the gas-flame until the blue colour appears at about a sixteenth of an inch from the extremity, at which time the leg is cooled to prevent farther softening. Hardening of calliper-ends should be performed after the calliper is finished and riveted together.

Making of Taps and Hobs.—Hobs and taps are made by four principal processes, including forging, turning, screwing, and fluting. The steel selected for taps from about an eighth to half an inch thick should be tough cast steel that was originally carbonised with charcoal; but the steel for large taps, two or three inches thick, should be bars or rods that were first carbonised with wood charcoal, but not afterwards cast; such metal is not so liable to break during the hardening process as steel which is cast, because casting destroys the fibrous shape of the metal, and makes it exceedingly good for all small or thin cutting tools, which require a close texture, but not suitable for large expensive implements which are to undergo the force exerted by the contraction while hardening. Steel which is made by the Bessemer process must, in all cases, be tested previous to selecting for taps; this testing consists in hardening in water a few pieces belonging to the same bars or rods of which the hobs or taps are to be made; and if the trial specimens will become very hard, without breaking or cracking in any part during cooling, the metal may be used, and only a very few of a large number will break at the final hardening. During the heating of these specimens some of them may exhibit a large number of small fissures whose lengths are parallel to the length of the rod or bar; if such marks are seen, it is an additional proof that the metal is suitable, and should in all cases be preferred if the steel is also capable of being made hard.

The only forging which is necessary for hand taps that are less than half an inch in thickness consists in making them of round steel, and cutting each tap or hob to its proper length while red hot, and afterwards trimming the rugged pieces from the two extremities, to make them flat and square to the tap's length. The small wire for taps only about a quarter thick, merely requires cutting partly through with a file and breaking while cold. A small piece thus prepared is shown by Fig. 536. Hand taps that are half an inch or three-quarters thick require the square heads to be forged; one of this class is shown by Fig. 537. Those that are to be about five-eighths thick, and all larger sizes, require to be forged sufficient to produce the stems extending from the thicker portions, and also the square heads. When thus shaped they appear as denoted in Fig. 538.

Long taper taps for engineers are not made smaller than about a quarter of an inch in thickness, and those that are not to exceed three-eighths in thickness may be forged by merely cutting them to length and squaring the extremities. All that are to be larger than three-eighths should be forged to a form resembling Fig. 539 ; this figure denotes a forged tap which is about as conical as it will be when finished, and the stem of which is of the same shape, having a square head, which is comparatively longer than the head of a hob.

The mode of producing the square head of a small tap or hob consists in shaping it with a set-hammer. This shaping is effected by first ascertaining the forged length of the cylindrical part of the stem, and then driving in the set-hammer at the proper distance from the thickest portion of the tap ; the set-hammer is driven in at this place to produce the four-sided shape, and is afterwards driven in to square the lump which remains at the end. After the head is properly shaped and flattened to the thickness, the total length of stem from the shoulder of the thickest part is marked upon the head, and the superfluous piece is cut off to complete the head.

To commence the shaping of a large square head a couple of narrow fullers are first driven in at a proper distance from the shoulder, and the squaring is afterwards completed with a sledge-hammering and smoothing with a flatter. The shaping of large square heads is also easily commenced with a couple of angular gap tools, the steel being held still while between the two tools, instead of being rotated as in a process for rounding. During the final forging of a tap-head the reducing and smoothing should be carefully managed to avoid all planing of the head, if the taps or hobs are only about an inch thick, and for all larger sizes, only about a tenth of an inch should be allowed for planing. By this means all the smaller taps' heads are finished with mere filing, and all the larger ones with as little planing as possible.

A long taper tap needs a careful straightening, while red hot, at the conclusion of forging, and this is effected by means of a straight-edge which is as long, or longer, than the tap ; this is applied to two opposite sides of the taper portion, and also to two opposite sides of the parallel portion ; and by thus placing the tool a few times to the work the operator can easily see if the conical portion is straight, and whether the stem is concentric and in line with the thicker part. In order to avoid unnecessary turning, each tap or hob requires to be reduced to a proper thickness and smoothly rounded with top and bottom tools. Taps not exceeding an inch in diameter should not be more than an eighth of an inch thicker when forged than they are to be when lathe-turned ; and those about two or three inches in diameter need not be more than a quarter of an inch thicker. The softening of taps after forging consists in heating each one to only just red throughout its entire length, and burying it in cinders or charcoal till cold, the charcoal being used if the tap is thought to be rather deficient of carbon. During this final heating the tap must be frequently rotated in the fire, and the air-blast gently administered to avoid bending the work.

Centring each tap or hob for lathe-turning is the next step, and is effected by two or three means, the precise amount of centring which is necessary for any one tap depending on its forging. The general rule for centring is to place the centre recesses in a straight line extending through the middle of that portion of the work which is nearest to the finished dimensions. By being thus centred, that part of the work which requires the least turning, is made to rotate truly in the lathe, and the entire surface of that portion is equally and smoothly turned by cutting of only a small quantity. Therefore if the stem of a tap is only an eighth of an inch larger in diameter than the finished diameter, and the thicker part a quarter larger, the stem is that which is made to rotate truly while on the conical pivots, because the stem may not be concentric, or in line, with the thicker part.

If the two ends of the work are properly squared at the time of forging, the extremites are easily squared with filing, but if rugged, unsound portions exist at the extremities, it is necessary to either cut them off with chiseling, or to turn them off with a lathe by means of a preliminary centring. When this first centring is adopted, the recesses made should be shallow, and it is not necessary to accurately centre the work for the entire turning, if the object is merely to cut off the uneven portions at the extremities; but if the object is to take a thin cut off the entire surface, previous to a preliminary hardening, the tap must be tolerably centred. The centring is done by first chalking and scribing a few lines on the two ends while the tap is supported with two vee-blocks on a lining-table. The work is next coned, and the extremities squared with a left-hand corner tool, similar to Fig. 433, and after turning a thin cut off the taper part, and also off the stem, the uneven centre-lumps are chiseled or filed entirely off, if much aslant; if not, they are merely filed to make them parallel to the turned surfaces. When this is done, the tap is hardened and again softened, and the work is again centred if necessary, or the original recesses may be drilled deeper and made broader, if they happen to be made in the proper places at the first centring. The recess in the tap's head is to be always made in the central line along the length of the head, because the head is, or should be, that which is forged nearest to its finished size; but the recess in the taper end may be made either in the centre of the flat extremity of the tap, or central with any other portion of the taper or parallel part which is forged very near to the finished thickness.

In order to exactly mark the places for the recesses, the tap is put upon two vee-blocks that rest on a lining-table or surface-plate, and one vee-block is put into contact with that part of the taper or parallel portion which is to rotate truly on the lathe-pivots, the other vee-block being put beneath one flat side of the square head. When a tap is to be thus marked, so that one recess shall be in the middle of the flat end of the taper part, the vee-block is put beneath that end, and the work appears as in Fig. 553; but if the recess of the taper end is not to be in its middle, but true with the middle of the cone, the block is put beneath the middle, as shown by Fig. 554. While the tap is situated in either of these situations, a short line is scribed with a scriber-block near the middle of both the tap's extremities; after which the square head is lifted up with one hand and the tap is moved partly round while still in the gap of the other block; the head is then again put upon the block, with one side of the tap's head at right angles to its first position; while in this position two more short lines are scribed, one on each end of the work; the tap is next shifted round twice more to put the two other sides of the head upon the block, and mark four more lines, so that four are marked on each end of the work; all these four short lines intersect and enclose a small four-cornered space shown in the Figures, in the midst of which are the centres desired. The places of the centres being thus found, a dot is put into each, and the work is ready for drilling and coning. The centring of hobs is very similar to that of long taper taps, only more care is necessary with taps, because of their comparative great length.

Drilling and coning of taps or hobs is effected in a lathe. Taps of only a few pounds in weight each are drilled by holding each one separately to a small drill which rotates in a drill-holder that belongs to the lathe. Small taps are thus held in one hand with one centre recess in contact with the drill-point, and the other recess in contact with the poppet-pivot point; while thus held, the other hand is employed to work the poppet-wheel, and thereby to advance the poppet-pin or cylinder, which pushes the work on to the drill while it rotates; when the drilling is done, the drill is taken from its chuck, and a cone driller is put into its place, and with this the drilled holes of the tap or taps are enlarged to the desired width and depth. During the coning of a tap or hob, it is necessary to occasionally move the work partly round, to cause the drill to cut equally around the small drill-hole first made; and if the tap is a large one, of twenty or thirty pounds weight, it is supported on packing blocks, or suspended with a small pulley-block hanging over the lathe. Taps about an inch or an inch and a quarter thick require the mouths of the centre recesses to be about a quarter of an inch wide, and taps of two or three inches in thickness require recesses that are three-eights or half an inch wide.

The angle between two opposite sides of a tap recess should be about sixty-seven degrees, if the recess is to be without oil-channels but with oil-channels, the recess may be seventy degrees. The angle subtended by two opposite sides of the conical pivots of the lathe should never exceed seventy degrees for ordinary lathes and ordinary work; and the pivots should therefore be sharpened as soon as they are become worn enough to make the angle between their sides more than seventy degrees, which renders it advisable to make the centre recesses of all work less than seventy degrees, to cause the edge of the recess to bear on the thick part of the pivot rather than make the pivot's point touch the bottom of the cone. By a proper arrangement, a small space always exists between the inner part of the recess and the point of the pivot, this space being that which is necessary to contain oil for lubricating the work while it rotates. Another advantage also results from making the recess-angle less than the pivot-angle, and consists in the pivot-point being protected from the wear attending an improper adaptation of the bearing surfaces to each other. Consequently, it is not proper to make the pivot touch the recess along its entire length unless oil-channels are provided to admit the oil; if such channels are intended they are made with a narrow gouge or other pointed chisel, and three grooves are cut at equal distances around the recess, after which each one is smoothly filed with the point of a file, and all burs are finally rubbed off with emery cloth. The drilling and coning of taps, hobs, and other work, is usually done in a simple sort of small lathe distinct from the lathes for turning; and when taps are to be turned, lathes of proper sizes are selected for small taps and large ones. Fig. 550 represents a poppet-pivot whose angle is seventy degrees, and on the pivot is a tap's end having a recess of sixty-six or sixty-seven degrees.

Hob Turning and Screwing.—The turning of two or three hundred hobs is managed by using a slide-rest lathe having a long traverse, although it need not have any screwing gear. Previous to commencing the turning it is necessary to examine the pivots and put them into shape, if required, and to turn the mandril-pivot if it happens to rotate untruly. When the hob is in the lathe, the first turning consists in taking a thin cut off the entire hob, both its stem and thicker part, using for this purpose a roughing vee-tool, shown by Fig. 429 ; and as soon as the work is made to rotate truly, by turning off only a small quantity, the hob is ready for a preliminary hardening, if it were not hardened at the first centring. A number of them are therefore thus roughly turned, so that all may be taken away together to be hardened. This hardening consists in heating each hob to redness and suddenly cooling it in water, after which all of them are again heated to redness, and without straightening them after being bent with hardening, they are gradually cooled in cinders to be softened for the final turning. During this tnrning, gap-gauges made of steel plate are used, to properly adjust each hob to its thickness previous to screwing. For each hob two gauges are necessary, or one gauge having two gaps; the width of one of these gaps is equal to the thickness of the hob's stem, and the width of the other gap is equal to the thickness of the hob's screw-part. The proper mode of making such gauges, consists in providing a distinct gauge for each class or size of hobs, and forming two gaps in each gauge near one end of it, each two gaps being made for one size of hobs. A gauge of this sort is shown by Fig. 548, having the name of each gap marked, one gap having the word stem and the other having the word screw. The thickness of each hob's screw-part indicates the name of the hob, consequently, the gauge bears the same name as the hob to be turned to the gauge. The stem-gap of any such gauge should be equal in width to the finished thickness of the stem, which is always less than the thickness of the hob at the bottom of the thread-groove when finished ; but the width of the screw-gap in the gauge must be a little greater than the finished diameter of the screw, if the screw-part is roughly turned previous to screwing; but if this portion is smoothly filed or polished, the gauge-gap is of exactly the same width as the diameter of the intended screw when finished. The preferable mode is to make the gap to the finished diameter of the required screw, and to always smoothly turn the screw-parts of the hobs, instead of leaving them to be screwed while rough.

The screwing of a large number of hobs with the ordinary Whitworth screws is usually effected in a lathe entirely devoted to screwing, and if only a small number are to be screwed with the same lathe in which they were turned, the screwing is a distinct process; consequently, all the hobs are entirely turned to their respective gauges, previous to any one hob being screwed. Ordinary screw-cutting lathes are always used for screwing hobs, whether they are small ones, only a quarter of an inch thick, or large ones, three inches thick. In some cases the slide-rest tools of the lathe are made to entirely form the screw, from the first making of the thread to the last finishing polish given to the completely-shaped work. In other cases the slide-rest tools are used to effect the greater portion of the screw-cutting, and the work is finally adjusted to dimensions and polished with hand screw-tools, such as are denoted by Figs. 407 and 408.

Before commencing the screwing of hobs, the lathe is adjusted to parallelism, if necessary, and this is partly effected by shifting the poppet-head until two dots, or other marks on the head, are made to coincide with each other; after this, a test piece of round iron is turned, and each end of the turned part is measured with callipers to discover which end is thickest; the poppet-head is then shifted a small quantity to reduce the thicker portion, until the entire turned part is cylindrical, at which time the lathe is adjusted.

In order to commence and finish a hob-screw without hand screw-tools, the slide-rest tools required are those shown by Figs. 440, 442, and 443. Tools of this sort are made of several sizes, to suit a small four-inch lathe for screwing quarter-inch or half-inch hobs, or to suit a twelve-inch lathe for screwing three-inch hobs. One-tooth vee-point tools, which are denoted by Fig. 440, are made with different angles in their cutting parts, some having ends whose angles are less than fifty-five degrees, and others having ends whose angles are greater than fifty-five degrees. This angle of fifty-five is that which is subtended by the two sides of the threads belonging to the Whitworth hobs and taps in general use throughout England; consequently, the screwing-tools are adapted to make the threads to the required angle; and because the angle of the thread belonging to a half-inch hob is the same as that of a three-inches hob, the points of all the vee-tools for finishing are of the same shape, although some are much larger than others to suit larger lathes.

To facilitate the cutting, oil is freely used during a screwing process, and the vee-point tool, which is first used to commence screwing a hob, is one whose cutting edges subtend about sixty-five or seventy degrees, and when this tool has made the width of the thread-groove nearly equal to its finished width, another vee-tool, having an angle of fifty-three, is put in, and the bottom of the thread-groove is cut out, but the mouth of the groove is not altered, because this tool cuts only at the bottom of the groove. The use of this is continued until the thread-groove is deepened to its finished depth, which is ascertained by the use of callipers having thin points; the screw-tool is then taken out, and a third tool is put into its place. This is a vee-tool having two teeth that were shaped to the thread of the particular standard hob to which the hob in the lathe is being made. This third tool is shown by Fig. 442, and will cut at the outer extremities of the thread, termed the summits, but will not cut at the bottom of the groove, because the angle of the one-point tool, previously used, is fifty-three, and the angle of the third tool is fifty-five, which is the same as that of the standard hob. This tool with two teeth is made to cut with oil and thin cuts, until the entire thread is smoothly shaped, and fits tightly in the steel gauge nut to which the hob is being screwed. After this, the final polishing of the thread should be effected with a springy tool having two teeth. One of this class is shown by Fig. 443, and when it is to be used the hob in progress requires plunging into small wood-dust to absorb the oil which is attached; it is next cleaned with a brush and dipped into soapy water, until the water will stick to the entire surface of the thread, at which time it is ready for the springy tool. In addition to cleaning the hob, it may be also necessary to clean the oil from the tool-holder and poppet-pivot; if much oil happens to be on them, and when the hob is again put on to the pivots, and the springy-tool into the tool-holder, the tool is adjusted for polishing the thread. The adjustment consists in making the two teeth of the tool fit any two steps of the thread, and is effected by carefully and slowly rotating the lathe-spindle and hob forwards, and slowly working the two upper screws of the slide-rest, until the cutting edges of the tool coincide with the sides of the thread. When adjusted, thin soap-suds are freely applied during a few light scrapings given with the tool, by which the screw is polished to its finished dimensions, and made to fit the gauge-nut. When it is intended to screw a hob so that its thread shall be nearly as possible of the same shape and dimensions with the thread of a standard hob, a steel nut must be used, which was adjusted to the standard by the hob being screwed through the nut, and cutting out a small quantity; after which, the nut is used as a gauge-nut without hardening it.

All hob-screws should be tapered at both ends, to avoid the trouble occasioned while entering a hob into a nut, or into any other screwed hole that requires measuring. If a hob-screw is tapered, it will smoothly polish a gauge-nut instead of roughing it, and the number of steps at each end of a hob-screw to be tapered should be five or six, as indicated in Fig. 551, in which the parallel portion of the screw is that between the two short straight lines extending from the screw at right angles to the hob's length. The tapering of the screw should be done with a comb screw-tool, either before or after it is finally adjusted to the proper diameter for the parallel portion, and the two extremities are to be made a fiftieth of the hob's diameter smaller than the parallel part in the middle, being careful to make the shape of the thread in the taper parts exactly the same as that of the thread in the parallel portion.

The mode of applying oil and water during screwing consists in providing a reservoir can for oil, and another for soapy water. Each of these cans is provided with a small outlet pipe situated at a short distance above the bottom of the vessel, and at the end of this feed-pipe is a small tap for applying and arresting the oil when necessary. Whichever one of the cans is required for use is suspended with a davit, or standard, which is fixed to the lathe-carriage, so that the feed-tap's orifice is exactly over that portion of the work being screwed. By being thus attached to the carriage, the feed-cock proceeds along the work just as fast as the screw-tool; consequently, an effectual and economical supply of oil or of water is secured. In addition to the feed-pots, two dishes are necessary, one for receiving the oil as it falls from the work, and another for receiving the water; either of these dishes is fastened to the carriage when a large quantity of screwing is to be done, so that some of the oil or water may be prevented from falling about the lathe and floor.

Tap Turning.—The smaller sizes of taps have square heads, which are as thick as the screw-portions; some of them are made in sets of three short taps each, and are termed hand taps; others are long taper taps, one of which is sufficient for completely screwing a hole, instead of three; these long ones are also hand taps, if small, because they are used with small tap-spanners. The larger sizes of long taper taps, that are one, two, or three inches thick, are termed machine taps, because they are generally rotated in screwing machines, although sometimes with ordinary tap-spanners. Such taps are turned by commencing with a vee-point roughing tool, in a manner similar to that for turning hobs; but at the preliminary turning only the smallest quantity which is sufficient to make the tap circular, should be taken off, in order to avoid straightening the tap after it is bent with the first hardening. Through the comparative great length of such a tool, it may bend so much in hardening as to require an eighth of an inch to be turned off only one side of the mid-portion to make it rotate truly in the lathe; therefore it is necessary to take off as little metal as possible at the first turning, that the greater portion may remain to be taken off at the second turning.

When the tap has undergone the first turning and hardening, it is softened for a final turning without being straightened. This turning commences by first reducing the thickest part of the tap to nearly its finished diameter, next reducing the stem entirely to its finished diameter, and also cutting off the metal at the shoulder of the thick part until the stem is of sufficient length. The stem is smoothed either with filing or with springy-tools, and made to fit a gauge-gap in a steel-plate gauge, which is made for the particular size of tap or taps being turned. The diameter to which a tap-stem is turned is rather less than the diameter of the tap measured between the bottoms of the thread-groove, the quantity less being about a fiftieth of an inch for taps whose screw-parts are under three-quarters of an inch in thickness, and about a thirtieth of an inch for taps between one inch and two inches; those which are two or three inches require the stems to be about a twentieth or a sixteenth of an inch smaller than the bottom diameter of the screw.

If a number of long taper taps are being turned, the turning of all their stems is finished previous to finishing the turning of any of their screw-portions and conical parts; but if only one tap is in progress, the gripper is taken from the taper end as soon as the stem is turned, and is fastened to the square head; and while thus gripped, the turning progresses by first reducing the thickest portion to its finished diameter. The turning of this portion resembles the turning of a hob's screw-part, in being reduced to the finished diameter of the intended screw, if the work is smoothly filed; but if rough, the work must be of the proper diameter at the bottom of the rough projections; consequently, the outer diameter is larger.

After the stem and thick parallel portion is turned, the conical part should be turned. This must be entirely reduced to its finished diameter at the time of turning, to avoid all necessity of thinning with planing, shaping, filing, and other unnecessary processes after the tap is screwed. In order to avoid hand labour during this cone turning, either of two methods is adopted; one of these consists in making the upper slide of the rest turn the cone, and making the lathe work the screw of the slide; and the other method consists in adjusting the poppet-head, and making the ordinary long traverse of the lathe move the tool along to produce the required cone. When the upper slide of the rest is to be adjusted, the poppet-head remains in its usual position for parallel work, and the arranging of the rest commences by first roughly placing the slide to about the proper angle, and turning with a vee-tool a short portion of the tap's point to nearly its finished diameter; the tool is next brought out from the work to make a space of about an inch between the tool's point and the short part just turned; while at this distance, the space is measured with an inside calliper, and the tool is then wound along with the upper slide screw without moving the carriage, until the tool's point is opposite the beginning of the thick parallel portion of the tap; while thus situated, this space also is measured, and if the tool-point is at the same distance from the parallel part, as it was from the tap's point, the slide is near enough to the proper angle to commence the turning of the cone along its entire length. As soon as the slide is thus found to be nearly adjusted, the fixing bolts are tightened and the conical part is roughly reduced along its entire length, until near its finished dimensions, at which time the adjustment is completed by working the proper screw, if one belongs to the rest; but because many of the best lathes have not such a screw, the final adjustment of the slide must be accomplished by partly unscrewing the fixing bolts and giving the rest a few blows with a tin hammer. During cone turning by such means, the traverse of the tool is effected by the operator rotating the screw with his hand, or by putting a grooved pulley on to the square end of the screw, and working it with a cord that is actuated by the traverse bar of the lathe, or by an arrangement over the lathe, or by one of several other means usually adopted.

When the cone is to be turned by adjusting the poppet-head, the slide-rest needs no adjustment, but the poppet-head is pushed towards the lathe front by means of the adjusting screws belonging to the head; or if the head is without such screws, it is driven forward and adjusted with a tin hammer. When the head is brought partly forward, a short portion of the tap's point is turned to near the finished diameter, as in the mode for adjusting the slide-rest; the tool is next brought out and the distance measured with a calliper; but instead of working the slide-screw to advance the tool along to the thick part of the tap, the carriage and slide-rest are moved along the bed with the carriage handle, and as soon as the tool-point is thus put opposite the beginning of the parallel part, the distance between the tool-point and tap is measured as before, and the poppet-head is shifted until the distance is the same at either end of the conical portion, at which time the turning of the cone along its entire length may be commenced. The turning next progresses by advancing the tool with the ordinary long traverse of the lathe until the conical portion is made circular and regular, when the poppet-head is finally adjusted, either with its screws, or with a tin hammer, according to the particular sort of head belonging to the lathe.

In order to properly turn the tap to its dimensions, a steel-plate gap-gauge is provided for each size of taps; such a gauge resembles one for hob-turning, but has three gaps instead of only two. Fig. 549 represents a gap-gauge for taps, having one gap for the thickness of the stem, another gap for the thickness of the intended screw-part, and a third gap for the small end of the cone, which is termed the tap's point.

By means of either of the two processes just mentioned, the cones of all the taps in progress should be turned, and thus made ready for the screwing in the same lathe, or in a lathe specially appointed for screwing; and when taps of different lengths and cones are to be turned, the small quantity of shifting, to adjust the head to turn each cone, is conveniently effected without interfering with the slide-rest or cutting-tools.

Tap-screwing.—The screwing of a long taper tap ought to commence by fixing a gripper to the square head, and beginning the screw at the thickest portion; this part is parallel, and is therefore screwed while the poppet-head is adjusted to produce parallel work; so that if the taper portion of a tap has been turned with the same lathe which is to make the screw, the first step is to put the head right, if not already in its proper position. When the head is adjusted, the parallel part of the tap is screwed with a one-point vee-tool whose angle is about sixty-five, which is used until the thread-groove is nearly equal in width to its intended finished width, when a one-point tool having an angle of fifty-three is put in and used until the groove is of the intended finished depth in the parallel portion. By the time this second tool has made the groove to its finished depth along the parallel part, a great portion of the cone is also screwed, but the extreme point of the tap is still without any screw, because the screw-tool has been travelling along in a direction which is parallel to the centre length of the tap, instead of in a direction parallel to its slant side.

When the parallel portion of the screw is thus roughly shaped with one-point tools, a vee-tool having two teeth is required to curve the summits of the screw, and smooth it to very near its finished dimensions. During the use of this tool it is necessary to adjust the poppet-head a small quantity, in order to slightly taper the bottom of the thread-groove along its entire length, and to cause a gauge-nut to fit loosely at the junction of the taper portion with the parallel part. The next step is to bring forward the poppet-pivot still further, to make the screw more taper, but with a one-tooth tool of fifty-five degrees, instead of one with two teeth; by this means the groove is gradually deepened at the small end of the cone, but nothing is taken from the large end, and this screwing is continued until the small end is screwed about half as much as the large end, which is termed screwing the small end with only half a thread. When this is done, and the work properly smoothed with light cuts, the thread-groove at the small end of the tap is widened, but not deepened; this is accomplished by using a one-point tool having a cutting end with an angle of about ninety degrees, and the widening is effected by bringing forward the poppet-pivot yet further, to make the screw more taper only at the point of the tap. The length along the tap to which this widening extends is about four-tenths of the entire length of screw, so that the cut becomes gradually thinner and thinner as the tool is moved along to about four-tenths of the length from the point, at which place the tool is entirely free from the thread. By means of this widening of the groove's mouth, the summits of the thread are sharpened, and the tap will be more efficient for its work than those which are not thus shaped.

After the taper part of the screw is thus screwed and nicely smoothed, the remaining operation is the final adjusting and polishing of the thickest part of the screw. The tools required for this purpose are two; one of these is the ordinary straight tool with two teeth that were shaped with a standard hob, and the other tool is a two-teeth springy tool, which also is shaped with a standard hob. These slide-rest tools are similar to those for finishing hob-screws, and are represented by Figs 442 and 443. A gauge-nut also is necessary, which fits a standard hob of the same diameter as the new tap being made. When these are to be used to adjust a long taper tap, the straight screw-tool having two teeth is first applied to the work while the poppet-head is adjusted to slightly taper the screw, so that a very thin shaving shall be taken from the parallel part of the screw and a portion of the taper part at one cut. The head being thus fixed, the screw-tool is carefully adjusted to make its teeth fit the thread, and a few light scrapings are given to the work; after which the tool is taken out of its holder, and the springy tool is put in to finally smooth the same portion of the screw. By now properly cleaning the thread and screwing on the gauge-nut, it will be easily and loosely screwed along the entire length of the conical part, but will stop at the beginning of the parallel portion; the poppet-head is then to be adjusted to parallelism for finally smoothing this thick portion until it fits the nut, the straight screw-tool being first employed, and afterwards the springy tool, which finally adjusts the thickest part to its finished diameter.

The taper and parallel portions being thus finished, another tapering is to be given, but at the end of the screw adjoining the tap-stem. To do this, the poppet-pivot is adjusted to taper the screw the opposite way to that for all the previous tapering, so that about three steps of the thread may be tapered until the extremity of the screw is about a fiftieth of the tap's greatest diameter smaller.

During the finishing of the parallel part of a tap-screw, a gauge-nut should be used whose screw exactly fits the hob, or other plug, to which the tap is being made. This nut is adjusted to the proper size by screwing the hob through the nut from both ends of the hole; and if the new tap is screwed to fit tightly in the gauge, the future hardening of the tap will enlarge it sufficient to screw the nuts so that they will fit loosely on the hob, while they are warm, through the tapping, and when cold, each nut will be about the intended size, and will fit the hob.

By means of the screwing process just mentioned, taps of all sizes are accurately finished without any hand screw-tools being used; but the quicker method consists in finishing the tap or taps with hand-tools; these, in the hands of a careful man or boy, will adjust and polish the screws of taps and hobs quite as accurately as the best screwing-lathe or die-nuts ever made. But to avoid the laborious exertion necessary to finish with hand-tools a large number of long taps whose screws may be two or three inches thick, it is always advisable to make the slide-rest tools do the greater part of the smoothing, and this cannot be effected without great attention to the tool, so that a large number of thin cuts shall be taken off, instead of a few thicker ones. Smaller taps, that are only about an inch thick, should in all cases be partly screwed with hand-tools.

The length of the parallel part of a tap-screw is only about two-tenths of the entire length of the screw, and in order to obtain a proper idea of the shape and dimensions of such a screw, it is necessary to refer to Fig. 565; in this Figure the entire length of the screw is considered as ten equal lengths, and the number given to each length or portion is used to plainly point to any stated portion of the screw that may be spoken of. The mark No. 1 denotes that length of the tap which should enter the hole of the gauge-nut when the tap is newly made; consequently, at the time the tap's point is turned and smoothly filed, the gauge-nut should fit at one inch from the tap's extreme point, if the tap-screw is to be ten inches long. From the tap's point to the mark numbered 4, is the length of that portion of the screw-groove which is widened with the one-point tool of ninety degrees that was mentioned. From the mark No. 4 to No. 6, the thread is about three-quarters of the complete shape belonging to the thread of the parallel portion, and at about No. 7 the thread is completely formed, being in exactly the same shape as any portion of the parallel part, but smaller, the entire thickness of the tap at No. 7 being less than the extreme thickness at No. 8 or No. 9. The difference between the diameters at No. 7 and No. 8 is about a fiftieth of the tap's greatest thickness; consequently, in a two-inches tap, the difference is a twenty-fifth of an inch. The portion of the tap between the marks 8 and 10 is parallel, and the thickest part of the entire tool. By referring to the screw in the Figure it may be seen that the bottom of the thread-groove when finished is nearly parallel to the tap's slant side, and not parallel to the centre length.

Fluting.—The fluting of a hob consists in forming narrow grooves along the entire length of the screw. Each groove has a curved bottom and two straight sides that are slightly inclined to each other, in order to make the mouth of each flute wider than its bottom. The lengths of all the flutes are parallel to the entire length of the hob; consequently, the depth of a flute is the same at one end as at the other end, because the hob-screw is parallel. Both sides of a hob-flute are sharpened to provide two rows of cutting teeth; the hob will therefore cut whether the stem-end of the screw is first entered into a nut, or whether the opposite end, named the plug end, is first entered. A hob is never required to cut out more than a very thin scraping from a nut or other piece of work, so that very little room for shavings is provided in the flutes—a large amount of bearing surface being allowed because friction is of no consequence.

The fluting of a long taper tap consists in making long narrow grooves having curved bottoms along the entire length of the screw. In almost every tap which is made, whether long or short, the number of flutes is either three or five, the proper number being three, because with three flutes the friction surface of the tap-screw while in use is at a minimum. The object when making a tap-flute is to provide a row of cutting teeth along the entire length of the screw, and to make a space for containing the shavings cut off while the tap is in use. The large quantity of shavings made with a tap renders it necessary to make wide grooves, and the bearing surface is at the same time reduced to avoid friction. Each flute of a tap forms one row of cutting teeth, the cutting edges of which are in a plane extending through the tap's centre and along its length; and through the tap having three flutes it is said to have only three cutting edges, although it has two or three hundred. While the implement is in use all these edges are successively made to cut, each tooth cutting off only a small quantity as the tap is rotated, and gradually forced through the nut, or other work being tapped. Through the tap-screw being taper, the screw which is being formed in the nut is gradually and continually enlarged, until the thickest portion of the screw has entirely passed through the hole. If the tap-thread at the seventh mark is completely formed, slightly tapered, and polished, as directed, the nut-screw will be fully formed and nicely polished. A long taper tap, whose screw is well shaped and hardened, and the flutes properly formed, will screw several thousands of nuts, so that every hole shall be of precisely the same diameter, and every nut will fit a screw-gauge plug in the same manner. Although, during the tapping of ten thousand nuts, the point of the tap becomes blunt several times, and requires frequent grinding, which may make it an eighth of an inch thinner than its original thickness, the parallel portion is of the same thickness as when newly hardened years before, because this portion is introduced to the holes in such a gradual manner by means of the taper part adjoining.

Hob Fluting.—The proper shapes of the flutes in a hob are shown by Figs. 566 and 567, the width and depth of each flute being indicated by Fig. 567, which denotes the flat extremity of a hob's plug-end. The flute of a hob is much narrower than that of a tap, because a hob is often used to screw dies, and to shape the teeth of screw-tools; it is therefore necessary for the screw to be nearly circular, to provide a good bearing for contact with the work while it is being cut with the hob. These flutes are made with narrow grooving tools, termed circular cutters, and also with ordinary slide-rest tools, having cutting edges of a curved shape. The circular cutters consist of round plates having teeth around their rims partly resembling saw-teeth. A cutter of this class is rotated while tightly fastened on a spindle, and the two together are shown by Fig. 557. The slide-rest grooving tools used for fluting are those having straight thin ends extending from the thicker portions; these thick parts are fixed in the tool-holders of the slide-rests belonging to shaping-machines, lathes, and planing-machines. It may therefore be inferred that any one of these machines which a maker may have, may be selected for fluting, and this is the fact, no special fluting apparatus being necessary unless a large number are to be fluted with the apparatus when made.

The simplest mode of fluting a hob consists in filing each flute to its proper shape with thin files, termed knife-files, such as are indicated by Fig. 555. Small hobs not exceeding half an inch in thickness are thus easily fluted, if conveniently fixed, and such fixing consists in gripping the screw of the hob in a vice which is provided with a pair of thick lead clamps. The fluting of those that are more than half an inch thick is easily commenced with an edge of a rough, three-cornered file, each flute being afterwards smoothly filed to its proper depth and shape with a knife-file, and also with a small round file. Knife-files are both rough and smooth, long and short, some being twelve inches long, and others only two inches. Hobs that are to be fluted by such means, without a lathe or other machine, require a kind of lining to denote the places for the flutes, the lines being made on the flat extremity of the screw part. This portion is smoothly filed, and upon it a circular line is scribed with a divider; after which the line is divided with the same divider into five, seven, nine, or other odd number of equal parts, an odd number being necessary that two flutes may not be opposite each other. The number for a half-inch hob is five or seven; a hob about an inch in diameter has nine, and one which is two inches, thirteen. For such dividing no line of polygons or other Tables are required, a small springy divider being quite sufficient.

Hobs are easily fluted while on the lathe-pivots in the same position as they were when turned and screwed. Such fluting may be done in the lathe that screwed the hob, or in any other lathe provided with a carriage and slide-rest. While the hob remains gripped with the carrier, and is fixed on the pivots tight enough to prevent unintentional movement, a narrow grooving tool, which is fixed in the tool-holder, is moved to and fro along the hob-screw, and the flute is gradually deepened to its proper depth. This depth is attained by working the slide-rest screw to gradually advance the tool further into the hob at each cut. The to-and-fro movement is effected by an operator who rotates the carriage-spindle forwards and backwards with the carriage-handle. If the lathe possesses a dividing-plate and stop, they are brought into use for moving the hob a proper portion of a rotation after each flute is made; but if the lathe has no dividing apparatus, one of the disk chucks may be divided, and a few dots put in for temporary use, or the flat extremity of the hob may be marked as for fluting in a vice. If thus marked, the hob is rotated by an assistant, who moves the lathe-band a sufficient distance each time a flute is formed, and keeps the hob in its proper position according to the directions of the operator near the hob, who watches the marks on the work. During such fluting the poppet-pivot is supplied with oil, and screwed rather tight, to prevent movement when it is not required. In order to easily move the lathe-band the power gear of the mandril-frame must be connected with the lathe-spindle, as if slow turning were to be effected. A hob in position for fluting in a lathe, by the means just mentioned, is represented in Fig. 564.

Hob-fluting by moving the lathe-carriage to and fro is suitable when only a few hobs are to be fluted; but to avoid the labour of fluting a large number by such means, a circular cutter is made to rotate while in contact with the hob-screw, and the hob is moved along in a direction which is parallel to its length, which produces a flute whose length is in the same direction. Fluting by this method is easily accomplished with a lathe by rotating the cutter and spindle while on the conical pivots, and placing the hob beneath the cutter, so that the length of the hob shall be at right angles to the length of the cutter-spindle. The mode of fixing the hob consists in placing it between two poppets, the screws of which fit in the centre recesses of the hob, so that it can be moved partly round whenever it is necessary to do so. The poppets are fastened to a wrought-iron bracket, which is forged to suit the lathe-carriage, or they may be fastened in a special fluting table which belongs to the lathe. A fluting table of this class, with a hob attached, is shown by Fig. 597, and the entire table, with the work to be fluted, is moved across the lathe by means of the ordinary across traverse screw, or by a special screw which belongs to the table. To raise the hob to the exact height during the fluting, and for making the flutes to the proper depth, a screw is provided at each end of the table, both being rotated at one time by means of two couples of wheels with bevel teeth, which are connected to a spindle having a handle worked by the workman; or the two lifting screws may be actuated by means of two worm-wheels. At each end of the table is also a dovetail guide and slide, so that the affair is a sort of slide-rest. To prevent the hob moving round when not required, one of the poppet-screw points, which is square or triangular, is screwed into the centre recess in the hob's square head; this recess is also square, to fit the screw-point, and when both poppet-screws are tightened, while the work is between, a secure fastening is effected. Those who object to make recesses of this shape, may use the slotted holdfast denoted by Fig. 558; this is bolted to the fluting-table, and the angular grips of the instrument are made to grip either the hob's square head, or its stem at any convenient distance from the head. The holdfast is fastened to the hob, after it is put between the poppets, and when it is necessary to move the hob partly round, the grip of the holdfast is merely loosened, and the poppet-screws also loosened, which allows the necessary shifting of the hob without removing any of its fastenings.

Hob-fluting is also easily accomplished with a small shaping-machine; if such is to be used, the hob is supported at a proper height above the table with poppets, that the hob may be rotated when required, similar to the mode for fluting with a cutter in a lathe; but no special apparatus is necessary for a to-and-fro shaper, because the machine-table is easily raised or lowered, for applying the cuts, by means of the usual screw of the machine. To fix the hob tightly, a poppet-screw with a square point is used, or a slotted holdfast, in the mode described for fluting with a circular cutter. The cutting tool employed to flute a hob on a shaping-machine is an ordinary slide-rest tool, having a cutting end of suitable width. This is fastened in the tool-holder and moved to and fro with the usual movement of the machine's shaping-head, while the hob remains stationary, except when moved partly round to operate upon another flute.

Marking each hob to indicate the places for the flutes may be done in a lathe while the hob is on the pivots, whether the hob is to be afterwards fluted in a vice, with a lathe, or with a to-and-fro shaper. The lathe for this marking must have a division-plate, or have a division chuck of some sort, that the required odd number of lines may be made along the hob's screw which is to be marked. After the hob is fastened in a gripper and tightly fixed on the pivots, a grooving tool having a thin cutting end is put into the holder, and advanced to the hob-screw by the slide-rest screw; the tool is then made to cut a sort of broad line along the screw by moving the carriage along the lathe; the hob is next rotated a short distance to put the part for the next flute to the tool, and the tool is again moved along with the carriage handle to make another line; after which the same operations are continued until all the places for the flutes in all the hobs are lined. Lining by this means avoids the use of division plates while the hobs are situated on the fluting-tables.

Tap-fluting.—The processes for fluting taps are similar to those for hobs, but much more extensive, through the comparative large quantity of steel to be cut out, and through the peculiar shape of the tap-flute. This shape is that of a groove having a concave bottom and one flat side, the length of the groove being about parallel to the length of the tap. The flat side of a flute is the cutting side while the tap is in use, and the opposite side is a convex projection having no cutting edges, a tap-flute being provided with only one row of cutting teeth, a hob-flute having two rows. The shapes of the flutes in any ordinary long taper tap are shown by Fig. 568, which are suitable for a small tap not more than an inch thick; Fig. 569 denotes the shape of the tap's flat extremity, such a form being scribed on the smoothly-filed extremity previous to beginning the cutting for the flutes. Taps about two inches thick have angular flutes, for the convenience of forming the flutes by planing on a planing-machine. A tap's extremity of this form is denoted by Fig. 570, which renders the tool quite as efficient for its work as a curved flute, although the angular one is not so elegant. Angular flutes are easier made, and the tap is also much lightened thereby. Such a flute will allow ample room for oil and shavings, without greatly weakening the tap, and will also provide good cutting edges; the tap will also pass through the work with but little friction, if other circumstances are favourable. The bottom of the flute of a large tap should be parallel to the bottom of the thread, in order to lighten the tool without weakening the thick portion by making the flute too deep in that part; but for a tap not more than an inch and a half thick it is sufficient to make the bottom of the flute parallel to the tap's centre length.

To indicate the places for the flutes, each tap requires three lines to be marked along the entire length of the screw; this is done either with a scriber-block while the tap is supported on a couple of vee-blocks on a lining table, or with a point tool while the tap is in a lathe, the marking in a lathe being preferable because a broad deep mark can be made thereby. After these three straight lines are made a circle is marked upon the tap's point to indicate the depth for the flutes; the shapes of the flutes are next scribed, and the work is ready for the planing-machine. Taps thus marked, may be fluted either in a vice with filing, if they are small, or fluted on shaping-machines and planing machines, if the taps are large.

The only tools required by a maker to flute a few small taps, not more than half an inch thick, are gouge chisels and files—a few round files of various sizes, and a few flat files. After the tap is lined, it is fixed in a vice with thick lead clamps, and a small gouge chisel is first employed to make a hollow in the stem at the extremity of each of the three straight lines, and when the three hollows are roughly chiseled, a rough flat file is used to commence a flute by filing a sharp-cornered groove along the tap-screw, so that one edge of the groove shall nearly coincide with one of the gauge lines; a small round file is next used to widen and deepen the groove to about its finished width and depth, and to form a curved bottom for the flute. If the tap is large enough, another larger round file is also used, when the first one will not sufficiently enlarge the groove. A rough flat file is next required to reduce all the teeth on the side of the flute which is not required for cutting, and the filing continues until enough metal is taken off to form the space for the shavings. After this portion is properly shaped and smoothed, and the short hollow in the tap-stem also smoothed, the cutting side of the flute is finished with a smooth flat file and flour emery cloth.

A few small taps may also be easily fluted while in the lathe, by means of the to-and-fro movement of the lathe-carriage, similar to that mentioned for hob-fluting. A small tap thus treated, requires only the straight groove with curved bottom to be made while in the lathe, the side of the flute which is opposite the intended cutting side being reduced afterwards with filing in a vice. To avoid some of this filing, a vee-point tool may be used; this is moved along the work after the groove is made with the grooving tool, the vee-tool being gradually advanced across the work by means of the slide-rest screw.

The circular cutters having convex teeth are also very useful for tap-fluting, if the work is small; the use of these obviates all chiseling with gouge chisels to make recesses previous to beginning the flutes. If a circular cutter is employed, the recess in the tap-stem is made in the ordinary course of cutting, being formed by merely continuing the fluting to the desired distance beyond the screw-part, or by commencing the flute-cutting at the stem, instead of at the tap's point. Circular cutters are used either by rotating them in a lathe, or by placing the cutter-spindle between two poppet-pivots that are attached to a shaping-machine, or to a planing-machine; while thus fixed, the spindle is rotated with a pulley and band, and made to cut the tap which is fixed between two poppets on the machine-table, or on a movable fluting-table. Such cutters are only useful to produce a simply formed groove, having two flat sides, resembling those of a hob-flute; consequently, a tap-flute thus commenced is afterwards completed with filing, chipping, or planing.

A small planing-machine is a very efficient means of fluting taps, especially large ones two or three inches in diameter. When the tap is lined, it is put on to the machine-table without using any poppets, if only a few taps are to be fluted, the tap being held with plates across the head and stem; but to flute a large number, a separate fluting-table is useful; this is a portable affair, called a chuck, resembling Fig. 559, in which poppets are fixed at the proper distance apart when the chuck is required for use. At such a time it is put upon a block at each end which rests on the planing-machine table; the poppets are then put in and the tap put between, after which a slotted holdfast is fastened to the head, or some other part of the stem, and the tap is adjusted to produce the flute in a proper direction by means of the straight line on the screw. The fluting apparatus is then fixed with plates and bolts to the planing-machine table, and the work is ready for planing with the ordinary grooving-tools and vee-tools of the machine. The chuck, with a tap fixed and a holdfast attached, is shown by Fig. 560. Fig. 559 represents such a chuck with a hob, when it may be necessary to flute a hob by such means, a holdfast being fastened to a hob-stem in the same manner as to a tap-stem.

Shaping of Tap-heads.—The shaping of the heads of taps and hobs consists in squaring the four sides and finishing each head to a proper length, the length of a tap-head being longer than the head of a hob, because a much greater amount of wear and tear attaches to a tap. The length of a head is marked upon the stem with a sharp vee-tool, and consists of a circular line made around the stem after it is turned and previous to commencing the screwing. The outer extremity of the head also is marked with a circular line which is scribed with a divider, the diameter of this circle being equal to the desired distance between two opposite flat sides of the head. The circular line on the extremity is indicated in Fig. 561.

If a tap-head were properly shaped and reduced to suitable dimensions during forging, as directed, the only finishing required is effected with filing. But great numbers of hobs and taps are forged without any attempt to produce the square shape required, so that the squaring is an important process. If the tap or hob has no square part, it is proper to make at least one flat side, previous to screwing, that the work may be securely held. The head-shaping may therefore be either partly or entirely effected after the stem is turned and previous to proceeding further with the work.

Those heads that are too large to be squared with mere filing are shaped with small shaping-machines, each hob or tap being fixed with its length at right angles to the direction in which the cutting-tool moves, the work remaining stationary and fixed between two poppets, that may be the same as those used for fluting. A hob thus situated on the table of a to-and-fro shaper is denoted by Fig. 563, the cutting-tool being a slightly bent corner-tool, for the convenience of neatly shaping the corners where the circular line indicates the termination of the head. After the work is properly fixed, so that its length is parallel to the across traverse, one of the head's four sides is planed until one extremity coincides with the circular line on the stem, and the other extremity coincides with the circular line on the outer extremity of the head; the poppet-screws are then loosened, and the work moved a quarter of a complete rotation, which places the planed side at right angles to its first position; the hob or tap is then again fixed while being adjusted with an el-square whose blade is in contact with the planed side, and whose pedestal is in contact with the table of the machine. When the work is fixed, another side of the head is planed to the gauge-lines, and afterwards two other fixings are effected to complete the head. To prevent unintentioned shifting of the work while planing, the stem is gripped with a holdfast, or with a couple of small poppets which are fixed to the head, so that each screw-point may bite one side of the head.

When poppets are not accessible, a head may be squared while the tap is supported on a broad vee-block; this is provided with a broad bearing for the gap, that the tap-stem may be firmly gripped; and the gripping is accomplished with a cap having a vee-gap, which is put over the stem and fastened to the vee-block and table by means of bolts and nuts. To avoid bruising the stem, soft iron packing-pieces are put into the vee-gaps, to prevent them being in immediate contact with the work.

It is necessary to carefully file and polish the cutting edges of all hobs and taps, whether they were fluted with round cutters or with straight grooving-tools. Much of the smoothing can be done with soapy water, while the work is being planed, and the polishing is completed with a flat smooth file and with emery cloth, the cloth being wrapped around the same smooth file, or wrapped around a wood polisher. The filing of long flutes is effected by using round files and flat ones whose tangs are cranked.

Hardening of Taps.—The hardening of a tap or hob is the simplest process of the making, and consists in heating the work to a dull red while in a clean fire of cinders or charcoal, and dipping it into water which has been in use a long time for purposes of hardening and forging. The heat of a plate-furnace is a convenient means for heating the tap if it is a long one, but short ones are easily heated in an ordinary forge fire, if the fire is at least as long as the tap, and the wind is gently administered to avoid bending the work. The bottom of the fire should be nearly flat, that the work may be supported along its entire length, this being a means of preventing the work bending while soft with the red heat. When the proper dull red is attained, it should be rolled into a few pounds of powdered prussiate of potash, if a large tap, and as soon as the powder which adheres is melted, the tap is put into the water while the length of the work is nearly vertical, but a little inclined to the water's surface; this allows the tap to bend while cooling, and tends to prevent it breaking. When in the water, it remains there till cold, when it is ready for tempering. The large numbers of taps and other tools that are broken in hardening result from using steel which has not been tested, or moderated with softening if it is found to be too brittle; there is no risk of breakage if the steel is not too solid, and the expense of breaking trial pieces of steel previous to the making is nearly nothing when compared to the breakage of tools after being lathe-turned, screwed, or planed. All trial pieces that are broken previous to the making of a tool can be used for other purposes.

The degree to which taps and hobs are tempered is the same for all sizes, and is indicated by a light golden tinge which appears on the surface if it is properly polished with flour emery cloth after hardening. All the flutes require polishing, and the entire surface of every flute; only by such means can it be known whether the tap or hob is equally tempered. The heat for tempering is slowly applied, that the interior of the tap may not remain too hard after the cutting edges are tempered; and the means of imparting the heat is a thick tube which is as long as or longer than the work to be tempered. The diameter of the hole in the tube is about three times the diameter of the tap, and the tube is heated to a yellow heat and allowed to remain in the fire while the tempering is being performed, if small taps are to be tempered, but for large ones it is necessary to bring the tube from the fire, and stand it with its length in a vertical position upon an iron block having a hole, or upon two blocks, so that a space shall exist beneath the tempering tube. While the tube thus remains, the tap to be tempered is suspended with a pair of one-sheave pulley blocks; and slowly moved up and down while in the hole, the head being gripped with a forge tongs having angular gaps and thick handles, which are tightly held with a coupling ring. It is necessary for the head of the tap to be equally hard with the other portions; consequently, it may be requisite to lower the tap until its head is at the bottom of the tube-hole, and allow it to remain there till the tong-grips are properly heated.

Wheels for Tap-Screws.—The lathes which are used for screwing taps and hobs are those provided with screws having either half-inch steps, or quarter-inch steps. Whether the lathe-screw has a quarter-inch step or a half-inch one, the wheels for screwing have the same numbers of teeth, although the wheels are always of a proper diameter and weight to suit their respective lathes, whether small or large. A lathe that has a quarter-inch screw will screw any size of taps or hob which is to be made with the ordinary Whitworth screw, by using only two screwing wheels for each different step. One of these is that which is put upon the lathe-spindle, and called the mandril-wheel, and the other is that which is put upon the lathe-screw and termed the screw-wheel. A screw having a half-inch step will also cut most of the screws required for taps, by using only two wheels, and when screws are made by using two screwing wheels only, the arrangement is termed simple gear. Any additional wheels that may be required are merely connecting wheels, which are put between the two screwing wheels to occupy the space and produce the particular direction of movement required for the traverse of the screw-tool. Without connecting-wheels, the motion of the mandril-wheels, which are of various sizes, could not be communicated to the lathe-screw wheels, which also are of various sizes.

Cutting a screw in a lathe is a much more important operation than selecting the proper wheels, because all the lathe-makers provide Tables which indicate the different wheels required for each stated pitch to be cut. Such Tables are hung on the walls of engineers' turneries near the screwing lathes for the use of those who require them, and to avoid calculation when a screw is to be cut. If it happens that such Tables are not provided, the proper wheels are discovered by very simple arithmetic, if necessary; but this is of no avail without a careful attention to the shape of the cutting tool, the position of the tool's point to form the thread at right angles to the work, also the proper height of the cutting edges, making the tool cut only at one side, applying the proper quantity of cut to avoid breaking the point, and all the other directions given in preceding sections, if hobs and taps are to be screwed.

In the Tables for dimensions of taps and hobs now given, a couple of wheels are indicated for each different pitch of thread. It may be noticed that several sizes of taps are screwed with threads of the same pitch for all; consequently, one couple of wheels are suitable for several sizes of taps and hobs, and the total number of wheels required for several thousands of taps is very small. In Table 5 the dimensions of hobs are given, the first column showing the name of each hob, which is the diameter of its screw-portion. The second column denotes the total length for each, including both stem and screw-part. The next three columns indicate the lengths of the screw-parts, stems, and heads, and the sixth column is useful to denote the depth to which the thread-groove is to be cut while screwing. Column seven is required to show the precise diameter to which each stem is to be turned, previous to beginning the screwing; the dimensions in this column are also the diagonals of the heads. In the eighth column is given the pitch for each size of hob, and in the ninth, two wheels are mentioned for each pitch, the first number of each couple showing the number of teeth on the mandril-wheel, and the second number showing the number of teeth on the wheel for the lathe-screw.

TABLE 5.

DIMENSIONS OF HOBS HAVING ORDINARY SCREWS.

Extreme diameters.	Total lengths.	Lengths of screw-portions.	Lengths of stems.	Lengths of square heads.	Diameters at the bottoms of the threads.	Diameters of stems.	Numbers of steps in one-inch lengths of screws.	Couples of wheels for cutting the screws with a lathe-screw having four steps to an inch.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		
$\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{11}{64}$	20	20 and 100
$\frac{5}{16}$	$2\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{15}{64}$	18	20 ,, 90
$\frac{3}{8}$	3	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{9}{16}$	$\frac{19}{64}$	$\frac{18}{64}$	16	25 ,, 100
$\frac{7}{16}$	$3\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$\frac{9}{16}$	$\frac{11}{32}$	$\frac{21}{64}$	14	30 ,, 105
$\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$\frac{5}{8}$	$\frac{13}{32}$	$\frac{25}{64}$	12	30 ,, 90
$\frac{9}{16}$	$3\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$\frac{5}{8}$	$\frac{15}{32}$	$\frac{14}{32}$	12	30 ,, 90
$\frac{5}{8}$	4	2	2	$\frac{11}{16}$	$\frac{33}{64}$	$\frac{31}{64}$	11	20 ,, 55
$\frac{11}{16}$	$4\frac{1}{4}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$\frac{3}{4}$	$\frac{37}{64}$	$\frac{35}{64}$	11	20 ,, 55
$\frac{3}{4}$	$4\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{19}{32}$	10	30 ,, 75
$\frac{13}{16}$	$4\frac{3}{4}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{21}{32}$	10	30 ,, 75
$\frac{7}{8}$	5	$2\frac{1}{2}$	$2\frac{1}{2}$	$\frac{15}{16}$	$\frac{47}{64}$	$\frac{45}{64}$	9	40 ,, 90
$\frac{15}{16}$	$5\frac{1}{4}$	$2\frac{5}{8}$	$2\frac{5}{8}$	1	$\frac{51}{64}$	$\frac{49}{64}$	9	40 ,, 90
1	$5\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{1}{16}$	$\frac{27}{32}$	$\frac{25}{32}$	8	40 ,, 80
$1\frac{1}{16}$	$5\frac{3}{4}$	$2\frac{7}{8}$	$2\frac{7}{8}$	$1\frac{1}{8}$	$\frac{29}{32}$	$\frac{26}{32}$	8	40 ,, 80
$1\frac{1}{8}$	6	3	3	$1\frac{1}{4}$	$\frac{59}{64}$	$\frac{57}{64}$	7	40 ,, 70
$1\frac{3}{16}$	$6\frac{1}{4}$	$3\frac{1}{8}$	$3\frac{1}{8}$	$1\frac{5}{16}$	$\frac{63}{64}$	$\frac{61}{64}$	7	40 ,, 70
$1\frac{1}{4}$	$6\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{3}{64}$	$1\frac{1}{64}$	7	40 ,, 70
$1\frac{5}{16}$	$6\frac{3}{4}$	$3\frac{3}{8}$	$3\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{7}{64}$	$1\frac{3}{64}$	7	40 ,, 70
$1\frac{3}{8}$	7	$3\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{5}{32}$	$1\frac{4}{32}$	6	30 ,, 45
$1\frac{7}{16}$	$7\frac{1}{4}$	$3\frac{5}{8}$	$3\frac{5}{8}$	$1\frac{9}{16}$	$1\frac{7}{32}$	$1\frac{6}{32}$	6	30 ,, 45
$1\frac{1}{2}$	$7\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{9}{32}$	$1\frac{8}{32}$	6	30 ,, 45
$1\frac{9}{16}$	$7\frac{3}{4}$	$3\frac{7}{8}$	$3\frac{7}{8}$	$1\frac{11}{16}$	$1\frac{11}{32}$	$1\frac{10}{32}$	6	30 ,, 45
$1\frac{5}{8}$	8	4	4	$1\frac{3}{4}$	$1\frac{23}{64}$	$1\frac{21}{64}$	5	40 ,, 50
$1\frac{11}{16}$	$8\frac{1}{4}$	$4\frac{1}{8}$	$4\frac{1}{8}$	$1\frac{13}{16}$	$1\frac{27}{64}$	$1\frac{25}{64}$	5	40 ,, 50
$1\frac{3}{4}$	$8\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{31}{64}$	$1\frac{29}{64}$	5	40 ,, 50
$1\frac{13}{16}$	$8\frac{3}{4}$	$4\frac{3}{8}$	$4\frac{3}{8}$	$1\frac{15}{16}$	$1\frac{35}{64}$	$1\frac{33}{64}$	5	40 ,, 50
$1\frac{7}{8}$	9	$4\frac{1}{2}$	$4\frac{1}{2}$	2	$1\frac{19}{32}$	$1\frac{18}{32}$	$4\frac{1}{2}$	40 ,, 45
$1\frac{15}{16}$	$9\frac{1}{4}$	$4\frac{5}{8}$	$4\frac{5}{8}$	$2\frac{1}{8}$	$1\frac{21}{32}$	$1\frac{20}{32}$	$4\frac{1}{2}$	40 ,, 45
2	$9\frac{1}{2}$	$4\frac{3}{4}$	$4\frac{3}{4}$	$2\frac{1}{4}$	$1\frac{23}{32}$	$1\frac{22}{32}$	$4\frac{1}{2}$	40 ,, 45
$2\frac{1}{16}$	$9\frac{3}{4}$	$4\frac{7}{8}$	$4\frac{7}{8}$	$2\frac{5}{16}$	$1\frac{25}{32}$	$1\frac{24}{32}$	$4\frac{1}{2}$	40 ,, 45
$2\frac{1}{8}$	10	5	5	$2\frac{3}{8}$	$1\frac{27}{32}$	$1\frac{25}{32}$	$4\frac{1}{2}$	40 ,, 45
$2\frac{3}{16}$	$10\frac{1}{4}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$2\frac{7}{16}$	$1\frac{29}{32}$	$1\frac{27}{32}$	$4\frac{1}{2}$	40 ,, 45
$2\frac{1}{4}$	$10\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{13}{16}$	$1\frac{7}{8}$	4	60 ,, 60
$2\frac{5}{16}$	$10\frac{3}{4}$	$5\frac{3}{8}$	$5\frac{3}{8}$	$2\frac{9}{16}$	2	$1\frac{15}{16}$	4	60 ,, 60
$2\frac{3}{8}$	11	$5\frac{1}{2}$	$5\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{1}{16}$	2	4	60 ,, 60
$2\frac{7}{16}$	$11\frac{1}{4}$	$5\frac{5}{8}$	$5\frac{5}{8}$	$2\frac{11}{16}$	$2\frac{1}{8}$	$2\frac{1}{16}$	4	60 ,, 60

TABLE 5—*continued.*

Extreme diameters.	Total lengths.	Lengths of screw-portions.	Lengths of stems.	Lengths of square heads.	Diameters at the bottoms of the threads.	Diameters of stems.	Numbers of steps in one-inch lengths of screws.	Couples of wheels for cutting the screws with a lathe-screw having four steps to an inch.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		
$2\frac{1}{2}$	$11\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{16}$	$2\frac{1}{8}$	4	60 and 60
$2\frac{9}{16}$	$11\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$2\frac{13}{16}$	$2\frac{1}{4}$	$2\frac{3}{16}$	4	60 ,, 60
$2\frac{5}{8}$	$11\frac{3}{4}$	$5\frac{7}{8}$	$5\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{6}{16}$	$2\frac{1}{4}$	4	60 ,, 60
$2\frac{11}{16}$	$11\frac{3}{4}$	$5\frac{7}{8}$	$5\frac{7}{8}$	$2\frac{15}{16}$	$2\frac{3}{8}$	$2\frac{3}{16}$	4	60 ,, 60
$2\frac{3}{4}$	12	6	6	3	$2\frac{3}{8}$	$2\frac{5}{16}$	$3\frac{1}{2}$	40 ,, 35
$2\frac{13}{16}$	12	6	6	$3\frac{1}{16}$	$2\frac{7}{16}$	$2\frac{3}{8}$	$3\frac{1}{2}$	40 ,, 35
$2\frac{7}{8}$	$12\frac{1}{4}$	$6\frac{1}{8}$	$6\frac{1}{8}$	$3\frac{1}{8}$	$2\frac{1}{2}$	$2\frac{7}{16}$	$3\frac{1}{2}$	40 ,, 35
$2\frac{15}{16}$	$12\frac{1}{4}$	$6\frac{1}{8}$	$6\frac{1}{8}$	$3\frac{3}{16}$	$2\frac{9}{16}$	$2\frac{1}{2}$	$3\frac{1}{2}$	40 ,, 35
3	$12\frac{1}{4}$	$6\frac{1}{8}$	$6\frac{1}{8}$	$3\frac{1}{4}$	$2\frac{5}{8}$	$2\frac{9}{16}$	$3\frac{1}{2}$	40 ,, 35

When the operator desires to ascertain whether the numbers of any couple of wheels are correct, he can multiply the number of the lathe-screw wheel by the number of steps in one inch of the lathe-screw, and then divide the product by the number of the mandril-wheel; if the quotient thus obtained is the same as the number of steps in the adjoining column, the wheels indicated are the right ones, although other wheels that are not too large or too small for the lathe, may be used, if necessary.

The hobs referred to in the Table are of no use for ordinary screwing of holes, but are only available as standards of reference, or to cut a very thin shaving from a nut or other piece of work which has been screwed in a lathe, and to shape the teeth of hand-screw tools, slide-rest tools, and sometimes teeth of dies.

Table 6 contains the dimensions for long taper taps, and each diameter of taps has the same sort of thread as the same diameter of hobs in Table 5, being that which is adopted by the tool-makers; but the length given for each tap is rather greater, to allow for wearing and also grinding the tap's point to sharpen it, so that the tool will tap a few thousands more nuts than a shorter one.

TABLE 6.

DIMENSIONS OF LONG TAPER TAPS HAVING ORDINARY SCREWS.

Extreme diameters.	Total lengths.	Lengths of screw-portions.	Lengths of stems.	Lengths of square heads.	Diameters of stems.	Diameters of taps' points at the bottoms of the threads.	Diameters of holes in nuts to be tapped.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
$\frac{1}{4}$	3	$1\frac{6}{8}$	$1\frac{3}{8}$	$\frac{5}{8}$	$\frac{11}{64}$	$\frac{9}{64}$	$\frac{3}{16}$
$\frac{5}{16}$	$3\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$\frac{11}{16}$	$\frac{16}{64}$	$\frac{13}{64}$	$\frac{1}{4}$
$\frac{3}{8}$	4	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{3}{4}$	$\frac{18}{64}$	$\frac{15}{64}$	$\frac{19}{64}$
$\frac{7}{16}$	$4\frac{5}{8}$	$2\frac{5}{8}$	2	$\frac{13}{16}$	$\frac{21}{64}$	$\frac{19}{64}$	$\frac{11}{32}$
$\frac{1}{2}$	$5\frac{3}{8}$	$3\frac{1}{4}$	$2\frac{1}{8}$	$\frac{7}{8}$	$\frac{25}{64}$	$\frac{23}{64}$	$\frac{13}{32}$
$\frac{9}{16}$	$5\frac{7}{8}$	$3\frac{3}{8}$	$2\frac{1}{4}$	$\frac{15}{16}$	$\frac{14}{32}$	$\frac{13}{32}$	$\frac{15}{32}$
$\frac{5}{8}$	$6\frac{3}{4}$	$4\frac{1}{4}$	$2\frac{1}{2}$	1	$\frac{31}{64}$	$\frac{29}{64}$	$\frac{33}{64}$
$\frac{11}{16}$	$7\frac{3}{8}$	$4\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{1}{16}$	$\frac{35}{64}$	$\frac{33}{64}$	$\frac{37}{64}$
$\frac{3}{4}$	$7\frac{7}{8}$	$5\frac{1}{8}$	$2\frac{3}{4}$	$1\frac{1}{8}$	$\frac{19}{32}$	$\frac{18}{32}$	$\frac{5}{8}$
$\frac{13}{16}$	$8\frac{3}{8}$	$5\frac{1}{2}$	$2\frac{7}{8}$	$1\frac{3}{16}$	$\frac{21}{32}$	$\frac{19}{32}$	$\frac{11}{16}$
$\frac{7}{8}$	$9\frac{1}{8}$	6	$3\frac{1}{8}$	$1\frac{1}{4}$	$\frac{46}{64}$	$\frac{39}{64}$	$\frac{47}{64}$
$\frac{15}{16}$	$9\frac{1}{2}$	$6\frac{1}{4}$	$3\frac{1}{4}$	$1\frac{6}{16}$	$\frac{49}{64}$	$\frac{43}{64}$	$\frac{51}{64}$
1	$9\frac{7}{8}$	$6\frac{1}{2}$	$3\frac{3}{8}$	$1\frac{3}{8}$	$\frac{26}{32}$	$\frac{23}{32}$	$\frac{27}{32}$
$1\frac{1}{16}$	$10\frac{1}{4}$	$6\frac{3}{4}$	$3\frac{1}{2}$	$1\frac{7}{16}$	$\frac{28}{32}$	$\frac{26}{32}$	$\frac{29}{32}$

TABLE 6—*continued.*

Extreme diameters.	Total lengths.	Lengths of screw-portions.	Lengths of stems.	Lengths of square heads.	Diameters of stems.	Diameters of taps' points at the bottoms of the threads.	Diameters of holes in nuts to be tapped.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
$1\frac{1}{8}$	$10\frac{3}{4}$	7	$3\frac{3}{4}$	$1\frac{1}{2}$	$\frac{57}{64}$	$\frac{51}{64}$	$\frac{59}{64}$
$1\frac{3}{16}$	$11\frac{3}{8}$	$7\frac{3}{8}$	4	$1\frac{9}{16}$	$\frac{51}{64}$	$\frac{55}{64}$	$\frac{53}{64}$
$1\frac{1}{4}$	$11\frac{7}{8}$	$7\frac{5}{8}$	$4\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{1}{64}$	$\frac{59}{64}$	$1\frac{3}{64}$
$1\frac{5}{16}$	$12\frac{3}{8}$	$7\frac{7}{8}$	$4\frac{1}{2}$	$1\frac{11}{16}$	$1\frac{5}{64}$	$\frac{63}{64}$	$1\frac{7}{64}$
$1\frac{3}{8}$	$13\frac{1}{8}$	$8\frac{3}{8}$	$4\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{4}{32}$	$1\frac{1}{32}$	$1\frac{5}{32}$
$1\frac{7}{16}$	$13\frac{3}{4}$	$8\frac{3}{4}$	5	$1\frac{13}{16}$	$1\frac{3}{16}$	$1\frac{3}{32}$	$1\frac{7}{32}$
$1\frac{1}{2}$	$14\frac{1}{2}$	$9\frac{1}{4}$	$5\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{4}{32}$	$1\frac{9}{32}$
$1\frac{9}{16}$	$15\frac{1}{8}$	$9\frac{5}{8}$	$5\frac{1}{2}$	$1\frac{15}{16}$	$1\frac{5}{16}$	$1\frac{6}{32}$	$1\frac{11}{32}$
$1\frac{5}{8}$	$15\frac{3}{4}$	10	$5\frac{3}{4}$	$2\frac{1}{16}$	$1\frac{21}{64}$	$1\frac{15}{54}$	$1\frac{23}{64}$
$1\frac{11}{16}$	$16\frac{1}{4}$	$10\frac{3}{8}$	$5\frac{7}{8}$	$2\frac{3}{16}$	$1\frac{25}{64}$	$1\frac{19}{54}$	$1\frac{27}{64}$
$1\frac{3}{4}$	17	11	6	$2\frac{5}{16}$	$1\frac{29}{64}$	$1\frac{23}{64}$	$1\frac{31}{64}$
$1\frac{13}{16}$	$17\frac{1}{2}$	$11\frac{3}{8}$	$6\frac{1}{8}$	$2\frac{3}{8}$	$1\frac{33}{54}$	$1\frac{27}{64}$	$1\frac{35}{64}$
$1\frac{7}{8}$	$18\frac{1}{4}$	12	$6\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{18}{32}$	$1\frac{15}{32}$	$1\frac{19}{32}$
$1\frac{15}{16}$	$18\frac{5}{8}$	$12\frac{3}{8}$	$6\frac{1}{4}$	$2\frac{9}{16}$	$1\frac{20}{32}$	$1\frac{17}{32}$	$1\frac{21}{32}$
2	19	$12\frac{5}{8}$	$6\frac{3}{8}$	$2\frac{5}{8}$	$1\frac{22}{32}$	$1\frac{19}{32}$	$1\frac{23}{32}$
$2\frac{1}{16}$	$19\frac{3}{8}$	$12\frac{7}{8}$	$6\frac{1}{2}$	$2\frac{11}{16}$	$1\frac{24}{32}$	$1\frac{21}{32}$	$1\frac{25}{32}$
2 [illegible]	$19\frac{5}{8}$	13	$6\frac{5}{8}$	$2\frac{3}{4}$	$1\frac{25}{32}$	$1\frac{22}{32}$	$1\frac{27}{32}$
$2\frac{3}{16}$	20	$13\frac{1}{4}$	$6\frac{3}{4}$	$2\frac{13}{16}$	$1\frac{27}{32}$	$1\frac{24}{32}$	$1\frac{29}{32}$
$2\frac{1}{4}$	$20\frac{1}{4}$	$13\frac{1}{2}$	$6\frac{3}{4}$	$2\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{25}{32}$	$1\frac{15}{16}$
$2\frac{5}{16}$	$20\frac{7}{8}$	14	$6\frac{7}{8}$	$2\frac{15}{16}$	$1\frac{15}{16}$	$1\frac{26}{32}$	2
$2\frac{3}{8}$	$21\frac{1}{4}$	$14\frac{1}{4}$	7	3	2	$1\frac{28}{32}$	$2\frac{1}{16}$
$2\frac{7}{16}$	$21\frac{5}{8}$	$14\frac{1}{2}$	$7\frac{1}{8}$	$3\frac{1}{16}$	$2\frac{1}{16}$	$1\frac{30}{32}$	$2\frac{1}{8}$
$2\frac{1}{2}$	$22\frac{1}{4}$	15	$7\frac{1}{4}$	$3\frac{1}{8}$	$2\frac{1}{8}$	2	$2\frac{3}{16}$
$2\frac{9}{16}$	$22\frac{5}{8}$	$15\frac{1}{4}$	$7\frac{3}{8}$	$3\frac{3}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$2\frac{1}{4}$
$2\frac{5}{8}$	$23\frac{1}{8}$	$15\frac{5}{8}$	$7\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{8}$	$2\frac{5}{16}$
$2\frac{11}{15}$	$23\frac{1}{2}$	$15\frac{7}{8}$	$7\frac{5}{8}$	$3\frac{5}{16}$	$2\frac{5}{16}$	$2\frac{3}{16}$	$2\frac{3}{8}$
$2\frac{3}{4}$	$24\frac{1}{4}$	$16\frac{1}{2}$	$7\frac{3}{4}$	$3\frac{3}{8}$	$2\frac{5}{16}$	$2\frac{3}{16}$	$2\frac{3}{8}$
$2\frac{13}{16}$	$24\frac{3}{4}$	$16\frac{7}{8}$	$7\frac{7}{8}$	$3\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{1}{4}$	$2\frac{7}{16}$
$2\frac{7}{8}$	$25\frac{1}{4}$	$17\frac{1}{4}$	8	$3\frac{1}{2}$	$2\frac{7}{16}$	$2\frac{9}{32}$	$2\frac{1}{2}$
$2\frac{15}{16}$	$25\frac{5}{8}$	$17\frac{1}{2}$	$8\frac{1}{8}$	$3\frac{9}{16}$	$2\frac{1}{2}$	$2\frac{11}{32}$	$2\frac{9}{16}$
3	26	$17\frac{3}{4}$	$8\frac{1}{4}$	$3\frac{5}{8}$	$2\frac{9}{16}$	$2\frac{13}{32}$	$2\frac{5}{8}$

The greater number of all taps that are made, are used to screw nuts for the ends of screw-bolts, connecting-rods, piston-rods, slide-rods, crank-pins, studs, joint-pins, spindles and keys; and because large bolts, rods, and other work of three, four, or six inches thick are now much more frequently made than when the Whitworth screws originated, it is the custom of engineers to screw the ends of such work with thin threads having short steps, that the thread-groove may not be too deep and break off the end of the rod while in use. Thin threads are termed fine threads, and are of the usual vee-shape having curved summits, the angle subtended by the two sides being fifty-five, as in the other thick threads having long steps. In Table 7 are given the various diameters of bolts and rods intended to have thin threads, and opposite are the respective numbers of steps per inch.

TABLE 7.

NUMBERS OF STEPS IN BOLTS' AND TAPS' SCREWS HAVING SHORT STEPS.

Extreme diameters of taps or rods.	Numbers of steps per inch of length.	Extreme diameters of taps or rods.	Numbers of steps per inch of length.	Extreme diameters of taps or rods.	Numbers of steps per inch of length.	Extreme diameters of taps or rods.	Numbers of steps per inch of length.
Inches.		Inches.		Inches.		Inches.	
1/4	20	1 3/8	8	2 1/2	5	5 1/2	4
5/16	18	1 7/16	8	2 9/16	5	5 3/4	4
3/8	16	1 1/2	7	2 5/8	5	6	3 3/4
7/16	14	1 9/16	7	2 11/16	5	6 1/4	3 3/4
1/2	12	1 5/8	7	2 3/4	4 3/4	6 1/2	3 3/4
9/16	12	1 11/16	7	2 13/16	4 3/4	6 3/4	3 3/4
5/8	11	1 3/4	6 1/2	2 7/8	4 3/4	7	3 1/2
11/16	11	1 13/16	6 1/2	2 15/16	4 3/4	7 1/4	3 1/2
3/4	10	1 7/8	6 1/2	3	4 1/2	7 1/2	3 1/2
13/16	10	1 15/16	6 1/2	3 1/4	4 1/2	7 3/4	3 1/2
7/8	10	2	6	3 1/2	4 1/2	8	3 1/4
15/16	10	2 1/16	6	3 3/4	4 1/2	8 1/2	3 1/4
1	9	2 1/8	6	4	4 1/4	9	3 1/4
1 1/16	9	2 3/16	6	4 1/4	4 1/4	9 1/2	3 1/4
1 1/8	9	2 1/4	5 1/2	4 1/2	4 1/4	10	3
1 3/16	9	2 5/16	5 1/2	4 3/4	4 1/4	10 1/2	3
1 1/4	8	2 3/8	5 1/2	5	4	11	3
1 5/16	8	2 7/16	5 1/2	5 1/4	4	11 1/2	3
						12	3

In order to screw taps or rods with thin threads, the teeth of the screw-tools employed are shaped with the same hobs as those for thick threads, except those having 4¾ steps, 6½ steps, or other similar fractional quantity per inch; tools for such threads are shaped with special hobs. The objection to a fraction on paper amounts to nothing in practice, because the same lathes, wheels, and tables of wheels, are used to produce threads of all classes, and are employed with equal facility for either sort of work. Taps having short steps have comparatively short screw-portions, the lengths and diameters of their stems being about the same as those of taps having longer steps. In Table 8 the length of each screw-part is shown opposite the tap's extreme diameter or thickness.

TABLE 8.

SCREW-PORTIONS OF LONG TAPER TAPS HAVING SHORT-STEP SCREWS.

Extreme diameters.	Lengths of screw-portions.	Extreme diameters.	Lengths of screw-portions.	Extreme diameters.	Lengths of screw-portions.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
3/4	5 1/8	1 1/2	7 1/2	2 1/4	11
13/16	5 1/2	1 9/16	7 3/4	2 5/16	11 1/4
7/8	5 3/4	1 5/8	8 1/8	2 3/8	11 3/8
15/16	6	1 11/16	8 1/4	2 7/16	11 5/8
1	6 1/4	1 3/4	8 3/4	2 1/2	12
1 1/16	6 3/8	1 13/16	9 1/8	2 9/16	12 1/4
1 1/8	6 1/2	1 7/8	9 3/8	2 5/8	12 3/8
1 3/16	6 5/8	1 15/16	9 5/8	2 11/16	12 3/4
1 1/4	7	2	10	2 3/4	13 1/4
1 5/16	7 1/8	2 1/16	10 1/4	2 13/16	13 1/2
1 3/8	7 1/4	2 1/8	10 3/8	2 7/8	13 3/4
1 7/16	7 3/8	2 3/16	10 5/8	2 15/16	14
				3	14 1/4

MAKING OF HAMMERS AND CHISELS, &c.

HAMMERS.—All hammers for hand use, whether chipping hammers or sledge hammers, should be made entirely of steel. The practice of welding steel faces to iron eye-portions in order to avoid using a larger quantity of steel, is more expensive than making the entire tool of one piece of steel, and an unsound inferior tool is made instead of a good one. The steel selected for hammers is a tough cast steel, and may be termed a soft fibrous steel that will bear hardening. Cast steel which has been well wrought with rolling and hammering, is suitable for hammers, and but little forging is necessary if the metal selected is of proper size.

The small chipping hammers and other hammers for vice-work, are easily made of round steel, but the larger sizes termed sledge-hammers, require to be made of square bar-steel. When several are to be made, a long piece is selected, that each hammer may be forged at one of the bar's ends, thus avoiding a great portion of the handling with tongs. While the work is attached to the bar, it is punched and drifted to shape the hole, and also thinned with top and bottom fullers at both sides of the hole. The greater part of the forging is thus effected previous to cutting the hammer from the bar, and when cut off, all rugged portions at the extremities are carefully trimmed off with a sharp rod-chisel, that the faces of the work may be solid.

A good hammer is that which has a long hole to provide a good bearing for the handle, and which has the metal around the hole curved with punching and drifting, the hole being oval, as in Fig. 571, and tapered at both ends or entrances of the hole. The entrances of the hole are principally tapered at the two sides which are nearest to the hammer's faces, the other two sides being nearly parallel. Steel taper drifts of proper shape are therefore driven into both ends of the hole, to produce the required form, and all filing of that part is thus avoided.

The making of small sledge hammers is conducted by forging each one at the end of a bar, similar to the mode for chipping hammers, but a sledge hammer, about twenty pounds in weight, is made either singly, or of a piece of steel which is only large enough to be made into two; the handling of a heavy bar is thus avoided. By referring to Fig. 573, it may be seen that the handle-hole or shaft-hole of a sledge-hammer is comparatively smaller than that of a chipping hammer; this is to provide a solid tool that will not quiver or vibrate when in use, and is therefore not liable to break.

Very little filing is sufficient to smooth a hammer, if properly forged, the shaping being easily effected with fullers and rounding tools; and after being filed, each of the two ends is hardened, but not afterwards tempered. After hardening, the two ends are finished with grinding on a grindstone. Polishing the faces of engineers' hammers is not necessary.

Through the handle-hole of a hammer being tapered at both ends, the shaft-end is made to resemble a rivet which is thickest at the two ends, one part of the shaft being made to fit one mouth of the hole with filing or with a paring chisel for wood, and the outer end of the shaft being made to fit the other mouth of the hole by spreading the wood with a wedge. The wood for the shaft is ash, and is fitted while dry so that the handle requires hammering to force its end into the hole, and when the hammering has made the taper shoulder of the shaft-end bear tight against the taper mouth of the hole, the driving ceases, and the superfluous wood extending beyond the wedge-end of the hole is cut off, and the wedge hammered into its place. This wedge is of iron and has an angle of about five or six degrees; consequently, the mouth of the hole should have the same angle, to cause the wood to fill the hole when a wedge is driven in. The principal taper of the wedge is in its thickness, its width being nearly parallel, to make it hold tight to the wood. When it is to be put in, it is placed so that its width shall be parallel with the parallel sides of the hole, the taper part will then spread the wood in the proper direction. An additional means of tightening the wedge consists in making a few barbs upon the edges, and also cleaning and chalking it when it is to be hammered into the wood.

In order to produce a large number of hammers of the same shape and dimensions, each one should be shaped while between a couple of top and bottom springy shapers. This shaping is effected near the conclusion of the forging, and the hammer being shaped is held with a long-handle drift, whose point extends a few inches through the hammer and also beyond the shapers, the length of the hammer being at right angles to the length of the drift. After such shaping, the mouths of the hole may be tapered with a drift or with filing; to avoid filing, a short taper drift is used for tapering the mouths of the hole, and the long-handle drift for holding the hammer in the shapers is provided with a taper shoulder, to fit the taper mouths of the hole; and when a hammer is to be put between the shapers, this drift is hammered tight into the hole until the taper shoulder of the drift bears on the taper mouth of the hammer.

Chisels.—Chipping chisels for engineers seldom remain long in use, through the continual hammering and consequent vibration to which they are subjected for cutting metals, and because they are made of a granular tool-steel which is too solid for chisels, and always breaks unless the cutting part of the chisel is too thick to possess good cutting properties. Every sort of steel which has been cast, but not afterwards made fibrous with hammering, should be rejected, and pure iron bars, that were carbonised with charcoal without being afterwards cast, should be selected, the precise quality of any one piece in all cases depending on the quality of the iron at the time of carbonisation.

It is not possible for the tool maker to know how or of what materials his steel was made, but he is able to ascertain the quality of any piece by testing it, which should always be done previous to making a large number of one bar, or of one sort of steel. It is also necessary to test each bar, and sometimes both ends of one bar, because one end may be much harder than the other end, and the operator be deceived thereby.

The bar-steel which is made for hand-chisels is in the shape of four-sided bars each having two flat sides and two curved convex ones; such a shape is produced with rolling, and is convenient for handling. A piece of such a bar, or a few inches at one end of it, is to be first tested by heating it to a bright red and cooling it in clean cold water until the steel is quite cold; it is then filed with a saw-file, or some other smooth file known to be hard, and if the steel cannot be cut, its hardening property is manifested. The next test consists in hardening it and allowing it to remain in the water till nearly cold, then taking it out and allowing the heat in the interior to expand the hard exterior; this will break it, if not fibrous enough to withstand the trial. A third test consists in making a grooving chisel of the steel, and hardening it ready for use. This is the proper test for all chisels, because it is easily and quickly performed; and it is advisable to make the cutting end rather thinner than for ordinary chipping, so that if it does not break nor bend while thin, it is reasonable to expect it would not break if thicker.

The forging of a chisel, whether a broad smoother or a narrow groover, consists in tapering one end, and next cutting off the cracked extremity which is produced whenever steel is forged thin and tapered. During the final reducing, the taper part is thinned with a flatter, and the flattening is continued till the end is below red heat. Hardening is next performed while the work is yet warm; this consists in gripping the chisel in tongs and heating five or six inches of the steel to redness, then placing about two inches of the taper part slantways into water and moving it quickly to and fro till cold; it is then taken out and tempered, which is effected with the heat in the thick portion that was not put into the water; this heat moves along to the hard end and softens it while the operator rubs off the thin scale with a piece of grindstone, which allows the colour to appear; and as soon as a purple is seen at the cutting part, the entire taper portion is cooled in water. This mode of tempering allows only about half an inch of the taper part to remain hard, all the remainder being soft; if not, the vibration caused while hammering would break the tool in the midst of the taper portion. Some sorts of steel require hardening at a very dull red, and tempering until a quarter of an inch at the end is blue.

Sharpening chisels ready for use is effected on ordinary grindstones. The cutting edge should be made convex, to obtain two results, one of which is rendering the tool less liable to break, and the other result is the greater ease of cutting while holding the tool to its work. Those chisels that are to cut brass or gun-metal have their long taper portions, and also their cutting parts, thinner than the taper portions of chisels for iron and steel, those for steel being thickest of all; but the angles of the taper parts are about the same for all chisels. When, however, a small difference is made in such angles, the smaller angle is given to those for cutting brass and gun-metal. The angle of a hand-chisel's long taper portion is only about six degrees, but that of the cutting end is about sixty. In Fig. 574 a narrow side of a chisel is shown, and a couple of lines are made that extend from the cutting end; two other lines are also shown, which extend from the long taper part, the difference between the two angles being indicated by such lines.

It is only during the mending of a chisel that the proper management can be exactly effected. After they have been in use, the workman can decide whether the metal he is cutting requires the chisels to be harder or softer than they were when first hardened, so that he instructs the tool-maker to make them harder, if necessary, or to make them thicker at the cutting part, if steel or hard iron is being chipped. By using a chisel it is also discovered whether it were left too hard at its tempering, and needs different treatment.

To prevent the head of a chisel burring around the edges with hammering, and causing pieces to fly off, the head should be frequently curved with grinding, at the time the cutting part is sharpened; and when a head is mended at a forge, the end may be tapered, but none of the burs is to be hammered; all these should be cut off with a small trimmer, or ground off with a grindstone, previous to the tapering on the anvil.

Files.—The processes to which files are subjected, after receiving them from the file-maker, include hardening, bending, cranking the tangs, and shaping the tangs to prevent their handles falling off.

Rough files are oftener made of inferior steel than smooth ones, and if the metal is not capable of properly hardening in ordinary water, salt water is used; and if an extraordinary hardness is requisite, the file may be hardened in mercury. Rough files are often softer than they should be, to prevent their teeth breaking off during use; this should be remedied by forming the teeth so that they shall be inclined at a proper angle to the files' broad sides, and by properly polishing the sides previous to forming the teeth; smooth teeth are more durable than rugged ones, and teeth having smooth extremities cannot be produced if the blank sides are not smooth. The cutting sides of a file must be convex, and to obtain this form the middle of the file is made thickest. The convexity of one side of a flat file is destroyed if the tool bends much in hardening, and if found to be thus bent, it is heated to dull red and hammered with a wood hammer while lying across a wood block having a concave face; this hammering is equally administered along the entire length to avoid forming crankles, after which it is heated to redness and hardened. Half-round files are always preferable if the half-round sides are convex and the point very much tapered. A rough file which is made of soft steel that cannot be properly hardened, is improved by heating it to a bright red and rolling it in a long narrow box containing powdered prussiate of potash; the file is then held in the fire a few seconds until the powder attached is melted, when the work is cooled in water. The tangs of files are not hardened, or, if hardened, are always made quite soft afterwards, to prevent them breaking while in use.

In order to crank the tang of a file without softening its teeth, it is necessary to bind a couple of thick pieces of iron to that portion which adjoins the tang, and to heat the tang as quickly as possible by putting it through the hole of a thick iron ring which is at near welding heat; this ring is narrow enough to allow the greater part of the tang's length to extend beyond the hole, by which means the thick portion in the hole is heated to redness while the thin end remains black. When the proper heat is thus obtained, the first bend to commence the cranking is made by bending the work while in the hole, if the hole is small enough; if not, the bending is performed on the anvil-edge. The situation of the first bend is near the file's teeth, and the second bend nearer the tang's point is afterwards easily made, because it is not necessary to heat the tang in its thick part.

File-handles frequently slip off through the tangs being too taper; this is remedied by grinding and filing the tang at its thickest end, without heating it and thinning it on an anvil, especially if the file is a good one. Handles also slip off through their holes being of a wrong shape, resulting from using one handle for several files. The proper mode of fitting a handle to a tang consists in making a small round hole which is nearly as deep as the length of the tang, and next shaping the hole to the desired form by burning out the wood with the tang; for this purpose it is heated to a bright red at the point, and a dull red at the thick part; it is then pushed into the handle, and allowed to remain in a few seconds, when it is pulled out and the dust shaken from the hole; the tang is then again heated and put the same way into the hole, to obtain the proper shape. One heating of the tang is sufficient, except it happens that the round hole were too small or too shallow, when two or three burnings may be necessary. In order to avoid the danger of softening a good file, it is proper to use the tang of an old file, observing that its shape is similar to that of the tang to be fitted.

Scrapers.—A scraper having a flat extremity is easily made of a small flat file, the thin taper portion of the file being first broken off, and a straight smooth extremity produced with grinding on a grindstone. The two broad sides are ground near the intended cutting edges, to destroy all convexity in that part, and to produce a slight concavity, for giving a cutting property to the edges, these two concave sides being afterwards polished with flour-emery cloth. The flat extremity requires to be slightly curved and convex, and is ground until about a sixteenth of an inch prominent at the middle. After such a scraper has been properly made, the several grindings for sharpening are entirely performed upon the flat extremity, so named, the broad sides not being ground, but merely rubbed on an oilstone. An oilstone is also required to smoothly polish the cutting part every time the tool is sharpened.

Three-cornered scrapers are much used, and are made of triangular files of various sizes; the points of these are ground on a grindstone until the three intended cutting edges are regularly curved and convex; and the tool is finally polished on an oilstone. Scrapers having broad thin ends for scraping sides of holes, concave surfaces, brasses, shells of steam-cocks, and similar work, require a concave side, that may be termed the bottom. This side or surface is that which bears on the surface being scraped, and, through being concave, the tool has a superior cutting property, and is also easily moved to and fro by the operator without being liable to rock or cant while on the work.

A mode of making a scraper very light, to promote an easy handling, consists in thinning the intermediate portion, thus making it much thinner than the cutting part. If a scraper thus lightened is not thick enough to permit its being firmly held by the workman, the thin portion is covered with a few layers of cloth, flannel, worsted, felt, or similar substance, to enlarge the mid-part of the tool to a convenient thickness. Such a covering is also useful for all scrapers, whether thick or thin, rectangular or triangular, if they are small, to avoid cramping the fingers.

Scrapers that are made of files by grinding need no hardening; but if one has been forged by thinning and spreading one end of a piece of round steel, the process of hardening is performed after the tool is roughly filed to its shape. For scrapers, no tempering is necessary.

Drifts.—Cutting drifts having teeth on their sides, similar to large file-teeth, are shaped by two methods; small ones not more than an inch thick being grooved by filing, and large ones that may be three or four inches thick being grooved with a planing-machine or shaping-machine.

The steel suitable for drifts is a tough, well-hammered metal that has not been cast, and the smaller the intended tool the greater is the need to select an elastic fibrous metal which will bend after being hardened, and not be liable to crack in hardening through being too solid. Small thin drifts may be made of a hard Swedish iron, and afterwards partly carbonised to steel the exterior. A drift thus made will sustain a severe bending while in a crooked hole, without being so liable to break as if the entire tool were of steel. The short drifts do not bend while being hammered through a piece of work; they may therefore be made of steel; but all long ones that are comparatively thin are more pliable if made of iron. The hammering of any drift, whether long or short, shakes and tends to break it, and it is advisable to make each one as short as its intended work will permit. Those for drifting small holes often require long handles, similar to that shown in Fig. 576; such a handle is thinner than the portion for cutting, that all its teeth may be driven through the work. Fig. 577 denotes a taper drift having a thick handle, which is an effectual means of strengthening the tool, a portion of the part having teeth being always outside the work to be drifted. Such a handle is also necessary for dislodging the tool after being tightly hammered into a hole, when the small end of the cutting part cannot be hammered to loosen it; in such cases, hammering the handle sideways must be performed.

The forging of such tools depends on their sizes. A small short drift is made without forging, by shaping the intended tool at one end of a short bar, and cutting of the tool with an edge of a file, after all the teeth are finished. The forging of a parallel drift with a handle is effected by reducing the handle or stem from a piece of steel or iron which is thick enough to become the cutting portion without upsetting. Another course is adopted to make a taper drift with a handle, and consists in tapering both ends of a piece to produce a thick portion in the middle; this thick portion becomes the large end of the cutting part, and also the junction of the handle, the thin portion at one end of the work being made into the drift's handle, and the other thin end being formed into the taper end for cutting.

While forming the teeth, the grooves are made only deep enough to allow sufficient room for the small shavings that are cut off while hammering, that the tool may not be weakened with deep grooves. In order to produce strong teeth, about a quarter of an inch should be allowed between any two contiguous cutting edges, if the drift is not more than an inch wide; large ones require teeth about half an inch apart; if the teeth are too close, the angle of the slant surface which extends to each cutting edge, will be too acute, and cause the teeth to break with the severe hammering which a large drift requires.

Filing is the means adopted for shaping the teeth of small drifts, the four blank sides being first carefully flattened and smoothed, that the places for the teeth may be properly marked. The marking is effected with a divider and scriber, the divider being used to place the teeth at equal distances apart, and the scriber used with a straight-edge to mark the lines upon the broad sides of the tool. These lines are inclined about fifteen degrees to the length of the tool, and are marked on all the four broad sides, if a safe-side is not required. When the marking is completed, a rough three-cornered file is employed to commence the grooves, by filing near to each straight line, which indicates the place for each intended cutting edge. This filing roughly shapes the cutting edges, and also the slant surfaces extending to each edge, these slant portions being afterwards finished with a smooth three-cornered file, or with a smooth half-round file. The finishing of the cutting surfaces, also, should be done with a smooth three-cornered file, because it is necessary for each cutting edge to stand at right angles to the length of the tool, and such a form cannot be easily obtained with a right-angular file, usually termed a flat file. After a proper smooth filing, the cutting edges are polished with flour-emery cloth wrapped around the same smooth file used for filing.

The teeth of large drifts are formed by planing. After the places for the intended teeth are scribed, the tool is put upon the planing-table of a shaper with the length of the drift properly inclined to the direction of the tool's motion, in order to incline the intended teeth to the proper position. If the drift is a short one, without a handle, it is held on a plate and properly wedged up, if the drift is taper, and fastened at each end with a screw-bolt and plate, and fixed at the middle with poppets. A short one may be thus held with a plate on each end, because it is seldom necessary to make teeth along the entire length of a drift, however short it may be. A parallel drift with a handle is partly held on the machine by gripping the handle, and teeth may then be made at the junction of the handle with the part for cutting, if the thickest portion of the tool is at the junction.

The shapes for the teeth of drifts are represented in Fig. 575, and if produced by planing, the tools required are grooving tools having short grooving parts, to prevent bending while at work. Of such a grooving tool the extremity of the cutting edge is flat, and also bevelled to the proper bevel, to produce the desired slant surface which is to extend to each cutting tooth. Such a tool will smoothly shape the teeth, if soapy water is applied, so that but little smooth filing with a three-cornered file is afterwards required.

In order to harden a number of small steel drifts, they are carefully heated in a clear fire of cinders, without applying any blast, the fire being heated sufficiently before the work is put in; or they may be put together into a covered iron box containing charcoal, and all heated together, which preserves the surfaces of the work clean, and does not injure the cutting edges. When heated to redness, each one is taken from the fire or box with a tweezer whose grips are fitted with wood, to prevent burring the teeth; each one is then put with its length vertical into water, and allowed to remain buried till cold. The next step is to temper them to make them soft enough to bend without breaking while being hammered into a crooked hole that needs drifting.

In order to harden a drift which has a handle, the entire cutting portion, and also an inch or two of the handle, is heated, which is done by first placing a covered iron box with charcoal into the fire and allowing it to become red hot to the centre, when the drift is put into the hot charcoal, with a short part of the handle also in the charcoal; the tool thus remains until heated, when it is immersed vertically into water, and moved to and fro, to cause the hard portion to gradually extend into the soft part; for if the tool is held still in smooth water, the hard part and the soft part will terminate in two planes that join each other, and because the shapes of the particles in the plane of the hard portion are suddenly altered and made to differ from the particles in the plane of the soft portion, the one plane separates from the other and breaks the tool. This always happens with such treatment, if the tool is thin enough to become hardened entirely through; but if the steel is two or three inches thick, the cooling will not harden the particles in the interior, therefore only the exterior is weakened, which greatly weakens the tool, although not sufficient to completely rend it asunder.

The tempering of drifts without handles is accomplished by laying them upon a broad bar or plate of iron, heated to redness. Such a plate may remain supported with two stocks of the forge fire, if a large number are to be tempered; or if only a few, a bar is heated and put upon a block or table, whose top is about four feet above the floor, for convenience of observation. While the tempering iron is being prepared, some tool-fitter is polishing the teeth of the drifts with emery-cloth, and when they are ready they are put upon the hot iron, and frequently turned upside-down, to apply the heat from two opposite sides, the drifts being moved about with a wood tweezer, or tongs having wood grips. The heat must be gradually applied, to soften the interior as much as possible, and the ends that are to be hammered should be made softer than the intermediate parts, the ends being tempered to a dark blue, and the mid portions to a brown. The general rule to observe is that the longer and thinner the drift the softer it should be; consequently, one which is only six or eight inches long, and two inches thick, requires no tempering of the teeth, but merely tempering to soften the two ends that will be hammered, and termed the head and point.

To temper a drift having a handle, the tool is held on the tempering iron so that the junction of the handle with the cutting part shall become quite soft, especially if the drift is a taper one that will require a hammering of the handle to loosen the cutting part while in a hole.

An iron drift is steeled by changing a thin portion of its exterior into steel with charcoal. This is effected in a manner resembling that for making other steel by means of charcoal, and consists in putting the work to be steeled among charcoal a proper length of time to allow the carbon to be absorbed by the work. After the surface of an iron drift has been steeled, it can be hardened, and the hardening is then termed case-hardening. The mode of steeling the exteriors of drifts and other small tools consists in putting the article or articles into an iron box, having a lid and a ledge near the mouth of the box; this box contains burnt hoofs, bones, and leather, the burning being adopted to reduce the bulk of the materials, and to leave but little more than the carbon which is to carbonise the tools. Previous to placing the articles into the carbonising materials every drift must be polished, to avoid smoothing after they are steeled. After being packed in the charcoal at proper distances apart, to prevent their getting together while moving the box, it is nearly filled with the charcoal, and the lid put down; all the crevices are then filled with loam, and a thick layer of loam is also put on to the ledge, this ledge extending all around the mouth for the convenience of supporting the loam. After all the crevices are thus filled, to keep out the air, the affair is put into a large clear fire, that plenty of room may exist around, and gradually heat all sides of the box at one time. A plate-furnace fire will afford a convenient heat, a substitute being a large forge-fire; if this is used, the blast is very gently administered until the work is red hot, when the blast is stopped, and the work is allowed to remain at the same heat for two hours, during which time the drifts have absorbed the carbon from the charcoal, and the surfaces are steeled. This being done, each one is taken carefully from the charcoal without bruising the edges, and allowed to cool separately, if they are required immediately; if not, the box is taken from the fire, the lid raised, and the work allowed to slowly cool while among the charcoal. When the drifts are cold, they are put into order for hardening. This may be done at any future time, and consists in sharpening the teeth and polishing the surfaces, to make them as they appeared previous to being heated, and when they are to be hardened they are again heated and cooled in water. This second heating is seldom necessary for drifts if they are properly finished previous to steeling, and they may be hardened while hot at the time they are first carbonised. Drifts thus steeled may be softened at any future time when the teeth require sharpening, and again hardened by merely heating and dipping into water, because heating the tool does not liberate the carbon.

This method of carbonising is also adopted for changing the surfaces of iron screw-taps into steel; taps thus treated are useful for several classes of work, if properly managed.

Punches.—A punch with a circular extremity, for making round holes into cold sheet iron and other metals, is about six inches long, and made of an old round file, to avoid forging. The file is first thoroughly softened along its entire length, and one end is reduced until of a proper diameter to make the holes desired; this reducing is often done with a grindstone, while the file is soft, when forging cannot be effected, and the intended cutting extremity is ground until flat. When properly shaped, the tool is hardened by heating to redness about three inches of its length, and placing about one inch into water, moving it to and fro as for hardening other tools; as soon as the tool's extremity is cold, it is taken from the water and cleaned, during which time the heat slowly softens the end, and when a blue colour appears at a quarter or half an inch from the extremity, the hard part of the punch is cooled, but the remainder is allowed to cool as slowly as possible, that it may be quite soft.

Square punches and other angular punches for hand use are of the same length as round ones, and are made of properly softened round and square files. Punches are not merely required to make holes; they are useful for smoothing and polishing the boundaries of various recesses that cannot be filed, scraped, or ground. A punch for such work is held in one hand, and applied to the work while the head of the punch is hammered until the surface in contact is shaped. Tools of this class have shaping extremities of various forms, some being curved and convex, others are concave, some are provided with ridges, knobs, teeth, and other protuberances, the extremities of others are rectangular, triangular, and oval, having recesses of several forms. All such punches require a careful polishing, both previous to hardening and afterwards, and the better the polish given to the punch, the smoother will be the surface to be punched. The ends of such tools are specially tempered after hardening, to suit their respective shapes, those extremities which are broad, and consequently strong, being tempered to a brown, unless the steel happens to be a brittle cast steel, for which metal the temper denoted by blue is necessary.

SPANNER MAKING, &c.

Gap Spanners.—The proper metal for spanners generally, is a soft fibrous Bessemer steel; such metal is produced by rolling and hammering the Bessemer product after being cast, that the fibrous character may be produced. If such steel is soft enough, it will weld, and spanners of all shapes may be made of it.

To make a gap spanner quickly for immediate use, one end of an iron or steel bar is heated to a bright yellow heat, and bent until a hook is formed; the work is next heated at the curved part, and lengthened or shortened until the gap is of a proper width. A gap spanner of this character is shown by Fig. 578.

Another simple class of gap spanners are those made of thin bar or plate steel. A spanner of this sort needs no thinning to produce the handle, because the gap portion is no thicker than the handle; it is therefore made by cutting out with chisels while the plate is at a bright red heat. Small spanners only, should be made by this mode, because of their wide gap portions, and are represented by Figs. 341 and 342.

Small gap spanners, of only a pound or two each in weight, are easily made of steel, and should have cylindrical handles, usually termed round handles, to promote an easy handling. Large spanners may have broad thin handles, that they may be light, and the two edges or narrow sides are curved. A gap spanner with only one gap end is made by providing a bar which is thick enough to be made into the spanner's gap portion without upsetting, and thinning the end of the bar until it is of the desired length and shape for the spanner's handle. The gap in the thick portion, is next made by first punching a hole at the place for the bottom of the intended gap, a round punch being used if the bottom is to be curved, and a six-sided punch or drift, if the bottom is to be angular. When the hole is made, two slits are formed from the hole to the extremities, and the superfluous gap-piece is cut out, at which time the work is roughly prepared for an after trimming. Another spanner is next partly made by the same means of the same bar, if necessary, and any greater number that may be required. A spanner in process of being made of such a piece is indicated by Fig. 580.

The forging of a spanner which is to have a gap at each end is effected by making two gap-pieces, each one having a gap of proper size, and an end or stem of about half the entire length of the intended spanner. These two stems are scarfed, or a tongue-joint is made, for the purpose of welding them together, which produces the desired spanner having a gap at each end. After being shaped at the gap parts, the spanner is bent, whether it has one gap or two, the bending being necessary that the spanner may be applied to the six sides of a nut by moving the handle to and fro in the shortest possible space. This bending consists in heating the junction of the gap part with its stem, and bending it until the handle or stem is at an angle of fifteen degrees with the gap-sides.

The final shaping of a gap-spanner consists in trimming the edges with a trimming chisel and curving the outer surfaces. Half-round top and bottom tools are employed for this curving, and the edges of the gap portions are shaped while between such tools, and also while a filler is in the spanner's gap. This filler is of steel, and is long enough to be supported on a couple of blocks, or across an opening of some sort, while the spanner's gap-part is held on the filler and shaped with the top and bottom tools. One narrow side of the filler is angular, similar to the bottom of the gap, and the thickness is the forged width of the gap; consequently, while the outer surfaces are being shaped at the time the filler is in the gap, both the gap and the outer edges of the gap portion are shaped at one hammering.

In order to provide good bearings in the gap-surfaces, and to prevent the entire gap-portion being too broad, and thereby occupying too much room, the thickness of a gap-portion belonging to a small spanner should be about equal to the height of the nut which is to be rotated, and the total breadth across the gap part, only about three times the diameter of the hole in the nut. Large spanners for nuts three or four inches in height, may have gap parts which are two-thirds of the nuts' heights. The proper shape for the bottom of a spanner's gap is angular, that it may fit any two contiguous sides of a six-sided nut or bolt-head. Gaps of such a form will suit hexagonal nuts and square ones. A gap with a curved bottom bruises the nuts' corners, and it must be made very deep to prevent the spanner slipping off while in use. By Fig. 579, a spanner is represented whose gap-part is of proper shape.

Gap spanners are often forged of ordinary fibrous wrought iron, and after they are properly finished and the gap surfaces smoothly filed to suit the nuts, the entire gap portion of each spanner is hardened; this is performed by heating it to a bright red, rolling it in powdered prussiate of potash, and then cooling it in clean water. Small iron spanners, that are only six or eight inches long, are put into a box with bones or hoofs, and their entire surfaces are steeled. similar to the mode for steeling other small tools.

Cast-iron spanners are those that are made by pouring the metal into sand moulds that are shaped with wood or iron patterns resembling the spanners to be cast. After casting, the spanners are softened by a long gradual cooling, which makes the metal soft, and prevents the tool breaking while in use, although the metal is not made fibrous. Cast steel thus used is a preferable metal to cast iron.

Socket Spanners.—The stems and handles of socket spanners are made of round iron or steel, and separate from the socket portions. The socket portion of the spanner consists of a tubular piece which is attached to the stem by welding its end in the socket-hole. This socket piece may be an end of a thick tube, if such a piece can be obtained with a hole of proper diameter. The socket may be made also by punching a hole through a solid piece, and drifting the hole to a proper shape and size; this produces a good socket if the metal is solid. The convenient mode of making a socket of an iron or soft steel bar, consists in curving to a circular form one end of a bar which is about as thick as the intended socket, and welding the two ends together by means of a sort of scarf-joint termed a lap-joint. Such a joint is made by tapering both the ends that are to be welded together, and curving the socket piece until its hole is about three-quarters of its finished diameter, which allows the socket to be stretched with welding to its proper diameter. After a socket is made by either of these means, its hole is shaped with a steel six-sided drift which is of the same shape and thickness as the required socket-hole. One end of the socket is next heated and upset, to make it thicker and larger in diameter than the remainder, at which time it appears as in Fig. 581, being then ready for welding to the stem.

The preparation of the stem consists in thickening one end by upsetting, and shaping it to a six-sided form to fit the socket-hole. A stem thus shaped is denoted by Fig. 582; and the thick part is made to fit tight in the hole, that it may be easily handled and welded in that situation. The length of the part which is in immediate contact with the enlarged end of the hole is about half of the socket's length, and while the two are together a welding heat is given them, and they are welded with a couple of angular-gap tools while the socket is between. During this welding, the tools are in contact with only that part which contains the end of the stem, in order that the hole may not be made much smaller by the hammering. This welding reduces the thick part of the socket to the same diameter as the thinner part, and also lengthens the bearing of the stem in the hole.

The final shaping of the socket, after it is properly attached to the stem, is accomplished by trimming off superfluous metal to make the socket to a proper length, and smoothly finishing the hole with a six-sided filler. This filler is parallel, and is carefully made so that it shall be the precise thickness and shape of the finished hole, being tapered a short distance at the point, that it may enter easily into the hole when necessary. The extremity of the part which is in the hole is smoothly shaped and curved, for smoothing the bottom of the socket hole. This smoothing is effected by heating that part of the socket and hammering the end of the stem while the filler is in the hole and touches its bottom. To conveniently hammer the stem, the filler is put into the hole, and the outer end of the filler is then put to the floor with the socket-stem extending upwards, the filler resting on a soft iron block or lead block, whose top is level with the floor; while thus arranged, the upper end of the stem is hammered and the bottom of the hole is shaped. A filler of this class, in the hole of a socket, is represented by Fig. 583. Through such a filler being nearly or quite parallel along a great part of its length, it cannot be released from any socket after being once hammered in, without heating it and enlarging the hole enough to let out the filler with pulling in a vice, or similar means.

The handle-end of the stem for a socket spanner is provided with a hole, if to be used with a separate lever, or provided with a tee-handle, if to be rotated by such means; and if the spanner has a bent stem, constituting a handle which is at right angles to the length of the socket, the stem is heated to make the bend in the right place, after all the joint-making is completed.

If a socket spanner is not to be lathe-turned, it is necessary to carefully reduce the work to a proper shape and dimensions while on the anvil; but if to be turned, a proper amount of metal is allowed, that the socket may not be too thin. A socket spanner is turned while its handle-end is supported on the mandril pivot of a lathe, and its socket part is supported on a broad conical pivot, which is large enough to bear on the edges of the hole's mouth. By this method, the socket is accurately turned so that one side shall be just as thick as the opposite side, and if the entire length of the socket were forged parallel to the drift while in the hole, the entire outer surface of the socket when turned will be also parallel with the hole.

Spanners with Square Holes.—A spanner which has a boss at one end containing a square, six-sided, or round hole, is forged at one end of a bar which is nearly as thick as the length of the boss which is to have the hole. At the end of the bar a portion is reduced until small enough for the handle, and the thick portion adjoining is punched with a taper, square, or round punch, and also drifted while at welding heat with taper drifts of proper shapes. In Fig. 584, a spanner being made at one end of a bar is shown, and may be partly drifted while attached to the bar, and also afterwards, while separate, as denoted by Fig. 585. When it is cut from the bar, the shaping of the boss is completed by hammering the outside while at welding heat, and by fullers applied to the junction of the boss with the handle; during both these processes a drift is in the hole; a drift is also in the hole of a boss which is circular, and being rounded with half-round top and bottom tools.

The drifts for enlarging the holes are very taper, similar to the one shown in Fig. 585, and those for adjusting holes to proper diameters are so nearly parallel that they appear parallel to ordinary observation. A parallel drift is indicated in Fig. 586, and is tapered at each end, to prevent its being stopped by the burs made with hammering while being driven into or out of a hole.

Several drifts of various sizes and shapes are always kept ready by the smith, and by a proper use of the parallel ones, a spanner with a circular hole can be enlarged until the desired amount of metal remains for boring the boss to the stated dimensions; and if the spanner being finished has a square or six-sided hole, it can be drifted until it fits the nuts, bolt-heads, spindle-end, plug-end, or other work for which the spanner is made, thus avoiding much filing, drifting with cutting drifts, and other lengthy processes.

Wrenches.—Wrenches for rotating taps, broaches, and similar tools, are made of three portions for each wrench, one piece being the boss which is to contain the hole or holes, and the other pieces being round straight pieces for the handles, the three being separately made, and the holes in the boss-part finished, previous to welding the pieces together. The length of the boss-part depends on the number of holes to be in it, and after the length is ascertained, a piece of soft steel is selected which is large enough for the boss, and long enough to allow a stem to be thinned at each end of the boss; this component piece is first properly marked while cold, to denote the commencement of each stem, and next fullered with top and bottom fullers to commence the thinning, which reduces the stems to a proper diameter. A boss-piece of this class is shown by Fig. 587, which is to have only one square hole. Another boss-piece, made by the same means, but having three holes, is represented by Fig. 589; in this Figure a mouth for a tongue-joint is shown at the end of each stem, such a joint being adopted when making large tap-spanners. A tap-spanner to be welded by means of scarf-joints is indicated by Fig. 588, in which the ends are thickened and bevelled ready for welding. When the handles are welded with tongue-joints, the joints are made very strong through the extremities being made to extend several inches along the handles, as denoted in Fig. 590.

A small wrench that is only about a foot long is made of only one piece of steel, and it is not necessary to select soft steel for welding, the stems which are produced from the boss being made long enough by thinning to become the handles, without welding them to separate pieces. Large tap-spanners, also, are occasionally made in this way if the operators have access to steam hammers for the reducing. For economy, small wrenches are often made of old files, and if the steel is not too brittle to be properly thinned for the handles, strong, hard, durable spanners are produced.

All the holes in wrenches are square, and are made by punching and drifting, having proper care to enlarge the holes with smooth drifts, so that only a very little filing shall be necessary. The handles of tap-wrenches are lathe-turned, and the junctions of the stems with the bosses are nicely curved with springy corner tools.

To make a capstan spanner having four handles extending from the boss, one thick piece for the boss is necessary, and four straight pieces for the handles; these are welded to the boss-part by means of stems that are produced from the boss by thinning.

The outer shape of the boss should be square, not circular; and to produce a boss which is to be four inches long and about four inches square, a piece of soft steel bar should be selected which is about four and a half square, which will allow a trimming to shape the boss after it is spread with punching and drifting, the length of the piece being about nine inches, that there may be ample metal for the four stems, in addition to the boss. This piece is first fullered at each side of the intended boss, and thinned, to form a lump in the middle, and which shall extend from only one side, as shown in Fig. 591; the two thinner portions are next punched with a round punch to make two holes near the boss, similar to those in Fig. 592; a slit is next made from each hole, to make the two stems or arms into four; these are separated, and the junctions fullered to make a rough four-arm boss, denoted by Fig. 593. The square hole is next punched in the boss, by commencing with a very taper square punch, which is driven from both ends of the hole, the punch being placed to make each corner of the hole opposite one of the four arms. After punching, square drifts are used to enlarge the hole, and a hammering is given to the boss while a drift is in the hole, and the boss at welding heat, which makes it rather more fibrous than before. The junctions of the arms are next shaped with a fuller and set-hammer, and the arms lengthened to a convenient length, that the boss may not be too near the anvil while welding the handles to the stems of the boss. The final shaping of the boss consists in cutting off superfluous metal with a flat chisel and a gouge chisel, and smoothing it with a set-hammer or flatter, also with a fuller at the junctions while a drift of the finished size of the hole remains in it. A boss of this class requires a careful trimming to shape it at the conclusion of forging, to avoid a lengthy shaping while cold, especially because it cannot be turned in a lathe. The boss, having its arms at right angles to each other, and reduced to a proper thickness, is represented by Fig. 594.

The circular boss, shown by Fig. 595, has an elegant appearance, and can be lathe-turned to partly shape it; but such a boss requires more metal around a square hole than is necessary for a square boss of the same strength. When bosses having four arms, or three arms, are being made in considerable numbers, each one can be easily shaped in a shaping mould, which is fitted to a steam-hammer anvil.

Broaches.—A small three-cornered broach, which is to be fixed in a wood handle resembling a file-handle, is made of an old small saw-file, the file teeth being ground off with a grindstone, and the tool finally smoothed on an oil-stone. A five-cornered broach is made by first forging a cylindrical broach with a square head and cylindrical stem of proper length for its use, and producing the pentagonal shape with planing, or with filing, if the tool is small. A taper half-round one is first forged conical, and also lathe-turned conical, and the half-round character produced by planing off half the cone. Both five-cornered ones and half-round ones are also made by forging them in their respective shapes, and finishing them with filing, without any other planing process. Taper half-round ones are thus easier finished than taper five-cornered ones. The shaping of a five-cornered broach on an anvil is performed with pentagonal tools; a couple of pentagonal top and bottom tools consist of a top tool which has a broad vee-gap, and a bottom tool that has a three-sided gap. The tools required for shaping a half-round taper broach on an anvil, are, an ordinary flatter, and a bottom tool having a half-round taper gap.

Fluted broaches are those having grooves with curved bottoms, which are termed flutes. A fluted broach may have one, three, five, or seven flutes, and the forging for either class is the same, all such tools being forged either conical or cylindrical, and afterwards fluted while cold. Those that are to be used with crank braces and swing braces are short, having square heads immediately adjoining the fluted portions. Fluted ones for lathes are provided with long cylindrical stems, each stem having a square head at the outer end. A broach of this sort is shown by Fig. 596, the long stem being necessary to reach the poppet-pivot without bringing the poppet-head too near the lathe-carriage. These broaches require to be carefully straightened and equally hammered at the conclusion of forging, while the tool is equally heated along its entire length; all the particles of a tool are thus equally condensed, and it is not so liable to bend during turning and hardening as it is when improperly hammered.

The lathe-turning of a long broach commences by first taking off a small quantity that is only just sufficient to make the tool rotate truly along its entire length while on the pivots; the work is next heated to dull red, and hardened by dipping it while its length is vertical; it is next heated with only a very little blast, and buried in cinders or powdered charcoal till cold, to soften it. During this heating, the tool should lie on a flat bed of small cinders, to prevent it bending while soft; and it is also properly supported while softening among the charcoal powder. The next day the lathe-turning of the broach is resumed without straightening it, and when another sixteenth has been turned off it is again softened, if the steel appears to be harder in some of its parts than in others, or if the entire piece is a hard brittle metal; if found to be brittle, it should be softened two or three times without charcoal. A large broach resembles a large screw-tap in being expensive; consequently, one or two preliminary hardenings and softenings should be given to every such tool if it presents the slightest appearance of being too brittle or too solid.

The particular character and diameter of a broach is determined during turning, whether taper or parallel; if to be taper, it is turned to the form of a straight-sided cone along the entire length of the cutting part; and if the broach is to be what is called parallel, it is also slightly tapered along the entire length of its cutting portion, in addition to a short bevel at the point, for entering it to the work to be broached. A broach slightly tapered is always easier to use and makes smoother holes than one which is exactly parallel, and it is seldom necessary to broach a hole so that it shall be parallel; consequently, the small amount of taper referred to is advisable. After lathe-turning, neither the extreme diameter of the parallel portion, nor the extreme diameter of the point of a broach, must be altered by filing; each one is therefore turned to its precise thickness required, previous to commencing the fluting.

The fluting of broaches is effected by the same means as for fluting taps, and the flutes are of similar shapes for both. Straight lines along the intended cutting part of each broach should be marked while in a lathe, by moving to and fro a pointed tool, and the shape of each flute also requires marking on the flat extremity of the small end, as described for marking taps. The centre recesses also are properly shaped and used for supporting each broach, to allow it to be rotated during the fluting process; and a slotted holdfast is useful for gripping the stem of a broach while being fluted, if the one in progress has a stem.

A broach having a stem which is smaller in diameter than the cutting part of the implement presents no obstruction to the free movement of the fluting tool along the entire length of the intended teeth; such broaches may be placed for fluting on vee-blocks, instead of between poppets. Those having stems are also easily fluted while in a lathe with the to-and-fro movement of the lathe-carriage referred to.

Short ones are sometimes made entirely without any cylindrical stem, having a square head which is as thick as the intended fluted part, and close to it. A broach thus made must have a groove formed around the thick part, if it is to be fluted by planing; the situation of this groove is at the junction of the head with the remainder, and the bottom is curved, to avoid angular corners. A groove of this sort is made with a proper grooving tool during the turning, and its depth is a little deeper than the depth of the flute to be made, the groove being necessary to provide a space at the extremity of the tool's travel while planing.

A broach-flute requires the same careful shaping and polishing of the cutting side, as a tap-flute; but if a broach has only three flutes, a greater amount of bearing surface behind each cutting edge must be allowed than is allowed for a tap of similar diameter. Smooth round files, and other files having cranked tangs, are also necessary for long flutes, to keep the workman's hand above the work while filing.

The hardening of broaches requires rather more care than the hardening of taps, especially if the broaches are long and slender. If a long taper tap bends in hardening, the tool is not greatly injured, except it happens to bend in some part of the parallel portion of the screw; when this occurs, the tap will screw a nut so that its hole will be larger in diameter than the diameter of the tap, unless the nut is very short—short enough to allow the tap to sinuate as it progresses, while its thick part is screwing the nut. If the nut is long, the sinuation of the tap is prevented, and the two extremities of the bent portion are thus made to cut at one time, which enlarges the hole beyond its proper size, the amount of enlargement depending on the length of the nut and the amount of bend in the tap-screw. A broach is much more often used for long holes than a tap, so that the bending of a broach is a much more important consideration. This bending is of only a small degree, if the broach were softened two or three times as directed; and when bending does occur, the tool may sometimes be straightened with careful management, even while in its hardened state.

The heating of a long broach for hardening resembles that described for a drift having a handle, and consists in placing the broach in red-hot powdered charcoal, to prevent the cutting edges being injured during heating. After a uniform dull red is obtained along the cutting part, and also an inch or two of the stem, it is put into old water with the length of the tool in a vertical position, to prevent bending, and not to allow bending, as when hardening a tap; the broach is next taken out, after a proper cooling, and tempered, while in the hole of a tube, in the same manner as for tempering a tap. During tempering, the stem is not allowed to remain as hard as the teeth, as for a tap, but is made quite soft; the hard junction of the stem is therefore held in the hole until thoroughly softened, so that the adjoining extremities of the teeth must also become soft, this softening of the teeth being of little consequence while the broach is in use, because that portion is seldom or never required to cut. The colour to which the fluted portion is tempered is a golden brown, but the extremities at the junction are black, through being soft. By this treatment no portion of the entire stem is harder than it was previous to hardening, which is a suitable condition to admit of being straightened at the junction, and also bent, if necessary, in any place along the length of the stem, to make the fluted part rotate truly while the broach is on the lathe-pivots.

After the tempering, straightening is effected. The portion which requires the most straightening is generally that which is easily straightened, being the junction of the stem with the thicker part; through this being soft it is easily rectified, without much risk of breaking, by means of a half-round top-tool and sledge-hammer. The straightening of a hard broach or other tool of similar character should be effected on a heavy block of cast copper or of lead, several inches thick, and of proper length and width to suit the work usually allotted to it; such blocks are represented by Figs. 613 and 614, and should have several broad gaps formed across their upper surfaces, to provide spaces over which the bent portions of the work are to be placed to receive the hammering. No attempt should be made to straighten any sort of steel while cold, whether it is soft or hard; and it is not only necessary to heat the bent part, but also the entire tool; consequently, to straighten a broach, it should be heated in a tube, or on a warm plate, until the whole tool is as hot as can be only just handled with a bare hand; it is then laid across the heavy lead block, and the bent part at the junction, or other portion of the stem, is placed over a gap with the convex side upwards; a top-tool is next applied, having a gap which is broader than the work, to admit a piece of sheet copper between the tool's gap and the part to be straightened. While such a tool is held firmly by the operator, and pressing tightly downwards on the broach, a sledge-hammer blow without recoil, if possible, is given by the hammerman. Such a dead blow, as it is named, is necessary to prevent vibration of the broach, which would tend to break it; the hammer is therefore held tight on the top-tool at the moment the blow is given, and all other blows that may be afterwards required are to be of the same character.

For delivering the blows, an ordinary steel sledge-hammer is suitable, if firmly held; but a large copper or tin hammer is preferable, when one is accessible.

A broach that requires its fluted part to be straightened needs the same sort of blows, while the bent portion is across a gap in the lead block; but the flute which happens to be in the convex side, and therefore upwards, must be occupied with a packing-piece or filler, to prevent the cutting edge being shattered by contact with the top-tool or flatter which is used to apply the blows. This filler is a piece of soft iron which fits loosely sideways in the flute and projects a short distance above the cutting edge, the length being about as long as the flute; the piece is laid into its place with a strip of emery cloth in immediate contact with the work, and a sledge-hammer blow without recoil, as directed, is given to the tool while it is tightly held on the filler. The top-tool employed should be either a flatter, or a half-round tool having a shallow gap with but little curve, to avoid possibibility of the tool's edge touching the broach while hammering.

An efficient mode of straightening hard broaches and other tools consists in applying a few proper blows to the work to be straightened while it is bolted to the cast copper block, instead of merely lying on it. This bolting is effected by placing a plate across the filler while in a flute, or across any other portion that may be bent, and fixing the plate with the screw-bolts, one through a hole in each end of the plate. These bolts are attached to another plate beneath the block, or may be tee-head bolts which are fixed in some of the slots in the upper portion of the straightening block, or of a large table, if such is being used for supporting the apparatus. When a tool is to be straightened by such means, it is properly heated and put across a gap, the plate and bolts applied and screwed tight until the work is straight; in this condition it should be allowed to remain a short time and kept hot, and the screwing will sometimes straighten it without hammering. To ascertain whether it is permanently straightened, the bolts are loosened, and a few minutes are allowed for the tool to resume its former bent shape, if it will do so; and in this case it is screwed down again, and again, if necessary, and also hammered while it is down, by striking the plate at that place immediately over the bent part of the tool. By means of a plate and bolts thus used much of the danger of breaking the work while hammering, is avoided.

There is less risk of breaking a thick broach while straightening than of breaking a thin one, because a thick one cannot be hardened at the centre, and is therefore more pliable and less brittle than a thin one, which is entirely hard. Although these methods for straightening are here recommended, it is frequently necessary to heat the work to redness if much bent during hardening, or bent in two or three places; after which it is straightened, while hot, with a wood hammer, while the tool is lying on a wood block, and when straight it is again hardened.

MAKING OF SCREWED PLATES, DIES, &c.

Screwed Plates.—Screwed plates have for many years been made of old flat files. Good plates are made of such materials if the steel were of the proper quality at the time the files were made, some being very brittle and others comparatively tenacious. At the present time a large quantity of brittle Bessemer product is made for files, which is only good because of its capability of hardening, having but little durability through not possessing much tenacity. The files selected for screwed plates and other tools should be the smoothest that are made, which are termed dead smooth, and are of better steel than the rougher sorts, consequently are much more useful when no longer fit for filing. Files are often made into screwed plates by drilling holes, but without altering the outer shapes; the preferable mode is to reduce each end of the file to form two handles, and to equally hammer all that part which is to contain the screwed holes. The forging of a file will indicate its quality; if it is brittle and comparatively worthless, it will not bear stretching without cracking, and will sparkle, while properly heated at a bright red, as much as a tough good fire would sparkle at a bright yellow.

Rough files that are to be reduced with forging require the teeth to be partly ground off with a grindstone; if not, the hammering will reduce the file without erasing its teeth, because during much of the stretching the teeth are driven upon each other, instead of being separated, this closing together resulting from the slant positions of the teeth. Another reason for grinding off the teeth is to prevent the file breaking asunder at the bottom of a tooth-groove while being hammered; this sometimes happens with hard steel, although it may be tolerably good.

In order to prevent the two handles of a plate coming into contact with the vice or the piece being screwed, the ends of the handles are placed a short distance above the mid-portion of the tool, either by cranking each handle or by bending it. Such a plate is shown by Fig. 600, and is forged to this shape with cylindrical handles, to avoid the handling of sharp corners.

After each plate is softened by a slow cooling in charcoal they are lathe-turned, if they possess round handles, and the mid portions are next filed to prepare them for being marked to indicate the places for the screwed holes. This filing should be rough, and if the plate is being made of a file no attempt need be made to entirely erase all the original file-teeth, except from the handles; if the mid part is left rough, there will be less risk of breakage in hardening. The thickness of a plate's screwed part should be about three-quarters of the diameter of the holes; such a thickness will allow one end of a hole to be tapered after being drilled; consequently a plate which is to have several holes, whose diameters average three-eighths of an inch, is about five-sixteenths thick.

The plate being properly marked to allow sufficient metal around each hole, becomes ready for drilling, and the first drilling consists in making all the larger holes that are intended to be screwed, the smaller holes to receive the shavings being made afterwards. In order to drill the holes correctly, a correct measurement must be effected by means of callipers, and the taps or hob from which the plate is to be screwed. It is especially necessary for each hole to have a completely formed or full thread, and it is advisable to drill each one a little smaller than the proper diameter rather than to incur the risk of making it a little too large by drilling it to near the proper dimensions. The diameter of the drilled hole should equal the diameter of the hob at the bottom of the thread-groove; and if the usual Whitworth screw is to be made into the hole, the proper diameter is obtained from Table 5, at page 177. In the sixth column of this Table, the diameter nineteen sixty-fourths of an inch, is given for the bottom of a hob-screw or other screw whose outer diameter is three-eighths of an inch; therefore the hole in the plate to be screwed must not be larger than nineteen sixty-fourths. After drilling, one end of the hole is tapered about a quarter of its length by means of a rosebit, whose cutting part is of suitable angle. The end of the hole thus tapered is that which will be upwards while using the plate for screwing a bolt-stem at the corner near the head; during such screwing the end of the hole not tapered is undermost, and in contact with the corner, because this corner cannot be screwed with the tapered end of the hole.

Forming the screw into the hole should be effected with a long taper tap made according to the directions given. The tap's teeth must be sharp, and while screwing the tap through the plate it is griped in a vice; a slow rotation while tapping and plenty of oil are also necessary. As soon as it has advanced about one-third of the tap-screw's length, it should be screwed out, and the plate put upside down in the vice, to allow the tap to be screwed in from the opposite side. The operator can then observe whether the tap's length is at right angles to the broad sides of the plate, and if not, he presses the tap in the desired direction at the same moment as he rotates it, and he continues so to incline it until it is put square and will remain square while screwing; the hole is then screwed until the tap is about half its length through the plate, when it is again brought out and put in from the opposite side, to advance the tap until its full-thread portion begins to cut, when it is again taken out and the hole examined. At this stage of progress the thread at one end of the hole may be quite fully formed, through the hole being rather too small; if so, it needs a careful filing with a small round file. The tapping is next resumed, and the plate reversed about once more while finishing the screwing. Near the conclusion, it is important to administer plenty of oil, that the work may be properly smoothed.

By means of such gradual tapping, plates may be screwed without making rugged threads, although the tap may not be so good as it should be; but a thoroughly good long taper tap will screw a steel plate by reversing it only once or twice during the process, if the hole is not more than half an inch in diameter; the larger the hole the greater the care required.

Another mode of screwing a steel plate consists in using short taps termed hand-taps; these are employed in various ways to screw plates, because such taps are of various shapes and sizes. When a plate is screwed by means of such taps, the screwed hole should be finally screwed with a hob of proper diameter, and having its screw tapered according to the directions given for hob-making.

When a long taper tap is the only instrument used for screwing a hole in a plate, and the thickest part of the tap is of the same diameter as that of the piece to be screwed with the plate, only one hole can be made for each size of screws to be produced, or for each piece of wire or small bolt to be screwed; it is therefore necessary to provide a thicker tap or hob which shall be screwed through one hole in the plate if two holes are to be used for screwing one bolt. The diameter of this larger one is about half the depth of the thread greater than the diameter of the smaller one. For general work, a screwed plate for screwing quarter-inch wire and smaller sizes needs only one hole for each size, those that are larger than a quarter of an inch requiring two.

The next operation consists in making the gaps or channels that are to receive shavings and admit oil while the plate is screwing a pin or bolt. This gap-making is done by drilling three holes near to each screwed hole, and at equal distances around it; an opening is next made from each small hole to the screwed one, with a thin file, and the edges are carefully smoothed. These gaps are thus principally made by drilling, merely because it is the quicker process; but if thin knife files and round files of suitable sizes can be obtained, they are as efficient as drilling. Screwed plates are comparatively thin, and therefore easily filed, and filing avoids the risk of breaking small drills.

When the hole is completely screwed and the channels made, all the burs made on that end of the hole which was coned previous to tapping, are carefully scraped off, and the surfaces polished with emery cloth. The opposite end of the hole also is trimmed, but not tapered, and the trimming consists in filing off the sharp end of the thread by means of a smooth file; this part is next scraped and polished. This filing off the thin end of the thread prevents it breaking off while in use.

Hardening the plate is performed by heating all the mid-part at one heating and dipping it edgeways into water. The fire for heating may be a charcoal fire, or an ordinary forge fire of cinders; and when a dull red heat is obtained, both the plate's broad sides may be covered by sprinkling thereon powdered prussiate of potash, which prevents the tool cracking through direct contact with the water, and also imparts a sort of steely surface to the work being hardened, resulting from the heated steel absorbing a portion of the carbon, which is liberated from the cyanogen belonging to the powder applied. After hardening, the plate may be smoothed by grinding it on a grindstone that rotates slowly, to avoid shaking the work and breaking it, and when the two broad sides are thus cleaned, the plate is ready for tempering.

The tempering of a screwed plate is effected by allowing it to remain on a red-hot bar or plate until a light golden tinge appears, being careful to put both sides into contact with the tempering iron, in order that one side may not be harder than the opposite when tempering is completed. The junctions of the handles need not be hardened, and if hardened, should be tempered till quite soft.

Die-Frames.—Die-frames, small and large, should be made of a soft cast steel, and cast in their respective shapes having the openings for containing the dies formed at the time of casting, so that only a proper amount of fitting shall be necessary. The bosses, which are to have inside screws, should be cast without any hole, to allow holes of proper sizes for the adjusting screws to be bored without trouble, and in their proper places. Although die-frames are of several different shapes in their intermediate parts, all sorts of frames may be cast, but the precise amount of shaping that is necessary afterwards, depends on the particular forms of the holes or slots to contain the dies. If the frame is to contain dies having vee--grooves the vee-ridges of the frame intended to fit the die-grooves, are easily shaped at the time of casting, but with sufficient metal to allow for fitting. A frame which is to have two sliding plates for holding the dies in their places, is easily slotted or planed, whether the dies to be put in are those having short stems, resembling those in Fig. 372, or whether the dies are to be taper, without any stem, slmilar to Fig. 379.

By casting a die-frame solid with its handles, some inconvenience may arise while planing the slots, through the handles extending across the machine; this is to be remedied by using a large planing-machine instead of a small one, if it is really needful to plane all the sides of the slot; but if properly cast, no planing is necessary except that for flattening the two broad sides of the frame, and this can be done on any small planing-machine while the lengths of the handles are parallel to the length of the planing-table.

Die-frames are frequently made of ordinary wrought iron and in three pieces for each intended instrument. One of these is the intermediate, which is forged without any hole whatever, similar to Fig. 604, the entire slotting and planing of the piece being done while cold. The two other pieces are the handles, which are of round iron and are welded to two short stems that are made to extend from the middle piece. A frame thus made is first planed on its broad sides, its curved junctions of the stems lathe-turned, next drilled, its slot shaped bosses drilled, tapped, and turned, previous to welding to the handles, and when these are attached, another turning is given to complete the cylindrical parts of the handles; consequently, the junctions that were previously turned, are made to rotate truly before commencing to turn the adjoining parts. Although this method involves a variety of processes, the turning of the junctions is greatly facilitated because it is done while the frame is short. This mode is therefore especially convenient for those makers who have not suitable stays for the lathe-turning of long slender articles.

The adjusting screws of a die-frame require to be of steel, although the frame may be of iron, and the step of the thread should be short, to prevent the screws shifting when not required, and to enable the operator to easily apply the pressure for cutting. The screw's end, which is to be in contact with the dies, is turned conical, about half an inch of the screw's length being without any thread. To prevent this tapered end spreading through being screwed tight against the hard die, the cone is also hardened and tempered to a dark blue. The frames also are hardened, if made of wrought iron, to prevent wear and burring of the edges, the hardening being done after the filing of the frame is entirely finished, by sprinkling thereon prussiate of potash and dipping into water in the usual way.

Making of Screw-dies.—The metal suitable for dies is a cast steel made fibrous with a proper hammering. Small dies for screwing bolts or other work, not more than five-eighths of an inch thick, are forged in the shapes of short right angular pieces, each resembling the one at the end of the bar shown by Fig. 601. The bar selected is thicker than the die required, that the steel may be reduced and condensed with hammering. When forged, the lengths of the fibres in each die should be parallel to the length of the adjusting screw while in contact with the die in its frame. By this mode of forging, each die when forged resembles Fig. 602.

Larger dies, for screwing articles one or two inches thick, also require the fibres to be in the same relative position to the adjusting screw, but each die is shaped to its finished shape while on the anvil, to avoid a lengthy reduction of the steel while cold. Each die, after being reduced with hammering, is therefore trimmed with chisels, to produce vee-gaps, or to form stems, if intended to fit frames that require such stems. Dies for tee-shaped slots, or for taper slots, are also shaped on the anvil with fullers and chiselling, and by carefully attending to the trimming of such articles, much time is saved from the planing. Although this trimming is tedious and requires good chisels and tongs to hold the work properly, it is better for the tool forger to make tongs, than to allow all the trimming to be done with shaping machines and planing machines.

When the dies are forged and softened, they are shaped for their respective frames by fixing three or four pairs of dies close together on a shaping machine, and planing all the upper sides at one operation. The dies are next shifted and fixed in another position to shape some other side, and if vee-gaps are to be shaped, all of them will be of the same shape and depth; or if the dies are to have stems instead of vee-gaps, by placing several together, a uniform character is obtained. Such planing is also advisable for the great economy of time which is effected. In order to properly reduce these stems, or vee-gap sides, to the desired dimensions, it is necessary to provide sheet iron or steel gauges that fit the slot-sides of the die-frames; such gauges are applied to the dies to measure them previous to unfixing them from the machine. Inside callipers and outside ones are also used, to allow as little filing as possible after releasing the dies from the planing-table.

Filing the vee-gaps and stems of dies is performed with half-round files and triangular ones, and each pair of dies is smoothly filed to fit loosely in their frame, to allow for the expansion to which all steel is liable while hardening. If the frame is finished and hardened, it is especially requisite to fit all the dies loosely; but if the frame is soft, it can be enlarged after the dies are hardened. The expansion and distortion of steel in hardening is greatly modified, and sometimes prevented, by one or two preliminary softenings after the planing is commenced. It is therefore proper to allow sufficient steel for possible bending, and for refixing the work to the machine. Preliminary hardening will also enable the operator to know the quality of the steel, which is of considerable importance in die-making, although not so necessary to ascertain as when forging a large expensive tap or broach.

The two faces of a pair of dies are the two surfaces that are in contact with each other while the dies are in their proper positions, close together in their frame. These faces are first filed flat and at right angles to the length of the slot, being thus flattened after the two dies are fitted to the slot-sides. The two dies being thus prepared, a packing piece of iron is put between the two faces, and all three pieces are forced tightly together by screwing the adjusting screw-point tight against one die. While thus fixed, small dies are planed to their proper thickness, if it happens there is sufficient metal to require planing. Large dies also are thus planed, for the convenience of making the sides of the dies parallel to the sides of the frame, and to easily hold the dies without gripping them with plates and poppets. The thickness of the packing piece is about an eighth of an inch for dies to make five-eighths or seven-eighths screws, and about three-sixteenths thick for larger sizes. The width of the packing is sufficient to allow it to project a little beyond the dies, so that when the dies and packing are planed together, the surface of each is level with the other. A pair of dies with packing thus planed, are shown by Fig. 603. The use of this packing-piece, or filler, is to keep the dies apart while drilling, so that the curved gap drilled in each die shall be less than half-round, or less than semi-cylindrical. The filler is also useful while forming the thread, when taps are used for screwing instead of hobs.

While a couple of dies are still tightly fixed in their frame, they are scribed on both sides with a springy divider, to indicate the place for the hole to be drilled, the drilling being done by boring only half-way through from each end of the hole. The ridge in the middle of the hole, that may not have been drilled out, is next filed out, and the dies become ready for screwing. Small dies, for making screws three-quarters or an inch in diameter, may be drilled to a proper size with only one drill, but larger dies require two drills, and sometimes a rosebit, to take out a small quantity, or to adjust several holes to one diameter. If the ordinary Whitworth screw is to be made in the dies, the proper diameter of the drilled hole is obtained by referring to column six of Table 5, in page 177, where it will be seen that the diameter forty-seven sixty-fourths is given for a screw seven-eighths in diameter; consequently, for a pair of dies to make seven-eighths screws, the drilled hole, after being filed to adjust it, if necessary, should be forty-seven sixty-fourths of an inch in diameter.

After drilling, and while the dies are fixed, without loosening the packing, the screwing should be done with a long taper tap. This is easily accomplished with small dies, by screwing the tap into both ends of the hole, and reversing the dies a few times, as directed for tapping a plate. Large dies require a partial screwing with a hob, and when the die-thread is shaped with the hob to nearly the complete shape, the long taper tap is slowly screwed through without any need of stopping to enter the tap into the opposite side. The hob which is used for such screwing is employed while the dies are loose, without the packing-piece, and the hob is screwed tight between the dies by means of the adjusting screw. During this screwing the hob's head is gripped in a vice, while the frame and dies are revolved around, if the frame is of sufficient length ; if not, it is gripped in the vice and the hob is rotated with a tap-wrench. In this process the thread is formed into the dies by the gradual closing together of the dies towards each other, by working the adjusting screw, and when the thread is nearly full, the hob is taken out, and the dies are screwed together with the packing tight between, that the long taper tap may be screwed through in an easy manner without risk of breaking any of its teeth through rotating it backwards.

The final polishing of a pair of die-screws is easily effected with smooth hobs, termed screwers for dies, which are shown by Figs. 380 and others. These tools are of various diameters, although they may have similar threads, for the convenience of using them to make threads of the same shape into dies of various sizes, dies of different dimensions being necessary for screwing rods and bolts that greatly differ from each other in diameter, although it may be requisite to screw all of them with threads of the same step and shape. A screwer of this class should not be parallel, but thickest about mid way between each end of the screw, the difference of diameter being about a fiftieth of the hob's greatest diameter. All such hobs require a greater length of screw than is necessary for a hob that is to be used merely as a standard, or for shaping a screw-tool, the extra length of screw being required to gradually advance the thickest part of the hob into the work, instead of suddenly, which would rough the thread instead of smoothing it. The mode of using a hob of this class for screwing dies, consists in screwing it slowly through with plenty of oil, while the dies are screwed tight with the packing between. If, after such screwing the thread is seen to be rough, the packing is taken out and filed thinner, and again put between and screwed tight; after this, the hob is again slowly screwed through with oil, and the thread is again examined, to discover if further smoothing is needed; if so, another small quantity is filed off the packing, and the hob again screwed through as before. When sufficiently smoothed, it becomes ready for polishing, and this is effected by cleaning off all oil that was used for screwing, and rotating the screwer to and fro while an abundance of soapy water is applied for lubrication, instead of oil. Only the thick mid-part of the screw is used for this final polishing, and the hob is rotated to and fro in the hole until it begins to loosen, at which time the thread is probably polished; if not, a minute quantity is filed off the packing, and the thick part of the hob-screw is again screwed to and fro as before.

By these processes it may be inferred that it is not necessary to adjust die-screws to any precise diameter, and this is the fact, because one pair of dies may be adjusted to any precise distance from each other that may be necessary, by means of the adjusting screw, during the screwing of a rod, bolt, or other piece of work; but although the adjustment of die-screws to a precise diameter or depth is never requisite, there are a few things to observe connected with the cutting capabilities, and, therefore, their future usefulness. Consequently, it is proper to mention a few circumstances that are usually forgotten in die-making.

Every pair of dies whose screw is finished with a hob of the same thickness as the bolt to be screwed with the dies, possesses good cutting properties, because the cutting of the bolt is free, and is free through only a small quantity of the die-screw bearing on the bolt at the time of cutting. At the beginning of screwing is the greatest freedom, the bearing surface being then very small, as represented by the contact of the dies with a bolt in Fig. 605. As the dies are gradually forced together to cut the screw, the bearing surface increases, and continues to increase until the conclusion of the screwing; but at the same time the cutting capabilities decrease, and at the conclusion the dies are in contact with the circumference of the bolt, as shown in Fig. 606. In this situation the dies cut little or nothing, unless the hob which finished the dies were a little smaller in diameter than the diameter of the bolt being screwed; if so, the dies will entirely screw the bolt to its finished diameter without causing the bolt-screw to bear on the bottoms of the die-gaps; therefore, to secure good cutting properties, a small hob for finishing the die-screws is requisite. Dies thus made are especially useful for small screws in general, such as those not more than about an inch in diameter. The greater the cutting properties of dies, the greater is the care required while using them to prevent them getting out of position and tearing the bolt-screw while being screwed; consequently, it is proper to put such tools into the hands of careful men.

A pair of dies which are finished with a master-tap possesses comparative inferior cutting properties, because the curves of the gaps in the dies are of greater angle than the curve of the bolt's surface to be screwed; or if not of greater angle, it is about the same. Master-tap dies may be made to cut only at the bottoms of the die-gaps, if the master-tap for finishing the dies is large enough in diameter. Such dies are often screwed with a hob which is as thick at the bottom of the thread as the outer diameter of the bolt to be screwed, by which means the bottom of the die-screw is made to bear entirely on the bolt at the commencement of screwing, and a firm steady bearing is thus obtained without much cutting property. Dies finished with such a hob cannot cut much at the outer edges, because the large curve of the die-gap causes the bolt to bear at the bottom of the gap when the screwing begins, and through this contact being effected most of the blunt character of such dies arises. It is to secure the steady bearing while cutting that dies made with master-taps are used, because little or no care is necessary to use them, through the firm grip which is given immediately the dies are screwed tight to the bolt. Probably it is better to sacrifice a little of the firm bearing quality, and to secure a power for cutting, because for nearly all the screws that are made with dies, an accurate thread is not required; superior threads are always expected from lathe-screwing, not from dies; therefore dies made with small hobs are preferable for most of the general screw-making when dies are the instruments employed.

A pair of dies finished with a master-tap are also much more liable to stretch the screw of a bolt while being screwed, than a pair screwed with a small hob, through the greater pressure and friction resulting from the greater bearing surface during the entire time of screwing; and this stretching is often sufficient to render a screw which is only two inches long, unfit for its nut, box, lever, rod, or other piece for which the screw is made. The stretching places the summits of the thread further apart than they should be, and the screw must therefore be reduced below its proper diameter to get it into its place. A pair of master-tap dies are also much weakened by the comparative large gaps for shavings, such gaps being necessary to cause the dies to cut at the bottoms of their screw-gaps.

Master-tap dies are represented in Figs. 607 and 608, by which it may be seen that all, or nearly all, of the die-screw must bear on the bolt during the entire time of screwing; Fig. 607 showing the situation of the dies at the beginning of a screwing process, and Fig. 608 showing their situation at the conclusion. In this Figure it may also be observed that if the dies were screwed with a master-tap of large diameter, the outer edges of the thread at the mouths of the gaps, cannot cut at all at the end of a screwing process, because they are then extended quite free from the bolt, as shown in the Figure.

To produce a couple of dies that shall cut well and also have a firm bearing while screwing, is very desirable, especially for large dies, to avoid a slow screwing of bolts, and to avoid the risk of spoiling a large screw through the dies getting out of a proper position during screwing. A couple of dies should therefore be made so that one shall have more bearing surface than the other, the one having the smaller surface being intended to cut, while the one with the larger bearing surface shall become a bearer to maintain the necessary parallelism of the die-screw with the screw being made. This difference of bearing surface is effected by using odd dies, and is obtained by either enlarging the mouth of one die-gap, by using both a large hob and a small one for screwing one pair of dies, or by making a very large gap for shavings in one die, that the bottom of this one die-gap shall not come into contact with a bolt during any part of its screwing.

A greater bearing surface in one die is obtained by screwing a pair while tight in their frame, by means of a small hob instead of a master-tap, and afterwards filing off the teeth at the two sides of the gap in one die, and allowing the sides of the gap in the other die to remain as when screwed; this die which is not filed consequently becomes the cutter, and the filed one the bearer.

To produce one couple of dies by screwing them with both a hob and a master-tap, it is necessary to drill them while tightly screwed together with a packing-piece between, as described, but to bore them so that the gap in one die shall be rather deeper than the gap in the other die. The diameter of the hole is equal to the diameter of the small hob at the bottom of its thread, and when screwing begins, this small hob is the one first put in, and the screwing progresses by gradually forcing the dies towards each other with the adjusting screw, and rotating the hob to and fro as for other die-screwing, without a packing-piece. When the complete thread is thus obtained, the die which has the smaller screw-gap is taken out of the die-frame and another blank die having a gap about the same size, but no thread, is put into the same place. After filing off a part of the thread at the edges of the large-gap die, the screwing again proceeds with the master-tap instead of the hob first used. This screwing widens the mouth of the gap in the die already screwed with a full thread, but does not make the gap any deeper, or if any, only a small quantity; the widening therefore gives a greater angle to the gap's curve, and makes it suitable for a bearer, as required. When the thread of the bearer is completed, the blank die, or the one having only a very shallow thread-groove, is taken out, being of no further use at the present. It is generally advisable to commence screwing the auxiliary blank die with the same small hob at first used, in order to more easily commence the screwing with the larger hob—or master-tap, as it is termed—the only use of the auxiliary die consisting in providing a bearing for the hob while the die having the smaller gap is out of the die-frame. After the bearer is screwed with the master-tap, it is necessary to again screw the small hob through both the dies a few times while they are together in the frame in their positions for use. By means of these processes, the die having the small gap becomes the cutter, as intended, because it has not been in contact with the master-tap, and therefore is of smaller curve.

The making of sharp cutting edges in a die by means of a broad gap for shavings, is easily effected, and the die thus treated should be one of a couple whose screws were both finished with a master-tap, both gaps being of one shape and depth until the large channel or gap for shavings referred to, is made. This broad gap is shown in the die named the cutter, in Fig. 611, and greatly reduces the bearing surface while screwing, also causes the cutting die to cut at the bottom of its gap during the conclusion of a screwing process when the thread of the bolt is fully formed. The opposite die, which is the bearer, also has a gap for an oil-channel, which is but small, through not being intended for cutting edges.

The cutting properties of all dies, whether screwed with long taper taps, small hobs or large ones, may be greatly improved by tapering the die-screw at one end of the hob. By whatever tap or hob the dies are screwed, the entire cutting of the dies while in use, is effected by about two steps of the thread at one end of the die-screw, if this screw is entirely parallel. But if tapered at one end, the dies will cut in a manner similar to that of a good tap, and several steps of the die-screw will cut at one time, instead of only one or two, so that the dies will execute more work without getting blunt, and will require less grinding than dies having parallel screws. Such tapering is easily done with filing, after the screwing of the dies is completed, and after a rough and smooth filing with small half-round files, the tapered surfaces are polished with emery cloth. It is also necessary to make the die teeth analogous to the teeth of a tap, by filing off a portion of the thread at the rear of each cutting tooth, which prevents the back of the tooth coming into contact with the bolt being screwed, in about the same way that the back of a tap-tooth is prevented touching the nut while being tapped.

In addition to tapering, another trimming is given to the dies after they are completely shaped with a tap or hob, and this trimming consists in cutting off all thin edges of the thread at both ends of the die-screw, so that all the cutting surfaces shall be as broad as the thread will permit. At the tapered end, none of the teeth can be made to present a section of a complete thread, but at the parallel end, two or three teeth can be thus treated, and by a careful filing, the desired across section of a full thread is obtained.

To avoid some of the filing when tapering die-gaps, rosebits should be employed. These are fitted to a drilling machine and made to cone the dies after they are bored for the screw, but previous to commencing the screwing. Each rosebit should have a long conical end for the convenience of making one rosebit cone dies of several sizes. If each pair of dies are thus roughly coned, the filing of the conical part after screwing, is quickly effected. Dies with tapered screws, require the parallel end to be put first upon the rod to be screwed, when it is necessary to completely form the thread from one end of the screw to the other; but a thread is less liable to break if its junction with the adjoining part of the bolt is tapered, consequently, to make such a thread, the tapered end of the die-screw requires to be put on first when beginning the screwing of the bolt or rod.

The small gap or channel which exists at the bottom of a die-gap, is of no use for cutting unless it is of great width and depth; if small, its proper use is to admit oil during screwing, and to diminish friction at the bottom of a broad die-gap intended for a bearer. The bottom of every such oil-channel, and also the bottom of every other gap or groove in dies, should be curved, which renders them less liable to break in hardening.

According to the processes now described concerning dies that are screwed with small hobs and taps, it will be seen that the principal cutting surfaces of dies in general, are those at the sides of the gaps, and not at the bottom; therefore the outer surfaces which adjoin the gap-sides, and are named the faces, require bevelling to make them cut easily, and are necessarily liable to become blunt during use and require sharpening. This is effected without softening the die, by merely gripping it in tongs and holding it to a grindstone. The bevelled faces are at about forty-five degrees to the length of the slot in the die-frame; both sides of the die require bevelling, because both sides should cut while screwing. The die termed the bearer, may remain with its faces at right angles to the length of the slot, because the bearer is not required to cut; but for uniformity, it should be bevelled to the same shape as the cutter. In a pair of dies that were entirely screwed with a taper tap or small hob, both the screwed gaps have similar good properties for cutting, so that both dies will cut if both are bevelled and sharpened by grinding when requisite.

The hardening of screw-dies is easily effected by heating them to a dull red in a charcoal fire, covering them with powdered prussiate of potash, and placing the screwed part of the die first into the water until about five-sixths of the die is in; it is then moved about, but not sufficient to suddenly cool the back of the die; this may be quite soft, or merely toughened, and should therefore be slowly cooled. All large dies are thus easily managed, but small ones, for three-quarters or half-inch screws, must be entirely hardened, to ensure a proper hardness in the teeth.

The tempering of dies resembles that for screwed plates, and consists in heating the dies on a thick plate which is over the fire, or placed in some other suitable situation, if sufficient daylight cannot be obtained while the tempering plate is at the forge. Each die while being heated, is put upside-down a few times, and tempered until a light golden colour is seen at the screwed portion, when it is cooled in water.

Die-nuts.—Die-nuts resemble screwed plates with regard to their action while in use, but not in the objects to which they are applied. Screwed plates are never used for screwing a rod, bolt, or other piece of work which is more than half an inch thick, but a die-nut is useful for screws that may be two or three inches thick. The height of the die-nut may be about one and a half times the thickness of the screw to be adjusted, a long bearing in the nut being allowable because only a very thin shaving is to be cut off while adjusting. A die-nut is of but little use if its screw is not tapered at one end of the hole; if its hole is parallel, and many of them are so, the few cutting edges around the mouths of the hole soon become blunt, and therefore soon require softening, sharpening, and hardening; but if one end of the hole is tapered, the nut will remain serviceable for cutting off the very thin shavings for which it is made, during several years without sharpening.

The tools required to grip die-nuts while in use, are gap-spanners, die-frames, or plates and bolts; a die-nut may also be forged solid with a handle, or forged in the shape of a tap wrench, having one or two screwed holes in the mid portion of the implement. A tool of this sort is especially useful if all the adjustment to be done with it is to be performed with the two hands while the screws to be adjusted are held by a vice. It is not often necessary to adjust screws in this manner, so that such nuts solid with handles are seldom wanted; the ordinary shape of the outer sides of die-nuts are usually similar to the outer sides of other nuts, so that they may be easily gripped with spanners, when it may be necessary to adjust screws while they rotate in lathes.

The drilling of such a nut requires care, to prevent the hole being made too large, and to produce a full thread without making the hole too small. When drilled, the screwing is properly done with a long taper tap having sharp teeth; and if the nut is for screws only about a quarter or three-eighths of an inch thick, the screwing of the die-nut, or gauge-nut as it is often named, may be managed by carefully using only one tap; but whenever more than one tap can be used for one hole, they should be employed if of a proper diameter, whether the die-nut being tapped is small or large. The final screwing of a nut of this sort, may also be easily done with a hob which is properly tapered to make it thickest in the mid part, such as were mentioned for the die-screwing and screwed plates. Whether long taper taps, hand taps, or proper hobs are employed for finishing die-nuts, it is quite necessary that the hob or tap for finally screwing the hole, should be only a very small amount thicker than the tap or hob that was put through next previous, because the screw cannot be smoothed unless a very small quantity only is taken out by the hob or tap; hence arises the necessity of providing hobs or taps that differ from each other in diameter only about a hundredth of an inch, but having threads of the same step and shape.

Large nuts of this class need a very gradual rotation of the tap or hob, also several backward rotations to release the tap and enter it from opposite sides, for if the tap is advanced until it becomes tight, the rotation backwards will break off some of the tap's teeth. The tap or hob used for finishing requires to be screwed through the nut two or three times from both ends of the hole, and if after such treatment, the screw is still rough, through blunt teeth, or through the hob cutting out too much, the remedy is to heat the nut to a dull red heat and harden it, which will make the hole smaller; the nut is next softened, and the hob or tap is again screwed through, after which, the hole may be again made smaller, by another heating, if required. The holes in screwed plates also, may be reduced in a similar manner.

The oil-channels are formed by drilling three, five, or seven cylindrical holes at equal distances around the screwed hole, being careful to mark the places at a proper distance to prevent the drill breaking through the thin side into the thread. After drilling, each channel is filed smoothly and its thin side filed out, to produce wide openings into the screwed hole and to smooth the edges; these openings also reduce the bearing surface of the thread, in addition to providing room for oil and shavings. The shavings will never at any time occupy much room, but it is highly necessary to prevent friction of the screw by reducing the thread, so that only a small amount of surface shall be in contact with a screw which is being adjusted. After the channels or gaps are finished, the thin extremities of the thread require cutting off, to make the cutting surfaces of the teeth broad, this trimming being similar to that for dies and screwed plates.

The coning of the hole of a die-nut, should be first partly done with a rosebit previous to commencing the screwing, and afterwards completed with a smooth filing and scraping when the screw is finished and the channels made.

The hardening of a die-nut, especially a large one for adjusting screws two or three inches thick, should be done while at a very dull red heat, to avoid distortion. If the screw is put much out of its proper shape, the nut when used for adjustment, will probably injure the screw instead of improving it, either by making it too small, or by roughing the thread. It is therefore necessary to soften the nut if distorted sufficient to do harm, that the finishing hob or tap may be again screwed through, and the nut again hardened. To modify such bending or twisting here referred to, two or three preliminary softenings, and planings or filings, should be given to the nut at the commencement of its making, but not till after the hole for the screw is bored; and the larger the nut, the greater is the need for such care. It is also proper to finish the screw of the die-nut with a tap or hob which is rather greater in diameter, than the required diameter of the screws that will be adjusted with the nut when it is finished.

It is now needful to close this chapter on tool-making, and it will be noticed that all definitions and descriptions that are not requisite, are omitted in these processes, for the sake of brevity, and to avoid explaining terms and peculiar tools at the time a process is detailed. For this reason a learner must refer to the definitions and sketches given in the second chapter, if not, the processes mentioned in the third one cannot be understood, except by machinists.

CHAPTER IV.

PLANING AND LINING.

To plane, signifies to produce a plane surface or surfaces. The original mode adopted by engineers for producing a plane surface, consisted in first using a planing chisel and hammer to roughly reduce the metal to proper dimensions for being completed with rough files and smooth ones. If a piece of work happened to be cast or forged with dimensions but little greater than the intended finished dimensions, the article was treated as it is now, being first ground on a stone, to remove the hard exterior, and next finished with rough or smooth filing, the precise amount of filing depending on the dimensions desired.

A plane surface belonging to any article is always relative, the surface cannot exist without being parallel to another plane which is in the same article; and if the object is a parallelopiped, any two opposite plane surfaces of the object are parallel to each other; but if it is a rectangular and taper key, or other object with slant sides, any selected slant surface may be a plane, but it cannot be parallel to its opposite slant side, although it is parallel to an imaginary plane in the object, existing at some stated distance from the slant surface. Through this parallelism of an object's plane surface to some other plane in the object, arises the necessity for considering the particular place of a plane surface which is to be produced on the object.

The production of any desired plane surface is the exposition of it; the plane exists in the metal beneath the rugged exterior, and is exposed to view as soon as sufficient metal is cut off, the precise quantity removed depending on the distance of the desired plane from the rugged surface. The planing of the object therefore consists in producing the hidden plane, and its place should first be determined and indicated, before it is produced and exhibited.

The original mode of determining the place and position of a plane in a piece of work, consisted in looking steadily at it and imagining the plane while looking; therefore, if one rough surface of the article required a sixteenth of an inch slice to be cut off, to attain the desired dimension, the operator decided that the plane he desired to produce existed at a sixteenth of an inch below the rugged exterior, and if the exterior were parallel to the hidden plane, he decided that the surface should be equally reduced, and would not cut off more than a sixteenth from any part of the surface.

As soon as the place and position of the hidden plane is determined, its boundaries also can be determined, because they are in the piece of work, and they may be plainly indicated to the eyes of an observer by means of lines, because the boundaries of planes are lines. Formerly, these lines were mere abstractions, which the operator conceived to exist on the piece of work while he looked at it, and he chipped or filed the piece until it was reduced to the places where he imagined the lines to exist. This is not very difficult to do, if the surface being cut is only a few inches across, and, at the present time, small surfaces are frequently planed by working to abstract lines in this manner; but the more mechanical and proper mode of planing now practised, consists in first indicating the boundaries of the plane, by marking lines upon the surface of the article, whether it is very small or very large. Consequently, planing, as now performed, is intimately related to this marking of the lines, which is termed lining.

The first step in tool-making should consist in making steel parallelopipeds, such as short straight-edges and small surface blocks, because all finishing of engine-work depends in some way on planing, and all planing depends on straight-edges. A beginner in machine-making should commence by attempting to make a tool of some sort that is intended for use afterwards; not merely to practise on something which he intends to throw away, or on something that is either too large, too small, or otherwise unfit to become a tool. If he knows he is merely practising, he is much more liable to become careless and spoil the work. If the beginner is to make a tool by means of planing, it should be one intended to have plane surfaces, and it is now presumed that he has bought or has made such tools as scribers, callipers, and short straight-edges, which are treated in the second and third chapters. Being thus provided, he should commence planing by making a small pillar-table of cheap granular steel, similar in shape to that shown by Fig. 615. This is a solid cylinder of ordinary rod-steel, about three inches long and two inches thick. If he is quite a novice, it is advisable for him to devote his attention to specially producing only one of the cylinder's planes, which will enable him to make a surface-table; but when he has advanced a little, his object should be to specially plane both ends of the block, and to make both the planes parallel to each other; this is more difficult, and produces a parallel block that will be more useful than if the implement had only one plane surface. Whether the work is to have one plane or two, it is proper to reduce the two ends without using a lathe or planing tool of any sort, except chisels and files, unless the piece is much longer than necessary; if so, it can be lathe-turned, reduced with a planing-machine, or cut while hot on an anvil, until about an eighth of an inch remains at each end for chipping and filing. The curved surface of the lump needs no reducing, and remains as it was when first cut from the rod shown in Fig. 618.

When the piece is forged, or otherwise prepared, the first planing consists in reducing one end of it until at right angles to the length of the cylinder, but without taking off any stated quantity. In order to make this end square to the length of the piece as required, an el-square is necessary, which is frequently applied during the rough filing, as shown in Fig. 619. This squaring is of little consequence, except for appearance, because the block is not to be a parallelopiped; so that the operator devotes his principal attention to producing the plane surface without precisely determining its relative position.

To grip such a piece, a couple of angular-gap clamps should be used, similar to those shown in Fig. 629. These should be made of soft steel or iron, and may be provided with gaps of three or four different sizes, to render them suitable for various work; or they may have but one pair of gaps, and be made to suit pieces of different thicknesses by placing packing-pieces between the gap-sides and the work. A pair of such clamps consist of four principal pieces, two for each clamp; one of these two is a thick lump of soft steel, iron, copper, or other material, which has the angular gap, and is therefore the grip, and the other piece is a thin plate of steel to which the grip is riveted, or fastened with screws that can be easily taken out when a different grip-piece is required. The thin plate is bent to fit the top of the vice-jaw, and the particular material selected for the grips, is suited to the pieces of work to be held. For rough forged iron and steel, the grip is of steel or iron; for smooth iron or steel that must not be bruised, copper grips are very effectual; for gun-metal and brass, ash wood grips, and also leather ones, are suitable, if the work is only a few pounds in weight, but for a heavy piece of brass it is advisable to use a pair of copper grips, and put a piece of canvas into immediate contact with each grip and the work, or instead of canvas, a sheet of clean emery cloth doubled together with the emery outwards. For the particular piece of cylindrical steel to be now heated, a pair of clamps having iron grips, are therefore suitable. Whatever may be the special use or shapes of the clamps, each one should be fastened to the vice-jaw by means of a small screw, which is denoted by S in the Figure. Such a screw prevents the clamp falling about, and is applicable to all classes of clamps, and the screwed hole in the vice-jaw is made to suit all the clamps that may be applied, by making the hole in each clamp large enough to allow freedom, and by providing screws with broad thin heads.

As soon as the cylindrical piece is smoothed at one end by means of smooth filing, it is ready for scribing. This consists in making a circular line around the work at a proper distance from the smooth extremity first filed and tolerably squared. The scribing is effected with a scriber-block while the work stands with its smooth extremity in contact with a table's plane surface, as represented in Fig. 621. If it is decided to make the piece about three inches long, the scriber-point is adjusted to three inches and a thirty-second above the table's surface, and the scriber-block is moved around the work while the point is in contact, both the work and block being held in close contact with the table during scribing. To render the mark distinct, a little soft chalk is rubbed upon the work at about the place of the intended line. When it is scribed, the boundary of the hidden plane to be produced, is indicated, and the rough end is next bevelled to make it resemble Fig. 620. If the piece is but little longer than the finished length, the bevelling is done with a rough flat file, while the lump is held in the vice, and when bevelled appears as in Fig. 620; but if a long rough piece is to be cut off, the work when scribed appears as in Fig. 621, and is next bevelled by making a bevelled groove around the piece at the scribed line, by means of a three-cornered file, or a half-round one.

After the work is bevelled or grooved, according to the amount of metal to be cut off, it is reduced with chipping or rough filing. When chipping is necessary, the bevel is an effectual means of preventing the breaking of the work at the edge of the intended plane during hammering. While the operator is chipping the front edge of the work nearest to him, there is no risk of breaking off more than is necessary, because he is driving the chisel towards the centre of the end, where there is an abundance of metal to resist the tendency to breakage; but during a chipping with heavy blows at the edge furthest from him, the work will break in an irregular manner at some place which is below the hidden plane to be produced, if the bevel referred to is not first made. The bevel is also quite necessary if the work requires only filing, because the operator is thereby enabled to continue the filing until the entire bevelled part is cut off, without being required to look at or examine the work in any way, to see if he is filing parallel to the plane end to be made.

To chip such an end in an easy manner, when chipping is necessary, it is advisable to first use a small grooving chisel shown by Fig. 322, to make a few narrow grooves across the bevelled part of the work, and to afterwards cut off the ridges that remain, with a proper planing chisel, denoted by Fig. 321. If a quarter of an inch or three-eighths needs cutting off, it will be necessary to make a few more grooves after the planing chisel has been once driven over the end; and to again cut off the ridges with the planing chisel as before.

By thus reducing the end until all the bevelled part is cut off, the work is made ready for measuring, either with an outside calliper, a gap-gauge, or a jaws shown by Fig. 421. Of these three tools, a tightly riveted calliper is preferable, especially near the conclusion of the filing. By frequently measuring the length of the work with the callipers, both planes are made parallel to each other at the same time that the piece is reduced to its desired length. The measurements for this purpose should be performed while the block is tightly gripped in the vice in position for filing, which will avoid unfixing and refixing the work in the vice, until the final adjustment of the planes to parallelism with each other, is to be effected.

The finishing of the planes consists in scraping the extremities with an ordinary flat-end scraper, shown by Fig. 330, both ends of the work being made equally plane, unless the piece is to be merely a surface-block. To try the surface of the work during scraping, a standard table may be used similar to that denoted by Fig. 298, which denotes a surface-plate whose plane surface was finally scraped for adjustment while the plate remained standing on one edge, as in the Figure; the plate is therefore used as a standard while in a similar position. The learner who is finally scraping the cylindrical block therefore rubs a little tange upon the standard to mark the prominent portions of the surface in progress when rubbed on the standard. This rubbing causes the oily mixture to adhere to the prominent parts, and the operator exercises sufficient care to scrape only those portions on which the mixture remains, that the desired plane surfaces may be produced.

Whatever plate may be selected as a standard, if a large one, it remains stationary, while the work is repeatedly applied to the plate; it is therefore necessary to frequently unfix and refix the work in the vice when a heavy surface-plate is used. But if a small plate or block is used as a standard, it may be rubbed upon the surface of the work while it remains fixed in the vice, and this mode of trial is especially advisable if only one end is being specially planed, without making it, just at that time, parallel to the surface at the other end. When, however, both surfaces are being made plane and parallel to each other, the work must be frequently removed from the vice for measurement.

A little care is required every time tange is applied to any standard surface. If the tange is thicker on one part of the surface than on some other part, the operator, especially if he is a learner, is liable to be misled, because the comparative thick accumulation of the marking matter will adhere to any part of the work that may be put into contact, whether concave or convex, and the portions of the surface to which the matter sticks may be hollows, and not projections. The layer of tange should be so applied that any portion of it shall be equally thick with any other portion, so that, while on the standard surface, both the outer surface of the tange and its inner surface which touches the plate shall be parallel to each other, and, consequently, parallel to the plate's surface. To obtain a near resemblance to this parallelism, only a very thin layer of the mixture should be on the plate, at the time the surface being adjusted is to be put into contact, the quantity of tange being only sufficient to be seen on the work after having been rubbed upon the standard. The nearer the surface being scraped resembles a plane, the thinner must be the layer of marking matter, so that at the beginning of a scraping process the composition may be in greater quantity, to roughly and quickly indicate the places of contact.

The mode of properly distributing the composition on the standard when the surface in progress is nearly finished, consists in rubbing off nearly all the tange that was on during previous trials of the work. This rubbing off is done with a clean smooth cloth, and is continued until a mere cloud of tange appears to remain on the plate's surface. During this final smoothing of the marking compound, the operator should carefully observe whether any bright portions of the plate can be seen, through being entirely deprived of tange with too much rubbing, and if such portions are noticed, the operator will avoid applying his work to the bright parts; but if the standard surface is too small to admit such a selection, more tange should be rubbed on to the bright places, and again smoothed until of a proper thickness.

Although the plane surfaces of the small pillar-table being made, have but a few inches of area, it is necessary for the learner to observe the same order of reduction as if the surfaces were large, the middles being scraped previous to the surrounding parts, according to the directions in page 157.

During the final adjusting of the planes, to make them parallel to each other, great care is necessary; and this parallelism can only be obtained by a proper use of a gap-gauge or calliper. A tightly riveted calliper is the preferable tool, which must be delicately adjusted with a gentle hammering, so that the points of the calliper's feet shall only very tightly touch the two plane surfaces while measurement is being performed. But such gentle measurement is of no avail unless one end of the cylindrical block is a plane at the time of applying the callipers. If one extremity is a little hollow, and the opposite extremity a little prominent, the measurement with callipers will cause both surfaces to appear flat, if the calliper only is used to ascertain the condition of the work. To avoid such an error, one plane surface must first be produced by careful scraping, and with repeated rubbings to the standard plate. When one plane is thus finished, it becomes a sort of base or primary plane to which the opposite end of the block is to be made parallel. Such a finished plane is therefore not altered during the final scraping in the course of adjustment by means of the callipers, all the scraping to make the extremities parallel to each other being performed upon the opposite end, which of course is the roughest. The plane surface first finished or the primary plane, here referred to, corresponds to, and resembles in some respects, the plane surface which is in contact with the surface-plate shown in Fig. 621, because the boundary of the hidden plane in the upper part of the block which is being marked with the scriber, could not be easily scribed without first smoothing the lower end sufficient to prevent it rocking on the table.

MODES OF LINING AND HAND-PLANING.

Lining of Straight-edges to be Hand-planed.— In order to enable a learner to fully understand and appreciate the making of straight-edges in general, he should entirely make one or two by hand-planing. This will teach him the value of machine-planing of straight-edges, when several are required at one time. He will also observe that much more lining is required for hand-planing than for machine-planing, if he desires to perform the work in an orderly and easy manner.

For making straight-edges in great numbers, smoothly-rolled steel of proper thickness is always used, so that little or nothing is done to the broad sides of the metal, because the entire straight-edge making consists in cutting the steel to proper lengths and widths. But a learner who is commencing the practice of planing is often obliged to use remnants of sheet steel or bar steel having rough broad sides, so that to make one or two straight-edges a large amount of filing, to reduce and smooth the sides, may be requisite. When a straight-edge is to be produced by such extensive reducing, it is necessary to have a proper idea of the form of the tool to be made, and to consider it as a right-angled parallelopiped. This is the form that should be intended by the operator, because, although the tool should be made so that the two edges shall be very accurately planed, and also parallel to each other, the straight-edge would be defective if its broad sides were rugged or irregular near the planed edges. Such a defect would not exist in a straight-edge which is made of the proper smoothly-rolled steel or iron; consequently, no attention need be given to such defects unless the rough filing referred to for reducing the broad sides is to be effected. A projection or a hollow existing at some part of a broad side is of little consequence when the straight-edge is in use for trying flat surfaces, but such a fault is often sufficient to prevent a straight line being scribed with a scriber which is moved along in contact. The small bevelled part which is sometimes made at one edge of a straight-edge is a means of remedying defects in the broad side; but previous to making such a bevel the operator should produce the parallelopiped, after which the bevelling may be easily and accurately done. A parallelopiped for a straight-edge is shown by Fig. 616, the letter C showing the place for the cut, if one tool is being made previous to dividing it into two.

The marking of a rugged piece of plate intended for a straight-edge is denoted by Fig. 622, in which a straight line is shown along the middle; this line is the primary, and is the one first scribed by means of a standard straight-edge, after which a number of circles are marked along the line, the number depending on the length of the intended tool. Each circle is of the same diameter as the desired width of the straight-edge, and after these are marked, two other straight lines are scribed, so that one line shall touch the circumferences of all the circles at one edge of the rugged plate, and the other line shall touch all the circumferences at the opposite edge, in order to make all the three straight lines parallel to each other. When thus marked, the piece is ready for reduction, either by rough filing, by grinding on a rotating stone, or by chiselling while red hot on an anvil, the mode adopted depending on the quantity to be taken off, and the particular implements accessible to the operator.

If a surface-table of sufficient dimensions is accessible, the scribing is conducted by another mode, which consists in first roughly hand-planing one edge of the plate, and next placing the piece with its planed edge in contact with the table's surface, as seen in Fig. 623; while it is held in this position by an assistant, who holds it at right angles by means of an el-square, an operator moves a scriber-block along and marks a line at the desired distance above the table.

By this means one broad side is marked with one boundary of the hidden plane which is to be produced and is to be called the straight-edge. Another straight line is next scribed by similar means, but upon the other broad side of the plate, to indicate another boundary of the small plane to be formed, the el-square being shifted and put into contact with the side first scribed. By this mode of marking, no primary line along the middle nor circles are necessary, because the table's plane surface constitutes the primary base or plane which guides the scriber-block in the desired path.

Right-angled Blocks.—The forging of these parallelopipeds, surface-plates, and similar implements, of granular Bessemer steel, has been described in the third chapter; it is therefore necessary to now mention only the planing and lining of such articles. The right-angled block shown by Fig. 617 is one of a set consisting of two, three, four, or any other required number of such tools, which are first forged either singly or in one long bar to be cut into short pieces, each of the desired length. Those that are forged singly are especially adapted for hand-planing, which consists in entirely planing the object with chiselling, grinding, filing, and scraping, without any machine-planing. A single block which is to be thus treated should first have one of its broad sides properly planed with smooth filing, and with reference to a standard plate. The plane thus first made becomes the primary, to which the opposite broad surface is to be made parallel, and the four adjoining surfaces made at right angles. Marking the block is next performed, and this can be properly done, because the primary plane is already produced. To quickly mark the place of the opposite broad surface, the work is put upon a table with the primary plane in contact, and a scriber-block is used to mark four straight lines, one upon each of the four sides that are at right angles to the primary plane, and therefore at right angles to the table's plane surface. While the block is thus situated, its primary plane is analagous to the primary plane of the block in contact with the table in Fig. 621, or to that in Fig. 628; and by adjusting the scriber-point to a proper height above the table, the four lines are made to denote that particular dimension of the block, and also to indicate the boundary of the hidden plane to be formed parallel to the primary. If pairs or sets of blocks having the same dimensions are being made, one broad side of each block should be first planed, and the opposite broad plane of every block next marked at one operation; this is effected by adjusting the scriber-point to the desired height, and scribing all the blocks without altering it. By this means the same dimension on each block is accurately indicated, and also without trouble.

This marking can be done also with a calliper, although such marking is far inferior to that of a scriber-block. If a calliper is to be used, the feet or points are adjusted to the desired distance from each other, and, while held in one hand, one calliper-point is put into contact with one edge of the primary plane at the same time that the other calliper-point is put upon the surface to be marked; while in this position the calliper is moved along, and a line is marked which is straight, because one calliper-point is in close contact with the primary plane, and this point is therefore a sort of guide to guide the other calliper-point which marks the line.

After the block or blocks are marked, the superfluous metal which is outside of the lines is filed off, or first chiselled off, if a sufficient amount exists to require chiselling; and the reduction commences by first bevelling the edges to the gauge lines by means of a rough file, similar to the mode of bevelling a cylindrical block. A right-angled block having one of its sides thus bevelled is shown by Fig. 625, and if much is to be cut off, a few grooves are made across while in a vice, as seen in Fig. 631, the end when grooved appearing as in Fig. 632. In Fig. 628 a block is shown with the boundaries of its hidden broad plane scribed, and is therefore ready for bevelling and reduction, in order to produce the hidden plane, whose boundaries only can now be indicated. During all such chiselling in a vice, the place of the cut must be as near as possible to the top of the vice, because the chisel cuts best at the place of greatest resistance, which is at the top edges of the vice-jaws; consequently, the work is placed as low in the vice as circumstances permit.

As soon as both the broad planes of the block are produced, and made tolerably parallel to each other, the two long narrow sides are chipped or filed, and made square to the two broad sides or planes. To make them right angular, an el-square is necessary, and this is used either with or without a surface-table, according to circumstances. If a standard table is accessible, the block is put upon the surface with the two broad planes at right angles to the surface; and in this position a scriber-block is made to scribe a line upon each broad plane, which will indicate the boundary of one of the narrow planes to be produced. The next step is to put the block upside-down, and mark two more straight lines upon the same broad planes, but at the opposite edges, the block remaining with its broad planes at right angles to the table as before. This scribing can be properly done only by carefully fixing the block so that its two finished or nearly finished planes are exactly at right angles to the table; it is therefore necessary to mention how this right angular position is obtained.

At the time the block remains on the table with one of the rugged narrow sides in contact, three or four little smooth steel wedges are put between the work and the table, and they are gently hammered in or pushed in while an el-square's blade is near the block's planed broad side, and the square's pedestal rests on the table. Through the square being thus situated, the operator can see which particular wedge or wedges require pushing in further, to put the broad sides into the desired position; and when the el-square denotes that a right angular position is obtained, the scriber-point is adjusted to the proper height, and the scribing performed.

The block being thus marked, is ready for bevelling and filing to the gauge lines, to produce two more planes, and if the scribing has been properly done, and only very thin marks made into the block, the four planes will be very near to the required right angular positions, but will afterwards need a further squaring with reference to an el-square. The extent to which this squaring is conducted need not be sufficient to entirely finish the surfaces, because the work may get bruised or damaged in some way, by fixing it in the vice with rough or dirty clamps; consequently, it is advisable to finally file and scrape the block when all its six planes are produced. The degree of precision to which this final adjustment of the planes to right angles may be conducted, depends on the accuracy of the standard square, or standard right angular block which is used for adjustment; and also on the particular idea existing in the mind of the operator concerning a right angle and a plane; for it is of little use to provide an operator with good standards unless he has a delicate perception of the purposes for which the standards are made, and of the ideal angles and planes represented.

The two smallest planes of the block are those termed ends; these should be the ones last produced, and the final scribing is that which denotes the boundaries of these planes, which exist in the block, although hidden by the rugged exterior, in a condition similar to that of the original state of the four planes now formed. A block having four planes and two rugged ends is shown in Fig. 627, where one end of the block is seen nearest the table, and resting on a wedge, wedges, or packing of some sort, that the planes may be put at right angles to the table, the method of adjusting being similar to that described for adjusting the two broad planes first made. But through four planes being now produced, additional care is now requisite to apply the blade of the square to all the four surfaces; and when the right angular position is obtained, the marking is performed by scribing four lines this time, upon the upper part of the block, instead of only two, each of the four lines being on one of the four planes. When marked, the block is ready for reducing at the scribed end, and when the hidden plane at this end is produced, it is put into contact with the table's face, and the boundaries of the plane at the opposite end are scribed; not, however, without applying the el-square, as before, because the small plane just made may not be very near to a right angular position to the four planes adjoining. If the square now detects a small divergence from a right angular position, a piece of thin paper is put under one edge of the block, to effect the requisite alteration. When this final scribing is completed, and the block reduced to the lines, the places and positions of all the six planes have been determined, and are now produced; consequently, the planing and lining of the work for producing the previously hidden planes, is effected.

The lining of three, four, six, or any considerable number of right-angled blocks, for hand-planing, consists in placing several together on a table, as in Fig. 626, after planing, or partly planing, those sides that are to be in contact with the table, whether they are broad sides, narrow sides, or ends. If four, six, or any other number of blocks are thus placed, the scribing of all is easily accomplished at one operation, as shown by the scribed lines in the Figure.

MODES OF FACILITATING HAND-PLANING.—Objects which are cast or forged so that only a very little filing will reduce them to the required dimensions, must be properly treated previous to filing, to avoid an unnecessary waste of files through rubbing them upon the hard sandy surfaces of the work. A piece which is too small for chipping should have its hard skin removed by holding it to a grindstone; and if the object is too small to be held in the hands, it is held either with tongs, bolts and plates, or with a lathe-chuck. After grinding, the filing proceeds in an easy manner, because the clean surface of the metal is exposed to the file. Objects having irregular surfaces can be only partly ground with the stone; and small pieces of such shapes may have their surfaces entirely cleansed from sand, if required, by allowing them to remain a few hours in sulphuric acid and water, which is provided in a proper vessel of suitable length and depth. This treatment allows the acid to slightly corrode the metal and remove the sand at the same time.

To avoid an unnecessary consumption of rough files, they are first used for filing brass and gun-metal, for which the files are suitable while their teeth are sharp. They are next applied to clean cast iron and forged iron; and when found to be blunted by these comparative soft metals, the files are applied to steel, and will then cut without being so liable to break their teeth as when they were new and sharp.

PLANING-MACHINES.

Machine-planing consists in producing a plane by the aid of a machine, in addition to employing some of the means adopted for hand-planing. Strictly speaking, a machine for planing is any machine which produces plane surfaces; but, in this place, the term planing-machine is meant to signify one of a large class that produce planes by means of a horizontal to-and-fro motion, termed, in lengthy language, a horizontal reciprocating rectilineal movement. Small planing-machines, for planing surfaces of only a few inches area, are named shaping-machines, and most of them are actuated by a crank-pin and a connecting-rod which moves the sliding head or tool-head to and fro in the desired path. To this head the cutting-tool is attached, and is moved while the work being cut remains comparatively stationary. This class of machines is represented by the one in the middle of Plate 35.

Large planing-machines are so made that the piece of work to be planed shall move to and fro, but not the cutting-tool. The piece is thus moved by means of a moving table, to which the article is fastened with screw-bolts and plates. The table is provided with planed vee-slides or ridges, that slide to and fro while in vee-grooves of similar shapes, the vee-grooves being formed in the upper part of the bed, which is a heavy fundamental portion of the machine.

Large planing-machines have no motion produced with a crank-pin and connecting-rod, and are represented in Plate 48, which shows all their ordinary arrangements. Of the two machines in this Plate, the one shown by Fig. 653 is the simplest, because it has only one slide-rest; and this portion, together with all the other portions, are named in the Figure. Such machines are of a great variety of sizes, that they may be suitable for planing an area of only about one foot, and for planing one of three or four hundred feet. They are distinguished into sizes by the length, width, and height of the articles that may be planed with them; and if the extreme length of the table's travel in one direction is twenty feet, the machine is said to have a twenty-feet travel. In the Figure the heaviest portion, termed the bed, is seen by its name, and the vee-grooves belonging to it are shown by V G. The vee-slides which fit the grooves are not seen, being under the table, and usually solid with it. In order to move such tables to and fro, several means are adopted. The most general of these consists in employing a step-rack and a step-pinion. This rack is either solid with the under side of the table, or firmly fastened to it, and the teeth of the rack are engaged with the teeth of the pinion, the pinion being in the intermediate space of the bed. To rotate the step-teeth pinion, it is provided with a spindle which is rotated by teeth-wheels, connected to the band-pulleys seen in the Figure at the further side of the machine. Another mode of moving a planing-table consists in using a screw and nut, the nut being firmly attached to the under side of the table, instead of a step-teeth rack, that the screw may be made to rotate in the nut while extending along the intermediate space or gap of the bed. This is the principal or main screw of the machine, and has but one sort of motion, which is a rotary movement around its major axis; consequently, the screw-nut on the screw must move in a path which is parallel to the length of the screw, and the screw is so placed that it is parallel to the planes of the table and its vee-slides. Whatever small quantity of motion the main screw may have in the direction of its length results merely from the small amount of wear of the shoulders.

By whichever of these means the table is moved, the band-pulleys are required to impart the motion; these are worked with leather bands which are driven by the shaft of the factory, and if a main screw is employed to move the table, the pulleys may be at one end of the bed, instead of at the back of the machine. The leather bands are, in many cases, actuated by a power shaft situated above the machine; but the preferable plan consists in providing a shaft beneath the machine, and placing the machine pulleys as low as possible. Such an arrangement involves less danger to workmen, if the pulleys are incased with sheet iron, and the conveyance of heavy pieces to and from the machine-table, is also greatly facilitated.

The to-and-fro motion of the table with the work fixed thereto, and the movement of a cutting tool, in contact with the work, together effect the planing; therefore the means of obtaining this result must be described. Through a planing-machine being required to produce a plane, either of three plans may be adopted; the piece to be planed may move and generate a plane by its movement, while the tool for cutting remains a fixed point; or the point represented by the tool may move and generate a straight line while the piece of work moves at right angles to the line; or both the tool-point and the piece of work may move, and both generate planes by the movement, the two planes coinciding with each other. Of these three arrangements, the one belonging to the machines here mentioned, is that by which the tool-point is made to generate a straight line across the direction of the table's motion to and fro. This rectilineal motion of the tool is its horizontal traverse or travel, and is obtained by the tool being fixed in a tool-holder and slide-rest which are moved across the table by means of the traverse screw and carriage. Through this screw being supported with shouldered bearings at each end of the carriage, the screw has but one sort of movement, which is a rotary motion around its major axis, similar to the motion of a main screw for moving a planing table. The travel of the slide-rest and tool is therefore effected by rotating the screw in its nut, which is fastened in the slide-rest, the rotation being done by an operator with the handle shown by H. By reference to the Figure it will be seen that the two standards of the machine are those portions to which the carriage is fixed, and this fixing is effected by screw-bolts and nuts situated at the further side of the carriage.

Because the pieces of work to be planed are of various heights and widths, and because a cutting tool cuts best at the place of greatest resistance, as before stated, it is necessary to raise or lower the slide-rest and carriage to any required height above the table, to suit either thin pieces to be planed, or thick ones; for if the carriage could not be lowered, it must remain at the top of the machine, to suit work of great height, and a very long tool must be used to reach down to a thin piece of work. If so arranged, the tool-point would present little or no resistance to the metal in contact, and therefore would not cut. This necesssary lifting and lowering of the carriage is performed with two lifting screws, one in each standard, as in the Figure, each working in its nut, which is fixed at the back of the carriage. The steps of both the lifting screws are of exactly the same length, for the convenience of allowing both of them to be rotated at one time by means of two couples of bevel wheels at the top of the machine denoted by B. W. In order to rotate these wheels, the hand-wheel or lifting-wheel, L. W., is rotated by one or two men, and when the carriage is put to its required place, its fixing bolts are tightened to secure the necessary rigidity. For a large machine, a ladder, or similar means, is required to reach the wheel; and to avoid using a ladder, it is advisable to provide a lifting wheel with a grooved edge and an endless cord, the cord being long enough to extend to the operator or operators while they stand below on firm ground.

The precise direction of the tool's travel does not depend on the position of the traverse screw, but on the position of the carriage. If the machine is in good condition, the traverse of the tool across and in contact with a piece of work on the table moving to and fro, produces a plane which is parallel to the table's face. This results from the slide-rest moving along the carriage, and the upper and lower friction surfaces of the carriage being planes that are parallel to the table. This parallelism should result, whether the carriage is at the top of the machine or only a few inches above the table; and, practically, the parallelism does result, being obtained partly by the machine's good condition and partly by the skill of the planer. The important consideration connected with this subject, is the precise position of the carriage immediately after it is raised or lowered, but previous to commencing the planing of a surface. At such a time an ordinary planer would tighten the carriage-bolts and proceed to plane; but a thoughtful geometrical workman would, after tightening the bolts, ascertain whether the carriage is really in its desired position. To discover this he should use a scriber-block of suitable height for the machine, and adjust the point to a proper height to coincide with a couple of dots or lines on the carriage, one at each end of it, such marks being known to be equally distant from the table's face when the carriage is properly adjusted. When it happens that one mark is seen to be too low, or too high, the bolts are loosened, and one end of the carriage must be raised by placing a thin packing-piece of paper or other material beneath the bearing surface of the bevel wheel which is keyed tight to the lifting screw. Another mode of adjustment is affected by means of adjusting screws and wedges, to be described in another place. After the carriage is properly placed by some means, the nuts are tightened, and if such tightening puts the carriage again out of its proper position, the packing or other adjusting apparatus is altered accordingly.

The various causes which render such adjustment of a carriage requisite when accurate planing is intended, may be briefly mentioned, and are usually these: unequal wear of the bottom surfaces of the bevel wheels; unequal wear of the lifting screws and nuts; planing small surfaces on large planing-tables, and thus wearing one end of the carriage more than the other; continual weight of the slide-rest at one place near one lifting screw; also a softness of a friction surface at one particular place; want of oil in some parts; accumulations of gritty substances; and a few other causes. In consequence of wear, the relative positions of the several parts are gradually altered; so that a couple of gauge lines on the carriage will not always serve for adjustment, and must, therefore, at some future time be erased, or attended to in some way, if new marks are not made. It may be also mentioned that the greater the distance which the surface to be planed extends across the table, the greater is the need for adjusting the carriage; and that the end of the carriage at the back of the machine must never be higher from the table than the front end of the carriage, but it may, in nearly every machine, be lower, to provide for wear of the tool-point during its traverse across the work, because the direction in which the tool usually travels during planing, is from the front edge of the table to its back edge.

It is only by means of thus fixing the carriage parallel to the table, that the plane surface being produced, can with certainty be made parallel to some other stated plane in the object, according to the elements of planing given at the beginning of this chapter; and because the hidden plane to be produced with the machine, could not be produced in its determined relative position and situation, without fixing the work with regard to some base or primary plane, the face of the machine-table is made to constitute a primary plane, and this face is that to which the hidden plane is made parallel during adjustment of the object for planing. No difficulty arises through the desired plane being hidden by the exterior metal, because through the boundaries of the plane being lines, such lines are marked upon the work to indicate the place and position of the plane, according to the elements in pages 205 and 206. Therefore, if the object is so fixed to the table that the boundaries of the desired plane are parallel to the table's face, the process of planing will produce the plane in the exact place required, because the tool-point moves across the table in the path of a line which is not only straight, but also parallel to the table's face which constitutes the standard or primary plane.

It is now requisite to mention the means for advancing the cutting-tool across the work and table, to effect the planing of the work while it moves to and fro. The direction in which the tool moves, and the various modes of moving it, are independent of the principles just given; whether it cuts while moving towards the operator standing at the front edge of the table, or cuts while travelling from him, or cuts while moving in both directions, is of importance only with regard to facilitating the work. In the earlier machines the workman moved the tool by rotating the traverse screw with a handle similar to that shown by H in the Figure; and the tool was made to cut while moving either way, according to the direction in which the handle moved. To avoid the tedium of this hand-traverse, a variety of apparatus are now used which are worked by the machines themselves; so that the same power which moves the table to and fro, is made to move the tool across the work. Such apparatus is termed feed gear or traverse gear, and the greater number of all such gear are actuated by feed-rods. A rod of this class is denoted by its name in the Figure, and its use is to impart a rotary motion to the traverse screw by means of levers, rods, and pawls, that are connected to the feed-rod and teeth-wheels on the end of the traverse screw. For this purpose, the rod is made to move upwards and downwards once during every travel of the table to and fro; and this up-and-down motion is obtained by a spindle and levers attached to the lower end of the rod, these levers being moved a short distance at every travel of the table by receiving a gentle knock from a stud or pin projecting from the table and situated just below its front edge. Two of these studs or pins are provided, and are named stops. These are fastened to the table either by a dove-tail ridge extending along the table's entire length, or by a dove-tail groove, the bases or bottoms of the stops being made to suit, so that they will fit any place along the groove. Each stop has a fixing screw, which is tightened and loosened with a spanner by the workman. Stops effect two results, one of which is knocking the lever and shifting the feed-rod, and the other result is shifting the band or bands on the machine-pulleys to reverse the direction of the table's motion. For this reason, the stops are at various distances from each other, according to the distance that the table is required to move in one travel. If only a very small surface is to be planed, the planer fixes the stops very near to each other, that the motion of the table may be stopped and reversed immediately the tool becomes free of the work, to avoid loss of time; but if a surface whose length is nearly that of the table, is to be planed, he fixes each stop at one end of the table, and the desired length of the table's travel is thus obtained.

The necessity for a gradual traverse of the tool over the surface being planed, arises from the fact that there is no machine capable of planing a piece of engine-work, so that more than half an inch, or an inch, of the tool's cutting edge shall cut at one time, the usual length of a tool's cutting edge in actual contact while cutting, being only about an eighth, or a quarter of an inch. If a machine could be made to cut off a slice of four feet in width and a quarter of an inch in thickness, at one effort or travel of the table, the cutting edge of the tool must be quite straight and four feet in length, the entire cutting edge must also be in contact with the metal during the whole time of cutting, to produce a plane by such means, and no travel or movement of the tool in any direction, would be necessary. But because this cannot yet be done, the entire planing of the surface is gradually performed by cutting off only a portion of the slice at each travel of the table, by using a pointed tool; consequently, the traverse by feed gear or other means, is indispensable. By these considerations it may be perceived that the precise amount of metal to be cut off, the time in which it is done, and other circumstances attending it, require distinct terms. The entire quantity of metal to be cut off any one side or surface of an object, in order to reach the hidden plane, is the krap; and the quantity which is cut off during only one traverse of the tool across the machine, or during one planing of the side, is a slice; therefore, if three-quarters of an inch is to be cut off, three slices, each a quarter thick, will be the entire krap. During one travel of the table in either direction, only a narrow strip or ribbon of metal is cut off, and this is the only portion to be named a cut. If a machine will cut the metal while travelling in both directions, it is a double cut planing-machine. A cut may be termed an element or portion of a slice, and a slice, a part of a krap, the krap constituting the entire quantity of metal to be removed from any one side or surface of the object.

Fig. 654 represents a planing-machine having two slide-rests on one carriage, each slide-rest being provided with its traverse screw, as seen in the Figure. This is an ordinary arrangement of planing-machines for the convenience of making them capable of planing two articles at one time on the table; and of planing two surfaces or portions of the same article at one time, although the two surfaces may be at different heights above the planing-table. Both slide-rests are used at one time through both traverse screws being rotated at one time by the teeth wheels and feed-rod; but if only one slide-rest is to be used, the necessary disconnection is easily effected. While preparing the machine for planing, either of the slide-rests may be quickly moved along to any desired place by the handle, which fits both the screws' square ends. To plane a surface so that it shall be at some stated angle with the table, one of the slide-rests may be fixed at the angle required; the slide-rest on the left of this Figure (654), is shown to be in position for this sort of planing. In order to accurately apply the tool of any planing-machine to the work for taking off a slice, or what is termed a cut, whose thickness shall be exactly that which is intended, the vertical traverse screw, shown in Fig. 653 by V T, must be slowly rotated until the tool-point is at the exact height, the rotation being easily managed with the hand-wheel on the upper end of the screw. Planing-machines which are specially intended for planing with vertical or oblique traverses, are provided with slide-rests having screws of suitable length for their work, and all are capable of being worked by the same feed-rod that actuates the horizontal traverse. A planing-machine having a vertical traverse gear of this sort, has a circular box on the vertical screw, containing some of the gear, instead of a hand-wheel, and the box is made to serve as a wheel by fixing in four handles.

In addition to the general arrangements now described, which belong to planing-machines of every size and class, it is necessary to briefly mention here that some of the large machines are each provided with two carriages, having two slide-rests on each carriage; some are also furnished with a couple of slide-rests to each standard, for planing surfaces at right angles, and at other angles to the table. We now proceed to consider the accessory apparatus which are indispensable to all sorts and sizes of planing-machines, for attaching and adjusting to planing-tables, objects possessing a great variety of forms.

AUXILIARY APPARATUS FOR PLANING-MACHINES.

Screw-bolts.—Bolts and nuts, plates, and chucks, which are employed for planing, are represented in Plate 47. Apparatus of this class are required for all planing-machines, whether they are small shavers like the one in Plate 35, or large machines for work of fifteen or twenty feet in length, represented in Plate 48. Auxiliary implements for planing differ from each other in size only, therefore each machine has bolts of a suitable diameter and length for the table, and for the character of the planing to be done with the machine. Consequently, screw-bolts for planing-machines have diameters varying from a quarter of an inch in diameter to about an inch and a quarter, which is about the thickest in use, except for special work to be afterwards mentioned.

The bolts and nuts required for small planing-machines are shown by Figs. 633, 634, and 637; these are of all lengths from two inches to two feet. Bolts for large work, are indicated by Figs. 634, 635, 636, and 637, the tee-head bolts being much oftener used than others, because some of the slots in a planing-table are tee-shaped, and also because a tee-head bolt is capable of being put through the table-slot from the face-side, whether the slot is tee-shaped, or of any other form. The lengths of bolts for large work are from five or six inches to ten or twelve feet. Every tee-head bolt should be provided with a narrow groove filed across the screw extremity, termed the point, with the length of the cut or groove parallel to the length of the bolt's head;

this will enable the operator to know the position of the head in the table while placing and tightening the bolt.

Hold-fast Plates.—Plates for holding or gripping the pieces of work, are always used in conjunction with bolts and nuts, the bolts being put through the holes or slots in the plates. A middle plate is one denoted by Fig. 638, or by 640, and is used when the bolt or bolts must be between two portions of the article to be gripped. An end plate is shown by Fig. 639, and is required when the part to be gripped is to be between the two screw-bolts, one at each end of the plate. An edge plate is represented by Fig. 641, and is principally used in contact with edges of various pieces of work when bolts cannot be applied near the centre parts. A U-plate is a very useful tool, and is made by bending a piece of bar iron or steel to the form of a letter U ; a plate of this class is shown by Fig. 642, and will admit a bolt at any place along the gap that may be requisite to suit a certain slot in the table. A slot plate denoted by Fig. 643, is rather more efficient than a U-plate, because neither end of a slot plate can spread open while tightening the bolt, which always results to some extent, with a U-plate. A slot plate is, however, more difficult to make, through the necessity for punching or drilling the long slot. A U-plate is remarkably useful in cases of emergency, because it can be made by a skilful man in two heats, if the bar used is not more than one inch thick. Figs. 644 and 645, represent bolts and plates together in their relative positions for use. By observing the ends of the plates in these Figures, it will be seen that they are thinner than the intermediate portions; this should be their shape for two purposes, to make the plate relatively strong at the hole, which is where the plate is liable to break, and to prevent the end of the plate projecting much above the work after being fixed. These thin ends, and all other ends of plates which grip or bear upon the work, are the paws of the plates. A cap plate indicated in Fig. 646, is not for general work, but is remarkably efficient for effecting a firm grip, and is a sort of superior end plate (Fig. 639). Cap plates are used for fastening long pieces of work that are comparatively narrow, such as spindles, rods, bars, shafts, and axles.

El-chucks.—An el-chuck consists of a cast iron or cast steel implement resembling a letter L, and having the two outer surfaces or planes, named faces, specially smoothed and made right angular to each other. A tool of this sort is shown by Fig. 647, and others near it. The name chuck is given to this instrument, because it resembles a lathe chuck in having pieces of work bolted to it. An el-chuck is required when it is necessary to plane a surface of an object to make it right angular to some other surface or plane of the same object, for which purpose the chuck is fastened to a planing-table, so that one of the chuck's faces is in contact with the table's face, the other face of the chuck being necessarily at right angles to the table. The object to be planed is next bolted to the chuck with the desired surface in contact, and the right angular position is thus obtained without trouble. El-chucks are of various sizes, to suit machines and work of several classes. A narrow one, for long slender objects, is shown fixed to the table denoted in Fig. 652. In this Figure at the right-hand end, is seen a plate and bolt in use, the plate's paw holding the chuck while the other end of the plate is supported by a packing-piece shown by P. All the larger el-chucks should be provided with straight and parallel lines marked on that face of the chuck to which the piece will be bolted, or if both faces are of similar dimensions, the lines may be on both. Each face requires two sets or lots of lines; one lot should be at right angles to the face of the machine-table when the chuck is fastened, and the other lot parallel to the table, and therefore parallel to the chuck's face in contact. Such lines are useful for a rapid adjustment of all pieces having right angular boundaries.

The el-chuck shown by Fig. 648, is provided with two gussets, one of which is shown in the Figure; these are cast solid with the two arms of metal which constitute the el-shaped portion. Such gussets are very effectual for obtaining a strong chuck which will not be liable to distortion while fixing, or planing, and is therefore suitable for accurate work; but for general work, gusset chucks are troublesome because they have but little room for the plates and bolts.

Spindle Chucks.—A spindle chuck is a plate or bar having a cylindrical portion at each end, these cylindrical parts being provided with shouldered bearings or pivots by which the chuck may swing or rotate on suitable bearers. The spindle chuck shown by Fig. 651, is a thick plate provided with several slots, such being required to contain fixing bolts. The two broad surfaces of the implement are smoothly planed parallel to each other, and named the faces of the chuck, because to these surfaces the pieces of work are bolted. On the faces should be several parallel lines similar to those described for el-chucks. In the Figure the letters B denotes the pivots or bearings referred to.

A spindle chuck is very useful for planing a surface of an object so that the planed surface shall be at any stated angle to some other stated surface of the same object. To do this, the chuck is supported at a proper height above a planing-table by means of bearers of a suitable height which stand on the table. One of these bearers is put beneath each bearing or spindle-end of the chuck, and if the supporters or bearers are tall enough, the chuck may be swung and completely rotated while in its place. Supporters or pedestals for this purpose, should be as short as the objects to be fastened will allow, to obtain as much resistance as possible to the cutting-tool. After the chuck is placed, the work is bolted thereto, and the chuck is swung and adjusted to the desired angle with the table-face.

To make both the chuck's faces parallel to each other, and also parallel to the planing-table while attached to the pedestals, the two faces should be planed, the spindle-ends next lathe-turned, the feet of the pedestals or standards planed, the bearer-brasses fitted (if any are used) and the entire apparatus next bolted to the planing-table to have a couple of finishing slices taken off the two faces. Only small quantities are to be planed off at this final adjustment, therefore the two broad sides or faces of the chuck should be planed to near the finished dimensions at the first planing, previous to commencing the lathe-turning of the spindle-ends. After this preliminary planing, the spindle-ends can be centered true with the intermediate planed part by a pair of parallel blocks and a scriber-block.

In order to properly grip the spindle-ends, the gap surfaces of the brasses, or other bearers, are made to tightly grip the bearings or necks by tightly screwing the cap bolts with a spanner, after the chuck is finally adjusted to the desired angle with the table. This tight grip is obtained by exactly fitting the bearers to the necks, and next filing off a small quantity from each flat face of the bearers to make a space between the two while the neck is tightly gripped. If a small space is thus provided, any degree of tightness may be obtained by screwing the cap bolts. The mode of adjusting the chuck to be finally planed, or to place a piece of work into the required position, consists in applying a few blows with a tin hammer when the bolts are loose enough.

In addition to these implements now described for all planing-machines and shaping-machines, right-angled blocks, cranked-plates, and other instruments are used, for special work, and will be introduced in another place.

PLANING AND LINING OF BOSSES, &c.

The lining of a small simply formed article, is done either with a calliper and scriber while the article lies on a bench, or is held in a vice, or is done with a scriber-block while both the work and scriber-block are on a surface-table. For the convenience of those who have but few tools, lining processes are here given which may be entirely conducted with straight-edges, callipers, dividers, and such ordinary implements, without requiring a scriber-block or lining-table. It will be here noticed that the reduction of the metal after these lining processes, may be done either by hand-planing, or by machine-planing, according to the size of the work, and whether the operator possesses planing-machines.

The precise amount of planing and lining necessary for any single article, depends on the shape in which it is cast or forged. The forged piece may be a piece of straight bar which is to be made into a taper-key; or several keys may exist solid together in one parallel bar. Lever bosses are often forged without any hole; also crossheads, slide-rods, and links. Crank-shafts also, are so made that when the forging is finished, the pieces are merely straight parallel bars.

Consequently, it will be necessary to apply the planing and lining with regard to the particular mode by which an object is made.

Some pieces of work require two or three linings, if a large quantity is to be planed off; and it is often necessary to first plane one surface of the object, previous to any lining of it being done, for the purpose of obtaining a primary plane from which to exscribe the lines; and when one set of lines are marked, the planing of the object may then proceed to reduce the piece to these first lines; after which, another lining is given, to indicate some other dimensions, or hidden planes which must be produced. Therefore planing and lining are closely related and subservient to each other. It may be also necessary to mention here that all scribed lines on parts of machines of all sorts, should be thin, or narrow and deep, rather than shallow and broad; the narrower the line, the nearer is the object lined to the desired dimensions. Lines for such purposes should be named gauge lines, and require dotting with a dotter after being marked.

In the course of these lining and planing processes, the planing-machines to be used for reducing the metal may be any of those which have been described, small or large, because any small piece of work can be planed by any large machine, and because the references to machine-planing apply to machines of all sizes.

Finding Centres with Calliper-points.—A large number of articles can be lined by means of a primary straight line marked on one surface of each object, and extending along its entire length. The place of this straight line along the length of any article may be found by springy dividers, compasses, and callipers, the more convenient of these being callipers having points resembling Fig. 543. For marking a primary line upon a surface of a small rugged piece of plate, bar, or other object only a few inches across, it is only necessary to roughly place a straight-edge to the middle by merely looking to find the middle, and marking the line with a scriber; but a large piece of work requires a little care, whether rough or smooth. To find the place of a primary with some pretension to accuracy, a calliper may therefore be adjusted, so that the distance between its two points is a little greater than half the width across the surface to be lined; the calliper is then put with one point in contact with one edge of the surface to be lined, and with the other point or foot extending rather more than half way across the surface; in this position the calliper is held with one hand, and a short arc marked through a little whiting on the surface. The next step is to shift the calliper to the opposite edge, and with the feet at the same distance apart, to scribe another short arc which shall intersect the first arc. The middle point between the two arcs is the centre of that particular portion of the surface, and it may be shown by marking a short straight line through the two points where the arcs intersect. To find the centre at any other particular part of the surface, the same means is adopted, with the difference of altering the distance between the calliper-points to suit the width of the surface, if it differs in width. By such centring, the place of a primary line along the middle of a key's taper side is easily indicated. If the surface of the small end of the key is two inches across, the calliper's feet are adjusted to one inch and a sixteenth from each other previous to scribing the arcs at the small end of the key. After these are marked, the calliper's feet are separated a short distance to suit the large end of the key; and if the distance across at this end is two and a half inches, the distance between the feet is one and five-sixteenths inches. With the points at this distance, two more short arcs are now made at the large end of the key, which shows the centre of this end, by the places of intersections of the arcs, as at the small ends; consequently, to indicate the centre line along the entire surface, a straight-edge is put to the four intersections of the arcs, and a line scribed, which is the primary required.

Square Keys.—Taper square keys are seldom forged near enough to the intended finished dimensions to dispense with planing, especially if they are intended for piston-rods, crossheads, middle-shafts, or paddle-shafts; so that lining is required for keys in general. If a taper key is forged solid with a handle at each end to hold the key while on a planing-table, the planing will be easy, because the four sides of the key can be entirely planed without applying any plate or poppet to any part. The planing of such is commenced by first planing those two surfaces of the key which are to be parallel to each other. These are smoothly planed until the object is reduced to that particular finished thickness required, after which it is unfastened from the table, and one of the planed sides is lined to show the taper shape of the key, and also its width at the intended large and small ends. This lining is begun by first marking a primary along the middle, and next scribing two circles, one at each end of the key, so that the primary line shall equally divide both circles. The diameter of the circle at the large end equals the finished distance across at that end, and the diameter of the circle at the small end equals the finished distance across at the same end; and when both are marked, a couple of straight lines are marked to connect the circumferences of the circles. By these two lines the shape and dimensions of the taper side is shown, and the key is now ready for planing to the lines, which is done either by packing up the small end while on the planing-table, or by tightly gripping the two already planed sides of the key between a face of an el-chuck and two poppet-screws, such as are seen in Fig. 652.

When a number of large taper keys are required, and all are to be alike, or very nearly alike, they can be made in a ready manner without any forging. By this mode, a long bar of steel about five or six times the length of one key, and rather more than twice the width, is first planed on both its broad sides to the finished thickness of any one key. The piece is next taken to a sawing-machine and cut to lengths, each being long enough for one key; and at this time each is also wide enough for two keys; consequently, each length is scribed on one of its planed sides to indicate two keys, which makes the piece resemble Fig. 655. Being thus marked, the piece is made into two by a planing-machine, parting-tool, or with a saw, if convenient. Whatever means are used to divide them, each one afterwards requires a final planing of the slant sides to the finished dimensions.

When gibs are made of a straight bar without forging, the processes are similar to those for keys, the dotted lines which denote the shape of the gib being shown in Fig. 656.

The screw-key shown by Fig. 657 should be planed, previous to lathe-turning and screwing the small end. By this mode the key can be properly lined and centred to place the screw-part into its proper position. If the key is a middle one, for tightening two gibs, one at each side, the major axis of the screw-part should be in line with the major axis of the taper part, or key proper. But if the key is for only one gib, the screw-portion should be parallel to one of the slant sides or surfaces. By these considerations it will be perceived that knowledge is required while lining, in order to properly place the screw-end, and thus avoid bending or breaking it during tightening the nut.

Bosses and Arms of Levers.—A lever, or other article having a boss, needs more consideration previous to lining and planing, than such a simply formed object as a straight rod or bar; and the more irregular, or the greater the number of dimensions of any object, the greater is the amount of consideration requisite.

Solid bosses, without any hole, are, for some sorts of work, forged singly, each having a short arm, or two arms, extending from the boss, for welding to the remaining portion of the work after the boss has been bored, turned, and planed. A boss of this class, having one arm, is denoted by Fig. 663. The lining of such a piece commences with making a primary dotted line along the arm, as seen in the Figure; and before this line can be properly placed, the operator must refer to the sketch of the finished dimensions, or ascertain by some means the required length of the boss, and the required thickness of the arm. When these are known, the rough piece of work is measured, to discover which portion is nearest to the desired finished size, the arm or the boss. If the arm is found to be only a sixteenth thicker, and the boss a quarter of an inch longer, the primary line is marked along the middle of the arm, without caring whether the line will pass through the middle of the boss. But if the boss is nearest to the finished size, the mid-length of the boss is the place for the line, without regarding the situation of it along the arm. From the primary line, however placed, the length of the boss should be measured in both directions, because it may be necessary to make the boss extend further from one side of the arm than from the opposite side. Marking the length of the boss by this means prepares it for boring and turning, and also shows whether the arm requires reducing more at one side than at another.

If a boss and arm of this sort were properly forged, the arm is that which is smoothest and nearest to the finished dimensions ; in this case, the arm is laid flat upon a right-angled block or blocks on a planing-table, or on a lathe-chuck, and the boss made parallel to the arm, without any previous planing being required. In addition to placing a line as in Fig. 663, a line is also made along the middle of that side of the arm and boss-face shown in Fig. 664. This line will show whether the boss is in line with the arm by scribing a circle on the boss-face with the straight line as a centre. If the boss is thus found to be out of its proper place, the metal will be lathe-turned from the proper side, because the boss will be adjusted for boring by means of the scribed circle, and not by the rough outline of the boss.

Fig. 665 denotes a boss having two arms, and such a piece is lined and adjusted with the same considerations as if it had but one arm, but with the additional necessity of making the dotted primary line along both arms; and if planing is intended, the parallel blocks are put beneath both arms. Fig. 666 represents a boss having two arms, which are either forged to the proper dimensions, or have been planed thereto; consequently, the piece is lined along the middle of both arms and the boss-face, to allow a circle to be scribed, to which the work is adjusted while fixing for boring and turning.

When a complete lever is forged, with all its bosses, as denoted by Fig. 667, and both arms are properly forged, it is fit to be placed upon parallel blocks which are in contact with the lever-arms, that the bosses may be bored, reduced to length, and the outsides of the bosses shaped, by means of two primary lines, one to get the centres of all the bosses' faces, as shown in Fig. 667, and the other primary line to adjust the arms, and to mark the lengths of all the bosses, which line is the dotted one seen in Fig. 668.

The connecting bar shown by Fig. 669 has a dotted line along the middle of one side or edge of the arm, to allow the length of each boss to be marked ; and a similar bar is shown by Fig. 670 to be lined along the middle of its broad side, to find centres for the bosses, that they may be so bored and turned as to be in line with the arm or intermediate part when finished. The marking of both these lines is in accordance with the remarks given concerning other bosses.

All the scribing processes just given may be easiest performed by means of right-angled blocks, which are to be placed beneath all the arms referred to, in the situation represented in Fig. 671, standing on the face of a table. Whether the object is a single-arm boss like Fig. 663 or 664, or a two-arm boss like Fig. 665, or a lever with three bosses similar to Fig. 667 or 668, the scribing is done with a scriber-block being moved entirely around the object while it rests on the blocks. By this marking, a sort of periphery is scribed upon two opposite sides or edges of the arm and the boss at one scribing. Either one block or two are required, according to the length of the arm and size of the blocks; and any boss-arm, lever, or bar may be placed on the blocks for lining, in any of the positions shown, whether as in Fig. 663 or 671 ; or in the position termed edgeways, as in Fig. 667 and 670. In order to adjust the scriber-point to the height for each line, the point is put as near to the middle of the surface as can be judged, and a short line marked ; the object is next put upside-down upon the same block or blocks, and another short line made without altering the height of the scriber. The point midway between these two marks is the desired centre, and to this the scriber-point is carefully adjusted, and the primary line scribed entirely around the work, bosses included, by moving the block around as directed.

AUXILIARY LINING.

Auxiliary lining is that which is performed upon all sorts of forgings and castings whose boundaries are quite different to those of the objects when finished. The difference is often sufficient to prevent any person knowing what the piece is intended for until distinctly informed ; and the lining of such pieces is mentioned because it is effected in conjunction with planing.

Preparatory or auxiliary lining need not be very accurate, because its use is to roughly indicate the shapes of the required articles, in order to produce them by sawing, drilling, planing, or some other sort of shaping, that they may appear somewhat like the intended forms. After the first lining, another is given to indicate the precise dimensions. Of such preliminary lining a few examples are now given.

A flat cake of steel intended for a link, appears lined for drilling and shaping, in Fig. 676, and such lining is done, in this case, after the piece is planed on both broad sides to nearly the finished thickness; so that this lining is sufficient for the entire slotting and outer shaping to the precise shape and dimensions, excepting the thickness of the link, which is obtained by a final smooth planing, or filing, if such is the usual treatment.

A spindle having a rough solid portion extending from the mid part intended for a crank, like Fig. 677, is lined and dotted, as in the Figure, when it becomes ready for planing, to form the gap, if the intended gap is not too deep for the planing-machine; or for being drilled, sawn, or slotted, if the crank is large. When this crank is thus roughly shaped, the crank-axle is lined, centred, the axle and crank-pin turned, and the gap-sides shaped, previous to finally planing the edges or narrow sides of the crank-arms. A crank-axle thus made, is also lined at the axle-ends of the arms, as seen in Fig. 678. Slotting or gap-making processes, similar to these now mentioned, are also adopted for a crank which is to have a taper gap, as shown in Fig. 679.

A single-crank axle is also made of a flat planed parallel bar, resembling Fig. 680. The dotted lines in this Figure indicate the marking for a two-crank axle; such a piece, therefore, requires the mid part of the axle to be twisted, after the superfluous pieces are drilled off, or gradually planed off. When a parallel bar of this shape (Fig. 680) is to be made into a single-crank axle, about half the marking is sufficient, and no twisting is needed. Whether the bar is to be made into an axle with two cranks, or into one having only one crank, another series of lining processes is always requisite after shaping to the preliminary lines.

Crank-levers also, are sometimes roughly planed and lined, previous to making the holes with a boring-machine, in order to prepare them for an accurate turning and boring with a lathe; a couple of lines for this purpose are shown in Figs. 681 and 682.

When the shaping of a tee-end and solid fork-end rod is to be commenced, the first step should be to place it upon the vee-blocks on a table, as seen in Fig. 683; and in this situation the particular shape of the forging is ascertained, and also whether it needs planing, previous to turning; but lathe-turning should in every case be the first process for such rods, unless the object is forged much too large in the tee-end and fork-end.

MODES OF FIXING FOR PLANING.

Having mentioned several modes of planing and lining, also the machines and implements required for planing, it is now presumed that a planing-machine and its instruments are available for having objects attached. Methods of properly placing objects, are here given; and it will be afterwards necessary to introduce such cutting-tools as are useful for planing, in addition to the slide-rest tools shown in Plates 33 and 34, and described in page 130.

A number of general appliances for attaching the various articles, are indicated in Plates 51 and 52; in which the front edge of the table, whether of a shaping-machine, or of a planing-machine, is the edge situated in the front of each Figure; consequently the relative situations of the objects on the tables are perceived by inspection. Those who have not noticed which is the front edge of a planing-table, may see it named in Fig. 653, and at this edge the workman stands during the attaching and adjusting processes to be given.

Right-angled blocks are quickly and accurately made in large numbers by the aid of machine-planing, and the making commences by first carefully planing a long steel bar on its four sides, to make it parallel and right angular, after which it is cut into short pieces, each being long enough for one block. Two, three, six, or any required number of such pieces, are next put together and fixed on a planing-table, to adjust the roughly-cut ends to make all the blocks of a proper length, and right angular to the four previously planed surfaces. A few blocks of this sort may be fastened against an el-chuck, by means of a thick plate and three or four poppets, as shown in Fig. 685. While in this situation, the upper ends of the blocks are planed, and they are next put upside-down and again fixed for planing the other ends. Right-angled blocks are very useful if provided with screwed holes; such holes are drilled and tapped after each block is carefully forged, cast, or otherways made right angular; but previous to being finally smoothed to the shape. When the holes are finished, the blocks can be fixed to a planing-table with screw-bolts, as shown in Fig. 684, and adjusted to very accurate shape and dimensions by taking off very thin slices after each fixing. During such planing, an outside calliper and an el-square are required, and if carefully used, but little filing and scraping afterwards, to finish the blocks, will be necessary.

Some blocks for packing and lining have only two sides of each block planed and made parallel; these are called parallel blocks. Right angled blocks and parallel blocks should never be cubes, except for special purposes; every one should have three dimensions differing considerably from each other, to make them suit a variety of work. Consequently, a bar two feet in length, to be cut into blocks, may be three or four inches wide, and about an inch thick. By cutting such a bar into lengths of three-quarters, one inch, one and a half, two inches, and two and a half, a great variety of sizes are obtained of one bar.

Fig. 686 indicates an appliance for planing edges and sides of long slender bars, rods, plates, straight-edges, twist-finders, and similar objects. By this plan, two el-chucks are used, which are bolted to the table, and also drawn towards each other with the work between, by means of three or four screw-bolts and nuts, the bolts for gripping the work extending through the slots or holes in the el-chucks. The thin pieces to be planed are above these bolts, and are raised to a proper height to clear the bolts, by resting on parallel packing blocks of a suitable height, and placed between the two chucks. The thin pieces are thus held until the upper edges are planed, when all are put upside down, and again fixed to plane the other edges. Straight-edges and other thin bars, may also be planed between an el-chuck and a thick plate tightened with poppets, as denoted in Fig. 685.

To plane a right angled block singly, if it is without any screwed holes, it is put against an el-chuck of proper height, and held with a plate, or two plates, and bolts, as in Fig. 687, the piece to be planed resting on a packing block beneath, and in contact with the table's face.

A tubular elbow which requires its two flanges to be at right angles to each other, is also conveniently planed while fastened to an el-chuck, as indicated in Fig. 688; and when it is requisite to plane the flanges at some other angle than a ninety, the el-chuck is easily wedged up at one edge, to place the flanges into the required position.

The first fixing of a tee-end excentric bar is shown in Fig. 689, which represents the length of the bar to be across the table, that the curved corner near the tee-part may be easily finished. All this upper surface is smoothly finished by means of a primary line along the middle of the bar's edge, similar to other such lines before mentioned, and the bar is also adjusted by this line, with blocks or wedges under the tee-part. In addition to the holdfast plates shown, another is required at the other end of the tee-part, and a plate is also required opposite the one in the fork-gap; and when all the upper surface of the intermediate portion is shaped, the plates are removed from the tee-part and put upon the mid portion, that the upper side of the tee-head may be planed. This completes all the planing that can be done with one fixing; the bar is next put upside down, and upon parallel blocks, to plane the opposite side; after which, the bar is lined on its planed side, and fixed edgeways on blocks, or fixed with its planed sides against an el-chuck, to plane the bar's edges.

When the machine is large enough, four such bars may be fastened to the table in the position shown, and all the four may then be planed at one fixing. When such planing is to be done, the holdfast plates require fixing at the outer extremities, at right angles to the positions shown in the Figure; if the plates are at the outer ends, the bars can be very near each other on the table; but the plates are placed as in the Figure if the table is not wide enough for the preferable arrangement.

An appliance for holding two or four semi-bands is denoted in Fig. 690. By thus fixing such articles so that all the semi-circular surfaces are at the same height above the planing-table, all the flat portions termed lugs, will be planed level with each other, and all the gaps of the bands will be of the same depth. In addition to the two plates shown, another is required across the gaps, but this plate is not placed till all the bands are adjusted to the proper positions.

To plane the broad sides of one, two, three, or four links, it is often convenient to place them upon parallel blocks as in Fig. 691. Each link is provided with two bolt-holes, and recessed a short distance into each end of each hole, to allow room for the nuts of the holding bolts. A link forged with plenty of superfluous metal, similar to that in Fig. 676, or having special holders at each end solid with the link, requires no holes for holdfast bolts, but is held by its holders until they are no longer required.

The planing of flanges parallel to each other, or, if necessary, inclined at some desired angle with each other, is effected by very simple fixing, as seen in Fig. 692. If the two flanges are not to be parallel to each other, a gauge line is scribed upon each flange so that the two lines shall subtend the required angle, and blocks or wedges are placed beneath the bottom flange and the planing-table, until the top flange is lifted at one edge sufficient to put the gauge line or lines parallel with the table's face.

Fixing for planing a key-bed at one end of a shaft is illustrated by Fig. 693. The shaft is placed upon a pair of vee-blocks and held with plates so that the plate nearest the intended key-bed shall not be too near the cutting tool. At the dot shown by H, a hole has been drilled as deep as the intended groove to be made, to prevent the tool's end knocking against the extremity or termination of the groove. The shaft is adjusted to its position by means of lines scribed, which show the shape and dimensions of the intended key-bed.

When it is necessary to plane a groove along nearly the entire length of a long slender bar or rod, an easy fixing is effected by placing the rod into a vee-groove which is planed into some thick planing-table. A spindle thus placed is shown in Fig. 694, and is held with six or eight thin small plates and bolts on the spindle or rod, allowing only just room enough for the passage of the grooving tools.

By referring to Figs. 687, 688, 689, and others in Plates 51 and 52, it will be seen that each plate is supported at one end with a packing-block; this is of hard wood, and is to hold the plate at right angles to the bolt's length while tightening. Such packing may always be a trifle thinner or lower than the part to be held with the plate, but never thicker, to avoid risk of raising the plate's paw from the work while tightening the nut.

The uses of handles which are forged solid with links, rods, excentric-bars, right-angled blocks, and other work, are illustrated in Fig. 696; where three keys are seen held by their handles, and resting on two parallel blocks. Such holders allow all the four sides of each key to be entirely planed without gripping any part of any planed surface; and the convenience of such handles must be placed against the necessity for cutting the handles off and shaping the ends at the conclusion of planing.

Adjusting a key without holders is denoted in Fig. 698, which represents one key of a special size which has had its broad sides planed while between small poppets at each edge, and is now lined to show the taper shape, that the key may be adjusted with a scriber-block. By means of the block, the scribed line is put parallel with the table by giving the key a few knocks with a tin hammer, at the time the scriber-point is held near the line. Another mode of adjusting a gauge-line to a scriber-point consists in wedging or packing up the intended small end of the key, or other object, as in Fig. 699, where the packing-pieces are shown by P.

Adjusting by wedges is also represented in Fig. 697, in which the scriber-block, S B, has a long scriber with a bent end to reach any part of the upper surface of the work, this surface is that which is being placed parallel to the table's face, therefore the wedges are pushed in to adjust the upper surface, without considering whether or not the bottom of the work is parallel to the planing-table.

Adjustment of objects is also facilitated by right-angular lines on the face of the table. Every table should possess such lines, and, when marked, the face appears as in Fig. 701. The mode of marking is shown by Fig. 700. In this Figure all the lines that are parallel to the length of the table are marked by the motion of the table while in ordinary action. One of these long lines near the middle of the face is next selected as a primary, from which to mark the places for the short lines across the face at right angles to the long ones. For this purpose dots are made along the line at the desired distance apart, as shown in the Figure; arcs are next scribed, as in an ordinary bisecting process, so that points of intersection may be obtained from which to scribe the short lines by means of a straight-edge. As soon as a few right-angular ones near the middle of the table's face are thus made, the places for the others at the ends of the table are found with a compasses or springy divider. When it happens that the operator has a large and accurate el-square, all the short straight lines may be marked with a scriber in contact with the square's blade, while its pedestal is in contact with the table's front edge, being careful to first plane the front edge, if not already in such a condition.

SLIDE-REST TOOLS AND GAUGES FOR PLANING-MACHINES.

The slide-rest tools shown by Figs. 427, 428, 429, 430, 431, 432, 433, 434, 437, 438, 439, 449, 450, 451, 452, 453, and 457, are used in all slide-rests, whether belonging to lathes or any other machines; but the implements to be here mentioned are specially suitable for all shaping-machines and planing-machines, small and large; the implements being both small and large, to suit all sorts of work.

Cutting tools for planing-machines are represented in Plate 53. In this Plate, Figs. 702 and 703 represent facers, or slicing tools. These are the most useful and numerous among all other classes of planing tools, being required for nearly every object which is to be machine-planed; and a great number of articles are entirely planed with facers only. Fig. 702 is a thin facer, and is suitable for either cast iron, forged iron, or steel, with a slight difference if the tool is specially required for steel, for which metal the cutting end is rather thicker; therefore a facer is suitable for steel after having been worn, and thereby shortened at the cutting part. Fig. 703 is a thick slicer or facer, and is pre-eminently adapted for removing thick slices from hard iron and steel, because the hump situated behind the cutting part renders the tool very strong, less liable to quiver while cutting, and also absorbs the heat generated by the friction of a thick or long cut. Facers are also termed roughing tools, but they are, in most cases, used to remove slices for both roughing and smoothing objects to their finished dimensions; and for the sake of distinction such tools are named facers. They are used in every machinist's factory for all planing of surfaces, whether of iron or steel, if the surfaces being produced are parallel to the face of the planing-table. A facer for planing brass and gun-metal, is merely a tool having a straight, tapered, and pointed cutting end resembling Fig. 427. Facers, and also every other class of slide-rest tools, possess what are termed stalks, or stocks; the stalk of any tool being the long straight portion which is gripped in the tool-holder of the machine.

The cranked tool shown by Fig. 704 also is a facer, and is provided with a cranked end to make the cutting part reach forward, to cause it to plane a long or broad object which is too large to pass between the two standards of the machine. Another mode of planing large surfaces of this class, consists in attaching a tool-holder of great depth to the slide-rest; such a tool-holder or tool-box is of sufficient depth or thickness to place the tool forward the required distance from the standards, the tool used being any ordinary facing tool, such as Fig. 702 or 703.

Fig 705 denotes a gapper or gapping-tool, which is cranked sideways instead of forward, being bent in the direction of length of the carriage. Such tools are provided either with straight cutting parts for planing brass and gun-metal, or with bent ends similar to that shown in

Fig. 702 for iron or steel. Such a tool may be cranked either way, either towards the front edge of the table, or towards its back edge, the tool being made to suit its special work. These tools are required for planing portions of objects which are too large to be planed with the machine without such a tool, such portions extending beyond the table's edge or edges. They are also required for planing the rectangular grooves of guides, and for dove-tail grooves; also for guide-blocks, whether dove-tailed or rectangular. Fig. 706 represents a bent tool of this class which is specially adapted for planing the under sides of dove-tailed grooves, and also right-angular ones; these under sides or surfaces being inaccessible to any other sort of tools.

Fig. 707 indicates a stocker or stock-tool. Such a tool consists of two principal pieces—the stock and the cutter, the stock being that which resembles the analagous part of any other slide-rest tool, with the addition of a tubular boss at one end to contain the cutter. Such a tool is a sort of facer, and is advantageous for an easy mending of the cutter; through this being merely a straight piece of steel, it is repaired after being worn or broken, by merely grinding it with a grindstone; and the cutter is unfastened and refastened when necessary, by means of steel fixing screws in the boss. Stockers are used by only a few machinists, and are principally suited to small work. The chief characteristics of a good stocker are these:—The stock and its boss are solid together, and are of steel, the boss being of great length that a long bearing may be provided, and at least two fixing screws inserted, as shown in the Figure. The cutter should in all cases be of triangular section, so that by grinding, a cutting point may be formed which resembles the points of the universally used facers, shown by Figs 702 and 703. To grip the three-cornered cutter, either a steel gripper is necessary, having an angular groove which fits one corner of the cutter, or the fixing screws must be so placed in the boss that their lengths are at right-angles to the upper flat surface of the cutter while in position for work, in which case, no separate gripper in the boss-hole is required; but in either case, the boss-hole should be amply large enough where the screw-points intrude, the hole being made so that only its two bottom sides shall be in immediate contact with the cutter. When a stock-tool is to be used for smoothing, it is only necessary to slightly curve the cutter's point while sharpening it; but neither stock-tools, nor facers of any other class, need be employed for polishing, because a springy tool is preferable. The stock-tools shown by Figs. 709 and 710, are those having their bosses extending from the sides, instead of being in line with their stocks; these are for reaching into corners, and the stock may be bent, to produce a long arm, similar to that in Fig. 705, if such an arm is required.

A right-hand corner tool is denoted by Fig. 708, which shows the form of tools everywhere used for brass and gun-metal, and occasionally for iron.

Springy tools are indicated by Figs. 711 and 712. The steel used for these tools is a thin bar-steel, which is only as thick as the spring or cutting end; by this means, the reducing of a thick bar is avoided. Fig. 712 shows a thin springy tool in front of a packing-piece or pieces; the packing being required to occupy the space usually occupied by the stock of another tool. In some cases it is convenient to put the tool behind the packing instead of in front. Springy tools of this class are used for polishing; and for a few other varieties of work which will be mentioned.

Slotted stock-tools are represented by Figs. 713, 715, and 716. These are very useful for grooving, planing gaps which are narrow but deep, and for shaping bottoms of grooves to any precise shape required. In the Fig. 713, a stock without its cutter, is shown, and the cutter-slot is long enough for both a key and cutter. The bottom side of the slot is a quarter or five-sixteenths from the bottom of the stock, consequently, the metal is about a quarter thick, although the mouth or front of the slot is enlarged for a short distance, to provide a firm bearing for the broad sides of the cutters. A stock of this sort will admit a large number of cutters of various shapes, and which may extend various distances beyond the stock's side, to suit many sorts of work. The cutting edges of the cutters may be curved, if necessary, either inwards or outwards, or may be straight, as in Figs. 714 and 716; or a straight tooth having a vee-point, may be keyed in, to plane a surface which is at right-angles to the planing-table. Fig. 714

denotes the cutter for Fig. 713, and the cutter keyed in, is shown by Fig. 715. Another sort of cutter, to cut on both sides of the stock, is denoted by Fig. 717, and in Fig. 716 the cutter is seen in its place.

The gappers indicated by Figs. 718 and 719 may be termed right-handed stock-tools; in these the cutters are similar in shape to other corner tools, but are held in the bosses of the stocks instead of being gripped in the tool-holder. A gapper may be either right-handed or left-handed, according to the particular position in which it is fastened in the tool-box; it may also be fixed to perform the work of an ordinary facer, having a small cutter of suitable shape for the purpose fixed in the boss.

Gauges for Measuring.—When an object is to be machine-planed with regard to some special dimension, or planed to fit, or very nearly fit, another object with which it is to be in contact, care is necessary to so finish the machine-planing, that when the article is unfastened from the table it shall possess the dimensions intended, because, in many cases, if the piece is too large after being planed, it cannot be again so accurately fixed precisely as it was before on the table to cut off another very small quantity. In order to fit one piece to another by planing, it is also requisite to have means for properly measuring the pieces, to prevent the one which is being planed being made too small. It is therefore needful to mention the implements and processes by which accurate measurements are conducted.

For measuring small objects of only a few inches in length, width, or thickness, outside callipers and inside ones are employed. For example, to plane a block, or a number of blocks, to special dimensions by means of outside callipers, three tightly-riveted callipers are adjusted to the desired distances between their respective points, one calliper being adjusted to the block's length, and the other two being adjusted to the desired width and thickness. The three tools are thus made the means of ascertaining the three dimensions of the block, and the planing is conducted with repeated reference to the callipers until the surfaces of the block or blocks are planed. Callipers thus used are liable to get their legs shifted during use, and previous to finishing the planing it is necessary to apply them to the standard, and again adjust them, if found to be altered.

To avoid the liability to be misled by unexpected alteration of callipers, gap-gauges are much used, especially by makers who supply numbers of machines of the same size and shape. Such gauges are of sheet iron, unless intended to be extensively used for a great number of articles, for which purposes they are of steel. A gap-gauge for three dimensions is denoted by Fig. 722; consequently, if such a guage were used for a surface-block, the largest gap would be the length of the block, and the two other gaps for its width and thickness. These gauges, by long usage, and also by improper usage, such as roughly thrusting them upon pieces of work, become worn, and therefore their gaps become too large; in such a condition, the remedy is to heat and hammer the gap-sides to diminish the gaps, and again smoothly file the sides to the proper dimensions.

Both an inside calliper and an outside one are required for measuring, either when a gap is being made by planing to fit a portion which is to be contained in the gap, or when an object or portion of it is being planed to fit an opening already made. To plane an object so that it shall fit the width of a gap, an inside-calliper's legs or points are separated until their distance apart is about a sixteenth greater than the gap's width, and are next adjusted with gentle hammering to the exact width of the gap. While in this condition, an outside calliper's points are adjusted by similar gentle hammering until they just very lightly touch the points of the inside calliper when both callipers are put together. During such placing of the two callipers together, they should lie with all their four points in contact with a tolerably flat plate or surface of some kind, to prevent the operator being misled by distortion or bending of the legs, which often occurs with large callipers. When an outside calliper is thus properly adjusted to an inside one, the outside one becomes a gauge to which the work is planed, and if the measurements were properly conducted, the object, after planing, will exactly fit the gap's width.

The object may also be planed to accurately fit the gap's width, by means of sheet gauges, and, if such are used, also without the risk of shifting, which was stated to be involved in the use of callipers. One of the sheet gauges for this purpose is an ordinary gap-gauge, such as that shown in Fig. 721; and the other sheet gauge is a straight flat piece of iron whose length exactly fits the gap's length or distance between the two arms of the gauge. This simply-formed straight piece is termed the male-gauge, and is smoothly filed to exactly fit the width of the gap to which the piece is being planed; after which the gap-gauge is carefully filed to fit the male-gauge, which renders the gap-gauge fit for use to adjust the object while planing, or that portion of it being planed.

A substitute for a sheet-iron male-gauge is a straight piece of wire slightly tapered, or merely curved at each end, although it is not requisite to make sharp points, pointed ones being specially adapted for lathe work. A straight wire gauge is denoted by Fig. 720; and for the convenience of easily lengthening a wire gauge after being worn, or after being filed too short, it may be made with a cranked mid-part, similar to that of the male-gauge shown in Fig. 721. If the wire is thus bent, the gauge is quickly lengthened by bending it slightly to open the gap of the cranked part; and to shorten the distance between its two ends it is bent the opposite way, which closes the gap.

The male-gauge of any couple is analogous to an inside calliper, whether it is a straight wire gauge, a cranked one, or one made of sheet iron; and the gap-gauge of the same couple is analogous to an outside calliper; therefore the same sort of measurement may be effected with sheet gauges as with callipers, with an advantage in favour of sheet gauges, because they are exempt from liability to mislead through shifting. Those who use great numbers of sheet gauges should keep them properly named and arranged in boxes, in convenient situations for reference when not in use.

Height Gauges.—A distance-gauge or height-gauge, is a piece of metal which serves as a kind of standard for adjusting the point of a planing-tool to a precise height above the planing-table, or to a precise height above a particular surface of an object being planed. The simplest and easiest to make of such gauges is merely a rectangular piece of sheet iron or steel, whose edges are smoothly filed to the desired dimensions. Such a gauge is used by standing it edgeways on the planing-table beneath the tool-point, and while the gauge is thus held square to the table with one hand of the operator, he uses the other hand to gently rotate the vertical traverse screw to advance the tool downwards until its point just lightly touches the upper surface of the gauge, at which time the tool-point is adjusted to the height required. Supposing it to be now necessary to plane an object so that its planed surface shall be at the same distance from the table as the height of the gauge, the horizontal traverse of the tool is put into operation after the tool-point is adjusted, and the planing effected. This planing will reduce the object so that its surface is at exactly the same height from the table as the height of the gauge. A distance-gauge is therefore a means of planing an object or a number of objects to a precise dimension without any necessity of measuring the objects with a calliper, or with any other gauge, until the objects are released from the machine. For a large quantity of work, no other gauge than a height-gauge can be used for measuring, while the objects are fixed to the table, because the undermost surfaces of the object or objects are frequently in close contact with the table-face, and therefore inaccessible to a measuring tool till released.

A superior class of height-gauges are represented by Figs. 724 and 725. These are preferable to sheet gauges, because they will stand on the table without being held. The one shown by Fig. 724 is a piece of round steel smoothly surfaced at both ends to the exact length required, the ends being also parallel to each other and at right angles to the length of the implement, to cause it to stand properly while in use. Fig. 725 denotes an ordinary right-angled block of three dimensions differing considerably from each other. Such a block serves as a distance-gauge, and is more useful for this purpose than a cylindrical gauge like Fig. 724, because the right-angular one represents three different dimensions. Either sort of these gauges are used by gently advancing the tool-point downwards, until it touches the gauge's plane surface, in the same manner as that mentioned for a sheet gauge.

Coupled Gauges.—Coupled gauges are those made in couples, each couple being fitted accurately together, so that when the two are put into contact the surfaces which adjoin each other shall exactly coincide and touch, the portions which touch having the same shape and dimensions. A couple of this class are shown in contact with each other by Fig. 723, and another couple are shown by Fig. 728. Such gauges are required for planing gaps or grooves in guides, slides, and similar objects; and both the gauges of any couple may be prepared previous to commencing to plane either the groove or the ridge which is to fit therein. Coupled gauges resemble all other sheet gauges in having their names painted on the broad sides, and in being kept for reference as standards, and also as references when an object is to be repaired after being worn, or when a new one is to be made to serve for the old one. Fig. 727 represents the male-guage belonging to the gap-guage, shown in Fig. 728, and in this Figure both are seen coupled together.

Coupled gauges are also denoted by Figs. 729 and 730, in which the angular gaps or mouths of the guages have bottoms with curved corners. Gaps of such shapes are required for planing the junctions and corners of a great variety of objects, such as the junctions of tee-heads with their rods or bars, bottoms of guide-gaps which are curved, outer corners of slides, entrances or mouths of plummer-blocks' gaps, corners of guide-blocks, crank-arms, guide-bars, lids, and base-plates.

Fig. 732 denotes a couple of gauges that are used in a manner similar to that of the gauges shown in Fig. 728, with the difference of the gap not being in the middle of one edge; by this means the ridge and groove to be formed by planing will fit each other, and also be in their proper places after being shaped.

DETAILS OF PROCESSES FOR MACHINE-PLANING.

In order to thoroughly exhaust this portion of our subject, several examples of detailed processes must now be given, in which the principles, implements, and machines mentioned will be applied to the planing of engine-work of various classes.

By reference to the hand-planing at page 207, it will be observed that bevelling of edges is practised previous to chipping an object; and a similar bevelling is sometimes effected for machine-planing. The particular cirumstances and conditions which render such treatment necessary are these: When a side of an object is to be roughly reduced to the required dimensions by removing one thick slice; in which case the bevelled edge is that at which the tool-point is liberated from the metal, and is at right-angles to the direction of the table's motion. Bevelling is also performed to remove hard edges and corners, such as the outer corners of cast-iron articles which become hard while cooling, and the sandy edges and corners of cast-iron and steel articles in general; in these cases, all the four edges of the side to be planed are bevelled. It is also necessary to bevel an object when it is especially necessary to prevent its hard flinty skin breaking or damaging a tool's edge at the moment it enters into contact with the object; bevelling for this purpose is performed upon one edge only, and this edge is that at which the tool enters the metal every time they meet each other.

Bevelling for machine-planing is effected either with rough filing, chiselling, or with a grindstone. Small hard iron and steel articles of only a few pounds each in weight are held in tongs and bevelled with a grindstone previous to fastening them to a planing-table. A large piece of work, which may have hard edges, is chipped after it is bolted to the table. When it is necessary to form very clean edges, previous to cutting off a very thin slice of any object, the bevelling is easily done with a file, which is applied to all the edges of the surface being planed.

It should also be mentioned here, that machine-planing of pieces having hard gritty surfaces is greatly facilitated by entirely removing the hard skin previous to planing, in addition to merely cleaning or bevelling the edges. Such preliminary cleansing of surfaces may be done either with old rough files, with a grindstone, with sulphuric acid and water, or with nitric acid and water; and if an article is allowed to lie in such a compound, it is said to be pickled. The particular mode by which a surface is cleansed depends on its size and shape. We now proceed to separately consider a number of details of processes as they are applied to the planing of ordinary portions of machinery.

PLANING OF NUTS.—The apparata required for planing screw-nuts, after they are screwed and turned, are shown by Figs. 733, 734, and 735. Fig. 733 denotes a nut-mandril or nut-spindle; this consists of a steel spindle which is smoothly lathe-turned parallel in its mid-portion, to fit the screwed holes of nuts of one size. The spindle has a collar at one end solid with the remainder, and a screw at the other end which fits a screw-nut. That shoulder of the collar which joins the middle parallel part is also smoothly turned, to make it right-angular to the length of the spindle, and the collar may be either cylindrical or hexagonal, as seen in the Figure, the six-sided shape being principally useful for large spindles, that they may be easily rotated with a spanner. When a nut-spindle is to be used, several nuts are slid thereon, and all are firmly fixed together, and against the collar's shoulder, by tightly screwing the nut belonging to the spindle. When it happens that the spindle-nut will not grip the nuts to be planed, through the end of the spindle-screw being too near the hole of the outer nut, the fixing-nut is made to bear against one or two packing-rings of iron, and if thus fastened they appear as in the Figure (734). These rings are termed washers, and six or eight are sometimes used on a nut-spindle, when it happens that only one or two nuts are to be planed at that particular time. There is also another sort of packing used for nut-spindles, and it consists of tubular pieces of thin sheet brass, or tinned iron. Such packing-pieces are made to fit each other, so that any tubular piece will tightly slide into the one which is of the next size larger, that two or three may be at one time on a spindle, the smallest one being in immediate contact with it. The length of such tubes is about equal to the length of that portion of the spindle for which they are made; and the packing is required to adapt the parallel part of a spindle which is too small for the nuts to be planed without such packing. Consequently, one nut-spindle may be thus made to fit several sizes of nuts, instead of one size only.

After the nuts are slid along the spindle, the washers and spindle-nut attached, also a circular divider-plate keyed upon one end, the spindle is put between poppet-screws, and appears as in Fig. 735. For small spindles, such as those for planing nuts belonging to bolts not more than an inch thick, the poppets are fastened to a planing-table with nuts beneath, this arrangement is denoted in the Figure (735). For large nuts, the spindles are supported with a couple of strong standards or supporters, having broad bases or feet, and these are bolted to the machine-table with screw-bolts and nuts, the bolts being put through the feet of the standards and also through the table near its front edge. Holdfast plates also, are sometimes used, their paws being placed upon the standards' feet. In order to properly fix poppets so that the poppet-screws shall be in line with each other, the planed ends of the standards' feet are adjusted to some of the straight lines on the table's face, this adjustment being effected previous to finally tightening the holding-bolts. The divider-plate or disc, is shown attached to a spindle in the Figure, and the diameter of the plate is of little importance, except with regard to convenience and lightness; it is, however, accurately marked, so that six holes can be bored at equal distances apart near its rim, s shown, in order to admit the point of the fixing-pin, which also is shown. While the spindle is on the poppet-screw points, the nuts to be planed are finally put into order by gentle hammering, to make all their upper surfaces parallel to the table, which is done after partly tightening the fixing-nut, and also after the fixing-pin is driven in; and when properly adjusted, the fixing-nut is thoroughly tightened to prepare for planing.

The planing of nuts thus arranged on a spindle, is done with ordinary facing-tools; and the six outer planes of the nuts are made equi-distant from the hole, as required, by the rotation of the spindle. Such rotation commences after one slice is cut off all the nuts, the fixing-pin being now taken out, and the spindle moved a sixth part of a complete rotation, which places another of the divider-plate's holes opposite the fixing-pin's point; the pin is therefore again driven in, to fix the nuts for planing a slice from the next lot of nuts' faces. When one slice is cut from these, the spindle is again shifted to place the pin into the next hole, for planing the third lot of sides or faces; and such rotation is continued until all the six sides have had one slice removed. All the sides are thus planed while the tool-point is at one height from the table; therefore some of the first slices cut off will not in any way affect some of the sides, unless the holes in the nuts happen to be exactly in the middle before planing. After the first planing, the tool is therefore advanced downwards a short distance, to cut off another slice from all the sides, by gradual rotation of the nut-spindle as before. The exact dimensions of the nuts, is ascertained either with an outside calliper, or with a gap-gauge, which is easily applied to the two opposite sides previous to adjusting the tool for taking off another slice. When the nuts are very nearly finished, they are polished, when necessary, by cutting off only a very thin slice, the same facing-tool being used for finishing, which was used for roughing, with the difference of having the tool's point sharp and slightly curved, while smoothing is effected. During this smoothing, soapy water is applied, if polishing is intended.

In cases of emergency, it may be necessary to plane a few large nuts for which there is no spindle. In such cases the nut or nuts, after being lathe-turned, are fixed to an el-chuck in the position shown in Fig. 736, resting on a packing-block situated on the planing-table, the nut being held to the chuck with a bolt, nut, and washers. Previous to placing the nut for planing, its hexagonal shape and dimensions should be marked upon one of the turned faces, the centre of the face being found by fixing a piece of wood in the screwed hole. Another mode of scribing, is effected by first making a circular line on one face with a tool-point, while the nut is in the lathe. This line is a circumference of the desired diameter, and is divided into six, to delineate a hexagon in the usual way, which is of the required size. Being scribed, the nut is adjusted while against the el-chuck, by applying the scriber-block's point, the nut being gently hammered until the upper scribed line is seen to be parallel to the table-face, this parallelism being discovered by applying the scriber-point to both ends of the line. When parallelism is obtained two more holdfast plates are attached, one at each side of the bolt shown in the Figure, and when all are thoroughly tightened, the planing of the upper side proceeds with ordinary facers, until the nut is reduced to the upper scribed line; after which, the nut is again adjusted, by means of another line, and again planed. Six fixings of this character are necessary to complete the planing of the nut. The length of the el-chuck, to which the nut is bolted, may be situated either at right-angles to the length of the planing-table, or parallel with it, this being the position of the one in the Figure.

Vices and Vice-chucks.—A vice is a very useful adjunct to a planing-table, especially for thin slender objects which can be gripped only at their edges, and which will not admit a holdfast plate at any part of a broad side. If poppets are fixed in or on a planing-table, to hold a thin object, by merely screwing the screw-points tight against the object's edges, the tightening of the screws frequently puts the object out of its proper position, because there is no plate to hold the piece in contact with the table's face; to avoid this tendency to shifting, a vice is highly effective, which will grip a plate or other article by its edges only, thus presenting the entire upper surface of the article to the cutting tool. With such a grip, there is no risk of moving the piece either upwards or downwards while tightening it. Vices for planing-tables should be parallel ones, and any size may be employed to suit the work and table. With vices, a large quantity of objects of various shapes can be quickly and firmly fixed; such as thin keys, screw-nuts, plummer-blocks, and thin caps, bearer brasses of various shapes, guide-bars, small crank-levers, small cranks, slide-valves, and, in fact, any object which will not admit a plate on its upper surface while being planed, if the article is not too large for the particular vice and machine to be employed.

A vice-chuck, is a sort of parallel vice, and consists of an el-chuck and a strong steel plate, the plate being connected to the remainder of the chuck by two strong fixing-screws resembling other vice-screws, having either globular heads with lever-holes, or hexagonal heads for a spanner. Fig. 737 represents a vice-chuck with screws intended for a spanner, and in the chuck an object is shown gripped for planing, the entire upper surface, and also a portion of the sides being free from any plate or poppet. In the Figure a straight line is indicated by L, and this is one of the lines on the table's face to which the lower edge of the chuck is adjusted while fixing it; consequently, when any object is gripped in the chuck, all the planing of its surfaces which are at right-angles to the table-face, will produce planes which are parallel to that side of the object which is in contact with the chuck's face. The vice-chuck may be also fixed with its length at right-angles to the length of the table, by means of one of the short lines across the table; this adjustment also is highly advantageous for a rapid adjustment of an object to be planed.

Bearer-brasses.—When neither a vice, nor a vice-chuck is accessible, small brasses are planed by fixing them with one plate and bolt through the gap of each brass while against an el-chuck, as shown in Fig. 738. Each brass is lined to denote the desired shape and dimensions, and each fixing of the brass is accomplished with regard to the line that indicates the plane to be produced at that fixing. Large brasses of this class require three or four hold-fast plates, instead of only the one which is seen in the Figure; and when more than one plate are used, they are situated both at the outsides of the brass and also across the gap. Such brasses are always planed and fitted to their respective rods and bars, previous to finally boring the semi-cylindrical gap-surfaces.

Strap-brasses, connecting-rod brasses, and gudgeon-brasses, are also fixed either in a vice-chuck, or in contact with an el-chuck, as seen in Fig. 739; and for such planing, the face of the chuck is adjusted to parallelism with the length of the table, by one of its straight lines; the line for this purpose being denoted in the Figure by L.

Accurate fitting of the planed surfaces belonging to bearer-brasses, is effected by careful smooth filing and scraping; therefore, accurate measurements must be conducted, previous to finally releasing the brasses from the chuck, both to avoid an unnecessary amount of filing, and to be certain that metal enough remains for filing. Measurements for these purposes are performed with inside-callipers and outside-ones, also with straight wire gauges, and coupled gauges of sheet iron, the use of which were described in page 229.

Guide-bars.—Guide-bars are often made singly, and planed singly, for the convenience of an easy adjustment afterwards, when the friction surfaces of the bars and guide-blocks in contact are become worn. A guide-bar is easily held for planing, while in a vice or a vice-chuck, the vice or chuck being situated in any convenient place on the planing-table. A guide-bar may also be planed while held in contact with a face of an el-chuck, with four or five plates and bolts, in the position denoted in Fig. 740.

The face of a guide-bar is the upper surface while being planed, or that surface which is to be in contact with the guide-block or slide; and at each end of the bar a shallow gap should exist below the face, after it is finished to its required dimensions. Such spaces are convenient both for planing, and to provide openings, into which the ends of the guide-block shall extend while in ordinary action. These spaces are formed at the time of casting, or if the bar is of forged steel, at the time of forging.

Guide-blocks.—Guide-blocks for ends of crossheads, are easily gripped in a vice-chuck, in order to plane all those surfaces which are at right angles to the holes, or intended holes; and the blocks may next be fixed on a table as shown in Fig. 741, the bottom edge of each block being adjusted to one of the long lines on the table-face, the line being denoted by L in the Figure. The blocks may be thus held by merely the plates which are shown in the Figure, if of gun-metal, but if steel blocks are to be planed, they require additional fastening by means of a couple of poppets being put to each block, one at each side.

Guide-blocks for standards, and for guide-portions which are solid with their framing, have usually flat surfaces for contact with the faces of the guide-slots; such surfaces belong to the blocks shown in the Figure (741) and their planing is effected with ordinary facing-tools. Guide-blocks for single guide-bars, are grooved, so that each bar can lie in its groove and be clasped by the block. The accurate planing of such is performed with corner tools, and the correct measurement, with coupled gauges, or as substitutes, with callipers only.

Planing with Cup-chucks.—The use of a cup-chuck for planing, is analagous to that of a vice, a cup-chuck being a sort of substitute for a vice, or for a vice-chuck. Either a vice, or a vice-chuck, will hold a cylindrical object above a planing-table, by means of vee-clamps, which were described in page 206; and a cup-chuck situated on a planing-table, also will grip a cylindrical piece, either with clamps or without them, because the points of the chuck-screws are made to bite the curved surface of the object being held. In Fig. 742, a cylindrical piece is shown gripped with the four screws belonging to the chuck, and a secure grip is thus obtained to plane the upper surface. A chuck of any special depth may be used to suit the lengths of the articles to be held; and for a deep chuck, four more fixing screws are required, which are situated at the bottom part of the cup-portion, near the planing-table.

Connecting-bars.—When the arms of connecting-bars and levers are forged large enough to require planing, it is done after the bosses are bored, faced, and short adjoining portions of the arms also shaped. These short parts are the junctions of the bosses with their respective arms, and are reduced to the desired finished thickness of the bar; consequently, a superfluous lump is left extending from each broad side, to be planed off for finishing the bar. A connecting-bar having such superfluous projections, is denoted in Fig. 743. This bar is fastened to the table with a bolt and washers to each boss, and if both bosses are of the same length, their faces are in immediate contact with the table, as in the Figure; but if one boss is shorter than the other, the short one is packed up, in order to raise the bar sufficient to place the two finished junctions at equal distances above the table, the adjustment being aided by a scriber-block whose point is applied to the upper surface of each junction. After being properly placed, a few slightly tapered wood blocks are gently pushed beneath the bar to prevent it bending while in contact with the cutting tool. For a large bar, it is also necessary to apply two or three poppets, to bite the bar's edges, the number of poppets used depending on the length of the bar. For removing the metal, facing-tools are employed, and the smoothing is effected with soapy water. When only one or two such bars are to be planed, they are fixed with their lengths parallel to the direction of the table's motion, as shown in the Figure; but to plane a number of bars at one fixing, they should be placed with their lengths across the table, if it is wide enough.

After the broad sides of such bars are planed, they are marked on their broad sides to prepare them for planing the edges; and this is effected either by gripping them in a vice-chuck of sufficient length, or by bolting each bar with one of its broad sides in contact with a face of an el-chuck. If fixed to an el-chuck, the plates and bolts are attached in a manner similar to that shown for fastening a key in Fig. 698, the number of plates required depending on the length of the bar to be planed.

Lever-Arms.—If a lever-arm is to be shaped with a planing-machine, the bosses are first bored and faced, and their ends also shaped, previous to planing, to allow the levers to be adjusted on the table by means of the smoothly finished parts, similar to the mode for adjusting connecting-bars. If the lever is a crank-lever with two bosses, it is fixed to a planing-table by bolts in the holes of the bosses, and plates on their faces, as denoted in Fig. 747; and if the lever is large, one or two poppets also are required at opposite sides of the arm. Packing pieces are not required beneath the arm, through its comparative thickness; but the smaller boss may need packing up with parallel blocks, which are shown in the Figure at each side of the bolt with which the boss is held. While thus fixed, the upper side of the arm is reduced to the required dimension; after which, the lever is put upside-down and the opposite side planed. It is now ready for marking, and the marking is done upon the two planed surfaces, in order to shape the other two sides of the arm. The bosses also are sometimes shaped by planing, in which case the lever is held with its boss in contact with an el-chuck.

Levers having three bosses each, are treated in a manner resembling that for crank-levers, the broad sides being first planed, and next scribed, in order to plane the edges. At this fixing for planing the edges, the bosses also are shaped, and if the lever is small, having bosses only about two or three inches in diameter, the curved shape of the bosses is easily obtained with springy tools having concave cutting edges. Tools of this class are applied with soapy water after the boss has been roughly reduced with facers and corner tools. It may also be mentioned that the outer cylindrical surfaces of lever-bosses in general, whether small or large, can be shaped with ordinary planing-machines and planing tools, if the machine employed is strong enough, and its table is wide enough to allow the lever to be placed with its length across the table.

Connecting-rod Brasses.—Flat-bottom brasses for connecting-rods should be planed previous to any other shaping being effected. The first fixing of them to the table is that by which the bottoms are planed, the bottoms being those surfaces which are to be ultimately in contact with the rod's tee-head, and also with the outer cap. While planing the bottoms, the brasses are held by plates situated on the half-round ridges, and four, six, or eight brasses may be thus held at one time on the table. When all the bottoms are thus planed, the brasses are put upside-down, in order to plane their faces, the faces being those surfaces which will ultimately be in contact with each other when the brasses are connected and in use. If only two such brasses are in progress, they are easily held for planing their faces, in the situation shown in Fig. 746, where two brasses are represented with their planed bottoms in contact with the table, and are held with one strong plate and two bolts. Being thus fixed, the faces are accurately planed to the required height above the table; and the brasses are then ready for being fixed in contact with each other, either with pins, or with the connecting-bolts. They are also ready for receiving the white metal into the recesses formed to contain it, if white metal is intended.

T-Heads of Connecting-Rods.—T-heads are planed while the rods are situated as denoted in Fig. 748, after the intermediate portions are lathe-turned. The holding plates are placed across the rods, having either emery-cloth, canvas, or leather, in immediate contact, to avoid bruising the turned surfaces. The two planed surfaces of each head are made equi-distant from the centre, by means of a circular line marked on the turned extremity, which line is seen in the Figure, on one extremity of each head. In some cases, the planing of such heads is conveniently done while the brasses, cap, and connecting-bolts are attached to the rods' heads, the bolts being used to tighten the brasses between the cap and head. When this plan is adopted, the bolt-holes in the head, cap, and brasses are finished, and the bolts also fitted, that when all are tightened together, each portion shall be in its required position. The planing of the T-head edges of the brasses and the cap can now be done at one fixing of the rod. Such planing is done previous to boring the middle hole of the brasses, and lathe-turning the outsides of the ridges; consequently, at the adjusting for boring the middle hole, the planed edges of the brasses are the portions which are put upon parallel blocks, in order to place the planed edges parallel with the chuck, and thereby to cause the hole to be bored at right-angles to the length of the connecting-rod as desired.

Gap-end connecting-rods are those having semi-cylindrical gaps in their heads, to contain half-round brasses, instead of having flat-bottom brasses. The planing of a gap-end resembles that for a T-end, the bolt-holes being finished, and the bolts fitted, that the cap may be connected and planed with the head. A gap-end rod which is forged solid with its cap, or with its two caps, is planed on both the broad sides of its heads previous to boring the middle hole, the bolt-holes, and separating the cap with a parting tool or saw. During all planing of gap-end rods and T-end rods the intermediate portions should be in contact with vee-blocks, in preference to other packing. The rod should rest on canvas or leather in the vee-notches; and several parallel blocks may be put beneath the vee-blocks, if necessary, to place the rod high enough from the table to allow it to be swung around its axis.

Faces of Slides and Valves.—Guides, slides, valves, and other objects that require accurate planing, are often bent during fixing, the bending resulting from an improper attachment of the plates and poppet-screws. Such distortion is the cause of a large amount of filing after the object is machined; because the plane surface is produced while the piece is in its bent condition under the pressure of the fixing apparata, and when released, the interior of the metal resumes the shape it possessed previous to being fixed, thus distorting the plane which the machine produced, and rendering a further planing or filing necessary. However thick the article may be, or of whatever metal it is made, it is bent in some way, to a small extent, by the holding plates; and because it is thought that thick heavy articles do not bend, the bad surfaces produced are sometimes thought to be the results of defects in the planing-machine. When a doubt exists in this particular, the smoothly planed surface is tried with a straight-edge, previous to unfastening or loosening the plates and poppets, and if the surface is then found to be right, any difference discovered afterwards will be through the interior particles of the metal springing back to, or resuming, their former relative positions. Such articles as axles, rods, thin surface-plates, and thin tubular objects, will bend with their own weight merely; and for a great quantity of work no attention is given to distortion, because it is not known to exist; but it is always indicated when a great amount of filing is necessary to finish a slide, guide, or plate, after it has been very smoothly planed while fixed on the machine.

Vices and vice-chucks are very effectual for preventing distortion. By gripping the chambered portion of a small slide-valve in a vice-chuck, with the valve-face situated upwards for planing, the risk of bending the face is avoided, because the direction of the grip which holds the valve is parallel with the face to be produced; but if the valve is held with plates, and its face adjusted to the planing-table by wedges beneath the valve, as shown in Fig. 749, the valve-face is liable to be bent while tightening the plates, because the wedges or other packing constitute fulcrums, on which the valve is bent. A similar result would follow if there were no packing beneath, in which case that portion of the table in contact would be the fulcrum; in either case, the portion of metal beneath the plate's paw is a portion of the lever by which the power is obtained, and bends the work. Large slide-valves cannot be gripped in vice-chucks to avoid distortion; and to prevent the ill effects of bending a valve, or other object, which must be held with plates, the fastenings are loosened, after the work is reduced to very near the finished size, and while gently held, a very thin cut is taken off, to complete the surface.

A vice-chuck of suitable length is also very efficient for holding a guide, or a slide, when it is especially desirable to avoid bending it, and if a slight distortion does result with the chuck's grip, the guide's face is not injured by the springing back of the metal, because the grip is parallel with the planed surface, as before mentioned.

Uses of Spindle-chucks.—A spindle-chuck is shown attached to its two standards or supporters, in Fig. 750. Previous to fastening the standards to the planing-table, the chuck's spindle-ends are connected and tightly gripped by screwing tight the cap-bolts, and while tight, the apparatus can be adjusted to any precise situation, either across the table, or parallel with its length. The foot of each standard should be planed, so that its ends are equi-distant from the centre of the spindle-end when connected, in order to allow the length of the chuck to be accurately adjusted to parallelism with the table's length when required; this adjustment is then easily effected by placing the extremity of each foot in line with one of the long lines on the table. When it is requisite to place the length of the chuck at right-angles to the table's length, the feet of the pedestals are adjusted to one of the short lines across the table instead of to one of the long ones. The chuck may also be adjusted by means of a straight line marked on the outer side of each standard, and extending to its bottom, which line passes through the centre of the spindle's-end.

Through the chuck being capable of being fixed at any desired angle, it is a convenient means of planing the surfaces of dove-tail gaps in guides, without the necessity of inclining the slide-rest, the guide being so adjusted that the plane to be produced is in a condition of parallelism with the table, consequently, the ordinary horizontal traverse of the tool will effect the planing. Dove-tail guide-blocks also are easily planed by the same means; also the steel guide-strips, which have plane surfaces inclined at about forty-five degrees with each other. Cylinders also, whose port-faces are inclined at some angle with the lugs, are easily fixed and planed to the angle required, as denoted in the Fig. (750.)

Clamp-plates.—Clamp-plates for planing consists of a couple of thick holdfast plates which are connected together with two or three screw-bolts and nuts. Such plates are required for gripping an object in a manner similar to that of a vice-chuck, and bolts of various lengths are used to suit the thicknesses of the articles to be held between the plates. An object thus held is shown in Fig. 751, and any piece may thus be gripped which is without any projecting ridge, or cannot be put into a vice, or into a vice-chuck. The surfaces of the plates which are in immediate contact with the piece being held, should be rough, or grooved, to prevent slipping. When the clamp-plates are tightly fastened to the article, the upper edges of the plates afford convenient ledges to receive the paws of any number of holding plates that may be required, in order to keep the work in close contact with the planing-table. Poppets also can be placed if necessary, so that their screw-points shall bite the sides of the clamp-plates, which will fix the object to be planed, and at the same time also tighten the clamps to the object. Instead of using two straight flat plates for clamping, two cap-plates may be used. A cap-plate is represented in Fig. 646, and two connected together with bolts constitute a clamp which is remarkably efficient for firmly gripping objects of all shapes, whether their surfaces are flat or curved.

Plummer-blocks.—Plummer-blocks or pillow-blocks are usually of cast iron, and are required for supporting axles of various classes during their rotation, the gap in a pillow-block being required to contain the bearer-brasses which are in direct contact with the axle-bearing or neck.

The first planing of a plummer-block should commence with regard to a centre-line; this line is marked on one broad side of the block across its gap, and extends across the intended centre of the brasses, or across the axis of the axle. From this line, considered as a primary, the distance to the bottom surface of the block is marked, if it can at that time be assertained by scribing a line along one edge of the bottom of the block. The distance from the centre line to the top of the block is also marked by scribing a line at the top edge, this line being parallel to the one at the bottom. After marking, the portion first planed should be the bottom, and the fixing for this purpose is effected with poppets, and with holding plates applied to the ledges extending from the block's sides. At this fixing for planing the bottom, two or three wedges are put beneath the rough portions near the table, to place the broad sides of the block at right-angles to the table. Those blocks which are without any ledge, are sometimes drilled at opposite ends, that two short pieces of iron may be put in to sustain the paws of holding-plates. The block may be held also by means of clamp-plates, as seen in Fig. 751. After the bottom is planed by some means, and the adjoining edges also planed, it is put upside-down, and placed with its planed bottom in contact with the table, and in this situation it is again fixed in order to plane the top and broad sides, or if not entire broad sides, to plane the ledges which surround the edges of the block's gap. At this fixing, the length of the block is parallel to the direction of the table's motion, as denoted in Fig. 752, the bottom planed edge of the block being made to coincide with one of the usual straight gauge-lines on the table. This line is shown by L in the Figure, and a rapid adjustment is effected thereby, which prepares the block for being planed on both its sides at right-angles to the table, and also for planing the top, which is reduced to the line scribed for the purpose. By these processes, three or four blocks may be fixed at one time on the table, whenever several of the same shape and dimensions are in progress.

After the bottom, sides, and top of a plummer-block are planed, it is ready for the planing of its gap-sides. These surfaces of a block, or of a number of blocks, are planed while the blocks are arranged in the position indicated in Fig. 754. Previous to fixing for shaping the gaps, each block requires a line to be scribed on one of its planed broad sides; this is the intended centre line of the gap. and it is at right angles to the block's bottom surface, extending from the bottom of the gap to the extreme edge of the bottom, which is in contact with the planing-table. In addition to this line, the intended shape and depth of the gap is marked on the side, either by means of a sheet gauge termed a templet, or by fixing a piece of wood in the gap, and scribing with a straight-edge and scriber. If a piece of wood is fixed in, the centre line on the metal is made to extend along the wood to the top of the block, so that the gap's sides may be marked at right angles to the bottom. When a sheet gauge is used for such scribing, it must be provided with a centre line, which is analagous to the line on the block; and when scribing is performed, the gauge must be so placed that the two lines are in the same straight line or in line with each other.

The blocks being properly marked, they are properly adjusted on the table by the aid of its right-angular lines. Three or four of the short lines across the table are used, the number depending on the number of blocks, and one of the long lines also is required. To this long line the centre lines of all the blocks are adjusted, and the short gauge-lines are those to which the bottom planed edges of the blocks are adjusted, thereby securing, with certainty, a right-angular position for the intended gaps with the blocks' broad sides. A block thus adjusted is indicated in Fig. 754, the line across the table being shown by L. If only one block is to be planed, it is not requisite to place the centre line on its broad side to a line along the table, because the cutting tools can be made to cut while the block is situated on any part of the table; but to plane several blocks together, all must be fixed with regard to one long gauge-line, in order that all the gaps may be centrally situated in the blocks when planed.

Caps of Plummer-blocks.—Several caps of the same shape and dimensions may be planed at one fixing, by placing them close, or nearly close together, and holding them with a plate and poppets, as denoted in Fig. 755. While thus held, the ends or lugs are planed, and also the short stems which are to fit a short distance into the gaps of the blocks. The holdfast plate is next taken from the middles, and plates are fixed upon the lugs, thus leaving the middles free to be planed for fitting to the brasses. Forged iron or steel caps are those consisting of plain flat bars without any stem; such are first planed on both their broad sides, either while held in a vice-chuck, or while gripped between poppets applied to the caps' edges, and are next bored, that the connecting-bolts may be attached, with the brasses between, to plane the caps' edges. Caps of this shape are used for flat-bottom brasses belonging to connecting-rods, and for a great number of plummer-block brasses which are rectangular instead of hexagonal or octagonal.

Broad sides of Crossheads.—A large number of crossheads are entirely finished by lathe-turning only, and have no flat or planed sides; but the crossheads here mentioned are those having flat broad sides which are shaped with a planing-machine, instead of another kind of shaping-machine. Such crossheads are shown in Fig. 753, with their broad sides situated upwards, in order that these sides, the curved surfaces of the bosses, and also the curved inner corners at the ends, may be planed at one fixing. All crossheads of this shape are planed after their bearings or pivots are lathe-turned, and their narrow sides, termed edges, also turned; but the holes in the bosses need not be bored till after planing, because then the planed broad sides may be put into close contact with an el-chuck, this chuck being fastened to a lathe-chuck.

After a crosshead's end bearings are turned, it is prepared for planing its broad sides by lining. This lining commences by placing the crosshead upon two vee-notch blocks situated on a lining-table, and the bearing-necks are put into the vee-notches or vee-gaps in immediate contact with the blank side of a piece of emery-cloth (if the necks are finished) to prevent damage. While thus situated, a scriber-block's point should be put to the centre of each of the conical recesses by which the crosshead was turned, and if one centre is found to be nearer to the face of the table than the centre at the other end, the lowest one is raised, by placing a piece of paper or other material beneath the neck or beneath the vee-block. Such packing up will make both centres equi-distant from the lining-table. The next step is to place either the broad sides, or the boss, parallel to the table, the boss being put parallel if it is nearer the required dimensions than the broad sides. This parallelism is easily obtained by merely swinging the crosshead while an inside-calliper is held beneath; and when the proper position is obtained, the scriber-point is exactly adjusted to the same height above the table as the centres of the bearings which, of course, is the same height as the centres of the recesses. The scriber-point is now at the desired height for scribing a primary centre line entirely around the crosshead, which will extend along the middle of each turned edge or narrow side, and also across the centre of each of the two faces or ends of the boss in the middle. Any points in this periphery can now be selected as centres from which to exscribe circles of the desired diameters to denote the thickness of the crosshead's arms, and a straight line at each side of the primary can next be scribed to connect the circumferences, the outer straight lines being those to which the arms will be reduced while planing.

The crosshead, being properly marked, is taken from the lining-table to a planing-table, and its primary line, or periphery, is adjusted to parallelism with the table by means of packing-blocks and wedges beneath the arms, similar to the packing shown in the Figure (753), a scriber-block being placed at the line while adjusting. Such adjustment will cause the arms to be planed parallel; but, in some crossheads the arms are slightly taper, and to produce this form the upper gauge-line, to which the metal is to be reduced, is the line which is put parallel with the table, instead of the primary; parallel arms are, however, preferable, especially for small crossheads. The fixing implements consist of plates and bolts, the plates being applied to the turned ends, and also to the boss, if the crosshead is large, that the upper surfaces of the arms may remain exposed to the cutting tools. The planing now proceeds until the surfaces of both arms are reduced to the gauge-lines, and the curved corners near the bearings also shaped; after this the plates are removed from the boss in the middle, if such plates were used, and plates are fastened to the arms; consequently, the crosshead is again tightly held while shaping the boss. This completes all the planing of one broad side, and the work is next put upside-down, to shape the other side by similar means.

The tools required for such surfaces are ordinary vee-point facers, corner tools, and springing tools having curved cutting edges, the corner tools and springing tools being required for the bosses, and the curved corners near the crosshead's necks.

Faces of Cylinders.—The planing of the port-faces and other plane surfaces of cylinders is performed after the cylindrical surfaces are bored, and, in some cases, also after the outer circular surfaces are lathe-turned. The port-faces, the slide-jacket faces, the faces of the lugs, and all other faces which may be solid with a cylinder, require to be parallel to the major axis of the cylinder, although such surfaces may be inclined at various angles to each other. The first step, therefore, towards preparing a cylinder for a planing-machine, consists in indicating the place of the major axis. This is done by first tightly fixing a bar of wood or iron at each end of the bore, and next marking the centre on each piece, after the centre has been accurately found with a compasses, or, if the cylinder is large, with a radius gauge of suitable length. Such bars, when used for centring, are termed enders, or extenders, and the centre dot on one ender indicates one extremity of the axis, the other extremity of the axis being shown by the dot on the other ender at the opposite end of the cylinder. Through these two dots being properly placed, the adjustment on a planing-table to produce planes that shall be parallel to the bore, or axis, is easily effected.

In some cases it is convenient to fix and plane two small cylinders at one time on the table, in order to produce a pair of cylinders having the same shape and dimensions. Two cylinders situated for this purpose are seen in Fig. 756. Each one is provided with two enders, for indicating the axes, and of the four enders two are shown, one in each cylinder. When two cylinders are to be thus planed, the axis of each one must be placed parallel to one of the gauge-lines along the table, and both ends of both axes must also be put at the same height above the table; consequently, the two axes are portions of one straight line extending through both cylinders as soon as they are accurately adjusted, but not till then. This double adjustment can be easily effected by means of plates and wedges beneath the cylinder and on the table, in conjunction with a scriber-block. A scriber-block in use for this purpose is denoted in the Figure (756); the bottom edge of this block is quite straight, sharp, and also of sufficient length to allow it to be quickly and accurately placed in line with one of the gauge-lines along the table, the line selected being as near as convenient to the axis of the cylinders. By thus repeatedly placing the block at each end of the cylinder with the scriber-point near the centre, and the bottom edge of the block on the gauge-line, the amount of wedging requisite is ascertained, and effected accordingly.

There is also another mode of adjustment for cylinders, which is especially suited to large ones of four, six, or eight feet in diameter. This adjustment is accomplished by the aid of the table's short gauge-lines. By this method the scriber-block is put very near to the enders, and the point is repeatedly applied to both centres during adjustment of the cylinders, until they are placed equi-distant from the table. The scriber-block is now taken from the axis and put near the turned or bored flange, the straight bottom edge of the block being also put exactly to some part of a short gauge-line. While the block thus stands, its scriber-point is raised or lowered to make it just touch the finished surface of the flange, and while the point remains at this height the block is removed and put to the opposite portion of the same flange, being also careful to adjust the bottom of the block to some part of the same gauge-line on which the block before stood. This second placing of the block, will determine whether the flange is parallel to the line, and, consequently, will show whether the cylinder's bore is parallel to the table's length, as required. If it is found to be not in the desired position, the cylinder is shifted by means of the poppet-screws in contact, and the scriber-point is again applied to the flange as before, to ascertain what further adjustment is necessary.

Headstocks.—A headstock is a species of double plummer-block, and consists of two plummer-blocks which are cast solid together, having an opening or hole between the two. Such castings are used to support crank-axles belonging to marine-engines of several classes; the intermediate opening being that in which the crank-levers revolve. By some headstocks are termed, entablatures.

The shaping of a headstock should commence with planing; and the lining which is necessary, previous to planing, resembles that described in page 236 for a single plummer-block. The position in which a headstock remains on a planing-table during the planing of the gaps and top surfaces, is shown in Fig. 760; and for this planing, a primary centre line, or some other mark, is requisite, in order that the top surfaces which will adjoin the intended caps, and also the under surfaces for contact with the columns, may be produced at the desired distance from the centre of the axle-gaps. Another primary centre line also is required, previous to commencing the planing of the gaps; this line is denoted by C in the Figure, and is marked exactly at right-angles to the upper planed surfaces termed the top of the headstock; the line is also properly situated at the desired place between the centres of the intended column-holes, in order that the line shall correctly indicate the centre of the axle-gap when planed. At each side of this line, and parallel with it, another line is scribed to show the intended width of the gap. This lining is performed also upon the other gap-portions of the headstock, and is the means of adjusting it on the planing-table, for the purpose of producing the gaps in the desired relative positions when planed. Through the lines extending downwards to, or nearly to, the planing-table, and also across the wood enders to the top of the headstock, adjustment is easily effected with a tall el-square by wedging up until the lines are seen to be square to the table, and are also seen to be parallel to the length of the table by observing one of its long gauge-lines. The gradual shifting for adjustment, is effected after the hold-fast plates and wedges are attached, but not finally tightened; and poppets of proper strength for the weight of the object, are used, to impart the small movement necessary.

Poppets which are specially intended for planing-tables, are shown by those in the Figure (760) and also by Figs. 757, and 758. Such poppets are provided with broad bases, that they may be held on the table with holdfast plates and bolts, instead of providing stems which will extend through the table, to receive nuts underneath. By means of such a broad base or foot, the poppet can be fixed at any place of the table's surface, whether in the middle or at one edge. The poppet shown by Fig. 758, is a forged one, and can be fastened to a planing-table with a plate situated in the space between the stay and the poppet proper. The pin extending from the bottom of this poppet, is put into one of the table's slots, to prevent the possibility of shifting backwards while tightening the poppet-screw. Fig. 759 represents a cranked middle plate, such being used for the purpose of placing the bolt's nut entirely below the gripping portions.

To facilitate the adjustment of a headstock by its lines it is proper, if the shape of the casting will permit, to first place it upon the planing-table with the bottom upwards, in order that the column surfaces may be those first planed. The quantity to be planed off these portions, is ascertained by a species of preliminary lining; and when these column bearings are planed, they are put downwards into contact with the table, or upon parallel blocks, which dispenses with all further adjustment of the headstock with wedges. Lining for the gaps can now be accurately done with a scriber-block and straight-edge, while the work remains on its planed surfaces; and in this condition, the poppet-screws will easily and quickly shift it to its desired position.

After the bottom, top, and gap-surfaces, are planed, the headstock is shifted to place the length of the axle-gaps exactly across the table. This is the position of the one shown in Fig. 761, and is thus fixed in order to plane the two ledges which adjoin each gap. These four ledges are those that will be in immediate contact with the flanges of the axle-brasses, and are planed right-angular to the gaps by means of the primary lines previously used. Each of these lines is now made to coincide with, or stand on one of the table's short gauge-lines, instead of on a long line as before; and after being adjusted and fixed the planing is effected with the vertical traverse screw or screws of the machine.

Crank-Shafts.—The only planing which a crank-axle requires after it has been finally lathe-turned, is performed upon the narrow sides or edges of the levers. A single-crank axle to be thus planed is denoted in Fig. 762, situated on a planing-table with the edges of the levers upwards. The adjustment for planing, consists in placing the centre of the crank-pin, and the length of the axle parallel with the surface of the table, without special regard to any other position. This adjustment is obtained by wedges and packing, which are put beneath both the crank and the axle' until the centre lines along both the levers are seen to be parallel with the table, this parallelism being discovered by applying a scriber-block as indicated in the Figure (762). The total thickness of the packing beneath the crank is not equal to the total thickness of that beneath the axle, because the crank's edges project beyond the axle; and after the work is put into position and fastened with plates and bolts, the upper surfaces or planes required, are produced by cutting off the metal to the gauge-lines marked at a proper distance from the primary line scribed for the purpose. One couple of edges being thus produced, the crank is put upside-down, and again fixed by similar means to plane the other two edges.

Two-crank axles are adjusted for planing by the same species of gauge-lines as those for single-crank axles; the difference of treatment necessary results merely from the axle having two cranks, and therefore more troublesome to move about. To avoid as much as possible this moving, and also refixing, it is proper to plane such cranks with a machine which is amply large enough, and which has a vertical traverse whose length is at least as long as the crank to be planed. With such a machine, a two-crank axle is easily planed with two fixings only. The position in which such an axle rests on the table after one fixing, is represented in Fig. 763. The adjustment at this fixing, is conducted with regard to two objects; one of which is to place the major axis of the axle exactly parallel to the length of the table; and the other object is to place this same axis at the same height above the table as the centre of that crank-pin belonging to the crank now lying down near the table. Such adjustment is effected by applying an el-square's blade, or a scriber-block's point, to the turned surfaces of the axle at the time the bottom of the scriber-block or square is adjusted to one of the table's long lines; and also by placing packing-pieces of suitable thickness beneath the axle and its crank, to make both ends of the dotted primary equi-distant from the table. As soon as this one crank is thus made ready for planing, the other crank situated at right-angles is also adjusted; and one adjustment is sufficient to allow both cranks to be planed, because the length of the axle is parallel to some one of the long gauge-lines, and therefore parallel to the direction of the table's motion.

The crank-axle being properly adjusted and fastened with two or three plates, similar to the one shown at the further end, is ready for reduction, the crank which is parallel with the table, being planed with ordinary facers, and the crank standing at right-angles being planed with right-hand and left-hand corner tools actuated by the slide-rest's vertical traverse. For planing this crank slotted stock-tools also may be employed, in which the cutters are short pieces of steel having vee-points. These tools are described in pages 226 and 227. If the crank is of comparative great length for the machine, the thickest tools which the tool-holder will admit should be used, because, to plane the lower portions of this crank near the table, the tool must extend as far beyond the tool-holder as the total length of the crank-lever, and it is proper to have the tool-point as near as possible to the bottom of the tool-holder. Both sides of this crank, and also the upper sides of the other one lying parallel to the table, can be planed while the axle remains thus fixed in its first position; after which it is only necessary to lift up the crank which was lying down, in order to plane its under edges or sides to complete the planing of the work. The position of this crank at this second fixing is the same as that of the other crank at the first fixing, being right-angular to the table; and the second adjustment is quickly effected with an el-square and one of the long lines, without any regard to the exact position of the other crank, this being already finished. In the Figure (763), the front end of the axle extends beyond the table, as in the case of a long crank-axle or other long shaft being planed which is too long for the table.

Recessed Tables.—A recessed planing-table is a species of carriage having two long vee-ridges extending from its upper side and along its entire length, being also provided with a large recess situated between the two vee-ridges. Tables or carriages of this class are represented in Figs. 764 and 765. At the under side of such a table vee-grooves are formed which fit vee-ridges belonging to the bed on which the table slides to and fro in ordinary action. On the table's vee-ridges are fastened two, four, or any required number of portable tables, which may be termed chucks, because to these the objects to be planed are bolted. By reference to the Figures it will be seen that these chucks are fixed with loop-bolts, the loops being held with short pins situated in holes along the table, and the nuts being situated in circular recesses that admit a socket-spanner when fixing and unfixing are intended.

A recessed table is advantageous for the convenience of having a large space beneath the chucks to admit portions of objects having irregular forms; also to allow poppets and bolts of any shape to be easily fastened and unfastened. Such a space is also convenient for the reception of shavings during planing, into which they may fall without doing harm, and from which they can be quickly removed. To aid this removal it is proper to use trays of sheet iron, which can be put at the bottom of the recess or trough in any required place along its length, to catch the shavings that will be made at that time; in these places the tray or trays remain until full, when they are easily drawn out at one end of the table, emptied, and again put in. Such trays also catch the water and oil occasionally applied to the surfaces during planing.

In Fig. 765 a gap-end rod is shown fastened to an el-chuck, this chuck being bolted to one of the chucks belonging to the table. Gap-end rods that require their gaps to be angular, instead of semicircular, can be thus fixed and planed, when it happens that neither a slotting-machine, nor a suitable shaping-machine, is available for the purpose.

Water-Cans.—Soapy water is applied to the surfaces of forged iron and steel to enable the tool to cut off thick slices without becoming heated, thereby avoiding some of the friction; and is applied also to smoothly polish a surface when it is reduced to very near its finished dimensions. It is therefore necessary to provide some means of applying only a proper quantity of water, and to supply it at the proper place, to avoid the inconvenience of having it running about the table, and into its slots, causing dirt to accumulate. To meet the requirement a water-can may be made, of a semi-cylindrical form, and allowed to hang in contact with the slide-rest, the can being suspended with a sort of wire hook, one end of which is in a hole in the can and the other end attached to a screw or pin projecting from the rest. A can of this class is denoted in Fig. 766, and it should be furnished with a flexible tube for conveying the water to any exact spot desired. One end of this pipe requires fixing at a short distance above the can's bottom, as seen in the Figure, to allow all dirt to remain in the can, instead of entering the pipe. The other end of the pipe should have a small cock, to arrest the flow whenever necessary, without shifting it; but a flexible tube may, if desired, be used without a cock, in which case the flow of water is stopped by lifting up the pipe's end and hanging it upon the slide-rest.

The running of waste water into the slots of a table is, however, of less importance than the falling of shavings into the same places. Many of these recesses in a table hold the pieces that fall in, through having bottoms, so that the shavings cannot fall entirely through. Through the slots being of a tee-shape, hooks are necessary to pull out whatever falls in, if it is large enough to cause an obstruction to a bolt-head while being entered. To avoid inconvenience of this sort, all the shavings which will lie on a surface after being detached with the tool during planing, should be swept or scraped into a narrow tray placed close to the work for the purpose. Brass shavings, gun-metal shavings, and other shavings which are driven about during cutting, are prevented falling into the slots by placing mats, pieces of canvas, oil-cloth, and similar articles, at those parts on which the shavings fall. By such arrangements as these, much of the otherwise necessary cleaning of the table after planing an object will be avoided, in addition to the advantage of keeping the slots clear, that bolts may be placed in whenever necessary.

Double Planing.—Double or binary planing, is that in which two planing-tools of one machine cut at one time, either while producing planes on two different objects, or while producing two planes on one object. This species of planing is denoted in Fig. 767, in which two pieces are seen fixed to two el-chucks, in order to plane both articles at one time on one machine. Triple planing is that by which three tools of one machine cut at the same time instead of only two. There are also planing-machines capable of producing four, five, or six planes at once, on one machine, by means of two carriages, and slide-rests attached to the machine's standards; and, in accordance with the terms just given, such planing may be named, quadruple, quintuple, sextuple, &c.

This chapter is now closed, by mentioning that a variety of curved surfaces also are produced with planing-machines in addition to the production of ordinary planes. The shaping of curved surfaces by planing-machines, has been partly treated in this chapter, because the shaping of curves cannot be quite distinctly treated, through some objects being both plane and curved. Planing, is a general term for work effected on a planing-machine, whatever may be the shapes of the surfaces which are formed; and it will be observed that planing constitutes a necessary portion of the next chapter, which is devoted to shaping in general.

CHAPTER V.

SHAPING, SLOTTING, AND LINING.

THE principal portion of the shaping to be now treated, is effected with shaping-machines, slotting-machines, and in a few cases with planing-machines. The production of surfaces which are curved, but are not completely circular, is also here described. Shaping of this class, is that which may be specially termed, shaping, because it is not done with lathes, nor with planing-machines but with those machines termed, universal shaping-machines. But, previous to introducing such machines and their processes, it is necessary to detail a few of the methods which are adopted for shaping without the aid of proper apparatus, such shaping being termed hand-shaping.

Although we now have a variety of machines, small and large, for producing curves and planes on objects of various shapes, however irregular they may be, a great quantity of shaping is also at the present time performed by hand; therefore, such operations must be noticed. Hand-shaping is that which is done by chiselling and filing, with the aid occasionally of drilling; and is resorted to by machinists of all classes, at certain times, in cases of emergency, sudden breakage, requirements on board ship, and in foreign countries. Hand-shaping is also adopted by numerous makers of small machinery, to avoid the expense of special shaping-apparatus.

In conjunction with the operations for hand-shaping, and also with those for machine-shaping, methods of lining must be given, because lines will indicate boundaries belonging to surfaces of all forms. And it will be perceived that in this chapter, the lining is required to indicate boundaries of hidden curves; in addition to indicating the boundaries of planes. Concerning this subject, refer also to pages 205 and 206.

All shaping of objects which is effected by removing portions of them while cold, without altering their internal shapes, may be termed, paring; in distinction to the shaping of objects by forging, which may be named, pressing, (see page 102). Machines which effect these paring operations are, consequently, paring-machines, and include shaping-machines, slotting-machines, planing-machines, drilling-machines, and lathes. For hand-shaping, the paring implements required, are vices, chisels, hammers, files, and templates.

TEMPLATES.—A template is a sort of gauge made either of sheet iron or sheet steel to represent the form of an object's side. They resemble gap-gauges and other sheet gauges in being used to measure objects and indicate their shapes, but differ from gap-gauges in being available for showing and marking one entire side of an article, if necessary. A template may have gaps, but such are not required for use in the manner of gap-gauges, for measuring lengths, widths, and thicknesses. The use of templates avoids a great quantity of lining, whenever a number of articles are required of the same shape and dimensions; for which purposes, templates are employed by laying them upon the rough forgings and castings, and scribing around the edges of the templates with a scriber. In order to properly place a template upon a piece, and thereby to make the marks in the proper places, a primary gauge-line is scribed upon some portion of the object to be shaped, previous to using the template, and this line is made to coincide with a similar gauge-line on the template. The adjusting of these two lines to each other, while the template remains on the object, prepares it for scribing, which is done with a scriber, as before mentioned. Such gauge-lines will be referred to when necessary, as we proceed.

The making of templates is extensively practised, because they are used for both hand-shaping and machine-shaping; and the principal considerations connected with their construction shall be mentioned. Those templates which are of sheet steel require to be first forged in a smithy by cutting the sheets to nearly the finished shapes required, while hot. The sheet, after being scribed while cold, and the gauge-lines dotted with a broad-point dotter, should be heated on a large iron plate which is kept in the forge-fire, or furnace-fire, for the purpose. When heated, it is brought out and placed upon a broad flat surface, anvil, or block of suitable dimensions, and the superfluous pieces are cut off with chisels. Chisels for such purposes are of various sizes at their cutting edges, and some are held in the hand to be struck with a hand-hammer, others being held with wood or wire handles, similar to those of chisels and fullers for forging. Gouge-chisels also are used for cutting the curved portions. Punches also, both circular and rectangular, are employed for making small holes, and for neatly shaping the corners of large holes which were formed with large chisels. For the cutting out of large templates that may be two, three, or four feet across, chisels having handles are requisite; therefore a striker or hammerman is employed to hammer the chisel or punch while it is held by the smith or other operator on the dots which denote the intended shape.

The making of sheet-iron templates is a similar process to that of making steel ones, with the exception of more care and time being required for steel, on account of its hardness. Sheet-iron templates which are only about a sixteenth of an inch thick are easily chiselled to shape while cold; but if it happens that the metal is an eighth thick, it should be heated and cut in the same manner as steel ones. The exact thickness of a template is important only with regard to its portability, and its capability of being moved about without risk of breaking it or bending it to any injurious extent. Small templates of only about sixty or eighty inches area need not be more than a thirty-second of an inch in thickness; those of two or three square feet not more than a sixteenth thick, and larger ones about a tenth of an inch. Any template which is comparatively weak in its mid-part, by reason of its shape, is strengthened by riveting a stay-piece to the mid-portion, by which means bending and breakage is prevented.

Those who are appointed to make templates are usually those who make gap-gauges, and other gauges of various sorts for measuring and shaping. The correct delineation of the lines marked upon the sheets previous to cutting out is effected by reference to the drawings, tracings, or other sketches which specify the finished dimensions of the objects to be shaped, the sides of which are to be represented by the templates.

A number of sheets, showing the lining necessary to denote the templates desired, are indicated in Plate 61. In this plate Fig. 768 shows the simplest method of finding the centre of a rectangular or other equal-sided surface belonging to a plate, sheet, or other object. The operation consists in scribing two diagonal lines that cross each other, as seen in the Figure, by placing a straight-edge diagonally upon the object. Fig. 769 indicates a mode of finding the centre of a surface which is not rectangular, or whose sides are crooked. This method is applicable to all surfaces, whether they possess curved boundaries or straight ones, and is performed with either callipers or compasses. In the Figure, a piece of sheet iron is shown, having four short arcs scribed in the middle of the surface, the middle point between the arcs being the place of the centre desired. In order to mark the arcs, either an outside calliper or a compasses is applied to the sheet so that one point shall touch one edge, while the other point extends across the sheet to nearly the centre, and scribes one arc. This being done, the calliper is applied to the opposite half of the sheet, and another arc is scribed without altering the distance of the calliper-points from each other. When two arcs are thus made, the calliper-legs are shifted to mark two more arcs across the two first made, the distance between the two calliper-points being now rather less than half the distance across, as at the first marking. The marks shown in the sheet denoted by Fig. 770 are somewhat similar to those shown in Fig. 769, with the difference of being scribed with a radius which is rather longer than half the distance across the sheet, instead of rather shorter.

Scribing processes of this character are often necessary for finding the centres of sheets intended for templates, especially if the sheets to be used are only just large enough; but if ample metal exists in the piece the centre is quickly found and marked by merely placing a straight-edge to about the middle, and marking with a scriber. A straight line of this sort is necessary for nearly every template which is made, although it is not always situated along the middle, being, in some templates, near one edge. The other sheets denoted by the Figures in Plate 61 are shown with the lines which are required for templates belonging to bosses, ends of rods, bars, straps, and levers.

In Plate 63 several operations belonging to the making of templates are shown. The lining of such articles can be conveniently effected on a lining-table, such as that shown in the front of the Plate. On this table a sheet, or a number of sheets, can be placed, flattened, and also scribed, by means of the various lining and marking tools which have been described; a compasses in use for marking a template being indicated by Fig. 827. A long table of this class is very convenient for general purposes of lining, whether for gauges or for portions of engine-work, the right-angular lines and the linear measures on the surface being useful for adjusting pieces of work, compasses, springy dividers, and radius gauges to suitable radii, in order to scribe the arcs desired.

When a number of templates have been properly marked, and also dotted, to plainly show the places for the intended chisel-cuts, the pieces may be cut to shape either on the same table that was used for lining, on another table or vice-bench devoted to the purpose, or on an anvil, as in forging. When a bench or table is used for chiselling, the sheet to be cut is laid upon a bench-anvil, the anvil selected being of a suitable length and width for the work. Bench-anvils are heavy blocks of iron or steel, some being only eight or ten inches long, and others being several feet long, a long block of this sort being necessary for supporting a long template or other object. A useful class of bench-anvils are those which are made of circular cakes of steel or iron. Such pieces are easily obtainable from a turnery, in which places superfluous slices of a circular shape are frequently cut from ends of shafts and axles during lathe-turning. A block of this sort is denoted by Fig. 826, and another one in use for chiselling is shown in Fig. 823.

Filing the rugged edges of a template, after chiselling, is effected while it is gripped in a vice. For a large template vice-clamps of great length are required, to avoid excessive vibration of the comparative thin sheet, the clamps being of either soft iron or hard wood. Templates which are seven or eight feet in length may be filed at a vice-bench specially arranged for the purpose. Such a bench is furnished with two or three vices, so fixed that the jaws of each vice are at the same distance from the bench. This arrangement will allow a long template to be gripped in three vices at one time, and three or four men can then work upon the same piece at one time. In some cases two vices may be sufficient instead of three, as indicated by Figs. 820 and 821, which denote two vices gripping a template by means of a couple of wood blocks. A long straight-edge also can be thus held while filing its edges. Vices thus arranged are also useful for holding a long rod, axle, or other object, during chipping and filing, if the vices are properly fixed in line with each other.

Whenever several templates or other sheet-iron gauges are to be made, the cutting out is greatly facilitated by means of shears, either hand-shears or those worked by steam. Those worked by hand are termed vice-shears; these are fastened to a vice so that one lever-arm is gripped between the jaws, and the other arm is free to be moved up and down for cutting. Although the entire cutting out of a template cannot be done with vice-shears, nor with machine-shears, unless the template happens to be of very simple form, yet such shearing should be adopted for all large templates, whether their boundaries are to be curved or straight, all the long cuts being easily made by properly guiding the sheet during shearing, and the short cuts for small curves and corners being afterwards effected with chiselling.

HAND-SHAPING.

Bosses.—Chiselling is the principal means of reducing objects which are shaped by hand, instead of by machines. Various modes of shaping by chiselling are denoted in Plate 62, in which the ordinary portions of machines are represented, and the modes of chiselling them are indicated. In this Plate Fig. 796 shows a lever whose two bosses have been bored, the boss-ends faced, and the short portions extending from the arm also lathe-turned. In this condition the lever is ready for reducing the outsides of the bosses to the intended dimensions, and also the arm or intermediate portion, if necessary. When the arm of a lever is to be thus reduced, a primary centre-line is required along the middle of the arm's side, to connect the centres of the two bosses, this line being that from which the width and shape of the arm's side is marked. But when the bosses only require chiselling, such a straight line is not necessary, a circular line scribed on the boss-face, to denote its diameter, being sufficient. This lining also is omitted if the boss were properly reduced at both ends by lathe-turning, previous to arranging for chipping. While a boss of this class is gripped in a vice, the first chiselling consists in forming a number of narrow grooves into the superfluous metal at a short distance apart, similar to those shown in the Figure (796), after which the remaining ridges are cut off with a planing-chisel. The grooves may be first made with an ordinary grooving chisel (Fig. 322), which is used until the total depth of the groove is nearly attained, the small remaining portion of metal at the bottom being next taken out with a curved groover. A chisel whose cutting edge is curved will form a groove having a curved bottom, instead of an angular one, which would be the result of using a groover having a straight cutting edge. The advantage of a groove with a curved bottom consists in the greater strength of the metal preventing its breaking off in an irregular manner during the chipping off the ridges with a planing-chisel; but a curved-nosed chisel is a slow cutter when compared with one which is only slightly convex (see page 182), and a curved nose should therefore not be used for rough or unimportant work. The total depth of a groove is equal to the entire thickness of metal to be removed, but a planing-chisel may be used when a groover has been driven to only about an eighth of an inch into the metal, when it happens that a quarter of an inch is to be cut off; and after the ridges are once cut off, the groover is again employed to form other grooves to the depth desired.

Blocks.—The hand-shaping of such articles as rectangular blocks, keys, and surface-plates, is shown by Figs. 797, 798, 799, 800, and 802. Blocks or plates which require well-formed corners and edges should, in all cases, be bevelled, previous to chipping, in order to prevent irregular breakage. Such bevelling is indicated in Fig. 797, and is done by either rough filing or grinding. After bevelling, grooves are next formed, by chiselling, similar to those seen in Fig. 798, which prepares the piece for reducing with a planing-chisel, as described for other work. If the bevelling of the block has been carefully done to the straight gauge-lines which are marked to show the place of the desired plane, the subsequent chipping with chisels will be also properly done, because the lines which constitute the junctions of the bevels with the block are those to which the operator works, instead of to the rugged superfluous metal.

Fig. 799 represents a surface plate which is bevelled in the mode just mentioned, and a similar plate, after bevelling and grooving, is shown by Fig. 800. The method of holding a small plate or block while being chiselled consists in gripping it in a vice, if the piece to be held is not too large; but, if so, it is laid upon a bench, or stood edgeways on the floor, or on wood blocks of suitable height, in which position it may lean against a bench, as indicated by Fig. 825. A plate which is heavy enough will thus stand while being filed and chipped, without any further fastening; but, for security, it is proper to place one or two heavy objects in front of the plate, or to drive in one or two wedges between the bottom edge and the floor.

In the Figure 798, the series of grooves are shown to be parallel to each other, and extending across the object in one direction only. Such grooves are suitable if the surface being reduced is only about six or eight inches across; but for larger surfaces another series of preliminary grooves should be made across, and at right angles to, the set first made. There is considerable advantage connected with such grooving, because the operator is thereby enabled to see plainly where he is chipping, and is not liable to drive the chisel too far into the metal, if the first series of grooves were carefully formed. This first set becomes a sort of guide or gauge by which the second set are easily and quickly made; therefore the means of knowing how deep to drive the chisel at any particular place of a groove during the first grooving, must be remembered. If a side of a plate or block is a plane previous to reducing it, and it is decided to make the object a quarter of an inch thinner, it is evident that the slice cut off must be exactly a quarter of an inch thick in any part of it; therefore the operator, while chipping such a piece, would carefully observe the chisel and prevent it entering the metal further than a quarter of an inch. But if a rugged piece requires reduction by chiselling, the surface must be examined, previous to chipping, to ascertain whether it is concave or convex, and to what extent. With this intention, a straight-edge is applied in various directions and in several places across the rough metal, and the extreme depth of the deepest concavity that may exist is thereby known. This hollow, and also any others that may be of consequence, are marked by chalking them, which will result in directing attention to them while chipping. If it is found that the rugged surface is convex in a few places, instead of concave, the prominences are chalked, and also chiselled off, previous to chipping the entire surface.

After the general condition of the rugged exterior is ascertained, and the edges bevelled to denote the required dimensions, the grooving proceeds, during which operation the amount of care necessary depends on the distance across the surface; the greater the distance, the greater is the care required, through the workman not being so able to guide the chisel and generate a large plane of three or four feet across, as to guide it in a plane of only an inch across.

During the grooving, a straight-edge must be frequently applied to the bottom of each groove, in order to discover whether it is tolerably flat, and also whether it is parallel to the desired plane, the boundaries of which are indicated by the scribed lines at the bottoms of the bevels.

By these remarks it will be seen that if due care is exercised at the first grooving, in order to make the bottoms of all the first set parallel to the plane which is to be produced, the making of the second set will be comparatively easy, because these can be formed accurately by looking to the bottoms of the first grooves while cutting. It will be also a very easy and straightforward operation to cut off the small four-sided projections which are left remaining after the second series of grooves are made. These portions are quickly removed with a planing-chisel, and without the need of applying any straight-edge until the entire surface is chipped and is ready for filing. The cross-grooving here referred to, is represented in Fig. 800.

The piece shown by Fig. 802 is a portion of steel or iron bar which is to be made into a taper key by chiselling. Such a piece is first lined to indicate the intended dimensions and shape, and next grooved as seen in the Figure, the deep grooves being only partly formed at the first grooving, to allow a planing-chisel to be used for cutting off the superfluous ridges without the risk of breaking off too much metal.

Holes of Bosses.—The cylindrical hole of a lever-boss, or other boss, can be accurately formed in cases of necessity by means of proper lining, chiselling, and filing. The lines for such a purpose should resemble those shown in Fig. 801. Such lines are delineated upon two opposite sides of the lever, and are marked while it rests on a lining-table, the two faces of each boss having been previously made tolerably flat and parallel to each other. While on the table, the faces of the bosses are situated at right-angles to the surface, and the lever is packed up with plates or wedges until the intended centres of the bosses are placed equidistant from the table. In this condition a scriber-block is employed to mark a periphery entirely around the lever, including its four boss-faces, the periphery being a primary centre-line which distinguishes the lever into upper and lower halves. From this line the intended diameter of the hole to be chipped is scribed upon the boss-faces, and if a taper hole is desired, the two different diameters are indicated by scribing circles of the proper diameters. By thus marking the places of the intended holes the entire quantity of metal to be removed is shown, and the different thicknesses to be removed at different places around the hole are also shown. Two circles for this purpose, marked on two faces of a boss, whether for a parallel hole or a taper one, indicate boundaries of the now hidden curve of the cylindrical hole or taper hole which is to be produced; and if the metal can be removed to form a straight hole which shall be terminated by the two circles scribed on the boss-faces, the entire boundaries of the hole will be in their intended places, and the dimensions of the hole will be those desired, supposing that the circular gauge-lines are situated exactly where they should be.

After lining the boss-faces, the superfluous metal in the hole is to be bevelled to the gauge-lines by filing, or by light chiselling, which prepares the hole for being grooved in the manner shown in the Figure (801). After grooving, the remaining ridges are partly cut off with flat chisels, and completed with chisels whose cutting edges are slightly curved, to suit the concave form of the hole. Chiselling a hole in this manner requires considerable care, especially if it is several inches in length, to prevent the chisel being driven too deep into the metal. To avoid this a straight-edge must be frequently put into contact with the bottom of each groove, previous to chiselling it to the total depth intended.

The hole being carefully chipped is ready for filing with half-round files, to obtain as near an approach as possible to the cylindrical or conical form which is required, the filing being conducted with frequent application of a straight-edge, square, and inside-callipers. These three tools are requisite for a cylindrical hole, to effect three objects; the straight-edge being necessary to make all sides of the hole straight, the square being required for adjusting the hole to a right-angular position with the boss-faces, and the callipers being needful to adjust the hole to a circular form throughout its entire length.

A hole which is conical must be adjusted to shape and dimensions without a square, inside-callipers being used for making the hole circular, and to the exact diameter required, as in the filing of a parallel hole, and an angle-gauge being employed to adjust the sides of the hole to the proper angle with the boss. Such a gauge has an adjustable blade or arm, which is made to subtend the same angle with its pedestal, as the side of the required hole subtends with the boss-face, this face being that adjoining the mouth or large end of the hole, consequently the blade of the gauge is entered at this end whenever it is requisite to ascertain the condition of the work.

Brasses.—Bearer-brasses can be quickly chipped and filed to dimensions, and if they are small, having but a small quantity to cut out, such shaping by hand is sometimes quicker than boring them with a lathe. By means of proper lining, and a subsequent rough and smooth filing, a couple of brasses for a spindle of only one or two inches in diameter can be shaped well enough for many purposes. The lining of such brasses requires to be done while both are tight in their plummer-block, rod, or bar; and both ends of the hole must be marked to denote the diameter of the spindle-bearing which is to fit the brasses. This bearing should have been previously smoothly finished to the desired shape and dimensions; and when the two half-round brasses are chipped and filed to the gauge-lines that indicate the boundaries of the curve to be produced, the filed surfaces can be rubbed upon the finished axle-bearing, to show the prominent portions that require additional filing. A bearer-brass which is lined and dotted, to be chipped and filed, is shown by Fig. 803.

Arms of Connecting-bars.—The intermediate portion or arm of a connecting-bar, or of a lever, is easily shaped while in a vice, if necessary, the arm being first bevelled to gauge-lines, and next grooved, in the mode described for other hand-shaping. A connecting-bar to be thus treated is shown by Fig. 804, in which one narrow side, termed the edge, is grooved ready for a planing-chisel. The lining of such a piece is similar to that for bars and levers which are to be shaped with machines, and is conducted by means of a primary centre-line along the entire length of the arm, which is analogous to other primaries, the uses of which have been fully treated in pages 146, 219, 221, 236, and 237.

Chiselling of Gaps.—The gaps of solid fork-ends, connecting-bars, cranks, and similar articles which are to be shaped by hand, should be formed with the aid of drilling. Such drilling consists in making holes at the bottoms of the intended gaps, the drilling being done next after lining, and previous to any other shaping. The intended fork-end of a connecting-bar is shown by Fig. 805, which denotes a solid lump marked with a dotted line showing the place and dimensions of the gap to be formed. At the bottom of the gap a circular hole is to be drilled, and so situated that its edge shall exactly coincide with the intended bottom, thus leaving no metal to be afterwards removed by chiselling, the bottom being properly shaped to the curve required by the rotation of the drill. When drilled, the cutting out of the superfluous lump proceeds by making two deep grooves with grooving-chisels, the grooves being situated close to the dotted line, and extending downwards along the entire length of the gap to the drilled hole. By such grooves, in conjunction with a previous drilling, the entire gap-piece is removed, and the bottom of the gap nicely shaped.

Fig. 806 represents a crank-axle having a crank-lump, the gap of which is to be made by the same means as that mentioned for a fork-end, with the difference of drilling three or four holes along the bottom of the intended gap, instead of only one. These holes are of small diameter, because they are required only to partly separate the gap-piece, and not to shape the crank-gap to its finished form, as while drilling the gap of a fork-end rod.

Instead of cutting out gap-pieces with grooving-chisels, sawing may be adopted for making the cuts. The saws used for this and similar purposes are of various classes, some being worked by hand and others by steam. The simplest class of saws for hand use are those termed hack-saws. A hack-saw for engineering purposes is one of fourteen or sixteen inches in length, and about a twentieth of an inch in thickness, which is attached to a holder or frame, and properly stretched with a screw-nut, to prevent the saw bending while in use. One end of the frame has a wood handle resembling a file handle, which is gripped in the right hand while the tool is in use. The mode of using it consists in moving it to and fro in contact with a piece of metal, in a manner similar to that of using a file, until the saw-cut is deep enough, or until the piece is cut off, according to circumstances. A hack-saw is very suitable for iron, brass, and gun-metal, and will cut easily and quickly while the article being sawn is firmly held in a vice which will not shift during the sawing.

Circular saws are also employed for making gaps, and are actuated by proper sawing apparatus. Band-saws are also very useful, especially for large objects.

Spindle-ends.—In order to chisel a cylindrical-end or pivot-end for a shaft, rod, or spindle, the end intended for the spindle portion is made tolerably flat and square to the length of the bar, and a circle is scribed upon the extremity, the diameter of the circle being equal to the intended thickness of the axle part or pivot. A circle for such a purpose is shown on the end of the bar denoted by Fig. 807. To mark the length of the desired cylindrical end a vee-notch is filed entirely around the bar at a proper distance from the extremity, and the notch is made previous to any other shaping of the end being effected, except slightly preparing the extremity for scribing the circle. One edge of the notch will become the shoulder of the pivot, therefore the exact intended place of the shoulder is carefully ascertained; because from this the total length of the pivot-end to be made is marked, and whatever superfluous metal exists at the extremity can be then known. In order to make the notch exactly right-angular to the length of the bar or axle, the scribing which is to show the place for the notch must be done with a scriber and a square, the blade of the square being put to the place for the line, while the pedestal is put into close contact with the sides of the bar.

After the notch is properly and deeply made by means of a rough three-cornered file, or with an edge of a half-round one, the chiselling commences by using a grooving chisel, and enlarging the vee-notch until it is nearly deep enough to reach the cylindrical end which is to be produced; consequently, this grooving cuts off all the four corners adjoining the vee-notch.

When this is done the piece is ready for a planing chisel, if the end is not more than an inch or two in length; but if longer, one or two other deep grooves or notches should be made around the end in addition to the one at the intended shoulder. After the proper number of grooves are made, the planing-chisel is employed to cut off the remaining projections, the direction of the cuts with this chisel being at right-angles to that of the grooves; consequently, the planing-chisel is driven in a direction which is parallel to the length of the shaft or bar.

During the chiselling of the grooves, the bar is held in a vice with the length horizontal, the portion which is chiselled being as close as possible to the vice-jaws, and the long end of the bar being supported with one of the author's screw-props. If the bar is short it may be thus held also while using the planing-chisel; but if long enough to reach the floor the long end should not be held on a screw-prop, but allowed to rest on the floor, as denoted in Fig. 822, in order to obtain as much resistance as possible at the place of cutting.

Chiselling of Teeth.—The forming of cogs belonging to wheels and racks by the aid of chiselling, is effected in conjunction with drilling, a circular hole being drilled at the bottom of each intended tooth-gap, previous to commencing the chipping.

In order to make a cog-wheel by such means, a circular plate or disk of metal, whether steel, iron, or gun-metal, is so prepared that its two broad sides are flat and parallel to each other, and its rim circular. If a lathe can be used for this purpose, the disk is thereby properly shaped, having its spindle-hole also bored by the same means. But if turning cannot be done, the place for the centre of the required wheel is determined, and is used for scribing circles upon the broad sides, and the rim is made circular by chipping to these lines.

In the case of a wheel which has its spindle-hole bored requiring circular gauge-lines, to which the rim is to be chiselled, it is necessary to tightly fix an ender at each end of the hole so that the centres can be found and accurately marked upon each. A circular plate having its hole thus bored, and containing an ender at each end, is indicated by Fig. 808, in which Figure one of the enders is seen tightly fixed. By means of the centre dot which is marked on each, both broad sides of the plate are delineated, three circles being scribed on each broad side as denoted in the Figure. Of these three, the one first marked is the outer one, and denotes the intended extreme diameter of the wheel. To this line the ragged rim is chipped, and as soon as it is made tolerably circular the plate is ready for the two inner lines. The scribing of these two circles will denote the middles of all the intended teeth, and also their depths; and when both broad sides are thus scribed, it is ready for marking with a springy divider to show the places and shapes of all the required cogs.

If several plates are in progress all are thus scribed, previous to drilling any one of them, that all the drilling may be done at one operation, either at a lathe or at a drilling-machine, according to circumstances. As soon as the places for the teeth are indicated, the circles for showing the places of all the holes at the bottoms of all the teeth-gaps can be scribed; after which the drilling proceeds by entering the drill from both broad sides of the wheel.

When all the holes are drilled, a hack-saw should be used, if the wheel is of iron or brass, in order to make two saw-cuts into each drilled hole, by which means the superfluous gap portion is cut out in one piece. By a series of sawing processes thus effected, the entire number of teeth-gaps and teeth required are roughly formed, and chiselling is avoided. Finishing the teeth to the exact shape required, is finally effected with filing.

A solid piece which is to be made into a rack, is shown by Fig. 809. The lining required for such a piece is done with a divider and scriber-block, the block being used for marking the long lines along the object while it is situated on a lining-table, and the divider being required to properly mark the intended teeth so that they shall be equidistant from each other. The long lines are marked upon two opposite sides of the object at one scribing with the block, which is moved entirely around the work while on the table. These lines denote the bottoms of all the intended teeth-gaps, the middles of the teeth, and also the extreme heights or distances from the bottoms of the gaps. In addition to the long lines, a series of short ones are marked; these are shown in the Figures across the top of the work, being square to the sides, and also equidistant from each other. Each one of these lines is marked along the centre of each intended tooth-summit, consequently one line only is made to represent one tooth, and is not erased until the entire shaping is completed. By exercising care to file each tooth so that this centre line is always in the middle, all the teeth-summits are made exactly at the same distance apart.

Chiselling of Key-ways.—To form key-ways by chipping, the object to be chipped is gripped in a vice; and if it is necessary to avoid bruising the surfaces in contact, vice-clamps of lead or copper are employed. If a key-way is to be made in a lever-boss, the two faces are first made tolerably flat and parallel to each other by lathe-turning or other means, and the place and the shape of the key-groove desired is shown by lining the boss with the lines indicated in Fig. 812. The middle line seen is a primary centre line extending along the middle of the lever-arm, from which line, in two directions, the width of the key-groove is scribed. The primary is also used to mark a centre line along the inner surface of the boss or along the hole, to show the centre of the key-way along its entire length, a line at each side of this one also being marked, that the exact width intended along the hole may be seen. By thus lining the faces, and also the hole, both the width of the key-way and its depth into the metal, are indicated. It is necessary for the lines in the hole to be exactly parallel to the axis of the hole, and this result is obtained by means of a square, the blade of which is placed through the hole so that one edge exactly coincides with the primary line on the boss-face, while the pedestal is held in close contact with the face. While thus held, a scriber is moved along the hole and marks the middle line, after which, the square's blade is shifted to an equal distance at either side, in order that the width may be marked.

After the scribing is completed, the mode selected for removing the metal, is that which suits the size of the boss and the quantity to be cut out. If the required key-way is only about two or three inches long, and a quarter or three-eighths wide, the entire chipping may be done with grooving chisels whose cutting edges are about a sixteenth shorter than the finished width of the groove. By chipping with a chisel of such a width, a small quantity of metal will remain at each edge after chiselling, which small portions will be afterwards removed by filing the key-groove to its exact finished width and shape.

Large key-grooves, such as those of one or two inches in width, for bosses of twelve or fourteen inches in diameter, require to be first grooved at each edge of the intended key-ways, which forms two narrow grooves along the entire length of the hole, and leaves a middle superfluous lump still unchipped. This lump is now ready to have other grooves formed therein, the number of which depends on the size of key-way, and, therefore, on the size of the lump.

The chiselling of a key-way which is several inches in length, is performed at opposite ends of the hole, instead of chiselling at only one end, in order that the cutting edge of the chisel may be as near as convenient to the operator. All small key-grooves require occasional bevelling at the ends, during chiselling, as the chisel advances deeper and deeper into the boss, in order to prevent the metal breaking off in an irrregular manner below the place intended.

The amount of filing which is required for any one key-way depends on the amount of care exercised during chipping, to produce smooth surfaces, and to make them uniform; and the larger the groove, the greater is the care requisite. All key-grooves, small and large, should be so finished that their widths are parallel, and their depths or distances into the bosses are slightly taper; for the purpose of causing one entire side of any key-way to bear upon its key, whether the key is partly in or entirely in its place, and to allow a key to be gradually tightened by driving it in, without causing much trouble to get it out, which would be the result if it were parallel. The angle of a key's thickness for securely fixing it permanently, when is required to remain in for many years, should not exceed one degree.

Spindle Key-ways.—The marking of a key-way or key-bed, at one end of a spindle, is effected with regard to its exact intended position, as in lining for one in a boss, in order that the length of the key-way may be parallel with the length of the spindle, and the width at right angles to a line extending exactly across the spindle's centre, which line is the spindle's minor axis. The line showing this axis should be the one first marked, and if the extremity of the spindle retains its centre recess on which it was lathe-turned and is nearly flat, the line is easily scribed by placing a straight-edge across the centre and scribing a line with a scriber. A line of this sort is shown in Fig. 813, and is also shown in the plan of the extremity which is represented by Fig. 814, being situated across the centre of the spindle-end and extending through the centre of the intended end of the key-way to be made. When it happens that a key-way is to be marked upon the end of a spindle having a curved or pointed end, the marking is done by placing the spindle upon two vee-blocks on a lining-table, in the position shown in Fig. 828, which represents a spindle being scribed with a scriber-block, and without the aid of any centre line resembling that in Fig. 813, for indicating a minor axis. As soon as the spindle's length is adjusted to parallelism with the table, the scriber-block point is applied to the end, and a line is marked along the metal, which line will denote the place of one edge of the intended key-groove. The workman now rotates the spindle a short distance and marks another line, so that the distance between the two shall be equal to the required width, the exact width being denoted by dots previously placed. Such lines will, in all cases, be parallel to each other, parallel to the spindle's major axis, and parallel to the table face, however great the length of them may be, because the spindle was put parallel with the table, and the scriber-point must move in a path which is parallel to the table (see page 111). While the spindle still remains on the vee-blocks, it is also easy to scribe a couple of short lines upon the extremity, to indicate the key-way's width at the end, in addition to showing it along the spindle.

The scribing processes just given will mark the places of key-ways so that their lengths are exactly parallel to the lengths of their respective lever-bosses and spindles or shafts; and if the scribing were properly done, and the subsequent cutting out also properly done, the key-way of any selected shaft will fit the key-way of that particular lever-boss which was fitted to it, although the two may not have been put into contact with each other during the formation of the key-grooves. But when it is especially desirable to make a key-groove of a spindle exactly fit the key-way of its lever-boss, or wheel-boss, the place for the groove in the spindle should be marked from the key-groove in the boss. This is done by first making the groove in the boss, and next placing the spindle into the hole, that the two may be carefully adjusted to their exact relative positions with each other during their future use. Being thus arranged, the place for the key-groove in the spindle is scribed by moving a scriber along in contact with the edges of the already formed key-way in the boss. For this and similar scribing, a scriber having a short bent end or arm is required, the arm being not too long for any easy movement to and fro in the boss key-way while scribing the spindle.

Chiselling of Key-ledges.—For some purposes, axles and shafts require their keys to be solid with their respective portions, instead of being separately made and fitted into key-ways. A key which is solid with an axle, is a key-ledge, and two such ledges may be required on one spindle, both key-portions or ledges being situated on a minor axis, one ledge at each end, which arrangement is usually termed, opposite each other, or, at opposite sides of the axle. Spindles or shafts of this class in general should be of steel, in order to possess a solid close metal which is nearly devoid of fibres, that no cracks may exist whose lengths are parallel to the lengths of the shafts. If such cracks exist in any part of a key-ledge, the strain on it during use would probably separate it from its axle.

A piece of steel which is to be formed into a spindle having two key-ledges, is denoted by Fig. 815. The accurate shaping of such a piece, previous to forming the keys, consists in lathe-turning the two small ends and also the larger portion between. The diameter to which this part is turned is equal to the required distance between the two extremities of the two intended ledges, the distance being measured across the centre of the spindle. The shoulders of this thick part are also smoothly turned to make them square to the spindle's length, and to admit scribed lines. The piece being turned to proper dimensions becomes ready for scribing, which indicates the places of the two ledges to be formed. This scribing is effected by placing the spindle upon two vee-blocks in a position similar to that of the spindle shown by Fig. 828. While on such blocks it is packed up, if necessary, to place it parallel to the table-face, and a scriber-block is then employed to mark the places for both key-ledges at one operation, the smoothly turned shoulders being also scribed while the spindle still remains in position on the blocks. The lines which are thus scribed for one key-ledge, are those seen in the Figure (815), consequently, a similar set of lines are marked also upon the further side of the object, because two ledges are required. The middle line of each set is a primary which should be lightly dotted, in order that circles may be scribed from it in the event of the lines which show the width of the ledge becoming erased by filing or other means.

When the places for the two key-ledges are thus shown, the work proceeds by gripping one end of the spindle in a vice and supporting the other end on a screw-prop. While in this situation grooving chisels are used to form grooves along the superfluous steel, the lengths of them being parallel to the lengths of the intended ledges. The superfluous ridges which are produced by such grooving, are now removed with planing-chisels. These chisels are employed until the thick intermediate portion of the spindle is smoothly chipped and the two ledges are produced as required; after which the object is finished to the exact shape and dimensions intended with rough files and smooth ones.

The uses of centre-finders to mark places for key-grooves, are illustrated by Figs. 816, 817 and 818. By means of a centre-finder the minor axis of a cylindrical shaft-end is easily indicated by placing the pedestal of the tool to the shaft-side with the blade extending across the extremity, and marking a line with a scriber. The position of the centre-finder during such an operation, is seen in Fig. 817, a plan of the tool and the shaft-extremity being shown by Fig. 816, in which Figure the blade's edge is seen to coincide with the shaft's minor axis as desired.

A centre-finder will also easily show the place of a centre-line across the face of a wheel-boss or a lever-boss. While using the tool for such a purpose, it may be situated either as in Fig. 818 with the pedestal nearest the lever-arm, or situated with the pedestal at the opposite side of the boss, the blade being therefore in this case over the lever-arm.

Chipping of Cylinders.—Chipping of the flanges belonging to steam-cylinders and similar objects, is necessary only when a planing-machine cannot be employed, or when it happens that only a very small portion of a large cylinder or other object is to be surfaced. In such cases the surfacing can be done with chiselling, in about the same time, or less, that would be occupied in moving the object and fixing it to a planing-machine.

A small cylinder which is to be chipped, instead of machined, is denoted in Fig. 819. After the cylinder is bored it is placed upon a table and enders fitted to the ends, in order to find the centres, and thus indicate the major axis. It is next packed up or wedged up with packing-pieces of suitable thickness, as seen in the Figure, to place the axis parallel to the table's surface, a scriber-block being repeatedly applied to both enders until adjustment is effected. During this adjustment the scriber-point must also be placed to two opposite sides of the steam-port flange, that the bottom edges of this portion may be also placed parallel with the face. This adjustment being completed, the cylinder is ready for being scribed upon the four narrow sides or edges of its flange. In order to properly place these lines, the desired thickness of the flange is ascertained and marked by a dot or a short mark on the edge, or, properly speaking, on the narrow side, the distance being measured from the bottom edges, which are those situated nearest to the table. Supposing the flange, now in its rough state, to be an inch and a sixteenth thick, and that it is to be finished to seven-eighths thick, a mark or dot is made upon the narrow side at seven-eighths from the lower edge, and such a mark will show, by inspection, that three-sixteenths of an inch of metal is to be cut off. The final scribing of the flange is now effected by adjusting the scriber-block point to the dot or mark on the flange while the block rests on the table, and scribing a periphery entirely around the flange upon all its four narrow sides. In the Fig. (819) a scriber-block is shown in position for marking this periphery, which is afterwards used as gauge-lines to which the rugged superfluous metal is chipped.

Machine-shaping.

The various methods of shaping by paring-machines include cutting operations by means of drilling-machines, slotting-machines, and shaping-machines. It is therefore necessary to describe such machines, and to indicate their mode of action; also to define whatever terms are ambiguous. Such terms will be frequently used in the details given concerning the shaping operations; therefore considerable attention to names and to the action of the machines described is requisite.

Shaping-machines.—All paring-machines are shaping-machines; but that class which are specially named universal shaping-machines, are those which act with a short to-and-fro travel of their cutting tools, and are therefore distinct from what are termed planing-machines, because the cutting tool of a planing-machine is stationary during the time the metal in contact with the tool is being cut.

The class of ordinary shaping-machines which are at the present time in use are represented in Plates 64 and 65. In Plate 64, Fig. 829 represents what is termed a long-bed shaping-machine, and is capable of shaping objects which are comparatively long and slender. Fig. 831 also represents a long-bed machine, in which an object to be shaped is seen gripped with two vices belonging to the machine. Fig. 830 shows a short-bed machine, and is therefore only suitable for shaping small objects, or for shaping short portions of large objects.

Shaping-machines are actuated by means of leather bands, or india-rubber ones, which are connected with auxiliary shafts, such shafts being driven by other bands from the power-shaft of the factory. This means of imparting motive power to the shapers is denoted in Plate 64, and is similar to the mode of driving lathes. But shaping-machines are easily actuated in the same manner as planing-machines, by connecting the machine-bands with a shaft situated beneath the floor.

In Plate 65 the various portions in a machine of this class are indicated by letters and names, and such names belong to similar machines of all sizes, whether long or short, small or large. The fundamental portions of the machine consist of a long heavy portion termed the bed, and two pedestals or standards, on which the bed is bolted, unless it happens that the bed and standards constitute only one casting, which is the case in some small machines. On the top of the bed is situated the carriage, which slides along the entire length of the bed and fits any part of it by means of dove-tail surfaces. The upper portion of this carriage is provided with a dove-tail gap, or with an angular gap of some class, for containing the slide portion or dove-tail of the moving head, in order that this part may easily move to and fro, and at the same time accurately fit the groove or gap in the carriage. Attached to the head, and often solid with it, is a circular flange-portion, named the flange, and shown by F, to which the slide-rest is connected. In front of the flange, a portion having a curved upper edge with worm-teeth is seen, termed the segment-rack or sector-rack, indicated by R, which portion is actuated by the worm-pinion and its spindle, denoted by W. Behind the worm-pinion is a straight slide, which is moved upwards and downwards by a screw within, which is not seen; but the wheel shown at the top is the means of rotating the screw, and thereby moving the slide. The motion of this slide is the slide-rest's vertical traverse; consequently the screw is termed the vertical traverse-screw. This slide, together with the other portions attached, are termed the slide-rest. The tool-holder is a portion connected to the sector-rack, and the two grippers or tool-clamps are denoted by T C. By means of the vertical traverse the tool which is fixed in the tool-holder is accurately adjusted to the precise height required, after an object to be shaped is fixed and is ready to be cut. This is the principal use of such a traverse, therefore the screw within the rest is only a few inches in length in the largest machines.

In order to properly place the article to be shaped, it is bolted to one or both of the chambered tables attached to the front of the machine. These tables can be fixed either close to each other or at any desired distance apart, to suit the intended shaping, being moved along the front grooves by rotating the screw. The exact height of a table when arranged for use depends on the thickness and shape of the piece which is on the table, the precise height being attained by working the screw in the chamber or space beneath.

The motion for moving the head to and fro, is obtained from the spindle belonging to the step-pulley at the back of the machine. To this spindle a small cog-wheel termed a pinion is keyed, the teeth of which are engaged with the teeth of a larger cog-wheel termed the power-wheel. The power-wheel is indicated by P W, and is connected with the crank-arm or lever-arm shown by L A, this being the arm which actuates the connecting-rod shown by C R, thereby moving the head slide-rest and tool to and fro in the manner desired. On the left-hand end of this spindle is connected a hollow cylindrical box, having the small gear for moving the cog-wheels seen at the ends of both the horizontal traverse-screws, such motion being necessary while the machine is at work.

The operation of a machine of this class produces planes, by the tool-point being made to generate planes by its movement, while the article remains comparatively stationary on one or both tables; and the plane is generated by the traverse screw moving the carriage and tool-head along the bed at the same time that the tool is moved to and fro with the connecting-rod. For producing curved concave surfaces, the piece of work also remains stationary; but in such cases the carriage also is stationary, the tool-point being made to generate the curved figure desired by the to and fro motion of the tool combined with its curved motion, which curved motion is effected with the worm and sector-rack.

Some of these machines will also produce convex surfaces, such as the outer surfaces of lever-bosses. The movement required for such shaping is obtained by partly rotating the boss which is to be shaped. With this object a couple of conical pivots situated in front of the machine are made to tightly hold the lever-boss by placing it between each cone and screwing tight the fixing-bolt, a portion of each cone being in the boss-hole, this hole having been previously accurately bored. While thus held the pivots are made to rotate slowly, and consequently the lever also, the rotary movement resulting from the pivot-spindle having a worm-pinion and wheel attached to the long horizontal spindle within the machine. The circular motion of the boss being shaped, combined with the rectilineal motion of the tool-point in contact, produces the curved shape required for the outer surface of the boss, no rotation of the worm and sector being necessary. Shaping outsides of bosses, is however, more easily done with up-and-down slotters, which are next described.

The cutting tools that are required for shaping-machines, are of the same shapes as those for planing-machines, with the addition of a few tools which will be introduced in connexion with the details of processes.

Slotting-machines.

The slotting-machines here mentioned are those which work with an up-and-down vertical movement of their cutting tools, while the pieces being cut or slotted remain relatively stationary. It will be seen in future sections by the several sorts of shaping and slotting effected with shaping-machines, and slotting-machines, that both these classes of machines will perform the same class of slotting and shaping; so that a choice of two machines exists for shaping one object. The relative movements of both machines are about the same, but differ in direction; the tool of a shaper moving in a horizontal direction, and that of a slotter moving in a vertical direction. For engine-work in general it may be stated that a slotter is the more valuable machine of the two.

In their action all slotting-machines, small and large, resemble each other, and the entire class are represented by Fig. 834. By this Figure it will be seen that the machine mainly consists of a standard somewhat like a letter F, and a lower fundamental portion which supports a circular table in immediate connexion with sliding apparatus beneath. The F-shaped portion is that to which the whole of the apparatus for cutting is attached, and the lower portion is that to which all the slides, screws, and wheels for gradually moving and adjusting the work are connected. The cutting tool, by which the superfluous metal is cut from the object being slotted, is shown by its name, and its movement upwards and downwards is its only motion, excepting a small movement for releasing the tool's edge from the metal during the upward movement. The vertical motion of the tool results from its being attached to the main slide, and partaking of its motion. This slide is moved by the connecting-rod, C R, in the lower end of which is the crank-pin, which is attached to the wheel or disk rotated by the main shaft of the machine, to which shaft the step-pulley and its gear are connected. The machine-band of this gear is seen attached to the pulley, and also to the auxiliary shaft above.

The vertical motion of a slotting-tool combined with the comparative slow motion of the work and table beneath, together effect the slotting, or other shaping which may be in progress. The table, and consequently the object attached, is capable of three motions; and in this capability consists the utility of the machine, the cutting tool being capable of only one motion. Beneath the circular table, and connected to it, are two sliding plates or slides, which move across each other in two directions, the one being at right angles to the other, the motion being similar to that of a slide-rest belonging to a planing-machine or to a shaper. The two motions are produced by the rotation of two screws within the apparatus, and, if necessary, both of these can be rotated at one time to produce a diagonal movement, across the machine. The third movement of the table is a rotary one; this is managed by providing a pivot at the centre of the table, by which means it is made to rotate, either singly or in conjunction with one of the rectilinear sliding motions. To produce the rotary movement, the table is connected to a worm-wheel, shown by its name, in the teeth of which a worm-pinion is engaged, the pinion driving the wheel by being fastened to the spindle S. By reason of this spindle being connected with the rod and levers, which derive their motion from the pulley-spindle, the table is rotated, and also the object which is bolted to it, whenever such a movement is desired.

The small teeth-wheels shown near the table, are the means of rotating both of the traverse screw for the rectilineal motion, and also the worm pinion for the rotary motion, one of the wheels being on one end of the worm-spindle, and the others being on the ends of the two traverse-screws. These screws may be termed the slide-rest screws, because the entire sliding apparatus constitutes a large compound slide-rest.

SLOTTING-TOOLS.

The cutters or slotting-tools for use in slotting-machines, are represented in Plate 61. In this plate, Fig. 782 represents a groover having a short thin end; and is suitable for cutting key-grooves which are but short, or of but small width and depth. The tool consists of but one piece, consequently, the cutting end is produced by reducing a portion of the thick part termed the stalk, (see page 225). A slotting-tool with such a small end is also used for commencing or partly forming slots and grooves, that are to be also partly formed with other slotting-tools.

Fig. 783 represents a slotted tool, in which is keyed a separate cutter. Such a tool is used for the convenience of making one stalk serve for a number of cutters whose shapes and sizes differ from each other; also for avoiding the reduction of the stalk, whenever a new cutter is to be made. The movable cutters are quickly made of steel of proper thickness and width, and the cutting edges are easily ground to any desired shape and angle, to suit their special work. The stalk shown by Fig. 784, is also used for holding movable cutters, but has its entire slot situated above the bottom, this arrangement being sufficient for holding very short cutters.

A tool which is employed to form comparatively long and narrow slots and grooves, is indicated by Fig. 785. When it is requisite to employ a slender cutting end of great length, the end is thinned behind its cutting edge, and spread out, as seen in the Figure, to obtain strength for preventing bending and breakage through the strain imposed while cutting the metal.

If it is required to form a very long groove, which is but shallow, a tool having a cutting-end projecting but a very short distance from the stock's side is suitable, because the stalk may then pass along very near the object to be cut, but without touching it. But for making a deep groove, or one which is to extend deep into the metal it is necessary to provide a long cutting end, and to keep the entire stalk-portion of the tool above the work. Consequently, a groove which is to be comparatively shallow, is properly cut with a movable cutter, similar to that shown in Fig. 783 or 786; and another groove, which probably is to be no longer than the shallow one, but is to extend much deeper into the metal, will be properly formed with a tool having a long end, resembling that denoted in Fig. 785.

Slotted-stock tools, which are necessary for shaping outsides of bosses, outsides of other articles having convex surfaces, and also articles having concave surfaces, are represented by Figs. 787 and 788. In these Figures, the cutters consist of short vee-point tools, similar in shape to slide-rest tools, but having short stalks. A one-point cutter of this class is keyed in the slot, so that the cutting point shall be at any exact distance from the stalk that is necessary. For shaping outsides of lever-bosses by such a tool, the point is in all cases situated very near the stalk, to obtain great rigidity while cutting, and because the point is, for such shaping, never required to extend deeply into the metal, as requisite while forming a groove. The cutter which is shown in Fig. 787, is one which is suited for iron and steel; and the one seen in Fig. 788, being straight, is suitable for brass and gun-metal.

Feather-tools are those which are indicated by Figs. 789 and 790. A tool of this class consists of a stock and a feather-portion, this portion being solid with the stock, and constituting the cutting part of the implement. Fig. 789 shows a half-feather tool, and has but one cutting portion; whereas that shown by Fig. 790 has a complete feather-part, and cuts at either or both sides of the tool, if required. Such tools are used for making key-grooves into lever-bosses and wheel-bosses, a tool which has a complete feather being employed to form two grooves into opposite sides of a boss at one fixing of the object. Two grooves of this character can also be easily made with a slotted tool and a keyed cutter, such as that shown by Fig. 795, and for a great quantity of work such tools are preferable to feather-tools.

Although feather-tools of large sizes are used, there is no advantage resulting from their employment, except that they sometimes avoid the necessity of making a slotted stock and its cutter. Feather-tools are troublesome to forge if large, because of the necessity for upsetting and fullering the sides, to produce the feather-portions; their use should therefore be avoided, except for small grooves which may be only about a quarter of an inch in width or depth. For a small groove, a feather can be quicker made by the fullering referred to, than by drilling and filing a slot and preparing a distinct cutter.

The slotting-tool shown by Fig. 791 is a mortiser. These are a very useful class of tools, both because they can be easily made and mended, and because they suit a great variety of work. The cutting end of such a tool is easily formed by thinning a part of the thick stalk-portion until a stem of the proper length and thickness is produced. This end, after being made small enough, is bent forwards, in order that the cutting-edge may at any time during cutting, be in contact with the metal without allowing the stalk to touch. This arrangement is termed clearing the stalk, and will permit a key-way or other groove to be made, the length of which is greater than the length of the tool's thin end or stem, because while cutting such a groove, a portion of the stalk is allowed to pass along near the object without touching it. The distance into the metal or depth, to which a mortiser's end will extend while cutting, depends on the distance which the tool's cutting edge is situated beyond the stalk; consequently, the greater the extent to which the tool is bent, the greater the depth to which the groove may be cut. There is, of course, a limit to which the bending forwards of the stem may be carried, because the tool is weakened thereby, and therefore made liable to quiver and break. In general, mortisers are suited to work of all sizes, and for all grooves which are of comparative great width.

A short springy tool keyed in a stocker is denoted by Fig. 792. Springy tools in slotting-machines are employed to smoothly polish surfaces, as in planing-machines and shapers. The tool seen in the Figure (792) is one having a nearly straight cutting edge, and is useful to smooth the outsides of bosses after they are roughly shaped with vee-point tools. Other springy tools, having curved cutting-edges, may also be keyed in the same stocker, when necessary;

curved tools being required to shape grooves with curved bottoms, and also to shape ridges and corners. Point-tools also may be keyed in, resembling those in Figs. 787 and 788. It will be noticed that the slotted ends of the stocks seen in Figs. 787 and 788 are of no greater thickness than the upper portions; consequently, such stocks are suitable for holding comparative small cutters; whereas a stock with a broad boss, resembling that in Fig. 792, may be employed for holding comparative thick cutters made of square steel.

The point-tools represented by Figs. 793 and 794 are used for the same class of work as the tools denoted by Figs. 787 and 788. The difference in the two species of tools consists in the one having cutting ends which are solid with the stocks, and the other species having slotted ends for containing distinct cutters. Those which are slotted should be used for large work in general, and the solid ones for all small articles, such as those that require stocks only about an inch square. Square steel of about this size is easily reduced to produce the cutting ends suitable for small objects. Both these species of tools will perform similar work, which consists in shaping convex surfaces, such as the outsides of lever-bosses and objects of similar shape. These tools will also shape concave surfaces, which include those belonging to rims of wheels, curved junctions of arms, links, and bearer-brasses.

A tool which somewhat resembles a feather-tool is denoted by Fig. 795; but in this the cutter is a distinct piece of any length and thickness, which is keyed in the slot when required for use. A tool of this class may be used in two ways, either by making it cut at one side of a hole, or at two opposite sides, as if it were a single piece like a feather-tool. Generally speaking, it may be said that this and all other slotted tools for holding distinct cutters, are more suitable for large work than small, because after the slots are formed at the first making of the implements, all future forging for repairs is performed upon the comparative small movable cutters, and is therefore much easier than forging the thick stalk-portions. Another advantage belonging to a slotted tool consists in its allowing the cutters to be detached when they are to be ground, without the need of removing the stock from the tool-clamps.

DRILLING-MACHINES.

The simplest class of drilling-machines are fiddling drills, which are represented by Fig. 272, and are rotated by the drill-bow shown by Fig. 274. The next class of what may be termed drilling-machines are crank-braces, shown by Figs. 276 and 360. Another class of small tools for drilling are swing-braces, denoted by Fig. 363, which should be termed ratchet-levers. (See page 122.) All such machines make holes by causing their drills to rotate while the pieces in contact being drilled are relatively stationary. The drilling-machines to be here mentioned, are also those which make holes by rotating their drills; but are specially termed drilling-machines. These are capable of making holes small and large, to about two or three feet in length and ten or twelve inches in diameter. All of them form cylindrical holes whose lengths are vertical; or, strictly speaking, form cylindrical holes whose planes are horizontal. While such are in action with the drills connected, the lengths of the drills are vertical, for which reason they are named vertical drilling-machines, or briefly, verticals.

The value of a vertical is estimated by its capability of making cylindrical holes. The forming of straight holes which are truly circular, is the great requisition in all such machines whether small or large, although they are occasionally used for a few other purposes, the details of which are given in the ensuing processes.

To produce a cylindrical hole whose planes are horizontal, either one of these three plans may be adopted: a drill-point or other tool-point may be made to generate a helical or screw motion whose axis is vertical, while the piece in contact being drilled is stationary; or the piece may be made to generate a circular motion while the drill-point is slowly advanced in a right line; or both the drill-point and the object being drilled, may be made to generate helical motions at the same time, in which case the direction of the object's motion while being cut, is opposite to that of the cutting tool or drill. Of these three modes, the first mentioned is that which is adopted for verticals; the second plan being that which is used in lathes; the third plan, consisting in making both the object and the tool rotate at the same time, is seldom resorted to. We have to here consider only the movements belonging to verticals.

The drilling-machine shown by Fig. 836, mainly consists of an F-shaped standard similar to that of a slotter, and to the standard the apparatus for rotating the drill is connected. The table may be termed the next principal part of the machine, being that on which the object to be drilled is bolted, and seen at the front of the Figure. The spindle whose length is in a vertical position is the drill-spindle, in the lower end of which the drill is fixed and thereby rotated. This rotary movement is obtained by means of the bevel wheel seen on the spindle, the teeth of which are engaged with those of another bevel wheel whose spindle is rotated with the step-pully and machine-band.

In addition to the rotary movement of the drill-spindle, it has also a downward vertical motion while cutting, which is obtained by rotating the hand-wheel named the feed-wheel, denoted by F W, to which the feed-spindle is keyed. At the upper end of the spindle is keyed a worm-pinion, and by this being rotated the worm-wheel in contact is also rotated, actuating a pinion situated at the further side of the machine. The use of this pinion is to raise and lower the row of teeth shown by R, termed a rack; and through the rack being attached to the drill-spindle, the up-and-down movement is obtained when desired by rotating the feed-wheel. The short band denoted by F B, is the feed-band, and is used when a long hole is being made to avoid the necessity of working the hand-wheel by the operator. At the time the feed-band is employed, a small worm-pinion is made to rotate the lower worm-teeth wheel, which is indicated by L W.

By reason of the bevel wheel situated on the drill-spindle being required to rotate the spindle while it advances either downwards or upwards, some means must be provided to admit this sliding motion, and the result is attained either by forming a key-groove along the length of the spindle and placing a key or ledge in the wheel's hole to fit the spindle groove, or by forming a ledge along the spindle to fit a groove in the wheel. Either of these arrangements will allow the spindle to be freely moved upwards and downwards without in any way altering the situation of the bevel wheel which transmits the rotary motion, and which must necessarily be at all times engaged with the bevel wheel situated on the pulley-spindle.

Fig. 837 represents a vertical whose action is similar to that of the one just described, but possesses additional apparatus termed power-gear. This consists of cog-wheels which are connected both to the pulley-spindle, and to the shaft immediately above, shown by A S. Both the wheels on this shaft are keyed tight in their required places, and remain so at all times. Such gear is required to obtain a comparative slow motion and great power for rotating the drill-spindle to make large holes. Such power not being required when making small holes, the wheels constituting the gear are disconnected at that time, and the disconnexion consists in sliding the shaft A S in the direction of its length in order to move the wheels keyed thereon away from the cog-wheels on the pulley-spindle. In order to cause the small wheel on the pulley-spindle to rotate independently of its spindle, when a slow motion is required, this wheel is allowed to be loose, but is permanently fixed or cast solid with the step-pulley, and therefore always moves with it. The large wheel on this same spindle is, however, keyed tight to it, instead of the pulley, and moves always in conjunction with the spindle either quick or slow, consequently when it is desired to quickly rotate the spindle for making small holes, the pulley is made to rotate its spindle by means of the fixing screw F, which slides along its slot in the wheel, and is made to grip a projection inside the pulley which is adjoining. To cause the pulley to rotate loosely, independently of the spindle, which is requisite when all the power wheels are connected with each other, the fixing screw is slid along the slot away from the projection or stop inside the pulley, and is firmly tightened at the inner end of the slot to prevent possibility of becoming loose while at work, and doing mischief.

The table of this machine (Fig. 837), to which the objects to be drilled are bolted, is similar to that shown in Fig. 836, and is a portable affair which may be detached when necessary.

While the table is in use it is situated at the required height, and can be raised or lowered by means of the rack seen in the Figure. When the table is not required, as in cases of a long boring-rod being used, the machine appears as in the Figure (837). The rod is seen extending downwards to a base-plate or table, which is fixed so that its top is level with the floor. In the table are formed a number of slots for containing holdfast bolts, with which articles are fastened that require boring. Right-angular gauge-lines also are shown for adjusting the pieces previous to a final fastening. About the middle of the table a circular hole is carefully bored, its axis being exactly in line with the drill-spindle; and in the hole a garnisher with a hole of any desired diameter is denoted by G.

A machine which is both a slotter and driller is represented by Fig. 835. This is suited for small objects that require accurate and easy grooving, especially if the grooves to be formed are of comparative great length and situated in holes of small diameter. To avoid the tedium of chipping through a small hole of this character, the article can be fastened between the vee-clamp chuck in front of the machine, and grooved in a comparatively easy manner. The machine is worked by hand, the long handle-lever being moved up and down while the slotting-tool is in contact with the metal.

If holes are to be drilled with this machine, the long lever is disconnected, and the spindle is rotated by working the handle seen connected to the two bevel wheels, which resemble analogous wheels in all other drilling-machines, with the difference of working them by hand-power instead of by steam-power. The vee-clamp chuck of this machine will be found remarkably efficient for a rapid and accurate fixing of all small articles. It should be made with the upper surfaces of the two vee-clamps parallel with the table beneath, and also at the same height above it, which arrangement will allow an object to be quickly fixed with its lower surface at right angles to the vertical motion of the drill or slotting-tool, as required.

ACCESSORY APPARATUS FOR DRILLING-MACHINES.

The auxiliary implements which are required for use with drilling-machines consist of drills, rosebits, guide-drills, boring-bars and their distinct cutters, el-chucks, spindle-chucks, vices, and holdfast plates with their screw-bolts and nuts. Some of these, such as el-chucks, spindle-chucks, plates, and bolts, are the same in shape as those described in pages 216, 217, and 218, for planing-machines; consequently, it is only necessary to here mention the implements that are specially intended for drillers.

Drills.—A machine-drill is a straight piece of steel, one end of which is conical for being held tight in the boss of the machine's drill-spindle, and the other end of which is thinned and pointed for cutting. The pointed extremity of a drill is a pivot on which the drill rotates while passing through the metal, and the two straight sides that bound the end are provided with two edges, which are the cutting edges, each drill having only two.

Figs. 838, 839, and 840 represent ordinary drills having conical points, which differ in shape from each other to render them suitable for various work. A drill with an end which is not very taper is shown by Fig. 838, and is fit for making holes that are to be comparatively shallow, but which require to be smooth. Fig. 839 denotes one with a sort of medium end for all sorts of holes in various metals. Fig. 840 shows one which cuts freely without being very steady; this one is provided with a couple of grooves in the cutting part, to form keen edges, one of which grooves is represented by the line across the end. Drills of this sort are termed roughers; if made in this form they are much keener than those denoted by Fig. 838 or 839, the keenness being the result of thinning the cutting edges, and therefore making them of comparative small angle. In order to properly shape these grooves it is necessary to form them with a true edge of an ordinary grindstone. This edge is what is termed sharp, when speaking of a grindstone, and will allow a drill to be held thereon without damaging or wasting the point.

Drills which have these grooved points are imitations of the joiners' centre-bits employed for wood; the pin-drills shown by Fig. 842 are also of similar character. While the grooved points remain entire they are very effectual for easy cutting; but when they are become worn and broken they lose their keen character by the grinding which is necessary, their shapes being thus made different to those they originally possessed. After being re-ground, all, or nearly all, of their previous keenness is lost, unless new grooves are formed; and if this is done the drill-end is very much thinned, and therefore weakened. The re-grinding also reduces the extreme diameter of the drill-point, which is termed the drill's size; and one or two grindings and groovings will reduce it sufficient to require it to be re-forged. By this it may be easily perceived that these drills are specially adapted for roughly boring holes where none exist, being more suited to gun-metal and iron than to hard steel. If a large amount of metal is to be removed, previous to finishing a hole with a smoothing tool, a keenly cutting drill is suitable to commence with, although it may make a rough hole; and if the drill-end is reduced in diameter with re-grinding, the difference of size is not important. For such work the drill-point may be shaped several times by grinding, without making it too small for its intended use.

Rosebits.—Machine-rosebits are represented by Fig. 841. It will be seen that the cylindrical part of the tool is provided with long narrow grooves, termed flutes. These are three in number, and are smoothly formed, to allow the oil or water applied to the tool while cutting to flow easily downwards to the cutting edges, and take with it all shavings that enter the flutes. These grooves also diminish the amount of bearing surface of the cylindrical part, and therefore lessen the amount of friction which would be incurred without them. Of the three grooves one is shown by the two lines in the Figure. Rosebits are used for smoothly finishing holes in objects of all classes, whether made of gun-metal, iron, or steel.

Guiders.—A guide-drill or pin-drill is one which is furnished with a cylindrical pivot-end, such an end being solid with the cutting portion of the tool. A drill of this sort is denoted by Fig. 842, and its pivot-end constitutes a guide that guides the cutting part while in use. For this purpose the pivot is made to rotate in a hole the diameter of which is equal to that of the pivot. The tool is only useful for enlarging holes that were previously made with other drills, and the pivot-end must in all cases properly fit the guiding hole, both to ensure an easy advancement of the pivot along the hole, and to ensure a steady guidance of the cutting edges, in order that the hole may be smoothly formed to its desired shape and dimensions. The pivot has no capability for cutting; consequently, if any portion of the guiding hole is too small, it will not be enlarged by the pivot arriving at that part, but it will tightly grip the pivot and break it off. When it happens that the hole is too large for the pivot, the operation of the drill makes the hole rough and also larger in diameter than the extreme diameter of the drill.

It is sometimes necessary to employ these tools in holes which are larger in diameter than that of the pivots; for such work the pivots are garnished. Garnishing is often necessary, because it is frequently requisite to use the same pin-drill for enlarging the mouths of holes which differ from each other in diameter, and which cannot be all bored to suit the pivot by reason of the different uses to which the holes will be applied.

Garnishing the pivot is done by fitting a small tube of gun-metal or steel to it, so that the outer surface of the tube just easily fits the guide-hole in which it is to rotate, and the inner surface fits the pivot tight enough to prevent shifting during use. When such a tube is to be used for a large quantity of work, it should be made of steel, and very smoothly finished, also provided with a small key to securely fix it For comparative thin garnishers that may be only about a sixteenth thick, a hole should be drilled through both tube and pivot, and a small steel pin driven in. Those that are an eighth or a quarter thick, may have flat surfaces or shallow key-grooves, the lengths of which are parallel with the lengths of the pivots, the keys being driven in at the pivots' points.

Fig. 843 denotes a pin-drill with cutting-edges inclined at a desired angle with each other. A tool of this shape will enlarge the entrances of holes, in a manner resembling that of the drill shown by Fig. 842, but will form conical holes instead of cylindrical ones. By making the taper cutting end of the tool of a great length, it can be used for coning a number of holes which differ considerably from each other in diameter.

Broach-Drills.—A broach-drill is analagous to the conical pin-drill indicated by Fig. 843; but is without a pivot-end, therefore not steady in its action, unless it is what is termed, nearly parallel. The tool is shown by Fig. 849, and is rotated in drilling-machines in the same manner as other drills. It is of no use for commencing holes, through having no point properly shaped for the purpose, but is available for all holes that have been previously bored with other drills. It is of very simple form, and easily made, consisting merely of a thin drill having a very long end for cutting along its sides, which end is easily shaped to the proper angle with grinding. The comparative great length of this portion renders it suitable for making conical holes of various diameters and depths.

The principal uses of broach-drills are, roughly enlarging mouths of holes that are intended to contain rivets, and tapering holes along their entire lengths to avoid broaching with other tools. For making a deep conical mouth to a hole intended to contain a rivet, the tool is very efficient, the rotation of it in the drilling-machine rendering the operation very easy, and the thin cutting end removing the shavings with but little friction. For cutting brass and gun-metal the tool is used dry, but for iron and steel oil or water is applied, with a much slower rotation. For broaching holes along their entire lengths, the tool is more efficient in short holes than in long ones, especially if the metal being cut is iron or steel. It is also requisite to apply only a gentle pressure during this broaching, to prevent the comparative thin end breaking off with the friction resulting from a great length of cutting edge being in contact with the hard metal.

Drilling-Bars.—A drilling-bar or drilling-rod is a cylindrical rod of steel, of any suitable length and thickness, in which is formed a slot for containing a distinct steel cutter and fixing-key. Boring-bars or drilling-bars are used in a variety of machines and in several different ways; and when one is used in a drilling-machine, it is held at its upper end in the boss of the drill-spindle, and rotated in the same manner as drills and rosebits; but no portion of the rod is capable of cutting, all the cutting tools used with the bar being distinct pieces. The boring-rod is, therefore, a holder for containing and properly guiding the various cutters while in use.

There are two principal modes in which the rod may be used, one of which consists in causing the rod's lower end to rotate in a hole already drilled in the object being bored, and the other mode consisting in causing the lower end to rotate in a suitable hole formed in the table of the machine. When the rod is so used that its end fits a hole in the piece of work beneath, the end in the hole resembles the pivot end of a pin-drill, because the guide-hole first made contains the rod's end and guides it during its passage downwards at the time of cutting, the cutter which is keyed in the rod performing in a manner similar to the cutting part of a pin-drill. The rod's end is also guided if situated in a hole in the machine-table, in which case, the hole is so bored, that its axis is exactly in line with the drill's axis of rotation. By referring to Fig. 837, a drilling-rod in the situation here referred to, may be seen fixed.

A boring-rod may have two or three slots for cutters, and for some purposes, all may be used at one time, when two or three cutters are required to cut at one time. Fig. 847 represents a rod having two cutters keyed in their places, and are fixed the one at right-angles to the other, in order to prevent the strain of both cutters acting in the same direction across the rod. The boring-rod shown by Fig. 848 is a comparative strong one, in which is keyed a cutter for facing; an operation which is to be detailed. It may be here mentioned that through all boring-rods being comparatively slender, the thickest rod which can be used for a stated work, is always selected, to avoid vibration while in contact with the object being bored.

To avoid the vibration and bending of a drilling-rod while cutting, is an important desideratum, when a long hole of comparative small diameter is to be bored, because the trembling of the rod always makes the hole rough, and sometimes entirely prevents the cutting of the cutter or cutters in the hole. An object with a small hole will not admit a rod of great thickness, consequently, a slender one must be used, and vibration prevented, as far as convenient. The mode of treatment resorted to for avoiding the trembling of a long-rod, consists in steadying it. This consists in adopting means for counteracting the strain of the cutter; and this is effected by fixing a piece termed, a steady, in the rod, so that one end of the steady shall be keyed tight in a slot, and the other end project from the rod a sufficient distance to bear tight against the side of the hole being bored. The steady should be of steel, and that end intended to bear in contact with the side of the hole, should be curved and smoothed, that an easy movement may be secured, and friction to some extent avoided. When only one steady is employed for the purpose, its friction surface is made to bear upon that side of the hole which is opposite to the side at which the cutter is cutting; but when two steadies are used in one bar, they are keyed at an angular position of about a hundred and twenty degrees to each other, and also to the cutter. This arrangement is named triangular, or tri-radial; the other mode, in which only one steady is used, being termed diametrical.

Spindle-Bosses.—The bosses of drill-spindles are denoted by Figs. 850 and 852. The hole in a spindle-boss for tightly holding ends of drills, boring-rods, and other tools, may be either square or circular. In either case, the hole is tapered, in order to easily enter and detach drills whenever necessary. A regular conical hole is that which is most frequently provided, similar to those shown in the Figures.

The boss denoted by Fig. 850 is furnished with a steel fixing screw for holding the drill after being pushed into the hole, the length of which screw should be at right-angles to the drill-spindle's long axis. In the dotted lines which indicate the place and shape of the drill's end, may be seen a shallow flat bottom gap, in which the screw's point is tightly screwed with a tommy in the hole of the screw's head, which effectually prevents loosening of the drill while at work. The bottom of this gap requires to be right-angular to the length of the screw, to ensure an equable bearing of the point when tightened. A boss having a screw of this class, should have a hole the sides of which are at an angle of only four or five degrees with each other, that the act of tightening the screw may not loosen the drill's end, which results if the hole is too taper. It is, however, necessary to remember that the nearer the sides of the hole resemble parallelism with each other, the greater is the difficulty of releasing the drill from the boss when requisite. But a nearly parallel hole is very effectual for obtaining a firm grip, which is necessary to make the drill rotate properly. Consequently, the trouble of hammering the drill to loosen its end if only slightly conical, is to be placed against the facility with which it can be tightly and accurately fixed.

To obtain a spindle-boss that will allow a drill-end to be immediately detached without hammering, and which will also exactly and tightly fit a drill-end within, it is necessary to provide the boss with a hole which is very taper, resembling that in Fig. 852; and instead of furnishing the boss with a screw, a thin key must be inserted as denoted in the Figure. By means of a key the entire conical part of the drill's end in the hole is made to fit exactly to every part of the hole occupied by the drill, the act of driving the key causing the cone to be wedged into the hole until in close contact. A very taper end cannot be made to fit thus closely by screwing the point of a screw thereupon; but with a key a perfect contact is secured, however great the amount of tapering may be. The use of a key also prevents distortion of the conical hole in the boss, such distortion resulting from the series of repeated strains imposed while tightening a fixing screw. The only objection to the use of a key for these purposes, is the extra time required for entering and dislodging it. This frequent shifting of drills and boring-bars is but seldom requisite for large work; therefore it may be said that keyed ends are suitable for large machines, and ends fixed with screw-points are suitable for small machines.

By Figs. 851 and 853 two drills' ends are shown detached from their respective spindles, the one denoted by Fig. 851 belonging to the boss shown by Fig. 850. In Fig. 853, which denotes an end belonging to Fig. 852, the shape of the key way is shown, having curved top and bottom surfaces.

Drills' Points.—Properly shaped drills' points are represented by Figs. 854, 855, 856, and others shown near them. To make a drill cut easily, and to allow sufficient room for the shavings detached to get out of the drill hole, it is requisite that the portion immediately adjoining the point be of less extreme diameter than the extreme diameter between the two cutting edges. This diameter is termed the drill's size; and the difference between the size and the narrower part adjoining, is termed the clearance. When the clearance is not sufficient the shavings become wedged between the drill's end and the sides of the hole and breaks the drill. But when the clearance is too great the drill is rendered very unsteady while cutting, which causes the hole to be rough and also tends to break the drill. A drill with this defect is also more liable to bore a crooked hole, than a drill which has only a proper amount of clearance. In addition to this there is an advantage in a properly formed drill not being much reduced in size by the grinding for sharpening.

The greatest amount of a drill's clearance exists at the place where the taper part of the drill's end terminates and the parallel part begins. At this place the diameter of the parallel portion for general purposes, should be about eight-tenths, or seven-tenths of the drill's size, which will provide a medium amount of clearance for general work, whether the holes to be made are small or large.

Figs. 854 and 855 represent drill-points whose cutting edges subtend an angle of about seventy-five or eighty degrees, which is that required to prevent the drill-point getting out of position while drilling, and thereby making a rough hole or shaking the drill. Such a shape will suit brass, iron, or steel; but if more pointed the point would break with the pressure which is applied while cutting. The end shown by Fig. 855 is more suited to hard iron and steel, being thicker than that shown by Fig. 854.

Drill-ends having grooved points for obtaining keen edges without much strength, which were mentioned in page 260, are denoted by Figs. 859, 860, and 861. The one shown by Fig. 859 has a narrow groove; this is required to avoid using a comparative large portion of the end when it happens that its length is of importance. A wider groove which occupies a considerable length of the drill-point is seen in Fig. 860; this shape allows plenty of room for the shavings, and is that usually made with ordinary grindstones. By reason of such grooves being always adjoining the cutting edges, the drill-points are grooved to suit the character of the drill, whether left-handed or right-handed; a grooved point of a left-hand one being indicated by Fig. 861.

Right-hand drills are those denoted by Figs. 854, 855, 858, 859, and 860. Left-hand ones are those indicated by Figs. 856, 857, and 861. Of these two species those employed in any one machine are suited to the direction in which the machine's drill-spindle rotates; some machines requiring right-hand drills, and others requiring left-hand ones. The drill-end represented by Fig. 858, is a right-hand one; and a view of the point is given for those who may wish to easily distinguish a right-hand point from one which is left-handed.

GENERAL MACHINE-SHAPING.

The details of paring processes here given include the applications to use of the ordinary machines and implements which have been treated, and also the use of additional apparatus required for special work. It may be here generally stated, that shaping-machine processes are more suited to both commence and finish the planing of an object than slotting-machine processes, because, although a shaper is comparatively small, its cutting tool has two motions, whereas a slotter has but one. A shaper will commence the planing of an object which has not been previously machined; but generally speaking, a slotter requires that the articles to be slotted shall be previously either planed, turned, or bored.

Bolt-heads.—Hexagonal bolt-heads after being lathe-turned, require the six planes to be produced, either by means of a small shaper, or with a planing-machine, the particular machine selected being suited to the dimensions of the heads to be shaped. Heads that are only about two or three inches in diameter, are shaped on a table of a small shaping-machine; several may be fixed at one time, and the bolts are so situated that their lengths are parallel to each other, and parallel to the to-and-fro motion of the cutting tool, the bolt-heads being in line with each other and near together. While thus situated one plane of each head can be produced at one planing by only one fixing; and for this purpose the stems of the bolts are supported in the notches of vee-blocks, and packed up to a proper height above the table. This packing-up is not necessary if all the bolt-heads to be shaped are of similar dimensions and belong to bolts of similar diameters; but by means of packing-pieces of various thicknesses, a number of heads belonging to bolts of different diameters may be placed at any desired height; in order that all the planes that are to be produced at one operation shall be at the same height from the table. If the bolts are only a few inches in length, one vee-block is sufficient for each bolt if it has a broad vee-notch; but bolts of one or two feet in length require two blocks for each bolt, one block being situated near the bolt-head and the other one near the junction of the stem with the screw. When only one bolt is to be planed by this means, its length is quickly placed parallel with the table as required, by a pair of vee-blocks being put beneath; but when several bolts are being fixed, and packing-pieces are used, it is necessary to place a scriber-block upon the table with the scriber-point at the centre recesses of the bolt-ends, in order to ascertain what thicknesses of packing are required to place both ends of the bolts at the proper heights.

The planing of large six-sided heads that may be nine or ten inches across, is done on planing-machines, because a large table is required on which to place several bolts together at one time, that all, or nearly all, of the bolts' lengths may rest on the table. The placing of the stems on vee-blocks, the packing-up, and the adjustment of the bolts' axes to parallelism with the table, is similar to that mentioned for smaller bolts on shaping-machines. While bolts are on planing-tables their lengths may be either parallel with the direction of the table's motion, or at right-angles to it, the situation depending on the lengths of the bolts and the size of the machine employed.

All bolts, small and large, whether fixed on shaping-machines or on planing-machines, if fixed, as just described, in vee-blocks, may have all the six planes of each lot of bolts produced while the bolts are in the same situation as when first fixed, it being only necessary to loosen the hold-fast bolts after one set of planes are produced, and rotate the bolts a short distance without removing them from the vee-notches, in order to again fasten them by tightening the bolts, to prepare for another planing. In consequence of this gradual rotation being effected it will be seen that sufficient room between the bolt-heads must be allowed, that they may be freely shifted.

Making of Key-grooves.—There are several modes of forming key-grooves, and any one mode selected should be suited to the characters and dimensions of the objects to be grooved. Either lathes, shapers, slotters, or planers are employed, according to the particular class of machines that may be available.

Small key-grooves for spindles and shafts which are not more than two or three inches in diameter, are quickly and easily formed in a lathe by means of a grooving tool which is tightly held in the slide-rest and moved to and fro in contact with the piece to be grooved, which piece is fixed on the lathe-pivots. When a groove is to be cut by this means the spindle is first properly turned, and next lined while situated on vee-blocks, or by other means, to correctly show the place and shape of the key-way required; after which it is again put into the same lathe, or into another one, in the same position as it previously occupied while being turned, a gripper being fixed at the end which is near the chuck, that the spindle may be secured and prevented from shifting when not required. If the groove is to be made into a collar-portion of the spindle, or into some portion which is considerably larger in diameter than the portions immediately adjoining, the piece is ready for grooving without any drilling. But if a groove is to be made into an end of the spindle, or into the mid-part of a spindle which is parallel, it is requisite to drill a preliminary hole previous to beginning the grooving, the hole being necessary to provide a space into which the end of the cutting tool may extend. If the key-way is to be at one end of the spindle, only one hole is drilled, and is situated at the inner extremity of the intended groove, which is that end furthest from the extremity of the spindle. The hole is so drilled that its diameter and depth are the same as the width and depth of the groove to be cut; consequently, an amount of space is provided which allows the tool to move freely to an extent which equals the groove's width. A space of this kind is sometimes provided at both ends of the groove, the two spaces being necessary when the key-way is to be made in the mid-part of a parallel piece before referred to. If the groove is in such a part, room must be provided for the tool to enter the metal at one end and to escape at the other end.

When the spindle is prepared by drilling, it is tightly fixed on the lathe-pivots by tightening the poppet-screw, and the grooving tool is fixed at a proper height in the slide-rest. In order to place the groove exactly to the tool, the lathe-band is moved a short distance to partly rotate the piece; after which the tool is advanced by rotating the slide-rest screw. The cutting now proceeds by moving the rest and tool to and fro, gradually advancing the tool into the metal a proper distance each cut. Small grooves that may be only about a quarter of an inch wide can be formed with only one tool, the length of whose cutting edge is equal to the width of the groove. For larger grooves it is proper to commence with a tool which is narrower than the groove, and afterwards use one or two wider tools to make the groove of a proper width. While finishing a groove by such a process it is necessary to use a tool the cutting edge of which is as long as the width intended, because if the spindle were rotated a short distance to make a narrow tool cut at one side, the groove would thereby be malformed, because the direction in which the tool would enter the spindle would not be parallel to that in which it entered at the beginning of the cutting. Concerning the shapes of key-grooves, refer also to pages 251 and 252.

The mode of properly adjusting the tool to make it advance into the spindle in the proper direction, consists in packing it up with pieces of sheet steel of suitable thickness until the centre of the tool's cutting edge is at the same height above the lathe-bed as the centres of the lathe pivots. To ascertain whether the tool-edge is at this height, it is necessary to place the height-gauge belonging to the lathe upon the bed, with the centre mark near the tool-edge, and then to observe its height, which will indicate the amount of packing necessary. Instead of the height-gauge a scriber-block of suitable height may be used. This adjustment should be done for all the tools that may be used for one groove, whether they are used to begin the groove or finish it.

A large key-way that may be of twelve or fourteen inches in length and two and a half in width may be made with a planing-machine, the shaft or axle to be grooved being fixed on the table. If a large shaft is to be thus grooved it is necessary to drill a preliminary hole at the inner end, as for grooving with a lathe, in order that the tool's edge may not break by coming into contact with the inner extremity. It is also necessary that the stops at the table's edge be accurately fixed in their proper places to cause the table and work to travel to the exact place desired, such adjusting of the stops being done after the shaft is finally fixed to the table. The planing of a wide groove of this sort should commence with narrow grooving tools, with which a narrow groove is made at each edge of the intended key-way, thus forming a ridge of metal in the middle. This ridge is next cut out with an ordinary vee-point facer having a comparative thin end, which end will allow the tool to reach the bottom of the key-way and travel across it with the machine's traverse, without causing the thicker part of the tool to touch the sides of the key-way. By this cutting out with such a thin end, after two grooves have been previously made, the key-way is roughly shaped to nearly the finished dimensions, and is ready for being finished smoothly to the exact size required with corner tools and with soapy water.

Through the necessity of first drilling a hole at the inner end of a large key-way which is to be planed, it sometimes happens that the entire groove can be quicker formed by drilling than by planing. In the case of a large shaft requiring to be moved from place to place without proper railways, it is better to make a number of holes along the place of the key-way, while the shaft is at the drilling-machine, instead of making only one at the inner end. Either one row of large holes may be made, or two or three rows of comparative smaller ones, the particular diameters of which depend on the width of the key-way. Such drilling should be done with two classes of drills, one of which is the ordinary point-drills, which are specially furnished with short points, to drill the bottom of the groove nearly flat; and the other class are pin-drills, which for this purpose are provided with very thin pivot-pins. These pin-drills are to be used after the holes are drilled with the ordinary drills as deep as their large conical points will permit, when the holes are ready for the pin-drills with small pins, which are made to cut out what metal remains at the bottoms of all the holes, and which could not be removed with ordinary drills without making the key-way deeper than necessary. After the drilling is done, the superfluous metal remaining between the holes is removed either with grooving-chisels or with planing-chisels, according to the thickness of metal to be chiselled. This chiselling can be done while the shaft yet remains at the drilling-machine, therefore all trouble which would result from moving it over rugged floors is avoided, and the adjusting and fixing on a planing-table also is avoided.

Key-grooves of Bosses.—The cutting of a key-way into a wheel-boss or into a lever-boss may be done with a driller, with a shaper, with a planer, or with a lathe. If to be done with a driller, the boss is placed upon the drilling-table with the faces parallel to the table, and therefore with the length of the intended groove at right angles, or, which is the same thing, with the length of the groove in the same straight line with the length of the drill-spindle, which will allow a hole to be drilled along the groove's entire length. As soon as the boss is tightly bolted in this position it is ready for drilling with a drill which has clearance enough to allow it to travel at least half way along the length of the key-way. If the boss is only one or two inches long, the drill should be capable of travelling the entire length; if not, it will be necessary to advance the drill half way, and then put the boss upside-down to drill the other half. This unfixing and re-fixing should be avoided for all small objects; therefore the drills for such work require the proper amount of clearance referred to. The diameter of the hole which is drilled, is rather less than the width of the groove, and the place of the hole is at the bottom or extreme depth of the groove. By the hole being drilled at this place, a small portion of superfluous metal is left remaining at the intended outer edges of the groove, which portion is easily removed afterwards in a vice by means of either a hack-saw, a chisel, or files. In order that the groove may be made in its proper place, the boss, after being bored to the requisite diameter, is lined according to the mode given in page 251, which lining is suitable also for grooving bosses on shapers or planers.

To form a key-way into a boss by means of a shaper, the lever or wheel is so fixed on the table that the length of the hole is parallel with the direction of the cutting tool's motion; consequently, one of the boss-faces is situated in front of the machine and in front of the operator. One of the boss-faces is also bolted in contact with a face of an el-chuck on the machine-table, and if a lever is being fixed, the length of it extends downwards, either near the table's surface or below it, according to the length of the lever. When attached to the chuck, the length of the key-way is put parallel to the tool's motion as required, by gently shifting the chuck previous to finally fixing it; and when this adjustment is effected it is only necessary to gradually advance the table up or down, to place the boss at the exact height for beginning the cutting. The cutting out is done with grooving tools of suitable width in their cutting edges, and all are cranked, this cranked form being requisite to obtain a long end which will reach forwards a sufficient distance to advance the tool's edge along the entire length of the hole.

If a planing-machine is to be employed for grooving a boss, the wheel or lever is bolted to an el-chuck, as for grooving with a shaping-machine; but on a planing-table the height of the chuck above the table must be sufficient to allow the entire length of the lever to stand above, unless the lever is small enough to be placed at the front edge of the table, at which place the lever may reach to the floor if necessary. If the boss is at this place, only a short el-chuck can be used; therefore the object and the chuck will not be liable to bend away from the tool while it is cutting. But when a tall el-chuck must be used, a stay should be placed to resist the strain imposed by the tool, and thereby avoid the bending referred to. The stay consists of either a piece of wood or iron which is long enough to reach from the table to the top of the chuck while the bottom of the prop is at a convenient distance from the chuck. For such a stay an iron bar is very suitable, because it can be provided with a couple of bent ends having holes punched therein for containing holding bolts, to fasten the stay to the table and to the chuck or object being planed.

To facilitate the adjustment of a boss to a parallel position with the tool's motion when a shaper is employed, or with the planing-table's motion when a planer is employed, the bottom edge of the el-chuck should be made to coincide with one of the gauge-lines marked on the table, a short line being selected if the object is on a planing-machine. Concerning these lines refer also to page 225.

Another sort of adjustment is necessary after placing the length of the boss into the proper position, and consists in placing the length of the lever at right-angles to the table-face, whether the object is on a shaper or planer. This adjustment will cause the key-way to extend into the metal in the required direction, which is in line with the diameter of the hole in the boss; or in other words, in line with one of the hole's minor axes. The right-angular position of the lever is obtained by means of a primary centre line along its side which faces the operator, the line extending through the centres of the boss-faces; while adjusting the object, an el-square's blade is put to this line, and the lever is gradually shifted until the line is seen to be parallel to the blade's edge, when the lever is at right-angles to the table as required. If an el-square of sufficient length cannot be obtained or used for this purpose, the primary line along the lever is put right-angular to the table by means of a scriber-block. This is used by placing the bottom edge of the block to one of the gauge-lines on the face of the el-chuck while the scriber-point is put to the line on the lever, the point being applied to both the upper end of the line and to its lower end. The gauge-lines on el-chucks are described in page 217.

The cutting tools required for grooving a boss on a planing-machine, are similar in shape to those that are used for grooving with a shaping-machine; the stalks of the tools being cranked forwards sufficient to advance their cutting edges along the entire lengths of the holes, in order that the upper portions of the tools may not come into contact with the faces of the bosses.

The cranked tools here referred to are represented by Fig. 704. Through the necessity of using such tools for making key-ways along the holes of bosses, when it is effected on shapers and planers, it is preferable to perform such work with slotting-machines, except when circumstances prevent a slotter being employed. A tool having a long cranked portion is troublesome to use on account of its tendency to bend while cutting, the cutting edge being at a great distance from the place or fulcrum of resistance in the tool-holder. Consequently, bosses which are comparatively short are much easier grooved with these tools than bosses of great length, because grooving tools having comparative short cranked parts are sufficient for the purpose.

Making Key-ways with Slotting-machines.—All key-grooves which are to be formed along the entire lengths of their respective wheel-bosses and lever-bosses, may be easiest made with slotting-machines, because the lengths of the intended grooves will permit a free action of, and ample room for, the traverse of the cutting tools, both above and below the extreme ends of the grooves; a space existing both at the upper and lower end of a groove from which the tool-edge may enter the metal and escape from it. A slotter is suitable for these key-ways, also because the length of a lever may extend to any distance from the place where the slotting-tool is cutting, without causing any inconvenience or requiring any el-chuck, as when the key-way is to be made with a planing-machine. But a slotter is not capable of grooving any portion of a long shaft or axle in the direction of the shaft's length, because it would be necessary to stand it with its length vertical, in which position it would occupy more room than can be obtained on a slotting-table. It may therefore be said that axles and other pieces of great length are preferably grooved with shaping, planing, or drilling; and short objects are preferably grooved with slotting-machines.

To cause a groove to be made in its intended place and position by means of slotting, it is necessary to adjust the wheel or lever on the table with regard to stated rules, as for adjusting objects on other machines. And for the convenience of effecting a rapid adjustment of an article previous to grooving, it must have been previously bored, turned, planed, or smoothly surfaced in some way to obtain uniform surfaces; which surfaces constitute tangible and definitely formed curves and planes that can be quickly put into any position without trouble, and can be easily observed in any position, whether right or wrong; whereas a roughly formed surface requires considerable observation to discover which is the place where the mean curve or plane should be, or would be if produced; and which is that required for adjusting the rough surface. The surfaces of all articles to be slotted are those which must necessarily be placed in some stated position, or at some desired angle with the slotting-table; therefore the surface of the table is considered as the base or primary plane to which all objects are referred during adjustment. Concerning primary bases or planes, refer also to pages 208, 209, 210, and 214; also to the chapter on lathe-turning.

The proper placing of a lever on a slotting-table, to have a key-way cut, consists in laying it with its length at right-angles to the machine front, and with one of its smooth boss-faces parallel to the table. This face may be either in immediate contact with the table, or in contact with a packing-ring resting on the table, the upper and lower planes of the ring being parallel to each other and parallel to the table. A packing-ring of this sort is required to keep the lower boss-face of the lever parallel with the table, and at the same time to provide a space of sufficient height between the boss and the table to allow the slotting-tool to escape from the metal without touching the table's surface, the space into which the tool enters being the hole of the ring. Rings of this class should be of iron or steel, to avoid liability to bruises, and should be of various diameters to suit bosses of various sizes. A good substitute for such a ring consists of a couple of long parallel blocks, each of the same height, one of which is placed beneath the lever-boss at each side so that the tool shall be between. When two blocks of sufficient length cannot be obtained, four short ones may be used, which are placed at equal distances apart, and at any required radial distance from the centre of the hole, to suit the diameter of the object being fixed. Placing the article upon such parallel packing here referred to, immediately causes the length of the hole in the boss to be put parallel with the direction of the cutting tool's motion, and therefore at right-angles to the table-face, which will cause the length of the key-way when formed to be parallel with the length of the cylindrical hole in the boss, as required. The object is consequently put into one of the positions necessary, and without trouble. It is next adjusted to make the lever's length exactly parallel with the traverse of one of the slide-rest screws, which screw is the one that advances the table and object from the front of the machine towards the back, or from the back towards the front. If the lever were not thus adjusted, the depth of the key-way would not be parallel with the diameter of the hole; or, which amounts to the same thing, the width of the key-way would not be at right-angles to the length of the lever.

It is now requisite to place the object into its proper situation under the tool, because the tool cannot be shifted to place it exactly over the intended key-way. The table and object are therefore gradually moved to the desired spot by rotating the two traverse screws of the slide-rest.

It may be seen that the lever has to be fixed with regard to three positions while on the table: with its boss-faces parallel to the table; with its length parallel with the direction of the traverse that advances the lever during cutting; and with the length of the key-way which is to be made, exactly under the slotting-tool. To render the movement of a heavy lever easy, while placing it at right-angles, poppets are used, the screw-points of which are in contact with the lever, while the poppets are tightly fixed to that part of the table convenient for the purpose. Poppets for slotting-tables are similar to those for planing-tables, (see page 239).

To facilitate the adjustment of the lever's length to parallelism with the traverse which effects the slotting, the right-angular lines on the table-face should be used, which are marked in the Figure 834, and are analogous to similar lines on shaping-tables and planing-tables, described in page 225.

To mark these gauge-lines upon a slotting-table, the traverse of the slide-rest should be employed, if the distance between the table and the main standard of the machine will permit, because the traverse will easily mark deep lines that can be plainly seen when required. The tool used for marking, is one of the slotting-tools of the machine, and is a straight tool having a thin end and a sharp vee-point. The tool is tightly fixed in the tool-clamps and gradually adjusted to the table's surface by rotating the lifting or lowering screw of the main-slide, which screw is shown by L S in Fig. 834. It is also now necessary to fix the table with respect to its rotary movement, which is done with a couple of screw-bolts and nuts, and when fixed, an el-square is placed with its blade to the table's edge and its pedestal upon the slide beneath, for the purpose of scribing a line upon the table's edge at the edge of the blade, and scribing another line upon the slide beneath at the edge of the pedestal. Such marks will be useful when it is required to again place the table into the same relative position. When the table is thus prevented from rotating, it is slowly advanced to the tool-point, the point being adjusted to enter the metal a proper distance for making a deep mark. The advancement of the table is next effected by rotating the traverse screw with a handle or with a longer lever, which belongs to the machine, if a large one. If there is room to advance the table and make a line entirely across it, the traverse is continued accordingly; and when the tool is released from the table's edge, the table is shifted into a situation for receiving another mark parallel with the first one. This shifting of the table is effected by working the other traverse screw, which is the one not used to mark the line, but which moves the table in a direction at right-angles to its motion while marking. When the table is thus moved three or four inches, according to the distance desired between the lines, it is again advanced to the tool-point, and another line marked by rotating the traverse screw before used; but this time, it is rotated in the opposite direction, which avoids the necessity of working back the table and commencing the second line at the same side as the first one.

By means of several shiftings of this sort and advancements of the table in contact with the tool-point, the required number of parallel lines are marked; consequently, the next step is to mark another lot of lines which shall be also parallel with each other, but at right-angles to the lot first marked. The second marking is conducted by the same means as that for the first, with the difference of advancing the table while in contact with the tool-point, by means of the traverse screw at right angles to the one used for marking the first lot.

When it happens that there is not room enough to move the table and make the lines entirely across, they may be partly marked with a straight tool, and afterwards completed with a cranked tool; or they may be completed with a straight-edge and scriber.

Slotting of Wheels.—If the bosses of wheels are to have key-ways formed with a slotting-machine, they are treated in a manner similar to that for levers, being first lined to show the exact shape and place of the intended grooves, and then fixed on the table with the faces parallel to it. But there is a difference in the packing-up of some wheels by reason of the faces of their bosses not being flat, and also because some wheels require to have key-ways without their bosses having been turned. If a wheel, pulley, drum, or such article is entirely lathe-turned, so that the faces of the rim are made parallel to the faces of the boss, the object can be quickly put into a proper position by placing it upon a parallel ring, or upon a few parallel blocks, similar to the mode of placing a lever. If the boss of the wheel is large enough in diameter, and is flat, the packing can be put into immediate contact with the boss-face; but for a boss having curved faces the packing is put beneath the rim. This arrangement has the same effect of placing the length of the hole at right-angles to the table as if the packing were in contact with the boss, because the edges of the rim were turned in the lathe and made right-angular with the length of the hole.

Placing a wheel with the parallel packing under the rim, instead of under the boss, leaves the boss without anything between it and the table. In this condition the action of the slotting tool would cause a shaking of the boss and arms of the wheel, which would prevent the tool cutting properly, and require very small portions of metal to be removed each time. If the wheel were of cast iron it would also break, unless extra strong, and would separate in some part of the arms. It is therefore necessary to support the boss, which is done after the wheel is finally adjusted and fixed with the plates and bolts; when the boss is packed up by entering a few short hard wood blocks between the arms, and pushing them under the boss to a short distance from the edge. These blocks are rather taper, in order that they may be gradually wedged between the table and the boss, to ensure a proper bearing; and packing-pieces of various thicknesses may be put to raise the wedges to any exact height when required. When the object is thus secured it is ready for grooving with tools of suitable width, and an easy and steady cutting is the result, through the tool being made to cut where there is great resistance by reason of the packing beneath.

Shaping Outsides of Bosses.—The outer curved surfaces of lever-bosses are shaped with shaping-machines, planing-machines, and slotting-machines. Of these machines, shapers are suited for all small levers in general, if they are not more than nine or ten inches in length. Shapers are also very effective for shaping lever-bosses which are situated in the mid-portions of levers, named fulcrum-bosses. Levers of this sort are also conveniently shaped along their entire lengths, when necessary, by the same shaper used to shape the bosses. Planing-machines are also available for this same shaping of mid-portions of levers, and through these machines being usually larger than shapers, the reducing of a large lever on a planing-machine is easier done than with a shaping-machine, the cutting tool of a planer being more capable of effecting thick cuts.

In order to shape the outside of a boss which is situated at one end of a lever, by means of a shaper, the rotating conical pivots at the front of the machine are employed for holding the boss, the two conical ends being in the hole of the boss while it is screwed tight between. To cause the boss to rotate in a path which is concentric with the cylindrical hole, the boss is properly bored, and its faces turned to make them right-angular to the hole's length. It is also usual to take off a portion of the metal at the outer edge of each boss-face; at which part the boss is reduced to the finished diameter intended for the entire boss when finished. If the boss-ends are of considerable length, causing the faces to extend a quarter of an inch or more, from the broad sides of the lever, it is also usual to lathe-turn the entire lengths of these boss-ends. By turning these two parts to the same diameter, and making this to be the finished diameter, the superfluous quantity of metal to be cut off with the shaper is plainly shown, and the boss is made ready for immediate fixing to the machine-pivots for being reduced to the proper dimensions, no lining being necessary. When the boss is without such projecting ends, it is requisite to scribe two circles, one on each boss-face, both circles being of the same diameter, that they may show the amount of metal to be removed, as if the boss were partly lathe-turned. For this scribing, the primary centre line along the lever's broad side must be used, in order to cause the boss, when shaped, to be in a straight line with the intermediate portion. It may be here mentioned that whatever straight gauge-lines may exist along the lever's length, which are now to be used during shaping, are the lines that were placed previous to lathe-turning or boring, and were employed to adjust the lever for the purpose; and the same primary lines should now be used, to make the outside of the boss parallel with the hole.

The boss being properly prepared, it is fixed between the pivots so that its length is nearly horizontal, in order that the upper half of the boss may be shaped at one fixing; after which, the boss is put upside down and the other half shaped. In some cases, the entire boss can be shaped at one fixing, when it happens that the lever is not too long to permit the necessary extent of rotary movement.

Adjusting the tool for cutting after the lever is fastened is effected with the vertical traverse screw of the slide-rest, an ordinary vee-point facer being used. The tool-point is so placed that it is exactly over the centre of the pivots and therefore over the centre of the hole in the boss, which situation is known by a gauge-line on the machine. The machine is next arranged to work with the to-and-fro motion of the tool, and the rotary motion of the pivots, all other movements being stopped except the small advancement downwards of the tool-point, for causing it to enter the metal a proper distance, and thereby taking off the required quantity. When the tool-point is put to the proper height the shaping proceeds until the half-rotation or three-quarters rotation of the object is effected, and therefore the entire boss reduced, one slice being cut off. The tool-point is then again advanced downwards a short distance and another slice is removed by another rotation as before. The reduction of the boss is thus continued by as many rotations of it as will suffice to attain to the finished diameter, which is shown by the circular gauge-lines on the faces or by the turned boss-ends which were before referred to.

It is now supposed that the boss is finished with the exception of the curved junctions of the boss with the other portion of the lever, and that it is required to shape this middle or straight portion. If this is to be done it may be next fixed so that its length is nearly parallel with the direction of the machine's horizontal traverse, the upper gauge-line to which the mid-part is to be reduced being adjusted exactly parallel with the traverse. The object is now in position for cutting off the superfluous metal at the upper narrow side of the lever and along its length. The curved junctions also can be shaped, both the junction of the boss already finished, and that of the boss to be shaped, if this shaping is necessary. The lever is next put upside-down, and the other narrow side of the mid-part is shaped and the junctions also. This leaves one of the bosses yet to be shaped, which is effected by removing the lever from the conical pivots and placing it end for end, placing the boss not shaped on the pivots in the same condition as the first one. The shaping now proceeds in the same manner as before by the rotation of the boss and the gradual advancement downwards of the tool.

To avoid unnecessary shifting when a comparative large lever is to be thus shaped, both its bosses and all its four curved junctions should be finished previous to beginning the reducing of the straight mid-part. This will avoid arranging the machine a second time for the rotary movement to shape the second boss.

A lever which is shaped by these methods is fastened in position during the reducing of the straight portion by one boss being fixed on the pivots, as when being rotated, and with the other boss bolted to a parallel ring or packing in contact with one boss-face. This mode of fastening suits small or short levers; but a long one should be entirely disconnected from the pivots when the straight part is to be shaped, at which time it can be properly held against an el-chuck; in this position the action of the cutting tool will not bend the lever, and thereby cause an unsteady cut.

When the outside of a boss is to shaped with a planing-machine, it is done by fixing the boss against an el-chuck, and gradually adjusting the tool-point by rotating the vertical traverse screw during the to-and-fro movement of the object in contact and being cut. This gradual raising and lowering of the tool while it travels across the boss is done by the hand of the operator, who watches the gauge-lines on the boss-face, and adjusts the tool accordingly. To avoid a tedious operation of this sort a special apparatus for a rotary motion must be supplied to the machine, but such a movement is not necessary now that shapers and slotters are accessible; and when, through sudden breakage, or other emergency, a planing-machine must be used for reducing a large boss, the hand adjustment of the tool can be effected without much difficulty.

For the shaping of a lever having three bosses, a planing-machine is frequently more convenient than a shaper, especially if a large amount is to be cut off, requiring very thick cuts. When a great quantity is to be removed, the horizontal traverse will effect the reducing, a tool having a broad vee-point being used and much of the hand-working of the screw avoided.

The planing of the object to the finished size desired, is conducted with regard to gauge-lines in the same manner as if the lever were shaped on a shaping-machine; the lever being in all cases adjusted so that the gauge-lines to which the metal is to be cut off, are placed parallel with the surface of the planing-table.

Shaping Bosses on Slotting-Machines.—The most rapid and effectual mode of shaping outsides of lever-bosses in large numbers is slotting; the object to be shaped being fixed on a slotting-table and rotated by means of the worm-wheel and pinion of the machine.

Any boss, small or large, to be thus shaped, requires fixing with the centre of the hole in the boss in a straight line with the axis of the machine-table's rotation; or rather, with the centre length of the hole and the table's axis both in the same straight line. This situation is occupied by the small lever on the table of Fig. 862, and is necessary because the outside of the boss when shaped, is to be concentric with the hole, which condition is termed, true with the hole, and results from the cutting tool acting in contact with the boss while it is gradually rotated with the table.

Each lever-boss, previous to slotting, is bored to make the hole of the required finished diameter, and its two faces are smoothly turned to make them parallel with each other and right-angular to the length of the hole. One of these faces is selected to be placed into contact with a parallel ring, or with a few parallel packing-blocks, that the length of the hole may be accurately placed at right-angles to the table, and that a space may be provided beneath the boss for the escape of the tool from the metal, which space resembles that required while slotting a key-way. For shaping the outside of a boss, it is necessary for the outer edges of the parallel ring, or other packing that may be used, to be entirely within the extreme finished diameter of the boss, that the tool may be prevented from touching any portion of the packing at the time of cutting; whereas, while slotting a key-way, the outer extent of the ring is not important, unless it is large enough to obstruct the fixing of the holdfast bolts. The thickness or height above the table of this packing, is about the same, whether for key-way cutting or for shaping bosses, and is sufficient to allow ample room for the tool-edge to disengage from the metal at the conclusion of each cut and not incur any risk of causing the edge to touch the table and do mischief, the height being usually from half an inch to an inch.

When the boss is thus supported parallel with the table, it is held in position with a couple of holdfast plates and bolts, which are placed opposite each other and at the two inner edges of the hole in the boss. If two bolts cannot be placed, through the smallness of the hole, or through a deficiency of slots in the table, one bolt is employed and is put at the middle; consequently, a plate having a hole in the middle is employed to grip the boss-face. Supposing that the article to be shaped is an ordinary lever with two bosses, the other end of the lever, which is not near the centre of the table, now requires supporting, especially if it is a large one, to prevent its length and consequent leverage exerting an injurious strain upon the screw bolts or bolt holding the boss. To avoid this, the end of the lever is allowed to rest on one or more packing blocks of the proper height, which height is just sufficient to sustain the weight of the lever-arm without affecting the parallelism with the table of the face belonging to the boss to be shaped. When it happens that the lever is not too long for both its bosses to rest on the table, the packing consists of parallel blocks, and they are placed between the surface of the table and the under surface of the outer boss; but if the lever is long enough to cause the outer boss to extend beyond the table's edge, the packing consists of blocks which are rather taper, and they are put beneath some portion of the arm or intermediate portion.

A large boss of ten, twelve, or fourteen inches in diameter, can be easily fastened to the table with bolts situated in the hole, and such bolts will not hinder the final adjustment of the boss to the exact situation required. A few poppets also can be placed along the lever-arm, and holdfast plates fixed across the top of the arm. All these fastenings may be attached before the object is precisely adjusted ready for work; they are therefore not tightened until adjustment is completed. But a small lever that may have a boss only about two or three inches in diameter, when to be shaped by slotting, must be fixed, either without any bolt in the hole of the boss at the middle of the table, or with a bolt which is put into the hole after the boss is finally adjusted. When bolts are put into such a small hole they sometimes prevent the observer seeing the bottom of the hole, and therefore adjustment is hindered. It is, consequently, necessary to first hold such a boss with a couple of plates and bolts at the outer edges of the boss, instead of at the inner edges; and while these are attached, the bottom of the hole can be adjusted as required, because the hole is empty. After adjustment, the necessary bolt or bolts can be put into the hole, and those that were put to the outer edges are removed, not being now needed, and which must be removed to allow the boss to be shaped. Small lever-bosses are rapidly and accurately adjusted by means of arbor-chucks, which are described in the next section.

Adjusting the boss to place it exactly in line with the table's rotation, or in line with the axis, is done with the poppets which gradually shift the object to the proper place. In order to ascertain the amount of shifting that may be needed to effect the adjustment, it is necessary to use the circular gauge-lines which are marked a short distance apart on the table-face. About twenty or thirty of these exist on the table, all being concentric with each other and with the table's axis of rotation. Therefore, any one of these circular lines which is conveniently situated for the diameter of the hole may be selected, and considered as a gauge-ring in which the truly formed hole of the boss shall be centrally located when adjusted. If the hole is large enough to admit an el-square, one of the gauge-lines which is of less diameter than that of the hole, may be selected, and the square put into the hole with its pedestal on the line on the table, and, consequently, with the blade extending upwards to the top of the hole. The bottom corner of the pedestal is put exactly upon some point in the circular line, at the time the situation of the boss is to be ascertained, and the distance between the edge of the blade and the side of the hole is then measured with an inside calliper. The square is next shifted to the opposite side of the hole, and stood upon the same gauge-line on which it stood before, but being now at the opposite side of the centre. The distance between the blade's edge and the side of the hole is now measured as before, and if found to be the same as when the square stood at the opposite side, the boss is in its proper place; if not, it is shifted, and again tried with the square in the hole as before. Two or three couples of opposite points in the gauge-circle should be selected on which to stand the square, in order to avoid being misled by using only two points, although two are sufficient, if the observation and measurements are accurately conducted. It may be mentioned that this mode of adjustment is most effectual with bosses having large holes, which permit an easy observation therein. The method is applicable to the fixing of bosses having either parallel holes or taper ones; but for a taper hole, the operator must exercise due care to measure the distance between the blade and the upper extreme edge of the hole, each time he applies the callipers, and not to place the callipers to any portion of the hole below the edge.

The boss can be adjusted also by means of a scriber-block. For this purpose a wood or iron ender is fitted to the boss-hole at that end which is uppermost while the boss is on the table. The ender is used to mark the centre of the hole's mouth, which is found with a compasses. From this centre, circular lines are scribed upon the boss-face; of which lines one denotes the diameter to which the boss is to be finished. Either this line or one of the others on the face, which may be more convenient, is selected for a gauge-line by which the boss is to be adjusted. The desired result is obtained by placing the line or lines exactly concentric with the axis, as intended. To do this the scriber-block is now stood upon the table with the bottom edge exactly coinciding with some point in one of its circular lines; and while it thus stands, the scriber-point is adjusted to a point in one of the gauge-circles on the boss-face. The scriber-point used for this purpose, is the one at the bent end of the scriber, which will allow the observer to see clearly whether or not the line on the boss-face is exactly beneath the point; and, consequently, will enable him to discover the precise amount of shifting of the boss which is required to adjust it. After the scriber-block has been stood at one side of the boss on one of the table's lines, the block is removed to the opposite side of the boss, and stood upon the same circular line, but now upon a point which is opposite to the point on which it stood before. By now observing the scriber-point and the gauge-line on the boss beneath, the relative positions of the two are seen, and the boss is gradually shifted until its gauge-lines show it to be in the proper place.

A boss may be adjusted concentric with the table, also by observing the edge or mouth of the hole. For this adjustment the edge of the hole must be sharp, instead of curved, which is an ordinary shape of a large number. If sharp, the scriber-point of the scriber-block can be put to the edge and observed, instead of placing the point to a circular gauge-line scribed on the boss-face, the operation being similar to the adjustment by placing the scriber-point to the line on the face, as given in the preceding paragraph.

ADJUSTING BOSSES WITH ARBOR-CHUCKS.—When a large number of bosses having holes of the same diameter are to be shaped, they can be quickly and accurately placed to their proper situations on the slotting-table by using an arbor-chuck. This implement consists of a cylindrical piece of iron or steel which is provided with a broad base or flange. The flange is exactly at right-angles to the cylindrical part or stem, and is large enough to contain holes for fixing-bolts, with which the chuck is bolted to the slotting-table. The diameter of the stem or pivot-portion, just suits the holes of the bosses to be shaped, and allows any boss to be easily put on, and at the same time to be tight enough to prevent the boss moving sideways while situated on the stem. If the stem is cylindrical along its entire length, it can only fit bosses with holes of one diameter; therefore, to make one arbor suit holes of different diameters it should be turned to two or three diameters along its length, so that one portion will fit holes of one size, and the other portions will fit holes of other sizes. The smallest diameter of the stem is at its end or point, at its largest diameter at the bottom; consequently, it may be termed, stepped. The entire chuck is truly lathe-turned, to cause any portion of its stem to be concentric with any other portion, and also to make the length of the stem exactly right-angular to the flange; if in this condition, the length of the stem is immediately placed right-angular to the slotting-table as required, by placing the face of the flange into contact with the table-face. The outer surface of the flange termed its edge or rim must be turned to make it concentric with the arbor or pivot, because by the rim of the flange the chuck is sometimes adjusted. By turning, the two broad sides of the flange are also made parallel with each other; and of these two sides, the outer one is that which is bolted in contact with the table when in use, the inner broad side being often required to be in contact with one face of a boss or other object to be shaped.

When the chuck is to be used, it is bolted to the table so that its stem may extend upwards, in which position it is ready for the boss to be put thereon. The outer edge or rim of the flange may now be used, for adjustment, which consists in placing it exactly concentric with the table's rotation, the stem being, of course, adjusted by the same act, because it is concentric with the rim. To gradually shift the chuck, during adjustment, a tin hammer is used, and a few blows are given previous to tightening the fixing bolts, the proper place for the chuck being known by its being centrally located in one of the gauge circles on the table. By reason of the implement being thus fixed to the table, both the table and chuck must rotate together, and also the boss thereon.

The chuck can be adjusted also by means of a shallow recess in the table, into which the edge of the flange is put, which immediately places the chuck concentric with the table, because the recess was formed by lathe turning and is concentric with the axis of rotation.

Many slotting-tables are provided with holes at their middles, such holes being required to provide spaces for the slotting tools and for containing stems of various objects. If the mouth of a hole of this class is sharp, and true with the table, the flange of the arbor-chuck may be furnished with a short projection, the diameter of which is exactly the same as that of the hole in the table; and by this projecting part being put into the hole the chuck is adjusted without further treatment. This means should be adopted for all work that requires the chuck to be frequently and quickly adjusted to the proper place.

The chuck is held on the table with a couple of screws which fit holes in the flange, the holes having broad mouths for containing the entire heads of the screws when tightened. This arrangement allows the upper surface of the flange to remain quite free from any projection after the chuck is fastened; so that a boss-face or other surface can be put into close contact with the flange, or into contact with a parallel ring on the flange, whenever it may be requisite.

An arbor-chuck which has a stem of two or three different diameters must cause all bosses placed thereon to remain several inches above the flange, and therefore also above the slotting-table, except those that happen to fit the lowest portion of the stem, which is its junction with the flange. If the hole of a boss fits this portion, the boss-face can lie in close contact with the flange while fixed, and no additional support beneath is required. But when a boss is held up at a distance from the flange, by reason of the hole fitting some comparative small portion of the stem's upper end, the boss is deprived of support beneath, and it is therefore necessary to pack up the boss. For this packing up either parallel blocks or parallel rings are used, a proper number being put between the boss-face and the flange to occupy the space.

When a great number of small lever-bosses having holes of the same diameter require shaping, an arbor-chuck with a stem long enough for three or four bosses should be provided, the stem being parallel along its entire length. On such a stem several bosses may be situated one above another, with their faces in contact with each other, in which positions all may be shaped at one traverse of the cutting tool. Lever-bosses thus arranged are quickly shaped, and also made uniform with each other without much lining or measurement.

A boss which is to be shaped while on an arbor can have but few fastening plates near the boss; consequently, the holdfast plates are put along the arm, together with a couple at the curved junctions near the boss which is on the arbor. This mode of fastening is suited to large objects; small levers can be held by means of a centre bolt in the extremity or point of the arbor. This bolt fits a screwed hole at the centre of the extremity, the length of the hole and the length of the arbor being in the same straight line. The head of this bolt bears upon a circular plate or washer, and the washer bears upon the boss-face; so that by tightening the bolt the boss is fixed. To prevent the rim of the washer touching the tool while cutting, its diameter is rather less than the finished diameter of the boss. Several washers may be used, if necessary, one above another, and are required when the upper end of the arbor extends beyond the upper face of the boss.

While a lever remains on the slotting-table fixed to an arbor, or to any other packing or rings for holding it to be slotted, the length of the lever is across the operator while he faces the machine-front, the lever extending either to the right hand or to the left. During the rotation of the piece while shaping is progressing, its length usually travels towards the machine-front, and, consequently, towards the operator, and not towards the main standard of the machine. If it travelled towards the standard, it would be necessary that the boss being shaped should be situated between the cutting tool and the standard; and such an arrangement would suit only those machines the cutting tools of which are not released from the metal during their upward motions. In a machine whose tool is released, the releasing movement causes the tool to retreat backwards from the machine-front towards the main standard; therefore, on such a machine, the boss to be shaped must be situated between the cutting tool and the machine-front. If thus situated, ample room exists for the tool to retreat from the metal, which could not exist if the boss were at the back of the tool and obstructed its backward retreating motion.

When a boss is properly fixed on the machine with regard to the proper relative positions, it is ready for placing into the desired situation near the cutting tool. The movement for this purpose is easily effected by rotating the traverse screws, by which means the boss is gradually moved until the centre of the tool edge is found to be in line with the centre diameter or minor axis of the hole in the boss. This relative situation is analogous to that of a lever-boss which is adjusted ready for shaping with a to-and-fro shaper, and is mentioned in page 271.

The cutting tools used to remove the metal from a boss during slotting are those shown by Figs. 787, 788, 793, and 794, and are described in pages 257 and 258. While one of these is in the tool-clamps, the table, and, consequently, the boss attached, is advanced to the tool by one of the transverse screws. This screw is the one which advances the table towards the machine's main standard, and by this screw the thickness of metal to be cut off during any one rotation of the boss is determined, the other traverse screw at right-angles not being used after the boss is once adjusted, but remaining fixed. The lever is therefore advanced to remove a slice from the boss of the intended thickness, the thickness of slice depending on the power of the machine or the quantity to be cut off. One slice is removed at each rotation of the boss, until it is reduced to the intended diameter; and when polishing is necessary it is done with sharp tools and soapy water, as described for other work.

Shaping Arms of Levers and Connecting-Bars.—The intermediate parts or arms of levers, and also of connecting-bars, are easily shaped with to-and-fro shapers, and with planing-machines, if they are not too long for the machines selected, each one being held with bolts through the holes in the bosses during the shaping of the broad sides, and held against an el-chuck with holding-plates, or held in a machine-vice while shaping the narrow sides termed edges. Arms of levers and bars which are to be shaped by these means are treated in page 233. It is therefore only necessary to here mention the shaping of lever-arms by shapers and slotting-machines.

When a shaping-machine is provided with a vice, and a small lever, or a number of them, require the narrow sides of their arms to be shaped, each one, after a proper lining to show the dimensions, can be tightly held in the vice with the broad sides in contact, a couple of wood or lead clamps being on the vice-jaws to prevent damage. If thus held, the narrow side of the arm is upwards and parallel with the motion of the shaping-tool; and it is next necessary to adjust the entire length of the arm to parallelism with the bed of the machine, and when this is done the lever or bar is in its proper position. If the object is too long for one vice, two must be used, in which case the article appears as in Fig. 866, having a long packing-bar in contact, to prevent bending. When the broad sides of the arm also require shaping, the arm can be held by gripping its two narrow sides instead of its broad sides; and if the arm is taper a piece of taper packing can be put between the small end of the lever-arm and the vice-jaw, to cause the vice to grip equally and hold the arm firmly, although it is taper. A lever or bar held in this manner is adjusted with a tin hammer, a scriber-block being on the table or tables to show when the gauge-lines on the sides of the article are parallel with the table-faces, and therefore parallel with the bed of the machine. When the piece is being fixed for shaping the broad side, the gauge-line on the narrow side need not be more than a sixteenth of an inch above the top edges of the vice-jaws, because the nearer the surface to be cut is put to the vice the steadier will be the operation of cutting. Taper arms of levers, rods, and bars, can also be tightly held without taper packing, by means of the author's vice arranged for the purpose.

To shape the broad sides of a lever with a shaping-machine without vices, the lever may be held with a screw-bolt through each boss, the entire lever being on one table, if short; but with one boss on each table, if the length of the piece requires such an arrangement.

Whether it is the arm of a lever, or that of a connecting-bar which is to be shaped by these means, the adjustment of each object is performed with regard to gauge-lines which are scribed on the broad sides and edges. These lines denote the boundaries of the hidden planes that are to be produced by the shaping; and they are therefore adjusted to make them parallel with the direction of the cutting tools' motions, in accordance with the elements of planing and lining in pages 205, 206, 212, 213, and 214. The lines are also the same as those used for shaping arms by slotting.

Shaping of Arms by Slotting.—The shaping of arms with slotting-machines is especially suited to large levers and bars. If a lever requires shaping along its arm and also around both its bosses, the bosses should be first reduced to the required dimensions by means of an arbor-chuck, or while fixed on other packing as before described, using the rotary motion of the worm wheel. The lever is next fixed for the purpose of shaping its narrow sides, with one or both bosses in contact with parallel packing on the table, and so that its length is nearly parallel with the machine-front, and consequently, nearly parallel with the traverse of the rest which is parallel with the machine-front. If it were intended to make the arm parallel, as for a connecting-bar, the arm's centre length would be adjusted exactly parallel with the traverse; but to obtain the taper form required for a lever, it is so placed that the side or surface to be produced, is parallel with the traverse referred to. To ascertain whether the object is properly placed, one of the straight gauge-lines on the table should be used as a species of standard to which the gauge-line that shows the quantity of metal to be cut off, is put parallel. For this purpose, a scriber-block having a straight bottom edge, is stood upon some part of the table's gauge-line, and the scriber-point is adjusted to one end of the line on the lever; after which, the block is removed to the opposite end of the lever and stood upon another part of the same gauge-line on the table. The scriber-point is now observed to discover how near the line on the lever is to parallelism with the line on the table, and therefore, how much shifting of the lever or bar is necessary to adjust it. When the piece has been moved a short distance, the scriber-point is again referred to as before, and another shifting is effected, which processes are continued until the object is properly placed.

As soon as the lever's gauge-line is adjusted to parallelism with the gauge-line on the table, and the piece properly fastened with plates and bolts, the lever is advanced to the cutting tool and the shaping of the arm's narrow side commenced. At this time the tool is at one end of the arm, which is the curved junction with the boss. The shaping progresses by the up-and-down motion of the tool, and the movement of the lever in the direction of its length, or rather in the direction of the gauge-line showing the place of the plane to be produced. By reason of this line being parallel with the gauge-lines on the table, the surface formed by the process of shaping must be also parallel with the gauge-line on the lever, because this line was put parallel with the table's lines, and these were marked with the same traversing motion of the rest which is now used for advancing the object during shaping. Concerning the marking of these lines upon slotting-tables, refer also to pages 269 and 270.

When the lever or bar is to be advanced to the tool to commence the shaping, or to take off another slice after the piece has been once advanced across the tool, the movement of the slide-rest screw causes the lever to move sideways. This is the direction in which it moves each time it is adjusted for having a slice removed, the movement being effected with the screw which is at right-angles to the machine-front, and at right-angles to the length of the lever. Immediately after this screw has put the piece to the place required, the screw is fixed to prevent unintentional shifting of it during the cutting; the cutting being executed by the rotation of the other screw which is parallel with the length of the lever-arm. The traverse performed with this screw is the only motion required besides the up-and-down action of the tool, to execute the entire shaping. If it happens that a large amount of metal is to be cut off, several travels of the lever in the direction of its length may be requisite, the amount removed each time, depending on the power of the machine. The quantity cut off during any one advancement, is named a slice; and the entire amount removed to reach the gauge-line, is termed the krap. A strip or cut, is the quantity cut off during only one downward travel of the tool. These various amounts of metal are analogous to those cut off with planing-machines; and the terms which represent them are given in the chapter on planing and lining, at pages 215 and 216.

Shaping of Junctions.—The curved junctions of a boss are shaped while the lever or bar is fixed with its boss-faces parallel with the slotting-table, as when the narrow sides of its arm are being shaped. Considerable care is required during shaping, to make the junction to a proper curve, to make it to a proper depth, and to nicely smooth it, that no ridges may be noticed after it is machined.

For the purpose of avoiding unnecessary trouble while a boss is between the conical pivots of a shaper, or on an arbor-chuck of a slotting-machine, the shaping of the boss by means of its rotary motion, should terminate at the commencement of each curved junction of the boss, all the superfluous metal at the junction being left untouched. Both bosses of the lever should be thus treated previous to commencing the shaping of the intermediate part or arm. The shaping of the straight arm, if effected with a shaper, is performed while it is fixed with its narrow side upwards, both the bosses and junctions being now finished. When a slotting-machine is employed for the narrow sides of the arm, the shaping of the straight portion, and also the shaping of the curved junctions, is done while the boss-faces are parallel with the table, and the narrow sides are parallel with the slide-rest traverse which is parallel with the machine-front. Whenever a lever or bar is required to present a special smooth and neat appearance, the bosses and junctions should be entirely finished previous to finishing the straight part of the arm. Supposing that the entire outer surface of a lever is to be machined, the bosses should be entirely reduced and finished, and the junctions also finished, previous to finally smoothing the arm's narrow sides; and all levers and bars that may require a great amount of metal to be removed, should have the straight parts of their arms roughly reduced before finally smoothing the junctions.

Curved junctions should be shaped while the levers or bars are in the same positions on the table in which they were during the shaping of the arms' narrow sides; consequently, the fixing of the lever for shaping the straight part is the fixing for shaping the junctions, no change being necessary. The straight mid-part of the arm is that which should be first roughly reduced, the reduction being continued till it is very near the specified dimensions. The two junctions which are now in front of the cutting tool should next be reduced, the entire quantity of metal being removed, and the curved surfaces carefully and finally continued from the finished surfaces of the bosses. These two curved parts being completed, leaves the straight part of the arm yet rough; and to finish the entire narrow side of the lever it is now carefully advanced to a sharp smoothing tool for taking off a thin piece along the arm. For this last slice a tool having a broad cutting edge must be used, and its edge made to only just lightly touch the finished extremity of the curved junction; when thus adjusted, the traverse of the lever is put into action, and the smoothing completed. For a finishing slice of this sort it is not necessary to cut off a portion along the entire length; about half the length of the arm is quite sufficient; and to prevent the tool entering the metal too far at the middle of the lever, it should be shifted a small quantity to cause the tool to leave the metal at the proper place. The middle of the surface being shaped may be, for any bar or lever, rather convex, instead of rather concave; so that after two junctions at one side of a lever have been finished, the tool which finishes the straight part may be made to take off two minute slices, one from each junction, and both towards the middle of the lever, which process will produce the convex form referred to.

After one narrow side has been finally smoothed, the lever or bar is put upside-down, and again fastened with its length in the same position as before. In this condition the other narrow side and its two junctions can be reduced and smoothed by the same means that were employed for reducing the side now finished.

The class of tools which will quickly remove the thick mass of metal at the junctions are the vee-point tools shown by Figs. 787, 788, 793, and 794; some of which tools have ends slightly bent, to make them resemble corner tools of planing-machines. These pointed tools are only necessary for large bosses, when it is requisite to cut off a great quantity of metal; and the tools are caused to form a few ridges at the place of the intended curved surface, by gradually advancing the lever to the tool by rotating the traverse screws. The junction being thus roughly formed with pointed tools, is made ready for being finished with a springy tool, the cutting edge of which is curved and convex, to suit the curved shape of the junction. Springy tools for this purpose are represented by Fig. 792; with the difference of a tool having a curved edge being keyed in the slot, instead of the one shown in the Figure, whose edge is nearly straight, this form of tool being required for smoothing the outside of a boss.

A small lever or bar may have its junctions entirely shaped with tools having broad cutting edges; a springy tool being used for polishing, in the same manner as for larger work. Any such curved surface, small or large, should be reduced and finished with tools which have as broad edges as the machine will permit; by using broad tools, the cutting edges of which are nearly as long as the extent of the junction, all the shaping of it is executed with very little rotation of the traverse screws, by reason of a comparative great length of the cutting edge being at one time in contact with the metal.

When it is requisite to form a junction to some exact curve of a desired length and shape, sheet-templates are used, the shapes of which are similar to the shapes required for the curves in the objects in progress. Concerning templates, refer to pages 244 and 245.

Shaping the Broad Sides of Arms.—Broad sides of arms belonging to levers and connecting-bars are shaped either by planing or slotting. It is, however, always requisite to shape the curved junctions with the boss-ends, by using some class of rotary movement, because these junctions cannot be formed with any rectilineal motion. After a bar has had its bosses bored, turned, its short boss-ends also turned, and short portions of the arm immediately adjoining also turned, the broad sides can be easily shaped by a planing-machine, whether small or large. A lever with these junctions shaped, and situated on a planing-table, is shown by Fig. 747; in which position it can be easily planed to cut off the lump on the middle; because, by reason of the ends of the bosses having been finished by turning, and their junctions with the broad side also turned, the planing-tool is allowed ample room to cut near the bosses without touching them

It is sometimes necessary to reduce the broad side or sides of a lever while it remains on a slotting-table; the lever having had its bosses, curved junctions with the narrow sides, and the straight parts of the narrow sides just now shaped on the same machine. And it is, in many cases, convenient to shape broad sides by slotting, to avoid removal of heavy pieces to other machines, also to avoid waiting for a planing-machine to be disengaged, and as a necessity, when a planing-machine is not available.

If the lever which is to have its broad sides shaped by slotting has had the junctions with the broad sides shaped by boring and turning on a previous occasion, it can remain on the table and be shaped; if not, it must be removed, and the junctions properly formed. The arm at these places is always reduced by the rotary shaping until it is of the exact finished thickness required; consequently, it is by these smoothly formed junctions that the arm is to be adjusted, rather than to the scribed lines.

The first placing of the lever for the shaping of its broad sides consists in putting one broad side at right-angles to the slotting-table, because this is the direction of the slotting-tool's motion. If the bosses have been properly formed, their outer surfaces are now parallel with the lengths of the holes; consequently, if these outer surfaces are put into close contact with the table, or with parallel packing thereon, the lever is, by the same act, put into one of the positions required, without further adjustment. If the two bosses of the object were of the same diameter, the centre length of it would now be parallel with the table; but through one boss being smaller, the centre length is lower at one end than at the other, which is of no consequence for this shaping, because only the straight part of the side is to be reduced. Although it is not requisite to place the centre length parallel with the table, it is quite necessary that the gauge-line on the upper narrow side, showing the boundary of the plane, should be put exactly parallel with the traverse screw which is parallel with the machine-front; or rather, parallel with the direction of the traverse-slide's motion, in order that the movement of the lever during shaping shall produce the broad side in its desired condition of parallelism with the gauge-line. If this line exactly coincides with the already finished junctions, either the line or the junctions may be referred to while adjusting; the finished surfaces being always considered rather than the scriber-marks. To adjust the lever to this position a scriber-block is stood upon one of the straight lines on the table, and the point is placed for observation to both ends of the line on the lever, or to its junctions, in a manner similar to that described for other adjustments.

As soon as the broad side is put into the required position, and the lever is tightly held with plates and bolts, the reduction of the metal proceeds in a very easy manner, a point-tool like Figs. 787 or 794 being in the tool-clamps while the lever is advanced in the direction of its length by the rotation of the traverse-screw. This operation is quite as simple as if it were done with a planing-machine, and consists in producing the hidden plane by means of the vertical motion of the slotting-tool, instead of by the horizontal movement of a planing-table.

When one broad side is produced, the object is put upside-down, and the opposite broad side is thus placed in front of the slotting-tool. The lever is now fixed with the same regard to the finished junctions or gauge-line that was bestowed during the adjustment for the previous shaping; after which the removal of the metal proceeds as before.

It may now be seen by reference to the foregoing sections on the shaping of arms and bosses in general, that if the entire outer surface of a small lever or bar needs reducing, the entire shaping can be done on a to-and-fro shaping-machine if the object has been properly bored and the ends of its bosses turned; and it is also seen that a large lever or bar that has been in a similar manner properly turned can be entirely completed on a slotting-machine, which machine will reduce and correctly finish the entire cylindrical surfaces of the bosses, their curved junctions with the narrow sides, and the four straight sides of the arm whenever it may happen that such an extensive reduction is requisite. And it may be here mentioned that thousands of levers and bars are at the present time thus entirely machined while cold, although it must be admitted that if greater care were exercised during the forging of such objects, the only machining which they would require while cold, would be boring the holes, turning the boss-ends, and slightly paring the junctions. Even less paring than this would suffice for those that were forged in pressing-moulds, concerning which, and also concerning other considerations during accurate forging, refer also to pages 1, 3, 4, 30, 32, 33, 77, 78, 87, 88, and 97.

Shaping Levers having Three Bosses.—Levers having three bosses each can be easily shaped on shaping-machines if small, and on slotting-machines if large; the several operations for lining, adjusting on the tables or on arbor-chucks, and removal of the metal, being similar to those detailed for shaping levers having only two bosses each.

Every three-boss lever which is to be reduced along the entire lengths of the arms' broad sides, requires the junctions at the boss-ends to be reduced to the finished thickness by the turning or boring, which reduction is similar to that for a two-boss lever, with the necessity of exercising more care to properly reduce the metal from around all the six boss-ends. These junctions are usually shaped with the same machine that finished the holes. When thus carefully treated it is ready for a shaper, or for a slotter, according to the size of the article. The order in which the several surfaces are produced is the same as that observed for other levers if they are slotted; the bosses and junctions being first shaped, and next the narrow sides of the arms; after which the producing of the broad sides is effected. This comparative easy operation of planing with a slotter, as it may be termed, is the last performed, and of course requires extra care during adjustment, because four broad sides are to be produced on each lever instead of only two.

Because the junctions of the boss-ends with the arm's broad side have been thinned on the boring-machine until they are smoothly finished to the specified dimensions, and because each pair of junctions are made equidistant from the primary centre line or periphery around the arm's narrow side (see pages 220 and 221), it is needful to fix the lever on the slotting-table with regard to these finished parts at the time the broad sides are to be produced, in order that the places where the junctions terminate and the straight sides begin may not be ridgy after shaping, and require considerable filing. Instead of entirely depending on the accurate shapes of the bosses for placing the broad sides into the exact right-angular position with the table, it is sometimes preferable to place the lever in front of an el-chuck and put parallel packing-pieces between the chuck's face and each finished junction. This arrangement will cause the lever to be correctly placed, if the bottom edge of the el-chuck is put exactly to one of the straight gauge-lines on the table. When it happens that the surfaces of the junctions are too small for being thus packed against the chuck, the faces of the bosses should be put to the chuck, packing-pieces of proper thickness being put to whichever boss may need them, in order that the requisite parallelism of the arm with the traverse may be attained.

During the adjustment of a lever or bar on a slotting-table for producing its broad side, or during the adjustment of the article for shaping its narrow side, a tool-scriber may be used. Such a tool consists of a stock similar to that of an ordinary cutting tool for the machine, in the lower end of which is a small hole of sufficient depth to hold a scriber; the scriber, or pointer, as it may be termed, being a piece of pointed steel wire like a scriber for hand use, but shorter. This pointer is held tight in the stock with a wedge or with a little screw, and when fixed it constitutes an index to indicate the relative situation of an object on the slotting-table beneath.

The pointer may be used for adjusting either connecting-bars, two-boss levers, or those having three bosses. As soon as the article is put somewhat near its intended place on the table and some holding plates attached, also some poppets placed, the tool-scriber is to be fixed in the tool-clamps, and the lever or bar is gradually shifted until one end of the gauge-line by which the lever is to be adjusted is put directly under the scriber-point, and very near to it. The lever is now advanced along in the direction of its length by rotating the traverse screw, and when the lever is moved along under the point about as far as the length of the gauge-line, the observer looks to see whether the point is now exactly over the line as it was while at the other end. If not, the amount of shifting necessary to make the gauge-line parallel with the traverse of the slide is plainly shown, and therefore effected.

Adjustment by means of a tool-scriber has the same effect of placing the gauge-line into the desired position, as if it were adjusted while the article is against an el-chuck whose bottom-edge is on a gauge-line on the table, or as if it were adjusted to a scriber-block point whose bottom edge is on a similar gauge-line; because the path in which the lever is now made to move during adjustment is parallel to the path in which it will move during the cutting off of the metal.

Shaping of Crossheads.—Shaping the broad sides of crossheads by planing is sufficiently treated at pages 237 and 238, and it is now requisite to here mention their shaping on slotting-machines.

The treatment of a crosshead previous to slotting resembles that which is adopted previous to planing, the lining, turning of the pivot-ends, turning of the boss-faces, and turning of the arms, narrow sides, being usually completed when the shaping of the broad sides is to be commenced. It is not quite necessary to finish the hole in the centre boss, although it may be roughly bored, nor to turn the boss-faces, until the broad sides are finished. But if the hole is entirely finished before commencing the broad sides, the boss-faces must be also turned while the crosshead yet remains on the same lathe or boring-machine that executed the boring of the hole. This must be done to make the faces exactly right angular to the length of the hole, because when the hole is finished and the arms require reducing, it must be done so that the length of the hole will be parallel with the broad sides when produced, the result being obtained by placing the truly formed boss-face into contact with the table-face, which puts the length of the hole right-angular, as intended; whereas, if the broad sides are first reduced to the ultimate or specified dimensions, the crosshead must be adjusted on the lathe with the broad sides parallel to the axis of the lathe-spindle's motion, that the hole may be made parallel with the broad sides, as intended.

Reducing the broad sides of a crosshead with slotting-tools is very similar to that of a connecting-bar or lever, with the addition of an extra amount of shaping in order to form the curved junctions of the middle boss, and also the curved junctions with the pivot-portions or ends. If the faces of the boss have been turned to the right-angular position with the hole referred to, one of the faces is selected and put into contact with a parallel ring on the table, the ring being thick enough to provide a space for the clearance of the tool, similar to that before mentioned for other slotting. By placing the boss-face upon the ring, the length of the hole is put exactly right-angular to the table, and therefore parallel with the direction of the cutting tool's motion, as required; the same act also places the two arms of the crosshead equidistant from the table-face, if they were equidistant from the lathe-chuck while the boss-face was being turned; but because it may happen that they were not so, it is sometimes needful to apply a scriber-block to the centre recesses in the extremities of the pivot-ends while the crosshead remains on the packing-ring. This operation is also necessary in case some irregular or hollow part of the table, in contact with the ring, causes the crosshead's arms to be put out of the parallel condition desired; consequently, if one centre recess is found by the scriber-block to be nearer to the table than the recess at the opposite end, a piece of thin packing is put beneath one edge of the boss-face. Such packing-up is, however, but rarely required, because no great precision is requisite when the intention is merely to shape the broad sides.

After a crosshead is fixed right-angular to the table, it is adjusted to make its middle boss concentric with the table's rotary movement, because this movement is required to about half rotate the crosshead and thus shape one side of the boss. The adjustment for this situation is effected by reference to one of the circular gauge-lines, unless an arbor-chuck is used the stem of which fits the hole in the boss, in which case the crosshead boss is put into the exact position required by merely placing it upon the stem, in the same manner as that described for lever-bosses (page 275).

While a crosshead is on the stem of an arbor-chuck, it can be swung around and either broad side presented to the tool, the shaping of the straight parts of the arms and that of the curved corners being executed with the same sorts of tools as those employed for levers and bars. Each time a flat portion of a broad side is to be reduced, the crosshead requires adjusting by one of the gauge-lines on its lathe-turned narrow side, or edge, as it is usually named. This line is put parallel with the traverse, and the crosshead is then fixed until the shaping of the surface is completed, which shaping is performed by the advancement of the crosshead by means of the traverse screw. The cutting tools employed are the same as those for levers and connecting-bars (Figs. 787, 793, 794, and 792).

Shaping of Gaps.—The gaps here treated are those belonging to levers, joint-rods, eccentric-rods, connecting-rods, and other rods and bars in general. Some of these are forged with the gaps roughly formed, but great numbers are forged without any gap and are made with solid lumps at the ends, which are to have gaps formed therein while cold by means of machine processes of various classes.

The entire number of the processes for shaping gaps while cold may be distinguished into two sorts, which are drilling and slotting. Those rods, levers, and bars which are forged without gaps are principally shaped with drilling, through the comparative large amount of metal to be cut out. Articles in which the gaps are partly formed at the time of forging have them completed principally with slotting, little or no drilling being done, because but little metal is to be removed, and also because gaps cannot be drilled without additional pieces being fixed therein.

The lining of a solid fork-lump in which a gap is to be formed is denoted by Figs. 805 and 811. The same lining suits a great variety of rods, bars, and levers, small and large, whether they are to be shaped by hand-shaping or by machine-shaping. When the end is properly lined the article is taken to a drilling-machine to have a hole made at the bottom of the intended gap, and also, in some cases, two or three additional holes made along the gap. If a number of holes are drilled, the superfluous metal which remains between the holes is easily removed afterwards either with a shaping-machine or a slotting-machine. Slotting-tools may be used also to cut out the entire gap-piece, if only one hole has been drilled, if the article in progress is small. For large rods and bars a circular saw should be used, with which two slits are cut from the extremities of the rods to the drilled holes, only one hole being made into each gap-piece when sawing is to be done. This is a quick and easy process for the forming of gaps in large numbers, nearly all of the superfluous gap-piece being removed in one lump, instead of in the condition of shavings.

Solid gap-ends are drilled while bolted against an el-chuck, in the situation shown by the small lever in Fig. 863. In this Figure an el-chuck is seen bolted to the circular table of the drilling-machine, and to that face of the chuck which is at right-angles to the table, the article to be drilled is bolted. Either one or both the bosses may be in contact with the chuck's face, according to the comparative length of the lever for the table and chuck. By the boss-faces being thus parallel with the chuck, the operation of drilling will form a hole whose length is parallel with the boss-faces, as required, because the downward vertical movement of the drill while cutting, and the face of the chuck, are parallel with each other. Therefore if the boss-faces of the object are truly turned, and the joint-pin holes also truly bored, previous to drilling the gap, the boss-face must be put parallel with the chuck-face, in order to make the drilled hole for the gap parallel with the boss-faces, and, consequently, right-angular to the length of the joint-pin holes, which is necessary.

Levers, rods, and bars, of all sizes are drilled while bolted to el-chucks; but the modes of fixing differ a little from each other through the different shapes and sizes of the articles to be drilled. The solid gap-portions are often drilled previous to boring and turning the bosses, so that it is not always needful to put the boss-faces into parellelism with the el-chuck's face; in many cases it is preferable to put the broad side of the flat mid-part or arm parallel with the chuck; and if the broad side is not close to the chuck-face the space is occupied by a parallel packing-piece or pieces. If the rod or bar is thus fixed, the arm is adjusted to parallelism with the chuck, and the boss is prevented from touching any part of the chuck by reason of the packing; the boss-face is therefore not parallel with the chuck-face, unless they happen to be parallel with the arm's broad side, which side is specially intended to be parallel.

Any lever or bar that has plenty of superfluous metal in the boss, and little or none in the broad sides of the arm, requires placing to the chuck with the arm in contact or against parallel pieces in order to cause the hole or holes to be drilled parallel with the broad side, and not necessarily parallel with the boss-faces. These faces having plenty of metal can be reduced after the drilling of the gap is finished, and can then be made parallel, both to the drilled gap and the mid-part or arm's broad side. But if the boss has the least amount of metal to be cut off, the object is fixed with regard to the boss instead of the arm.

A lever which has both its bosses truly faced, when to be drilled, is fixed with one or both of its bosses in contact with the chuck. When both bosses are of the same length the two faces are put close to the chuck; but when one boss is shorter than the other, a parallel ring, or parallel blocks are put between the face of the chuck and the face of the boss which is the shorter. During the fixing of such a lever it is therefore necessary to first tightly bolt the longest boss to the chuck in order to see exactly what thickness of packing is required to occupy the space between the face of the short boss and the chuck's face. By tightly screwing the fixing bolts which are holding the longer boss, the shorter one is forced into parellelism with the chuck, and also forced to the proper distance from it. Consequently the exact thickness of packing necessary is now shown by the space referred to.

The direction in which a gap extends into a rod or bar, must be parallel with the length of the rod or bar; for which, an adjustment is required previous to drilling, if the gap to be made is of comparative great length, and several holes are to be drilled in line with each other. This adjustment consists in placing the bottom edge of the chuck's face parallel with the traversing movement of the slide belonging to the machine-table. If the chuck is thus placed with the object properly bolted thereon, the object can be easily moved in the exact direction required during the drilling, in order to cause the holes to be made in line with the length of the piece as required. After the rod and chuck are at first correctly fastened and adjusted, and one hole bored, it is only necessary to advance the table and chuck a short distance by rotating the traverse screw in order to place the gap-end exactly into the required situation for another hole to be made. This hole being formed, the table is again advanced as before to make another hole, this gradual shifting being continued till all are made.

A drilling-machine which is not provided with slide-rest movements, which is the condition of the one shown by Fig. 863, requires the el-chuck to be shifted after each hole is made, instead of shifting the table and chuck at one time with a sliding apparatus. Every time a new hole is to be drilled with such a machine, the gap-end must be re-adjusted to place it into the required position; and to facilitate the adjustments after each shifting, the table should be provided with parallel straight lines. One of these lines is selected to which the bottom-edge of the chuck's face may be put parallel; and if it is thus situated, the line constitutes a sort of standard to which the bottom-edge will be again adjusted after being shifted. After one hole is drilled in the gap-end, the bolts which hold the chuck to the table are loosened, and the chuck is slid along the table in a direction which is parallel with the gauge-line; and when moved a proper distance for the next hole, it is again fastened by tightening the bolts, and the hole is next made. A drilling-table which is devoid of lines, or which may have lines too far from each other, may be specially marked for the occasion with a scriber. This marking is done after the el-chuck is first properly fixed for drilling one hole, at which time a line is scribed upon the table parallel to, and very near to, the bottom-edge of the chuck's face.

Shaping of Gaps by Shaping and Slotting.—If a lever or rod is forged with the gap roughly formed in its fork-end, the gap-sides and bottom are afterwards entirely shaped with a shaping-machine, or with a slotting-machine; unless the depth or extent of the gap in the direction of the rod's length is much less than it should be. If too shallow, enough metal may exist at the bottom of the gap to constitute a proper bearing on which the point of a drill will rotate. When such an amount of metal does exist it should be removed by drilling, because it is the quickest process. After a superfluous piece of this sort has been cut out, the gap is formed to about the same shape it would have had at the conclusion of its forging, if the smith had enlarged it with punching and chiselling while on the anvil.

As soon as the gaps in rods or other articles are roughly made, either by forging, by drilling, or by forging and drilling combined, the various articles are ready for an accurate shaping to finish the gap-surfaces. The operations for these purposes include shaping with to-and-fro shapers, with planing-machines, with slotting-machines, and with drilling-rods connected to drilling-machines. In this place, it is, however, only requisite to mention the shaping and slotting processes.

A small short lever or connecting-bar which is now ready for having its gap finally shaped, can be fixed to an el-chuck which is bolted to the face of a shaping-table, the broad side of the object being put parallel with the direction of the shaping tool's motion. This being the position, it is of course requisite to put the chuck's face parallel with the tool's motion, because the broad side is parallel with the same face. Sometimes an el-chuck can be dispensed with; this is the case when the machine is provided with a chambered table, which is a table having, in addition to the usual upper table-face, another face or faces at right-angles to the upper one, the plane of the upper one being horizontal, and the planes of the others, therefore, vertical. These latter ones are also right-angular to the machine-front, which may be perceived by referring to Fig. 833, in which chambered tables are represented.

To one of these side-surfaces at right-angles to the machine-front, or bracket-surfaces as they are sometimes named, the broad side of a lever or bar can be bolted, and the desired position of it is obtained as easily as if it were against a separate el-chuck on the table. A bar thus attached can extend downwards to the floor, consequently, the greater the height of the table above the floor, the greater is the room allowed for the lengths of whatever objects may be fixed. If it happens that a number of rods or bars require their gaps to be shaped with a machine whose table is not high enough, the remedy is to cut a hole into the floor at the proper place for the work, or to dig a hole into the ground if the machine is on the ground-floor.

In order that the bottom of the gap when shaped may be at right-angles to the length of the rod, the centre length of the rod must be adjusted to a right-angular position with the cutting tool's motion, which position is vertical, if the machine is fixed as it should be. This adjustment is effected after the rod is fastened with its broad side in contact with the chuck, or with the side-surface of the table, as directed, although the holding bolts are not tightened. In this condition the rod can be easily moved with a few blows of a tin hammer, until the rod's centre length is put into the right-angular position required. During the adjustment, one of the straight gauge-lines on the table's side-surface should be used, to which line the primary centre line along the rod is made parallel. Gauge-lines of this species are shown marked according to the author's method on the side-surfaces of the tables seen in Fig. 833.

When the length of the bar is correctly placed, and the broad side of it also correctly placed, the adjustment for positions is complete; and it is only necessary to raise or lower the bar to the desired height, by rotating the screws with which the table is furnished. The vertical traverse of the slide-rest is next adjusted, to put it exactly right-angular, if it has been recently inclined for some purpose; and the tool is fixed in the clamps. This being done, the to-and-fro motion of the tool is put into action, and also the downward vertical traverse of the rest. These two motions suffice to advance the tool correctly down in a direction of parallelism with the broad side and centre length of the bar, because its length was adjusted to a vertical position, and its broad side to right-angles with the machine-front, previous to commencing the shaping.

The cutting tools required to remove the metal are grooving tools and corner tools. These are of various sizes at their cutting parts, to suit large gaps and small ones. The corner tools, having bent ends, are used to shape the two sides of the gap; a right-hand corner tool and a left-hand one being both required for one gap. The bottom of the gap is shaped with a groover having a curved cutting edge, because the bottom is curved, for both strength and pleasing appearance. To smooth the surfaces, soapy water is applied during the finishing cuts; and to make the gap to specified dimensions, or to make it fit the portion with which it is destined to act, accurate measurements must be conducted, either with callipers or sheet gauges, for the uses of which refer to page 227.

Slotting of Gaps.—In order to finally shape the gap-surfaces of a bar on a slotting-machine, to cause the depth of the gap to be parallel with the bar's length, and the broad sides of the gap to be parallel with the broad sides of the bar, as intended, it is necessary so to place it upon the slotting-table that it shall occupy a position exactly at right-angles to the position it would occupy if it were to be shaped on a shaper. On a slotter the centre length of the bar is horizontal, because the motion of the slotting-tool is vertical, and the narrow side of the bar is also horizontal and upwards; consequently, the vertical motion of the tool while cutting will form the gap parallel with the bar's broad side, and right-angular to the centre length.

The apparatus required for fixing the rod or bar to a slotting-table is the same as that used for drilling-tables and shaping-tables, consisting of an el-chuck, screw-bolts, and plates. The chuck should be adjusted to a straight line on the table, to cause the chuck's face to be parallel with the sliding motion of the slide-rest, for the purpose of using this same sliding movement to advance the lever in the direction of its length, the lever being attached to the chuck. As soon as the chuck is adjusted and fixed, the bar, or other article having the gap which is to be shaped, is bolted to the chuck's face with the length of the article parallel with the face of the slotting-table, the broad side of the bar being parallel with the chuck. Between the under side of the bar and the table-face, a space is allowed, in which the slotting-tool may disengage from the metal at the end of each cut. For a comparative small or short bar this space is not required, because the gap-portion of such a piece can be put a short distance beyond the table's edge; and, consequently, will cause the slotting tool to be also beyond the table's edge, instead of being over it. To adjust the centre length of the bar to parallelism with the table a scriber-block is stood upon the table, and the scriber-point is adjusted to one end of the centre line on the bar's broad side; the block is next removed to the opposite end of the line, at which place the scriber-point will show whether this end of the line is at the same height as the other end; if not, a few blows of a tin hammer are given to the highest end, and the scriber-point again referred to.

Placing the bar or rod parallel with the slotting-table completes the adjustment for positions. By the el-chuck having been at first bolted in the proper situation parallel with the traverse which will advance the bar in the direction of its length, and by the bar being next adjusted against the chuck-face, only one other shifting is now required to put the object into a proper place for commencing the cutting. This shifting is partly effected with the traverse of the slide to which the bar's length is parallel, and is that which is at right-angles to the machine-front. By rotating the screw of this traverse the lever or bar is of course advanced endways to the tool, and away from it, when requisite. The other traverse screw, which is parallel to the machine-front, is also rotated; consequently, the bar is easily and rapidly moved in two directions to place the gap exactly under the slotting-tool, but without altering the relative positions of the bar, chuck, and slotting-table, which are bolted to each other.

The slotting-tools used for shaping a gap, are those having slotted stocks, which are represented by Figs. 786, 787, 788, and 792. The cutters that are keyed in the slots, are, for small gaps, similar to the one keyed in Fig. 786, which projects beyond the side of the stock a sufficient distance to prevent it touching the gap side during the cutting. A small gap may be also shaped with a cutter like the one in Fig. 795, which is provided with two cutting edges. This tool can be used so that one or both the edges may, with proper management, be made to cut at one time, thereby shaping both sides of the gap at one time. Large gaps, of six, eight, or ten inches inwidth or depth, require longer cutters, similar to those seen in Figs. 787, 788, and 792. The cutting ends of these for large gaps, are bent to form corner tools, both left and right, a right-hand one and a left-hand one being both required for one gap. The solid tools shown by Figs. 793 and 794 also are used for shaping large gaps, and when employed for this purpose, are furnished with ends which are bent to suit either side of the gap; consequently, they are then right-hand tools and left-hand ones, but each one is in one piece with the stock, instead of being distinct.

Shaping Teeth of Wheels by Planing.—A planing-machine may be often used for teeth-shaping; although other processes, which are to be given, are preferable for shaping considerable quantities.

The operations here given are suited to wheels which are to be made of circular plates or discs, which are lined on their broad sides to show the exact shapes and dimensions of their respective teeth ; such lining being necessary because no special dividing apparatus is to be used. The operations therefore suit those who do not possess the dividing apparatus referred to.

The simplest mode of planing wheel-teeth consists in fixing the wheel to an el-chuck on the machine-table, and cutting out the metal with grooving tools of proper shapes and sizes while the wheel is moved to and fro with the table. In Fig. 864 a small wheel is seen fixed for this purpose, one broad side being in contact with or parallel with, the chuck's face. A wheel thus situated usually requires parallel packing between the chuck and the wheel's side, because the ends of the boss project beyond the side, and must be prevented from touching the chuck. The packing is, therefore, thick enough to keep the boss-face a short distance from the chuck when the wheel is bolted in its place. If a number of wheels of similar sizes are to be planed, the packing should consist of a ring, because it is easily kept in its place and constitutes a broad bearing-surface for contact with the wheel. The substitute for a ring is a couple of parallel blocks, one at each side of the boss.

Any wheel which is attached to an el-chuck in this simple manner will have its teeth formed parallel with the axis of the wheel's rotation, as required; but it requires a tedious shifting and re-adjustment, which must be performed the same number of times as the number of teeth formed on the wheel. And because no means are provided in such an arrangement for rapidly effecting the several adjustments, the method is especially applicable in cases of emergency, or when only a few wheels of unusual shapes and sizes are to be planed.

For planing wheels in considerable quantities, an arbor-chuck is necessary. A chuck of this class for wheel-planing is much like the author's arbor-chuck which was mentioned for boss-shaping, with a difference of relative position between the two chucks while in use. On a planing-machine the arbor's axis of rotation is horizontal, instead of vertical, as while on a slotting-machine. The base or flange of the arbor-chuck is bolted in contact with the face of an el-chuck, which face is right-angular to the table and in the same position as the el-chuck shown in Fig. 864, although this is without an arbor-chuck. The stem or pivot of the chuck is therefore at right-angles to the el-chuck in whatever relative position it may be to the planing-table. Consequently, if the el-chuck is at first accurately fixed, the act of fixing the arbor-chuck puts it into the desired position without further treatment.

The broad sides of the wheel-teeth to be now made require to be right-angular to the broad sides of the wheel, and consequently, parallel with the axis of rotation; and to cause the planing tools to produce the teeth in this position, the bottom edge of the el-chuck's face must be adjusted to right-angles with the planing-table's motion. This condition is known by the edge of the chuck being parallel to one of the short gauge-lines on the planing-table; and as soon as thus adjusted, the arbor-chuck can be attached, and a wheel placed upon the arbor. Any wheel thus situated, is caused to immediately assume the proper position, by reason of the pivot properly fitting the hole in the wheel. Every wheel which is to be thus shaped by planing, should have had its hole in the boss accurately bored, and its faces truly turned to make them right-angular to the length of the hole. The broad sides also require turning, to make them parallel with the boss-faces; and when it is not convenient to turn the entire broad side, a portion at the rim must be turned, because it is imperative that a truly formed broad surface at right-angles to the axis of the hole shall exist, and be put into exact parallelism with the el-chuck's face, either in contact with the flange of the arbor-chuck or in contact with parallel packing, according to circumstances. It is highly necessary that the broad side of the wheel shall be accurately turned, in case of a slight looseness existing between the arbor and the sides of the boss-hole; this would allow the rim of the wheel to deviate considerably from its proper position when it was tightened with the fixing bolts, if the broad side in contact were not correct; but a small quantity of room in the hole sideways is not detrimental if the wheel's side is accurate, because the tightening of the holding bolts maintains the required parallelism with the el-chuck. With a wheel whose broad side bears exactly as it should, after being fastened, the only deviation of the rim from its proper position, which will occur through a little room around the pivot, will be in the direction of the wheel's diameter, and not in the direction of its thickness. Such deviation merely causes the bottoms of the teeth-gaps to be either deeper than, or not so deep as, they should be; but does not prevent all the broad sides or contact-sides, of the teeth, being planed exactly right-angular to the broad sides of the wheel, which is to be done.

In addition to the method of planing teeth by using arbor-chucks, another of the author's plans for teeth-planing may be mentioned, and consists in attaching the wheels to the el-chuck without using either parallel packing-pieces or arbor-chucks. By this mode the boss of the wheel to be planed is put into a hole in the chuck instead of being put into an arbor, or by other means kept at a distance in front of the chuck's face. The hole in the chuck is circular, and may be large enough to admit bosses of several sizes; or it may be specially bored to suit bosses of only one size, when it happens that a quantity of wheels having bosses of one size are to be planed. The sort of el-chuck used for this purpose, should be one of considerable length, to allow several holes to be bored side by side, and of different diameters to suit the bosses to be put therein. By means of this chuck, the broad side of the wheel is put into close contact with the chuck's face, however long the boss may be, without requiring any packing, because the boss-end extends along the hole in the chuck to any desired distance, nothing being in the way to prevent it. If a hole is specially provided for a number of wheels which are alike, the boss-ends of every wheel should be lathe-turned to the same diameter, which diameter is that of the hole, a minute amount of looseness being allowed for an easy rotation and placing of the boss into and out of the hole. A hole to be thus used must be bored exactly right-angular to the chuck-face, that the wheel's broad side may not be made to bear unequally upon the chuck when the wheel-boss is in the hole. When a wheel is thus arranged, and loosely bolted to the chuck, its adjustment is easy when compared with that of a wheel which is fixed on packing-pieces, although more tedious than that of a wheel on an arbor-chuck.

As soon as an arbor-chuck is properly fixed, and a wheel slid thereon, all the adjustments for positions required previous to planing are completed excepting one. This adjustment consists in rotating the wheel on the pivot a short distance, in order to place the centre line of one of the intended teeth-gaps exactly right-angular to the table. In this position the wheel is to remain during planing; it is therefore next firmly fastened to the chuck, and is then ready for the cutting out.

A small wheel of a few inches in diameter can have its teeth entirely formed with the grooving tools of the planing-machine, without any preliminary drilling; but a wheel of six or eight inches in diameter, or any larger size, should be drilled previous to planing, a hole being made at the bottom of each intended gap. In some cases, two holes can be drilled for each gap, one hole being made at the extremities of the intended teeth. If such holes are carefully drilled to the scribed line on the wheel's broad sides, the bottoms of all the gaps will, by drilling, be correctly shaped; such a half-round form being suitable for many classes of wheels; consequently, no subsequent shaping of the bottoms by planing is necessary. Such drilling also suits wheel-teeth of any form, because, whatever special shape may be intended, can be produced afterwards by planing, when drilling has been adopted for partly obtaining the required form. Whenever it is convenient, drilling the gaps should be resorted to, because it is the quickest of all processes for removing metal in such places.

To commence the planing of a wheel which is not drilled, the vertical traverse of the slide-rest is adjusted to right-angles with the table, and a grooving tool having either a curved cutting edge or a straight one, is first used. The cutting edge must not be any longer than the desired distance between any two teeth at the bottom of the gap; although the edge may be, and usually is, rather shorter. This tool is advanced down to the bottom of every gap of the wheel previous to using any other tool. It is therefore necessary to loosen the fastening bolts, rotate the wheel a short distance, and again fix it, as many times as the number of gaps, the entire rotation of it being effected while the grooving tool remains as it was when first fixed in the clamps; unless it required taking out through being broken, or to be sharpened. By the time one rotation is completed, all the teeth-gaps are formed in the proper places, if the wheel were accurately adjusted by the centre line of each gap; but all the gaps are parallel, and are therefore of a shape which is different to that indicated by the lines on the broad sides. The shaping is consequently continued with other tools, and additional rotations of the wheel. When the work is well managed, and the tools good, two more rotations will suffice to complete the teeth; a corner tool, and sometimes also a tool with concave edge for the curved broad sides, being used for each rotation. These final shaping operations for changing the original parallel shapes of the gaps when first made, must be done while the slide-rest, and consequently, the tool also, is inclined at a proper angle to the planing-table, in order that the advancements of the tool downwards may widen the mouth of each gap and produce the taper form intended.

There are two modes by which the tapering of the gaps may be executed. One of these requires the slide-rest to be inclined and fixed twice at one fixing of the wheel; and the other mode requires it to be inclined only once. If the rest is adjusted twice, the two sides of each gap are finished at one fixing of the wheel; but if the slide-rest is adjusted or inclined only once, only one side of the gap can be finished at one fixing. This mode being adopted, renders it necessary to gradually shift the wheel tooth by tooth, until a complete rotation is effected, during which every tooth is shaped on one side only, and while the slide-rest remains the whole time in one position. When one side of each tooth is thus treated, the wheel is entirely removed from the arbor-chuck and reversed, now placing to the flange that broad side of the wheel which was previously outwards. When reversed it is again fixed, and gradually rotated, to shape all those sides of the teeth that were not shaped during the previous rotation. At the shaping of the second lot of sides the slide-rest remains in the same inclined position it had before, because the wheel is adjusted each time by the centre line of each gap being put right-angular to the table, as directed. Generally speaking, it may be said, that all small wheels should be shaped by reversing the wheel side for side, and with only one fixing of the slide-rest; and that all large wheels which are troublesome to move about through deficient lifting apparatus, and other causes, should be shaped without reversing the broad sides, and with the rest adjusted in two positions inclined to the table, and also inclined towards each other.

Planing the teeth of a wheel which has been previously drilled at the bottom of each intended gap can be entirely executed with the slide-rest inclined in the two positions referred to, without requiring the downward traverse of the slide-rest in a vertical direction at any time during such shaping. While a wheel which is drilled is on the arbor-chuck and properly fixed with the centre line of a gap right-angular to the table, the oblique traverse of the rest will advance a tool down to the drilled hole with great facility, because it is not necessary to advance the tool-point to the bottom of the gap, this part being already shaped by the drilling. When one side of the gap has been formed with the oblique traverse of the rest in one position, the rest is next shifted and fixed for shaping the opposite side of the gap, being now inclined at the same angle as while shaping the first side, but now at the opposite side of the tooth-gap's centre line. It may by this be seen that the entire superfluous gap-portion can be removed by the two oblique traverses referred to, without any vertical traverse, as before stated. This mode of cutting out will be found a very easy means of forming the teeth-gaps of large wheels having wide gaps, because a wide gap will allow almost the entire gap-portion to be removed in one lump. This can be done by using a narrow grooving tool and advancing it down with the two oblique traverses; which of course will form the superfluous piece into a wedge-shaped lump, because the directions of the two traverses are inclined towards each other, the lump being completely detached as soon as the two narrow grooves made with the tool have extended to the drilled hole.

When the gap-piece has been removed, the roughly shaped sides are next carefully finished to the desired form; for which process tools having broad cutting edges are employed; these, and also springy tools, should be used for this finishing, whenever the particular wheel in process possesses comparative great strength to sustain the strain imposed by the broad edges referred to. A careful finishing is always necessary, to avoid a subsequent filing.

It may be here stated that teeth-shaping by planing-machines much resembles that executed by shaping-machines, the el-chucks and arbor-chucks being used in about the same way for either class of machines; the only difference consisting in using shaping-machines for comparative small wheels, and using planing-machines for large ones.

Shaping of Angular Holes.—Angular holes are those of which the across sections and entrances possess angular boundaries. The boundary of a hole's entrance may be either rectangular, hexangular, octangular, or of some other angular form, the precise form of the boundary depending on the number and shapes of the hole's sides. If a straight hole in one end of a connecting-rod is hexagonal or hexangular along the entire length of the hole, it is said to be a six-sided hole, and possesses six sides or planes. Previous to a correct filing or other paring process these six planes are hidden by the rough exterior metal; and the methods for producing and exhibiting these planes are among the processes here given.

The portions of engines and machines which require angular holes are the ends of slide-rods, coupling-rods, connecting-bars, connecting-rods, and side-rods. The mid parts of a few classes of slide-rods also require angular holes, and the holes in these pieces are usually of a rectangular section, some being square and others oblong. A middle portion of this class is shown by Fig. 890. All angular holes in boss-portions are required for nearly the same purposes, being employed to contain bearer-brasses or friction-blocks, and prevent their rotation by reason of the angular surfaces of the brasses and blocks being made to fit the angular boundaries of the holes.

The paring processes which are adopted for producing angular holes include drilling, shaping, planing, and slotting. If drilling is employed, it serves as a species of preliminary process for commencing a hole, or originating a hole where none exists; consequently, drilling is the means of roughly making holes into solid ends of rods and bars, which were forged in this condition instead of having their square or six-sided holes partly shaped by punching and drifting while on the anvil, according to the processes for drifting mentioned in page 80. The shaping, planing, and slotting of angular holes always serve as processes for finishing them after they have been roughly made, either by casting, forging, drilling, or by forging and drilling combined.

The lining which is performed previous to the formation of angular holes, is required to indicate the boundaries of their entrances, and is about the same, and is executed by about the same means, whether the pieces lined have holes or are without them. An end of a rod or bar is prepared for lining by means of planing, or by lathe-turning, according to convenience; and both sides or surfaces of the part in which the hole is to terminate are planed, and also made parallel to each other. Substitutes for these planing processes may be mentioned, which consist of grinding the two sides with a grindstone, and of filing them while the article is held in a vice. When an end of a connecting-rod or coupling-rod has been flattened by one of these preparatory processes, the piece is in a condition to be easily lined, and also to be accurately fixed after lining, in order to be drilled or slotted.

Angular holes in the boss-ends of rods and bars are slotted after the other portions of the pieces have been smoothly reduced to the finished dimensions and shapes intended, by means of lathe-turning and planing; and the flat surfaces of the boss-portions, which are lined to show the desired shapes of the holes, are produced exactly in their proper places and positions with regard to the other portions of the objects. These flat surfaces of any rod or bar must be accurately formed parallel with the rod or bar's centre length; because, to these, considered as bases or primary planes, the planes which will constitute the boundaries of the hole must be made right-angular. In an end-boss of a connecting-rod the centre line extending along the length of the hole through the boss must be right-angular to the centre length of the entire rod, because it is intended to be connected with its pivot-pin or joint-pin at one end, and with the crank-pin at the other end; of which two portions the axes of rotation are right-angular to the rod's length, and parallel with each other. This being the ordinary arrangement also for a great number of bars, levers, joint-rods, and other portions, it is necessary to plane and line the boss-faces of all such articles with regard to one general method, whether the holes are to be square, hexangular, octangular, circular, or oval; and whether they are to be parallel along the lengths of the holes, or rather taper. The taper form is preferable for the greater number, which will be shown as we proceed.

In order that the hole in any end-boss of a rod may be centrally located, it is only necessary to shape the hole with regard to the gauge-lines on the flat surfaces referred to, which are the boss-faces, and are the top surfaces in the Figs. 890, 891, and 892. The lines on these faces are marked from the primary centre lines which extend, or would extend if continued, along the entire lengths of the respective rods. Two such centre lines are used for every boss, one line being on each face, consequently, across each of the two entrances, or intended entrances, belonging to the hole. A primary line of this character is seen in Fig. 893, extending along an ender to the end of the boss. The ender is required to show the centre dot, whenever a boss is to be lined in which the hole is already forged; but a boss without a hole is lined from the centre dot, which is situated on the superfluous metal to be drilled out. From the dot circles are scribed to indicate the size of hole intended, after which the exact angular form for the hole is marked with a straight-edge and scriber. This marking will denote the shape, and also show the quantity of superfluous metal to be cut out, whether equally or unequally around the hole. It is not quite necessary to mark both ends of the hole, although it is sometimes done; the marking on one boss-face is quite sufficient for all the drilling and slotting that may be required, the lines on both faces being used only during a final filing of the hole to the exact form. It may be perceived that by reason of the two boss-faces being parallel with the machine-table, the one adjustment of the boss by the gauge-lines on the upper face must at the same time adjust the lower face, and therefore cause the hole to be drilled and slotted in the exact right-angular position desired.

Adjusting the rod or bar for drilling consists in placing the planed boss-end upon a parallel ring or parallel block situate on a drilling-table, as seen in Figs. 886, 887, or 897, such packing being necessary to keep the boss high enough above the table to prevent contact with the drill-point. While the boss thus remains it is adjusted to place it exactly beneath the drill for one of the holes to be drilled; or if only one hole is to be drilled, the dot showing the centre is placed accordingly. Adjusting an article for drilling should always be performed by rotating the drill and observing the dot which shows the centre of the hole to be drilled. If the point of a drill which is fastened in the machine-spindle, and the axis of the spindle's rotation were exactly in the same straight line, the centre of the hole to be made could be put directly under the drill-point while it is at rest, and the adjustment would by the same act be completed; but because the drill and the spindle's axis do not coincide with each other, it is necessary to put the machine into action when the drill is tightly fastened, and then gradually shift the object beneath until near enough to easily observe the relative situations of the drill and dot. During this observation the drill-point will be seen to move in the path of a small circle's circumference, which may be only an eighth or a quarter of an inch in diameter, the size depending on the care with which the drill was made and straightened. The diameter is seldom less than an eighth of an inch; but, whether larger or smaller, the centre of the circle traversed by the point is the exact place in which the centre of the hole to be made must be put. The article is known to be properly situated when the drill-point travels in the path of a circumference whose centre is exactly over the centre-dot of the hole to be drilled; consequently, the article must be gradually shifted to the place either with a tin hammer, with the screws of the poppets that hold the article, or with the traverse-screws, if the table is provided with them. To enable the operator to see plainly when the work is adjusted, the drill-point is allowed to be as near as possible to the piece without touching it.

Circular gauge-lines marked on a drilling-table are also useful for adjusting. These lines resemble gauge-lines on a slotting-table, being concentric with each other, and with the centre of the table, as indicated by Fig. 899. They are only serviceable for adjustment when the centre of the drilling-table is exactly beneath the axis of the drill's motion; consequently, a table which slides to and fro on vee-slides, or dove-tail slides, must be moved until the gauge-lines are concentric with the drill, as required. This position is known by marks or dots, and when properly placed, any one of the gauge-circles may be selected and considered a standard ring in the centre of which the hole to be drilled shall be located when adjusted. Some drilling-machines are provided with tables which are fixed, therefore the gauge-circles of these are at all times available for adjustment. Such a table may also have a circular hole truly bored at the middle, in which packing-rings having holes of different diameters may be placed. Upon a ring of this class, a boss-end to be drilled can be fixed, if small; but if too large for a ring the boss-face can be put into contact with straight parallel blocks, which are put at any desired distance from the centre, to suit the diameter of the piece to be drilled. In some cases the parallel packing beneath the piece can be entirely dispensed with, the hole in the middle of the table being deep enough and wide enough to provide ample room for the drill-point to disengage from the metal at the conclusion of drilling.

Although an end of a rod or bar can be adjusted with a tolerable approach to precision by means of these circular lines, it is always proper to adjust the object by observing the rotation of the drill-point, in case any irregularity or wear of surfaces prevents the gauge-circles being concentric with the drill-spindle, as required. As soon as the piece is correctly placed beneath the drill by some means, it is also in a suitable position for causing the hole to be drilled in the desired right-angular position with the length of the rod and with the two planed boss-faces, because these are put square to the drill either by means of the parallel ring, parallel blocks, or the surface of the drilling-table. The correct placing of the piece being now effected, it is next finally tightly fastened, and the drill-point is put into the centre-dot for commencing the drilling. If it happens that the drill has been carefully straightened, the point will properly enter the dot without any guiding; but it usually requires guiding into the dot by being pushed sideways with a lever at the moment the point is caused to touch the metal. The distance which the point is thus moved sideways, is exactly half the diameter of the small circle in which the point rotates while free from the metal, as when it was referred to for adjusting the piece of work; therefore, if the circular path is a quarter of an inch in diameter, the drill-point is moved an eighth of inch, by which movement it is put exactly into line with the hole to be made, and also with the drill-spindle's axis. In this condition the drill is maintained by its continual contact with the metal during drilling, because the rod or bar is tightly bolted to the table, and because the drill is flexible enough to allow the necessary straightening while it rotates. During the drilling, the drill-point continues in very nearly the same relative position into which it was first pushed, unless it gets out at the beginning of the drilling; to remedy which a gouge-chisel is used to again put the point to its proper place. The use of a chisel for this purpose is mentioned in page 144.

The drilling of a boss-portion is executed with care to allow sufficient metal for a subsequent slotting of the hole to the finished dimensions; therefore, the drill is not allowed to obliterate any of the gauge-lines on the face, but is caused to cut as near as possible to them, that but little slotting may be afterwards necessary. If a hole several inches in width is to be made, a comparatively small drill should be used, with which a number of small holes may be made near the gauge-lines in order to remove most of the superfluous piece in one lump.

Holes that are partly formed by forging, are entirely machined by slotting, whether little or much metal is to be removed, because such holes do not furnish any metal for bearings on which a drill-point could rotate. To properly place a boss-end upon a slotting-table, the same means are adopted as for drilling, one boss-face being put upon a parallel ring or packing-pieces to maintain the boss at a suitable height for the clearance of the tool. The downward vertical motion of a slotting-tool is analogous to the vertical motion of a drill; therefore the parallel blocks will cause the hole to be slotted in the desired right-angular position.

A rod or bar which is to have its boss slotted for an angular hole, may be so situated on the table that the rod's length is parallel with the slide-rest traverse which is parallel with the machine-front; by this traverse, the rod will in due course be moved in the direction of its length; and such movement will shape a plane of the hole which is parallel with the rod's length. It will be perceived that the boss should be situated at the middle of the table, because a gradual rotation of the table is necessary. It is presumed that a boss is to have an octangular hole, requiring eight planes to be produced as boundaries of the hole when finished. Such a hole can be shaped by a gradual rotation of the boss, the movement being much like the rotation of a lever-boss which is having its cylindrical outside shaped. But instead of rotating it during the entire process of cutting, it is only shifted each time one of the eight planes is to be commenced, the table and piece at this time being moved an eighth part of a rotation. This gradual movement will cause the hole to have the shape of a regular octagon, and will cause each plane to be of the same width as any other belonging to the hole. If the boss were rotated a sixth part of a rotation each time, the entrances of the hole when complete would have a hexagonal form; or, if moved a third part, the entrances would be triangular. It may therefore be seen that if the boss of a rod is in the middle of the table-face and concentric with the axis of rotation, a regularly formed hole having either three, six, eight, or any desired number of planes, may be accurately formed, and all the planes of the holes will be of the same width.

But angular holes which are of regular hexagonal or octagonal forms, are seldom required for boss-portions of rods and bars; nearly all are oblong, the greatest length of the hole being in the length of the rod or bar to which the hole belongs. Consequently, a regular gradual rotation of the table and boss at only one adjustment of the slide-rest, will not produce the shape desired; and, in addition to fixing the boss in the middle of the table-face, it needs an additional adjustment by the traverse-screws, every time the table is moved the sixth, eighth, or other portion of its rotation. For these adjustments the tool-scriber can be used, the point of which will indicate the exact situation of the object beneath by observing its gauge-line; and after the boss has been shifted by partly rotating it, in order to commence a plane, the traverse screws of the rest are caused to slowly adjust the boss until the gauge-line is seen to be in the proper place. In this condition the table is now fixed, to prevent further rotation till the plane is produced, and another one to be commenced. Every adjustment of the article for commencing a plane, causes the hidden plane to be placed parallel with the machine-front, and therefore parallel with the traverse which moves parallel to the front, as directed; and to allow room for the backward retreating motion of the tool from the metal during the upward travel, the plane surface being formed is always between the tool and the machine-front, and not between the tool and the main-standard. Consequently, shifting the boss by rotating the table an eighth of a rotation, puts each one of the planes successively into the same condition of parallelism with the machine-front, and also into very nearly the same place beneath the tool, the small additional adjustment that was said to be needful, being performed with the traverse.

The slotting-tools suitable for planing the boundaries of an angular hole, are corner tools, vee-point tools, groovers, and mortisers. The tool first used is either a mortiser similar to Fig. 791, or a groover with a curved cutting edge resembling Fig. 782. It is specially necessary to first employ a groover where a comparative large quantity of metal is to be cut out. The groover is made to enter the metal at each corner of the hole, which is the junction of each two contiguous planes. At every corner the tool is caused to form a groove which shall extend into the metal as far as the gauge-lines that exist at that corner; so that if three-eighths of metal is to be removed from that corner, the groove will be three-eighths deep. If the edge of the tool is curved the corner will be curved, and this shape is preferable to a sharp angular form, to avoid weakening the boss or whatever article may be in progress. Eight grooves are therefore made for an octangular hole, each one requiring the table to be partly rotated and adjusted. By this grooving, if carefully done, all the eight junctions of the planes belonging to an octangular hole, may be finished, because the metal can be removed as far as the gauge-lines which show the specified dimensions. This treatment also forms eight superfluous projections, one on each of the eight bidden planes to be produced. To remove these portions, an ordinary vee-point tool, similar to Fig. 787 or 794, can be used. Such a tool will operate effectually after grooving, because it is not required to cut at any junction, the vee-point being suited for traversing flat surfaces; whereas, if it were used to commence these surfaces previous to grooving the corners, the sides belonging to the thick part of the tool-point would greatly hinder the cutting, through coming into contact with the metal at the corners. A vee-tool may, however, be used for commencing, when only a very small quantity of metal is to be cut out; in which case, the vee-tool is caused to first remove the metal from the plane, without removing any from the corners; these are left untouched, and after the plane is finished, the small amount of metal at the junctions is removed with a corner tool, or with a narrow groover (Fig. 782).

Tapering of Angular Holes.—The operations just given are suitable for the correct formation of any angular hole of a rod's boss-end, or other boss-part, if both entrances to the hole are to be of the same dimensions; or, in other words, if the hole is to be parallel. But it is proper to make all holes in such portions rather taper, for the convenience of an easy fitting of the bearer-brasses, and also that the brasses may be easily entered into and removed from their respective holes.

A small angular hole of only about an inch in diameter can be tapered with filing, after it has been first regularly formed parallel with slotting. But to taper a large hole of several inches in width and length, a proper adjustment for the purpose must be performed while the object is on the slotting-table. By this means, all, or nearly all, subsequent filing is avoided. To correctly place a boss to be tapered, it must be raised at one edge, so that the truly formed boss-faces are prevented from occupying a position of parallelism with the table-face. To support the boss in a proper inclined position with the table, and therefore also in a proper inclined position to the vertical motion of the slotting-tool, suitable packing is placed between the lower boss-face and the table. This packing consists of either a taper ring, or taper packing blocks. Such pieces must be permanently fixed during all the operation of tapering the entire hole; and will incline one edge of the upper face of the boss towards the tool during the shaping of any one of the planes belonging to the hole. The thickest part of the ring or other packing, is situate between the machine-front and the front side of the boss; therefore the upper end of the hole is inclined towards the tool and must be enlarged by the process of cutting. Each time the tapering is to be commenced the boss requires to be partly rotated on the packing, in order to place every plane into one and the same relative position with the table; therefore, by the time the boss has been entirely rotated, and all the planes produced, the upper end of the hole is enlarged to a greater diameter than that of the lower end, and the intended tapering is executed.

When only two opposite sides of an angular hole belonging to a boss require tapering, it can be conveniently done by means of the author's slottil or slotted holdfast represented by Fig. 558. This instrument can be bolted to the slotting-table at some convenient part, and the vee-grips can be made to grip some portion of the rod and hold the boss at any desired angle with the table, after being properly adjusted.

The final shaping of angular holes is conducted with regard to sheet gauges, which are provided with taper stems, if the holes in progress are to be tapered. Inside-callipers also are used; and when a hole is being slotted to fit a hard steel block, or other object that cannot be easily reduced to fit the hole, the callipers must be adjusted with a gentle hammering so that the points of the feet shall only very lightly touch the surfaces in contact, as described in page 208.

Slotted Guide-Standards.—The guides here treated are those used for containing bearer-brasses and guide-blocks, which are connected to ends of crossheads belonging to piston-rods and pump-rods. A guide of some class is required for every engine whose to-and-fro motion is to be changed into a rotary one. When slotted guides are used, they are fixed so that the guide-slots are parallel with the direction of the piston-rod's motion; and in order that each guide may be properly attached to its engine, it is provided with a broad base or foot which is solid with the other part, and is planed right-angular to the length of the guide-slot. A planed foot of this kind causes the slot to put into the desired parallelism with the piston-rod, through the plane surface of the foot being bolted in close contact with the cylinder of the engine, with its table, or with its base-plate, all of which portions should be furnished with surfaces which are planed right-angular to the length of the piston-rod.

Small guide-standards are often cast without any slot; and therefore require a number of holes to be drilled along the places for the intended slots; after which the portions remaining between the holes are removed by planing, shaping, or slotting, and the slots are thereby formed. The lining to show the proper place and position of the slot, is the same for a solid guide as for one in which the slot is roughly formed by casting, with a little difference in the methods of marking small guides and large ones.

The lining of a guide may be executed either on a lining-table, or on the table of the planing-machine with which the planing is to be performed; and commences by marking a centre line or periphery entirely around its narrow side. To do this the object may be placed upon a lining-table with the broad sides parallel with the face, and having parallel blocks in contact with the lower broad side of the guide; which will cause it to be supported a few inches above the table. A guide in this position is shown in Fig. 901. For a small guide, two parallel blocks are sometimes sufficient, one at each end; but three or four blocks are preferable, if the shape of the broad side will admit them. Each block is put into contact with a portion of the casting which is not to be reduced, or which may require only a small skim to be taken off to attain the specified thickness. If the blocks are in contact with such surfaces, these surfaces must necessarily be kept paralled with the table-face; and any lines that may be marked upon the guide by means of a scriber-block on the table, must also be parallel to these surfaces. As soon as the object is properly placed upon the blocks, the point of a scriber-block is adjusted to somewhat near the middle of the narrow side, and a short line or two are marked. The precise place of such marks is of little consequence, and merely require to be within a sixteenth or an eighth of an inch from the centre. But after the marks are made, it is important to avoid shifting the scriber-point until the guide has been put upside-down, and one or two other marks have been scribed parallel with the first ones. At the time the object is put upside-down, it is placed with the parallel blocks in contact with those surfaces which are correspondent to the surfaces that rested on the blocks at the first marking. Therefore, the point which is midway between a couple of marks of this kind, is the centre of that part of the guide which touched the blocks; but is not necessarily the centre of the slotted part unless the two portions happen to be cast true with each other. By placing the parallel blocks to the proper portions, the centres of these portions are found, and when found, the scriber-point is raised or lowered thereto, and the block moved entirely around the standard to plainly and deeply scratch a line upon the entire narrow side, including the foot or base, the oil-cup portions, and all other projections that may be in the path of the scriber as it is moved around. This scribing produces the centre periphery required, and it is now dotted to plainly indicate its place, and to provide dots into which a point of a compasses or divider can be put for measurement when requisite.

As soon as the periphery is scribed, it becomes a sort of primary line from which the intended thickness of the standard can be accurately marked in two directions. The ledges of the slotted part may, or may not be, equidistant from the centre line; but the exact distance to each ledge can be shown by measuring from the line, whether it is in the middle or elsewhere. By measuring with a compasses from the centre to show the intended extreme thickness of the slotted portion, the place for another gauge-line is shown, and this also is scribed by adjusting the scriber-point to the proper height and moving the block around as before. When one line is scribed the scriber is again adjusted to show another line at the other side of the centre, which two outer lines show the finished thickness of the guide, and also constitute gauge-lines to which the superfluous metal is to be cut off.

When the three lines on the narrow side or edge are marked, the object is ready for the scribing to indicate the place and shape of the slot. The primary lines marked for this purpose are straight lines along the broad sides of the guide showing the centre of the slot's intended width. To execute this scribing the object may be placed upon the lining-table with the broad sides at right angles to the table, as seen in Fig. 902, and therefore in a position which is right-angular to that in which it remained while scribing the narrow side. While the broad sides are square to the table the guide requires supporting by placing a few heavy blocks of sufficient weight at each side of the foot; or by lightly bolting the foot to the face of an el-chuck which is on the table. It is now necessary to determine which is to be the centre length of the slot, and a couple of dots are put at this place, one at each end of the slot. The centre length being thus shown, it is next needful to put the dots equidistant from the table-face, which is done by packing up the guide with blocks of suitable thickness. The broad sides must be also adjusted exactly square to the table, and an el-square's blade of suitable length is applied to the sides to indicate their position, and is also applied to the gauge-lines on the extremity of the foot which were scribed during the previous marking while the guide's broad sides were parallel with the table. When the sides are seen to be in a proper position, and the dots showing the centre length of the slot are seen to be parallel with the table, the guide is ready for being scribed upon both its broad sides. This marking commences by first adjusting the point of a scriber-block standing on the table to the same height as the centre-dots, and next scribing a centre-line to intersect the dots and thereby indicate the entire centre length of the slot. The line is also continued beyond both ends of the slot portion, and is therefore seen on the broad side; it is also dotted so that its place may be known for a considerable time and be used for reference. The scriber-block is now shifted to the opposite side of the guide, and another centre line is scribed which is exactly analogous to the previous one, the scriber-point being now at precisely the same height from the table as before. These two lines indicate the centre length of the slot on two sides of the guide; and from these the desired width to which the slot is to be finished, is scribed by means of two other straight lines on each broad side, one line being above the centre and the other line below the centre. These are accurately marked parallel with the centre line by merely adjusting the scriber-point to the suitable heights and scribing as before.

The lining to indicate the thickness of the standard, and to show the place and width of the slot is now completed; and if the article is cast without any slot it next requires circles to be scribed along the intended slot to prepare it for drilling; but if the slot is already cast it is ready for planing.

If a standard is thus lined on its broad sides and narrow sides previous to any planing of it being executed, it is necessary that those surfaces which are put into contact with the parallel blocks should be uniform and parallel with the remainder of the broad sides, so that such surfaces may constitute tangible and definitely formed planes that are capable of being easily referred to; if not the lines scribed on the broad sides cannot with certainty be made right-angular to the lines on the narrow sides. It is therefore advisable that all roughly cast guides be first put upon a planing-machine instead of upon a lining-table, that some portion of the planing may be done before lining, and that the uniform surfaces referred to may be produced. By this mode, either the foot or the broad sides may be planed previous to lining for the slot; and the entire lining of the standard is executed while it is on the planing-table. In accordance with this method the centre of the narrow side must be determined and a periphery scribed around in about the same manner as if the object were on a lining-table; it is also requisite to mark a line above and below the centre one to show the thickness, to which lines the metal is to be planed off. Without these the standard cannot be properly adjusted parallel with the table, nor the quantity of superfluous metal indicated. The adjustment for commencing the planing therefore consists in packing up the standard with wedges and blocks beneath the broad sides until the scribed lines on the narrow sides are placed parallel with the table as required. During this planing the length of the slot-portion should be situated right-angular to the length of the table; and the holdfast plates should at first be situated across the extremity of the guide-portion adjoining the slot, and also across the foot, thus exposing the entire slot-part free to be planed. This mid portion being planed, the plates are removed from the foot, and are fastened across the planed slot-portion without shifting the standard on its packing-blocks. After being fastened the second time the foot is planed, and will be parallel with the planed slot-portion. It is, however, proper to so place the plates that both the foot and the slot-part can be planed at one fastening, if the shape of the casting permits, because shifting and again fastening the plates is liable to prevent the surfaces being planed parallel with each other.

After the standard has had one broad side planed it can be put upside-down and the opposite side planed; and if it were properly lined wedges are now dispensed with, and only parallel blocks are put between the table and the object, the blocks being now put into contact with the planed surfaces. Previous to fixing for this second planing, the centre length of the slot should be determined; and the condition of the foot or base ascertained. If it is found that the extremities of the foot are tolerably square to the intended centre length of the slot, the article can be adjusted for this planing either with regard to the foot or to the slot-part, the particular portion selected for adjusting being in any case that which possesses the least quantity of metal to be cut off, according to the elements of planing and lining in page 220. If the standard is properly made, it has a comparative great thickness of metal to be removed from the foot because this is usually a much shorter portion than the guide-portion containing the slot. The centre length of the slot is therefore considered to coincide with the centre length of the entire guide-part, and after this length is shown by placing a straight-edge and marking with a scriber, the line is used as a gauge-line for adjustment; whether or not it is right-angular to the extremity of the foot. To effect this adjustment the line is placed exactly across the table or right-angular to the direction of the table's motion. For this purpose a scriber-block having a straight bottom-edge is put to both ends of one of the short gauge-lines on the table, and the scriber-point is put to both ends of the line on the guide, that the relative positions of the two lines may be observed and the guide shifted accordingly.

It may now be perceived that the length of the slot-portion or guide-portion should be across the table during the planing of the broad sides, as directed, because at the two fixings of the standard, the two sides of the foot, and also its outer extremity, can be accurately planed, in addition to planing the broad sides parallel with each other and to the specified thickness. The extremity of the foot is also planed right-angular to the length of the slot as required, because this part is planed with the vertical traverse of the rest while the standard remains adjusted with regard to the slot's centre line. With proper care at each fixing, and at the cutting off of the metal to the gauge-lines on the narrow sides, the standard is finished, except the slot-surfaces, and these can be completed with only one more fixing; therefore three fixings suffice to execute the entire planing.

At the third planing of the standard its length is right-angular to its position during the two previous planings, in order to now plane the slot. To shape this part, the centre line of the slot is put exactly parallel with one of the long gauge-lines on the table, and therefore parallel with the table's motion. A scriber-block may be used for this adjustment, as for previous ones, with the difference of placing the block upon a long line instead of a short one. This centre line is the same which was used at the previous planing, the guide not having been put upside-down, but merely shifted to alter its position on the table. If the guide is adjusted by means of this line for planing the slot, the correct position will be obtained if the same line were exactly right-angular to the table's motion while the foot was being planed; but because it may not have been in this condition through some fault in the fixing, it is preferable to adjust the object by means of an el-chuck. For this purpose the chuck is fixed with its length across the table, the bottom edge of the chuck's face being exactly adjusted to one of the short gauge-lines. To the face of the chuck the foot or bottom of the standard is bolted in close contact, which must necessarily so place the slot-portion that the slot shall be planed exactly right-angular to the foot, whether or not the foot were right-angular to the centre line while being planed. The parallelism of the length of the slot with a long line on the table is, therefore, not considered when an el-chuck is used, the right-angular position being obtained by merely bolting the planed extremity of the foot to the chuck's face. At this fixing the standard must rest on parallel blocks, as at the previous fixing, the blocks being in contact with portions of the planed broad sides, and situated in proper places to avoid contact with the cutting tools extending through the slot while planing.

The guide is now in position for planing both sides or faces of its slot. When such an article is made with the slot formed by casting, it should be so cast that a clearance space is formed at each end of the slot. This space is a semicircular gap, the width of which is about a quarter or half an inch greater than the width of the slot; consequently the broad surfaces or faces of the slot project into the two clearance gaps, and will form corners or steps, instead of coinciding with the curved junctions of the gaps. These spaces are not noticed in Fig. 902, but can be seen in the comparative large sketch denoted by Fig. 903. Such openings are useful for a convenient planing, because they constitute clearance spaces in which the tool may disengage from the metal, and are also advantageous for preventing the formation of ridges during the future wear of the slot-faces. By making the guide-block of sufficient length to cause its ends to protrude while in action into the half-round spaces, the formation of a ridge is prevented. If it happens that the guide is without such spaces, they require to be made previous to planing, either by a drilling-rod in a drilling-machine, or by chipping and filing. It is also frequently necessary to prepare the clearance spaces, although they are now roughly formed by casting, in which cases a small amount of chiselling and filing is sufficient for the purpose. Those guides which are made without any slot whatever are furnished with clearance gaps by drilling a hole of proper diameter at each end of the place for the slot, the diameter of the hole being necessarily greater than the finished width of the slot.

If the clearance spaces are suitably shaped by some means, the slot-part is ready for planing with grooving-tools, or with right-hand corner-tools and left-hand ones. Springy tools, also, and slotted tools are occasionally used. Supposing that a small gun-metal guide is to be planed which has had a hole drilled at each end of the intended slot, but no portion of the slot formed, the slot-making should commence by using a groover, which is gradually advanced down with the vertical traverse until a narrow slot is formed through the guide, the slot extending from one clearance-hole to the other. This opening is next widened either with another groover having an edge of suitable length, or is widened with corner tools, until the required width of slot is attained. A small guide-slot of this class can be shaped also with a slotted-stock tool (Fig. 716). The cutter of this implement is shown by Fig. 717. Previous to this being used for planing a guide-slot, grooving-tools of proper width are caused to form the slot to nearly its intended width, leaving a small quantity of metal to be removed at each gauge-line indicating the slot's mouth. These two small portions can now be cut out with the slotted tool and cutter at one operation. To do this, the tool must be carefully adjusted to place its edge exactly midway between the two gauge-lines showing the width, after which it can be advanced down with the vertical traverse and caused to cut the two faces of the slot at one time. Such a cutting out will suffice to roughly form a slot, but will not smoothly adjust a slot to a precise width which may be specified. Consequently, a cutter whose width is rather less than the finished width of the slot must be used, which is first allowed to cut two sides at once, but is afterwards made to cut only one side at a time, to finally attain to the exact width intended.

The planing of a large slot of four, six, or seven inches in width, is generally executed entirely with corner tools, whether the metal is gun-metal, iron, or steel, because large slots of guides are always formed by casting, and therefore easily admit the ends of corner tools from the beginning to the end of the slotting. Corner tools for gun-metal are shown by Figs. 431, 432, and 708. The cutting parts of such tools for planing faces of slots are but slightly bent, the amount being only sufficient to cause the cutting part to clear the side of the stalk, and thus allow as much room as possible between the tool and the face of the slot while the tool is therein. Tools of this sort, whether small or large, are available for slots of any width, if wide enough to allow a free movement of the tools employed. When it happens that a large slot is to be planed, and there is not a corner-tool small enough to enter the slot, the slot can be planed with a stalk and cutter similar to Fig. 715, the cutter used being similar to Fig. 714, if the guide is gun-metal; but if iron or steel, the cutter's end is similar to an end of a corner-tool. In the slot of the stock a cutter of any desired shape, left-handed or right-handed, may be keyed, the length of the cutter depending on the amount of room in the slot. The planing of a slot with such a tool somewhat resembles that mentioned in the preceding paragraph for a small slot which has been previously commenced with a grooving-tool.

During all these planing-processes for slot-shaping, the vertical traverse of the slide-rest must be exactly square to the table, and therefore truly vertical, if the machine is properly fixed. This right-angular position is requisite because the broad sides of the standard are parallel with the table, and the direction in which a slot extends through from one broad side to the other, must be square to the broad sides. The rest is therefore adjusted to the proper position by means of a dot or other mark existing for the purpose; but the tool-box, or whatever tool-holder the slide-rest may possess, may be inclined at any angle, if necessary, when a corner tool is in use, that the thick part of the tool's end may be prevented from touching the side of the slot while advancing downwards. Inclining the tool-holder without altering the traverse-slide, has about the same effect as merely shifting the tool, the travel of the slide not being thereby affected; unless the tool-holder happens to be solid with the slide, in which case, only the tool can be inclined.

Near the conclusion of planing a guide-slot, it requires a careful measurement with sheet gauges, or with callipers, the points of which are delicately adjusted that they may only very lightly touch the surfaces in contact, as described in page 208. By such gentle measurement, the operator can ascertain whether the upper mouth or entrance to the slot is of the same width as the lower entrance next the table-face; also whether it is parallel along its length, or wider at one end than at the other. Defects of this character often exist in guide-slots, especially if the metal planed is steel, or a hard iron, either of which may wear the tool-point during the removal of a slice, sufficient to cause one end of the slot to be half a sixteenth wider than the other. It sometimes happens that a slot of several feet in length cannot by any means be made parallel and smooth with a slide-rest tool; and the work is therefore afterwards completed with a considerable filing.

It should be here mentioned that considerable care is required during the fixing of a standard, to avoid distortion, such as described in page 234. The author's method of preventing this injurious bending of a guide, consists in placing each holdfast plate directly over a packing-block, always avoiding, when possible, the fixing of a plate to any portion of the object which is not supported with a block beneath. It is also requisite to use plates having paws of only about three-quarters of an inch or an inch in width; the height or thickness of the paw being sufficient to secure proper strength to compensate for the comparative small width. With this method the tightening of the screw-bolt of a plate causes the paw to bear upon the metal which is exactly over the packing-block, but prevents the paw bearing upon any other part; therefore the fixing of the plate cannot injuriously bend any part of the metal, however tightly the bolt may be fastened, because, although the block is a sort of fulcrum, no leverage exists for causing the distortion, through the plate's paw being situate exactly at the fulcrum, and not at any distance from it, which distance would be necessary to provide the leverage referred to.

It may be also stated that by observing the same rules as these given for fastening guides, during the fixing of all other objects in general, small or large, the distortion referred to will be reduced to the minimum.

Shaping of Guide-slots with Shaping-machines and Slotters. — In addition to the modes of forming slots by planing, given in the preceding section, it is requisite to mention a few other methods of slot-making, which are resorted to in cases of emergency.

A small guide that requires a slot of only a few inches in length, can be slotted on a shaping-machine. The article can be lined by the same methods as those given for a guide situate on a lining-table, or for one on a planing-table, the only difference consisting in adopting the shaping-table or tables as standard planes to which the work is adjusted, instead of adjusting it to a planing-table.

A guide-standard on a shaping-machine can be entirely shaped with three fixings, which are analogous to the three fixings of a larger guide on a planing-machine; the two broad sides and the foot being shaped with the first and second fixings, and the entire slot being formed at the third. The placing of the broad sides upon parallel blocks, the attachment of the plates, and the tools used for removing the metal, are also the same as if the guide were to be planed.

The formation of a guide-slot on a slotting-machine, is executed after the standard has been previously planed with a planing-machine, to reduce the broad sides to proper dimensions and make them parallel with each other. Although a slotting-machine is not suitable for planing these sides, the outer extremity of the foot can be easily planed with a slotting-tool; for which purpose, it is necessary to adjust the centre length of the slot to parallelism with that traverse of the slide-rest which is square to the machine-front. Such adjustment causes the outer surface of the standard's foot to be parallel with the front; and therefore allows the standard to be advanced in this same direction during the removal of the metal. To allow the releasing motion of the tool during its upward travel, the surface to be planed is situated between the tool and the front; so that, if the operator now stands at this place, the length of the slot-portion extends from the foot or bottom towards him.

After the foot or bottom is surfaced, the formation of the slot may be effected while the standard yet remains in the same position on the table. But the slide-rest traverse which is to be now used, is the one at right-angles to the machine-front. During the slotting, the guide is moved from the front of the machine towards the main-standard; for which reason the tool will commence to cut at that end of the slot which is nearest to the main or F-standard. The other traverse of the rest, parallel with the front of the machine, by which the foot was surfaced, is now only used to adjust the object exactly to the tool for removing a slice of a certain thickness; therefore, after this adjustment, whenever a slice is to be commenced, the traverse screw is fixed to prevent an unintended movement and consequent mischief.

A guide-slot which is to be shaped on a slotting-table, is provided with a clearance space at each end, the same as if it were to be planed; therefore ample room exists for the slotting-tool to retreat back from the metal while the end of the slot nearest the tool is being shaped. The tools employed are the slotted ones, which admit cutters of any length and shape to suit the width of the slot to be formed. (See Figs. 786, 787, and 788.) The solid tools having bent ends, denoted by Figs. 793 and 794, are also available. A quick mode of shaping a slot consists in causing a tool to cut both faces of the slot at once. This plan is suited to any guide which requires its slot to be rapidly although roughly formed. If the article is strong, and properly supported with packing-blocks, to sustain the comparative severe strain while the tool is cutting, a considerable amount of time may be economised. It must be remembered that the action of any slotting-tool has a much greater tendency to break the guide, than the action of a shaping-tool or planing-tool, by reason of the slotting-tool's motion being square to the guide's broad sides. Consequently, when a slot is to be formed by a tool cutting both sides at once, only a thin strip of metal should be cut off at each travel of the tool. While a guide is being slotted, it should be supported on packing-blocks of great length, their length being, if convenient, as long as the slot; and they require to be close to the intended mouth of the slot when finished, allowing only a sixteenth of an inch between each block and the slot's edge. Blocks thus placed afford great resistance to the tool in addition to preventing the breakage of the standard.

Semi-cylindrical Surfaces.—The half-round surfaces or gaps here mentioned are such as those belonging to bearer-brasses, concave junctions of crossheads, levers, and bars; also the gaps of U-end connecting-rods, termed gap-end rods, or rods with semi-solid heads. A great number of these curved surfaces are formed by turning, and are consequently treated in the chapter devoted to that subject. But it is sometimes needful to produce half-round gaps by means of shapers and slotters which possess worm-pinions for generating curved motions; and the paring-processes connected with such motions are here given.

The shaping of curved concave junctions belonging to levers, bars, and crossheads, is frequently executed by means of broad-edge tools, as described in pages 278, 279, and 282, without using the rotary motion of the table by means of the worm-wheel. Such shaping is suitable when only one or two objects are in progress; but whenever a number require to be shaped, the circular motion should be employed. This process involves several additional shiftings and adjustments of each object; but this very circumstance facilitates each adjustment, when several levers or other articles are moved about, because the operators become thereby accustomed to the work.

Perhaps the simplest of the concave surfaces now mentioned, are those belonging to half-round gaps of bearer-brasses; consequently the shaping of these are first treated. The hidden curve which is to be produced on a bearer-brass is indicated by two curved lines, one on each end of the brass, denoting the boundaries of the intended surface. A brass lined in this manner is shown by Fig. 803, in which one of the two semicircular lines is seen on the front side of the Figure. If the two gauge-lines are of the proper curve, and in their proper places, they correctly show the boundaries of the required surface, according to page 243; and they also serve as lines by which the brass can be adjusted on a machine-table for shaping.

A brass may have its gap formed either on a shaping-machine, or on a slotting-machine, if the machine selected is furnished with the apparatus for generating the necessary curved movement. When a shaper is employed, the brass is held on the table so that the intended gap in the brass is parallel with the table, and, consequently, parallel with the direction of the cutting-tool's motion. The article is adjusted to this position by applying a scriber-block point to both the curved lines, while the block is on the table; and also by fixing a tool-scriber in the tool-holder and observing the scriber-point and the straight gauge-line which is marked on the upper surface or face of the brass. This line is put parallel with the motion of the head, and therefore parallel with the tool's motion, by gradually shifting the brass sideways until the tool-scriber's point moving slowly to and fro, is seen to be exactly parallel with the line. Packing-plates and wedges are also required beneath the brass, to raise either end to a suitable height and cause the bottom of the gap to be produced parallel with the gauge-lines. Poppets also are needed for shifting it sideways.

A bearer-brass may be fixed also by bolting it to an el-chuck on the shaping-table. For this purpose a half-round gap is provided at the upper edge of the chuck, and the brass is put in front of it, so that the gap to be formed in the brass is about midway between the sides of the gap in the chuck. A chuck of this description is shown by Fig. 885. A brass which is to be held against an el-chuck, must have at least one plane surface for contact with the chuck, which surface should also be square to the length of the gap to be formed; this will cause the brass to be immediately put parallel with the tool's motion by the act of bolting to the chuck, the face of which is placed square to the tool's motion by means of one of the parallel gauge-lines on the table. But if the surface of the brass touching the chuck is not square to the length of the intended gap, the chuck's face must be adjusted square to the gap without regard to any line on the table, in order that the straight gauge-lines on the top of the brass may be properly situated.

As soon as the brass is fixed, the cutting-tool is fixed to the rest in a vertical position; and the brass and tool are next adjusted to each other by placing the centre of the tool-point exactly over the centre of the gap to be made in the brass. To ascertain whether the proper position is obtained, the tool-point is moved in a curved path by rotating the worm-pinion with the handle. For such movement, the point is put very near to the semicircular line to which the metal is to be pared off, or is put very near to another line which is concentric with it; and if, during the rotary movement, the point is seen to be concentric with the half-round gauge-line, the adjustment is effected. The tool can, therefore, be now made to cut by means of the to-and-fro motion combined with the curved motion imparted from the worm-pinion. A convenient tool to remove the metal is an ordinary grooving-tool. A taper tool having a vee-point may also be used, if it has a thin end, which is necessary to prevent the thick part of the tool coming into contact during the time the tool is cutting at the gap-sides. While the tool is at the bottom ample room exists, at which place the operation of cutting is somewhat like planing.

While the tool moves to and fro, its curved motion can be generated by the operator rotating the worm-pinion with the handle on its spindle, which process is suitable for a small gap. But this hand-traverse is avoided by causing the machine itself to rotate the spindle. This is performed by a small rod and lever connected to the machine-carriage and the worm-spindle.

It is not every to-and-fro shaper that will thus shape a half-round gap, because the tool cannot be advanced through the entire semicircle at one travel. Consequently, when such a gap must be formed with a machine whose sector-motion is too short, the gap is shaped by fixing the brass twice instead of only once, half of the gap being shaped at each fixing. The entire gap may also be shaped at only one fixing, if cranked tools are employed; in which case the tools are shifted instead of the brass.

The shaping of a half-round gap can be easily managed on a slotting-machine having a worm-wheel motion. On a slotting-table a brass or other object can be completely rotated if necessary, by reason of the table having a complete circular worm-wheel, instead of only a sector. To adjust a half-round brass on a slotting-table, it is placed upon a parallel ring or blocks near the middle of the table, with the length of the desired gap vertical, because the motion of a slotting-tool is vertical. The brass is situated between the machine-front and the tool; and the adjustment must be conducted without reference to the half-round gauge-line which is near the table, this line being quite hidden from the operator. The bottom surface on which this line is scribed, must be square to the length of the gap, and also square to the flat sides of the brass termed faces, which are those that adjoin the mouth of the gap, and are nearest to the slotting-tool. If these faces are right-angular to the bottom surface, they must necessarily be vertical, while the brass remains on the parallel packing; and because these vertical faces are parallel with the gap to be made, the brass is known to be in position by the blade of an el-square, which is put to the faces while the square's pedestal rests in contact with the table.

When the brass is placed square to the table, it is ready for adjustment by the half-round line on the top surface. This is to be put concentric with the table's axis of motion, because this motion is that which will rotate the brass during the cutting. A tool-scriber may therefore be fixed in the tool-clamps, and gently lowered until the point is very near the gauge-line; the table, and therefore the brass, is now rotated, and the point observed, which will show exactly how much shifting of the brass is necessary to place the line concentric with the table. The small movement for this adjustment is effected with the poppets which are near the brass and fastened to the table, and also with the traverse screws; and after the brass is correctly situated and fastened with plates across the top, it is ready for the shaping by rotating the worm-wheel.

The tools employed for slotting a half-round gap are the slotted ones shown by Figs. 786 and 788; and the solid ones shown by Figs. 793 and 794. While a tool is being fixed in the tool-clamps, the cutting edge is adjusted to the exact height intended, in order to prevent it extending too far below the lower edge of the brass during the downward travel, and thus prevent it coming into contact with the table.

Whenever it happens that several pairs of large brasses require to be shaped with a slotter, two should be fixed at one time on the table, and slotted at one operation. By this plan, each two brasses which constitute a pair or couple, are fixed together, so that both brasses can be shaped at one rotation of the table.

It may be also stated that because the cutting-tools of slotting-machines cannot be easily adjusted every time to the same relative position with the gauge-lines on the object beneath, it is necessary to shift the table and object thereon a short distance, when it is seen that the metal is not being equally cut off concentric with the gauge-line or lines.

Shaping the concave junctions of a crosshead, lever, or bar, by means of a circular motion, is, in most cases, easier performed with a to-and-fro shaper than with a slotter, unless the lever or bar is several feet in length. An object situate on a shaping-table always presents the surface which is to be reduced in a horizontal position, which allows the operator an easy and full view of all operations while he stands in an ordinary vertical position. This is of considerable importance; but such a view of an object on a slotting-table cannot always be obtained, especially while it is placed for shaping a concave junction, the surface of which is hidden from the operator, unless he is situate between the tool and the F-standard.

For the production of each surface belonging to a concave junction of a bar, crosshead, or other article, the article requires a distinct adjusting process, that the gauge-line showing the desired curve may be adjusted concentric with the table's curved motion. Therefore, a three-boss lever would require eight adjustments, in addition to the several fixings for shaping the cylindrical parts of the bosses and the eight flat surfaces of the two straight arms. And a crosshead having one boss in the middle would also require eight adjustments for similar purposes. The tedium connected with such a number of operations should, therefore, be placed against any advantage that may be considered to result from adopting such a course. Perhaps the principal consideration is the great ease and order with which the metal can be removed and the concave surface produced after the object is once properly adjusted.

As soon as the gauge-line is properly placed and the object fastened to the table, the shaping or paring of the junction proceeds by the action of the rotating apparatus, and by using any ordinary vee-point tool, whether the object is on a shaping-table or on a slotting-table. No broad-point tool is required from the commencement to the end, nor any springy tool. The entire paring can be executed by removing slices with the point-tools, because the travel of the object in a curved path while being reduced is quite as easy as the travel of an object in a straight path while being reduced, the only tedium belonging to the process being the adjustment for each curved surface which has to be formed. By using a sharp vee-tool, the point of which is slightly convex, and applying soapy water during the removal of the last slice, the surface is entirely finished, and no filing is afterwards needed, except a small quantity at the places where the concave junction merges into the convex boss, and merges into the straight part of the arm. But a junction that is machined with broad-point tools and springy tools, for the purpose of avoiding the adjustment for the rotary movement, requires the entire curved surface to be afterwards filed, and in some cases also chipped, unless the lever or crosshead in process is very small; if so, its junctions can be smoothly finished with a springy tool having a broad convex edge. It may, therefore, be easily perceived that large junctions in general should be finished with vee-point tools and the circular traverse of the table; and that small junctions in general should be finished with the straight to-and-fro movement of a shaper or slotter and the use of springy tools.

The shaping of a half-round gap belonging to a U-end connecting-rod is easily executed by boring or by turning; but when it is imperative to produce such a gap by the curved motion of a shaper or slotter, the rod is fixed with its length either vertical or horizontal, according to the machine selected. The processes for adjusting are very similar to those described for joint-gaps having plane sides, in pages 283, 284, 285, and 286.

Making of Key-slots.—A key-slot is a key-way that consists of an oblong hole which is formed entirely through the thickness of a rod, bar, or other article. Consequently, a key-slot requires to be made by processes which are different to those adopted for making key-grooves, which extend to only a short distance in the direction of the rod's thickness.

The lining for a key-slot of a piston-rod end, or an end of a crank-pin, is the scriber-marks which are made upon the end while it is in its place in the boss of the lever or crosshead; in which boss the key-slot has been previously made, and constitutes a sort of template for scribing the piece within. It is therefore requisite for the slot in the boss to be in line with the diameter of the circular hole, in order that the key-way to be made in the end of the rod or pin may be exactly in the centre; or rather, in line with the diameter. It will be seen that the lining of the bosses must be given in conjunction with the lining of the rods, pins, spindles, or other portions.

The key-slot of any boss is not shaped till the boss has been accurately bored and turned in a lathe, and is also, in most cases, the last machine-process to which it is subjected. The lining of such an article can be easily executed, because all its surfaces are smooth and uniform. If the boss of a small lever or other article is to be lined, it can be readily handled in any position on a lining-table; and a boss of a large article can be lined on any machine-table, with but very little moving about, because of the several plane surfaces and parallel surfaces which it possesses.

A small lever can be taken to a lining-table and have its boss lined while the lever's length is vertical, extending upwards from the table and at right-angles to it. A lever in this position is shown in Fig. 904. It should be held in position with packing-blocks, or by gently bolting it to an el-chuck on the table. The centre length of the lever is adjusted exactly square to the table by means of an el-square, the blade of which is put to the centre or primary line seen in the Figure, the object being gradually shifted until seen to be in the proper position. The bottom cylindrical surface of the boss may, or may not, be in immediate contact with the table, because it is parallel with the centre length of the hole, whether the hole is taper or parallel. And supposing that the boss should not be exactly parallel with the hole, through a defect in shaping, the length of the lever will be correctly adjusted by being in contact with the el-chuck.

While the article is held upright on the table, the place for the key-way can be marked upon both sides of the boss, by means of a scriber block, the point of which is adjusted to the desired height at the time the block rests on the table. This height is the same as that of the centre of the boss, and is easily shown on an ender that fits the mouth of the hole. The scriber-point is therefore put to this centre, and a centre-line is marked across the boss-face; the line is also continued along the cylindrical surfaces of the boss at opposite sides of the hole. These marks are exactly right-angular to the lever's length, as usually required, and accurately indicate the centre of the intended key-slot, because the lever is right-angular to the table on which the block moves while marking. From this centre line in two directions, upwards and downwards, the specified thickness of the key-slot can now be marked, by using a compasses or divider; and to these marks the scriber-point is next adjusted to scribe two more lines upon the boss, parallel to the centre one and equidistant from it. These outer lines now show the thickness as intended, and the width is next marked to cause the key-way to be mid-way from either face of the boss; after which it is ready for the cutting out.

Lining a boss of a large lever for a key-way, is performed while it remains in any place, no moving about being necessary. It is, however, advisable to put the article into a proper position; and this consists in shifting it until the boss-faces are about horizontal. In this condition a straight-edge, scriber, and compasses, can be easily used, to mark the required lines upon the lever, the principal one first marked being a straight centre line across the upper face of that boss which is to have the key-way. This line is exactly analogous to one which is made with a scriber-block on a lining-table, and therefore indicates the centre of the key-way required. For this purpose an ender is caused to show the centre of the hole's mouth, which is, of course, a point in some part of the centre line along the lever's side. The centre of the mouth and boss-face being shown, it is next needful to scribe the line referred to square to the lever's length, and also in the desired place to pass through the centre dot on the ender at the hole's mouth. To do this, short arcs are scribed to intersect each other on the boss-face, a compasses or radius-gauge being used. The centres from which the arcs are scribed may be any points in the centre line along the lever; but the convenient points to be selected are those two which constitute intersections of the straight centre line with a circular one on the boss-face. This circular line is shown in Fig. 905, near the edge of the boss, and is of no special diameter; but merely concentric with the boss-face; therefore, from the points of intersection four arcs are marked, and a straight-edge is next put to the two intersections of the arcs, to scribe the line required. In the Figure (905) this lining is shown, the centres from which the arcs are marked, being denoted by the letters C. Fig. 910 is a larger sketch, in which similar lines and letters are seen.

It is now necessary to mark two straight lines upon the boss, one at each side of it, so that they shall be right-angular to the boss-face, and shall also join the line already scribed across the centre of the face. To do this a bisector, having pins of proper length, may be used; and if such is employed, its pedestal is put upon the face near the edge while its blade extends downwards, as shown in Fig. 906; the implement is now gently moved until one edge of the blade, or the straight line on the pedestal which is continued from the edge of the blade, is seen to exactly coincide with one extremity of the centre line previously marked upon the face, which extremity is shown by E in Fig. 905. While the bisector is in position, it appears as in Fig. 906, and a line is now scribed upon the side of the boss at the edge of the blade, which is one of the two lines required, and will show the centre of one entrance for the intended key-way. The bisector is now removed to the opposite edge of the boss-face, and its blade adjusted as before to the same line, but now at its opposite extremity, which also is shown by E in the Figure. Another line is now scribed, which is the second one, and indicates the centre of the other mouth or entrance for the key-way. In Fig. 907, one of these lines is seen, extending from E to E.

The boss is now marked with a set of lines which resemble those marked with a scriber-block on a lining-table; and lines are also scribed equidistant from the centre ones, to show the thickness of the key-slot required, which lines are seen in Fig. 908. In addition to these, lines can be marked to show the place of the key-slot in the hole of the boss; for which purpose the bisector is put with its blade in the hole, and the pedestal near the hole's edge, as represented in Fig. 909; which will allow lines to be scribed in the hole opposite each other, and thus indicate the place of the key-slot in the hole, in addition to indicating it outside, this marking being especially advisable when a large boss is in progress. One of the author's bisectors is described in page 113. When it may be desirable to mark the key-way in the hole of a lever-boss on a lining-table as in Fig. 904, it is only necessary to use a scriber-block having a scriber of sufficient length to extend to the proper place in the hole; so that after the scriber is adjusted and the outer surface of the boss marked, the scriber can be put into the hole, and the necessary lines marked. These must necessarily be at the same height as the others, because the height of the scriber is the same for all.

There is also a mode of scribing the outer surface of the boss, and also the hole, without using a bisector. This plan involves a little extra moving and lining of the lever, because it is necessary to mark centre lines across both the faces of the boss, instead of only one. Therefore, the same lines shown on one boss-face are also scribed upon the opposite face; and two enders are used, one at each mouth of the hole, to denote the two centres required. When the two centre lines are shown, four extremities are shown, two for each line, and of these four two are shown in Fig. 907, by E and E, one at each face. The straight line between these two, which is that required to show the centre of one mouth for the key-way, is easily marked by merely placing a straight-edge and scribing. The centre of the other mouth or entrance is also shown by a similar scribing.

The lining of a crosshead to show its intended key-way, is similar to that for a lever, and can be executed without removal to a lining-table. The primary lines with which the lining commences, are the straight lines along the middles of the narrow sides of the arms; these are intersected by two circles, one on each boss-face, each circle being concentric with the face, because of being scribed from the centre-dot existing on the ender at the hole's mouth. Such lines are therefore analogous to those on a lever-boss. At the two points shown by the letter C in Fig. 912, which points are plainly shown in the larger sketch, Fig. 911, where the circle intersects the straight line on the face, a compass-point is put, and with the other point short arcs are marked which intersect on the boss-face near its edge. The distance between these two points where the arcs intersect, is a straight line which is right angular to the length of the crosshead, and also passes through the centre-dot at the end of the hole. A straight-edge is therefore put to the two points and the line scribed across the face. One end of the boss being thus treated, the opposite end or face is next treated in a similar manner, to show another centre line right-angular to the crosshead's length. These two lines are two boundaries of a plane that distinguishes the boss into halves; and it is now needful to scribe the other two boundaries of this plane, which are two straight lines along the length of the boss, one on each side of it, and so situate that the extremities shall exactly coincide with the extremities of the straight lines across the boss-faces. One of these two lines is denoted by E and E in Fig. 913, and is easily marked by merely placing a straight-edge, as for marking a lever-boss.

As soon as the centre lines along the outside of the boss are scribed, they can be used as centres from which the thickness of the key-way is marked; and its width also marked. By this lining the two entrances for the key-way are correctly delineated opposite each other; or in other words, are correctly shown at each extremity of a diameter of the boss-hole. The lines for one mouth of the key-slot, are indicated in Fig. 914.

In some cases it is requisite to form key-ways at some other angle than a right-angle to the length of the lever or crosshead, for which no special lining is required to mark a line across one boss-face; it being only necessary to place a straight-edge upon the face at the desired angle, and mark the line. A centre line of this character is seen on the boss-face in Fig. 924. To mark another line upon the other face, which line shall be at the same angle to the crosshead as the first one, it is only necessary to provide a circular line on each face, both of one diameter, and measure from the intersection of the line referred to with the circle, to the intersection of the centre length of the crosshead. This distance is ascertained with a compasses, and marked upon the opposite face of the boss, as required, by applying the compasses with one point at the intersection of the crosshead's centre line, and the other point reaching to the circular line at a point which shows the place for the desired straight line, which is therefore marked by placing a straight-edge to the point and to the centre of the hole's entrance. When the two analogous straight lines across the two faces are thus shown, a straight-edge is put to the side of the boss and to the two lines, and a line is scribed to show the centre of the desired key-slot, which line is exactly analogous to the one seen extending from the top to the bottom of the boss in Fig. 913, although it is at a different angle to the length of the crosshead.

After a lever or crosshead is lined by some of the means just given, to show the key-way, it is adjusted either on an ordinary driller or on a slot driller for cutting out the metal, and this adjustment is conducted with regard to the same gauge-lines across the centre of the boss-face which were used to mark the key-way; therefore if the object is bolted to an el-chuck on a drilling-table, the end of the lever or crosshead is raised or lowered until the line across the face is seen to be vertical, which is square to the table, and parallel with the downward vertical motion that executes the drilling. By referring to Fig. 925, a lever may be seen which is in position for drilling, supposing that the key-slot is to be square to the lever's length, which is the usual arrangement. Consequently, the centre length of the lever marked along the broad side is parallel with the drilling-table, and the line across the face showing the centre of the key-way's mouth is at right-angles, as denoted by the el-square blade seen in contact. Fig. 926 represents a crosshead, the key-way of which is to be in this same right-angular position; for which reason the adjustment is effected by the same means. The crosshead seen in Fig. 924 is required to have its key-way inclined to the centre length, and is therefore bolted against an el-chuck of suitable height and supported on packing-blocks; the line for the key-way being placed vertical, as for the others, but the crosshead is inclined at the proper angle.

When one side of the boss has been drilled, it is put upside-down, if a large one, and again fixed to drill the other side. After drilling, the key-way can be completed with a slotting-tool while on a slotting-table, because, by slotting, the desired uniform shape for the key-way can be accurately produced along its entire length.

Key-slots in Ends of Rods and Crank-pins.—When a lever-boss or crosshead-boss has had its key-way formed, and an end of a rod or pin has been turned to fit the circular hole, the end can be marked while in the hole, which will ensure the required coincidence of the two key-ways; therefore the usual mode is to adhere to this plan, whenever circumstances permit.

The end of a piston-rod, pump-rod, slide-rod, or similar object, is usually turned to fit its hole while the boss is cold; but crank-pins, pivot-studs, and gudgeons, are usually made to fit the holes while their respective bosses are red-hot, or nearly so; consequently, the end of a pin which is taper, such as that of a crank-pin, will not enter its hole while cold so far as it will enter while hot, at which time the taper end will be in the exact place intended for it when in future use. Therefore, to properly show the key-slot of a taper end belonging to this class, it must be scribed both while in its hole and also afterwards, when it is out. Presuming that the taper end has been well fitted to the hole, and that it has been hammered into the hole just enough to tighten it, the marking of the key-slot is performed while the pin now remains in, by scribing with a scriber which is put successively into the two extremes of the boss key-way. This will accurately show the place for the key-way's thickness on the pin, but not its width, because the taper end is not now in its ultimate situation. The pin, or whatever other piece may be in progress, is therefore taken out, and the intended width marked; for which purpose it is necessary to scribe the key-slot as much beyond the present lines as the taper end was short of its ultimate situation while it was in the hole. It is also requisite to allow the draught at the proper extremity to make the key bear properly; if not, it may tend to push the object out of the hole, instead of tending to keep it in.

By Fig. 915 a crosshead-boss and rod's end is shown, which end is properly fitted to allow it to enter the full distance intended while cold, no heating of the boss being intended in this case; consequently, it is only requisite to allow the proper amount of draught after the end has been scribed when in the hole, and is taken out to complete the scribing to show the exact place. The crank-pin denoted in Fig. 916 is also seen in the proper place for scribing, although its taper end is not now in its ultimate place in the boss, through the intention of expanding it with heat, at which time the small end of the cone, shown by a dotted line, will be made to coincide with the boss-face. The marking of the key-slot is therefore now partly done, and the pin removed to complete it, when the width of the key-way is shown further along the cone, as represented in Fig. 917.

In many cases the ends of crank-pins and rods can be finally marked to show their key-ways while on the drilling-machines which are to execute the drilling. As soon as the rod or pin has been partly scribed while in its hole, it can be taken to the drilling-machine, and placed upon vee-blocks on the table, as indicated by Figs. 918, 920, and 921. If the object is heavy, a rotator should now be attached, similar to the one shown in Fig. 921, which is in two halves, and may be bolted to the rod at any convenient place. The rotator is much like a gripper for lathe work, and one of these can be used, if necessary. By means of the straight stem or handle which extends from the rotator, the rod or crank-pin can be gradually rotated on the blocks until it is in the exact position desired; therefore if the rod's end has been scribed on two sides when in the hole, a scriber-block's point can now be adjusted to the middles of the intended entrances for the key-way, the rod being gradually rotated until both entrances are seen to be parallel with the table. While the object thus remains, the scriber-block is now shifted to the extremity of the rod or pin, and a line scribed across it, which is now of course parallel with the table, and represents the centre of the key-way or key-slot. This line constitutes a gauge-line, to be used while adjusting for drilling, at which time it is only necessary to rotate the rod or pin on the vee-notch blocks until the line is at right-angles to the table, as denoted in Fig. 920. An el-square is employed to effect this adjustment, as seen in Fig. 919; and as soon as this is done, and the length of the object put parallel with the table, the holdfast-plates are fastened across the object, and it becomes ready for being put exactly beneath the drill-point for drilling.

The cutting out of the metal from the key-slot can be entirely performed with a slot-driller, or by means of drilling a number of holes and a slotting afterwards. At the time this slotting is to be executed, the crank-pin or rod is fixed with its length parallel with the slotting-table, as while drilling; and the centre line across the extremity is also vertical, as in drilling.

A slotting-tool suitable for forming a key-slot is shown by Fig. 782, and the one denoted by Fig. 791 is also suitable, if sufficient room exists for the end of the tool to enter at one end of the key-way. An accurate method of making a deep key-slot in a short time consists in first drilling a hole at each extremity of the intended slot, by advancing the drill half way from both sides, and next fixing the object on a slotting-table to remove the remaining metal with a slotting-tool. By this mode no risk is incurred of the drill-point getting out of the proper place while drilling, which risk is involved whenever drilling is effected without a drilling-rod to guide the cutter, whether a slot-driller or one of any other class is used.

It is now needful to close this chapter on shaping, but it should be mentioned that a number of other shaping processes are included in the chapter on turning, because a great number of objects exist which require turning in addition to other paring processes. It is therefore convenient to introduce a number of shaping and slotting processes in the next chapter.

CHAPTER VI.

TURNING, SCREW-CUTTING, AND LINING.

LATHE-TURNING is an art by which circular surfaces are formed by means of lathes; and lathes are machines for rotating objects in order that their surfaces may be made circular. Although lathes are principally used for making such surfaces, they are employed also for planing, screw-cutting, and a few other operations that will be mentioned.

In connexion with these processes for turning, modes of lining must be given in many cases, although a large number of objects can be commenced and completed by means of turning, without any lining being executed, as will be observed in the ensuing details.

Engineers' lathes are sufficiently described in a general manner at pages 133, 134, and 135; and it is now convenient to indicate the several uses of lathes for shaping various portions of machines in general. This will necessitate the introduction of additional apparatus and implements which are required for special work; such as grooving, screw-cutting, and other operations that are but very little known.

We now proceed to consider the paring of objects with regard to their lathe-turning, and also to other operations requisite in addition to turning, to produce the desired form for each object.

TURNING OF PINS, KEYS, SCREW-STUDS, SMALL BOLTS, ETC.

TURNING OF PINS.—Pins are those small straight pieces of machines which hold or connect portions of machines together. Pins are distinct from bolts through having no heads, and are of any size to suit the work for which they are made; they are either cylindrical or conical. The greater number are conical or taper; and these are now specially referred to. All taper pins are of steel, unless they are several inches thick, some of these larger ones being of iron.

The turning of taper pins is usually effected by means of temporary square holders or handles. Each pin is provided with one of these at the thickest end, in order that it may be held and rotated in the lathe while turning, and that it may be held while being fitted or tried into the pin hole. A pin having a handle is shown by Fig. 927. Fig. 928 represents a pin in use, being tightly fixed through a boss and spindle.

Small pins of only about half an inch thick, and smaller sizes, have their handles consisting of extra lengths of the wire or rods of which the pins are made, the handle of each being as large in diameter as that of the pin. Large pins require their handles to be smaller in diameter than the pins, both to avoid the trouble of turning any portion of the handles, and to economise steel.

A taper pin which is used for permanently holding a boss on a rod or axle, must be tightly and properly fitted to the pin-hole, and be finally driven into its place with hammering, that it may not become loose and fall out in consequence of the shaking of the boss and spindle while in motion. To ensure a good fit, the hole must be nicely broached, and smoothed; and during the fitting the pin is gently hammered into its hole a few times with a tin hammer, that the pin may be thus marked to show which part was in contact, and consequently, which part needs reducing to obtain a proper bearing. It is also necessary to make the pin-hole only very slightly taper, the angle of its sides being only about two degrees.

Those pins which are very taper, are sometimes used for quickly connecting and disconnecting a rod, bar, plate, or joint. Most of those belonging to this class are furnished with ornamental knobs or handles; therefore each pin is forged with its handle in the desired form, and no temporary handle is required.

Screw-Studs.—A screw-stud is a cylindrical piece of metal screwed at one or both ends, and intended to be fixed in a flange, rim, or other portion. A stud having a screw at only one end is provided with a small pin-hole at that end which has no screw, the hole being required to contain a taper pin similar to those treated in the previous section. A stud with a screw at each end, is provided with a screw-nut at one end, the opposite end being that which is to be fixed in the flange or other portion. All the studs here treated are such as those employed for connecting cylinder-lids to their cylinders, and for connecting a great number of flanges of several classes. It may be here generally stated that studs are a class of substitutes for bolts, and are never used except in places that will not admit headed bolts. Studs should never be made of steel unless they are to be screwed with a lathe.

Studs that are intended to tightly connect two flanges together, are of two sorts, each of a distinct shape. One of these is that of a piece which is screwed along its entire length, and the other is that of a piece having a thread at each end, and a cylindrical or plain part in between. Those that consist entirely of screws, are denoted by Fig. 930, and those having plain mid-parts are denoted by Fig. 929. Either of these sorts may be used for any one purpose; but those which have plain portions are superior to the others, although those that are entirely screwed are quicker made. The forming of the two varieties must be separately described.

Screw-studs which are to be without any plain part, are made in lots of four, six, or eight, of one diameter, and at one time. A piece of wire or rod is prepared of sufficient length to make six, eight, or whatever number may be convenient, and it is screwed along its entire length, excepting an inch or two at one end, which is square, and smaller than the remainder, the square end constituting a holder or head by which the piece is held during screwing. A long stud-piece of this class is shown by Fig. 931, being screwed alon its whole length and ready to be cut into studs of proper length. Studs thus made are screwed with dies, and if not exceeding five-eighths or three-quarters of an inch in diameter, the stud-piece can be gripped with the square head in a bench-vice and screwed with a pair of dies in an ordinary die-frame. Comparative large stud-pieces of this class that may be an inch or more in diameter, are screwed with machine-dies. As soon as a long piece has been screwed to the exact diameter desired along its length, it can be cut into pieces of a proper length for use, by means of sawing.

The mode of thus making a number of studs together in one piece, is a rapid method of formation only suited to small studs. Dies will not form the threads of such pieces properly if they are more than an inch in diameter; and some dies will not properly screw a piece if it is more than three-quarters in diameter, or of greater length than five or six inches. The characters and modes of making dies are described in the chapter on tool-making.

In order to accurately screw a stud-piece, care must be exercised to make the screw as nearly parallel as possible along its whole length; and if the diameter is that desired, any part of the piece can be used for a stud. But it will be discovered that most of the pieces thus made are smaller in diameter at their mid-parts than at the ends; so that when the studs are produced by sawing off, those that are too small must be rejected. The gauge-nut or measuring-nut, used during the screwing, should have its screw a little larger in diameter than the diameter of the intended studs, and the piece is to be screwed to tightly fit this nut; consequently, a small portion of metal will remain for reducing the thread to the finished diameter. This small quantity can now be pared off with a good die-nut which has been properly formed for its use; with this the studs can be finally adjusted to the diameter with but little trouble.

Another mode of screwing several pieces to one precise diameter, consists in fixing packing pieces of proper thickness between the two dies in their frame; in order that while a piece is being screwed, the operator may know it to be reduced to the proper diameter by the time the dies are advanced tight against the packing-pieces, after which they cannot be brought nearer to each other, and, therefore, cannot make the screw any smaller. Stud-pieces are also accurately formed by means of lathe-screwing, by which the required parallelism is easily obtained, and the thread properly shaped.

It is now needful to mention the making of studs having plain mid-portions. These should be made singly, each one being cut to the finished length at the time of forging, with only an additional sixteenth of an inch at each end, when it may be specially necessary to finish them in the lathe to the precise shape. After forging, each lot require to be turned and screwed; and the particular lathe selected for any one lot, is suited to their diameters, because small ones not more than three-quarters of an inch in diameter can be screwed by hand-screwing; whereas larger ones require to be screwed with wheels. By means of lathe-turning and screwing, studs of three inches in diameter or any larger size, can be perfectly and accurately made, which cannot be done with dies.

When several hundred studs are required at one time, their turning is executed in one lathe, and their screwing in another. By this mode, one lathe can be kept turning them to their exact diameters by means of gap-gauges, while another lathe is appropriated entirely to their screwing. This will avoid shifting a variety of apparatus for the purpose of putting a lathe into order for screwing; and will also allow studs to be centred and turned with a lathe which is entirely without screwing apparatus.

If studs are to be screwed by hand, it is proper to commence the screwing of every one with the wheels, whether it is to be finished with a hand screw-tool, or with a slide-rest tool. The quickest mode of smoothly finishing the thread is by hand-screwing, whether the studs are small or large. But the amount of wheel-screwing which small studs require is very little compared with that required for large ones. If the stud is only three-eighths or half an inch in diameter, the wheel-screwing should consist in merely making a thread-groove by only one advance of the tool along the stud; after which, the hand-screwing is a preferable and rapid process for removing the remaining metal. Small studs should therefore be principally screwed by hand, and large ones by wheels. Those that may be an inch or more in diameter, should be screwed with wheels until near their ultimate diameter, after which it is proper to smooth them with a hand screw-tool, that they may accurately fit their respective gauge-nuts, and also be smoothly finished. All hand-screwing of this character constitute processes which are distinct from wheel-screwing; therefore, if the same lathe is required to both commence and finish the screwing, all the studs require to be first screwed with the wheels, previous to finishing any one of them by hand.

Studs are also forged singly with handles. A stud thus made is furnished with a small square handle which is produced at one end by thinning the metal; consequently, the square part of a stud is similar to that of a long stud-piece to be cut into proper lengths. Studs having handles are denoted by Figs. 932, 933, and 934. Such can be very conveniently held while being turned and screwed in a lathe, and also while in a bench-vice, or in a screwing-machine.

Small Bolts.—Bolts in general are of two classes, consisting of those that have no screw-parts, and those that have them. By small bolts are here signified such as are not more than an inch, or an inch and a quarter in diameter.

When a large number of small plain parallel bolts which are to be without screws require turning, all are first partly lathe-turned to their respective diameters by means of gap-gauges. The gaps in these are of proper sizes to roughly indicate the finished diameters, and to cause a small amount of metal to remain for finishing. After a lot of bolts are thus reduced, all should be finished to the exact sizes by using other gap-gauges, and removing the small amount of metal with springy tools.

A large number of small bolts are required to be accurately turned to some specified diameter. The turning of such commences by a first reduction to callipers or gap-gauges, previous to a final smoothing to ring-gauges. When a ring-gauge is used for this purpose, the holes which the bolts are to fit must necessarily be of the same diameter as the gauge-hole in the ring. Instead of a ring, a temporary block can be used. A block for this purpose consists of a piece of metal in which a hole is bored that shall constitute a gauge-hole to which the bolts can be fitted. A piece having such a hole is denoted by Fig. 939. The hole is exactly the same in diameter as that of the holes in which the bolts are to be placed; therefore the block can be kept close by the turner at the lathe, and all the bolts of that size be fitted to the gauge-hole. By carefully fitting a number of bolts to one hole of this character, all of them are accurately reduced to the desired diameters previous to taking them from the lathe in order to put them into their places. During the use of a soft block for such fitting, the hole must be kept quite clean and oiled, to prevent damage to any bolt that may be tried in, and to prevent damage to the hole. Every bolt must also be smooth at the time of trial; if not, the gentle hammering which is needed to drive it into the hole, will probably cut off the rough tool-marks, and make it too small. The gauge-block shown by Fig. 940, is one having a number of holes of various sizes. Some of these are taper, and some have conical mouths, for the fitting of bolts with conical heads; others are furnished with recesses for bolts with cylindrical heads.

Small bolts that are to be screwed, named screw-bolts, are turned to their required diameters with regard to the screwing process, in addition to turning their intended plain parts to fit gauge-blocks. A well-formed screw-bolt is provided with a plain part adjoining the head, which is smoothly turned to fit its place, as in the case of a bolt which has no screw. When the bolt has been thus treated, the exact required length for the plain part is ascertained and marked, by which the place for the screw is shown. This part is therefore reduced to the diameter suitable for producing the desired screw. The exact diameter of this end depends on the means to be used for screwing. If to be entirely screwed without dies, the diameter is exactly the same as that of the screw when finished. But if to be screwed with dies, it may be, in nearly every case, smaller than the finished diameter, to allow the dies to squeeze up the thread to the proper height. Gauges are employed while turning these ends; but each gauge will only suit one pair of dies at one time; and as the dies become more and more blunted by use, the bolt-ends to be screwed require to be turned smaller and smaller. Concerning this subject refer also to page 18.

Small bolts are sometimes made with square handles, similar to those mentioned for taper pins and screw-studs forged singly. Such handles are provided for both plain bolts and screwed ones; and it sometimes happens that the lathe to be used will not turn them without handles of proper length, by reason of the lathe being too large for the comparative small bolts. A bolt with a handle is seen among those shown by Figs. 935, 936, 937, and 938.

Screw-nuts.—Screw-nuts are principally made of forged iron or steel, and cast gun-metal. After a nut has been either cast or forged, it requires three principal shaping processes; these are, screwing the hole, turning the two faces, and shaping the six sides or planes. Nuts are distinguished into sizes with regard to the thicknesses of the bolts or screws for which the nuts are made; therefore a nut to fit a screw one inch thick is termed an inch-nut, although it may be two inches or more in diameter.

After forging, nuts next require screwing. This is effected either by means of a long taper tap, shown by Fig. 312 or 317, while the nuts are held in a vice, and the tap rotated with a spanner; or is effected by means of a tapping-machine. It is to be here noticed that whether hand-tapping or machine-tapping is adopted, a properly shaped long tap should be used, in preference to two or three short ones, such as are denoted by Figs. 309, 310, and 311; or Figs. 314, 315, and 316. Nuts that have been properly forged are furnished with holes of proper diameters for the respective taps; and the holes are also tolerably square to the broad surfaces of the nuts, termed faces. Consequently, when they have been tapped by allowing them to travel freely along without improper hindrance, the screws are also square to the faces, as intended.

Gun-metal nuts are usually cast without holes, unless they are of comparative large sizes, such as inch and a half or two inches in diameter. Some classes of gun-metal nuts are furnished with flanges, and resemble those denoted by Figs. 942 and 943. A nut without a hole is shown by Fig 943; and on the top of this a couple of lines are shown for indicating the centre, in order to mark it for drilling. Two cross-lines of this sort are sufficient to show the centre, supposing that the nut is regularly formed; in which case, two straight lines from four corners will intersect at the centre, as represented in the comparative large Fig. 944. At the centre a deep dot is put with a coning-punch, and from it a circle is scribed of the same diameter as the intended hole; this is dotted as seen in the Figure, and becomes a gauge-circle to which the drill-point is made central for drilling. The opposite or flange side of the nut is easily marked with a similar circle, by means of an outside calliper, as before described. When each nut is thus lined it is ready for drilling.

The centre of a very irregular face belonging to a nut cannot be found by marking cross-lines. The lining for such a nut is effected with callipers. Fig. 945 denotes an irregular nut-face, at the middle of which six arcs intersect each other, and in their midst is the centre required. To mark the arcs, a calliper is opened until the distance between its points is a trifle greater than half-way across between two opposite flat sides; one point is then put to about the centre of one of the six edges, while the other point is extended across the nut-face and a short arc scribed. The calliper is next shifted to the opposite side, and another arc scribed to intersect the first one. The point midway between these arcs is the centre of that portion of the surface over which the calliper was extended while marking; and by next shifting the calliper to the other four sides or edges, four more arcs can be marked; so that the mean centre of all the arcs, and therefore of the entire surface, is clearly shown. This being found, a dotted circle is marked, similar to any other required for drilling, and the lining is completed. In the Figure the six centres from which the arcs are marked are denoted by the letters C. Those nuts that are irregular along the entire lengths of their six sides are properly lined by placing them into vee-blocks on a lining-table.

After lining, the nuts can be drilled so that the holes are square to the faces, by employing a suitable chuck for holding each nut. Such a chuck may consist merely of a parallel block in which holes are bored of different sizes. When this is to be used it is put beneath the drill with one of the holes concentric with the drill, and it is then fixed with holdfast plates, or with little screws belonging to the chuck. A nut which is properly lined is now put upon the chuck and held with a spanner, or with ledges situate on the chuck, to prevent the nut rotating while being drilled.

When several thousand nuts are to be drilled, a chuck should be used which has a couple of vee-grips. These are caused to slide either towards each other or apart, by being attached to a screw which is both left-handed and right-handed. The action of this screw is like that of one belonging to a lathe-chuck, and causes the vee-grips to hold nuts of several different diameters. Each nut is also fixed concentric with the drill by the act of tightening it between the grips, supposing that the chuck is well made and fixed at the proper place on the drilling-table. Consequently, with such a chuck no adjustment of the nut after fixing is necessary.

Whenever it is specially desirable to drill a number of long nuts so that their holes shall be as nearly as possible square to the nut-faces, it is necessary to centre both faces of each nut, and drill half-way through from each face, instead of entirely through from one face.

Nut-Facing.—After nuts have been screwed by some means they are ready for facing. This operation consists in making the faces or broad sides of the nut plane and parallel with each other; and also square to the nut-screw, which is the same as being square to the length of the bolt. The facing of nuts is always executed by turning; and it is needful for at least the inner face of every nut to be turned that it may be caused to properly bear upon the surface of the object to be held. The opposite or outer face need not be turned except for appearance, unless the nut is too thick, or it is required to have a specified form.

The instruments required for nut-facing are screw-arbor chucks, and screw-arbors. A screw-arbor chuck is also termed, a nut-chuck, because it is employed for facing nuts while it is screwed tight on the lathe-spindle as other lathe-chucks. A screw-arbor is also termed a nut-arbor, being an arbor specially used for turning nuts. A nut-chuck consists of a short screw which projects from a chuck that rotates with the lathe-spindle, through being attached to any convenient disc-chuck which is on the spindle-end. The screw of the nut-chuck is so made as to be exactly true with the lathe-spindle axis; it is also rather taper and very short, being only long enough to tightly hold a nut when screwed thereon without allowing the screw's end to extend to the mouth of the hole in the nut. By referring to Fig. 948, a nut-chuck may be seen attached to a small disc-chuck in position on the spindle-end; and in the comparative large Fig. 949, a nut is shown which is tightly screwed on a nut-chuck and ready for facing. It will be seen that this Figure shows the outer face of the nut wholly free from the chuck-screw within, and therefore capable of being easily turned without causing the turning-tool to touch any part of the chuck-screw. Each size of nuts requires a distinct chuck, because each nut must tightly fit the screw and remain without shifting while being turned ; and the chucks are named the same as the sizes of the nuts to be placed thereon.

A nut-arbor consists of a spindle having a taper screw near one end. The screw part is analogous to the screw of a nut-chuck, being made slightly taper, and to fit some special size of nuts, and rotate them while screwed tight thereon. But a nut-arbor is used by rotating it and the nut thereon while on the lathe-pivots; consequently, the arbor is of a convenient length, such as eleven or twelve inches, and should be furnished with large centre-recesses at its ends, to bear properly on the pivots.

The nut-arbor shown by Fig. 950, consists of a spindle having a shoulder or bearing for the nut, in addition to the screw. An arbor of this class has a parallel screw because it is not required to tightly fit the nut. Such an implement allows a nut to be quickly screwed along the screw to the shoulder, causing one of the nut's faces to come into contact and fix it ready for turning. Although nuts can be rapidly fixed and unfixed from such an arbor, it will be found that if the nut-face which touches the shoulder is not square with the nut-screw, the facing will not be effected square with the screw, as required.

One of the author's nut-arbors is shown by Fig. 951. This consists of a steel spindle having an end which is screwed and slightly taper, and also a comparative small cylindrical portion extending from the screw-part. The screw being taper, causes a nut to be held tight thereon without the need of coming into contact with any shoulder, consequently, none is provided. The diameter of the stem or small end is considerably less than that of the holes in the nuts to fit, because ample space should exist around the stem between its surface and the nut-thread, in order to allow the point of the cutting tool room to disengage from the metal that adjoins the hole. The opposite or handle-end of the spindle is that by which it is rotated in a lathe, this end being gripped with a distinct carrier unless the spindle is provided with a carrier as part of the instrument. This is the case with the one shown by the Figure (951) the end having a hole formed for holding a sort of lever consisting of a straight piece of iron or steel. A carrier of this class may be slightly bent after being put into the hole, to prevent it shifting while in use.

Only one face of a nut can be completely faced at one time on an arbor, whether it is on a nut-arbor or on a nut-chuck. It is therefore necessary to smoothly finish one face and take off the nut to place it again upon the arbor for turning the other face. At the reversal of the nut to have the second face turned, and after it is again screwed tight upon the arbor, the already turned face should rotate exactly true and right-angular to the spindle's axis of motion. But this is not always the case; and it is sometimes necessary to again take off nuts after they have been screwed tight upon the arbor, and clear out dirt or shavings that may hinder the nut-screws from properly fitting the screw of the arbor. Such hindrances will in some cases cause the nuts to rotate so much out of their proper directions as to render them after turning rather inferior to their condition before turning.

In some cases nuts are shamfered. Shamfering consists in bevelling the corners belonging to a face of a nut, some having both faces shamfered. The principal reason for shamfering, is to ornament one of the faces; consequently, the face to be outwards is the one to be shamfered. That which is termed the shamfer of a nut, is, therefore, the bevelled portion referred to, which usually includes a small portion of the face adjoining. In Fig. 946 the shamfer of a nut is shown, and it is usually formed by turning with a tool of proper angle, which is applied after the face is finished. The angle of a shamfer with the face of a nut, should be 45°, and the greater the shamfer of any nut, the smaller is the face that has the shamfer; consequently, it may be seen that the inner or gripping face of a nut should not be shamfered, because it diminishes the available bearing surface. One of the author's shamfer-guages is shown in contact with a nut in Fig. 947. The handle is of convenient size for holding; and the lower arm of the gauge is comparatively short, that it may not be much in the way when applying it to a nut which is on an arbor.

The stop-nut shown by Fig. 953, is of a class much used; and the stem or cylindrical part of such a nut is the portion last turned. After the opposite face is finished the distance to the commencement of the stem can be shown, and the stem's length also shown; the stem is therefore reduced to the proper size, and the superfluous length of metal is cut off the face adjoining the stem.

Shaping the six outer sides or planes of nuts, is the last paring-process to which they are subjected. This is effected either by planing or shaping, while a number of nuts are held together on an arbor, according to the instructions in page 230; or is effected by means of rotating cutters that rotate in the manner of a chuck belonging to a lathe.

Turning of Spindles, Rods, &c.

Spindles.—A spindle usually possesses at least two bearings or necks, which are intended to constitute friction parts on which the spindle will rotate. The necks of any such spindle require to be in line with each other; or, their axes require to be in line with each other, in order to secure a proper bearing upon the pillow-block brasses, or upon whatever other friction surfaces may be provided. A simply formed spindle is shown by Fig. 954, which is without bearing collars or flanges, and therefore will allow a wheel, lever, or other object to fit at any place along the spindle's length. Fig. 955 represents a spindle with flanged bearings; this is a light and elegant form suitable for a spindle that does not require any wheel or other article to be slid along and fit at the mid-part.

An easy and accurate method of turning a spindle that may not be more than about an inch thick consists in performing the entire turning while the spindle remains in one position in the lathe. For this purpose a piece of metal is provided which is a few inches longer than the intended spindle; and after it is centred it is put on to the lathe-pivots and gripped by fixing a carrier to the superfluous few inches near the lathe-chuck. The piece can now be rotated and the entire spindle accurately produced in its required length and several diameters without shifting the carrier by which it is rotated. Therefore any portion of the spindle which is truly turned circular will be made concentric with any other portion which is truly turned; so that all the necks it may have will be exactly true with each other, and true with the other parts of the spindle that are made to fit the lever-bosses, wheels, or other articles to be connected. A spindle produced in this manner is not cut from the extra piece at one end, until the whole of the turning and fitting is quite finished; so that it is necessary to carefully measure it, and ascertain what are the exact dimensions intended; also to thoroughly fit every part, previous to cutting off the end, in order to avoid the liability of having to centre it for some further turning that was not foreseen. When the end is to be removed, a deep groove is made around at the proper place, to allow of an easy breakage. A groove of this sort is seen in the spindle shown by Fig. 956.

It may be also stated that if a spindle is specially required to have a centre recess at each end, it may be first cut to the length and centred at each end; consequently such a piece will require reversing end for end in the lathe, and the carrier or gripper must be fixed to both ends.

Rods.—The rods here mentioned are those which are cylindrical along nearly their whole lengths; and the remarks principally refer to the mid-portions of joint-rods, some classes of simply formed connecting-rods, and gland-rods.

Joint-rods.—A joint-rod having a boss at each end, resembling Fig. 957, is centred with regard to the portion which has the least metal to be removed, according to rules given in a previous chapter. It may happen that the straight mid-part remains to be turned after the bosses and their joint-holes are finished. But in general it is more convenient to turn the mid-part at the first commencement of the paring, and to next line the bosses to show their lengths, while the truly turned mid-part is in vee-blocks on a table. By this mode it is convenient to use the centres of the recesses for adjusting the scriber-point, in order to mark the centres of the boss-faces, and, consequently, the centres of the holes also.

If the turning of a rod's mid-part is the first operation, the bosses are rough, and perhaps without any hole; therefore a carrier of any sort can be fixed to either boss without risk of damaging it. But when the bosses are shaped, and the holes also, the carrier which is to rotate the rod must be carefully attached. Such a boss can be gripped with a carrier similar to the one in Fig. 956; and it is attached by means of two flat smooth packing blocks, one on each boss-face and both in the hole of the carrier. Grippers are also used consisting of holdfast plates and bolts. The simplest one of this class consists merely of a plate and bolt such as are seen attached to the rod in Fig. 958, the plate being inclined towards the lathe-chuck, to conveniently engage with the driver. Fig. 959 represents a boss gripped with two plates and two bolts; in this case it is not necessary to put either bolt through the hole in the boss, both bolts being put through the holes which are suitably located in the plates.

Slide-rods.—The slide-valve rods here noticed are small and simply formed rods, which are principally parallel, these instructions being chiefly directed to the production of the cylindrical parts. The remarks apply also to piston-rods of simple form. Further details will be given as we proceed to the consideration of the paring operations for large rods.

The cylindrical parts of rods are easily produced by the aid of the long traverse motion with which every engineer's lathe is supplied. But it is necessary to ascertain whether the lathe to be used is in a proper condition for parallelism previous to commencing a parallel portion, especially if the diameter of the rod to be turned is but very little greater than the finished diameter. In such a piece the slide-rest tool is liable to enter the metal too far, and make it too small in some part, if the lathe is not properly adjusted to parallelism before beginning the turning. This adjustment need not be effected for a rod that has plenty of metal to spare, until the tool has been once along the rod, after which both ends of the turned portion are measured, and the poppet-head is shifted accordingly.

When it occurs that a number of cylindrical parts require turning at one lathe, all of them should be first turned with vee-tools until near the specified diameters, allowing only about a sixtieth of an inch to be cut off each one to complete it. After the entire number have been thus treated, the use of vee-tools should be discontinued, the author's method of finishing consisting in finally turning the several pieces with springy tools, although they may be only about an inch, or less, in diameter.

GENERAL TREATMENT OF JOINT-RODS, CONNECTING-RODS, ETC

It is now needful to consider the treatment of several sorts of rods and bars in connexion with their respective joint-pins, brasses, and other portions belonging to them.

Joint-parts of Slide-rods and Connecting-rods.—The joint-ends of small rods and bars in general should be made of steel, and be hardened, to obtain great durability. Large rods also should have steel joints, supposing that the maker has arrangements for making them. It is therefore, in most cases, convenient to make an entire rod or bar of steel, to avoid the attachment of steel ends to an iron mid-portion.

Excellent joint-parts are produced by a final process of hardening, after an accurate shaping and fitting of a steel joint has been effected. But because of such portions being liable to break during the cooling, it is usual to harden only comparative small pieces, and to allow large objects to remain soft.

The gap in the joint-end of a slide-rod is usually so made that the gap is larger than the end-boss of the rod which is to fit. The joint-nut or other joint-part, which is secured to the slide-valve, is furnished with a gap of sufficient size to allow an eighth or a quarter of an inch of room between the slide-rod boss and the side of the joint-gap, when both are connected. In Fig. 962 a gap having an amount of room for this purpose is shown. Such a space provides for the future wear of the slide-valve face, and also of the cylinder face; so that at a future time the friction surfaces can be reduced and flattened without interfering with the relative position of the slide-rod in its packing-box and gland.

Nuts of Slide-valves.—The nuts here referred to are those by which the valves are attached to their respective slide-rods. A nut of this class is termed a tee-nut, through resembling a letter T; it is made of gun-metal, and furnished with a thick flange similar to a bolt-head. The nut is represented by Fig. 963, and in Fig. 964 a slide-rod is shown having a tee-nut attached to its end. In the slide-valve to be connected is a tee-shaped recess for containing the nut, and the mode of connecting the rod to the nut consists in forming a screwed hole in it, and forming a screw upon one end of the rod to fit.

The tee-shaped recess in a slide-valve is deeper than the nut intended to be therein, and at the first fitting of them together, the nut is situated at the bottom of the recess. Therefore the valve-nut is allowed a free movement from the bottom of the recess to its mouth, and, consequently, when all are connected together, a free movement of the valve towards the cylinder is allowed without straining the rod or packing apparatus. Also, at a future time, the faces of the valve and cylinder can be reduced for repair, without requiring alteration of the rod's relative position. By thus providing a space for the nut and valve to shift their relative positions, the necessity for providing a space in the rod's joint-gap is usually obviated; but this space also is sometimes provided.

The mode of properly fitting a tee-nut to its rod and valve consists in first drilling and screwing the nut and screwing the rod's end to fit, previous to finally fitting the nut to the recess in the valve. If the rod is only about an inch in diameter, its nut can be drilled and tapped at the first beginning of its treatment; but a large nut requires to be first flattened on one or two sides, because it may then be quickly fixed upon a lathe-chuck, this being required for effecting the screwing.

After the nut, whether small or large, has been fitted to the rod's screwed end, it can be properly lined in order to accurately shape it, so that its sides shall be parallel with the rod's length, and its bottom or flange-part shall be square to the rod's length. To make the shoulders or bearing surfaces square, the nut may be put upon a nut-arbor and partly turned, the parts not turned being afterwards made true with chipping and filing. The nut can also, in some cases, be turned while on its slide-rod, instead of on an arbor. The right-angular surfaces required for the nut can also be indicated by lining, and entirely produced without lathe-turning. For this purpose, the slide-rod having its nut screwed on, is put upon vee-blocks on a lining-table, and the nut is lined with a scriber-block. As soon as the rod's length is adjusted to parallelism with the table, the scriber-point is adjusted to a proper height to mark lines upon the nut to indicate those surfaces to be parallel with the rod's length. In order to scribe the lines to show the right-angular surfaces or shoulders of the nut, it is only necessary to place an el-square upon the table with the blade in contact with the nut, and scribe lines along the blade's edge with a scriber. This latter marking is done while the rod yet remains in the same position on the vee-blocks as at first arranged. The scribing of these lines, which denote the nut's shoulders, is of course not required if the nut is turned, as stated, on an arbor. A slide-rod in position on vee-blocks is shown by Fig. 965.

When a tee-nut has been lined and regularly reduced to the lines, by means of filing, if small, or a planing-machine if large, it becomes a sort of gauge by which the recess in the valve can be chipped and filed if necessary. The principal bearing surfaces are the shoulders; and these must be carefully made to bear equally upon the surfaces of the recess; if not, the action of the rod to and fro in ordinary work, will in time break the rod or do other mischief. Steel slide-rods are often broken at their thread-junctions by reason of improper fitting.

Socket-connexions of Rods.—A great number of rods with circular ends are joined to their respective portions by means of sockets or socket-ends. A socket-end is a tubular boss or projection situated at one end, or both ends, of an article, and usually in one piece with it. A socket is always furnished with a hole of some shape, and, although a few socket-holes are square, the greater number are circular, and are either straight simple holes slightly tapered, or holes that are screwed.

Ends of slide-rods, piston-rods, pump-rods, and others, are frequently fitted with socket-ends, and are represented by Figs. 966, 967, 968, and 969. These denote the ordinary classes of sockets, some being fastened together by screws, and others by keys. Those fastened with keys are the easiest to connect and disconnect; but it may be said generally that the screwed ends are preferable for obtaining a maximum strength with a minimum amount of metal, supposing that the thread-grooves of the respective parts are not deeper than is needful. The author's plan is to furnish all such screwed ends with threads having comparative short steps.

The ends of rods and bars to be entered and fixed in sockets require to have special bearing surfaces, if to be fastened with keys, that the keys may effectually tighten the respective pieces together without exerting any improper strain. Supposing that an end of a piston-rod is to be thus connected, its principal bearing surface is at the bottom of the hole. In Fig. 968 a cross-head boss is shown, in the hole of which is a rod's end. This end is of a regular curved form, and accurately fits the hole's bottom; consequently, the hole must have been previously carefully bored to its proper shape, a suitable bearing of this character being required because the rod cannot be furnished with a flange for contact around the hole's mouth.

The necessity for making a piston-rod's end, or a slide-rod's end, bear in close contact with the bottom of the hole, arises from the small amount of bearing-surface presented by the shoulder of the rod at the mouth of the hole. Such a comparative small surface soon gets out of shape by the action of the rod; and an irregular recess is also formed into the metal of the boss at the hole's mouth. This necessitates a frequent driving in of the key, to tighten the rod, although such fastening is not effectual for any considerable time. An end of a rod that does not touch the bottom, is also liable to be weakened by the act of keying the parts together. It may, therefore, be seen that a proper bearing must be provided either at the bottom of the hole or at its entrance.

An end of a connecting-rod, or of an eccentric-rod, can have a flange, similar to that seen in Fig. 969; and the rod's end can be screwed and the flange made to bear tight upon the boss by the act of screwing the end into the hole. The fastening may be also effected by means of a key, the end of the rod being fitted into merely a plain hole. An eccentric-rod attached in this manner is shown by Fig. 970, the flange or collar being tightly forced against the face of the boss while driving the key into its key-way.

In some cases an end is both keyed and screwed; but keying is quite unnecessary if the screw-cutting is properly done.

Crosshead Nuts for Slide-rods.—An ordinary class of slide-rods are those having long screws at their outer ends. These ends are connected to their respective crossheads by means of nuts, the slide-rod screws being in the crosshead bosses, and nuts on the boss-faces. An arrangement of this class is show by Fig. 971. The diameter of the hole in the boss is sufficient to allow the screw to slide easily to and fro, so that it can be put at any desired distance through the boss, and be tightly fastened in that particular place by screwing the nuts forcibly against the boss-faces. A connexion of this character is very convenient for adjusting the slide-valve to any desired place on the cylinder-faces; and the adjustment can be performed without trouble either at the first attachment of the valve, or at any future time when repairs are in progress.

In order that the ordinary to-and-fro motion of a slide-rod may not loosen its nuts, and thereby allow the valve's relative situation to be unintentionally altered, the rod's end should be screwed with a thread of comparative short step, and made to tightly fit the nuts. In some cases, four nuts are used for each rod, instead of only two, two nuts being situate at each end of the crosshead-boss.

TREATMENT OF STRAPS, STRAP-BRASSES, ETC.

Straps.—Straps are used for connecting the pivot-ends of crossheads with their respective side-rods; also for connecting crank-pins with connecting-rods belonging to pumps, steam-engines, and several other classes of machines.

The simplest class of straps, and the easiest to make, are those having arms of equal thickness. A pair of straps of this shape are shown in Fig. 972. Straps are of all sizes, being used for machines of all sizes; and the metal of which they are made is forged iron or steel; the preferable mode of forging consisting in bending a straight bar, as stated on page 33.

Straps of ordinary shapes are denoted by Figs. 973 and 974. These have arms which are thicker at the ends than at the bent portions, to provide strength for the key-way portions without causing the other parts to be too heavy. The strap shown by Fig. 973 is one with comparative thin arms, being suitable for a pin or pivot whose bearing is of great length, the strap-brasses being also of great length, thus causing the strap to be of considerable thickness.

To ensure a proper fitting for a couple of strap-brasses, it is necessary to first accurately shape the strap. The gap or opening of any strap may be either parallel or slightly taper. A taper form is preferable; and the smallest part of the gap should be the bottom. But when it happens that the bottom is the largest, the brasses will require to be forcibly driven along the length of the tight or small part, every time they are put into or removed from the strap, unless they are so much reduced as to fit the strap very loosely when in their places. The small amount of taper is also suitable for an easy fitting of the strap to the square end or boss of the connecting-rod, or other rod, to which the strap belongs. The strap should also be rather taper in its thickness; but in this respect it should be smallest or thinnest at the entrance of the gap or extremities of the arms.

Large straps are sometimes made of blocks of steel or iron in which gaps are formed by drilling and slotting. This mode avoids a tedious bending of thick heavy pieces of metal; and the forging consists in well closing the particles of the lumps and trimming them with chiselling, to produce the curved form for the ends which will be the outer portions of the straps when made. A strap-lump of this class is shown by Fig. 979.

The first treatment of straps after forging consists in shaping their gaps; the outer surfaces not being shaped until the gaps are finished, or at least finished excepting filing. The gaps are formed by drilling or lathe-boring, and by planing or slotting. Those straps that possess solid lumps which are to be cut out, require a sort of preliminary planing of their two broad sides to make them parallel with each other and fit for lining. Two flat surfaces are thus formed on which the intended shape and dimensions for the strap can be scribed. The lumps are next drilled or bored, to accurately form the desired half-round bottoms of the gaps. This process makes a round hole at the bottom of the intended gap, and causes the strap lump to resemble Fig. 980. A row of holes are next drilled along each arm of the strap, as denoted in the Figure, extending to the already finished circular hole. The piece is now ready to have the superfluous middle removed by a grooving-tool of a planing-machine or a slotting-machine, according to circumstances. When the strap happens to be small enough, chiselling is adopted for separating the middle piece instead of employing a machine.

The gap of a strap can be almost finished with planing, if proper care is exercised at the fixings, and the measurements are properly conducted. The strap should have both sides of its gap finished while it remains in one position on the table; this will cause the gap to be parallel, and the cutting tools can be easily adjusted to the already finished half-round surface at the bottom of the gap. After a gap has been planed parallel, the small amount of enlargement at the mouth to taper it as directed, can be easily performed with filing.

After the gap is completed the entire outer surface should be smoothly reduced to the desired form, and made parallel with the finished gap-surface. Each strap is to be next fitted to its rod or bar by reducing the rod's end to the exact width required. For an easy fitting of a large rod it is convenient to support it on vee-blocks on a planing-machine; and after scribing the width of the strap's gap upon the rod's end, the metal is planed off with regard to the lines, and by using inside callipers and outside ones near the conclusion of the planing. The strap is next tried upon the square end while the rod yet remains fastened as when being planed; consequently, the strap can be placed on and taken off several times without removing the rod from the machine. By this mode, a large rod's end can be accurately reduced until the strap will slide a short distance upon the end, and a very little subsequent filing will suffice to complete the fitting.

As soon as the strap is fitted to its rod, the keyway can be made, and the keys partly fitted thereto. During this operation the strap is kept in its proper place on the rod by means of a packing piece which is fixed between the surface at the bottom of the gap and the flat extremity of the square boss. The length of this piece is about the same as that of the brasses; consequently, while in position it is fixed by the act of tightening the key. A strap keyed to its rod by means of a packing-piece is shown by Fig. 974; in which condition it is held while the edges are planed.

The next step is to plane both the broad sides of the rod's end and the narrow sides or edges of the strap's arms; this being done while the strap is keyed to its rod and the rod supported on vee-blocks, in a situation similar to that occupied while it was being planed to fit the strap. This planing makes the rectangular boss of the rod parallel, and, consequently, the narrow sides of the strap's arms are also made parallel with each other. It is therefore needful to afterwards taper the strap slightly with filing, when it is apart from its rod or bar. This tapering is that before referred to for making the strap thinner at its extremity, which will allow an easy fitting of the flanges belonging to the brasses.

It is next needful to ascertain the exact intended length of the connecting-rod or bar in progress; the particular distance here referred to being the length between the centre of the hole in the brasses at one end and the centre of the hole in the brasses at the other end, supposing that the rod is being fitted with a strap at each end. If a fork-end connecting-rod is in hand, the distance referred to is the length between the centre of the brasses at the strap-end and the centre of gudgeon-hole at the fork-end. For a rod having a strap at each end, the length is indicated as shown in Fig. 975. A radius-gauge is adjusted to the length, and its points can be used for reference, and for scribing the length at two opposite sides, by means of an ender or packing-piece of some kind which is fixed for the purpose. It is also needful to show the length on the narrow sides of each arm. Therefore, after the centres have been scribed, an el-square is used, and its blade is put to the centre while the pedestal is put to the planed outer surface of the strap. When the square is placed, a line is scribed along the blade's edge upon the arms of the strap. This line is seen on the narrow surfaces of the straps denoted by Figs. 976 and 977; both sides of the strap are thus marked, and the lines become gauge-lines to be afterwards used when fitting the brasses. These lines may be termed length-marks.

Fitting of Strap-brasses.—Strap-brasses should be fitted to their straps with regard to the length-marks shown on the straps' edges. The bottom brass is first made to bear properly upon the bottom of the gap; after which, the intended face of the brass can be shown by reference to the length-marks. Whatever superfluous metal is seen beyond these marks, is the amount to be planed off or by other means cut off the brass. The other brass is next fitted down until its face touches the face of the first one. The amount of metal to be cut off the faces of both brasses, depends on their thickness, and the room to be allowed between the brasses and the rod's extremity.

If the two brasses are fitted to the right places, the two faces or surfaces which touch each other will exactly coincide with the length-marks on the strap, which indicate the centre of the entrance of the hole when bored. Consequently, each brass when bored will possess a semi-cylindrical gap, instead of one brass having a gap deeper than the other. If the required centre of the hole is not first shown on the strap previous to fitting the brasses, it may happen that the gap in one brass when bored will be an eighth or a quarter of an inch deeper than the other. This irregularity causes a large amount of filing and improper reduction of that brass having the deepest gap, in order to fit it to its spindle or crank-pin, although the hole may have been bored to the proper diameter.

Lining of Strap-Brasses.—After a couple of brasses are properly fitted into their strap, they should appear as in Fig. 982, the faces being quite close together, and both brasses tightly fixed in their places by means of packing-pieces in contact with the key. They can now be properly prepared for lathe-boring by a suitable lining. The lining commences by fixing a wood ender at one mouth of the rough hole; and a centre-dot is put into the ender at a point exactly coinciding with the length-marks on the strap, when it is known that these marks are carefully put at the proper places; if not, it is now needful to accurately mark the centre of the required hole by an additional measurement, or by using the radius-gauge as before.

It is now requisite to ascertain the centre of the gap in the strap, and indicate it on the brasses. This is necessary in order to cause them to be so bored that an equal thickness of metal shall exist at either side when bored. The simplest mode of showing the gap's centre is performed with a straight-edge and scriber. A thin flexible straight-edge is used, and while in position it appears as in the Figure (982), being denoted by S. One edge of the tool is first put into close contact with the strap's inner plane surface, and it is there held by the operator or an assistant while the opposite end of it is bent sufficient to make it touch both brasses. A line is now marked upon the brasses by moving a scriber along the straight-edge, which line will indicate one of the gap's sides. In the Figure, on the left of the brasses, a dotted line is seen, which has been marked by placing the straight-edge as directed; and the tool is now shown situate at the opposite side, in position for scribing another line. When the two lines are scribed both sides of the gap are indicated; and the centre of the gap can now be easily shown by placing a compass-point to each line.

When a thin flexible straight-edge is not available, and the strap is not too heavy, the sides of the gap can be easily shown on the brasses by means of a parallel block or blocks on a lining-table. By this mode, the strap is held with its inner surface on the top of a block having a ledge extending into the gap of the strap. While resting on the block, the point of a scriber-block on the table is adjusted to the exact height of the strap's inner surfaces, and the two required lines showing the gap-sides, are scribed upon the brasses. These lines resemble those scribed by means of a straight-edge as before described. If a parallel block having a ledge is not accessible, two blocks may be selected, a thick one and a thin one, the thin one being put upon the top of the thick one, and the strap put above both.

As soon as the centre of the hole required in the brasses is shown, with regard to both the centre of the gap, and the length of the rod, a circle can be scribed showing the diameter to which the brasses are to be bored. Another circle also is usually marked, of larger diameter, and this is that which is used for adjusting the strap to be bored.

Boring of Strap-Brasses.—Strap-brasses are bored while they remain tightly keyed in their respective straps as when they were being lined. They may be bored either on an ordinary disc-chuck in a lathe, or on a table of a drilling-machine or boring-machine.

In order to cause the hole of a couple of brasses to be bored square to the length of their bar or connecting-rod as required, the smooth narrow sides or edges of the strap's arms are considered as standard planes which are to be put parallel with the face of the lathe-chuck, because these surfaces are parallel with the broad sides of the connecting-rod's end, and the lathe-chuck's face is square to the motion of the lathe-spindle which performs the boring. These surfaces cannot be put into direct contact with the chuck, because the flanges of the brasses project beyond, and because a space must exist between the chuck and the brasses, in which the boring-tool may disengage from the metal. To provide this space, parallel strips of proper thickness are placed between the chuck and the strap; or, instead of two separate strips, a single bent packing-piece similar to a letter U, may be used; but two separate strips are more useful for a great variety of straps of all sizes, because, when the two are to be used, they can be fixed on the chuck at the exact required distance from each other to suit the particular size of the strap in hand. Each parallel strip should be furnished with slots and small screws, with which it can be fastened at any part of the chuck.

As soon as a strap is put into contact with the parallel packing on the chuck, by the aid of an assistant, or with pulley-blocks above, it is partly fastened to the chuck with plates and poppets, and becomes ready for adjustment by the gauge-circle on the brasses. This is effected by gripping a tool-scriber or pointer in the tool-holder, and adjusting until the point is near the gauge-circle. The lathe-chuck and strap are next slowly rotated while the operator observes the point and the gauge-line; and the strap is gradually shifted with the poppet-screws until the circular line is seen to rotate exactly concentric with the path of the lathe-spindle, which condition is known by the pointer exactly coinciding with the path of the circle as it is moved slowly around.

After the strap is adjusted, it is finally fastened with additional holdfast plates, if its size requires them; and weights also are bolted to the chuck on the portion opposite the strap, in order to balance it properly during rotation. The boring next commences with a drill, if the hole is of comparative small diameter, and a great amount of metal is to be taken out; or with a borer similar to Fig. 431 if the hole is five or six inches in diameter. A borer similar to Fig. 435 is only employed for small holes which will not admit a thick strong tool like Fig. 431. The drill, or whatever tool is used, is held tight in the rest, and advanced through the hole with the usual long traverse belonging to the lathe, the traverses being repeated a proper number of times to obtain the desired diameter for the hole. It is next necessary to smoothly turn the flanges of the brasses, that they may be reduced to the proper thickness, and be parallel with the strap, and also square to the bored hole.

Some strap-brasses require the mouths of the holes to be curved instead of presenting sharp corners. The curved surface is necessary to fit a pin, spindle, or gudgeon that is curved at a corner, for the purpose of obtaining great strength with a comparative small amount of extra metal. The edges of the brasses are curved after the hole is bored to the finished diameter, and also after the flanges are turned to the proper thickness. For this curving a pointed corner tool should be first used, and the curve finally smoothed with a springy tool having a concave edge of proper curve.

Those strap-brasses that require but one mouth of each pair to be curved are, for boring, lined on that same side which is to be curved; this causes the lined side to be outwards while the strap is fixed on the chuck; so that the curving can be done at the first fixing, which avoids the necessity of again accurately adjusting the strap to the truly bored hole, after one side is turned and the strap is reversed. But when both mouths of the hole are to be curved, the strap must be adjusted to the hole after being reversed, in order to cause the surface of the curved corner to be concentric with the hole.

Oil-channels of Strap-brasses.—The making of oil-channels or gutters belonging to brasses is usually the last process to which they are subjected. In the middle or other convenient part of each brass is a round hole, which is connected with the lubricator; and when this has been drilled the channels can be formed to properly conduct the oil from the lubricator and distribute it over the surface of the pin which is to be in contact. To cause the oil to spread over a comparative great portion of the pin's bearing, instead of allowing it to be confined to a small part, the brass is furnished with a channel or groove similar to a cross. A groove of this shape is shown in Fig. 983, the middle of the cross being the drilled hole extending from the lubricator. Channels of this character have curved bottoms, and are cut with chisels which have curved convex cutting edges, a few inches of the chisel's end being also bent to a curved form, to make it suit the concave surface of the brass. The deepest parts of a channel are those that adjoin the round hole; and from the hole as a centre, each arm of the channel decreases in depth until it has none at all, each branch or arm terminating a short distance from an edge of the brass. Such oil-ways will effectually oil the entire friction surfaces, but will not greatly tend to waste the oil, by reason of the grooves not extending to the edges.

It is necessary for every oil-way to be smoothly formed, although it need not be straight, except for appearance. After a channel has been smoothly chipped it requires filing with round files having bent portions similar to those of the chisels. Such files can be used also for the final polishing; or, instead of a file, a piece of round wire can be employed, the polishing being done by using the tool as in filing, but with emery cloth wrapped around it.

When a uniform appearance is intended for an oil-way, the brass can be properly lined previous to chipping by means of a card. The card has a straight edge, and it is placed into the gap of the brass and pressed into contact until the card is bent enough to cause every part of its straight edge to touch the metal; it is at the same time inclined sufficient to indicate the oblique direction of the intended groove; and while properly held in position, a scriber is moved along the card to mark a line extending from the round hole. The card is next shifted and put into position for marking another line; and such marking is continued until the required number of lines are scribed.

The practice of filing the faces belonging to a couple of brasses, to provide a space between, should be avoided. Such openings should not be allowed, because they require packing-strips, without which the keying of the strap brings both brasses into forcible contact with the pin or gudgeon, and tends to heat and tear the friction surfaces while at work.

Boss-brasses.—Boss-brasses are those that fit the holes in the bosses of levers, side-rods, joint-rods, and a few classes of connecting-rods. Such bosses are represented by Figs. 890, 891, and a few others adjacent. The boss having an octangular hole, shown by Fig. 893, requires a couple of brasses each like Fig. 803.

Boss-brasses have no flanges, and are cast separately, in the manner of strap-brasses, each having a half-round gap formed at the time of casting, unless the hole is to be only about three-quarters, or an inch, in diameter; in which case no gap is formed at casting, but the entire hole is formed by boring. In order to cause the gaps in a couple of boss-brasses to be of equal depth, it is advisable to place length-marks upon both faces of the boss, similar to the marks described for straps.

Boss-brasses should be fitted to their respective holes in about the same manner as brasses for straps, one of a pair being first made to properly bear on one end of the hole, and the superfluous metal next removed which extends beyond the length-marks on the boss-faces. The fellow-brass can now be fitted to the opposite part of the hole, while the first one remains out; after which both brasses should be fitted together, both being driven together several times into the boss by hammering them with a tin hammer or wood blocks, which will mark the places of contact, and thus indicate the prominent portions to be removed.

A pair of boss-brasses cannot be properly fitted to their hole unless it is taper, as directed in page 294. It should also have straight sides, or sides which are rather concave, but not to any extent convex; a convex form prevents the brasses bearing at the small end of the hole, however tight they may fit at the large end. After each pair of brasses are made to tightly fit their boss, the superfluous metal which extends beyond both faces of the boss is taken off, and the two ends of the brasses are thus made plane, and made to exactly coincide or be level with the boss-faces; therefore when a pair of brasses are fitted, their length is the same as the distance through the hole in the boss.

When a pair of brasses are fitted tight in their boss, and a wood-ender fitted in, they are ready for lining, to cause the hole to be properly bored; and the two surfaces or faces of the brasses which touch each other will indicate the place for the centre of the required hole with regard to the length of the rod or bar, supposing that the length-marks are properly situated on the boss, and have been attended to during fitting. It is next necessary to indicate the centre with regard to the sides of the hole in the boss, that the lining may cause the hole to be bored so that the metal shall be of equal thickness at either side. To show this centre-point between the hole's sides, a straight-edge is used in a mode somewhat resembling that for showing the centre of a strap-gap. But on a boss the straight-edge is laid flat, no bending being necessary. One edge is put to exactly coincide with one side of the brasses, which is the same as one side of the boss-hole, if the brasses fit properly and no spaces are seen. A line is now scribed along the opposite edge of the straight-edge, which will be near the centre; when this is scribed, the straight-edge is put to the opposite side and another line marked; a middle line between these two is the centre line required, and the point in this line which is intersected by the line connecting the length-marks on the face, is the required centre for boring the hole. A circle is therefore scribed from this point to show the desired diameter of the hole, and another larger circle is marked to be used while adjusting the boss to be bored, in a mode similar to that described for strap-brasses.

The middle of the boss-hole can be shown also with compasses, if the brasses fit accurately to the edges of the hole, in which case the points of the compasses are extended until the distance between is a trifle greater than half way across the width of the hole; one point is then put into the place where the brass touches the boss, while the other point is put to about the centre and an arc scribed. The compasses is next shifted to the opposite side, to scribe another arc, the mid-point between the two being the centre required.

Boring of Boss-brasses.—A couple of brasses which are tightly fixed in their boss can be bored either while they yet remain in the boss, or after they have been removed and again fastened together by some means. If they are to be bored while in their boss, the key-way and key are partly fitted that there may not be any risk of the brasses shifting while being bored. The boring of such is executed with a boring-machine or driller, and the holes are easily bored square to the lengths of the rods, as required, by adjusting the lengths of the rods to parallelism with the drilling-table. If brasses are bored in this manner, considerable care, good boring-rods, and good cutters are requisite to produce smoothly-formed parallel holes of the exact diameters required, and to properly curve the edges of the holes' entrances. When a number of brasses are to be bored to the same diameter, the boring can be completed with a good rosebit.

If a number of boss-brasses of several sizes are to be bored, a lathe should be used. A lathe will easily produce any exact diameters required for any number of holes, by using the ordinary slide-rest boring-tools, although the brasses cannot be so firmly held while on a lathe as while tight in their rod on a drilling-machine.

After a pair of brasses have been exactly fitted into their boss, and the circular lines for boring also correctly placed while in the boss, the brasses must be driven out and fastened together again, if a lathe is to be used for boring, and must be so fixed together that they shall be while out of their boss as near as possible in the same relative position to each other as when in the boss. To facilitate this refixing accurately together, a couple of cross-lines are scribed upon the ends of the brasses, which surfaces are plane and level with the boss-face, as before directed. This scribing is done while the brasses are tight in their places; the lines should be thin and well defined, that they may be easily referred to afterwards when being fixed together. The brasses are next driven out and fastened together with clamp-plates and screw-bolts, either two or four plates being used, according to the size of the brasses. When bolted together, they are gradually shifted into the proper positions by hammering them with wood blocks. To effect this, two things must be referred to; these are, the cross-lines which were marked while the brasses were in their rod or bar, and the plane smooth surfaces termed the ends of the brasses. They are therefore adjusted while on a surface-table, one smooth end being in contact with the surface, and the other end, on which the gauge-lines are scribed, being upwards. In this position they require hammering downwards to keep the bottom ends in close contact with the table, and they require hammering sideways to adjust the brasses until the cross-lines are seen to coincide as when they were first marked.

As soon as the cross-lines are put right, the circular lines also are by the same act put into order, and the brasses are ready for being fixed on a lathe-chuck to be bored. This is effected with a thin boring-tool, if the hole is small, and with a strong corner-tool if the hole is large. Care is necessary during boring to avoid shifting the brasses, because they cannot be bolted together very tightly without squeezing them out of shape, and because the faces of the brasses in contact are but small; consequently but little adhesion can be expected. These faces must be thoroughly clean, and not be in any case convex, but may be slightly concave, to prevent slipping; they may also be dusted with flour emery previous to fixing them together.

While the brasses are attached to the lathe in position for boring, they are held on a couple of parallel strips, or on a parallel ring, to provide a space for the tool's end, and also to cause the hole to be bored square to the ends of the brasses, and, consequently, square to the two faces of the boss belonging to the rod. The ends of the brasses are the only surfaces that can be referred to for obtaining the desired right-angular position with the lathe-chuck; therefore great care must have been previously exercised, during the fitting, to make the faces of the rod-boss parallel with the length of the rod, and to make the ends of the brasses parallel with the boss-faces.

Oil channels in the brasses just treated are similar in shape, and made by the same means as are adopted for the channels of strap-brasses; the round holes constituting the naves of the crosses, being either in the middles or sides, according to whether the connecting-bars or rods are to work with their lengths horizontal or vertical.

THE VARIETIES OF GLANDS, PACKING-BOXES, AND OTHER PACKING APPARATUS.

Packing-glands.—A packing-gland is a sort of flanged tube, which so fits a slide-valve rod or a piston rod that it can be easily slid along the rod. Glands are made of either gun-metal or cast-iron, and are employed to squeeze the packing tight around their respective rods, and to maintain it in this condition during the to-and-fro motion of the rods while at work; by which means a steam-tight joint or a water-tight joint is secured. The packing is a pliable material, consisting of hemp or india-rubber; and it is this which grips the rod, but not the gland, which is always loose. The simplest mode of using packing consists in placing it between the extremity or bottom of a gland and the bottom of the packing-box, nothing being put between the packing and the bottom of the box.

In Plate 80 several classes of packing-glands and other packing apparatus are represented. The simplest class of glands are those denoted by Fig. 984; these are used for small engines, pumps, and other machines having rods not more than about an inch in diameter. The flange portion of the gland is hexagonal, and fits a spanner, by means of which it is screwed into its place in contact with the packing. The portion which is screwed is named the stem, and in Fig. 985 the extremity of the stem is shown, which is the surface to be in close contact with the packing. The gland denoted by Fig. 986 is employed for both small rods and large ones. This is furnished with an oblong flange having a hole at each end. These holes admit two studs, which are the means of squeezing the packing around the rod, instead of screwing the gland in with a spanner on the flange. The stem and dish-shaped extremity of the gland is shown by Fig. 987, which is analogous to that seen in Fig. 985, and acts in the same manner. A circular flange is sometimes adopted, instead of an oblong one, as indicated in Fig. 988; such being furnished with three or four holes for the packing-studs.

All flanges of glands should be curved at their corners or junctions with their stems, to obtain strength without making the flanges too thick. A curved corner of this shape is shown in Fig. 989.

The glands denoted by Figs. 985, 987, and 988, are situated in their packing-boxes in the positions denoted in Figs. 990, 991, and 998. The packing-box is a tubular portion that extends from the cylinder-lid, or other lid, and is cast solid with it. In the bottom of the box is a hole to admit the piston-rod, and above is a larger space, the diameter of which is about the same as that of the stem belonging to the gland. In this space is situate the packing wrapped around the rod, the dish-end of the stem being in contact. If a screwed gland like Fig. 985 is to be used, the hole in the packing-box is screwed to fit; but nearly all glands for rods an inch in diameter, or larger, are provided with plain cylindrical stems; and are consequently forced into their packing-boxes by means of screw studs. A gland with two studs is shown by Fig. 991, the studs being screwed tight in the flange of the packing-box, and of suitable length to allow them to extend a short distance beyond the flange at the time the stem enters the mouth of the box.

Fig. 998 represents a mode of forcing the gland into the box by means of loop-bolts instead of studs. In this arrangement a flange solid with the box similar to that of the gland is not admissible, room being required for the bolts. The loops of the bolts are connected by being placed upon short studs extending from the box; or they may be connected by short screw-bolts having plain parts adjoining the heads to fit the loop-holes, and having short screwed ends to screw into the packing-box. To obtain a proper amount of metal around these bolt-screws a couple of small bosses may be cast solid with the box similar to that shown in Fig. 999.

In Fig. 998, the situation of a rod in the gland and packing-box is also shown, being indicated by dotted lines. A packing-bush or garnisher, is also shown by dotted lines. This is of gun-metal, and situate at the bottom of the box and around the rod, the flange of the bush being in contact with the bottom and its stem extending through the hole. By this means the india-rubber or other packing is prevented from touching the bottom, and is caused to rest on the flange of the garnisher, a surface of gun-metal being thus provided for the friction surface of the rod, because the stem of the bush fits the hole in the bottom, which hole is larger in diameter than that of the rod. The diameter of the flange of a packing-bush is the same as the diameter of the stem belonging to the gland, both being made to loosely fit the hole in the box.

Figs. 996 and 997 are comparative large sketches of a gland-stem and its accompanying bush, the bush being shown by Fig. 997. In each Figure the dished or cup-shaped extremity is shown, by which it may be seen that the thin rims of metal around the dishes are of suitable shape to be wedged between the packing and the sides of the packing-box; consequently, when the gland is forced upon the packing, it is not only squeezed together, but also, to some extent, wedged away from the side of the box, and into close contact with the rod, by which the desired steam-tight joint, or water-tight joint is obtained.

For some varieties of very small rods, glands are made without any cup-shaped ends, the extremities which bear upon the packing, being flat and square to the stems. These flat surfaces require a comparative great amount of forcing with the gland-nuts, or with the six-sided flanges, and therefore involve a large amount of squeezing together of the packing to obtain the necessary grip around the rod; consequently, glands having flat bottoms are never used for rods which are more than about half an inch in diameter.

Notched Glands.—A notched or grooved gland is one having a number of notches formed in its outer flange or belt, which is circular. This class are represented by Figs. 992 and 993. These are caused to operate upon the packing by means of the notches into which the end of a hook-spanner is placed when adjustment of the gland is to be effected. Notched glands resemble hexagonal ones in sometimes having stems which are screwed outside to fit the screwed holes of the packing-boxes. The one shown by Fig 992 has a stem of this sort; but the one denoted by Fig. 993 is screwed inside its stem, and the screw therefore fits the outside of the packing-box. A gland of this shape is shown connected with its cylinder-lid in Fig. 995.

The hook-spanners, with which notched glands are adjusted, are represented by Fig. 1002; and in Fig. 1003 a spanner of this shape is shown in position for advancing a gland upon its box.

Notched glands are used in conjunction with packing-bushes which operate like those of other glands. If the gland has the outside of its stem screwed, it requires but one bush, which is situated at the bottom of the box and is of the same shape as the one seen in Fig. 998. But a gland like the one in Fig. 995, requires an additional bush. This is necessary because the screwed hole of the gland is furnished with a flat bottom, which surface communicates the pressure to the packing in the box, and because this flat surface is always outside of the box. Therefore, to apply the pressure to the packing, a bush is put into the hole of the box, the outer end of the bush bearing against the bottom of the hole in the gland, while the inner end of the bush is in the box and squeezing the packing This inner end is therefore dished to properly grip the india-rubber, and acts in about the same manner as the dished end of any other gland.

GLAND-RESERVOIRS.—A gland-reservoir is also termed a gland oil-cup. Almost every gland, small and large, is furnished with an oil-vessel of some kind, the simplest of which consists of merely a concave space or dish formed in the flange. Such spaces are shown in the flanges of the glands denoted by Figs. 984, 986, 988, 990, 991, and 998. If the gland is large, the dish is formed to nearly its finished dimensions at the time of casting; but the dishes of small ones are entirely formed by lathe-turning. An oil-cup of this shape is only suitable for a gland which is to be vertical while in use, in which the dish will be horizontal, and therefore will hold the oil or tallow put therein.

Those glands which are to be horizontal, have no dishes in their flanges; but the flanges are furnished with oil-cups and oil-holes that convey oil either from the cups which are cast solid with the flanges, or from small supply pipes connected to lubricators at some convenient distances from the glands. This mode of lubrication is also adopted for inverted vertical engines, whose rods are below and the cylinders and slide-valves are above.

The oil-cups belonging to the glands shown by Figs. 992, 993, and 994, are suitable for nearly all classes of engines and pumps, whether vertical, horizontal, or oscillating, except inverted vertical engines with piston-rods beneath, as mentioned in the preceding paragraph. These cups constitute convex projections extending beyond the flanges of the glands and cast solid with them. In the interior of each projection, a roomy recess or chamber is formed, the diameter of which is two or three times the diameter of the piston-rod or slide-rod. In this chamber the oil or tallow is put, and is not very liable to be spilled about, although the gland may belong to an oscillating cylinder, and the oil is retained in the cup by reason of the comparative small hole at the extremity of the cup-portion.

A small gland that may be for a rod only about an inch in diameter, is so cast that the convex projection is a solid lump without any chamber therein; the space is therefore entirely formed by means of lathe-boring. But the oil-chambers of large glands are formed at the time of casting. By this means, all subsequent shaping by boring is avoided, because no polishing of such a recess is necessary. Therefore the small quantity of shaping which is executed after casting, consists in merely clearing out the sand, and breaking off any partly detached pieces that may be formed in the recess at the time of casting.

WORM-WHEEL GLANDS.—A worm-wheel gland is one that has an oblong flange similar to that in Fig. 991, and it has also a pair of screw-studs, similar in shape to the studs of other glands; the stem also of the gland is straight, and it is forced upon the packing in the packing-box in the usual manner. But the means adopted for applying the power to the screw-studs, differs from the ordinary hexagonal nuts and spanner, instead of which a couple of worm-wheels and a spindle are employed.

Worm-wheel glands are indicated by Fig. 1004. By referring to this sketch it will be seen that the screw-studs are fixed to the flange of the packing-box, in about the same manner as the studs of other glands; and that the upper ends of the studs pass through holes in the flange of the gland, the same as if hexagon nuts were to be placed thereon. But in the places usually occupied by such nuts, are placed a pair of worm-wheels having screwed holes in the bosses. These wheels may be termed a species of broad screw-nuts having worm-teeth on their rims instead of six planes. Both the wheels are rotated at one time by means of a worm-pinion or worm, engaged with the teeth of each wheel, both of these pinions being rotated at once because both are fastened on one spindle. The spindle is denoted by S, and has a square part at each end which fits the hole of a socket tee-spanner, such being used to effect the rotation.

By thus screwing down both the wheels at once, both ends of the gland-flange are forced down an equal distance with one rotation by the spanner; consequently the studs are not liable to be bent and broken, nor the flange bent or broken, which is liable to occur when only one end of a gland is operated upon at one time. The action of these glands is therefore the same as that of glands having six-sided flanges, or having notched flanges, similar to Figs. 984, 992, 993, and 995. But worm-wheel glands are more complicated by reason of the greater number of parts. It is therefore advisable to avoid using them whenever notched glands can be employed.

Those glands which have oil-cups connected to the flanges, and intended for vertical inverted engines, are represented by Fig. 1005. Such oil-cups are either cast solid with the flanges, or are cast separately and attached with small screws. The cup may have a lid and be connected with one side of the flange, as seen in the Figure, or it may be attached at one end, according to convenience. Oil-cups of this sort are supplied with oil by means of pipes of proper length, and having funnels at the ends, to allow oil to be given at any time, although the gland may be quite inaccessible to the engineer.

Fig. 1006 represents one of the author's arrangements for inverted engines, which is available whenever the space around the packing-box will admit the free use of a spanner. By this mode two headed bolts are employed instead of two studs, the heads being beneath in contact with the gland-flange, and the nuts above situate on the flange of the packing-box. Through the nuts being thus located, their rotation with a spanner is much easier than if they were beneath in the places occupied by the bolt-heads.

GENERAL TREATMENT OF GLANDS AND PACKING-APPARATUS.

Hexagonal Glands.—Nearly all small glands which have six-sided flanges, are made of cast gun-metal. When a considerable number have been cast, and are ready for the lathe-process, all the comparative large ones, if they happen to be cast without any hole, should be first drilled with a drilling-machine to somewhat near their intended diameters; this being a much quicker mode of roughly boring out a large amount of metal, than drilling it out with a lathe.

When the holes of glands have been partly formed, either at the time of casting, or with a drilling afterwards, each one requires to be bored on a lathe-chuck, which boring is necessary to properly smooth the hole to suit the diameter of the slide-rod or piston-rod, and to cause the hole to be nearly concentric with the outer rough surface. All the glands are thus bored previous to smoothly shaping their outsides to the exact dimensions intended, in order that unnecessary alteration of the lathe-apparatus may be avoided.

The mode in which a small gland is held in order to be bored, is depicted by Fig. 1007, and consists in gripping it in a cup-chuck having three or four screws. During the fixing of a piece in this manner, the entire outer surface is caused to rotate truly, supposing that the whole of the surface is to be equally reduced to obtain the finished dimensions. But when it is known that some stated part has but a comparative small quantity to be cut off, this part is caused to rotate truly without regard to the other portions; which treatment is analogous to that described for the adjustment of articles to be planed or shaped.

After the gland is tightly fixed, the boring can be entirely executed with a drill. This is a very good tool for boring a small gun-metal object, although it may be without any hole; in which case a drill of proper size can be selected to both originate the hole and afterwards enlarge it to the exact diameter. The drill is held in the slide-rest in the same manner as a boring-tool; and it will be found that, however small the required hole may be, a drill having a properly shaped end can be easily provided and used; whereas an ordinary slide-rest tool requires a comparative tedious shaping, and when made, it is only suitable to enlarge a hole which has been previously commenced.

The oil-dish of a gland is first roughly shaped to very near the ultimate depth and width, by means of a corner-tool; and the same tool is also used to turn the front surface or top of the flange while the gland yet remains in the cup-chuck. But it is not always requisite to turn this surface until the gland's entire outside is to be turned; although it is imperative to complete the oil-dish at the first fixing when the hole is bored, because it is conveniently placed to admit a tool-point to the bottom of the dish adjoining the hole. A dish or recess of this class is smoothly finished with a hand-tool which has a convex cutting-edge of suitable curve.

A gland which is large enough to require a dish in the end of the stem, to facilitate the squeezing of the packing around the rod, requires the top-surface of the flange to be truly turned at the fixing for boring the hole, because this surface is to be put into direct contact with the lathe-chuck or parallel blocks thereon, in order to be fixed with the stem outwards, that the required dish may be easily formed. A gland held in this position is depicted by Fig. 1008.

Turning the outsides of small glands is performed by means of arbors; and also, in some cases, by means of the slide-rods and piston-rods to which the glands belong. If a set of glands, bushes, and their rods are to be turned in one lathe, all the glands and bushes are first bored and dished at one operation. The lathe is next put into order for turning the rod or rods. These can now be wholly turned to near the finished diameters, and a short portion at one end of a rod can be smoothly reduced to tightly and accurately fit all the holes in the glands and bushes. When this end is reduced to the proper size, it is driven into the glands with a tin hammer, and all are successively turned while on the end of the rod, which constitutes a spindle that causes each gland or bush to rotate truly concentric with its smoothly finished hole. To allow a rod's end to be thus used for several holes, it is requisite for them to have been previously bored carefully to one diameter; and it is also requisite for the rods to be finished after the glands and bushes are finished.

In many cases, slide-rods and piston-rods are completely turned to their finished diameters previous to commencing their glands; consequently, such rods cannot be used as spindles for turning the glands. It is therefore necessary to provide a distinct arbor for this purpose, because after the rods are finished the glands are so bored as to slide loosely along their rods, and therefore cannot be held tight thereon for turning.

Fig. 1009 denotes a gland on an arbor or temporary spindle, on which it is tightly hammered, and can now be put on to the lathe-pivots and have its stem turned and screwed; also both sides of its flange turned, if required.

Turning of Circular Glands.—Those glands with circular flanges or oblong ones, are usually much larger than those having hexagonal flanges, and therefore need a somewhat different treatment.

A large gland, or a large packing-bush, should be bored and entirely turned without using any arbor or spindle for turning the outside, the entire outer surface being turned while the article is fastened to the lathe-chuck. By this means, the lifting and moving of a heavy slide-rod, piston-rod, or arbor, is avoided, and therefore the fitting, fixing, and unfixing of an arbor to the glands and bushes, is also avoided.

Large glands frequently consist of cast iron, and are furnished with friction bushes of gun-metal. Such a gland is bored so that the hole is larger in diameter than the diameter of its rod, that a bush of proper thickness may be put into the hole and remain between the cast-iron and the piston-rod or other rod. The bush or tube is turned to cause its outside to tightly fit the hole in the gland, and may be bored to fit the rod either before it is put into the gland, or afterwards.

A gland which is provided with a bush, and is truly made, can be easily repaired when the hole has become worn too large, at which time the old bush can be taken out, and a new one put in, without in any way altering the hole in the gland. It is therefore proper to accurately form the outside of the gland concentric with the hole, at the first making.

The form to which the hole of a gland should be bored for a bush, is depicted in Fig. 1010, in which the shape of the hole is indicated by dotted lines. It will be observed that the mouth of the hole in the outer end of the stem is furnished with a recess which is of greater diameter than the remainder of the hole. Such a form will allow one end of the bush to be rather larger in diameter than the other end, and when the bush is in the hole, the larger part will be a sort of head which fits the mouth of the gland-hole and prevents further shifting of the bush. During the use of the gland, its stem will be forced upon the packing, and therefore the pressure will merely tend to tighten the bush in its place.

The shape of a gland-bush is depicted by Fig. 1011. It may be here stated that a bush of this form may be used in two ways. It may be turned so that its head or flange is but little larger in diameter than the remainder, and be suitable for the hole shown in Fig. 1010; or the bush may be turned so that the diameter of its large end is equal to the diameter of the gland-stem. If thus shaped, the hole in the gland is parallel, and the entire flange or head of the bush will therefore remain outside the gland and in contact with the bottom.

In order to turn a bush to fit the gland, it is put upon an arbor without boring the hole, the arbor being made to tightly fit the rough hole, and when together appearing as in Fig. 1012. But when it happens that the hole is not cast concentric with the outside, and there is not much superfluous metal to remove, it can be first bored in a cup-chuck, while the outer surface rotates truly, and next turned while on an arbor, to complete the shaping.

A bush having its hole not true with the outside can also be turned by means of a middle-bolt or centre-bolt. This is a screw-bolt and nut attached to the lathe-spindle with a key at one end, and having a nut and washers at the other end to bear upon the bush and hold it to the chuck while being turned. In Fig. 1015 a centre-bolt is seen in use; but in this Figure the bolt is employed to force a bush into its hole. If a bush is thus held tight to a parallel ring on the chuck, the outside can be easily adjusted true, after which a few poppets can be placed, if the bush is large, to grip the large end while the stem is being reduced. The middle-bolt requires ample space around it, to allow the object to be easily shifted to the exact place desired; consequently it may be necessary to first enlarge the hole to a convenient size with a drilling-machine previous to fixing it to a lathe.

In order to prepare a large gland for its bush, it may be firmly held to a disc-chuck, as represented in Fig. 1013. It will be seen that the flange is in contact with a pair of parallel blocks, and that the object is held to the chuck with a couple of plates and bolts. These are the first fastenings, and hold the gland a short time till other plates are fixed, and poppets are put to the edge of the flange. At this fixing it is necessary to turn the outer surface of the stem, in addition to boring the hole for the bush. This will cause the hole to be concentric with the outside, and will also provide a true surface by which the article can be again truly adjusted on the chuck a second time.

The second fixing of the gland is necessary after its bush has been fitted and driven in, when it is again put to the chuck for boring the hole in the bush, unless the bush was before accurately bored and has been turned while on an arbor, in which case the gland is fixed to the chuck to have the dish shaped. In order that the gland may be quickly adjusted the second time, it is necessary to bore and turn the entire stem, at the first fixing, to its finished diameter and length; the dish which is to grip the packing should also be roughly shaped, and the surface or shoulder of the flange adjoining the stem is also to be turned; this is done by means of a centre-bolt and small poppets whose screw-points bite the edge of the flange, as seen in Fig. 1014. This arrangement allows the flange to be entirely free from plates, and therefore can be entirely turned.

When the gland-stem has been finished, and the hole properly shaped for the bush, the gland may be removed from the chuck and the bush put into its place. The gland is next fixed to the chuck the second time in the same position as before, and the dish in the end of the stem is now smoothly finished to the desired shape, the superfluous end of the bush being cut off until it exactly coincides with the cast iron, supposing that the bush is without any flange projecting outside the bottom of the stem; but if it is furnished with such a flange, the entire dish is contained therein, and it must therefore be thick enough to admit a dish of proper depth.

In many cases this second fixing of glands can be avoided. To do this, it is necessary to have the bush turned previous to finishing the boring of the gland; and while the gland yet remains fixed on the chuck the bush must be forced into its place. To effect this easily, it is carefully turned to the proper size by accurate measurements, and is put into the hole by using a middle-bolt. A bolt in use for this purpose is indicated in Fig. 1015, and is of sufficient length to reach from the lathe-spindle to the outer end of the bush when it is entered about half way into the hole, which is the condition of the bush in the Figure. On the outer end of it is situated a plate having a hole in the middle, through which the end of the bolt extends to receive a nut. The nut bears upon the plate, or perhaps upon one or two washers, and the plate bears upon the bush ; therefore, by screwing the nut with a spanner the bush can be slowly squeezed into the gland with but very little hammering, if it is not too large. Hammering should be avoided as far as possible, because it shifts the object on the chuck ; and the small quantity of hammering that may be required should be applied to the plate which is in contact with the bush, and given every time the nut is advanced a short distance by the spanner.

The last fixing of the gland to the chuck is performed after the stem is finished, and the bush also finished ; and this fixing is necessary for turning the outer or top surface of the flange, and the oil-cup or dish, also whatever ornamental ridge may exist on the flange. This turning is done while the object is held with its stem tight against the chuck, as seen in Fig. 1016, if comparative large and long poppets are accessible, and the object is not large or consists of soft metal. But in some cases it is preferable to put the gland with its stem into a parallel ring, as seen in Fig. 1017, the ring being of sufficient length to cause the flange of the gland to bear upon one flat face of the ring without allowing the bottom of the gland-stem to touch the chuck. Instead of a ring, parallel blocks of proper height should be used for large glands ; and this mode of fixing firmly holds the object, because the broad surface of the flange is in direct contact with the parallel blocks. The middle-bolt shown in the Figure keeps the gland and blocks tight to the chuck, while three or four poppets are fixed to bite the stem, as in Fig. 1016. The object is therefore in position to have the rim entirely turned, and also a part of the front surface adjoining the dish ; after this is finished, holdfast plates are fixed upon the flange, and the centre-bolt with its attachments are removed, which allows the dish and ornamental ridge to be turned true with the rim, because the gland has not been shifted, although the centre-bolt has been taken out.

A very convenient mode of turning the flanges of small glands, and other articles of similar shapes, consists in first boring and turning their stems, and next driving them into a wood chuck with the flanges outwards, the hole in the chuck being truly turned to tightly fit the stems, after it is finally adjusted and bolted to the disc-chuck. A wood-chuck fastened to a disc-chuck in this manner is denoted by Fig. 1018, and a gland is shown in the hole ready for turning, no poppets or plates and bolts being required.

Packing-bushes.—The most usual class of packing-bushes are those like the one seen in the packing-box of Fig. 998, or like the larger Figure 997. Small bushes of this form are easily bored in a cup-chuck in the same manner as small glands, and are afterwards completed by turning the outsides while on an arbor. But large packing-bushes are finished on the chuck, and are treated in about the same manner as glands that do not require to be bushed. The bottoms or extremities of the stems belonging to packing-bushes are flat, no dish being required, through not being intended for contact with the packing. Two fixings in the lathe are sufficient to completely turn a bush of this sort, the dish-part and rim being turned at the first fixing, and the stem and one side of the flange at the second.

The bushes represented by Fig. 1019 are those employed for the glands shown in Figs. 995 and 1003. The stem of the bush is furnished with a dish, because this end is to bear upon the packing. The flange is a thin portion which prevents the bush being forced below the mouth of the packing-box, and is also a means of removing the bush when it may stick in the hole.

Packing-bushes of this class are seldom used for rods which are more than an inch and a half or two inches in diameter. Consequently, they are easily turned, either while on their respective rods, previous to the rods being finally reduced, or while on arbors which are fitted to them for the purpose.

Shaping of Notched Glands.—Glands having grooved flanges are usually lathe-turned in conjunction with the turning of the cylinder-lids, or valve-box lids, to which the glands belong.

A gland intended to have a screw on the outside of its stem is first bored in a cup-chuck, as denoted by Fig. 1020, the stem being gripped with the screws. This allows the hole to be finished, and the oil-reservoir to be also finished at the one fixing. While the gland is thus held the front surface or shoulder of the flange or belt should be also truly turned, to provide a surface at right-angles to the length of the hole, which surface will be required for the next fixing of the gland. It can therefore be next removed, and is ready to be placed upon a parallel ring, as indicated in Fig. 1021, in order that the end of the stem may be dished for the packing, the surface of the flange before turned being now in contact with the ring.

When the packing-dish is finished the article is now ready for being completed on an arbor, to have its stem screwed, and the entire outer surface finished, which completes the shaping, with the exception of forming the notches. A number of small glands can be rapidly shaped in this manner, if all are first bored, and their dishes formed, previous to screwing the outsides while on an arbor; but it should be mentioned, that if the holes for the piston-rods or slide-rods are comparatively short, the glands cannot be caused to hold tight on their respective arbors, through the small amount of surface in contact. Consequently, it is preferable, when convenient, to first grip the gland by its flange with the stem outwards, as shown in Fig. 1022. In this position it can have its hole bored, the packing-dish formed, the stem screwed, and the shoulder adjoining the stem turned, by the one fixing. This prepares the gland for being screwed into its packing-box, as soon as this is ready. If the cylinder-lid, or other lid, has not yet been screwed, it is therefore now fixed to the chuck, and the hole screwed to fit the gland-stem. The gland is next screwed into its place with a ring between the mouth of the box and the flange of the gland, as indicated in Fig. 1023. While thus fixed, the oil-reservoir can be made, and the turning of the flange and dome-portion completed. By this plan of screwing such a gland, no arbor is required, and therefore no risk of shifting is incurred while turning.

The notches on a gland-flange are easily made, either while the gland is on an arbor on the pivots, or while it is screwed tight in its packing-box, at the time the lid or other object is fixed on the chuck as it was during turning. The number of notches in a flange are usually nine, eleven, or thirteen, according to its diameter. To remove the metal a slotted grooving tool, similar to Fig. 457, is used, and it is held in the slide-rest in the same manner as a tool for boring the hole. But the grooving-tool is placed in front of the flange-portion, as denoted in Fig. 1024, a small cutter being keyed in the slot. If the notches are to be only about a quarter of an inch in width, one cutter is sufficient, its width being equal to that of the groove required. Wide grooves are formed first with a comparative small cutter, and finished with a larger one. The operation of the tool consists in advancing it gradually into the flange and moving it to and fro with the slide-rest in the manner described for fluting hobs, in the chapter on tool-making, with the difference of the article being grooved while on a packing-box fastened to the chuck, instead of being on the lathe-pivots.

Notched glands intended to have screws in the holes of their stems are always finished while on their respective packing-boxes, because the holes for the rods are always too short to allow such glands to be tight on an arbor. Each one is therefore first held in a cup-chuck, that the screw may be formed in the hole. At this fixing the bottom of the screwed hole is also nicely flattened, because it is to bear upon the flange of the packing-bush (Fig. 1019). A short chamber or recess should be also smoothly shaped at the inner end of the screw. This chamber is shown by the dotted lines in Fig. 1025, its diameter being a little greater than the greatest diameter of the screw. Such a space allows the points of the screw-tool a free disengagement from the metal at the conclusion of each advancement of the tool; it also prevents the tool breaking, and causes the screwing to be effected in much less time than is required if done without a chamber. This space also allows the gland to be easily screwed upon the packing-box the full distance required without trouble.

When the gland has been screwed, and the chamber at the bottom smoothly finished, it is ready to be screwed upon the packing-box, as soon as the object having the box is attached to a chuck and the screw formed on the outside. While thus held in its place, the whole of the gland's outer surface can be turned, its oil-chamber formed, and its notches made, as before described for a gland with the outside of its stem screwed, instead of its inside.

Boring-tools.—It is proper to here describe the sorts of tools required for shaping the objects just mentioned, or for shaping any other objects of similar shapes. The student will perceive that the same tools are available for operating upon any other articles, in addition to the glands and bushes just treated, if the forms of the articles resemble those specially referred to, or resemble portions of them.

The drill which is required for executing the entire boring of a small hole is shown by Fig. 1026. This has a square stalk which is held in the tool-holder in the same manner as any other slide-rest tool. The cutting part of the drill is always less in diameter, than the finished diameter of the desired hole; consequently, after the drill has made a hole which is of the same diameter as its cutting part, the operator shifts the drill a short distance towards himself, by working the slide-rest screw. He next again advances the drill through the hole, and thus increases its diameter. The drill travels in the same manner, and acts in the same way as a borer, being advanced with the lathe-carriage which is caused to traved by the usual long traverse of the lathe.

The tool shown by Fig. 1027 is a hand-tool, and is employed for smoothing the curved surfaces of the dishes, and is applied after a pointed slide-rest tool has roughly removed the metal to nearly the finished dimensions.

When a hand-tool is used in conjunction with a slide-rest, it is supported on a stalk or branch, similar to Fig. 1028, 1029, or 1030. One of these is fixed in the tool-holder by gripping the straight part and the branch is advanced to that portion of the object which is to be treated with the hand-tool. The hand-turning is then executed by holding the tool on the branch in about the same way it would be held on the tee-piece of a hand-rest. It may, therefore, be seen that the use of a branch in a slide-rest, avoids the necessity of placing a hand-rest and tee-piece into the requisite situations; and also that a small amount of hand turning can be easily performed without fixing any apparatus except the branch. These stalks or branches are also termed dummies.

Fig. 1032 represents a boring-tool for shaping a hole having a flat bottom, such as that of a gland with the inside of its stem screwed. The point of the tool is the most prominent portion when fixed in the tool holder; therefore the shape of the end allows it to both bore the hole and flatten the bottom. After the bottom of such a piece is finished, the tool shown by Fig. 1033 may be required. This is a grooving tool having a bent end for grooving the bottom of a gland hole previous to being screwed. A space of this sort was mentioned as being necessary to facilitate the screwing, and can be formed with the tool shown, because its cutting part is the most prominent part, and will therefore cut at the extreme inner end or corner of the hole, without coming into contact with the bottom surface, which is already smoothly finished.

A screw-tool which is suitable for screwing the outside of a gland-stem, is denoted by Fig. 1034. This has only one point, and is fixed in the position of a boring tool in the slide-rest, when required for use; but with the cutting end outside and in front of the object, instead of in the hole, the stalk of the tool being gripped in the front side of the tool-holder in the place occupied by the dummy in Fig. 1031.

To allow the end of a screw-tool to easily disengage from the metal at that end of the screw adjoining the flange of a gland, or a similar shoulder of some other object, a groove having a curved bottom is formed close to the shoulder, into which the screw-tool enters, previous to being removed out from the object being screwed. Such grooves are represented in Fig. 1036, and are made with a tool resembling Fig. 1035 previous to beginning the screwing.

A screw-tool for screwing the inside of a gland-stem or other hole, is denoted by Fig. 1037. This also has but one tooth, and the end is bent the opposite way to that of an end belonging to an outside screw-tool. These tools are very efficient for commencing and finishing the screws of gun-metal objects, and especially the screws of glands, because they are furnished with fine or shallow threads. In conjunction with such screw-tools, steel hobs are sometimes employed. When a hob is to be used, the screwing with the wheels is continued until the screw is very near the size, when the finishing hob is screwed in with a spanner while the object yet remains in the chuck. Any desired number of glands or other objects can be thus screwed so that all their screws shall be alike, and no measurement will be required at the conclusion of screwing. A gauge-hob of this class is denoted by Fig. 1038, and should be used also for finishing the inside screws of packing boxes.

A rapid mode of screwing small holes of gun-metal objects consists in commencing the screws with hand-tools, a quick speed being adopted instead of a slow one, a slow speed being necessary when the usual screwing-wheels are used. As soon as the screw is ready for the hob, it is screwed in, and the hole is about as correctly finished as if it were screwed with wheels.

If a number of small stems require screwing on their outsides, they all can be commenced with hand-screwing, and accurately completed to one diameter by means of die-nuts, the uses of of these being analogous to the uses of hobs for finishing holes.

Treatment of Worm-wheel Glands.—In consequence of the considerable wear of the screws and nuts belonging to all gland-studs in general, it is advisable to make them all of steel. But the worm-wheels of glands are made of gun-metal, or of cast iron, and because they require to have screwed holes in their bosses, for rotation on the studs, loose screwed bushes may be provided. These can be made of steel, and keyed in the wheels, so that they can be easily removed when worn, and new bushes put in. But bushes are only necessary if the threads are very fine or shallow; the threads should be very coarse, compared with those usually adopted for stated diameters; and coarse threads for such articles will prevent the necessity for future repairs.

TURNING OF LEVERS, WHEELS, ETC.

Treatment of Levers.—In general, the bosses of a lever are both bored and their outsides turned, while the lever remains on a lathe-chuck. This avoids the necessity of fitting and handling an arbor with the lever thereon, and is also an easier mode of turning the outsides of all large bosses, because the slide-rest can be advanced to the centre, and thus be close to the portion being turned. In this arrangement, the cutting tool will occupy nearly the same place that would be occupied by the arbor, if an arbor were to be used for the turning.

The first treatment of a large lever after forging, should consist in planing one of its broad sides. This side is that which is flat, or nearly so, being the side in which the two boss-faces are nearly or quite level with the arm. This is termed the connecting-rod side, or piston-rod side, and is the bottom surface of the lever shown by Fig. 1042. While this is being planed, the lever is held with poppets of proper height, which are caused to bite the bosses and also the narrow sides of the arm. If a great quantity of metal is to be cut off the boss-faces and the broad sides, and but little from the other surfaces, which is the case if the lever is properly forged, the object is adjusted on the machine until the lengths of the bosses and narrow sides of the arm are square to the table, without regard to whether the boss-faces are parallel with the table. To put the article into the proper position, wedges and thin packing-pieces are driven in between the bottom side and the planing-table, an el-square resting on the table and applied during adjustment.

The planing of the lever consists in making the entire broad side plane; no boss-ends being considered because the boss-ends for this side will be very short, if any at all are to be formed. Large levers are never forged with such short projections, but having one broad side of each lever flat. Consequently, if the short ends are to be produced, they are entirely formed by lathe-turning. This broad side is therefore the one which is considered as a primary plane, with regard to which the adjustments and lining operations are conducted.

Nearly all levers are forged without any hole. It is therefore requisite to first roughly remove the comparative large amount of superfluous metal in the bosses, previous to finally boring each boss-hole accurately to the diameter required. The boring of a large lever commences with a powerful vertical boring-machine or driller, and concludes with an accurate boring on a lathe-chuck, because a lathe is not so well adapted as a driller to quickly remove a large amount of metal from the hole, and a drilling-machine is not so efficient as a lathe for a final correct shaping. But there are means whereby a vertical driller can be used to both commence and finish a large hole correctly; these processes require special boring and cutting apparatus, which will be described.

A lever must be bored so that the centre-lengths of both holes in the bosses are parallel with each other, and also at the precise distance apart which is necessary. This distance is the length of the crank's throw, and it is marked previous to boring either boss. The marking is done by means of a primary centre-line which is scribed across those two rough boss-faces that are opposite to those which are planed.

The methods by which such centre lines should be scribed, are shown by Figs. 1040 and 1041. When it happens that the arm of the lever is nearest to the specified width, four centre dots are put into the arm at about a sixteenth or an eighth of an inch from the edges in the places indicated in Fig. 1040. These dots are shown by the letter C, and constitute centres from which four arcs are scribed, which are seen on the boss-faces. The exact situations of these arcs are of no importance, but it will be seen that their points of intersection indicate the place for the required primary line. A straight-edge is therefore put to these points and the line scribed. It is not necessary to mark the line along the entire length of the arm unless it happens to be nearly level with the boss-faces; in which case the straight-edge is slightly bent to the arm while marking. It is also necessary to bend it while scribing the bosses if one is longer than the other.

When the bosses of the lever have but little metal to be turned off to attain the specified diameters, the centre line should be found by the lining given in Fig. 1041. In this case the centre-dots from which the four arcs are scribed are put near the edges of the bosses, as indicated by the letters C, from which points the arcs are caused to intersect and show the straight centre line as seen in the Figure. It may be here mentioned that the centre lines which are marked by these means, are also centrally located with regard to the opposite broad sides of their respective levers, because these were planed while the bosses and narrow sides of the arms were situated square to the planing-table, as directed. Consequently, as soon as a straight centre line is marked, the length between the centres of the two required holes can be shown, and dots are put at these places from which to scribe circles showing the diameters and situations for the holes.

It is to be here noted that the length of the lever's throw is the length of a straight line which is parallel to the planed level broad side of the lever; but if the bosses are of different lengths at the time of scribing the length of the throw, the straight line represented by the distance between the points of the compasses, or points of radius-gauge, with which the scribing is performed, will not be parallel to the plane side of the lever, and some error may thus occur in the marking. To obviate this, the scribing may be done with a wire gauge or bar-gauge having a pointed arm at each end bent square to the length of the gauge. One of these arms is longer than the other, and is just as much longer as one of the lever's bosses is longer than the other. With this gauge the length can therefore be properly marked after a centre-dot is put into one boss, the point of the longest arm of the gauge being put over the shortest boss.

While applying a gauge with arms of unequal length to a measure for adjusting it to a specified distance, the length of the gauge must be kept parallel with the length of the rule or measure; therefore a broad rule of sufficient width is necessary because the point belonging to the short arm of the gauge will be further from one edge of the rule than the point of the long arm. The use of bar-gauges for lining levers can be avoided by scribing the lengths of throws upon the flat plane sides, in which cases it is necessary to plane both sides of each lever to allow it to be properly adjusted for boring. But it may be said that planing is only requisite for levers which are very irregular when forged; if the boss-faces are smooth and square to the lengths of the bosses and sides of the arms, the lengths of the throws should be marked upon the flat sides without any preliminary planing whatever.

Where convenient lifting apparatus is accessible, any lever, small or large, can be easily and quickly lined on a lining-table; the length of throw being marked upon both sides of the lever with a tall scriber-block while the lever is held up lengthways on the table.

Boring of Levers.—To adjust a lever on a drilling-table for boring, it is necessary to put the planed side parallel with the table by means of parallel blocks, which are put beneath and in contact with the plane surface to keep it high enough above the table for the boring-tools to freely disengage from the metal. Both the shaft-hole and the crank pin-hole are formed on this machine, and a proper amount of metal is allowed to remain for the lathe-boring. Two fixings for each lever are therefore necessary on the drilling-machine, although it need not be very accurately adjusted because its boring will be completed with a lathe.

The modes of attaching levers to lathe-chucks, are represented by Figs. 1044, 1045, and 1046. The first fixing of a lever is denoted by Fig. 1044, in which a lever is seen in position for boring the shaft-boss, being situate on two parallel blocks shown by B and B. On the front or narrow side is seen a dotted line, which is scribed exactly parallel with the planed boss-faces. This can be easily marked with a scriber-block on a table if the lever can be easily moved thereto; but a large one may be scribed while it remains fixed on the planing-table at the time of planing the boss-faces. The line can be marked also while the lever is on the lathe-chuck, the scriber-block being put against the chuck's face instead of upon a lining-table. The line is marked upon both sides, and is a species of gauge-line from which the lengths of the bosses can be shown, and is also useful to refer to during the adjustment of the lever to parallelism with the chuck. Supposing the distance between the two faces of a boss is required to be eleven inches, and the gauge-line to be situate five inches from the planed boss-face, and that this face is finished, it will be necessary to reduce the outer face of the boss until it is six inches from the line, which distance is shown by adjusting a compasses to six inches, and scribing a short arc upon the boss near the face being reduced.

The holdfast plates and bolts shown in the Figures are the principal ones required to hold the levers, and are attached at the first fixing to the chuck. In addition to these, three or four other plates and poppets are placed along the arm, as soon as the object is put nearly into its proper place on the chuck. The piece near the lower edge, is a balance-weight of lead or iron, denoted by W. This is bolted to the chuck opposite the lever, in order to balance it during rotation. These weights are of various sizes and thicknesses, so that several may be used together if needful, that the quantity of metal applied may be neither too little nor too great. To ascertain whether the lever is properly balanced, it is put with its length exactly horizontal, by rotating the chuck a short distance without the leather band; the power-gear and step-pulley, are also disconnected from the lathe-spindle; and if the lever will now remain horizontal while thus free to move in either direction, the weight of the balance-pieces is that which is required.

While finally adjusting a lever-boss on the chuck, a pointer or tool-scriber is used, which is bolted tight in the slide-rest. The lever is next slowly rotated and gradually shifted with the poppet-screws until the circular gauge line on the boss-face is seen to exactly coincide with the point during any portion of the lever's rotation. The object is now to be finally fastened by screwing tight the plates; and is in position for smoothly boring the hole parallel, and to the diameter required, which is done with the slide-rest tools. When the hole is finished the holdfast plate is removed from the boss-face, if such a plate were used, that the face may now be reduced until the boss is of proper length. The circular boss-end is also turned to the proper diameter; and a short portion of the lever-arm adjoining, is also turned, which forms a ridge, if it is intended to reduce the arm; if not the projecting boss-end is carefully curved to cause the junction to merge into the straight part of the arm without leaving any ridge.

The turning connected with the first fixing is now completed, and the object is next put into position for boring the smaller hole. This crank-pin hole is to be either parallel or taper, according to whether the lever is for a middle-shaft or for a paddle-shaft; or whether the lever is to tightly hold a crank-pin's stud-end, or to contain a crank-pin's outer end. If the hole is to be taper the largest end is usually that which adjoins the flat or level side of the lever; consequently, this side must be outwards while on the chuck, as indicated in Fig. 1045. By this Figure it will be seen that one face of the shaft-boss is in direct contact with the chuck, this face having been made parallel with the opposite broad side when the hole was bored. It is therefore necessary to place packing-pieces or wedges between the smaller boss and the chuck, as shown; a holding plate also is shown in contact with the boss face, which need not be removed when other plates and poppets are fastened to the arms, unless the face is to be turned. Through only a comparative small surface of the object being in contact with the chuck at this fixing, it is proper to put a scriber-block upon the chuck with the point to both ends of the gauge-line, in order to ascertain if it is exactly parallel, and to alter it if necessary. Such alteration is easily effected with a wedge driven between the packing-pieces at the small boss, or driven between the packing-pieces in contact with the arm.

The boring required to shape a parallel hole intended for a parallel end of a crank-pin, is the same as the boring for a shaft-hole, being effected with the usual long traverse of the lathe. But a taper hole must be bored without this traverse; and the traverse-gear must be so disconnected as to prevent all possibility of being accidentally put into action by the operator while boring with other means. The means whereby the tool is advanced in the desired direction, is the top slide and screw of the rest; and it is inclined until situate at the proper angle with the centre length of the hole; the exact adjustment being performed after the tool has been a few times through the hole, and partly bored it.

The attachments of poppets for adjusting levers to the exact required places on the chucks, are represented in Figs. 1046 and 1047. In Fig. 1046 a vee-block is shown in contact with the small boss of a lever, so that the vee-gap may firmly grip the boss, and also provide a flat surface for contact with the poppet-screw point, which will move the lever downwards during its adjustment. A couple of poppets must also be put at the other or lower end of the lever, to move it upwards; and another poppet at each side of the arm, to shift it sideways. The two packing-blocks, denoted by B and B, are parallel ones, and are in contact with the arm's broad side, and are of sufficient thickness to prevent both bosses touching the chuck.

It will be noticed that the lever in Fig. 1046 is one of a class having the two broad sides parallel with each other; such a lever being used for a shaft that requires but one lever to be situate at one extremity, or one lever at each extremity. A lever of this shape is very convenient for fixing; and if the arm is carefully shaped during the forging, the paring should commence without any preliminary planing of the arm; in which case the smoothly forged broad side is put into contact with the parallel blocks, and is considered a primary plane. When planing is adopted as a first paring, the lever should be adjusted on a table until the bosses and arm's narrow sides are square to the table; in which condition the two broad sides are to be reduced until the arm is of the exact specified thickness. During this planing, the length of the lever is across the length of the table, and at the second fixing no adjusting of the narrow sides square to the table is required, it being only necessary to put parallel blocks in contact with the side first planed. The lever is now ready to be fixed on parallel blocks on a lathe-chuck, for boring both bosses, and for turning both the boss-ends to the exact length required, which length can be accurately measured from the broad sides of the arm, because these were carefully planed to the finished dimensions.

The lever seen in Fig. 1047 is being held tight against the parallel blocks by means of a wood block. This piece is forced tight to the face of the boss with a flat end of a dummy, or of another slide-rest tool, which is advanced against the piece of wood by working the top screw of the rest. By this method a comparative small lever or other article, can be held a short time until additional poppets and plates are attached.

Boring of Wheels.—The wheels here treated are those that possess arms with which the bosses or naves are joined to their respective rims, whether they are spur-teeth wheels, bevel-wheels, or other teeth-wheels; or whether they are fly-wheels, hand-wheels, and others with plain rims which may require to be rough as when cast, or to be smoothly turned in lathes.

Disc-wheels also are here noticed; these resemble circular discs having bosses in the middles and teeth on the rims. Such are also termed plate-wheels, through resembling plates of metal, and being destitute of arms or spokes.

A small wheel only a few inches in diameter, is held to the lathe-chuck with two or three plates and bolts. These are fixed so that the bolts, and the greater portions of the plates, are outside of the wheel's rim, the paws of the plates being on the rim. No other fastenings are required for a small wheel; and this mode of fixing is suitable whether the article has spokes, or is without, supposing that it is to be only bored, while fixed in this condition.

While adjusting a wheel to be bored on a lathe-chuck, two relative positions are to be considered; and with due regard to these, almost any wheel, small or large, may be properly fixed. The first of these positions is obtained when the wheel rim is placed parallel with the face of the chuck, which is usually effected by fastening the rim in direct contact with a few parallel blocks situate on the chuck. The second position is obtained as soon as the rim is placed concentric with the rim of the chuck, and therefore concentric with the lathe-spindle's motion. This position is secured after the rim is put into contact with the parallel blocks, and results from the wheel being gradually shifted to the exact place, either with hammering it, or moving it with poppet-screws.

In all wheels whose rims are not to be turned, the rims are the portions to be regarded during fixing, because they are cast to the specified dimensions, and therefore have no superfluous metal to be turned off. The bosses of such wheels are sometimes turned to make them true with the rims, and one end or face of each boss is also turned, to produce a surface at right-angles to the axis of the truly bored hole.

In consequence of the necessity for exactly adjusting the wheel's rim, it is requisite to first hold the wheel to the chuck without placing any holdfast plate upon the rim, because such would hinder the operator's observation during adjustment. A centre-bolt is therefore put through the boss-hole, and this, with a plate or washers in contact with the boss-face, will hold the wheel a short time until correctly placed. If the wheel-boss is without a hole, a couple of middle-plates or slot-plates may be put across the spokes; these plates have bolt-holes at about midway between the ends, so that when a plate is in position, its two ends are caused to bear upon two spokes, by means of a screw-bolt in the middle and extending through the space between the spokes to the chuck. While the wheel is held with a couple of these plates, its rim is quite free from all articles except the parallel blocks next the chuck, and these must be of sufficient thickness to keep the inner face of the wheel-boss far enough from the chuck to allow room for the tool-point, when advanced through the hole. The wheel rim can, therefore be now put true with the lathe spindle by gently hammering with a wood hammer or a tin hammer, while a pointer or other slide-rest tool is situated near the rim for adjusting.

As soon as adjustment is complete, the rim is seen to rotate truly while the lathe-spindle is rather quickly rotated; and the wheel can now be finally fastened with the holdfast plates on the rim, which will not affect the adjustment, because the rim is in close contact with the blocks behind. Boring can, therefore, be next commenced, and the hole will be produced concentric with the rim, as required, although the outer surface of the boss may not be concentric with the hole, unless the wheel happened to have been truly formed at the time of casting.

In some cases, small wheels having arms are fixed for boring with regard to their arms. This is necessary when the rims are to be turned, in addition to turning or partly turning the bosses. A wheel to be thus treated is fixed to the chuck with parallel blocks in contact with the wheel arms, instead of in contact with the rim. This arrangement will cause the length of the hole when bored, to be square to the lengths of the arms, rather than square to the rim, unless the wheel happens to be truly cast, so that the rim is parallel with the arms. Wheel-arms are always cast to the specified shape and dimensions; therefore, nothing is to be removed from them, except by the ordinary trimming with filing. Consequently, it is requisite to bore the hole in such a wheel with regard to its arms, to avoid the risk of cutting deeply into one side of some one arm, at the time the rim is turned; whereas, if the arms are put parallel with the chuck, the subsequent turning of the rim will either equally reduce all the junctions of the arms, or not reduce them at all, according to the distance in the metal, to which the tool-point enters at the junctions.

Boring of Wheels in Wood Chucks.—A great variety of small wheels, not more than six, eight, or ten inches in diameter, can be easily and accurately bored in wood chucks. A wheel which is bored in such a chuck will have its hole exactly concentric with the rim, but not with the boss, unless the wood chuck is specially shifted for this purpose, after the wheel is put into the chuck.

The piece of wood to be made into a chuck is fixed to a cast-iron disc-chuck of the lathe in the same manner as shown in Fig. 1018 for holding a gland; and when firmly fastened, the hole in the middle is truly and smoothly turned to fit tight around the rim of the wheel to be bored. During the process it is necessary to consider whether the axis of the hole is to be right-angular to the arms, or to the rim, in case the arms may not be parallel with the rim, as before mentioned. When it is decided which is to be square to the hole, either the arms or the rim is considered to be a sort of primary base or plane which must be put parallel with the chuck. Therefore a bearing surface is accurately formed by turning in the hole of the wood chuck. If it is desired to place the wheel-rim parallel with the chuck, the wood at the middle is cleared out to allow ample room for the boss to extend inwards, and a smooth true surface is turned adjoining the extreme boundary of the hole which fits the rim. But if the arms are to be placed parallel, the wood must be cleared out to allow both boss and rim to extend inwards, without bearing upon any surface, thus forming two circular recesses, one for the wheel-boss and the other for the rim. If the chuck is now accurately bored to fit the extreme outer circumference of the wheel-rim, the wheel can be driven in, and when in its place, the arms will bear upon the truly turned surface of the wood, and the rim will be firmly gripped by the wood around its outer surface, usually termed the edge.

Wood chucks are particularly useful for boring wheels which are cast without any hole in their bosses, and which are too small to need a preliminary boring with a driller. Disc-wheels are easily held, and should be bored in wood chucks, especially if cast without any hole in the bosses, and consequently in a condition to prevent the insertion of a centre-bolt until drilled.

Boring and Turning of a Wheel at one Fixing.—Large wheels are frequently both bored and partly turned with one chucking, or, as it is termed, one setting-up, for each wheel. Some sorts of wheels, such as a grooved wheel for a foot-lathe, can be entirely completed with only one fixing, because only the hole and one side of the wheel are operated upon, the other side remaining as it was when cast.

A cog-wheel of two, three, or more feet in diameter, having spokes, is turned and bored as stated, with only one chucking, and is fastened to the chuck with plates across the spokes, and poppets in the spoke-spaces, so that the screw-points shall bite the inner side of the rim. For the fixing of a wheel of this class parallel blocks are put at the proper places on the chuck to suit the size of the wheel, and are usually put into contact with the rim, unless it is specially desirable to turn and bore the wheel square to the arms rather than to the rim.

The holdfast plates employed to hold the wheel should be slot-plates, which allow the screw-bolts to be easily put at any required place along the slot to suit the holes or slots in the disc-chuck. The paws of the plates are to be put near the inner part of the wheel's rim, upon the junctions of the arms, and this arrangement will allow the front side of the rim to be turned, and also the outer surfaces of all the teeth, the wheel's rim being at the same time firmly held and its tendency to tremble greatly mitigated.

After the wheel is adjusted for placing its rim concentric with the chuck, it is in position for turning. But, previous to commencing, the boss must be supported to keep it steady and afford great resistance to the cutting-tool, and to avoid the risk of breaking the spokes. For this purpose smooth hard wood packing-blocks are pushed in behind the junctions of the arms with the boss, and also in contact with the boss itself, if large enough. Both parallel blocks and those that are slightly taper, are used, and are driven in only tight enough to remain in position without distorting the wheel.

The turning and boring can now be safely done, and the cogs will be true with the hole when turned, supposing that the wheel does not shift during the process, or bend in some part, which it is likely to do, especially if it is several feet in diameter. To avoid trouble that may result from such occurrences, it is proper to first roughly bore the hole, and turn the boss to near its finished size, and next turn the rim and teeth. These parts can be now entirely finished, after which the boss is to be smoothly finished, and its hole finally enlarged to the exact diameter by removing very thin slices with a sharp tool.

A circular line can also be marked, if necessary, upon the rim at the intended bottoms of all the teeth-gaps, the line being required as a gauge-line during shaping.

The outer circumference of the wheel and one side of the rim are now completed, also the hole and one end of the boss, all these surfaces being true with each other; consequently the wheel can be next reversed, the side which is not turned being now put outwards, and the turned surfaces of the teeth put against the parallel blocks, in which condition it is again adjusted to execute what little further turning may be requisite.

Turning of Wheels on Arbors.—It has been shown that large wheels are turned and bored while attached to disc-chucks, therefore for such wheels no arbor is required.

Whenever the wheels in progress are those having spoke-spaces large enough to admit bolts, the turning of the rims should be done while on the chuck, whether the wheels are small or large, because a chuck affords a firm support for the objects and prevents shaking; whereas a wheel on an arbor is devoid of all support, except at the boss, where it is least required.

To properly turn a wheel by means of an arbor, the arbor must be carefully turned to fit along the entire length of the truly shaped hole in the wheel-boss, and should be as short as possible, with only length enough to allow room for the lathe-carriage. The shorter the arbor the greater will be the resistance to the cutting-tool, and the less will be the vibration. It is also necessary to rotate the wheel with two drivers in the chuck, one opposite the other. In order to yet further avoid vibration, the wheel is made to fit at one end of the arbor, so that while on the lathe-pivots the wheel is only a few inches from the disc-chuck. The two drivers are caused to bear against two of the wheel-arms, and between each arm and driver some pieces of leather, felt, or india-rubber are fixed, instead of allowing the two metals to be in direct contact.

In the event of a cog-wheel being turned, it is specially requisite to steady it during the turning, to prevent the teeth being suddenly jerked against the tool-edge, and either breaking the tool, roughing the surfaces being turned, or doing other mischief. To obtain the requisite regular onward movement, the drivers are fastened to the wheel-arms, and all backward motion thus prevented. This fastening is effected with poppets, if the arms present enough flat surface for the screw-points; or with clamp-plates and bolts, if the arms are curved. Drivers are fastened also by tying them to the spokes with cord, and afterwards driving in one or two wedges to tighten the cord.

TREATMENT OF BOLTS AND NUTS.

The operations here detailed are those by which comparative large nuts and bolts that may be three, four, or six inches in diameter, are bored, turned, and screwed. Small bolts and nuts are screwed with dies and screw-taps; but it will be seen that these processes are those that involve the use of lathes and their accessory apparatus.

Fixing of Nuts.—In some cases large nuts are forged without holes, to avoid the operation of punching them on the anvil. It is therefore necessary to treat all such with a preliminary boring on a drilling-machine, so that only a proper amount of metal may remain for the lathe process.

Nearly all the nuts now made are hexagonal, consequently the modes of fixing here given are adapted to such ordinary nuts. Those intended to be afterwards turned on proper nut-arbors need not have any portion turned while undergoing the first treatment on the chuck, only the boring and screw-cutting being then executed; the fixing for this purpose can therefore be done without poppets, by placing holding-plates to bear upon the nuts' faces. But there are several sorts of large nuts which require to be entirely turned to the specified dimensions while attached to the chuck; consequently, in order to properly set up a nut the operator must know, previous to commencing, whether the articles can be afterwards turned on an arbor, on its bolt, rod, or other piece to which it belongs, or whether it must be completely turned on the chuck.

There are two principal methods by which nuts are fixed for screwing, one of which consists in holding them in cup-chucks, and the other in holding them between poppets fastened in a disc-chuck. Those that are not too large should be held in a cup-chuck, which allows one face of a nut to be outwards while firmly fixed, and therefore allows the face to be turned in addition to the hole being screwed. This mode is convenient for a comparative small nut only a few inches in diameter or length, because, while in the chuck, the operator can easily see whether the six planes rotate truly, or whether the hole rotates truly, the nut being adjusted with regard to either the one or the other, according to whether most metal is to be removed from the inside or outside.

A large nut which requires its entire turning to be done while on the chuck must be held with poppets. At least four of these are needed, and if they are too small for the comparative large nut, six or eight are employed; but a small number of long and strong poppets are in all cases preferable to a large number of small ones, because small or slender ones bend during the tightening of the screws, and greatly tend to shift the nut or other object being fixed, out of the proper position.

During the adjusting of a nut to its exact position on the chuck, a few slightly taper steel wedges are employed, in conjunction with packing-blocks of suitable thickness. These are driven in between the chuck and that face of the nut next to it, but not till after the poppet-screws are partly tightened and the nut partly fixed. By this wedging process the nut can be placed so that its six-sided part is square to the chuck, which condition is known by applying an el-square; or if it is requisite to place the front or outer face of the nut parallel with the chuck, the wedging is continued until the outer face is seen to rotate truly by applying a dummy, which is fastened in the slide-rest. It will be found that this mode of wedging or packing is necessary for any large nut which is forged or cast with irregular surfaces, because neither one of the nut's faces can be put into contact with a parallel ring on the chuck, unless the face selected happens to be square to the six planes. One of the planes of a nut is denoted by P, in Fig. 1048.

When six poppets are used to hold one nut, each of the screw-points can be caused to bite one of the six planes; and if the poppets are of proper length from the chuck, the screws will bite near the front or outer face, and the nut will be firmly held without any other fastening. While in this condition the outer face can therefore be entirely turned, because no plate is situate thereon. If the chuck is large enough, the poppets should be situate far enough apart to grip the six corners of the nut, instead of the six sides. It will be found that a large nut can be thus more securely held, and that the six sides can be more easily put square to the chuck, than if the screw-points were caused to bite the flat sides. This security is obtained by using packing-blocks having vee-notches. A pair of such blocks are shown by Fig. 1050, and are made of steel or iron. Each one has a flat side or surface to receive the poppet-screw point, and has at the opposite side a vee-notch or gap. A pair of these implements will consequently grip two opposite corners of a hexagonal nut, or other article of similar form. Supposing that six poppets are to be used, six of the blocks are put into position, one at each corner of the nut, and in contact with the contiguous poppet-screw. In Fig. 1049 two poppets and two vee-blocks are seen in use, gripping a nut, which is the appearance presented at the beginning of a fixing process, previous to attaching other poppets. When all the poppets and vee-blocks are applied, the tightening of the screw-points upon the blocks will cause the nut to be gradually shifted in any desired direction across the chuck, to accurately adjust it; but it will not be moved either towards the chuck or away from it, because the surfaces of the vee-gaps in the blocks are parallel with the opposite flat sides.

It may here be noticed that the stability of the nut greatly depends on the amount of gripping surface in the vee-gaps, because if no vee-blocks are employed, only the small points of the screws can grip the nut, and because of such a small surface being in contact, the nut is caused to move in various directions during tightening, and frequently very much away from the position desired.

For the fixing of a large number of nuts which may not be of great size, or not more than eight or ten pounds' weight each, four poppets are sufficient, instead of six. In this case the fixing can be effected with only two vee-blocks, one opposite the other, and in contact with two opposite corners of the nut, as indicated in Fig. 1049. The other two poppets are caused to bite two of the flat sides, consequently the poppets are at right-angles to each other. But four vee-blocks should be used, if available, and so placed that two of them are in contact with two planes of the nut, the flat sides of the blocks being next the screw-points, and the vee-gaps next the nut.

Boring and Turning of Nuts.—As soon as a nut is fixed the outer face should be reduced, a proper amount of metal being left for turning the opposite face. This reduction of the face at the beginning of turning is more or less requisite in proportion to the amount which is to be removed, because if this superfluous part is not at first cut off, it must be both bored and screwed. By shortening the length of the hole previous to boring, it can be bored and screwed with but a comparative short length of the slide-rest tools projecting from the tool-holder, and therefore can be more easily cut, through the tool affording proper resistance to the metal.

For boring an ordinary iron or steel nut an ordinary slide-rest borer may be used, having a vee-point cutting part similar to that shown by Fig. 1054; but not a U-point, or round-nose, as it is termed, the small amount of curved part which is requisite being shown in the Figure. In order to allow such a tool a free passage through the nut, the hole must have been previously made large enough, either by having been punched, cast, or drilled, supposing that the hole is small when compared with the thickness of the borer.

It is not requisite to use a solid tool, except for small holes; for holes of three, five, or seven inches in diameter a slotted tool is preferable. An end of such a tool is denoted by Fig. 1051, in which small cutters can be securely held, and from which they can be easily detached to be repaired, or to make room for others. The cutter shown keyed in this Figure is suitable for boring iron or steel, and has a vee-point slightly curved at the extremity, resembling the point in Fig. 1054.

Gauges for Boring Nuts.—In order to accurately bore a nut so that the hole shall have the exact diameter required, the operator should make or be provided with a sheet gauge similar to Fig. 1055, especially if a number of nuts are to be bored to one diameter. The gauge is a piece of steel, if it is intended to remain a permanent tool for a large number; but an iron one is available for most purposes. One gauge of this class can be made to suit two sizes, if the two sizes differ greatly from each other, in which case the operator is not liable to use the larger dimension of the gauge instead of the smaller.

The two opposite narrow surfaces termed edges, of a sheet gauge for boring should not be exactly parallel to each other, nor quite flat, as appears by the Figure, but each end or point should be slightly tapered, the taper part extending to about a quarter or a sixth of the gauge's length. The intermediate part between the two taper ends, is to be parallel, and of the exact diameter required for the hole to be bored. It is also proper to curve the edges, which is done with a smooth file, the curve produced being about the same as that of the hole required. By bestowing the necessary attention to the gauge while being made, it will accurately measure a hole, will retain its original size a greater length of time, and will readily enter a hole by reason of its taper form. By the gauge entering only a short distance into a hole, the operator is also able to know how much more is to be removed.

The diameter to which the hole is to be bored before commencing the screw-cutting, is the shortest diameter of the intended screwed hole, usually termed the diameter at the bottom of the thread. This distance is therefore the diameter of the gauge to be used; and while a gauge is being adjusted to a proper size, it can be either fitted to a screwed hole or nut which is known to be correct, or it can be adjusted to some stated diameter to suit the purpose. When one of the usual Whitworth threads is to be used, the proper diameter for the gauge may be known by referring to Table 6, pages 178 and 179. Suppose now that a nut intended for a bolt three inches in diameter is to be made, and that a screw-tap three inches in diameter can be used for forming the thread, the diameter of the hole should be two and five-eighths inches, as appears by the last line of the Table. Therefore, three-eighths of an inch of the hole's diameter is the amount occupied by the thread, and this is the difference between the shortest diameter and longest diameter of the screwed hole to be made. This difference is the same, whether the nut is a three inch one, or a ten inch one, if the thread referred to is formed therein, and is exactly analogous to the difference in a three-inch hob referred to in Table 5, column the sixth, because the thread of a three-inch hob is the same in shape and size as that of a three-inch tap.

But the sort of screw-thread referred to in these Tables is too large for a bolt or rod only three inches in diameter, being too broad and too deep, the pitch being, as indicated in column eighth of Table 5, $3\frac{1}{2}$ per inch. This size of thread is large enough for a bolt seven inches in diameter, as indicated in Table 7. Consequently, if a nut is now to be screwed for a seven-inch bolt, the diameter of the hole when bored ready for screwing must be $6\frac{5}{8}$ inches, allowing that the usual Whitworth-shape thread is to be adopted, such as that used for three-inch nuts. It may therefore be inferred from the foregoing remarks that each sheet gauge requires to be named in order to indicate two things, which are, the extreme or largest diameter of the screws for which the gauge is made, and the step and shape of the screws.

Screw-cutting of Nuts.—The shapes of the screw-tools employed for nuts, are not dependent on the nuts' sizes, but on the sizes and shapes of the threads to be produced. The tools which will cut an ordinary vee-thread into a three-inch nut, will also cut a thread of the same thickness, step, and shape into a seven-inch nut. For commencing any large nut-thread, single-tooth screw-tools should be used, because they cut much easier and remove the metal quicker than tools having two teeth. The tool or dent first used, should be one whose cutting-edges subtend an angle of sixty or sixty-five degrees. This is advanced into the metal until the summit of the thread thereby formed is but a minute amount wider than it will be when finished, in which condition it is ready for another dent, the angle of which is fifty-five. The point of this cutter is properly curved to correctly form the bottom of the thread groove; and, with this tool the bottom can be entirely finished, and the entire thread also very nearly finished, if care is exercised to take off thin cuts at the conclusion. After this the final adjusting and polishing of the thread to the exact size required, is performed with a cutter or dent having two teeth.

The tool employed for finishing must be very carefully adjusted to cause its teeth to cut equally at both sides of the thread, and the smaller the quantity which is to be taken out with this tool, the greater is the necessity for an accurate adjustment. This operation is done after the stock of the tool is tightly fastened in the tool-holder, when the top screw of the rest is gently rotated a short distance in conjunction with a similar gentle rotation of the chuck and nut, the operator observing at the same time when the teeth of the dent bear properly against each side of the thread.

The dents which are required for cutting the usual vee-threads are denoted by Figs. 1073, 1071, and 1070. The single-point tool shown by Fig. 1071, is made of small bar steel without any forging, the vee-point being ground until it subtends the desired angle. One of these is seen keyed in its stock in Fig. 1072; and if the same stock is to be used for holding a wider tool having two teeth similar to Fig. 1070, the slot in the stock must be wide enough to admit the widest cutter and also a key; consequently, in this case, it is requisite to use two keys for one stock, one narrow key for the cutter with two teeth, and another wider key to fasten the small cutter having one tooth.

In order to avoid the necessity of using two keys, a cutter shaped like Fig. 1073 is used.

The widest part of this one is of the same width as the widest part of Fig. 1070, so that both may be held in the same slot with the same key. But it is preferable to employ two or three stocks while screwing nuts, so that all unfixing and fixing of cutters may be avoided, except for repairs.

The method of forming a thread with two or three tools having the same angle for their cutting edges is much practised; but the author's method just indicated is a quicker process. Any vee-tool's point which is caused to advance a distance into the metal becomes soon jammed, and the capability for cutting soon ceases; and this results sooner in proportion to the smallness of the tool-point's angle. It becomes jammed also because there is no room between the extreme point of the tool and the metal in contact, so that the shavings or slices cut off cannot easily get away when detached. To relieve a tool-point from this jammed condition while using it for screw-cutting, it should be used so that only one cutting edge can cut at one time, which will provide a relief-space between that edge which is not cutting and the contiguous side of the thread. Both sides of the vee-point are to be used for cutting, but alternately, and in conjunction with the gradual advancement of the tool into the metal. To effect this result, the operator must carefully shift the tool-point to and fro by rotating the top screw of the slide-rest.

But although the alternate cutting of the tool's two edges greatly facilitates the production of the thread, it is not the less necessary to employ a tool with a point of sixty or sixty-five degrees, because such a comparative broad point is stronger and less liable to break than a comparative sharp point of fifty-five degrees. For the making of very large vee-threads, such as those having only two or three steps per inch, the point of the cutter or dent first used should have an angle of seventy, rather than sixty-five degrees.

Gauges for Nut-screwing.—For the purpose of properly measuring nut-screws during the screw-cutting, two or three sorts of gauges are employed. These consist of sheet gauges, wire gauges, the author's valin, and the screwed gauges, such as hobs, taps, and plugs.

The simplest mode of measuring a nut-screw consists in using the flat sheet gauge, to which the hole was bored. If this method of measuring is adopted, the hole to be screwed is bored so that the gauge fits tight therein, a minute quantity of metal being left for the screw-tool to remove while finally adjusting the smallest diameter of the screw to the finished size. In order to make a number of nut-screws to one exact size, by means of a sheet gauge, a two-teeth screw-tool must be used which has been properly cut with a hob, to make the two teeth to the exact required shape and length; consequently, if the screw-cutting is continued with such a tool until the sheet gauge will exactly fit the smallest diameter of the screw, the largest diameter of it must be that which is required, if the right tool is used, because its teeth are of a known and prescribed length, and therefore extend into the metal a known distance. A sheet gauge in use for measuring a nut is shown in Fig. 1056.

A wire gauge for screw-cutting is a piece of wire pointed at each end, and should be of steel, to avoid the risk of wearing the points, and thereby making the gauge too short while in use. The length from one extreme to the other is not analogous to the extreme diameter of a sheet gauge, because a wire gauge is intended to measure the largest diameter of the screw, and not the smallest. The length of the wire is a trifle greater than the greatest diameter of the intended screw, and this trifle is more or less according to the relation between the diameter of the hole and the step of the thread to be cut. The points of the gauge are smoothly filed and thinned to exactly fit the bottom of the nut's thread-groove; consequently the points should not be circular, but oblong, in order that about an eighth of an inch of surface may exist for contact with the bottom of the groove during measurement. A piece of wire thus shaped can be gently screwed into the nut as soon as the groove is deep enough, the mode of entering the gauge being similar to the entering-in of a bolt-end. A gauge of this class is shown by Fig. 1057, and a similar one, but with a wire handle, is indicated in Fig. 1058.

To adjust the wire to a proper length, it can be fitted into a nut which is already screwed, if such a nut is known to be of the desired size, and can therefore be considered as a standard;

in which case it is not requisite to know the exact length, because the length is known to be correct as soon as the gauge will properly screw into the standard. But if a number of nuts are to be screwed to a specified diameter, and no standard nut exists to be referred to, the length between the extremities must be adjusted with regard to a measure and to the step of the thread. For example, suppose a quantity of bolts are to be made, and that their screwed ends are to be five inches in diameter, furnished with threads of four steps to an inch, the nuts for the bolts should, in a regular way, be first bored and screwed previous to screwing the ends of the bolts. To be sure that all the screws of the nuts will exactly fit the five-inch bolts, the longest diameter of the screws must be at least five inches; and consequently an accurate mode of measurement must be adopted to ascertain when the nuts are sufficiently enlarged. In nearly every such case it will be found necessary to make the thread-groove deep enough to prevent the bottom touching the summits of the bolt-thread, so that for a five-inch bolt the longest diameter of the nut-screw must be more than five inches.

The adjustment of a wire gauge for screwing five-inch nuts should be effected by means of a diagram similar to Fig. 1066. This is marked upon a flat piece of sheet iron, or piece of smooth board, and consists of a couple of parallel lines as far apart as the diameter of the bolt, and a few lines marked across, which denote the step of the thread and the extreme length between the points of the gauge to be made. The Figure is one-fifth of the actual size that would be required for five-inch nuts, and the one inch between the two lines S and S therefore denotes the bolt's or nut's diameter. The line L is scribed exactly square to the bolt's length, and is a sort of base from which the length of the step is marked, which, in this case, is a quarter of an inch. The step is therefore the space between the parallel lines L and T, and when these are scribed a rectangle is delineated. The angle of the thread with the screw's length is to be next shown by scribing the diagonal D from one corner of the rectangle to another. The length of this line is the exact length to which the wire is to be adjusted for producing nuts whose screws are to be five inches diameter. The amount of length which the gauge is to have in addition to the specified diameter of the screw, is shown by scribing the arc, A, with a compass-point at the centre, C. The extra length thus denoted is, for a five-inch gauge, only about a fiftieth of an inch. The wire must therefore be at least a fiftieth of an inch longer than five inches. But because the gauge is to suit nuts for bolts five inches in diameter, and because the summits of the bolt's threads should not touch the bottoms of the grooves in the nuts, the gauge should be a thirtieth or a twentieth of an inch longer.

In order to plainly show the relation between the length of a gauge and the diameter of a screw, a full-size diagram for a screw one inch in diameter is given. This is denoted by Fig. 1068, and has a step of half an inch, which would be much too great for a bolt only an inch thick; but the diagram serves to plainly show the difference alluded to. By this Figure it will be seen that the extreme length of gauge would be about an inch and an eighth, for the production of a screw an inch in diameter.

Fig. 1069 is a full-size sketch for an ordinary Whitworth screw of an inch and a quarter in diameter. The step of this is a seventh of an inch, and the diagonal shown is the length for a gauge suitable for screwing a nut or any other article with an inch and a quarter screw, supposing it could not be screwed with a tap. Fig. 1077 is a full-size sketch for four-inches nuts, which are to have screws with the length of step shown, the length of the diagonal showing the exact length of gauge, as in the other Figures.

The author's valin, or springy divider for measuring nut-screws, is denoted by Fig. 1067. This is a very efficient tool, the one implement being capable of measuring several different sizes, when the nuts in progress are only about three, four, or five inches. For larger sizes the straight wire gauges are preferable, because the large divider which would be required for such sizes would be liable to bend in use after being adjusted, and would therefore mislead the operator.

If the feet of the valin are bent to subtend the angle subtended by the feet shown in the Figure, the instrument can be used for a variety of sizes without causing the thicker parts of the feet to come into contact with the thread while the tool is in the hole. While adjusting the points to the distance required for a nut of a specified size, they are applied to the extremities of the diagonal shown in the diagram for the purpose; consequently, the distance between the two points is analogous to that between the points of a wire guage. The valin can be also adjusted to fit the screw of a standard nut, when such a nut is to be employed.

Screwed plugs, hobs, taps, and similar gauges, for screwing nuts to stated diameters, are only available for such as are not more than two or three inches in diameter, because of the comparative great amount of time required for the making of screwed gauges; but it may be mentioned, that they, of all classes, are the best, being the least likely to mislead.

In order to facilitate the screw-cutting of nuts, a bevel should be formed at the entrance or mouth of the hole at which the screw-tool enters. This bevel is about as deep as the step of the thread to be formed, and the diameter is equal to the largest diameter of the screw. In Fig. 1074 a bevel of this class is indicated by the oblique dotted lines at the right-hand end of the nut, the two diameters of the same bevel being shown by B, in Fig. 1076.

Screw-cutting a deep hole in a nut, or in any other object, is also facilitated by the author's channelled stock, denoted by Fig. 1079. Such a stock would be highly useful for screwing the further end of a chambered nut similar to Fig. 1078. The peculiarity of the implement consists in its having a shallow groove or gutter formed along its upper surface, as seen in the Figure. The gutter has a very smooth bottom, and is broad, but not deep, in order that it may contain enough oil without weakening the end of the tool. That extremity of the gutter at the extremity of the tool is the deepest part, to allow the oil to flow freely along and fall upon the metal of the nut or other article to be screwed. There are also two other outlets for the oil situate near the cutter-slot, one at each edge of the stock, and directly over the slot; these outlets cause a portion of the oil to flow from them to the tool and to the nut, instead of allowing the entire quantity to flow to the extremity.

By means of a stock furnished with a channel of this sort, oil can be supplied at any moment during the screw-cutting, without directly pouring it into the hole of the nut. The operator can pour oil into the outer end of the channel, and it will flow along to the cutter-point, although this may be at the middle or further end of the hole out of sight.

Inclined Threads.—An inclined thread is one which is not situate square to the length of the bolt. Generally speaking, all vee-threads should be square to their respective rods and bolts, if not, their nuts will not enter upon the screws both ways; the nut will not advance unless it is placed so that the thread inclines in the same direction as that of the bolt-thread, supposing that both nut-thread and bolt-thread are inclined, and that they properly fit each other.

If a vee-thread in a nut is properly situated, its base is exactly beneath its summit, whenever the nut is held with the axis of the hole horizonal. Consequently a line which is right-angular to the length of the hole or axis, and which equally divides the thread at its base, will also equally divide it at its summit. A knowledge of this fact enables us to make gauges, whereby the relative positions of threads in their nuts can be ascertained quite near enough for practical purposes.

A gauge for ascertaining whether a thread is right-angular to the length of the screw, is termed a dentin, and represented by Fig. 1060. The tool is a straight-edge having a tooth extending from one end, and solid with the remainder or straight-edge portion. The tooth is shaped to fit a vee-thread's groove, and the entire tooth, during the final adjustment, is made to extend exactly right-angular to the length of the straight edge. This position is obtained by a careful lining, after the tool is filed straight and smooth, but previous to shaping the tooth. The lines first made for this purpose, are three, which are straight, parallel with each other, and square to the length of the tool. In Fig. 1064 these three lines are shown, the Figure being a comparative large sketch of a dentin which has a gap opposite the tooth. The middle line of the three is the one first marked, and is scribed with an el-square and scriber. A springy divider is next employed to scribe a small circle at each end of this primary line, the diameter being equal to the intended width of the tooth, and gap, if a gap is desired. The two outer lines are now to be marked, and by means of them, the angular lines showing the shape of the tooth, are marked; after which the shaping proceeds, and is conducted with regard to the lines, and completed by fitting to the thread-groove of a Whitworth-hob, supposing that such a thread is desired.

Fig. 1061 indicates a dentin in use. The tool is placed with its tooth in a thread-groove of a nut, so that the tooth shall be fairly situate in the groove. While it is thus held, the observer can plainly see whether the length of the straight portion is parallel with the hole or screw; if so, the thread is not inclined to any great extent, but is situated as it should be. But if the length of the dentin is seen to be inclined to the length of the hole, while the tooth is exactly placed in the groove, the thread must be also inclined, instead of being situate square to the length of the hole.

A dentin can be used to ascertain the condition of a thread after it is finished; and can be used for a thread during its formation in a nut attached to the lathe-chuck. If the tool is applied to a nut already formed, and the thread is found to be inclined, the operator can observe to which face of the nut the thread leans, and can accordingly incline the bolt-thread to fit the nut, in which case a good fit will be secured, but the nut will not enter either way first upon the bolt.

When the dentin is used during the screw-cutting of a nut, it is applied to the partly formed thread, and to the screw-tool. For this purpose, the end of the dentin is shaped like Fig. 1064, having both tooth and gap. The gap is employed at the fixing of the stock in the tool-holder, at which time the gap is put into contact with the tooth of the screw-tool, and the length of the dentin observed, to see if it is parallel with the length of the hole to be screwed, and if not, the stock in the tool-holder of the slide-rest is shifted, until the tooth of the cutter is in the proper position, when the stock may be firmly fastened. The tooth of the dentin is not used until the thread is partly produced, at which time the tooth will enter the thread-groove and indicate the inclination, if any exists; but it will be found that if the screw-tool is accurately placed in the slide-rest, no application of the dentin to the nut will be necessary.

Centring of Bolts.—Bolts are centred for turning by several modes, either of which may be adopted to suit the sizes and shapes of the bolts in hand. If a bolt has several dimensions differing considerably from each other, such as a conical one denoted by Fig. 1080, a little care is requisite to measure it before centring, that the portion nearest to the desired size may be known and centred accordingly.

Short bolts shaped like Figs. 1081 and 1082 can be held in a vice and their ends dotted without any preliminary turning; but all bolts that are large enough or long enough, to be troublesome while being moved about, should be lined. Lining will indicate the places for the dots, and in many cases will entirely obviate the lifting of heavy pieces during the whole time, from the beginning of their centring to the conclusion.

Fig. 1083 represents a holdfast bolt or nut-head bolt, the article consisting of a straight rod screwed at each end, and having a screw-nut to serve instead of a head. Such bolts should be so forged as to require little or no treatment in the lathe, except the screw-cutting. It is, therefore, necessary to select iron or steel rod, the diameter of which is exactly equal to the diameter of the intended screwed ends. If steel bolts are required, the proper lengths of rod are cut off while red hot, and each extremity should be pared with a trimming-chisel until somewhat like the intended form; and this trimming while red-hot is especially necessary if curved extremities like those in the Fig. 1083 are desired. Each piece is next carefully straightened, and the ends softened, that the threads may be easily cut, and the bolts be not so likely to break. This completes the forging and prepares the piece for the lathe process.

Iron bolts also may be forged in exactly the same way as steel ones, if the iron rod used is of solid texture; but nearly all sorts of iron require to be forged after its first making, to properly prepare it for screw-cutting. This forging consists in thickening and welding each end of each bolt piece, until all are rendered solid, and of a larger diameter than the specified diameter of the screws. An amount of superfluous metal is thereby provided which will be turned off with the lathe. When a large number of pieces are to be thus thickened, it is necessary to first completely forge one of each size, that the forger may know the exact length of iron required for each bolt, by which means the cutting off waste pieces will be avoided.

When all the bolts are forged and straightened, they are ready for centring by the aid of vee-blocks and scribing, while situate on a lining-table as indicated in Fig. 1084. It will be seen that the comparative straight and smooth intermediate part of the bolt is in contact with the vee-block, and the marking with the scriber-block will therefore indicate the centres of those portions which touch the vee-gaps. If the blocks are put near the thick ends, as in the Figure, the entire middle part will be centred, if it is exactly straight; but if it is not, only the ends will be centred, and it will therefore be necessary to straighten the mid-portion afterwards, if found to be bent enough to require it.

The centring of steel bolts is effected by using the vee-blocks in the same manner as for iron ones, with the difference of placing them nearer to the extremities—in contact with the portions to be screwed, instead of near the thread-junctions, because it is specially requisite to find the centres of the ends, by reason of no metal existing thereon to be turned off. Consequently, such a bolt is first accurately centred to cause its ends to rotate truly on the pivots, and the intermediate part is afterwards carefully straightened, if necessary.

In order to centre a connecting-bolt it is put upon vee-blocks, as seen in Fig. 1085. This bolt resembles, in some respects, the one in Fig. 1084, being forged so that the end for the screw is thicker than the remainder of the stem. It is made of iron, the diameter of which allows little or nothing to be turned off; consequently, the vee-blocks are put beneath the smooth parallel part of the stem; and the scribing will show the places for the centre recesses, although these places may not be in the centre of the bolt's extremities. The heads of such bolts when forged, are usually of comparative large diameter, so that no attention need be given them during centring. But when it is specially requisite to turn a bolt head, or a number of them, to a specified diameter, and but little metal is to be removed, one of the vee-blocks must be put beneath each bolt-head for scribing; and not, as in the Figure, beneath the part of the stem adjoining the head.

When the head of a bolt is tolerably concentric with the stem, and the bolt's entire surface is to be about equally reduced, the marking should be done with a callipers. Each extremity of the bolt is chalked, and the marking performed resembles that shown on the middle of the bolt-head in Fig. 1087, in the centre of which is the required centre. This point is easily found and dotted, because it is only about a sixteenth of an inch from either of the four lines.

Figures 1086, 1088, and 1089, relate to the mode of centring by means of a centre-finder devised by the author, termed a rectol. The instrument alone is denoted by Fig. 1086, and consists of a sort of gap straight-edge, in one end of which is a gap large enough to admit bolt-heads of several sizes. The lower edge of the tool is its principal straight part; and the edge of the short portion at the left hand of the gap, is in line with the edge of the longer portion at the right hand. The entire tool consists of a thin piece of steel, that it may be easily moved about.

A rectol in use is denoted by Fig. 1088. The implement is in contact with a bolt-stem, which is forged tolerably parallel, and therefore allows the edge to touch at several places along the stem. While on the bolt, the rectol is slid along a short distance until the edge of the short end touches the outer surface of the head. In this condition it appears in the Figure, and is thus held while the operator scribes a mark upon the head exactly at the place touched with the rectol. This mark is in line with the stem of the bolt, because both portions of the rectol are in line with each other. The implement is next shifted a quarter of a revolution around the bolt-stem, and again put into position for scribing another short line, in the same manner as before, which mark is analogous to the first one because of being in line with the bolt-stem. After this, two more marks are made, by shifting the rectol twice more; consequently, four marks are shown, which represent four points of a circle, in the centre of which is the centre required for the bolt-head. To plainly and easily show this point, it is only necessary to place a divider with one point in each of the four marks, and scribe short arcs across the middle of the surface, which produces four lines similar to those in Fig. 1087.

It will be easily perceived that a rectol is very useful for centring heavy bolts, and other pieces which may not be very heavy, but are too long to be conveniently moved about. By employing this instrument a lining-table and surface-blocks can be dispensed with; and the article can be centred wherever it may be, either on the floor or on the lathe-bed ready for turning.

In order to centre a large bolt having its end thickened, a rectol with a shallow gap may be used. One of this sort is shown in Fig. 1089, and can be quickly made, in emergency, of any piece of sheet iron which is available. In such a case only one edge of the tool is made straight, and the gap is but roughly formed with chiselling, no filing being performed except upon the straight edge of the implement.

Formation of Centre-recesses.—After the extremities of bolts are properly lined and centred, they can be immediately drilled and coned for turning, if they have been properly forged so that they are square to the bolt's lengths. If not, a species of preliminary lining and centring may be requisite to allow the rugged ends to be cut off, or at least to allow them to be properly shaped with a preliminary turning. If the extremities are not prepared with turning, they must be chipped, a hammer and chisel being employed to prepare a surface about half an inch around the intended recesses. The places for the recesses can now be shown by some of the modes described, and can be drilled with a fiddling-drill. When drilled, they are coned with a half-round coner, which is rotated with a hand-brace.

The diameter of each conical recess, when finished, should be about a tenth of the bolt's diameter; and the small drilled hole must be deep enough to prevent the point of the lathe-pivot from touching the bottom; an eighth or a quarter of an inch of space being allowed between the pivot and the bottom of the hole. Consequently, if the fiddling-drill is not properly shaped to enter the metal far enough at the first drilling, the drill-hole must be deepened after the coning is completed.

Turning of Bolts.—In order to allow a short bolt to be turned and screwed along the entire length of its stem, it requires to be kept as far as convenient from the chuck by means of a comparative long centre-pivot, which belongs to the chuck, unless a special chuck is provided for such work. To adapt an ordinary disc-chuck to the turning of short bolts, the arrangement depicted in Figs. 1091 and 1092 are resorted to. In Fig. 1091 a gripper or carrier, consisting of two plates and bolts, is seen fastened to the bolt-head; and one of these plates has a long cranked end, which is driven by the driver seen fastened in the chuck. This mode of driving is suited to any bolt which is more than an inch and a half thick. Smaller bolts may be rotated without any gripper, as indicated in Fig. 1092. By this mode a thick strong driver resembling an el-square is employed, which is bolted to the chuck with two or three bolts and nuts, the long arm of the driver having a slot to allow it to be fixed at any place on the chuck to suit the diameter of the bolt-head.

By either of these two appliances a short bolt can be turned and screwed to the head, if required, and the shoulder of the head can be also turned. It may be said that this mode especially suits bolts whose stems are to be turned, and perhaps screwed, but whose heads are to be left exactly as they were forged. Such a bolt is therefore centred with regard to the head and to the outer end of the stem. Every such bolt must be forged with superfluous metal on the stem; the lining for centring can then be done with a calliper, with which four short lines are marked, similar to those in Fig. 1087, both ends being thus treated.

All comparative long bolts are rotated with ordinary carriers, because, while they are on the lathe-pivots, ample room exists between the mandril-frame and the poppet-head to allow the traverse of the carriage to and fro the required distance. Carriers or grippers are always preferable to el-shaped drivers, if the articles to be turned are long enough to allow the carriers room in which to rotate without coming into contact with the lathe-carriage.

Connecting-rod bolts and several others are furnished with stems having curved junctions resembling that shown in Fig. 1093. The formation of this curved portion is entirely effected by lathe-turning, unless it is to be extra large, in which case the bolt must be thickened at that place, to avoid using iron of large diameter, and thereby causing great reduction of the entire stem.

Bolt-ends.—The shapes usually adopted for ends of bolts are indicated by Figs. 1094, 1095, and 1096. Bolt-ends should be formed to their respective shapes and sizes with turning-tools, previous to beginning the screw-cutting, in order that unnecessary screwing of the ends may be avoided. After the screws are entirely finished, each extremity or point should require merely a smoothing with light cuts, or with polishing, to complete it.

The bolt-end denoted by Fig. 1094 is that suitable for the greater number of all the bolts which are made, whether small or large, screwed, or without screws. It will be seen that the entire point or curved extremity in this Figure has the curve of a semicircle for its boundary. Such a form presents an elegant appearance, and also allows an abundance of metal to guard against injury to the screw.

In Fig. 1095 the end has a comparative short portion extending beyond the screw, and is suitable when but little room exists at that place while the bolt is in use. An end of this character also allows a pin-hole to be made therein, if it is specially desirable to prevent the nut's rotation after being adjusted.

Fig. 1096 shows an end having a point of comparative great length, in which a key-slot is made to admit a key. Plenty of metal also exists in such an end to prevent injury to the screw's end, and to allow a great amount of hammering without doing much damage. Such an end is therefore suitable for any bolt which is liable to become fixed tight in its hole, and which must at some time be removed without thickening the point to any great extent, which would prevent its being driven out.

In Fig. 1099 two nuts are shown on one bolt-end. The outer nut is termed a lock-nut, because it is intended to fasten the nut next to it, and thus prevent it shifting on its bolt. The efficiency of a lock-nut depends on its amount of screwed surface, and therefore depends on its thickness or height. It is more likely to fasten its companion in proportion as it possesses greater screw-surface or friction-surface. If it is no thicker than the inner nut, it cannot fit the bolt tighter, unless the outer one has a smaller screw than the other. A lock-nut should not, in any case, be thinner than its companion, but can be as much thicker as the length of the bolt-screw will admit. A thin nut is always more liable to shift than a thick one, because of the smaller amount of screwed surface in contact with the bolt, and because of the difference between the pitch of the bolt-screw and that of the nut-screw.

Plummer-block Bolts.—Bolts for pillow-blocks are turned so that their intermediate parts are no larger in diameter than the smallest diameter of the screws. A bolt of this sort is shown by Fig. 1101, and is lighter, more flexible, and less liable to break than one having a cylindrical mid-part of the same diameter as the screw, such as that in Figs. 1103 or 1090. There are also several other classes of bolts which should be thus treated, such as framing-bolts and those for entablatures, indicated by Fig. 1103.

Bolts for pillow-blocks and framing-bolts also require screwed holes to be formed in their ends, for the convenience of lifting them. A bolt-end of this sort is indicated in Fig. 1104, having a loop-bolt in the end, ready for lifting. The outer diameter of the loop must be less than the diameter of the bolt-hole in the framing, or pillow-block, because when the lifting-bolt is in its place it must pass through the framing previous to the bolt being lifted.

The small hole for the loop-bolt may be made either before the large bolt is turned, or afterwards, when the screwing is finished and the superfluous piece cut off, if any exists. If the small hole is made previous to turning, it serves instead of a conical recess; and in such a case, the rugged extremity of the bolt must be properly reduced, and whatever extra length exists must be cut off previous to drilling the hole. The exact place in which the hole is to be drilled, is shown by the lining, previous to centring, and while entering the drill it needs keeping in the intended centre of the bolt; because if the hole is made in the wrong place it will be necessary to put a short bolt into the hole and to centre this bolt.

Screw-cutting of Bolts.—The junction of a bolt-thread with the remainder of the stem should be taper, being so formed that the depth of the thread-groove may gradually decrease along about two steps, thus preventing the thread-groove being as deep at its termination as at any other place along its length. This gradual enlargement of the bolt at the bottom or base of the thread renders it less liable to break than if it terminated suddenly; but a little extra length of thread is requisite, and this is the only objection to the tapering-process. The three screws shown by Figs. 1094, 1095, and 1096 are tapered in this manner; but the two shown in Figs. 1097 and 1098 are nearly or quite parallel from one end to the other.

To facilitate the making of a screw parallel very nearly to its termination, a shallow groove is formed at the proper place, similar to that seen at the termination of the thread in Fig. 1097. Such a groove would suit a connecting-bolt, if the screw were required to be parallel; and it is formed previous to beginning the screw-cutting. The width of the groove is about equal to the step of the thread, and the depth of it is about three-quarters of the intended thread-groove's depth. A groove of this shape is very efficient to avoid tapering the screw, and is suitable for any bolt which is to have a comparative large or coarse thread.

Fig. 1098 represents a joint-bolt, or pivot-bolt. The cylindrical portion situate between the head and the screw is that which is to sustain the rod-boss, lever-boss, or other portion to be connected, and the screw is to hold a nut, or two nuts. While such a bolt is in use no strain is exerted upon the screwed end, and it may therefore be smaller than the intermediate part, and may have also a comparative large groove at the thread-junction, similar to the one shown in the Figure, to facilitate the screw-cutting.

Outside Screw-tools.—The process of cutting a large vee-shaped thread on a bolt is analogous to the cutting a similar thread in a nut. If the thread required is an ordinary Whitworth-shaped thread, the pitch, the diameter required for the bolt at the bottom of the thread-groove, and the requisite screwing-wheels, can be ascertained by referring to Table 5, page 177. This Table is only useful if the required screws do not exceed three inches in diameter, and the bolt-screws are to be produced previous to screw-cutting or tapping the nuts. Whenever large bolts of four, six, or eight inches in diameter are to be screwed, the nuts should have been previously screwed, and should be now available for measurement, in order that the bolts may be accurately fitted.

When the particular nut is selected for the bolt-screw to be cut, it must be measured with two gauges, if its size is not known, a pointed wire gauge, and a sheet gauge. These two must be specially made for the purpose, unless two such gauges exist to which the nut has been screwed, and the operator has access to them; but supposing that he possesses these gauges, and also possesses the necessary outside screw-tools, he can proceed with the screw-cutting without other measuring tools, except an outside calliper with thin points.

The outer diameter required for the bolt-screw is known by the length of the wire gauge, and considering the pitch of the thread, a diagram being formed which is similar to those for nut-screws, shown by Figs. 1066, 1068, and 1077. While using such a diagram, the wire is placed upon the Figure in the place occupied by the line D; or the gauge can be carefully measured with a calliper, and the calliper placed upon the line. It must be here mentioned that the diagram is not first made, and the gauge made to it, as for the screw-cutting of a nut; but the gauge is first placed upon the board, and the Figure, or at least part of it, is made to the gauge. To do this, the straight or primary line shown in Fig. 1066 or 1068 by L is first scribed, although it need not be of any exact length, if it is as long as the gauge. One extremity of this line is next selected as a centre, to which one point of the gauge is put. While one point is thus placed, the other end of the wire is moved or inclined away from the line L, until exactly as far from it as the step of the thread. As soon as the wire is thus accurately placed, it resembles or represents the diagonal D before referred to; and an el-square is to be now put upon the board so that the pedestal shall exactly coincide with the line L, while the blade exactly touches the point of the wire, but without moving it away from its inclined position with the line L. If this is carefully done, that length of the line included between the square and the extremity of the gauge which touches the line is the diameter to which the bolt-end must be turned previous to beginning the screw-cutting.

The sheet gauge referred to is necessary to indicate the depth to which the thread-groove is to be cut, and its diameter is rather less, strictly speaking, than the diameter of the screw at the bottom of the thread, if measured with a thin calliper; but this gauge will be found quite sufficient to correctly denote the depth of any ordinary vee-thread when the nut can be tried upon the bolt previous to finishing it. The calliper is therefore adjusted to the gauge, and the bolt measured without removing it from the lathe-pivots.

The screw-cutting commences with a vee-point tool having an angle of sixty-five or seventy degrees; consequently, its point is similar to that of a tool for beginning the screw-cutting of a nut. This tool is used until the width of the thread-groove made is about five-sixths of the ultimate width, when it is removed from the tool-holder and another fixed in its place having an angle of fifty-five. The thread-groove is with this tool, deepened to the desired depth indicated by the sheet-gauge; but only a small amount can be taken off the sides of the thread, because of the broad-point tool previously used having removed so much metal from the groove's mouth.

During the use of the single point-tools, they should be caused to cut alternately at both sides of the thread, in the manner described for screwing a nut; and this process can be more conveniently adopted while screwing a bolt, than while screwing a nut, because the operator can more plainly see the condition of the thread.

The final shaping and smoothing of the bolt screw is performed with a tool having two teeth; but this should not be used until the thread-groove is deepened to its ultimate depth, in order that the finishing tool may not cut anything whatever from the bottom. It is therefore necessary to carefully measure the bolt at the bottom of the thread, by means of the calliper having thin points, and to finally deepen the groove with a single-point tool, whose extremity is properly curved to produce the requisite form. If this is properly done, the finishing tool will cut easily without being likely to tear or injure the thread, because the points of the tool cannot bear upon the bolt in any way, the entire cutting of this tool consisting in removing metal from the summits and sides of the thread, without taking any metal from the bottom.

It is to be also noticed that if a comparative large vee-thread is being cut, such as one having only three or four steps per inch, it is necessary to make the tool with two teeth cut alternately at both sides of the thread, as if a single tooth were in use, in order to avoid the considerable friction occasioned by the two teeth being in contact. But while finishing a small thread, it is seldom necessary to alter the tool after it is at first adjusted.

Outside screw-tools are represented by Figs. 1105, 1106, 1107, 1108, and 1109. The one shown by Fig. 1105 has a single point having an angle of seventy degrees, and therefore is principally used only for beginning all vee-threads in general, unless a thread is to be made the sides of which are to subtend an angle of seventy degrees, in which case, such a tool will both commence and also finish the screw-cutting, if circumstances require such a course.

Fig. 1106 denotes a tool having a point of fifty-five degrees, the extremity of the cutting part being curved to the exact shape required to produce the Whitworth-threads. The tool shown by Fig. 1107 is similar to Fig. 1105, but its point has a sharp extremity, to render it suitable for a thread that requires a sharp angular bottom for the thread-groove, instead of the usual curved bottom. The actual sizes of the cutting parts belonging to these, and other slide-rest screw-tools, is dependent on the sizes of the lathes to which they belong, and the sizes of the threads to be cut.

Fig. 1108 represents a tool having two teeth, and Fig. 1109 denotes one with three teeth. Both these are used for finishing threads which have been partly shaped with single-point tools; but the tool with three teeth is employed only for very small screws, such as those having twelve, fourteen, or a greater number of steps per inch. For the finishing of all larger threads than these, tools with only two teeth each, are amply sufficient. The larger the thread being cut, the greater is the friction of the screw-tool, and the greater is its liability to dig forcibly into the bolt or other object, and do mischief.

TREATMENT OF CROSSHEADS.

There are three principal sorts of crossheads,—comprising the old crosshead having two comparative broad flat arms, the crosshead which is circular and is shaped entirely with lathe-turning, and the two piston-rod crosshead employed in marine engines.

LINING AND CENTRING OF CROSSHEADS.—At the conclusion of a crosshead's forging, it should be carefully straightened while yet in the smithy, by means of a large anvil or table situate beneath a steam hammer, such as the table shown in Plate 19. While on the table the crosshead is supported on iron or steel packing blocks; these are put beneath each arm, and are situate, either near the boss in the middle, or near the two pivot-ends, according to whether the arms are bent near these ends, or bent near the boss. After being properly straightened and made about equally soft along its entire length, by being equally heated and allowed slowly to cool, the article is ready to be lined and centred for lathe-turning.

However large the crosshead may be, or however much superfluous metal it may possess to be cut off, it should be turned previous to being planed; unless it happens to be a two piston-rod crosshead, in which case, the planing should be done previously to the turning.

To perform the lining, the object is put upon a lining-table of suitable dimensions, and scribed with the scriber-block, which rests on the table. During this operation it is situate with parallel blocks in contact with its two arms, as indicated in Fig. 1110; and while on these blocks it is adjusted to parallelism with the table. To do this, a few arcs are marked upon the narrow sides or edges with a calliper, in order to find the centres of a few places along the surfaces. In Fig. 1111 such marks are seen, each set of marks consisting of a couple of arcs having a short straight line midway between. Both edges of the crosshead are thus marked, the short centre lines being easily scratched with a scriber as soon as the arcs are made with a calliper, in fact, a mere dot with a dotter is sufficient. The dots or centre marks thus obtained, represent a few points in a sort of primary line extending entirely around the crosshead; and constitute points which are to be put at about one height from the table, which is done by placing packing-pieces and wedges of proper thickness beneath the arms, and by referring to the point of the scriber-block standing on the table.

As soon as all the centre-marks are put as nearly parallel to the table as their relative situations will admit, the crosshead's broad sides are, by the same act, put parallel with the table, supposing that they are parallel with each other; but if not, both the upper sides, and the lower sides, are equally inclined to the table, in consequence of the centre of both narrow sides having been found, and adjusted to the scriber-point. The crosshead is, therefore, in position for partly scribing the centres for turning, and the point of the block's scriber is next adjusted to the mean height of all the centre-dots, and then placed to scribe a short straight line upon the outer extremity of each pivot-end. In Fig. 1110 one of these lines is seen, and the places for the desired centre-recesses are partly indicated.

The centres being now marked, with regard to the narrow sides, it is next necessary to indicate the centres with regard to the broad sides. For this purpose, the crosshead is lifted and stood edgeways upon the table. At the second placing, it is not requisite to adjust either of the broad sides exactly square to the table, or square to the previous situation of the crosshead; but it is requisite to place the centre length of the broad sides parallel with the table, that the axis on which the crosshead will rotate, may be in line with the centre length. Callipers are therefore used, as before, to scribe a few couples of arcs, which are shown on the broad side in Fig. 1112, a dot being put between each two arcs to mark the centre length. These dots are used in the same way as those on the narrow side, the point of the scriber being adjusted to the mean height of all the dots, as soon as both ends of the crosshead are put equidistant from the table. By now scribing a short line upon each outer extremity of the pivot-end, causing them to intersect the two lines marked at the previous scribing, a couple of crosses are delineated, one of which is denoted in Fig. 1113. A dot is now put into the centre of each cross, which indicates the exact places for the desired conical recesses.

The mode of centring just given, is suitable for any crosshead which is so forged as to possess the usual amount of superfluous metal on the pivot-ends. By centring the object with regard to the arms, it is presumed that these are the portions having the least amount of metal to be cut off; but if it happens that the pivot-ends and the middle boss have but little extra metal, these must be considered in preference to the arms. The lining, in this case is, therefore, performed by placing vee-blocks beneath the ends, instead of placing flat blocks and wedges beneath the arms. When vee-blocks are used, the finding of centres along the arms with a calliper, and adjusting the scriber-block thereto, is dispensed with; but it is necessary to find the centre of each face of the middle boss, with a calliper, and to adjust the scriber-point either to these centres or to those shown by rotating and reversing the crosshead on the blocks. To ascertain which of these are to be regarded, the operator discovers, as in other cases, which portion is forged nearest to the desired size.

The first centring of a circular crosshead is, in any case, effected with vee-blocks. The blocks are put beneath those portions which are somewhat nearer to the specified dimensions than the other portions; and because the boss in the middle, and the junctions of the arms, are the parts which should be nearest to the intended diameters, the vee-blocks should be in contact with such parts, as indicated in Fig. 1114. This will cause the centres to be scribed without regard to the ends, which have an abundance of metal, and which can be much easier turned than the mid-portion.

The first centring of a two piston-rod crosshead, is conducted with regard to its planing; and the lining can therefore be executed while the article is on a planing-table. The position in which the object is first placed, if on a planing-machine, is that indicated in Fig. 1115, its length being across the length of the table, and the intended flat sides of the arms situate upwards. In this condition, without any lining, the crosshead is ready for commencing the planing, supposing it to have an abundance of superfluous metal. But if it is forged somewhat near the dimensions, it requires to be now lined, in order that the upper surfaces may be planed exactly to the lines, and thereby finished at the first planing, so as not to require any additional fixing in the same position at some future time in course of shaping.

To properly mark the lines for planing, a primary centre line is first scribed around the sides, and this line is that which is to be put parallel with the table during the first fixing. The primary line or periphery is analogous to the dots which were stated to be necessary for adjusting an ordinary straight crosshead; but while scribing the crosshead now in hand, it is necessary to plainly show the entire line by scribing with a scriber-block, and to dot the line afterwards. A crosshead of this class is usually forged with a large amount of superfluous metal, being but very little bent, and in some cases, not at all, the object consisting of a piece whose shape resembles that in the Fig. 1115. Consequently, it is seldom necessary to scribe the first line with regard either to the mid-portion, or to the ends for the piston-rods; but, if the line is marked, it becomes a means of planing the arms to a proper thickness.

In order to adjust the crosshead into the proper position for scribing, it is raised gradually with plates and wedges, the wedges not being, in any case, in contact with a table, and therefore not capable of injuring its plane surface. This wedging-up is continued until the surfaces of the parts to be planed are somewhat near to parallelism with the table, which condition is known by means of a tall scriber-block having a scriber with a bent end. The block, while on the table, is put at various sides of the crosshead, and the bent end of the scriber is placed and fixed at a suitable height above the rough surface, to enable the operator to see whether the scriber's point is at about the same height above the crosshead while standing at any side.

The article being now put parallel, is ready for marking the centre line. The place for this line is found with a calliper, which is used in about the same manner as described for finding centres along the arms of a straight crosshead. The marks made are seen in Fig. 1115, and are easily made while the article is on the packing-pieces, because its lower side is then a few inches above the table, and therefore allows the end of one calliper-leg to be put close to the lower surface, as required while marking. These centres or middle points being shown, the scriber-block's point is next adjusted to the mean height of all the dots, and the periphery is marked around. From this line the specified thickness to which the arms are to be planed can now be marked, upwards and downwards, which completes the lining for this occasion. The crosshead is now ready to be fixed with plates and bolts; and if it does not greatly alter its position while tightening the plates, it is ready for planing as soon as fixed. If it is specially desired to fix it with regard to the lines, the wedges are adjusted accordingly, previous to finally tightening the bolts.

The first planing of the crosshead consists in reducing it to the upper gauge-line, and planing one face of each of the two bosses for the rods; after which it is put upside-down, and reduced to the opposite gauge-line, and the other two faces of the bosses are planed. This reduces the arms to the proper thickness, and the bosses to the proper length. At the fixing for the second planing no wedging-up is required, because the already planed surfaces are put upon parallel blocks, which immediately places the planed surfaces parallel with the table.

When two opposite sides have been planed the crosshead is ready to be fixed against an el-chuck, which is bolted to the planing-table in order to plane the two sides of the arms not yet planed. These are the crooked or curved surfaces of the arms, and because one of the previously planed surfaces is against the el-chuck, the curved side will be planed square to the flat side or edge. To indicate the intended shape another lining is now necessary; and during this planing the crosshead is shifted about four times to obtain the proper form. For a large crosshead it may be preferable to use two narrow el-chucks instead of only one comparative wide one; these can be so situate on the table that the middle boss can be put between the two chucks, as denoted in Fig. 1116, which arrangement will obviate the necessity of placing parallel blocks between the chuck-face and the arms, to keep the middle boss from touching the chuck.

After the four sides of each arm have been planed the centring for lathe-turning can be properly executed. This also can be done on the planing-table by the aid of parallel blocks, el-chucks, and a tall scriber-block. The centring is partly effected while the object yet remains against the el-chucks, in somewhat near the position it occupied during planing, but with the arms properly inclined to the table, the exact position being shown in Fig. 1116. While in this condition the faces of the piston-rod bosses can be also lined, to show the centres for the holes. By this mode the centres for the axis of the large boss in the middle, and the centres for the holes in the end bosses, can be accurately marked at the proper distances from each other. The first scribing should consist in making a short line upon each of the superfluous centre-pieces, which are seen to project from the arms in the Figure (1116), and are allowed to remain solid with the arms until lathe-turning is finished. To adjust the scriber-block to the proper height for this marking it is first adjusted to the top and bottom surfaces of the planed junctions of the arms, and a couple of lines are marked upon the thick mid-portion, which lines are equidistant from the centre or axis required; the middle point is therefore found with a calliper, and the scriber-block's point is adjusted thereto, for marking the centre-pieces or ledges, as intended.

The lines which are now scribed on the ledges indicate the exact height of the axis for the middle boss; and from this, above and below it, the vertical distance to the intended centre of either face of the end bosses can be scribed. For this purpose a three or four feet measure is employed, and stood upon the table to measure the exact height of the axis, or the height of the scriber-point from the table. We now suppose that this height is twenty-four inches, and that the vertical distance between the centre of the middle boss and the centre of either end boss is specified in the drawing to be fourteen inches. This fourteen inches is to be added to the twenty-four inches, making three feet two inches, which is the height above the table to which the scriber's point is to be adjusted for scribing the two faces of the highest boss. To mark the faces of the lowest boss, the fourteen inches is subtracted from the twenty-four inches, which gives ten inches as the height above the table at which the scriber is to stand for scribing.

When the crosshead has been thus partly scribed, it is removed from the el-chuck, or chucks, if two were used, and it is put upon parallel blocks to complete the marking for the centre-recesses. The blocks are placed beneath the planed flat surfaces of the arms, and are of sufficient height to keep the mid-part from touching the table. Each of the centre-pieces or pivot-pieces is to be now marked with a couple more lines to complete the indication of the places for the centre-recesses, one line of each couple being marked while the crosshead is in one position, and the other line being marked after the crosshead has been put upside-down. But for a heavy crosshead, this reversing should be avoided, and it is preferable to accurately measure from the edge of the planed surface to find the place for the centre, and adjust the scriber-point thereto. By this method only one line is scribed upon each extremity, and the object is not reversed.

The centring of a two-piston-rod crosshead, can be done also while it is on a slotting-table, if it is large enough in diameter. This plan is to be adopted for a crosshead which is very crooked, in which case the crooked surfaces of the arms are obtained with the slotting-tool instead of by planing; the planing of such surfaces is more suitable to a crosshead having comparative long arms, and which is nearly straight. Previous to placing the crosshead upon a slotting-machine, it should have been planed on a planing-machine to make its two flat sides parallel with each other, and to make the arms of a proper thickness. It is next lifted up and put against an el-chuck, and lined while on the planing-table, or on the slotting-table, if large enough.

When the centres of the end bosses have been shown, the outside of the bosses can be reduced to circular lines scribed thereon; the curved junctions also can be shaped; and the straight mid-parts of the arms also shaped; all these operations being effected with slotting-tools while the crosshead remains on the slotting-table with its planed surface situate parallel with the table—in the same position as that which it occupied while it was on the planing-machine.

Turning of Crossheads.—Crossheads should be turned previous to boring the holes in the bosses, because it is easy to adjust a crosshead correctly for boring, by means of its uniform surfaces, which are produced by turning. A crosshead having but one piston-rod, is bored while fixed on a lathe-chuck, and a crosshead for two piston-rods, is bored while on a vertical driller; but by whichever mode the boring is to be performed, it will be found advantageous to execute the turning, and, in most cases, the planing also, previous to boring.

At the commencement of the rough turning of a crosshead, it is necessary for the turner to measure from the centre of the boss in two directions, when marking the places for the shoulders, bearings, and junctions. For this purpose, pointed wire gauges having bent ends of proper length are used; such gauges being requisite when the objects to be measured possess surfaces which are not level with each other.

Previous to measuring with gauges the crosshead is truly turned along its entire length; and when proceeding to mark the shoulders, a centre-dot is put about midway between the two faces of the middle boss, supposing that the hole is not yet bored. This dot is shown in the middle of the boss in Fig. 1117, and its place is found with a calliper, with which the four arcs seen on the boss are made by placing one calliper-leg to each of the four corners or junctions shown by the letter J. But when it happens that the hole in the boss has been accurately finished previous to turning the ends, the turner measures from the centre at the end of the hole, which is denoted on an ender fitted therein. In any case it will be easier to first turn the ends, and afterwards bore the middle hole square to the turned parts, than to first bore the hole, and next turn the ends so that their axes shall be square with the hole. The centring operations required for this latter purpose are described in another place.

The narrow sides of a crosshead's arms require to be turned with a slide-rest having a circular movement, in order that the requisite curved form may be obtained in an easy manner. But if the lathe employed does not possess such a rest, the curved form for the arms must be produced with the ordinary top slide of the rest, which is used in about the same way as for turning straight cones. By this mode, it is necessary to first scribe curved lines along one broad side of the arms, to accurately show the intended shape and dimensions; after which the metal is cut off to the lines by means of a series of turnings with the slide-rest, but with the top slide inclined at different angles with the lathe-spindle; only a part of the arm being turned with one adjustment of the slide.

The turning required for a two-piston-rod crosshead, is that by which its middle boss is made cylindrical and to fit the bearer-brasses belonging to it; also to properly form the collars and shoulders of the bearing to suitable dimensions, and to the required distance from the end-bosses. The middle boss is first reduced until its diameter is rather greater than the finished diameter of the two collars, or flanges, when it can be marked to show the exact places for the two required shoulders. If the crosshead has not been shaped on a slotting-machine, and therefore its end-bosses are not yet reduced to the finished dimensions, the exact situations of the two shoulders of the large bearing are not of great consequence, because the distance from a shoulder to the centre of the hole in either end-boss can be easily shown after the shoulders are accurately turned by placing a straight-edge thereto. But if the end-bosses are finished, or if they have but very little metal to be cut off, the crosshead should have been accurately lined with regard to the centres of these bosses in order that the shoulders of the mid-bearing shall be made in the proper places.

SHAPING OF LINKS.

The shaping here specially referred to, is that by which the curved slots of valve-links are produced. But it will be necessary to briefly mention also the planing of their broad sides, and the slotting of their outer edges or narrow sides.

Link-slots are so formed, that when newly produced, their curves constitute portions of circular arcs which are parallel to each other; consequently, the width or distance between the two sides is the same as at any place along the slot. It may be also mentioned here, that nearly all link-pieces when just forged, consist of flat bars or slabs of steel or iron devoid of any slot or hole whatever.

There are four modes of shaping links, and the mode which should be adopted in any one case, depends on the resources of the maker, and the number of links he may have to shape. A link-slot can be easily formed with drilling, chipping, and filing, without using any other shaping apparatus. Slotting a link, while on an ordinary slotting-machine, is also resorted to. A link may be slotted also while on a lathe-chuck; or while on the table of a short-stroke slotting-machine specially adapted to the purpose.

A piece intended for a link is first planed to make both broad sides parallel with each other, and reduce the piece to a suitable thickness. To hold the piece during planing, it may be provided with a couple of holders or handles, one at each end, and forged solid with the link-piece; or it may have a couple of holes drilled in some part of the place which will become the slot, these holes being provided with recesses which are large enough to contain nuts. A link thus held for planing is shown in Fig. 691. After the planing is completed, one of the broad sides is scribed to show the intended outer shape of the link, and to show the place and shape of the slot. This scribing is executed by means of a template, if a number of links are required to be of the same shape and size, to avoid the necessity of marking each one separately. But to scribe a link-piece without a template, it is put upon a table of sufficient length, and the arcs are marked with a radius gauge, one point of the gauge being put into a dot which is made into a block on the table, the block being of the same thickness as the link, and fastened on the table at a suitable distance from the link.

Although link-slots are finished by one of the four modes mentioned, they are always principally formed with drilling, vertical drillers being used for the purpose. The amount of metal removed with drilling is thirty or forty times the quantity taken out with either of the finishing processes, and there is no other class of machines which will so quickly remove the superfluous metal.

When a link has been lined, the drilling is performed both to produce the slot, and to remove the greater portion of the metal from the link's outer edges, if sufficient metal exists at the edges to admit a drilling. The drilling for the outer edges consists in making a row of small holes around the link close to the gauge lines. For drilling the slot, the mode selected depends on the size of the work. If the required slot is to be only about an inch and a half wide, a single row of holes are made along the middle of the slot, with a drill about a quarter of an inch smaller in diameter than the slot's width. But a slot of two, three, or more inches in width, is formed by drilling two rows of small holes, one row at each side, and also a few other small holes, or one large one, at each end. The drills used for this purpose need not be more than half an inch or three-quarters in diameter; and by such drilling, nearly the whole of the slot-piece can be removed in one lump.

In order to completely detach the slot-piece it is either chiselled or slotted. If the piece is small it is gripped in a vice, and the thin portions between the holes are cut through with a hammer and chisel. But if the link is to be machined, the slot-piece is removed in the course of shaping with the slotting-tools. A mortiser or a grooving-tool of proper width is first fixed and caused to cut two narrow slots or channels along the places occupied by the holes, thus removing the thin portions between the holes, and therefore the entire slot-piece also.

One of the modes referred to for accurately finishing a link-slot, consists in fixing it upon a slotting-table having a circular movement, and paring the slot-sides with a tool during the gradual movement of the link with the table. Any slotting-machine having a table of sufficient diameter can be used for this purpose, the link being fixed on the table so that the curves of the intended slot are exactly concentric with the table's rotary motion, and therefore concentric with the parallel circular gauge-lines existing on the table. In order to keep the link at a proper height above the table to allow room for the slotting-tools, and to keep its planed broad sides parallel with the table, it is put upon parallel blocks which are situate along each edge of the slot, and very near it, being only far enough from the edges to allow room for the cutting-tools to extend through without touching the blocks. Holdfast-plates are now placed at the outer edges, and the link is adjusted with poppets which are fixed to the table. To ascertain the exact relative position of the gauge-lines a pointer is fixed in the tool-holder, so that its point is very near one of the lines, and the table and link are next partly rotated while the observer watches the progress of the line beneath the point. As soon as the point is seen to exactly coincide with the line during its entire passage beneath the pointer, the link is adjusted. The slotting can therefore now commence, and one side of the slot can be finished.

In order to finish the opposite side of the slot, the link is shifted, and again adjusted; but this time to the opposite line, that the side having this line may be put near enough to the tool. After each fixing of the link, it is necessary to adjust the tool also; because, when an ordinary slotting-table is employed, it may not be capable of the movement suited to the adjustment of such objects as links.

Another of the modes for finishing a link-slot, consists in shaping it with a small slotter which is specially adapted to the purpose. This machine resembles any other slotter, excepting that its table is not capable of being entirely rotated, and that it is furnished with an extra couple of slides and adjusting screws, for adjusting the links to suit the situations of the slotting-tools. The table need not be circular; it is sufficient if it consists of about a quadrant; consequently, instead of requiring a complete circular worm-wheel, about a quarter of one would suffice. By adopting such a table, the amount of room which would be occupied by a round table is economised. In addition to the movement for accurately adjusting a link beneath a slotting-tool after the gauge-lines have been put concentric with the circular motion, the tool-holder also should have a movement by means of an adjusting screw to properly place the tool.

Another mode for accurately finishing a link-slot now remains to be mentioned, in which the use of a lathe is involved. This is a convenient mode if a lathe having a large disc-chuck is available. The link is first drilled to remove the greater part of the metal, as before stated, and is next attached to the lathe-chuck by means of parallel blocks, the blocks being first fastened to the chuck, and the link next fastened thereto with plates and bolts. The exact part of the chuck occupied by the link depends on the radius of the link's curves. Only one adjustment is sufficient for the shaping of both sides, because the slide-rest will adjust the tool after the link is fixed; and while being adjusted, the point of a tool held in the tool-holder is situate very near one of the gauge-lines. The lathe-chuck is now partly rotated to and fro by one or two assistants, while the operator observes the relative position of the point and the curved gauge-line. To shift the link easily and exactly to its proper place, a few poppets are fastened in the chuck, near the link, which poppets are very small, because the object is not to be mainly held with them, but with the holdfast plates on the broad sides. These plates can be very firmly tightened upon the link without distorting it; whereas, poppet-screws are liable to alter the shape of the entire link, if screwed too tight. It is, therefore, necessary to exactly adjust the object by the gauge-line previous to finally tightening the holdfast bolts.

This method of slot-shaping with a lathe, can only result in paring the metal from the slot-sides; the ends must be shaped by other means, either by chipping and filing, or by slotting; and in either case, they should be finished previous to fixing the link to the lathe-chuck. In addition to finishing these ends, it is also requisite to finish a short portion of each of the two sides, at both ends of the slots, in order that the cutting tools may have room to enter into and disengage from the metal.

When the link is attached to the chuck, the operation of slotting consists in partly rotating the chuck to and fro a proper distance, while a slide-rest tool is in contact for removing the metal. The tools employed are ordinary borers, the ends of which are right-handed and left-handed, to cut both sides of the slot. The chuck is moved to and fro by the assistants, who actuate the chuck by working the leather band, or by rotating one of the power-spindles belonging to the lathe spindle-frame, the end of such spindle having a square part that fits a handle. In order to prevent the chuck being moved too far in either direction, and thereby breaking the tool or doing other mischief, a couple of stops are fixed in the chuck at a proper distance apart; these are situate at the chuck's lower edge, and are caused to come into contact with the lathe bed's side, or into contact with a couple of brackets or plates bolted to the bed.

To cause the slot-sides to be parallel with each other, and also square to the broad sides of the link, when the slot is finished, the top slide of the rest is adjusted, so that its length is square to the chuck-face, and this one adjustment of the rest is sufficient for the shaping of both sides. But it is also, in most cases, requisite to further adjust the rest, after both the slot-sides have been shaped and nearly finished, at which time the slot is measured with an inside calliper, and the slide rest is altered accordingly.

During the upward or backward motion of the work, the tool-point is in contact with the metal, the same as during the downward movement, although it does not cut; and to prevent the point of the tool breaking during the up-stroke, it is necessary to use a tool having a thick strong stalk, which is less liable to bend and dig into the metal than a tool having a slender stalk.

After a link-slot has been shaped by one of the methods here indicated, the link is completed by paring its outer edges. The most suitable machines for this purpose are shapers and slotters; and the link is fastened on the table with two or three holdfast plates having bolts extending through the slot of the link.

The boring of a link consists in accurately forming its circular holes with a vertical drilling-machine. These are first roughly drilled with ordinary drills, and afterwards completed with rosebits, which will produce holes having smooth surfaces, and which are square to the link's broad sides, as desired. The boring of these holes can be finished either previous to the shaping of the outer edges or afterwards.

MIDDLE-SHAFTS AND PADDLE-SHAFTS.

Centring of Shafts.—Straight middle-shafts, paddle-shafts, piston-rods, and other heavy forgings of similar shapes, are all centred in about the same manner. The centring of such a piece is performed while it hangs suspended with a portable crane, which is placed over the lathe for the purpose, and is the means of conveying the shaft to the lathe. To avoid unnecessary placing of the object to and from the lathe-pivots, it is centred so that the centre-recesses shall be exactly in the desired places to cause the shaft to rotate truly the first time it is put into the lathe.

The tools required for centring a shaft are callipers, a rectol, a scriber, a monto, and a fiddling drill and coner to form the recesses. A chipping-chisel also is usually requisite, to flatten a small surface at the middle of each shaft extremity, and make it tolerably square to the length. If a shaft is tolerably straight, and has an abundance of metal to be turned off, the place for each centre-recess can be found with a calliper only, the legs of which are separated to a proper distance for scribing four lines similar to those seen in Fig. 1087. Previous to centring with a calliper, the condition of the article must be ascertained with a long straight-edge, and the hollow or concave parts discovered. These being shown, the operator can, after he has found the centre of each extremity with a calliper, alter the dot to suit the concave part or parts discovered with the straight-edge.

Centring a shaft with a rectol is a rapid and accurate mode of showing the places for the recesses, and is suited to any roughly forged shaft, or one which may be crooked. The length of the rectol used for this purpose is suited to the length of the shaft, and is furnished with a gap, or two gaps, of ample size, into which the bearing-flanges or collars of shafts can extend while the instrument is in contact with the objects to be centred, supposing that they are forged with the collars or flanges referred to. One such gap is usually sufficient for two flanges, if of proper length, and one long gap in a rectol is more useful for general work than two shorter gaps. The rectol is placed upon the shaft so that the outer portion is in contact with the shaft extremity, as denoted in Fig. 1119, four marks being made with a scriber in the same manner as for the centring of a bolt, described in page 348.

There is also a mode of centring with a straight-edge and parallel blocks. This method is analogous to the centring with a rectol, but is not so convenient, because of the blocks being distinct from the straight-edge, and therefore liable to fall about while in use. Blocks are available when a gap straight-edge of sufficient length is not accessible, and it is thought unnecessary to make one. In Fig. 1121 the implements for this centring are seen in use, the two parallel blocks being first put upon the shaft, and the straight-edge next put upon the blocks. One end of the straight-edge is situate over one end of the shaft, and while held in this condition by an assistant or two, a calliper is adjusted to place its points about as far apart as the distance between the top edge of the straight-edge and the centre of the shaft-end, which distance is denoted in the Figure by the dotted line which connects the two dotted lines T and M. One point of the calliper-foot is now put upon the top of the straight-edge shown by T, and held there in about the same manner as a compass-point would be held in a centre-dot, and the other point of the calliper is caused to make a short arc upon the shaft-end. This effects the lining in one position ; and the straight-edge and blocks are next shifted to about a quarter of a revolution around the shaft, and again held in position for another mark. After this two more marks are made by similar means ; and all the four are made while the calliper-legs remain at the same distance apart.

The four marks thus scribed indicate the centres of those portions of the shaft upon which the blocks were placed for scribing ; consequently, to centre any stated portions of the shaft it is only necessary to put the blocks into contact with those portions.

Long shafts can be centred also with a monto. This is an instrument devised by the author, and is applicable to a number of purposes, including centring of shafts. The tool is represented by Fig. 1118, and consists of a straight-edge having a pair of vee-blocks attached. The stem of each block is furnished with an opening having smooth parallel sides, which admit the straight-edge and allow the blocks to be slid along and fastened at any desired place. It is necessary for the edges of the straight-edge to be parallel with the lower edges of the blocks and also the entire surfaces of the vee-gaps; and after the blocks have been shifted to the intended places, they require to be fastened either with taper keys or with a couple of fixing screws.

A monto is used in the same manner as described for a pair of parallel blocks and a straight-edge; but it is much more convenient because its blocks cannot fall from the implement; it can, therefore, be easily held either at the top, side, or bottom of a shaft while it hangs suspended over the lathe, or while it remains on the lathe-bed or floor. The marks which are scribed upon ends of shafts by means of a straight-edge, a rectol, or a monto, are similar to those marked with callipers, and are seen in Fig. 1120.

Centre Recesses.—The two conical recesses of a large shaft require to be well formed in order to freely admit oil to the lathe-pivots, and to avoid injurious wear of the friction surfaces, and thereby prevent the liability of some finished part of the shaft rotating not concentric with some other finished part.

If the centre-recesses of a shaft or other article are properly shaped, the article will rotate as truly in one lathe as in another, although the angle of the pivots belonging to the one lathe may differ greatly from the angle of the pivots in the other lathe. The angles of the recesses in any article may also greatly differ from the angles of the pivots belonging to the lathe in which the article rotates; in fact it is better that a slight difference should exist. The only requisite which is necessary in order to make a shaft rotate truly on any pivot in any lathe whatever, is the right-angular position of the shaft's two extremities with its length, or rather with its axis of rotation. No great attention need be given to the angles of the cones; but it is needful to regularly form each recess exactly in line with the axis of the shaft, and to make each shaft-extremity right-angular to the extent of at least a few inches around the recess, if not entirely across.

The outer diameter of a centre-recess for a large shaft, should be at least a tenth of the shaft's diameter, being about the same as for a bolt. After the cone is completed with a half-round coner, and the drill-hole made to a proper depth, a large coner, similar to Fig. 271, should be held in the hole while a few sledge hammer blows are given to it, which will smooth the surface and also tend to harden it, with the view of avoiding injurious wear with the lathe-pivots. After coning, two or three oil-gutters should be made into each recess. These consist of grooves which are formed with a gouge chisel and hammer, and extend from the mouth of each recess to the small drill-hole at the bottom. If three grooves are made, they are put in equidistant from each other, that they may not tend to enlarge one side of the recess more than the opposite side; and for the same reason, if only two gutters are made, they are made opposite each other. Supposing that the outer diameter of a recess is an inch, the width of each oil-channel should be about an eighth, and its depth about an eighth of an inch. The bottom of each gutter should be filed smooth with a round file, and polished; which will provide an easy passage for the oil, and allow dirt or shavings to be cleared out from the gutters while the shaft is in the lathe. When such clearing out is requisite, a small wire is pushed down each gutter and the obstructions removed; and a channel is known to be clear when oil will flow immediately down.

Turning of Straight Middle-Shafts.—Middle-axles, paddle-axles, and other large axles, are rotated on the lathe-pivots by means of grippers or carriers consisting of plates and bolts. The lightest of these consist of semicircular bands. Two of these together constitute one carrier, and they are caused to tightly grip the piece in the lathe with screw bolts and nuts. A carrier of this sort need not be very thick, and therefore does not occupy much room; but the two bands together must constitute a sort of ring whose curve is about the same as that of the object to be rotated, to avoid placing packing-pieces between the carrier and the object. A carrier which is suitable for a number of objects of different diameters is one composed of grips having vee-gaps. This also is formed of two thick plates, which are bent to produce the vee-gaps, and punched while on the anvil to produce holes for the screw-bolts. The entire carrier, when complete, somewhat resembles the upper part of the author's slottil, represented by Fig. 558.

The first turning of a shaft consists in roughly removing the greater part of all the superfluous metal from the entire surface, thus making it rotate truly along its entire length previous to finishing any one portion. To do this it is necessary to reverse the article end for end after having reduced about half of its length, and then reduce the other portion. It will be found, when the shaft is removed, that the part which is turned may not rotate truly, by reason of some difference between the conical surfaces in contact, and their wear during the heavy cutting which has been performed, or through the shaft-ends not being right-angular. By reversing the shaft during the roughing, both recesses will become equally worn, and, therefore, not so liable to wear during the finishing of some part, and cause it to rotate untruly.

The tools with which the greater part of the metal is pared off are vee-point tools, having cutting edges slightly curved at the points. Such a tool is caused to cut with both its cutting edges in succession, if the lathe has a traverse gear that can be easily caused to move the slide-rest both ways, in which case both cutting edges of the tool are of the same length. But if the lathe is without such a convenience, single-edged tools are employed. Such a tool will require to be oftener sharpened than one with two edges.

To make the tool cut easily, and to prevent it becoming too soft with the continued friction, it is lubricated with thick soapy water. This is contained in a reservoir which is suspended from a bracket or davit attached to the lathe-carriage, the liquid flowing out upon the shaft from a pipe having a small stop-cock to furnish and arrest the supply as required.

For the purpose of causing a tool to cut with both its edges in succession, two traverse-bands should be provided. These can be applied to any lathe having a proper traverse-gear, similar to that shown in Fig. 1125, and consist of a long band and a short one. Both these are kept ready for use, the long one being crossed, as in the Fig. (1125) when in use, and the short one being used without crossing it. By thus employing two bands, the trouble of buckling in a long band, if only one is used, is avoided.

As soon as a shaft is reduced along its entire length, to very near its finished diameters, and all its shoulders also partly formed, it is said to be truly rough-turned; and to do this properly, so as to leave only a proper quantity for finishing, requires considerable skill. For this purpose, the turner must accurately mark the places for the shoulders as soon as the shaft is made circular, by means of a gauge denoting the various lengths, which is held upon the work for a correct scribing. The making of length-gauges will be mentioned presently; it is sufficient to state here, that after the shaft has been marked, to show the exact places for the shoulders, the metal must be pared off very near to each mark, so as to leave only about a thirtieth or twentieth of an inch to be removed with finishing tools. For producing the shoulders of a straight shaft, it is a good plan to first enter in a short strong grooving-tool having a cutting edge about a quarter or five-sixteenths wide. This is caused to make a series of grooves along the shaft, one at each intended shoulder, an adjusted outside calliper being used at the time, to prevent the tool being entered too far into the metal. Such a tool must be used with oil, or thick soap solution, to make it cut easily; and its cutting edge should be curved outwards and not straight. A tool of this character is shown by Fig. 438, with a slight difference, consisting in the concave recess, or gap at the point, not being quite so deep. Tools of this shape are termed U-point groovers. When all the grooves are formed along the shaft, the superfluous ridges of metal adjoining the grooves can be easily removed with ordinary vee-roughing-tools having narrow cutting ends; consequently, much of the reduction with right and left corner tools is avoided.

It is now presumed that the shaft has been accurately rough-turned, so as to cause its entire length to rotate truly, and leave about the same quantity to be cut off any part, in order to attain the finished diameters and lengths. The finishing process can therefore now commence, and the operator should begin by smoothly finishing all the shoulders, or nearly all of them, while the shaft remains in one position in the lathe, without reversing it end for end, if the shaft is of sufficient length to allow room for the lathe-carriage to be moved to the required places. But if it is too short, three or four shoulders at one end of the shaft are to be finished, and also the cylindrical parts of the neck or necks, together with the outer end, previous to reversing the shaft, to complete the other portions. A straight middle-shaft has, in general, two bearing-necks for the plummer-blocks or entablatures, and two necks for the cams; there are also the two stems or ends for the cranks; consequently, ten shoulders are to be made.

All the shoulders can be smoothly turned, and the curved junctions of the necks also smoothly turned, with the same corner tools which were used for the rough turning, these tools being properly sharpened after the heavy cutting, and the points curved for the smoothing. With these tools it is also necessary to turn a short portion of the cylindrical parts adjoining each curved corner, in order that the sheet gauges for these corners may be applied, and proper curves obtained. The corners, and short portions of the cylindrical parts of a neck, can be finished with right and left corner-tools, excepting a minute amount which is afterwards taken off with polishing tools.

The final smoothing of a bearing-neck is executed with springy tools having convex edges of proper curves to suit the corners or junctions. These corners are finished previous to the middle or parallel part, a calliper being carefully adjusted to make the neck of proper diameter, and carefully used to make both corners of the same diameter. After this, it is easy to reduce the middle or parallel part to the diameter of the two finished ends, with but little or no measurement. The curved corners of a neck belonging to a straight middle-shaft are not very large, the curves resembling those seen in Fig. 1122; neither are the adjoining shoulders very deep; consequently, in many cases, the same convex springy tool which finished the two corners, will also finish the cylindrical part between, and also the two shoulders at right-angles to it. If the mid-part has been smoothly turned to a proper diameter, as it should have been, either with a corner tool, or with a front vee-tool, only a small amount now remains for finishing, which is easily taken off with a springy tool.

It must be noticed that soap solution should be used during the smoothing with both sorts of tools—both the pointed front-tools, and corner-tools, and also the springy-tools. If the work is not carefully smoothed with the point-tools, previous to finishing, it cannot be accurately measured, and therefore the proper amount to be left for finishing with the spring tools cannot be easily determined.

Shaft-ends for Levers.—Turning the lever-ends of a middle-shaft consists in making them parallel and of a suitable diameter and length for the levers which are to be connected. These ends can be finished either before the holes in the lever-bosses are bored, or afterwards, with equal convenience, because no placing of the two objects together is requisite, the proper sizes being obtained with measurement. The shaft-end, when finished, is larger in diameter than the diameters of the hole to which it belongs, with the view of tightly fixing the lever to its shaft by shrinking. The shrinking of a lever-boss of great size on its shaft is the only effectual means of fastening it, and is also the only sure mode of obtaining a permanent connexion after they are first fastened together, and avoiding all future risk of getting loose.

The difference between the diameter of a shaft-end and the diameter of the hole in its lever-boss should never exceed a sixteenth of an inch, although the hole may be ten or twelve inches in diameter. The custom of many turners is to make the shaft-end nearly as large as they expect the hole to be when the lever is heated; and because the diameter of the hole will be an eighth of an inch greater when the boss is heated, supposing it to be a foot in diameter, it is thought that the shaft-end should be an eighth of an inch larger than the hole while the boss is cold. But it may be easily seen that such a great difference between the two is, at least, liable to cause the lever-boss to stick when only about half way to its place, if it happens to be not quite hot enough, or if a piece of scale or clinker gets in the way and must be removed. It is also liable to render the boss, after being fastened, much less secure, than if only a small difference had been allowed. The differences between the ends of shafts and the holes in their respective lever-bosses, when both are cold, should average thus: for shafts whose diameters are between five and ten inches, only a thirty-second of an inch; for those between ten and fifteen inches in diameter, only a sixteenth, and for larger sizes a tenth, as an extreme amount. These differences are adopted for levers which are made of excellent tenacious iron, which is not liable to crack during the cooling, and which can be heated to a bright red heat. When steel levers are employed the differences for the respective diameters must be only half the amounts here given.

Whenever the hole of any lever-boss is enlarged by heat, whether to redness, or to nearly red, and is cooled, it will be found to have resumed its former diameter which it possessed previous to being heated, if nothing is in the hole to prevent it; and if the boss is steel or iron, and has been heated to redness, the hole is now smaller than before it was heated. Therefore if a cold shaft-end is large enough to just fill the hole of a boss while hot, the cooling must greatly stretch the metal of the boss, without tending to tighten it; and if it is brittle it will crack. Consequently, the result will be that the boss will not be so tight when cold as if it had been loose on the shaft, through a smaller difference between the two having existed.

A large lever-boss needs a little care while heating, to prevent some part getting burnt, and to prevent clinker adhering to some place in the hole, which would require to be removed with a broom and scraper having long handles. Pieces of clinker will sometimes stick tight in h hole, and therefore require a scraper with a sharp edge to detach them. To conveniently expand the hole of a small boss which is only a few inches in diameter, it need not be put into any fire, but can be heated with a few pieces of round iron, which are successively heated to near welding heat, and put into the hole. A small lever can be heated also on a thick iron plate which is placed over a forge fire, and kept red-hot a sufficient time to heat the boss, the boss being put upside down a few times, that both faces may be in contact.

For heating a large lever, having a hole of twelve or fourteen inches in diameter, a furnace is the best means. The lever is suspended with a chain while the shaft-boss is in the furnace and covered with fuel. The furnace-fire should have been properly made and heated, previous to placing the lever therein, which will cause it to get hot sooner, and without being liable to have some part of the surface slowly burnt off, or being made scaly. The fuel should consist principally of wood, with a little clean coals, thus avoiding the formation of clinker. While the boss is getting hot, the shaft is put into a proper position and situation, so that its length is horizontal, and the entire shaft at a suitable height for the lever to be swung out of the furnace to the shaft-end. A pendulum-hammer also is slung up at a proper height, to drive the lever quickly to its place before it has begun to cool, which quickly progresses immediately it enters upon the cold shaft. As soon as it is driven to the shoulder of the shaft, it is adjusted to place its key-way exactly over the key-way of the shaft, which must be quickly done either by hammering the top end of the lever, or by pulling it with a couple of chains attached to the top end.

In order to cause the key-way of the boss to be of the same width as the width of the key-way in the shaft, when the boss has been cooled and is tight, it is necessary to make the shaft's key-way a little wider than the boss key-way, so that after the boss has been cooled, both key-ways may be of very nearly the same width. But it should be observed, that if only a proper difference between the shaft-end and the hole in the boss is allowed, the width of the shaft's key-way need be but little or nothing wider than that of the boss.

Another mode of heating a large lever-boss may be mentioned, which consists in using a portable wrought-iron apparatus, similar to a bogie or devil. This is capable of being moved to any place which is convenient for the placing of the lever upon the shaft, and has a fire-place of ample size to admit the largest boss which may be put therein. When such an apparatus is used, the lever-boss is put into the firebox previous to making the fire, the wood and coals being afterwards packed around. A substitute for a bogie consists of a structure which is built up of old fire-bars, in any convenient place.

The cooling of a lever-boss must commence immediately it is adjusted to the desired place on the shaft. This is necessary because, by reason of the boss being of great size, it imparts a great amount of heat to the shaft-end within, which heat would greatly enlarge the shaft, and stretch the boss during cooling, if allowed to cool slowly, and the boss would probably be loose, because after the shaft-end has been enlarged with the heat and stretched the boss, the subsequent cooling of the shaft makes it smaller than the hole. To hasten the cooling, a stream of water as large as convenient, is therefore supplied to the boss as soon as it is adjusted.

Turning of Paddle-axles.—The turning of a paddle shaft somewhat resembles that of a straight middle-shaft, with the difference of a paddle-shaft not requiring its entire mid-portion to be smoothly finished. The turner should therefore centre a paddle-shaft to make its mid-part rotate truly, without specially regarding the two ends, unless the forging happens to have but little metal to be cut off the ends. A paddle-shaft can be easily so forged that its middle part shall be of the exact diameter required when finished, a thick portion being formed at each end, which is large enough in diameter to allow the flanges to be formed with turning to the finished diameters.

A paddle-shaft is first rough-turned, and reversed end for end in the lathe to equally wear the centre-recesses, the same as during the turning of other large shafts. The shoulders of the bearings are also produced, previous to the smoothing of any part. The smoothing of the bearing-necks and their curved corners, and also their final reduction, is the same as for middle-shafts' being effected with springy tools.

Gauges for Shaft-turning.—The gauges employed for turning paddle-shafts to the exact required diameters and lengths are the same as those for straight middle-shafts, and others of similar forms. The gauges for indicating the several lengths are termed length-gauges, and include bar gauges with short pointed arms, wood gauges consisting of straight staves of wood, radius gauges having adjustable scribers, straight wire gauges, sheet iron gauges, and inside callipers. For measuring diameters, outside callipers and wire gauges are used, and in a few cases, but very seldom, gap-gauges made of sheet iron are used. Sheet gauges are not generally available for measuring large diameters, because of being too large and occupying so much room.

A gauge to show the several lengths and distances between the shoulders of a paddle-shaft can be made at any time, and the axle, or a pair of them, can be completely turned with regard to the gauge, or gauges, because the outer pillow-blocks, which are to be situate in the paddle-boxes, can be accurately fixed in the exact places to suit the outer bearings of the axles; and this fixing can be done after the axle is entirely finished and in its place. But a gauge to show the lengths belonging to a middle-shaft cannot be properly made until its two entablatures are finally adjusted and fixed. The gauge should be made or marked while the ship is afloat, which is to be the ordinary condition when the axle is in its place. The material used for the gauge is a thin bar of iron, or of dry wood, wood being suitable because of its lightness, if it is to be immediately used, and is therefore not liable to alter its length while in use. When the gauge is being scribed, it is held edgeways in contact with the brasses; consequently, it is to be held in the same position when on the axle which is to be turned thereto, to avoid being misled by the bending of the gauge, which would result if not placed edgeways. The marks on the gauge should indicate the exact distances of all the shoulders of the brasses from each other, allowing for any irregularity in any brass, if any exists; and whatever room may be intended for the shaft can be afterwards allowed when the shaft has been marked by the gauge.

In order to cause all the four shoulders of the two shaft-bearings to be exactly in their proper places, to suit the four shoulders or sides of the brasses, and to cause both bearings to be of a correct length for their respective brasses, the turner must attend to two things. These are, the total lengths between the shoulders, as indicated on the gauge, and the length of each brass individually considered with regard to its respective bearing. To proceed orderly, he first smoothly turns all the four shoulders of the two necks to the proper length from each other, as shown with reference to the gauge. When this is done, each neck should be next fitted to its respective brass; and at this fitting both shoulders of each neck must be equally reduced, to give the requisite amount of room for the brass, which is about a thirtieth of an inch for a large brass. By adopting this plan the length between the two outer shoulders of the shaft, when finished, will be about a sixteenth greater than that indicated on the gauge, and the length between the two inner shoulders will be about a sixteenth shorter; consequently, the needful amount of room required for the shaft in its brasses is secured, and is also equally distributed to the shoulders of both bearings. The smoothing of these shoulders is accurately done at the first, previous to finishing the mid-parts of the bearings, and is so done as not to require anything whatever to be afterwards removed when the curved corners and cylindrical parts are being finished.

The completion of the necks now proceeds with respect to the brasses only, the lengths having been finally determined; consequently, it is now only necessary to turn the curved junctions and the straight mid-portions of the bearings to the proper diameters, by means of pointed corner tools, or with springy tools, according to the amount to be removed.

The final reduction of a bearing neck should be effected with reference to one of the half-brasses belonging to it, the brass being suspended over the neck, and lowered into its place, when a trial is to be given. After being lowered to the shaft, the brass will easily be moved to and fro, if the neck is small enough; but if not, the brass will stick tight, and therefore needs further reducing in some part. It is necessary to put some tange upon the surface, previous to trial, in order to plainly show whether the cylindrical parts are in contact, or whether the curved junctions only are in contact; by which means the risk of reducing the neck at a place where it is not necessary is avoided. At this fitting of the brasses nothing whatever is to be removed from the four shoulders; these are already correct, as before stated, both for the lengths of the brasses individually and for their distances apart when in the headstocks.

The length-gauges now remaining to be mentioned are straight wire-gauges, bar-gauges, radius-gauges, and inside callipers. A straight wire-gauge is useful when only one bearing-neck is to be fitted to a pair of brasses without special regard to its distance from any other neck or shoulder. In this case the wire is filed until its two extremities are as far apart as the length of the brasses. This distance is obtained either by accurately measuring the length of the brasses with an outside calliper, and filing the points of the gauge until they fit the calliper, or by placing a straight-edge to each end of the brasses, and adjusting the gauge to the distance between the straight-edges. When the gauge is in use it is placed in between the two shoulders of the neck, and the neck is lengthened until it is as much longer than the wire as the intended amount of looseness for the brass when in its place.

A pointed bar-gauge, or a radius-gauge, is only useful for measuring a shaft when stated distances are to be marked between the centres of any two bearings, or between any two shoulders, or when the centre of a shaft's length is to be found, and all other lengths measured from the centre. An inside calliper is used for lengths when a shaft-end for a lever is being finished to its exact length to prevent it extending beyond the face of the lever-boss when connected. In this case an outside calliper is first adjusted to the length or distance of the hole through the boss, and an inside calliper is adjusted to the outside one.

The wire gauges mentioned for measuring diameters are highly useful and accurate in their indications. These should always be used for large objects because they do not alter while in use, and mislead the operator. Whereas, if large callipers are used for measuring large objects there is always a risk of the legs shifting and indicating wrong dimensions. For the measuring of a hole not exceeding three or five inches in diameter, an inside calliper can be carefully adjusted so that its points only very gently touch the surface of the hole, and the correct diameter can thus be shown. But if a large calliper is adjusted to a hole of twelve or fifteen inches in diameter, the legs will be slightly bent, either inwards or outwards, in the course of using them, but without their being at all shifted with regard to their joint-pin; consequently, the distance between the calliper-points is either too little or two much, the exact distance depending on the position in which the calliper is held or placed.

In order to correctly turn a bearing neck to a suitable diameter for a pair of brasses, the diameter of the hole in the brasses must be correctly measured while both brasses are together in their positions in which they were bored. Either an inside calliper or a wire gauge is then adjusted so that its points gently touch the two sides of the hole, and it is requisite to measure several parts of the hole, to find the smallest place. When the gauge is fitted and is to be used, it should be laid with its length horizontal, and upon a piece of flat board, or plate, or, as a substitute, on the floor at the turner's feet. An outside calliper is now adjusted until its points gently touch the points of the wire, being careful to hold the calliper during measurement, so that it stands vertical on the plate or floor. By reason of this being the proper position of the calliper during adjustment, it is also necessary to hold the outside calliper in the same position when it is applied to measure the bearing-neck in the lathe.

It is to be noticed that no bearing-neck can possibly rotate in a couple of brasses if their hole is no larger than the neck within, unless sufficient power should be applied to tear out some of the metal at the time of rotation. By not considering this fact, and by attempting to make what are termed good fits, a great number of misfits are made; and much time is occupied in subsequent fitting. The difference between the diameter of a neck and the diameter of its brasses, when both are properly adapted to each other, is much greater than usually supposed. For a neck about six inches in diameter, it is about a sixtieth or a fiftieth of an inch, and for one of fifteen or sixteen inches, at least a thirtieth of an inch.

PISTON-RODS AND CRANK-PINS.

Piston-rods.—Heavy piston-rods are lined and centred while they hang suspended from a crane, either callipers, a straight-edge, or a rectol, being employed and used in the same manner as described for centring axles. A piston-rod having at one end a conical part with the large end of the cone at the rod's extremity, should be forged with a short holder or handle, this being a stem or superfluous piece solid with the rod. This holder is produced by thinning the rod's superfluous end at the conclusion of forging, and is necessary for the convenience of having a carrier fixed to it for rotating the rod while the cone is being turned, and also while the adjoining screw is being made. If a carrier is fixed to this handle at the beginning, the entire rod can be turned and screwed without the need of reversing it end for end in the lathe. The handle will also support a drift, which will be hammered against the outer end of the cone while being fitted to the piston.

Piston-rods, small and large, are made of steel, because of its hardness and consequent non liability to wear; but whether a rod of this shape is steel or iron, the order of its turning is about the same in any case. The entire rod is to be first rough-turned, so that the cone, the parallel part in the middle, and the small end are very near to the specified diameters; the middle part, at this turning, being made small enough to pass through the smallest part of the hole in the piston. The rod's cone is to be now finished to fit the piston. If the rod is being entirely turned without reversing it end for end, it is necessary to re-fix the gripper to the same position on the handle or stem, after every time it may have been removed to try the cone; because through the centre recess at the conical end being always on the mandril pivot, it cannot wear its surface to a proper bearing, and also because the mandril-pivot may not rotate truly.

To avoid the trouble of placing the rod into the piston several times during the fitting, the hole should be accurately measured with wire gauges, and the cone carefully turned thereto. Two gauges are required, one for the large end of the hole, and one for the small end; and their points are smoothly filed to gently fit their respective places, as described for the fitting of other wire gauges. The turning of the cone commences by reducing about a quarter of an inch of the cone's length at the small end, until its diameter is about an eighth greater than the length of the short wire. The length of the piston-cone is next ascertained, and marked upon the rod's cone by measuring from the short turned part at the small end. Consequently, if the length of the piston-cone is nine inches, a mark is made upon the rod's-cone at nine inches from the small end. The thick part of the cone is to be now reduced until its diameter at the mark is an eighth of an inch greater than the length of the long wire. This leaves an eighth of an inch to be turned from both ends of the cone, to make them of the specified diameter; and the two turned portions indicate the two extremities of a cone whose angle is about that which is required to fit the piston. And if the rough mid-portion be next reduced until level with the two extremities, the entire cone will possess the desired angle, although it will be an eighth of an inch too large in diameter.

The turning of the cone is effected while it is near the chuck, because the gripper is fastened to the stem; and to remove the metal the top slide of the rest is employed. This is adjusted to the proper angle, partly by means of the two turned ends. For this purpose, a pointer, or an ordinary front vee-tool, is fastened in the tool-holder, and the point is put opposite one of the short turned portions, and the exact distance between the tool-point and the turned surface is measured with an inside calliper. The pointer is now moved along, by rotating the screw of the top-slide until it is opposite the other turned end of the cone; and the distance between the point and the turned surface is measured with the calliper as before; and if not the same as while the tool was at the other end, the slide is shifted accordingly.

As soon as the slide-rest is arranged and the cone smoothly reduced thereby, each end of it is carefully measured, and the two gauges referred to, to discover in which direction the slide-rest is to be further adjusted to obtain the exact angle desired. By this means the entire cone will be accurately turned to fit the hole, and will also be situate at the required place in the hole when tried into the piston, if the turner has properly marked the length of the cone upon the rod, and has measured exactly at the two extremities when referring to the gauges.

For turning cones, two outside callipers are indispensable, one of which is adjusted to each wire, and lightly adjusted so that the legs may not be bent by pushing them tightly across the gauge-points. By attending properly to the measurements, a cone can be turned to very near the exact size and shape previous to removing it from the lathe to try it into the piston. Such cones are always forged with ample length for their respective holes; consequently, the exact distance to which the rod will enter is not important, the great requisite consisting in marking the cone's length upon the rod, and turning each extremity of it to its respective gauge.

When a rod is to be tried into a piston, the piston is stood edgeways between packing-blocks, and fastened thereto, either with bolts, wedges, or a screw-jack, that the rod may be inserted while horizontal. As soon as the rod is put in and pushed to its place, the long end is raised or lowered a short distance with the crane, until the rod's length is exactly square to the piston; at which time a few powerful sledge-hammer, or pendulum-hammer, blows are given to the outer end. To do this, a tubular drift is used, in one end of which is a hole large enough to allow ample room for the entire stem or handle of the piston-rod. This drift is attached to an ash handle, and is held on the stem while the blows are delivered. By this process, the cone of the rod is driven forcibly into contact with the piston-cone and marks are made upon the surfaces, which indicate the exact places of contact, and therefore show which portion of the rod's cone needs further reduction, and whether or not the slide-rest needs a slight alteration. At the trying-in the distance to which the rod enters is observed; and if the cone has been finally fitted far enough into the hole, a mark is scribed upon the rod at each end of the hole. One of these marks will be required to show to what place the screw is to be cut, and the other mark will serve to show how much is to be cut off the outer or thick end of the cone, if any is to be removed from this part.

The next step is to cut the thread adjoining the cone. This thread is to fit a sort of cylindrical or ring-shaped nut of gun-metal, with which the rod is to be fastened in the piston; which nut has been previously finished, being bored, screwed, and also, in some cases, turned to make its outside fit the recess in the piston. The length of the screw for this nut, or the distance along the cone to which it is to extend, is known by referring to the mark which was scribed upon the small end, at the time the rod was situate tight in its place in the piston. This mark is the place which will be occupied by the inner face of the nut when screwed tight against the bottom of the piston-recess; therefore, a quarter, or three-eighths of an inch beyond the mark, is the place at which the thread is to terminate. The place for the thread being thus known, it is turned cylindrical at that place, and of a proper diameter to suit the already-formed thread in the nut. To ascertain this diameter, the outer diameter of the nut-screw is measured with a pointed wire gauge, made according to the instructions in page 351 for bolt-screwing. The cutting of the thread next proceeds while the nut is on the rod, or on the poppet-cylinder, in order that it may be accurately fitted upon the screw without removing the rod from the lathe. When the nut is screwed upon the rod to about the place it will occupy when in the piston, it appears as in Fig. 1124.

After the screw adjoining the cone is finished, the opposite end of the rod is turned to fit the crosshead, and also screwed, if a screw is intended. To mark the place for the crosshead-shoulder, the distance can be measured from the piston, or from the piston-nut, because these are finished. Turning of the mid-part exactly parallel is next performed, and is the last process. This is done by first taking off a thin slice along the entire length with a vee-point tool, and afterwards finishing it with a springy tool. To polish this portion and make it truly cylindrical, it is ground with a couple of wood grinders, or wood grinders having two pieces of sheet lead in contact with the part being ground, the grinders being supplied with emery and oil. But such a process is never requisite for a piston-rod; it is quite sufficient to smoothly file only the outer end of the parallel part, or to polish it with a springy tool. The remaining portion, which will be inside the cylinder, polishes itself by friction with the packing.

Turning of Crank-pins.—A crank-pin is turned in about the same manner as that described for a piston-rod, the entire pin being first rough-turned, and the cone next fitted, previous to finishing the other portions. A handle which exists solid with the cone is also necessary, similar to that mentioned for a piston-rod; although no such stem is required if the crank-pin in hand is one which has the smaller end of the cone outwards. A pin of this class is to have a screw on the end beyond the cone; therefore on this portion a carrier can be fixed.

The cone of a crank-pin which is to be fastened with a key only, should subtend but a small angle—six or seven degrees is sufficient—in order to prevent it getting loose while at work. But a nearly parallel cone renders the pin difficult to get out, in the event of breakage or other emergency. Consequently, it is advisable to provide a crank-pin with a screwed end and nut, if room for it exists, and to furnish a cone having an angle of about twelve or fifteen degrees, which is the angle for a piston-rod's cone. Such a cone will allow the pin to be easily detached when necessary, but must have a nut to prevent it getting loose.

The threads for piston-rods and crank-pins should never be larger, for the respective sizes, than those mentioned in Table 7, page 180; but threads having smaller numbers of steps for the respective diameters are preferable for the nuts here treated, to prevent them getting loose after being fixed. The office of these nuts principally consists in drawing the rods or pins to their proper places in the holes, and in afterwards keeping them in their relative positions during use, which will be the result if the cones exactly fit their holes. The strain upon a crank-pin nut when in ordinary work is nothing, unless the pin shifts in its boss through not fitting properly; consequently the thread may be very small, about five or six steps per inch being quite coarse enough for a screw seven or eight inches in diameter. Smaller than this would suffice, if it were not necessary to remove the nut and pin at some future time.

But the thread of a piston-nut differs from a crank-pin nut in that it really does sustain a great strain, which is nearly equal to the entire strain exerted by the engine to which it belongs; and supposing that the piston-rod is kept in the piston solely by virtue of the nut, the strain is exactly equal to that exerted by the engine; consequently, a too small thread would be dangerous. But it is to be remembered that the strength of a thread does not depend on its thickness or step, but on its length; therefore any desired strength of nut-screw may be obtained, however fine the thread may be, by making the nut of sufficient length. The length or distance through the hole of a piston-nut is, however, always limited, to avoid having a great portion of the nut outside of the piston. The length is seldom more than half the diameter of the hole; but although finer threads than those in Table 7 are used, and although so short, such threads never break, neither from the rods nor from the nuts, unless the material is bad, or the threads are not fitted to each other. It may therefore be seen that thin threads are highly efficient for the purposes referred to, both because they occupy less time in making, and because they are less liable to become loose after having been fixed.

The exact turning of a crank-pin cone to fit its lever-boss is not so important as that of a piston-rod cone, because, when the pin is to be put into its final place in the boss, the boss can be easily heated; and after the pin is put in and tightened with its nut, or with the key, the subsequent cooling of the boss will cause it to exactly fit every part of the cone. But a piston can be only very slightly heated when the rod is to be fixed, so that the cone must be carefully fitted with the lathe. The final fitting of such a cone may be done with a file, after the piston-nut is fitted, and has been screwed tight in the recess while the rod was in the piston. By this time, in consequence of the hammering which has been given, and through the nut having been screwed tight, the cone is plainly marked, and a slight filing can be given accordingly.

To facilitate the screw-cutting of bolts, piston-rods, and nuts, the nut of the lathe screw is disconnected from the screw at the conclusion of every advancement of the screw-tool to the end of the thread; and while disconnected the carriage and rest is moved back by the operator working the carriage-handle. By this means the comparative slow backward motion of the lathe is avoided; but by the use of the authors double-screwing apparatus all this laborious moving back of a heavy carriage and slide-rest is abolished. This affair, although one of the oldest inventions by the author, has never been superseded by any later method (for screw-cutting).

SCREW-CUTTING GEAR.

In connexion with the turning of piston-rods, crank-pins, and other objects, a few general instructions must be here given concerning screw-cutting wheels, including Tables of wheels for stated pitches, and methods of finding proper wheels when Tables are not available.

Tables of Wheels.—Before Tables of wheels can be understood, the wheels themselves must be considered, and the lathes to which they belong; therefore a few sketches are given in Plates 91 and 92, which indicate the ordinary arrangements of screwing-wheels for all lathes in general.

In Fig. 1125 an end of a lathe is shown having a set of screwing-wheels attached. The lathe-screw with which the slide-rest and its cutting-tool are moved along, need not be seen in this Figure, because it is presumed that the student has perused the general description of screwing-lathes in page 134. The wheels which impart the required motion to the lathe-screw are denoted by the four letters M, C, C, and S. The wheel M is fastened on the mandril or spindle of the lathe, and termed the mandril-wheel. This is the primary wheel of any set of wheels for screw-making, whether two, four, or any other number are employed; and it is by virtue of this wheel's motion being properly communicated to the lathe-screw by means of the wheel S, that all screws are cut. The proper arrangement of wheels for screw-cutting, therefore, consists in causing the primary wheel to so rotate the screw-wheel that it shall move exactly at the required rate to cut the desired screw.

There are two sorts of arrangements adopted for screw-cutting, which are termed simple gear and compound gear. An arrangement of simple-gear wheels consists of only two screwing-wheels, and a compound arrangement consists of four, or any greater number.

There are also two sorts of wheels used during screw-cutting—screwing-wheels and auxiliary wheels; these being termed, in page 176, connecting wheels. Connecting wheels are employed to occupy the space existing between a set of screwing-wheels, and to cause them to rotate in the direction required. Either one, two, or three of them may be used in conjunction with a set of screwing-wheels; but the connecting ones are never considered when referring to Tables, nor when calculating for wheels required, because each auxiliary rotates on its own spindle, independently of any of the screwing-wheel spindles. In the Fig. (1125) the two connecting wheels are distinguished by C and C.

Screwing wheels themselves also consist of two classes, drivers and driven. These are conventional terms, because all the wheels are driven by the lathe-mandril; but it is convenient for reference, to name the primary or mandril-wheel of any simple gear arrangement a driver, and the screw-wheel of the same set a driven one. Also by analogy, to name the first and third of a compound set drivers, and the second and fourth driven.

The most usual wheels employed for screw-cutting, are those whose numbers of teeth advance by fives, from 15 to 150.

All the wheels which are used for a screw-cutting process, except the primary and the screw-wheel, are maintained in their proper places by means of a swivel-arm, in which two straight slots exist parallel with each other. This is termed a radiol, a portion of one being shown by R in Fig. 1125, and the whole of one, by R in Fig. 1126. The radiol is attached to a boss or flange belonging to the lathe-screw, and is capable of being raised or lowered while being swung on the screw-end as its pivot. Consequently all the screw-cutting wheels to be used may be caused to exactly engage with each other in their proper places. In the slot, or slots, one, two, or three, spindles are fastened; and after the wheels have been placed thereon, the spindles are slid along the slot, the radiol is adjusted, and all are fixed with a spanner.

The set of wheels in Fig. 1125 is a simple-gear arrangement for cutting a left-handed screw, supposing a right-handed lathe-screw is fitted to the lathe, the two connecting-wheels, C and C, serving to rotate the screw-wheel in the proper direction. To cut a right-hand screw, it is only needful to take off the two middle wheels, and put on a larger one of sufficient diameter to fill the space between the screwing-wheels. This will cause the screw-wheel to rotate in the opposite direction, but will not alter its rate of motion. It will therefore be perceived that the Tables of simple-gear wheels which are given, are applicable for cutting both right-handed screws and left-handed ones. These Tables are numbered 9 and 10. It is now necessary to mention the compound wheels.

Compound wheels are represented in Fig. 1127. In this the four screwing-wheels are indicated by 1, 2, 3, and 4, the primary or mandril-wheel being shown by 1, and the next in order, which is a driven one, by 2. The third, shown by 3, is a driver, and rotates on the same spindle with No. 2. No. 4, is the screw-wheel, being a driven one and the last of the set. By employing these numbers, no confusion can arise from the variety of names which are given to these wheels by some persons; such as stud-wheel, axial wheel, intermediate wheel, pinion, spindle-wheel, and others. The two wheels shown by C and C, are connecting-wheels, and of any suitable diameters to communicate the motion from the mandril-wheel to the second one. By using C and C, the lathe-screw is caused to rotate in the same direction as the mandril and piece to be screwed; consequently a right-handed screw will be produced, because the lathe-screw is right-handed. It may be here mentioned that the lathe-screw will rotate in the same direction if the two auxiliary wheels are taken off, which is accordingly done when the screwing-wheels employed are large enough to engage with each other without auxiliary ones.

In the case of a left-handed screw requiring to be cut with these compound wheels, only one connecting-wheel is employed, instead of the two required for a simple-gear seen in Fig. 1125.

By referring to the Figure 1127, it will be seen that the spindles of the connecting-wheels are quite distinct from each other, and from the screwing-wheels as before stated, so that they cannot affect the relative speed of the wheels between which they are placed; consequently the wheels mentioned in the Tables of compound wheels, are, like those for simple wheels, calculated as if no auxiliary wheels are to be used. The Tables of compound wheels are numbered 11 and 12. In Table 11, the steps per inch to be cut are situate between their respective four wheels, above, below, to the right, and to the left.

TABLE 9.

Simple-gear Wheels to be used with a Lathe-screw having 4 Steps per inch.

Numbers of Steps per inch in Screws to be cut.	Numbers of Teeth on Mandril-wheels.	Numbers of Teeth on Screw-wheels.	Numbers of Steps per inch in Screws to be cut.	Numbers of Teeth on Mandril-wheels.	Numbers of Teeth on Screw-wheels.	Numbers of Steps per inch in Screws to be cut.	Numbers of Teeth on Mandril-wheels.	Numbers of Teeth on Screw-wheels.
24	20	120	10½	40	105	4½	40	45
23	20	115	10	20	50		80	90
22	20	110		30	75	4¼	80	85
21	20	105		40	100	4	50	50
20	20	100	9½	40	95		60	60
19	20	95	9	20	45		90	90
18	20	90		40	90	3¾	80	75
17	20	85	8½	40	85	3½	40	35
16	25	100	8	30	60		80	70
	30	120		25	50	3¼	80	65
15	20	75		40	80	3	40	30
14½	40	145	7½	40	75		60	45
14	20	70	7	40	70		80	60
	30	105		60	105	2¾	80	55
	40	140	6½	40	65	2½	80	50
13½	40	135		80	130	2¼	80	45
13	20	65	6	40	60	2	60	30
	40	130		50	75		80	40
12½	40	125		30	45		90	45
12	20	60		60	90	1¾	80	35
	25	75	5½	40	55	1½	80	30
	30	90		80	110	1¼	80	25
	40	120	5	40	50	1	80	20
11½	40	115		60	75		100	25
11	20	55	4¾	80	95			
	40	110						

TABLE 10.

Simple-gear Wheels to be used with a Lathe-screw having 2 Steps per inch.

Numbers of Steps per inch in Screws to be cut.	Numbers of Teeth on Mandril-wheels.	Numbers of Teeth on Screw-wheels.	Numbers of Steps per inch in Screws to be cut.	Numbers of Teeth on Mandril-wheels.	Numbers of Teeth on Screw-wheels.	Numbers of Steps per inch in Screws to be cut.	Numbers of Teeth on Mandril-wheels.	Numbers of Teeth on Screw-wheels.
15	20	150	6	20	60	2¾	40	55
14½	20	145		30	90		80	110
14	20	140	5¾	40	115	2½	40	50
13½	20	135	5½	20	55		60	75
13	20	130		40	110	2¼	40	45
12½	20	125	5¼	40	105		80	90
12	20	120	5	20	50	2	20	20
11½	20	115		30	75		50	50
11	20	110		40	100		60	60
10½	20	105	4¾	40	95	1¾	40	35
10	20	100	4½	20	45		80	70
9½	20	95		40	90	1	40	30
9	20	90	4¼	40	85		60	45
	30	135	4	20	40	1¼	40	25
8½	20	85		25	50		80	50
8	20	80		30	60	1	40	20
	25	100	3¾	40	75		50	25
	30	120		80	150	$\frac{9}{10}$	100	45
7½	20	75	3½	20	35	$\frac{8}{10}$	100	40
	40	150		40	70		75	30
7	20	70		60	105	$\frac{7}{10}$	100	35
	30	105		80	140	$\frac{6}{10}$	100	30
	40	140	3¼	40	65	$\frac{5}{10}$	100	25
6¾	40	135		80	130	$\frac{4}{10}$	125	25
6½	20	65	3	20	30			
	40	130		30	45			
6¼	40	125		40	60			

TABLE 11.

Compound wheels, to be used with a Lathe-screw having 2 Steps per inch.

Driving wheels.

Driven wheels.	20	20	20	20	20	20	20	20	20	20	20	Driven wheels.
70	29·75	23·8	19·833	17·	14·875	13·222	11·9	10·818	9·916	9·153	8·5	85
70	28·	22·4	18·666	16·	14·	12·444	11·2	10·181	9·333	8·615	8·	80
70	26·25	21·	17·5	15·	13·125	11·666	10 5	9·545	8·75	8·076	7·5	75
65	48·75	39·	32·5	27·857	24·375	21·666	19·5	17·727	16·25	15·	13·928	150
65	45·5	36·4	30·333	26·	22·75	20·222	18·2	16·545	15·166	14·	13·	140
65	42·25	33·8	28·166	24·1428	21·125	18·777	16·9	15·363	14·083	13·	12·071	130
65	39·	31·2	26·	22·285	19·5	17·333	15·6	14·181	13·	12·	11·142	120
65	35·75	28·6	23·833	20·428	17·875	15·888	14·3	13·	11·916	11·	10·214	110
65	32·5	26·	21·666	18·571	16·25	14·444	13·	11·818	10·833	10·	9·285	100
65	30·875	24·7	20·583	17·642	15·437	13 722	12·35	11·227	10·291	9·5	8·821	95
65	29·25	23·4	19·5	16·714	14·625	13·	11·7	10·636	9·75	9·	8·357	90
65	27·625	22·1	18·4166	15·785	13·812	12·277	11·05	10·045	9·208	8·5	7·892	85
65	26·	20·8	17·333	14·857	13·	11·555	10·4	9·454	8·666	8·	7·428	80
65	24·375	19·5	16·25	13·928	12·187	10·833	9·75	8·863	8·125	7·5	6·964	75
65	22·75	18·2	15·166	13·	11·375	10·111	9·1	8 272	7·583	7·	6·5	70
40	14·	11·2	9·333	8·	7·	6·222	5·6	5·091	4·666	4·307	4·	70
40	13·	10·4	8·666	7·428	6·5	5·777	5·2	4·727	4·333	4·	3·714	65
40	12·	9·6	8·	6·857	6·	5·333	4·8	4·363	4·	3·692	3·428	60
40	11·	8·8	7·333	6·285	5·5	4·888	4·4	4·	3·666	3 384	3·142	55
40	10·	8·	6·666	5·714	5·	4·444	4·	3·636	3·333	3·076	2·857	50
40	9·	7·2	6·	5·142	4·5	4·	3·6	3·272	3·	2·769	2·571	45
35	26 25	21·	17·5	15·	13·125	11.666	10·5	9·545	8·75	8·076	7·5	150
35	24·5	19·6	16·333	14·	12·25	10·888	9·8	8·909	8·166	7·538	7·	140
35	22·75	18·2	15·166	13·	11·375	10·111	9·1	8·272	7·583	7·	6·5	130
35	21·	16·8	14·	12·	10·5	9·333	8·4	7·636	7·	6·461	6·	120
35	19·25	15·4	12·833	11·	9·625	8·555	7·7	7·	6·416	5·923	5·5	110
35	17·5	14.	11·666	10·	8·75	7·777	7·	6·363	5·833	5·384	5·	100
35	16·625	13·3	11·083	9·5	8·312	7·388	6·65	6·045	5·541	5·115	4·75	95
35	15·75	12·6	10·5	9·	7·875	7·	6·3	5·727	5·25	4·846	4·5	90
35	14·875	11·9	9·916	8·5	7·437	6·611	5·95	5·409	4·958	4·577	4·25	85
	20	25	30	35	40	45	50	55	60	65	70	

Driving wheels.

TABLE 12.

Simple and Compound Wheels to be used with a Lathe-screw having 1 Step per centimetre.

Numbers of Steps per centimetre in Screws to be cut.	Driving wheels.		Driven wheels.		Numbers of Steps per centimetre in Screws to be cut.	Driving wheels.		Driven wheels.		Numbers of Steps per centimetre in Screws to be cut.	Driving wheels.		Driven wheels.	
1	50			50	1·9	50			95	3·1	20			62
	60			60	2·	20			40		30	40	30	124
	30			30		30			60		50	20	20	155
1·1	50			55	2·1	50			105		20	30	30	62
	100			110	2·2	25			55	3·2	25			80
1·2	50			60		50			110		20	50	40	80
	100			120	2·3	50			115	3·3	20	50	55	60
1·3	50			65	2·4	25			60	3·4	25			85
	100			130		50			120		20	75	60	85
1·4	25			35	2·5	20			50	3·5	20			70
	50			70		40			100		30			105
	100			140	2·6	25			65	3·6	25			90
1·5	20			30		50			130	3·75	20			75
	40			60	2·7	20	100	45	120		40			150
	50			75	2·8	25			70	3·8	20	75	95	60
16	25			40		20	100	40	140	3·9	20	100	60	130
	50			80	2·9	40	50	40	145	4·	20			80
1·7	50			85	3·	20			60		25			100
1·8	25			45		30			90	4·1	20			82
	50			90							30	20	30	82

SELECTION OF SCREWING-WHEELS.

In Tables 9, 10, 11 and 12, are given several sets of wheels for cutting all, and more than all, the various threads required for engine-making; but in order that any other desired step may be cut with a lathe-screw of any step, the proper modes of calculation are here given.

The general fundamental principle which is involved in the cutting of all sorts of pitches with all varieties of wheels and lathe-screws is, the relation between the pitches of two screws, which screws are the lathe-screw, and the one to be cut. As soon as these two pitches or steps are properly ascertained and stated, the relation is immediately seen; and when this relation or ratio is known, the relation which must exist between the required wheels is also known. For example, suppose the lathe-screw with which a thread is to be cut, has one step per inch of its length, and that the desired thread is to have also one step per inch, the ratio is as one to one. Therefore, any two cog-wheels which possess this ratio to each other will cut the thread; and any two wheels of proper sizes for the lathe can be used if their numbers of cogs are the same, whether 40 and 40, 100 and 100, 50 and 50, 134 and 134, or any other numbers.

Again, suppose that the thread to be cut is to have 7 steps per inch, and the same lathe-screw to be used. In this case the ratio is as 1 to 7, and it is only necessary to multiply each number by 20, to obtain the numbers of teeth required. Thus:—$1 \times 20 = 20$, and $7 \times 20 = 140$. 20 and 140 will therefore cut the thread. And, because the step of thread to be made is smaller than that of the lathe-screw, it is evident that the larger wheel must be put upon the lathe-screw that it may rotate slower than the screw to be cut.

Selection of Simple-gear Wheels.—The general rule which is applicable to all screw-cutting should be thus stated:—As the step of the lathe-screw is to the step of the screw to be cut, so is the number of teeth on the driving wheel or wheels to the number of teeth on the driven wheel or wheels.

We now first apply this rule to the cutting of a screw with simple-gear wheels. The screw required is to have 4 per inch, and the lathe-screw to be used has 2 per inch, the wheel on the mandril has 20 teeth; consequently, by applying the ordinary rule of three to these three terms, the number of teeth on the desired screw-wheel is obtained thus:

$$\begin{array}{r} 2 : 4 :: 20 \\ 20 \\ 2\overline{)80} \\ \overline{40.} \end{array}$$

A 40-teeth wheel is therefore the one required. Again, if the screw to be cut is to have $1\frac{1}{2}$ steps per inch, the numbers appear thus:

$$2 : 1\tfrac{1}{2} :: 20 : 15.$$

Or, if the 20 and 15 wheels are too small to engage with a connecting-wheel, a 40-wheel is put upon the mandril, and the figures appear thus:

$$2 : 1\tfrac{1}{2} :: 40 : 30.$$

It is now presumed that the fractional pitch 2·3 per inch, is to be cut with a lathe-screw having 1·8 per inch, and that a 20-wheel must be used on the mandril. In this case, the figures appear as follow:

$$1\tfrac{8}{10} : 2\tfrac{3}{10} :: 20 : 25\tfrac{5555}{10000}.$$

This fourth term correctly represents the teeth of a screw-wheel which, together with a 20-wheel on the mandril would cut the desired pitch, supposing that a wheel with 25 and the fraction of teeth which is noted could be obtained. Therefore, in order to cut the thread with wheels in ordinary use, it is requisite to employ some of them in such a manner that they possess the same relation as that existing between 20 and 25 $\frac{5555}{10000}$. It will be seen presently that four wheels can be easily selected for the purpose; but it is requisite to here give one or two more examples of simple-gear.

If a thread to be cut is required to have only half a step per inch, with a lathe-screw of 2 per inch, the two terms are placed in the same order as for the shorter steps before given. Thus:

$$2 : \tfrac{5}{10},$$

and when placed, the operator immediately sees that the step of the one is four times as great as that of the other, so that he must select some comparative large wheel for the mandril, in order that the one on the screw may not be too small. Either a 100-wheel, 80, or 120, can therefore be selected, and the screw-wheel ascertained thus:

$$2 : \tfrac{5}{10} :: 80 : 20$$

or,

$$2 : \tfrac{5}{10} :: 100 : 25$$

or,

$$2 : \tfrac{5}{10} :: 120 : 30.$$

Either 20, 25, or 30, on the screw, will therefore cut the desired thread with half a step per inch.

Suppose now that a small thread to have 15 an inch is required, and to be cut with the same screw of 2 per inch. By placing the two terms, the operator sees that the intended pitch is seven and a half times smaller than that of the lathe-screw, and therefore selects about the smallest wheel he has for the primary, such as 20, or 25, and obtains the following:

$$2 : 15 :: 25 : 187\tfrac{1}{2}$$

or,

$$2 : 15 :: 20 : 150.$$

Consequently, the 150-wheel must be put upon the screw, the term $187\frac{1}{2}$ not having any single wheel to represent it.

In all these examples of simple-gear screw-cutting, it is to be remembered that the two first terms of any proposition contain the representatives of the required wheels, independently of the third and fourth terms. For this reason, both of the two simple-gear wheels required for a stated pitch can be ascertained by inspecting, multiplying, or dividing the two terms only. In these operations the thing to be observed is, the numbers of teeth on the wheels which the operator has at command. For instance, suppose a pitch of 15 per inch is to be cut as in the last example with a screw having 2 an inch. Place the two terms according to the rule in page 374, thus:

$$2 : 15.$$

These very symbols alone indicate two wheels which would produce the thread—a 2-cog wheel, and a 15-cog wheel, which is proved by inspecting the four terms annexed:

$$2 : 15 :: 2 : 15.$$

But because such wheels are not in use, the multiplication or division referred to is necessary in order that ordinary wheels can be employed. For this purpose the two terms, when requisite, are reduced to their lowest names, and next multiplied or divided by $2\frac{1}{2}$, 5, 4, 10, 20, 25, 100, or any number which suits the wheels of the lathe. In the example now presented, no reduction is needful, it being only necessary to multiply each term by 10, as here shown:

$$2 \times 10 = 20, \text{ and } 15 \times 10 = 150.$$

They can be also multiplied by the other multipliers given, and other wheels indicated:

$$2 \times 15 = 30, \text{ and } 15 \times 15 = 225,$$

or,

$$2 \times 5 = 10, \text{ and } 15 \times 5 = 75,$$

or,

$$2 \times 2\tfrac{1}{2} = 5, \text{ and } 15 \times 2\tfrac{1}{2} = 37\tfrac{1}{2}.$$

By these and similar operations, it is seen that 20 and 150 are the only suitable wheels which will cut such a small pitch with simple-gear only.

It is now intended to cut a pitch of $2\frac{1}{4}$ per inch with a lathe-screw having 2 per inch. This is a case in which reduction is employed, the 2 and the $2\frac{1}{4}$ being shown as improper fractions. The two terms appear thus:

$$\frac{8}{4} : \frac{9}{4}$$

Having now reduced both terms to one name, which in this case is fourths, it is not necessary to regard them further when calculating for two wheels only; and the only thing which need be done is to take away the two numerators or upper symbols, and multiply them, because the same relation exists between 8 and 9 as between 2 and $2\frac{1}{4}$. The 8 and 9 are therefore multiplied by 5:

$$8 \times 5 = 40, \text{ and } 9 \times 5 = 45.$$

40 and 45 are thus seen to be the wheels desired. And because the second term 9 represents the intended screw to be cut, therefore the fourth term 45 represents the screw-wheel, according to the rule (page 374), the first and second terms of any proposition always denoting the lathe-screw and required screw, while the third and fourth terms denote the mandril-wheel and screw-wheel.

The next example consists in cutting a thread of $2\frac{3}{4}$ per inch with a lathe-screw of 1 per inch. After changing the terms to fractions as directed, they are seen in this form:

$$\frac{4}{4} : \frac{11}{4}.$$

By now taking away the two upper ones, which of themselves exactly indicate the relation between the desired wheels, and multiplying them by 5, we have 20 and 55 as the wheels which will produce the pitch.

A few instances in tabular form are now subjoined, in which the reduction of the two terms are involved, as will be observed by the student.

Steps per inch in lathe-screws.		Steps per inch in screws to be cut.						Mandril-wheels.		Screw-wheels.
2	:	6	::	$\frac{2}{1}$	:	$\frac{6}{1}$;	and	$2 \times 10 = 20$,	and	$6 \times 10 = 60$
2	:	9	::	$\frac{2}{1}$	:	$\frac{9}{1}$;	and	$2 \times 10 = 20$,	and	$9 \times 10 = 90$
2	:	$\frac{9}{10}$	::	$\frac{20}{10}$	:	$\frac{9}{10}$;	and	$20 \times 5 = 100$,	and	$9 \times 5 = 45$
4	:	$10\frac{1}{2}$	::	$\frac{8}{2}$	:	$\frac{21}{2}$;	and	$8 \times 5 = 40$,	and	$21 \times 5 = 105$
2	:	$\frac{7}{8}$	::	$\frac{16}{8}$	:	$\frac{7}{8}$;	and	$16 \times 5 = 80$,	and	$7 \times 5 = 35$
3	:	$2\frac{5}{8}$	::	$\frac{24}{8}$	:	$\frac{21}{8}$;	and	$24 \times 5 = 120$,	and	$21 \times 5 = 105$
$1\frac{3}{4}$	:	$1\frac{7}{8}$	::	$\frac{14}{8}$	:	$\frac{15}{8}$;	and	$14 \times 5 = 70$,	and	$15 \times 5 = 75$
$1\frac{1}{2}$	:	$1\frac{1}{8}$	::	$\frac{12}{8}$	:	$\frac{9}{8}$;	and	$12 \times 5 = 60$,	and	$9 \times 5 = 45$
1	:	$2\frac{3}{4}$	::	$\frac{4}{4}$	:	$\frac{11}{4}$;	and	$4 \times 5 = 20$,	and	$11 \times 5 = 55$.

In the first and second of these examples it is not requisite to use the improper fractions $\frac{2}{1}$, $\frac{6}{1}$, and $\frac{9}{1}$; the two first terms can be merely multiplied by 10, as before stated; but the fractional forms are given to show that the method is applicable to all. To obtain the improper fractions, the first and second terms of the examples are multiplied according to the ordinary rules of simple arithmetic.

Sufficient has now been stated to illustrate the selection of simple-gear wheels, and to show that they will cut a great number of fractional threads, in addition to those in every-day use.

Selection of Compound Wheels.—In order to select four compound wheels to cut a stated pitch, the first and second terms should be treated in a manner similar to that described for simple gear. But when calculating for a set of compound wheels, the whole of the factors or symbols belonging to the fractions are used, both numerators and denominators. For instance, select the first example in the tabular set just given, which requires a screw of 6 per inch to be cut with a screw of 2 per inch. The two integral symbols 2 and 6 are put into their simplest fractional forms $\frac{2}{1}$ and $\frac{6}{1}$, and all the four are multiplied by 20, thus:

$$\frac{2 \times 20 = 40}{1 \times 20 = 20} \qquad \frac{6 \times 20 = 120}{1 \times 20 = 20.}$$

The four products which result are the numbers of four wheels that would cut the thread; therefore inspect them and see if they are available. In some cases they would be unsuitable, because the lathe does not possess two 20-wheels; so that the four factors are to be multiplied by some other number, or two numbers, such as 25 and 20, which give these products:

$$\frac{2 \times 25 = 50}{1 \times 25 - 25} \qquad \frac{6 \times 20 = 120}{1 \times 20 = 20.}$$

The four wheels thus indicated are 20, 50, 25, and 120, which are always available. Those two which are to be drivers are 20 and 50, and produce a smaller product, when multiplied together, than the driven wheels indicated by 25 and 120, because the screw to be cut is of finer pitch than the lathe-screw. If the intended screw were to have 2 per inch, and to be cut with a lathe-screw of 6 per inch—the reverse of the example—20 and 50 would be driven wheels, and 25 and 120 would be drivers. When the numbers of wheels are obtained by multiplying the two terms in the above relative situations, the two drivers and two driven ones are always diagonally situated opposite each other, because the relation between the lathe screw and required screw is divided between two drivers and two driven wheels, instead of between one driver and one driven.

The pitch 2·3 per inch to be cut with a screw of 1·8 is to be next treated, which was mentioned in the section on selecting simple wheels. The two terms, when reduced, are:

$$\frac{18}{10} \quad : \quad \frac{23}{10}.$$

By now multiplying 18 and 10, each by $2\frac{1}{2}$, and both 23 and 10 by 5, these are produced:

$$\begin{matrix} 45 & \quad & 115 \\ 25 & \quad & 50; \end{matrix}$$

25 and 115 denoting the driven wheels, and 45 and 50 the drivers.

Proceed next to select wheels for $6\frac{1}{4}$ per inch, the lathe-screw being 2 per inch. The symbols, when changed to quarters, appear thus:

$$\frac{8}{4} \qquad \frac{25}{4}.$$

The two left-hand figures are to be now multiplied by 10, and the two right-hand ones by 5, which produce 20 and 80 as drivers, and 40 and 125 as driven wheels, each one being here shown distinct from its fractional symbol:

$$\begin{matrix} 80 & \qquad & 125 \\ 40 & \qquad & 20. \end{matrix}$$

It is to be remembered that the two terms by themselves alone, when put into fractional forms, indicate four wheels which would cut the thread; and if a large quantity of wheels were provided whose numbers advance by ones, instead of fives, it would not be necessary to multiply any of the figures, because the same relation exists between 4 and 8 as exists between 40 and 80, and the same exists between 4 and 25 as between 20 and 125.

It is now required to cut a thread with $\frac{5}{9}$ of a step per inch, the lathe-screw having $1\frac{6}{7}$ in an inch. In this case, the $\frac{5}{9}$ needs no reducing, being already in a fractional form; but the $1\frac{6}{7}$ is to be changed into $\frac{13}{7}$, after which the two terms are placed as in other cases, and multiplied by 5 and 10, as here represented:

$$\frac{13 \times 5 = 65}{7 \times 5 = 35} \qquad \frac{5 \times 10 = 50}{9 \times 10 = 90.}$$

Consequently, 35 and 50 are driven wheels, and 65 and 90 are drivers, which will produce the intended thread with $\frac{5}{9}$ per inch.

In many cases the threads are denoted with decimals instead of vulgar fractions. In such case the two terms, together with their decimals, are to be put into improper fractions by ordinary arithmetic, and are then used as before directed. Suppose a thread of 2·75 per inch is wanted, and a screw of 2 per inch is to be used, both the terms are put thus:

$$\frac{200}{100} \qquad \frac{275}{100}.$$

After which the four factors are divided by 4 and 5, and these products obtained:

$$\frac{200 \div 4 = 50}{100 \div 4 = 25} \qquad \frac{275 \div 5 = 55}{100 \div 5 = 20.}$$

25 and 55 are therefore the driven wheels, and 20 and 50 the drivers. From this example it may be seen that the process of dividing by any numbers which suit the wheels is as effective as multiplying. Division is resorted to when several figures appear in each term, and multiplication when only one or two. Another example in which division is involved is now given, which need not be further explained:

Steps per inch of Lathe-screw.		Steps per inch in Screw to be cut
2	:	3·625;

or, in improper fractions,

$$\frac{2000 \div 40 = 50}{1000 \div 40 = 25} \qquad \frac{3625 \div 25 = 145}{1000 \div 25 = 40.}$$

It is now required to cut a long lathe-screw with one step per centimètre, and using a lathe-screw of 2 per inch. The two terms, previous to being changed to vulgar fractions, are indicated in this manner:

2 : 2·539954,

because 2·539954 is the quantity of centimètres in one inch. When in the fractional forms, ready to be divided, they are indicated in this manner:

$$\frac{1000000}{500000} : \frac{1269977}{500000}.$$

The fraction $\frac{1269977}{500000}$ is in its simplest form, and obtained by dividing the fraction of $2\frac{539954}{1000000}$ by 2, beyond which it cannot be reduced, and changing the term into an improper fraction by the ordinary arithmetical method. Similarly the fraction $\frac{1000000}{500000}$ is obtained by multiplying 2, the pitch of the lathe-screw, by 500000. After this, all the four are divided, the two left-hand ones by 20000, and the two right-hand ones by 10000, because such numbers suit the screwing-wheels. This gives the result here indicated:

$$\frac{1000000 \div 20000 = 50}{500000 \div 20000 = 25} \qquad \frac{1269977 \div 10000 = 126{\cdot}9977}{500000 \div 10000 = \ \ 50.}$$

By this we see that 25 and 127 are driven wheels, and that 50 and 50 are drivers. The ·9977 of a tooth is considered as one tooth, and by using the set indicated no error can be appreciated in a length of 100 inches; consequently, the wheels are absolutely correct for all practical purposes; and only the 127-wheel requires to be made in addition to those in ordinary use. It must be observed that a considerable difference exists between the lathe-screws which are said to have 2 steps per inch. Therefore a correct screw of great length with 1 centimèter step cannot be cut except with a screw possessing exactly two steps per inch along its entire length, and every inch equal to 2·539954 centimètres.

Concerning this screw of 1 centimètre step, it is proper to refer to the section on selecting simple wheels, in which it is stated that the two numerators of two improper fractions by themselves alone indicate the wheels required. Suppose we now take away the 1000000 and the 1269977, and divide each by 10000, we get this result:

$$1000000 \div 10000 = 100, \text{ and } 1269977 \div 10000 = 126{\cdot}9977.$$

By this we see that a 100-wheel on the mandril, if there is room for it, in conjunction with the 127-wheel on the screw, will cut the same pitch as the four wheels before indicated.

It is next requisite to give the method whereby any set of wheels can be proved correct for a stated pitch. The rule is: Multiply the driven wheel or wheels together, and also the driving wheel or wheels together; then divide the product of the driven wheels by the product of the drivers, and multiply the quotient thus obtained by the pitch of the lathe-screw. If this product is the same as the pitch desired, the wheels are the right ones. For instance, What pitch can be cut with 127 and 25 as driven wheels, and 50 and 50 as drivers, the lathe-screw having 2 per inch? The result is thus obtained:

```
           50   127
           50    25
           --   ---
                635
               254
        2500 ) 3175 ( 1·27
               2500      2
               ----   ----
                6750 2·54 per inch. Ans.
                5000
                ----
               17500
               17500
```

It is thus seen that the quotient $1{\cdot}27 \times 2$ equals 2·54 per inch, which will be the pitch produced.

What pitch will be cut with 105 as a driven wheel, and 20 as driver, the lathe-screw having 2 per inch? In this case the operation is very short, the driven wheel being immediately divided by the driver, as here seen:

$$20 \;)\; 105 \;(\; 5\tfrac{5}{20}$$
$$2$$
$$\overline{10\tfrac{10}{20}} \text{ Ans.}$$

What pitch will 35 cut as driven wheel with 80 as driver, the screw being 2 an inch?

```
80 ) 350 ( ·4375
     320       2
     ───  ─────
      300 .8750 Ans.
      240
      ───
       600
       560
       ───
        400
        400
```

What step will be cut with a screw-wheel of 45, and a mandril-wheel of 60, the screw possessing 1·5 per inch?

```
60 ) 450 (   ·75
     420    1·5
     ───   ───
      300   375
      300   75
           ─────
           1·125 Ans.
```

TREATMENT OF CRANK-SHAFTS.

The two principal sorts of crank-axles are, middle axles having one crank each, used for single engines, and also for pairs of paddle-engines, and the two-crank axles which are used principally for screw-engines. All crank-shafts, small and large, require to be carefully straightened at the conclusion of forging, especially if they happen to be forged somewhat near the finished sizes. By proper straightening the subsequent lining and centring is facilitated, and the possible necessity for again heating the shafts after they have been tried in the turning-lathes, is avoided.

Large crank-axles are forged so that plenty of metal exists to be removed from the crank or cranks, and also from the axle-portions; the article is therefore first lined and centred with regard to the axle-portion, because it is easier than lining with regard to the crank or cranks.

After the gap-piece of a crank has been roughly cut out with drilling and slotting, or sawing, the first paring given consists in truly turning the axle; after which the article is lined with regard to the turning.

A small axle can be easily lined for the centring by employing a table with a scriber-block and vee-blocks. Fig. 1128 represents an axle thus treated. The piece is placed in the position shown, and a mark is made upon each end with the scriber-block, and the piece is then rotated in the vee-gaps for making two or three more marks, the operation resembling the centring of a straight piece with the exception that tall vee-blocks are used, to allow room for the crank. When an axle with two cranks is lined in this manner, one vee-block should be situate between the two cranks, as denoted in Fig. 1131.

To centre an axle with regard to its crank it would be necessary to place its crank upon parallel blocks, or upon a single one, as in Fig. 1129; and after scribing a line upon each end to put it upside-down that the opposite broad side of the crank might be in contact with the block during the scribing of another line. The middle between these two lines is the centre required, and to complete the centring a couple more marks are to be made with the axle in vee-blocks.

When the centre recesses and the extremities of an axle have been properly prepared as directed for turning other objects, the piece is ready to have its axle-portions rough-turned, leaving about an eighth of an inch in diameter to be turned off for finishing, after the crank-pin has been turned, if the axle is only an inch or two in diameter; but leaving at least a quarter of an inch for axles of seven or eight inches. This is necessary because, during the rough-turning, the article will become distorted, both while the axle is being reduced and during the turning of the crank-pin.

When the axle has been turned so that a part of each axle-end is of the same diameter, the piece can be prepared for turning its crank-pin. The lining to show the places for the crank-pin centres is executed on a lining-table, or planing-table. The object is placed, with the two portions of the axle of the same diameter in contact with a pair of vee-block gaps, and with the crank standing at right-angles to the table, as denoted in Fig. 1130. An el-square is to be used, and put to both sides of the crank, so that if the two broad sides are not parallel with each other, both of them will be equally inclined to the table. The crank is now in position for the marking of the centres, and a holdfast plate is fixed upon the axle to prevent its shifting. The intended length of the crank's throw is to be next shown from the centre length of the axle, because this is indicated by the centre recesses on which the axle is turned. A scriber-block is therefore adjusted until its point is at exactly the same height from the table as the centres of the conical recesses, and a straight line is marked across the crank's two levers, which is denoted by A and A in the Figure (1130). At the adjustment of the scriber-point for this marking it will be found that if the point is at the height of one centre-recess, it is also at the height of the other one, because the axis of the axle is parallel with the table on account of the two axle-portions in the pair of vee-gaps being of one diameter. But if it occurs that one portion is larger than the other, the two centre-recesses are not equidistant from the table, but can easily be put equidistant by packing-pieces in contact with the vee-blocks.

The axis of the axle being now shown by the line A and A, a compasses is adjusted to place their points as far apart as the length of the throw; one point is then put into two points in the line, each at about the middle of the lever, and two arcs are scribed upon the upper part of the crank, shown in the Figure by R and R. These are at the same height from the table as the centres for the crank-pin, supposing that the marked side of the crank is exactly square to the table, and the scriber-point is next raised to the highest portions of the arcs, and a couple of lines are marked across the intended centres for the crank-pin. One of these lines is seen and indicated by P.

Having shown the length of the throw, the centring is next completed with the crank lying down on a block, as seen in Fig. 1132. While in this position the point of the block's scriber is placed somewhat near to midway between the crank's broad sides, and a short line marked across each of the two lines P scribed at the previous scribing. The axle is next half rotated, and the same packing-block is put beneath the opposite side of the crank now near the table, and the scriber-block again applied to mark another line across each end, while the point is at the same height as before. The three lines now existing on each end of the crank-pin are seen in Fig. 1133. The point situate midway between is the centre required, and is dotted accordingly. A circle is also scribed around, to guide the operator during drilling.

In order to prevent the centre-recesses being put rather out of place during the drilling, a small fiddling drill is first used, and observed at its entering-in, to see that it is in the centre; after which the drill-holes are enlarged and coned as before described.

A crank thus centred is to be turned with its crank-pin ends in immediate contact with the lathe-pivots; consequently, the turning is performed with a lathe having a mandril-pivot and a poppet-pivot of suitable length and thickness for the crank in progress. Any large lathe will thus easily turn a comparative small crank. When on the pivots the axle-portion near the chuck constitutes a means of rotating the work. A crank in this situation is represented by Fig. 1134. The axle can be held with a poppet and short driver, as shown; or with a poppet and long thick driver—one which is long enough to reach to, and bear against the crank.

Turning should commence by widening the gap to very near its ultimate width, by means of right and left corner-tools. This will allow room for the turning-tools to turn the crank-pin portion, which must be effected with the ends of the slide-rest tools projecting as far from the slide-rest as the depth of the crank-gap.

Large Single-crank Axles.—A large crank axle of about five, ten, or twelve inches in diameter, requires rather different treatment to that for a small one only a couple of inches in diameter, principally in consequence of its greater weight. It is, however, always advisable to use vee-blocks for large axles in about the same way as for small ones, because the portable cranes now employed will easily lift and move heavy objects to and from a lining or planing table, and also alter their positions as required while on the table.

To centre a crank-shaft without vee-blocks, it is suspended with a crane and marked with a gap straight-edge or rectol. Rectols having gaps of suitable shapes for cranks are indicated by Figs. 1135 and 1137; and an implement of this class in use is seen in Fig. 1136. By means of a rectol being placed in contact with the axle-portions at both sides of the crank the centres are shown with regard to the parts adjoining the cranks, and also the ends; and if the axle is crooked the centring will cause the crooked parts to rotate about as truly as the straight portions. While a rectol is in contact a calliper is adjusted, and placed upon the outer edge, to make marks upon the axle-ends, in the same manner as described in pages 348 and 360, for centring bolts and straight shafts.

A monto also can be used to centre a crank-shaft, if the vee-blocks of the implement are tall enough to keep the straight-edge part from touching the shaft. A long straight-edge and a couple of parallel blocks also can be employed as a substitute for other implements.

When the shaft is centred and coned, the rough-turning proceeds while a packing-block, or blocks, is in the crank-gap. This packing is required to resist the pressure of the poppet-pivot imparted to the shaft in the direction of its length, and also to assist in steadying the shaft against the strain of the cutting tools. As soon as the axle-ends are turned along their lengths, the adjoining two sides of the crank, also turned, and a portion of each end turned to one diameter for resting in the vee-blocks, the ends can be fitted to the pivot-carriers.

The pivot-carriers are required for turning crank-shafts' crank-pins; and are two in number, one situate on each end of the shaft. Implements of this class are indicated by Figs. 1138 and 1139. Each carrier consists of a kind of lever which is to be tightly fixed on a shaft-end so that one end of the carrier shall be opposite the crank-pin portion. In this condition a conical recess can be made into each carrier, to fit the lathe-pivots; consequently, while the shaft is thus supported, both it and the carriers can revolve around the axis of the required crank-pin.

An axle having its two pivot-carriers attached ready for turning, is denoted by Fig. 1141. Each carrier is furnished with a circular hole the diameter of which is amply large enough to allow the shaft-ends to be reduced after the crank-pin is finished; and if a number of axles of the same size are to be turned, all the ends are accurately fitted to the holes in the carriers so that the same pair may be used for all. Each carrier-hole has a key way, that a headed key may be inserted to avoid risk of shifting. The axle-ends are smoothly turned so that the carriers can be easily hammered upon them and be easily removed, being only tight enough to prevent looseness when attached.

Adjusting the carriers to the proper positions on the axle, is performed on a lining-table or planing-table, while resting in vee-blocks, as in Fig. 1140. The operation consists in placing them and marking them at the same process; and when the two carriers have been placed upon the shaft to somewhat near their intended positions, the axle is lifted and maintained with its crank lying near the table, by means of a few packing-blocks, as in the Figure. The carriers are now keyed tight in their positions in which they are to remain during the turning, their outer sides being nearly level with the extremities of the shaft. A straight line is marked along the crank, as soon as it is put parallel with the table, in order to show the centre of the crank, and the centre of the crank-pin also, which line is indicated by C. The line is scribed parallel with the table so as to extend across the axis of the shaft, by reason of the crank being kept at the proper height with the packing-blocks.

When the centre line existing on the crank is adjusted to parallelism with the table, by referring to the scriber-block, the block is moved to the carriers, and a line scribed along each of their outer sides, one of which is seen denoted by P. These partly indicate the places for the intended centre-recesses, because they are marked at exactly the same height from the table as the gauge-line C. It is next requisite to mark the length of the throw upon each line P, and thereby complete the centring of the two carriers.

By this method, the axis of the crank-pin is indicated exactly parallel with the axis of the axle, which is required; and a small circle is next scribed around each centre, and dotted, that the centre may be afterwards found if necessary, when the conical recesses are made.

In addition to scribing the length of throw upon the carriers, it is requisite to scribe the centres for turning the extremities of the crank or lever-ends. These centres are marked upon the same lines on which the crank-pin centres are situate, both being equidistant from the axis of the axle. But this distance depends on the intended length to which the lever-ends are to extend from the axle; therefore the length is ascertained and the centre scribed accordingly. One of these is denoted in Fig. 1141, by M.

The turning now proceeds by first turning the lever-ends just referred to, in order that the crank may be thus caused to occupy as little room as possible during the turning of the crank-pin, and thereby generate as small a circle of revolution as possible. These lever-ends can be entirely finished at this turning. The work is next shifted, and caused to rotate on the crank-pin, the gap being first widened, to allow room for the long slide-rest tools to operate at the bottom of the crank-gap to shape the crank-pin. During these operations the crank is stayed with the wood packing-blocks indicated by B and B, in the Figure (1141) situate in line with the axis of the crank-pin. After the stays have been fixed, they must not be shifted until the turning of the pin is finished, especially if it is very nearly reduced to the specified dimensions. By shifting the stays, and also by adjusting them, the crank is liable to be sprung or bent to some extent.

During the turning of the crank-pin, the slide-rest tools should be supported at their cutting ends. This may be effected either with a screw-bolt and nut with a few packing-pieces, or with a tall wood block of proper height which is fastened with a wedge. By either of these appliances, the tool can be effectually supported during all the rough and smooth turning which is executed with the lathe's long traverse, because the supporter, when fixed, rests on the lathe-carriage, and therefore moves with it in conjunction with the tool. The supporter should be used also when finishing the crank-pin's curved corners with the slide-rest, but without the long traverse motion; because, although during the finishing, the tool is moved independently of the carriage, the amount of movement is not enough to interfere with the easy operation of the cutting-tool. The fixing of a supporter beneath a tool-end, consists in gently tightening the wood prop with the wedge, or the screw-bolt with its nut, after the tool has been properly placed and fastened in the slide-rest; and in the case of a prop being applied to a tool for finishing a corner, the tool is first advanced to about a sixteenth from the corner, by working the slide-rest screw, and the prop is then fastened in the desired situation

One of the author's props for crank-turning consists of a screwed rod having a clasp at the upper end, the clasp being fastened with a little fixing screw to hold it to the tool. The clasp also swings around the rod or prop, so that it can be fixed at either side of the tool, and not come into contact with the crank during its revolution, however near the edge of the tool may be to the edge of the crank.

Crank-pins are finished with springy tools and soap solution. The tools should be made of thin bar-steel, and are to be used in conjunction with a thick slide-rest tool, or a dummy, on the top of which the spring tool is fastened. Tools of this class are also used for planing, and are indicated by Figs 711 and 712.

After the crank-pin and adjoining sides of the gap are finished, the pivot-carriers are removed, and the axle-ends are finished to the specified diameters and length. During this turning one stay is required, and is gently wedged in the crank-gap without distorting it.

Large Two-crank Axles.—An axle having two cranks is lined and centred for the first turning of its axle-parts, in the same manner as a single-crank axle, either by placing the axle into vee-blocks and scribing with a scriber-block, or by using a gap straight-edge and marking with a calliper. The rough turning of the axle next proceeds, together with the turning of the four crank-sides adjoining the axle. If a great quantity of metal is to be cut off, it should be done previous to cutting out the gap-pieces of the cranks with the drilling, slotting, or sawing. While the cranks are devoid of gaps, the shaft is not so liable to tremble in course of turning.

As soon as the axle is reduced so that two portions are of one diameter for resting in the vee-blocks, the two ends turned to fit the pivot-carriers, and the gap-pieces cut out, the lining for turning the crank-pins proceeds on a table with the aid of vee-blocks used as for a single-crank axle. For this lining two centre lines are requisite, one on each crank, both being analogous to the line C in Figs. 1140 and 1141. The two lines on a two-crank axle are indicated by C and C in Fig. 1142. These are required to be right-angular to each other, and also properly situated to pass through the axis of the axle. The first step, therefore, is to put the scriber-block to each centre recess, to see if the axis is exactly parallel with the table; if not, by reason of a difference between the vee-gaps, or other cause, it is easy to pack up one block with a thin packing-piece. The axis bein gnow parallel, that crank which is lying near the table is put as near to parallelism with the table as the rough surface will allow, by merely measuring with a calliper the distance of both ends of the crank from the table. The shifting for this purpose consists in merely rotating the axle a short distance in the vee-gaps; and when the crank is placed, the scriber-block, with the point adjusted exactly to the height of the shaft's axis, is put to the crank, and a line scribed along it, which is one of the centre lines C required.

To mark the other centre-line upon the other crank, the shaft is rotated a quarter of a rotation, so that the line just marked may be put square to the table. An el-square is therefore put close to the crank, which is now upwards, as represented in the Figure (1142), and the distance between the edge of the blade and the line is measured with a compasses at top and bottom. By this means, and rotating the shaft a little, the line is placed right-angular, and the entire shaft into position for scribing the other centre line upon the other crank, now parallel with the table. Therefore, the scriber-block, with the point of its scriber at the same height as before, is put to the crank and the line scribed. Both lines are next dotted along their lengths, that they may be easily referred to in the event of some portion getting erased.

The second centre-line can be marked also with a square and scriber, instead of with the scriber-block. In this case the centre-line marked on the first crank is put parallel with the table, without regarding the other crank which stands at right-angles. In this position the square is put to the crank standing up, and at both sides of the axle, so that two parallel lines are marked from top to bottom of the crank; after which the desired centre line is placed parallel with those marked with the square. Large cranks can have their centre lines marked also by means of right-angular cross-lines, which are marked upon the smoothly-turned shaft-extremities. This mode suits taper cranks belonging to axles of large diameters. Also, by using the author's gap-square, only the one centre line need be scribed.

The two centre-lines now exist right-angular to each other, and are next referred to for adjusting the pivot-carriers to their proper positions on the shaft. These are therefore put upon the shaft with their ends opposite the crank-pin to be first turned, the centre-line along each carrier being parallel with the table, and so that their outer surfaces are about level with the shaft-extremities. In this condition the shaft-ends are scribed for the key-ways, which is done by moving a scriber along inside the already-finished key-ways in the carriers. The key-ways are next cut, the keys well fitted, and the carriers again put upon the shaft to be keyed tight. Both of them are to be now lined, to show the places for the centre-recesses. This is partly done by placing a scriber-block to each carrier and marking a line along their middles while the scriber-point is at the same height as the axis of the axle, and while the centre line of the crank to be first turned is parallel with the table. To finish this marking it is now only necessary to mark the length of throw and the places for the two middle recesses upon the two carriers, measuring from the shaft's axis. While marking the length of throw, a compasses, or wire gauge with pointed bent ends may be used, and the outer surfaces of the carriers may be situate as far inside the extremities of the shaft as the depth of the recesses. This will cause the length of throw to be correctly scribed while one point of the gauge touches the bottom of the drill-hole, and the other point is scribing an arc across the centre-lines on the carriers.

The conical recesses can now be made into the carriers, and the crank-pin and gap-sides finished; after which the carriers are removed from the shaft and again fixed for turning the second crank. This fixing is quickly done if the carriers were previously correctly fitted with regard to their circular holes, their keys, and key-ways. To fix them the second time the axle is put upon the vee-blocks, and the crank to be turned is put parallel with the table; therefore in the same position as the first crank at the previous fixing. On this occasion the centre lines on the two carriers and the centre line on the crank to be turned are all put parallel with the table. Being thus adjusted, the places for the second couple of shaft key-ways are accurately marked by moving a scriber along inside the carriers as before. The key-ways are next cut and fixed to the lines, which will cause the three gauge-lines to be parallel with each other when the keys are driven in and the carriers fixed. This marking of two key-ways in the proper places, and fastening the carriers thereby, prepares the work for turning the second crank-pin without in any way altering the centre-recesses, the same recesses being used for the second crank as for the first.

It may be here noticed that it is scarcely possible to so accurately form the key-ways that all the three gauge-lines shall be exactly parallel with the table when the carriers are finally fixed; but any careful fitter can form the key-ways so that the lines shall not diverge more than a thirtieth of an inch from parallelism. Such small divergence merely causes one crank to be not quite right-angular to the other, supposing that both carriers are caused to diverge in the same direction, and such a difference is of no importance. The length of the throw cannot be affected by error in the key-ways. It is, however, usual to try the lines previous to finally widening the key-ways, at the time the keys will enter only a short distance. At this stage the shaft is moved and the scriber-block put to the lines, which will indicate which sides of the key-ways require most filing.

In order to balance the overhanging metal of the shaft and its crank or cranks in the lathe, balance-weights are fixed either to the lathe-chuck or to the pivot-carriers. If attached to the carriers, a hole is provided in one end, to admit a stem or rod, on which weights of any convenient sizes are bolted, and at the distance from the axis of rotation desired. Stems of this class are seen attached to the carriers denoted by Figs. 1138 and 1139. Adjustment of the weights, therefore, consists in shifting them to their proper places while the lathe is at rest, observing whether the chuck will remain in any position in the course of its rotation.

To turn the cranks of an axle having discs, the discs can have holes drilled therein, and the carriers be attached with bolts and nuts. Or, if a shaft having only one disc is to be turned the disc-end can be provided with an extra length of shaft, on which portion one carrier can be keyed. This is the mode adopted for the shaft in Fig. 1142.

To turn a single-arm crank situate at one end of an axle, only one pivot carrier is required, and is fixed at one end, as in Fig. 1143.

It is necessary to here mention how crank-pins of solid cranks can be shaped without requiring the fitting of distinct carriers, and also without involving the revolution of a great weight of overhanging metal in the lathe.

Single-crank axles with the cranks situate at some distance between the two ends can be, in nearly every case, forged with superfluous crank-arms or levers, each axle having two, one at each end, and solid with the remainder of the shaft. A crank thus forged is shown by Fig. 1144. It is easy to place the two arms so that they extend from the shaft in the same direction as the crank, and they can be easily centred after the axle has been partly turned, as described for other cranks. When the crank-pin has been finished by such means, the superfluous arms are cut off with drilling and slotting, and the axle-ends finished.

Superfluous arms of this character would not be so serviceable for two-crank axles, because four arms would be required; and their cutting off would occupy nearly as much time as fixing two distinct carriers. But in the case of only one crank-shaft of a size being in progress, and no pivot-carriers existing for the turning, it is decidedly preferable to forge the shaft with the carrier-arms, whether it has one crank or two, or whether small or large. It is preferable to cut off the arms, rather than to cast new carriers, fix them, and detach them.

An axle having only one crank with its crank-pin existing at one end of the shaft, requires but one superfluous arm—to exist at the opposite end—which allows the turning to be done with a centre-recess in the crank-pin, and a centre-recess in the extra arm.

An axle with two discs requires a piece to be forged solid with each disc, the piece extending from the proper side of the axle and to a sufficient distance. This arrangement will be found very effectual for a disc-shaft, especially if the throw of the crank is short, as often occurs, in which case the extra pieces will need to extend only a very little beyond the discs, and can therefore be easily turned off with the lathe without any previous drilling.

The crank-pins of shafts can also be easily shaped while the entire shafts and cranks remain at rest. For this purpose rollions are employed. A rollion is a paring-machine, which mainly consists of a table similar to a planing-table, and a revolving apparatus which travels around an axis which is parallel with the table. A shaft requiring its crank-pin to be shaped is first lathe-turned sufficient to entirely finish the axle-portions, after which it is put upon the table of the rollion, the axis of the shaft put parallel with the table, and the axis of the crank-pin put into line with the axis of the revolving cutting apparatus or head, in which position the crank-pin is shaped. There are several sorts of rollions in Britain and the Continent, those having their tables situated vertical being suitable for short crank-axles, and those with their tables horizontal being best for heavy axles of great length. By using a horizontal table it is not necessary to fix the length of the shaft vertical.

SCREW-SHAFTS AND PROPELLER-SHAFTS.

Screw-shafts.—The screw-shafts of a pair of engines properly include the crank-shaft, all the intermediate shafts, and the propeller-shaft; but the intermediate shafts only are here meant. These are connected to each other and to the crank-axle by means of circular discs, bolted together with screw-bolts. In order to cause any set of screw-shafts to be fastened together in line with each other without improperly straining the connecting-bolts, the outer surface of each disc is truly turned while in the lathe to make them all square to the lengths of the shafts. The inner surfaces of the discs are also turned, that the bolt-heads may bear properly. No other turning need be executed for a mere intermediate shaft, unless it is to have a pillow-block.

Thrust-Axles.—A thrust-axle is usually one of the intermediate axles, and its thrust part should be situate near one of the discs, that the turning of this portion may be performed at a part not liable to tremble during turning. The thrust part is always forged devoid of any groove, in the condition denoted in Fig. 1146. The thrust-ridges are produced first with grooving-tools, next with narrow right-hand and left-hand corner-tools, and finished with narrow spring tools.

In order to cause all the ridges of a thrust-portion to fit and bear equally against all the ridges of the thrust-block, a pair of sheet gauges are used—one fitting the block, one fitting the axle, and both fitting each other.

Propeller-axles.—A considerable amount of turning is executed upon a propeller-shaft; its disc being turned, its middle part turned to suit the packing-bushes, its cone turned to fit the propeller-boss, and a thread sometimes formed, which is situate beyond the cone to fit a nut whose face is screwed tight against the boss.

If a propeller-axle is to be furnished with gun-metal linings or coverings for contact with the packing-bush or tube, the portion of the shaft on which the lining is to be situate, must be either larger in diameter than the rest of the axle, or smaller. If larger, the portion can be truly turned, and separate bushes provided which can be placed upon the shaft and fixed with keys and pins. But if such part is smaller, it must be furnished with gun-metal in a liquid state which is poured around the heated shaft, and becomes as if solid with it, so that at a future time it requires cutting off, and fresh metal to be poured around. For this purpose the shaft should have been so forged that the portions intended for the linings are of the finished diameter, and need no turning except at the corners. The shaft is then centred with a rectol, or monto, to cause these smaller portions to rotate truly in the lathe. The larger parts adjoining the necks for the gun-metal, are now to be truly turned, which prepares the work for the pouring. The metal is poured into a mould properly built around the heated shaft, to cause the lining to be of about equal thickness. This process bends the shaft, and requires it to be straightened, which can be done either in the lathe with which the turning is to be effected, or with a proper lathe for straightening in the smithy, before referred to (page 56). When it is straight the truly turned portions adjoining the gun-metal are seen to rotate truly as before bending; after which the turning proceeds to shape the lining, cone, and effect other turning and screwing intended.

The thread for a propeller-shaft should be cut with the same lathe which executes the turning. But when it happens that a long shaft is to be screwed with a comparative short lathe, or one having a comparative short screw, the screw-cutting can be effected while the shaft is situate with its propeller-end next the chuck, as in Fig. 1147. The propeller-nut is of gun-metal to resist the water; but a cast-iron one is suitable, if its face is smoothly turned, and its screw fits the shaft to keep out the water.

The discs or couplings of screw-shafts are also, in some cases, of cast-iron, and keyed in their places, instead of providing forged iron or steel discs solid with the straight portions. When separate discs are employed they are fitted and keyed in their respective places, either previous to finally turning their outer surfaces, or afterwards; because the tightening of the keys will not alter the relative positions of the discs if they are properly bored to fit the shaft-ends.

A long slender shaft during turning, requires the aid of a stay to prevent vibration, and thus enable the tool to cut. A stay for this purpose consists of a pedestal which is fastened to the lathe at about midway between the two ends of the shaft. The upper portion is furnished with bearers which should be of wood, with which the shaft is gripped and thus steadied during its rotation. To prepare the shaft for such a stay, it is gently reduced with thin cuts without the stay, until it rotates truly at the place to be gripped; after which the apparatus is attached and the heavy turning proceeds.

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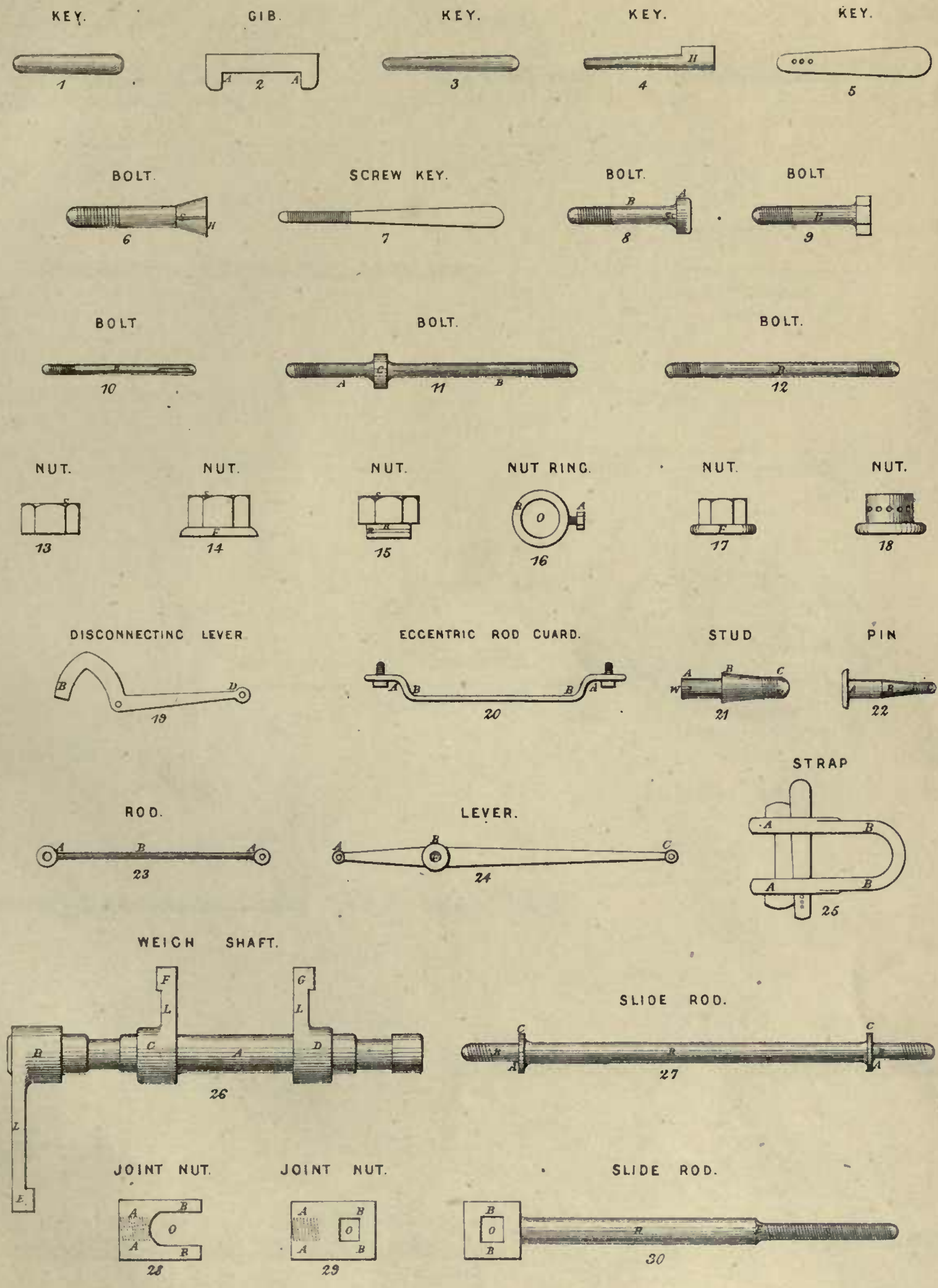

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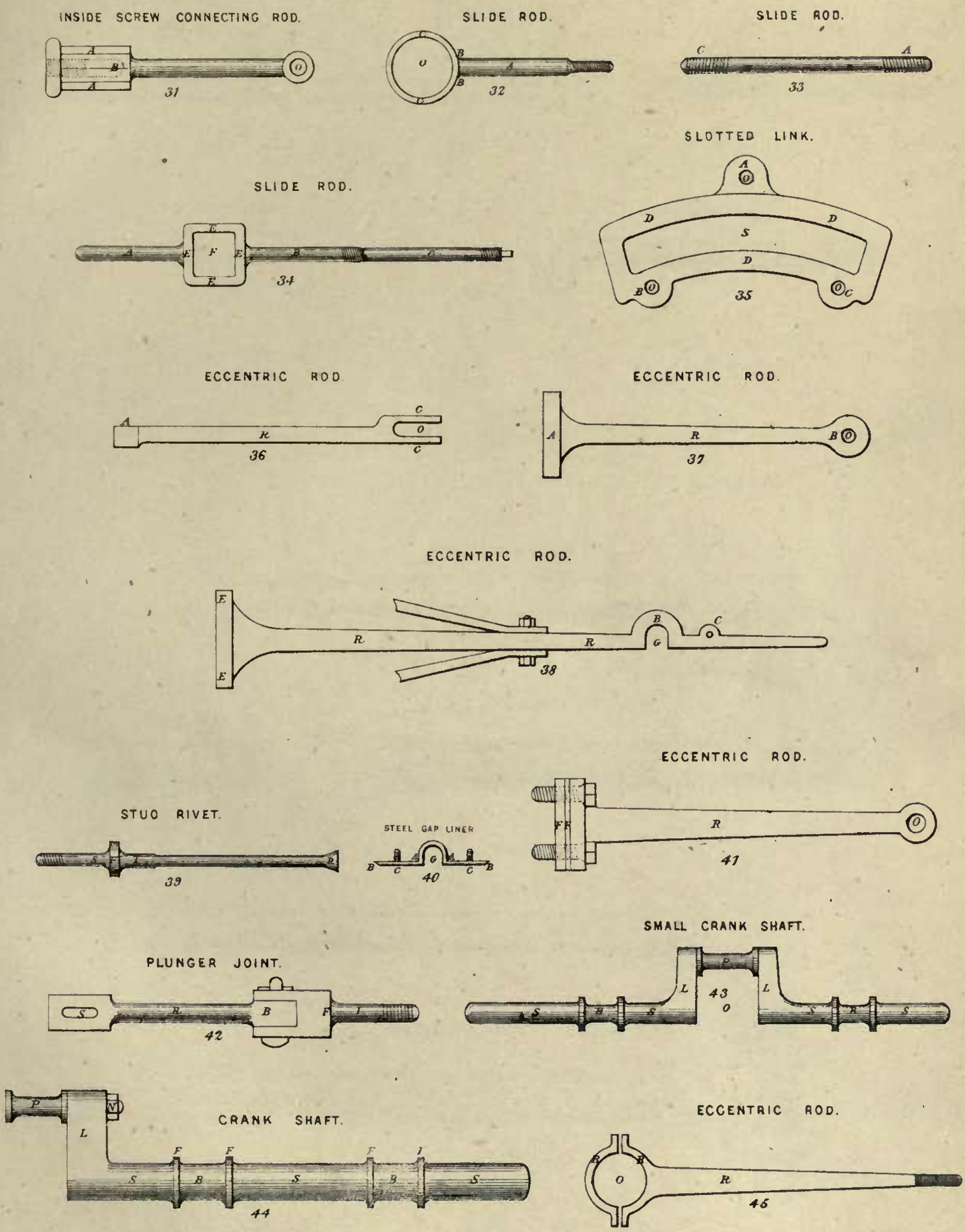

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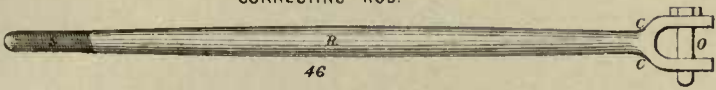

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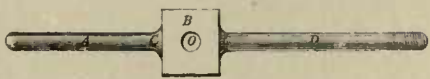

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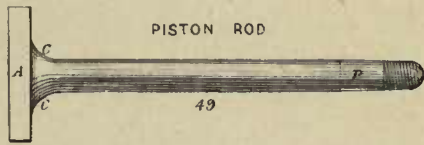

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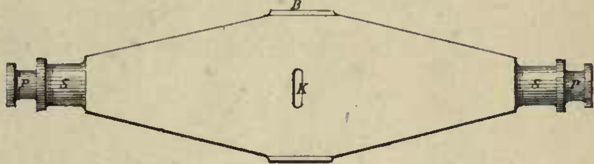

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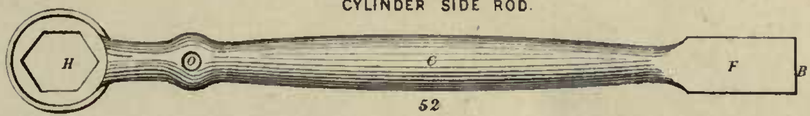
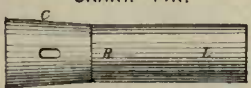
CYLINDER SIDE ROD.



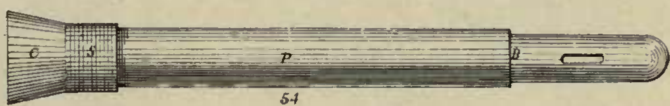
52

CRANK PIN.



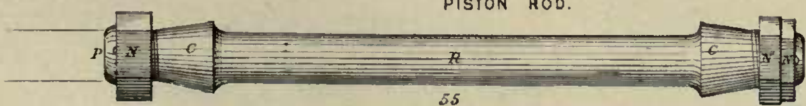
53

PISTON ROD



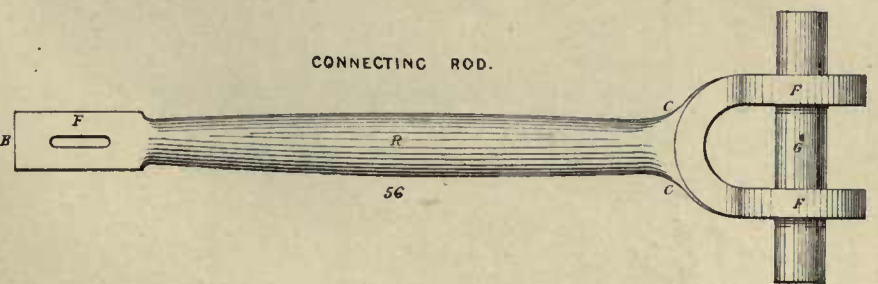
54

PISTON ROD.



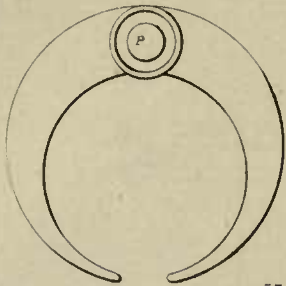
55

CONNECTING ROD.



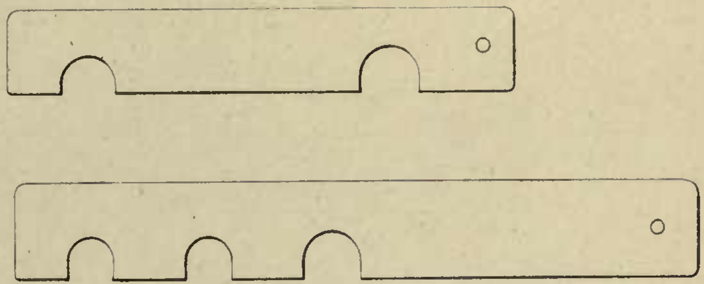
56

CALLIPERS



57

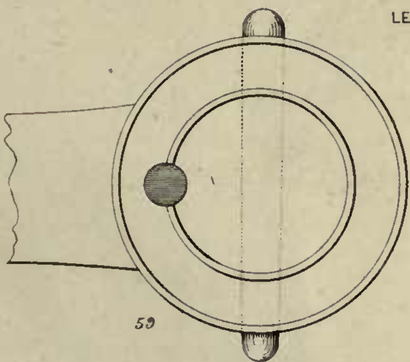
CAP GAUGES.



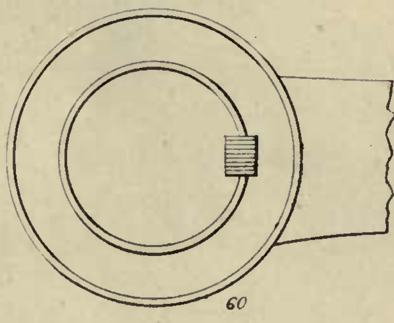
ROUND PIN WITH HOLDER

58

LEVER BOSSES.



59



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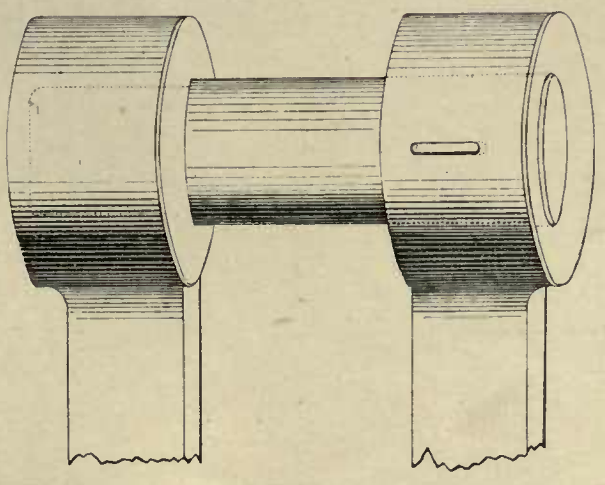

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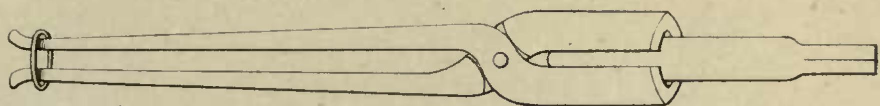
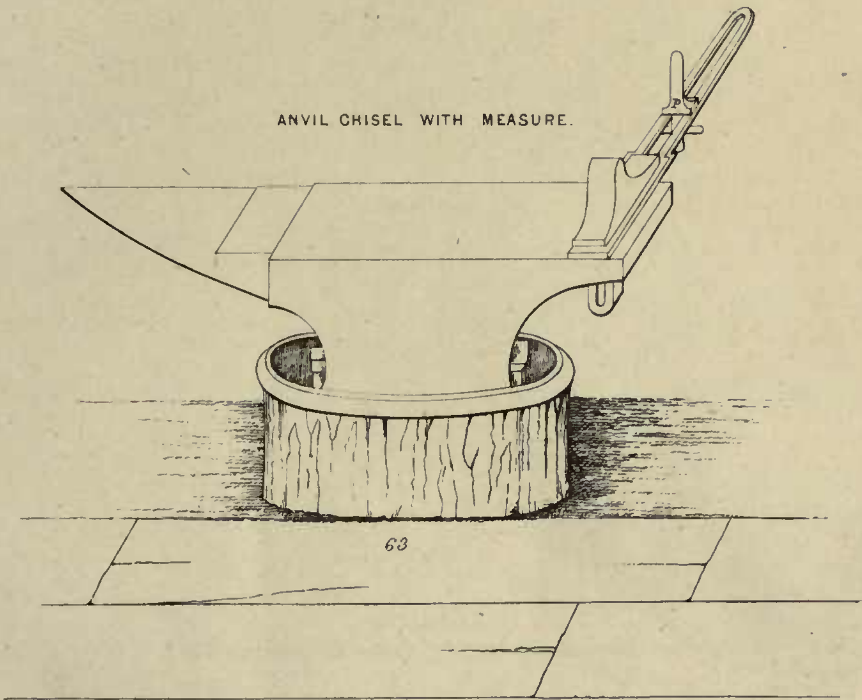
61

ANGULAR CAP TONGS.



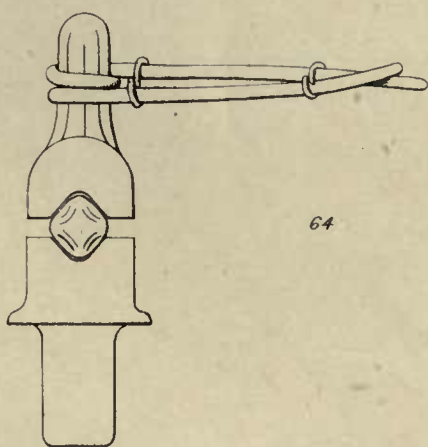
62

ANVIL CHISEL WITH MEASURE.



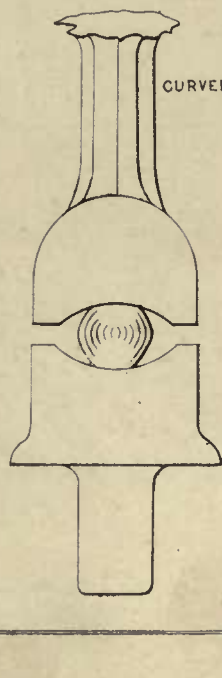
63

ANGULAR ROUNDING TOOLS.



64

CURVED ROUNDING TOOLS.



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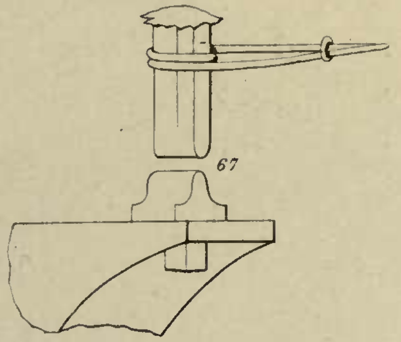
ROD CHISEL

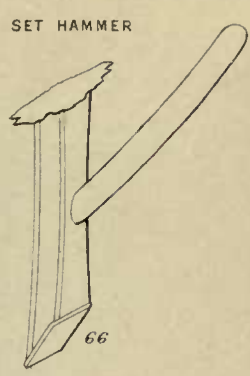
65

SMALL FULLERS



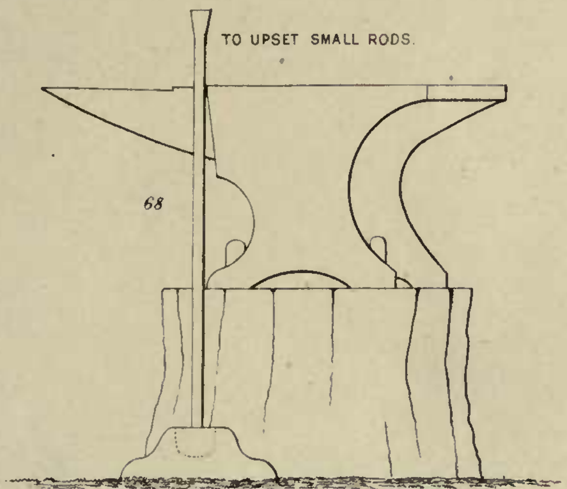
67

SET HAMMER



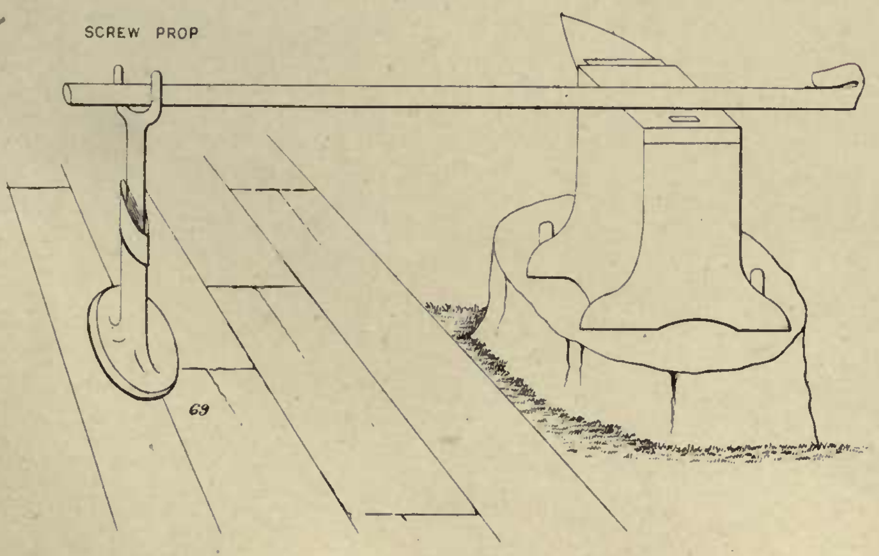
66

TO UPSET SMALL RODS.



68

SCREW PROP



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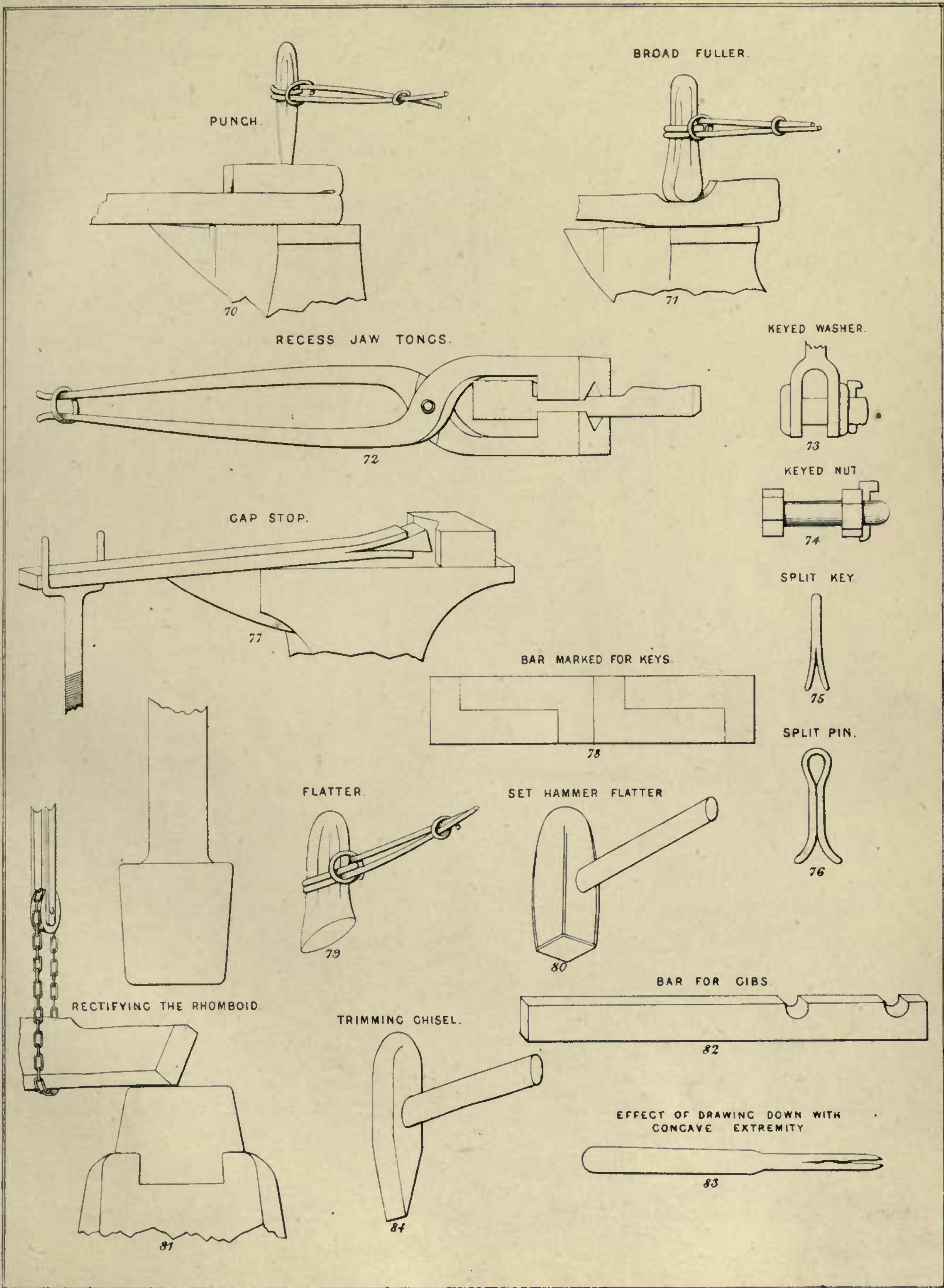

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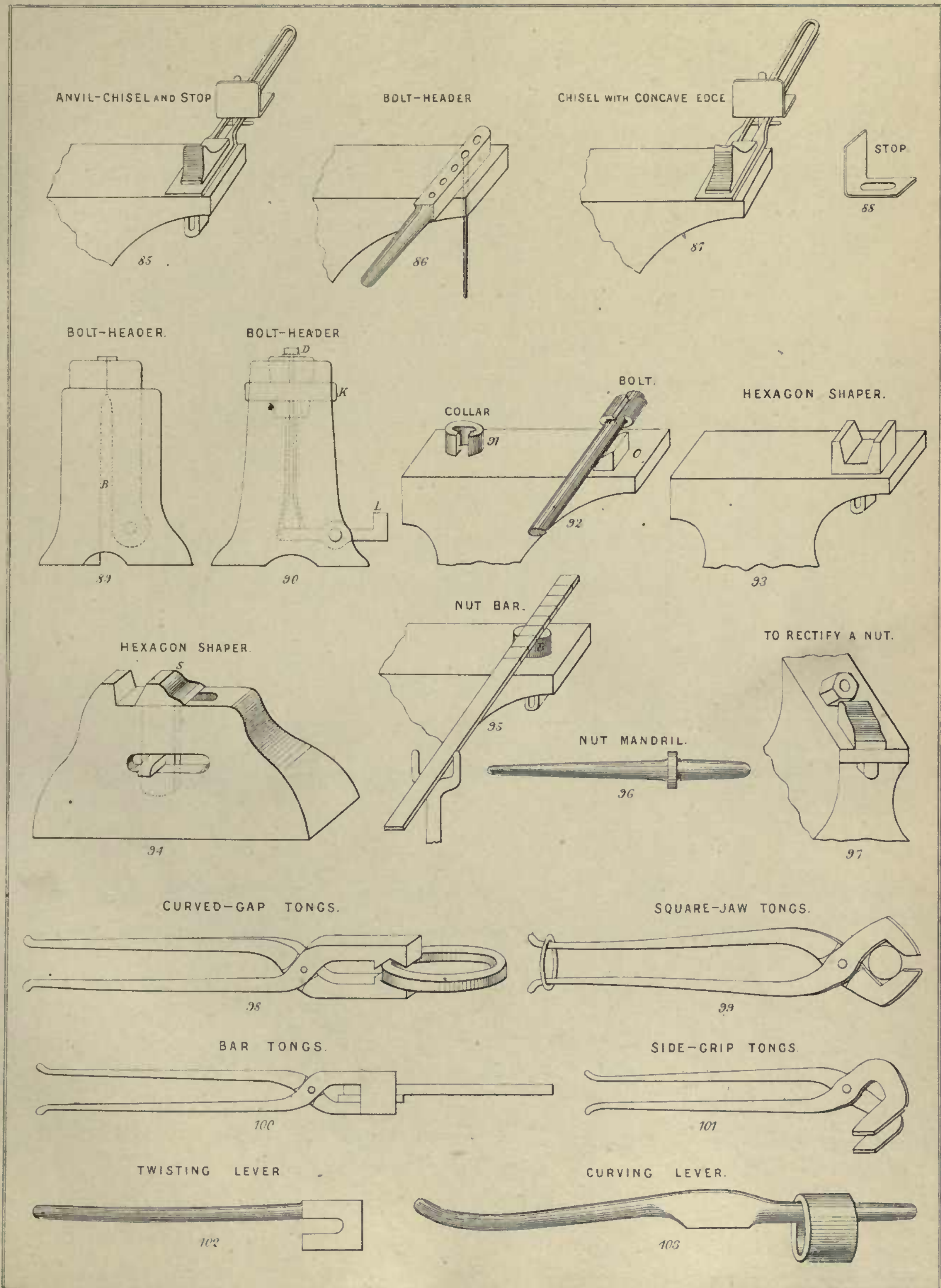
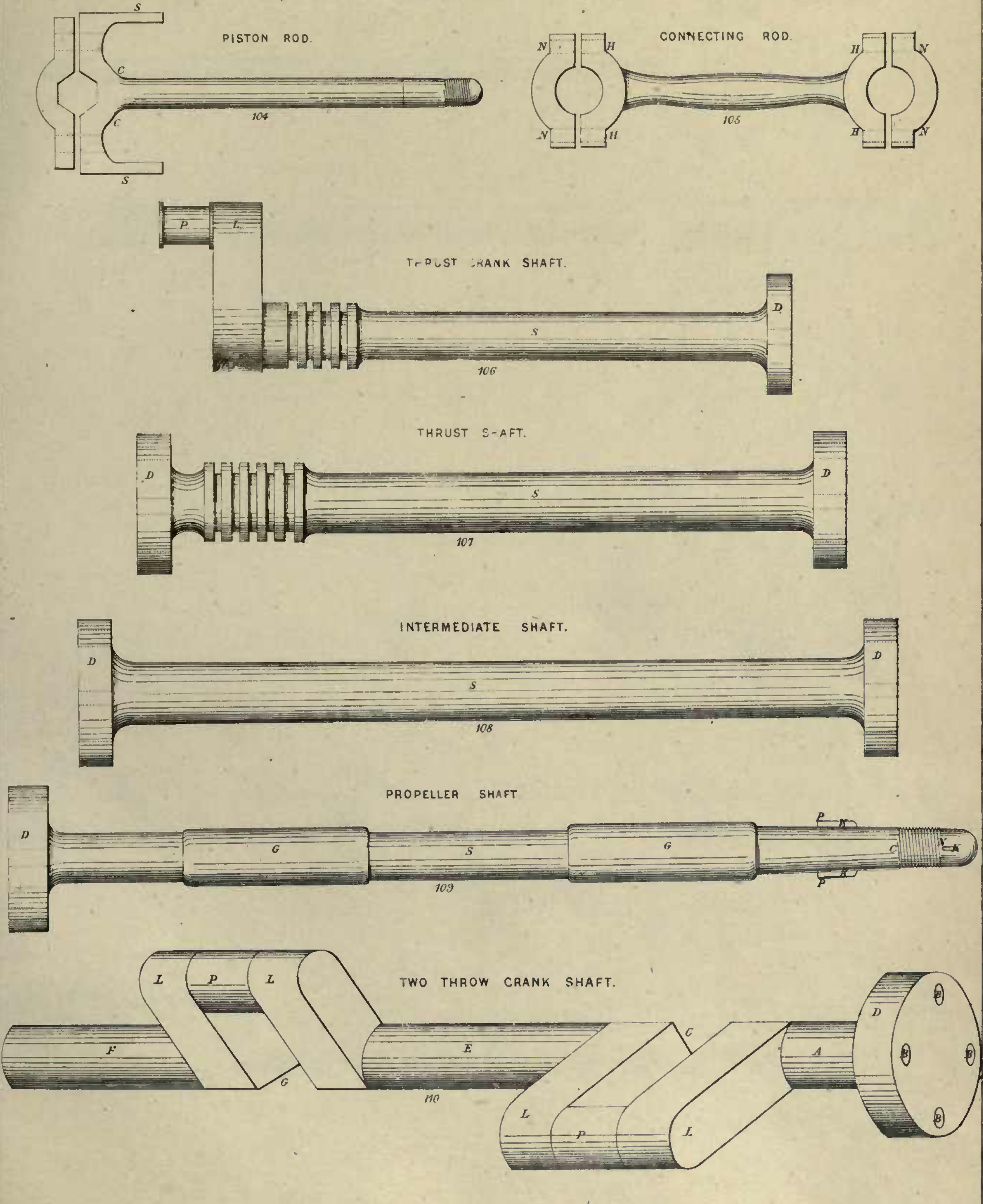

ANVIL-CHISEL AND STOP
85
BOLT-HEADER
86
CHISEL WITH CONCAVE EDGE
87
STOP
88
BOLT-HEADER.
B
89
BOLT-HEADER
D
K
L
90
COLLAR
91
BOLT.
C
92
HEXAGON SHAPER.
93
HEXAGON SHAPER.
S
94
NUT BAR.
B
95
NUT MANDRIL.
96
TO RECTIFY A NUT.
97
CURVED-GAP TONGS.
98
SQUARE-JAW TONGS.
99
BAR TONGS.
100
SIDE-GRIP TONGS.
101
TWISTING LEVER
102
CURVING LEVER.
103

ENGINE FORGINGS



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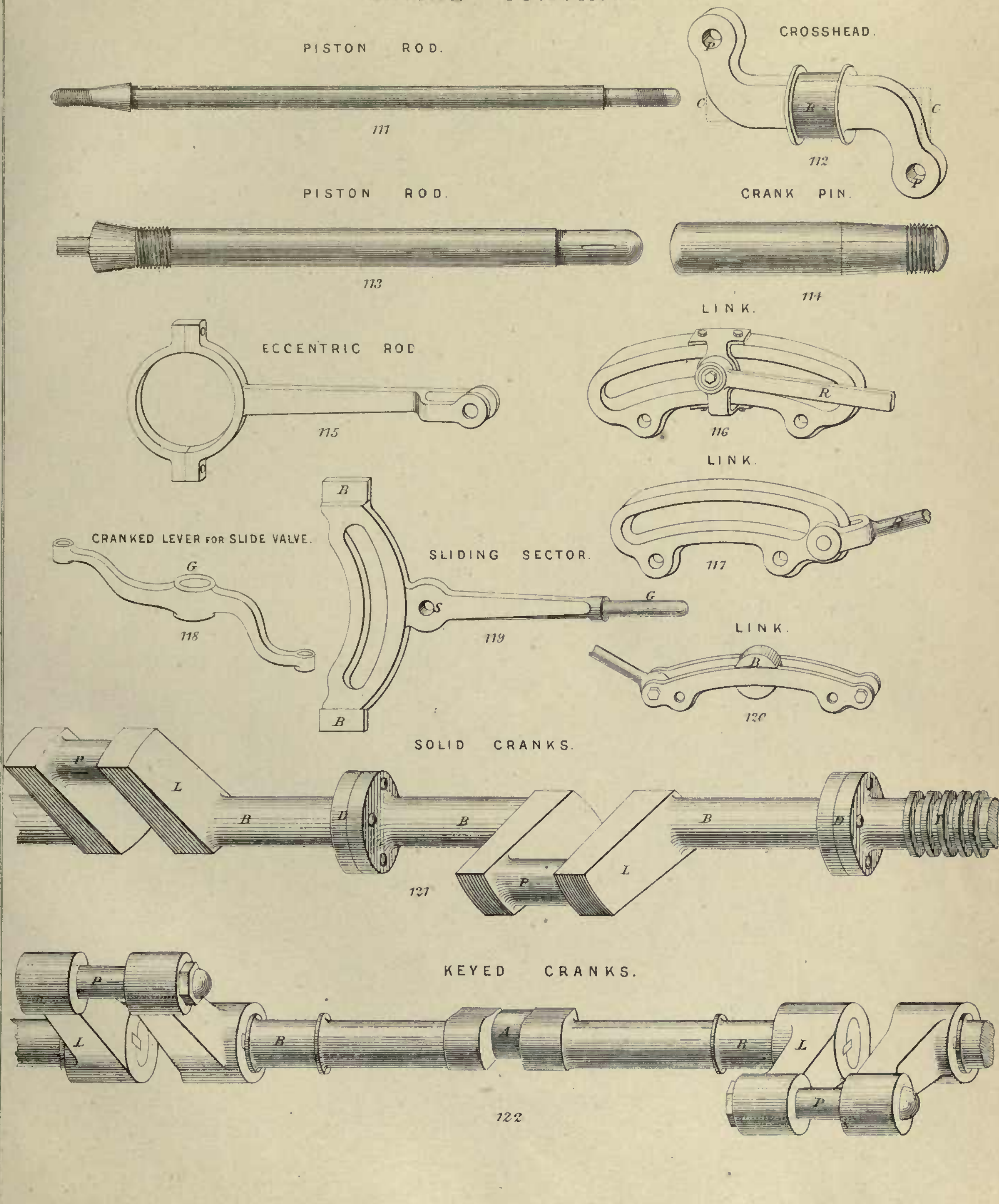
ENGINE FORGINGS



ENGINE FORGINGS

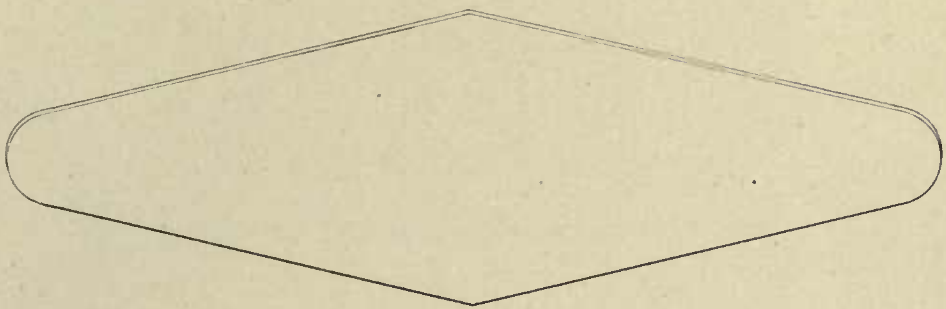
GUDGEON.

123

GUDGEON.

124

BEAM SLAB.



125

BEAM.

GUDGEON RIVET.

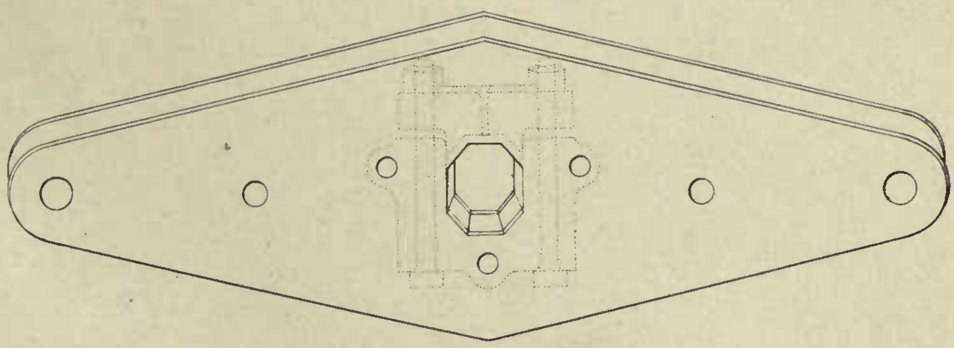
126

127

BEAM RIVET.

128

BEAM.



129

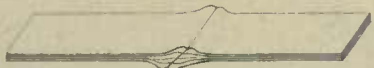
COLUMN.

130

SCARF-JOINT

131

SCARF-JOINT

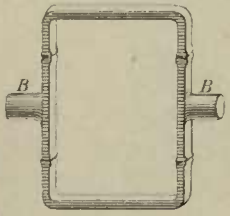


132

TONGUE-JOINT

133

VALVE-PIECE



134

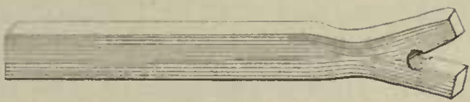
CRANK-PIECE

135

CRANK PIECE

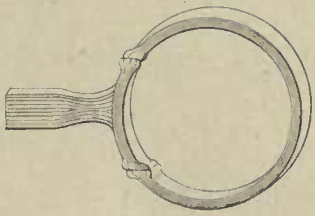
136

BAR FOR T-PIECE



137

T-PIECE AND RING-PIECE

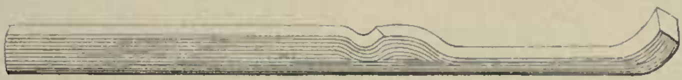


138

RING

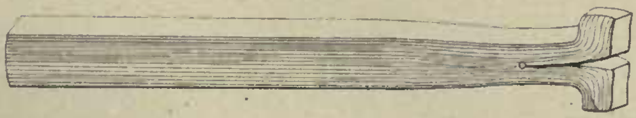
139

BAR FOR SEMI-HOOPS



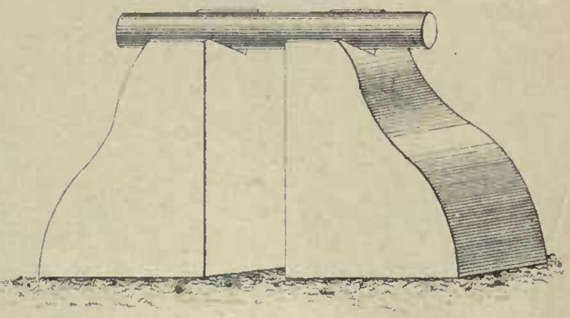
140

BAR FOR FORK OR HOOP-PIECE



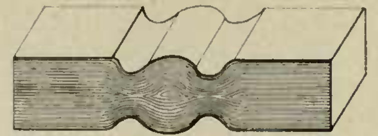
141

CYLINDRICAL-FILLER



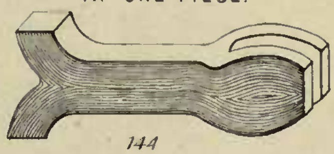
142

CROSSHEAD



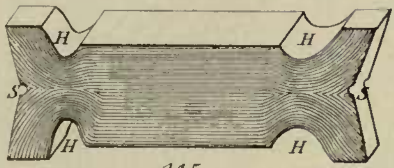
143

SMALL FORK-END ROD IN ONE PIECE.



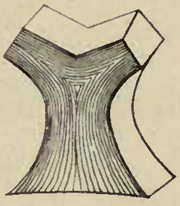
144

CONNECTING ROD BAR.



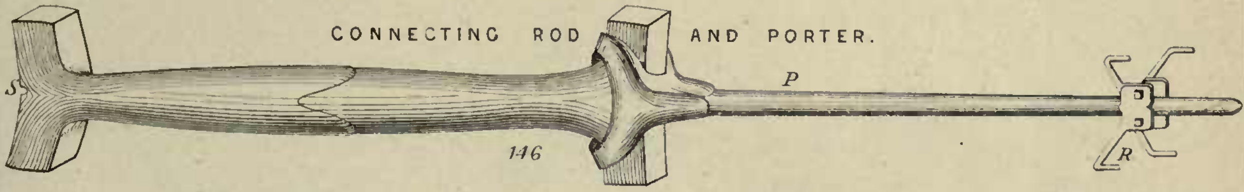
145

SHORT T-PIECE



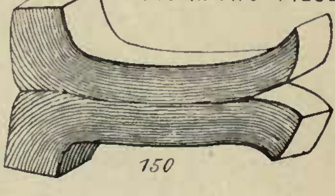
149

CONNECTING ROD AND PORTER.



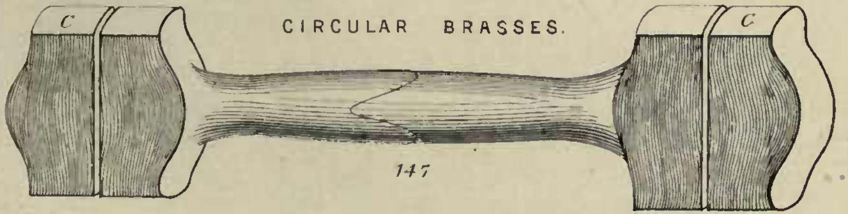
146

T-END IN TWO PIECES



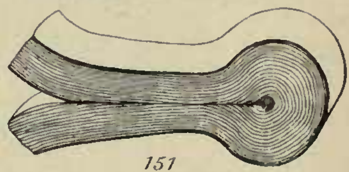
150

CONNECTING ROD FOR CIRCULAR BRASSES.



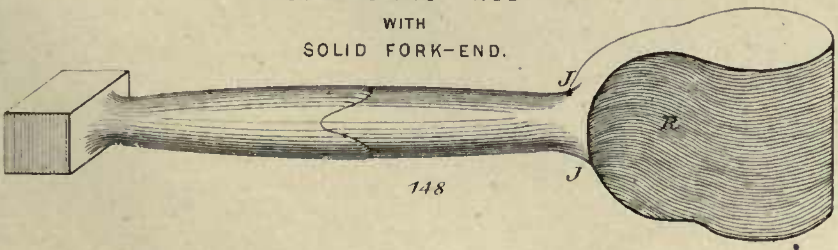
147

FORK-END IN ONE PIECE



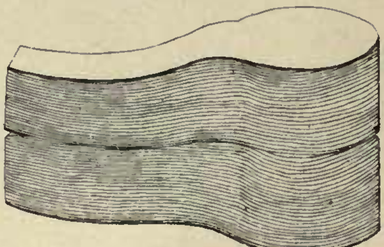
151

CONNECTING ROD WITH SOLID FORK-END.



148

FORK-END IN TWO PIECES



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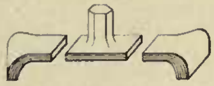
STUD-PLATE

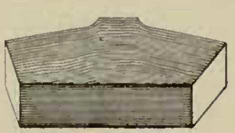
153

STUD-PLATE.



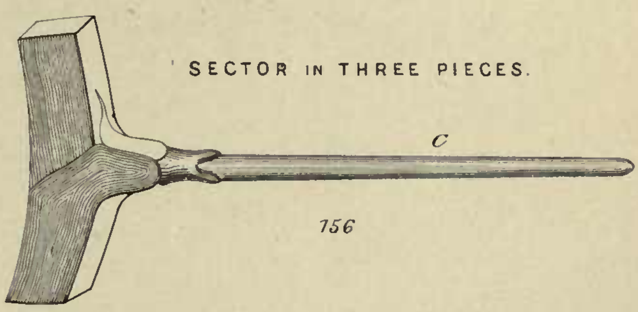
154

SECTOR PIECE.



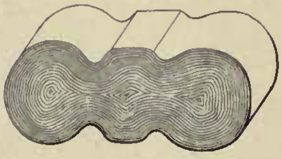
155

SECTOR IN THREE PIECES.



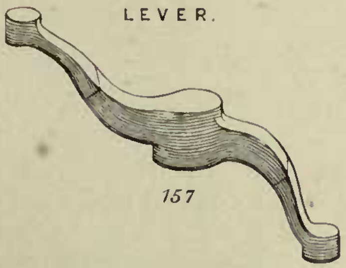
156

CRANK LEVER.



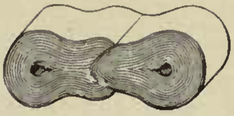
159

LEVER.



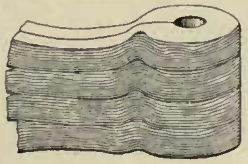
157

CRANK LEVER.



158

BOSS-PILE.

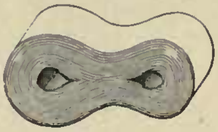


161

CRANK LEVER.

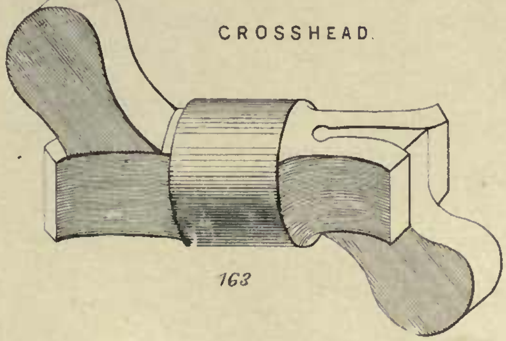
160

CRANK LEVER.



162

CROSSHEAD.



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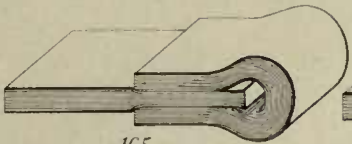
BOSS BARS.

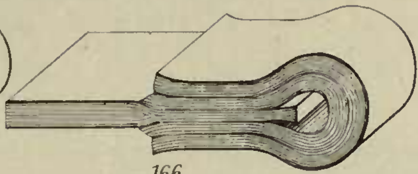
164

BOSS.



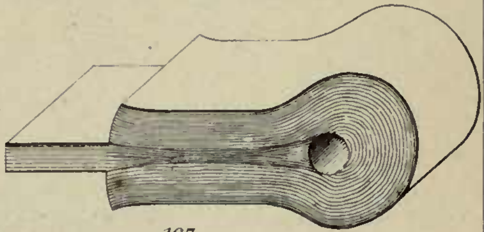
165

BOSS.



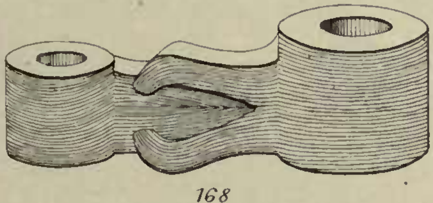
166

BOSS.



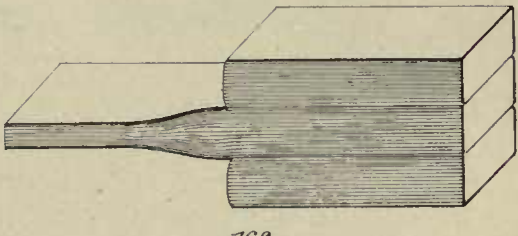
167

CRANK-LEVER.



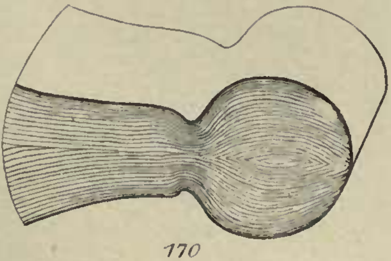
168

BOSS-PILE.



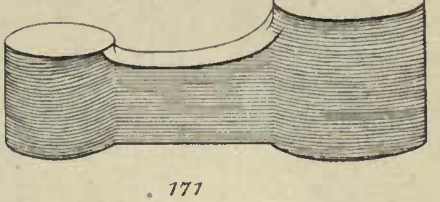
169

BOSS



170

CRANK-LEVER.



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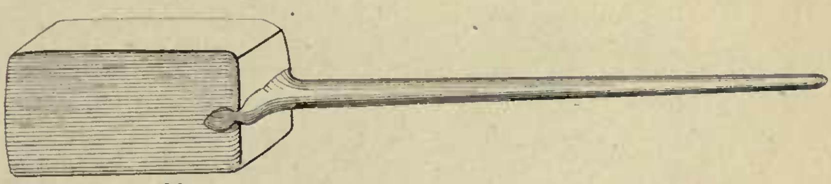
PADDLE SHAFT.



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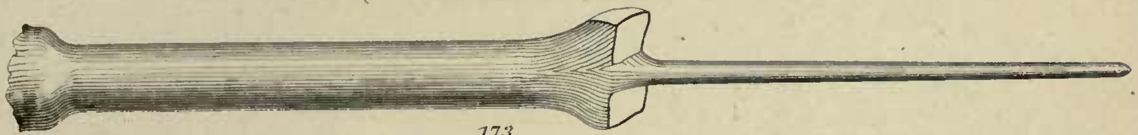
PADDLE SHAFT.



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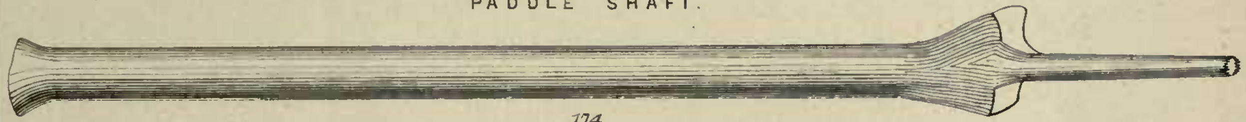
PADDLE SHAFT.



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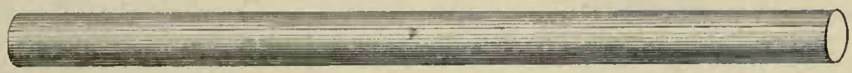
PADDLE SHAFT.



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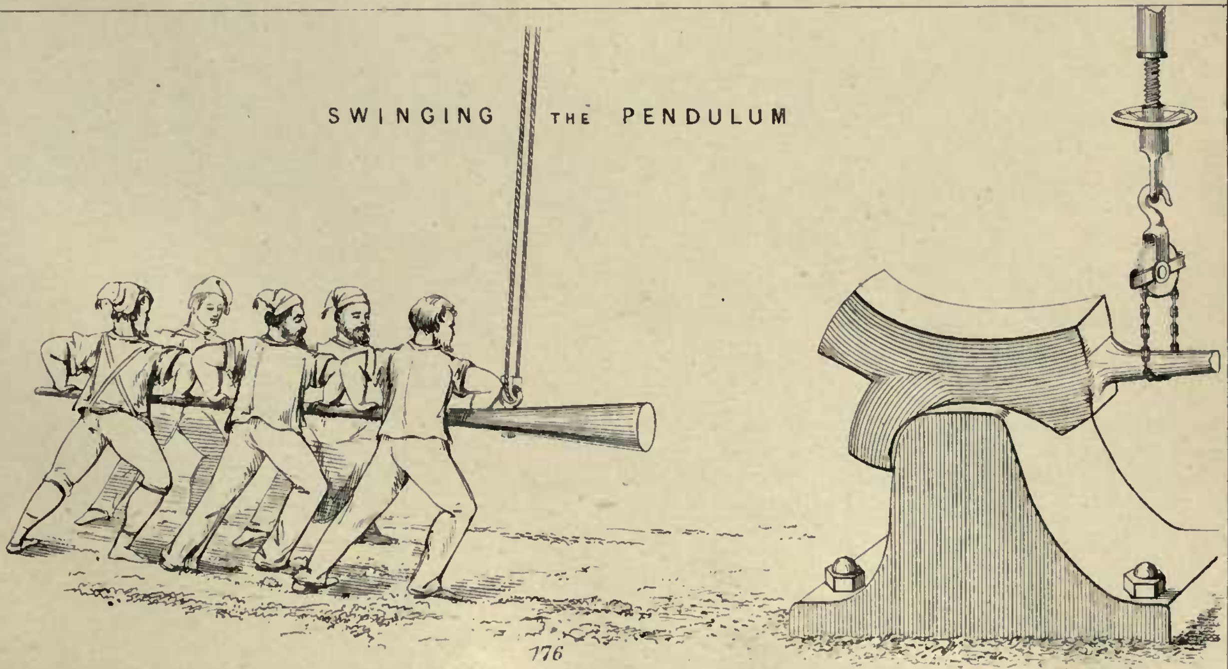
SWINGING THE PENDULUM



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PADDLE SHAFT.

177

MIDDLE SHAFT.

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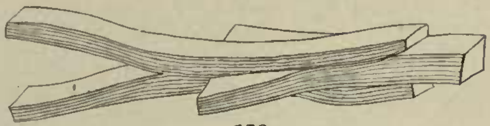
FORKED PIECES.



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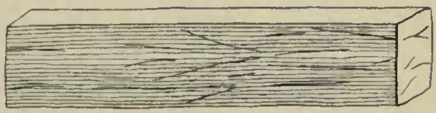
BAR OF FORKED PIECES.



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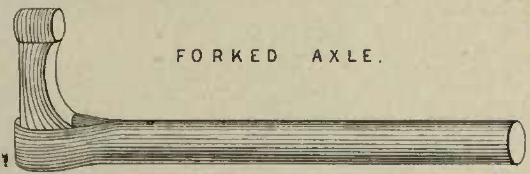
FORKED AXLE.



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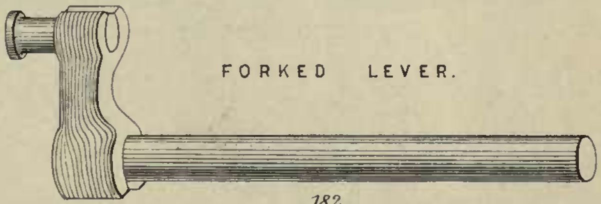
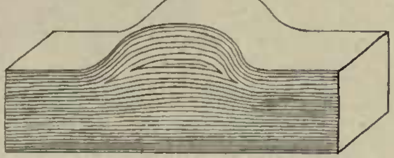
FORKED LEVER.



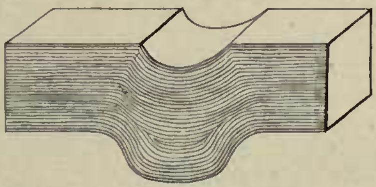
182

CRANK LUMP.



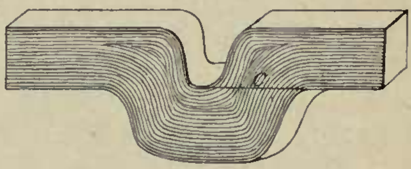
183

CRANK LUMP FULLERED



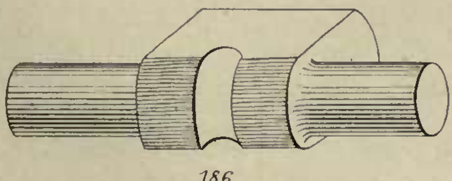
184

CRANK.



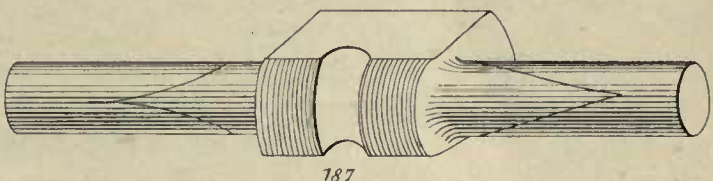
185

INTERMEDIATE AXLE IN ONE PIECE



186

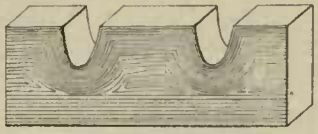
INTERMEDIATE AXLE IN THREE PIECES.



187

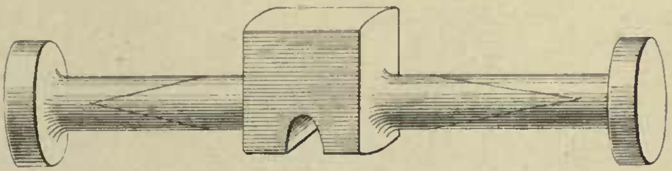
E & F.N. Spon 48, Charing Cross London

CRANK BAR



188

CRANK WITH SOLID DISKS.

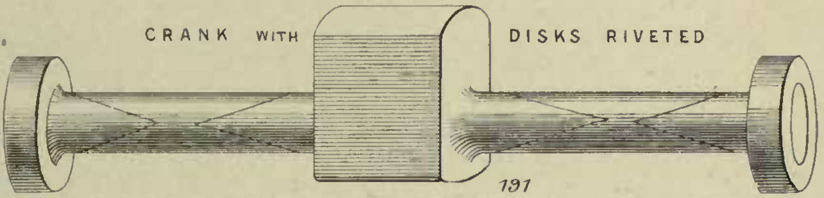


189

DISKS.

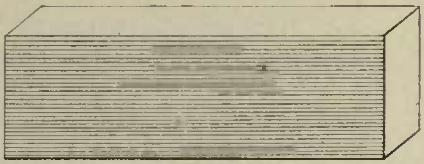
190

CRANK WITH DISKS RIVETED



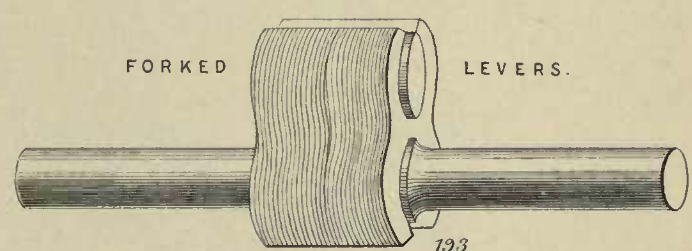
191

CRANK BAR.



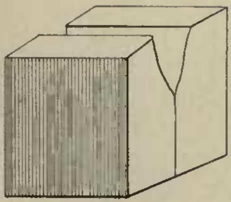
192

FORKED LEVERS.



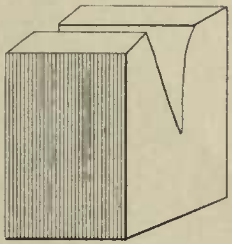
193

CRANK PIECE.



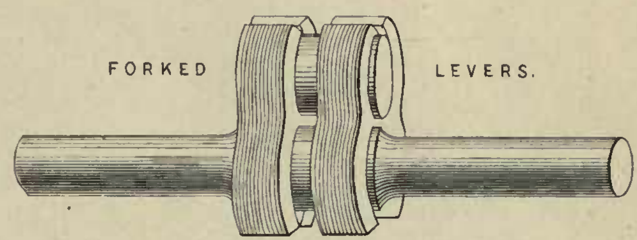
194

CRANK PIECE.



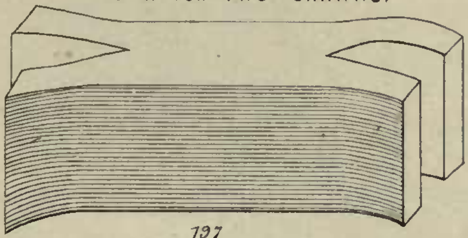
195

FORKED LEVERS.



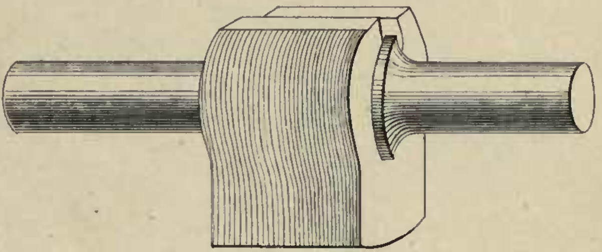
196

BAR FOR TWO CRANKS.



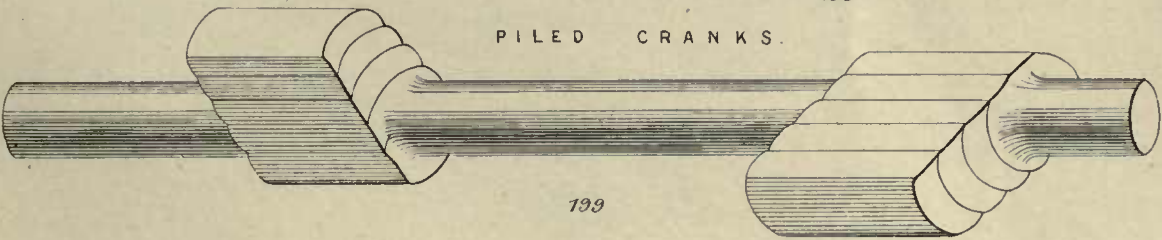
197

JOINT FOR CRANK WITH AXLE.



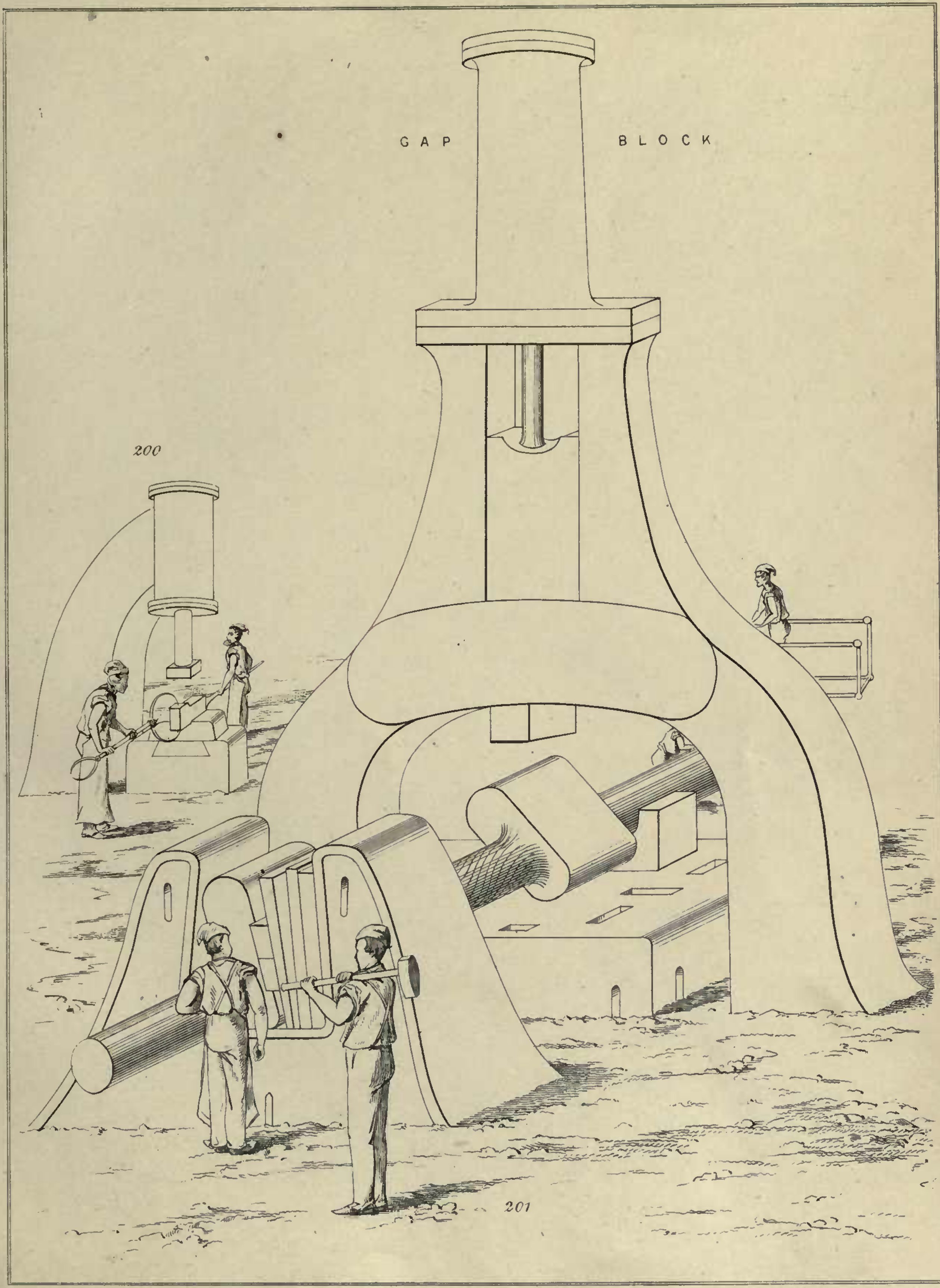
198

PILED CRANKS.



199

E. & F. N. Spon. 48, Charing Cross. London



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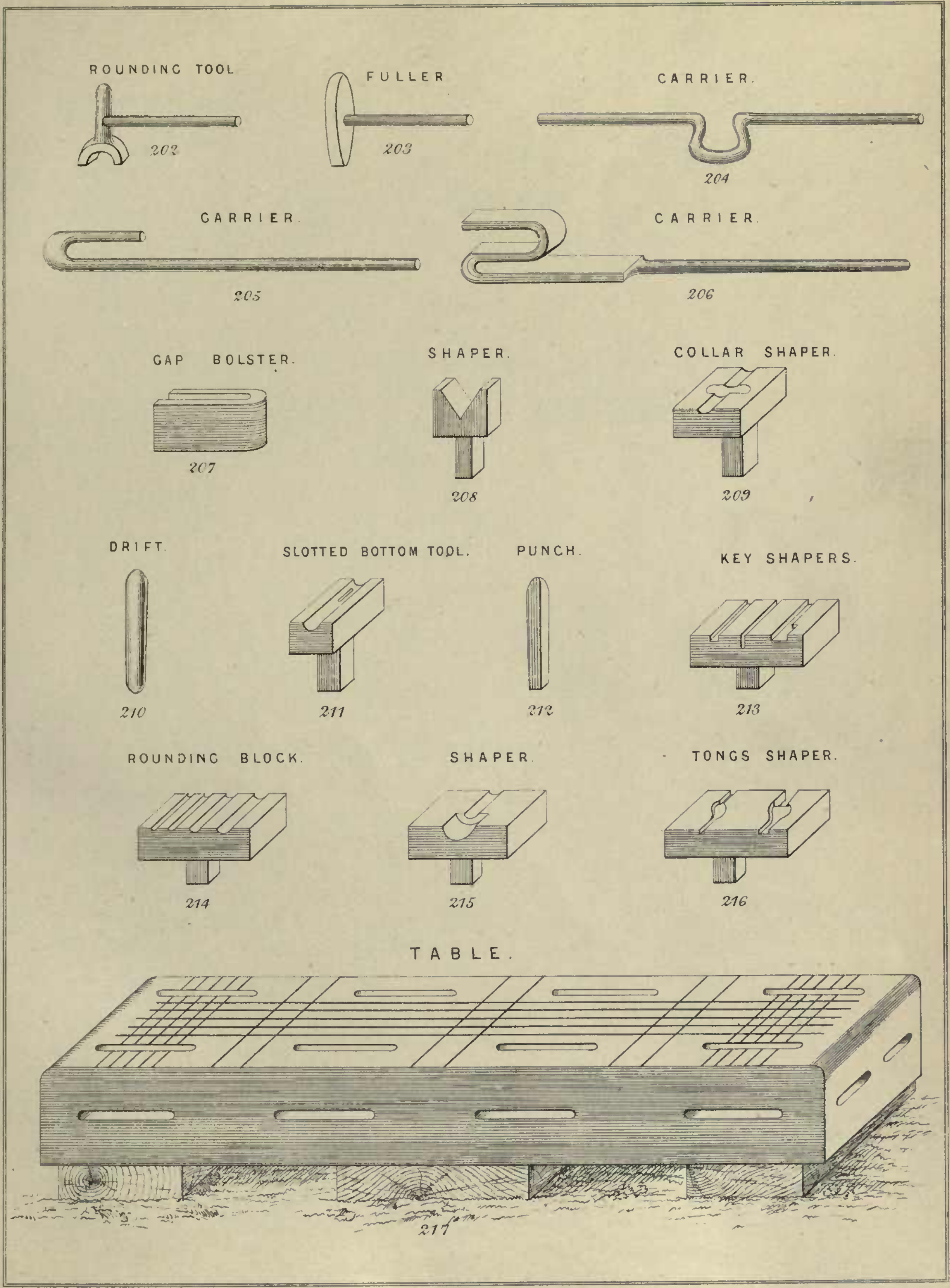
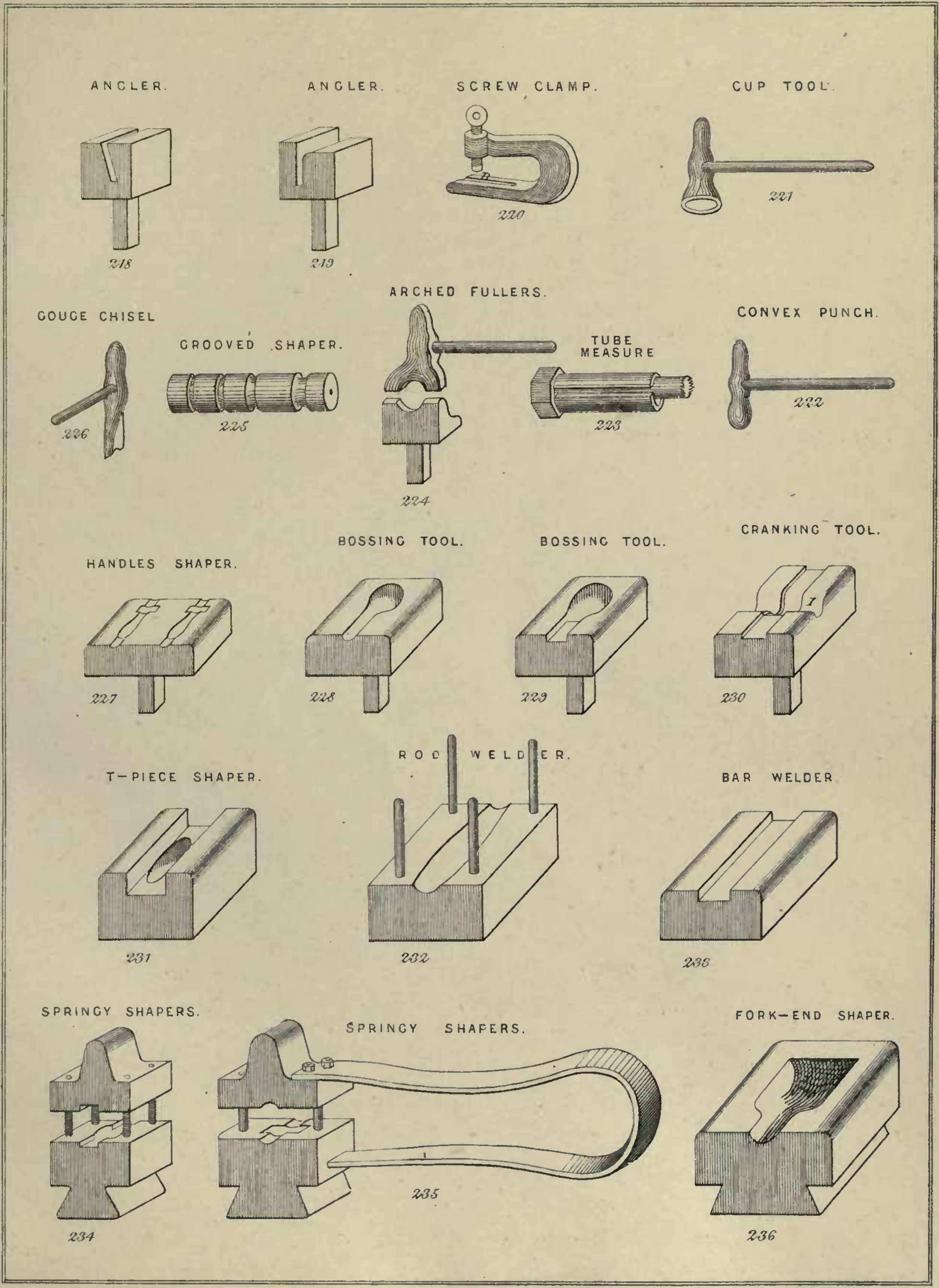


E & F N Spon 48 Charing Cross, London



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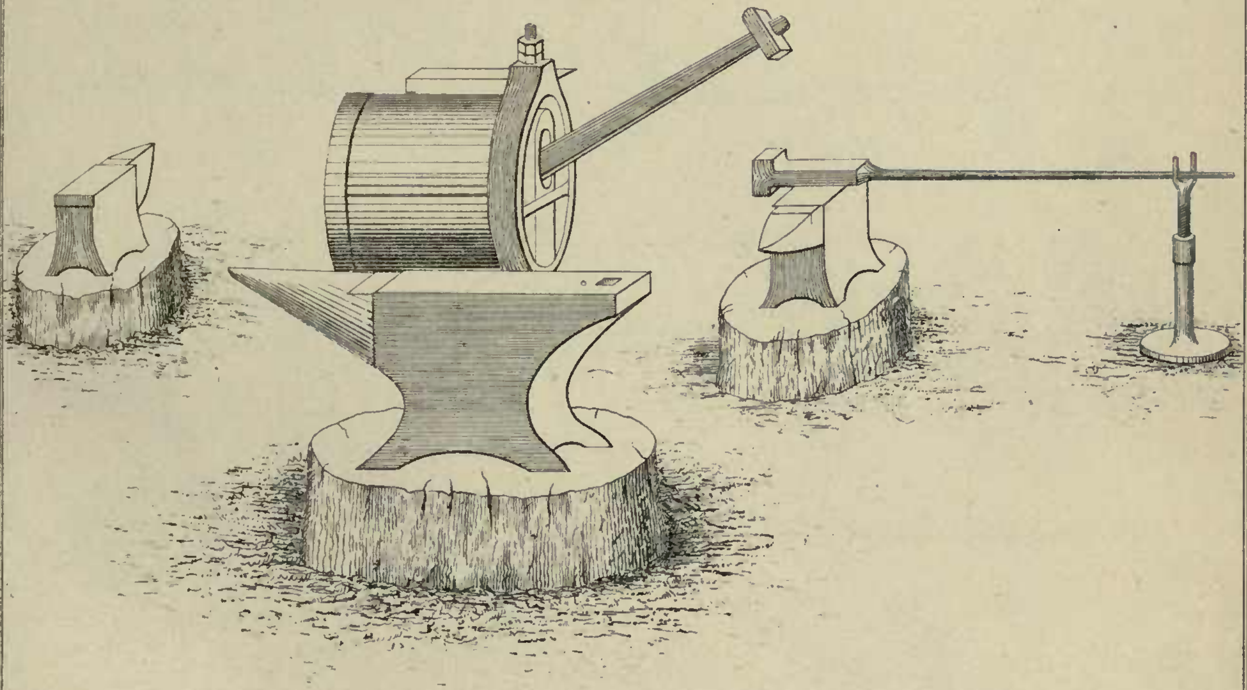
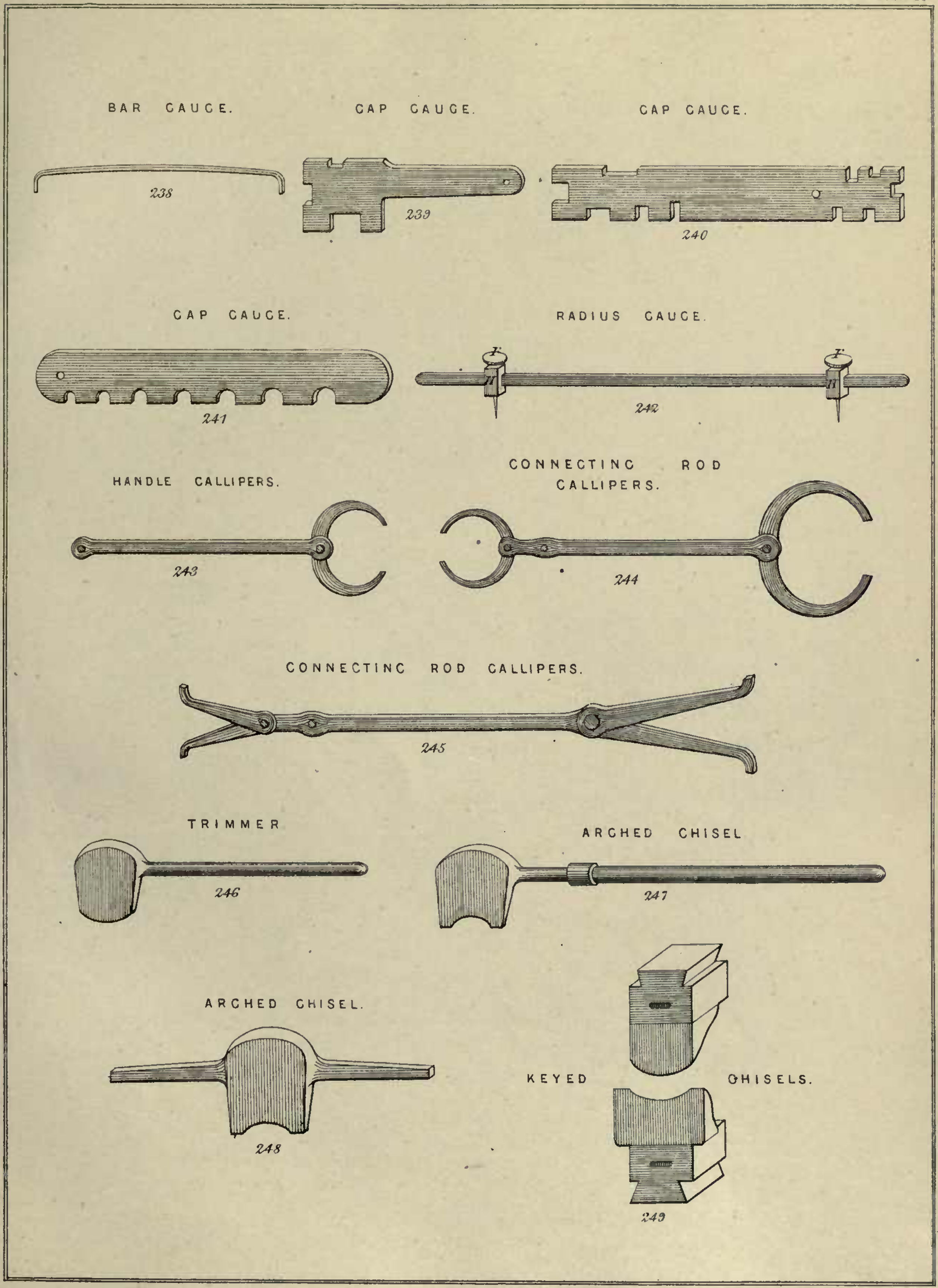
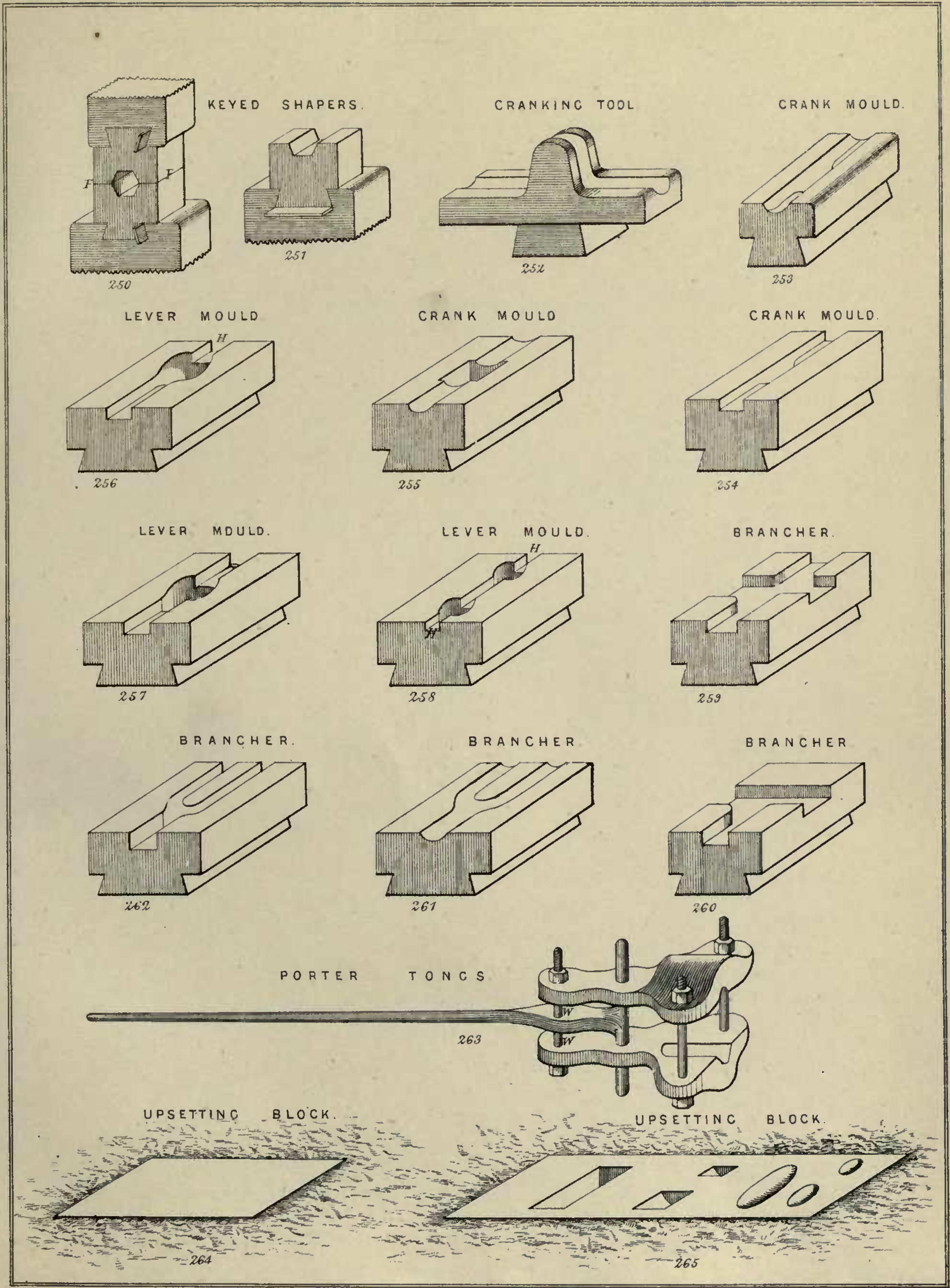
ONE STRIKER TO FOUR ANVILS.



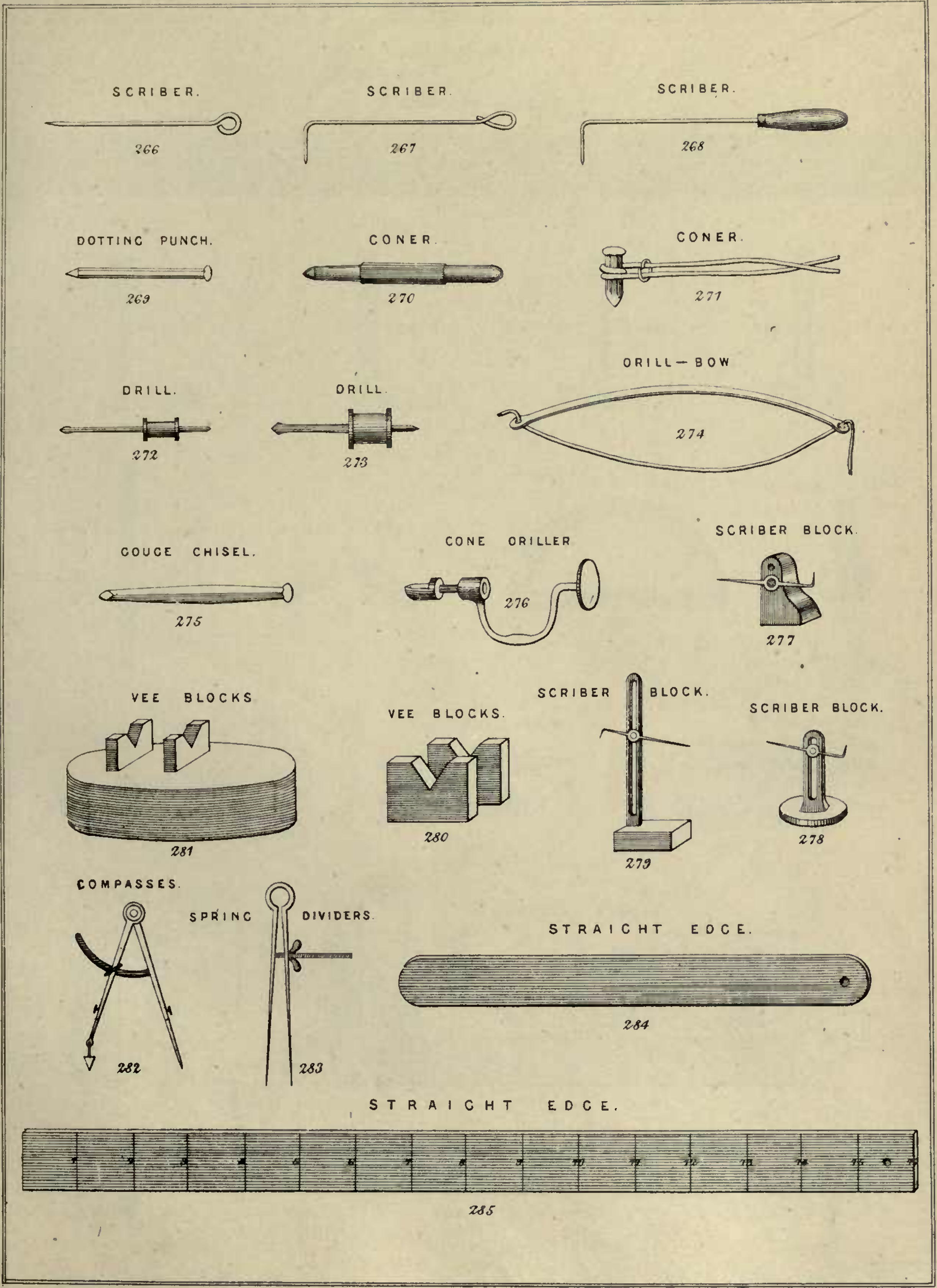
237

E. & F.N. Spon. 48, Charing Cross, London.

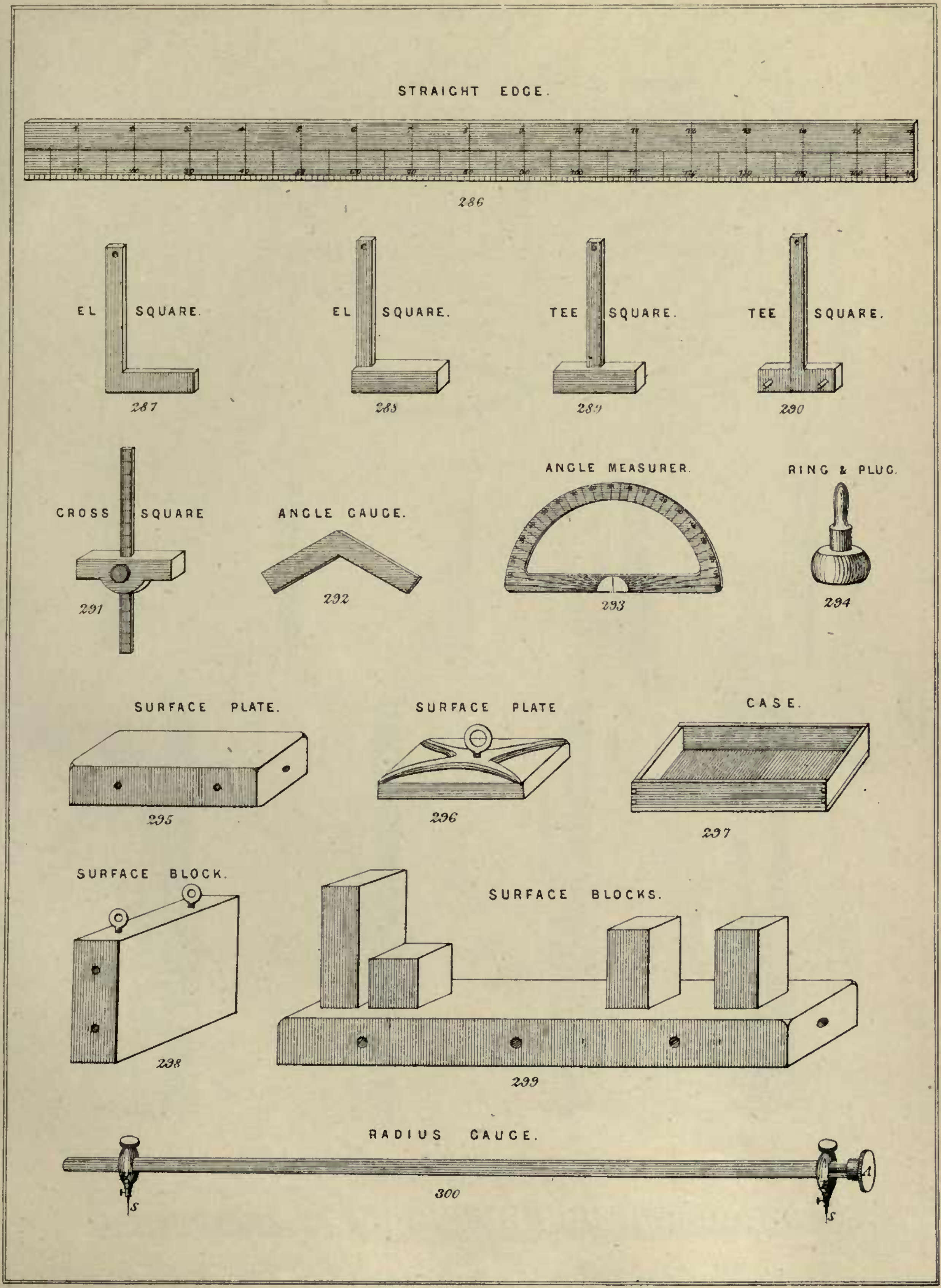

BAR GAUGE.
238
CAP GAUGE.
239
CAP GAUGE.
240
CAP GAUGE.
241
RADIUS GAUGE.
242
HANDLE CALLIPERS.
243
CONNECTING ROD CALLIPERS.
244
CONNECTING ROD CALLIPERS.
245
TRIMMER
246
ARCHED CHISEL
247
ARCHED CHISEL.
248
KEYED CHISELS.
249



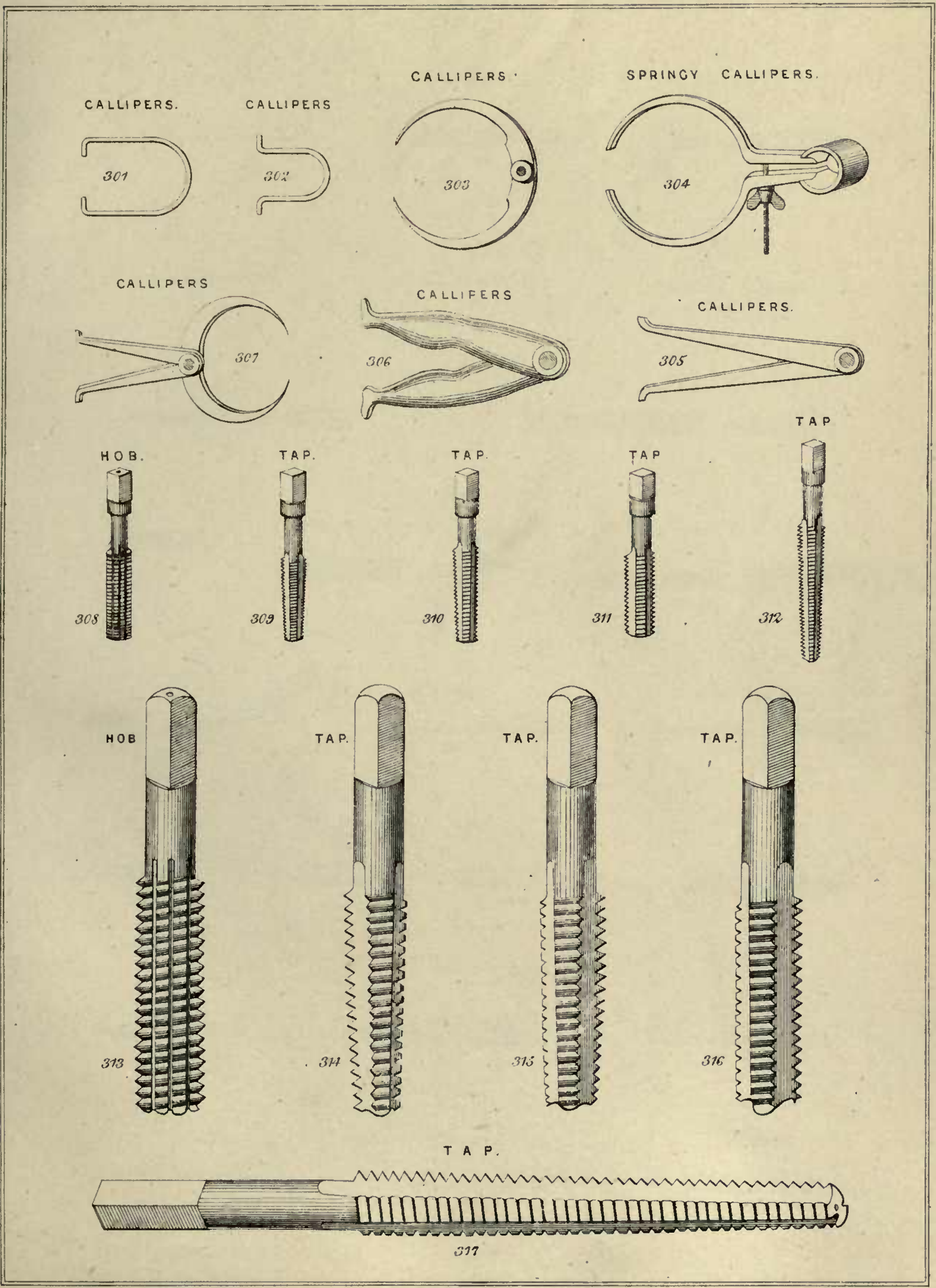
E & F N. Spon. 48. Charing Cross. London.



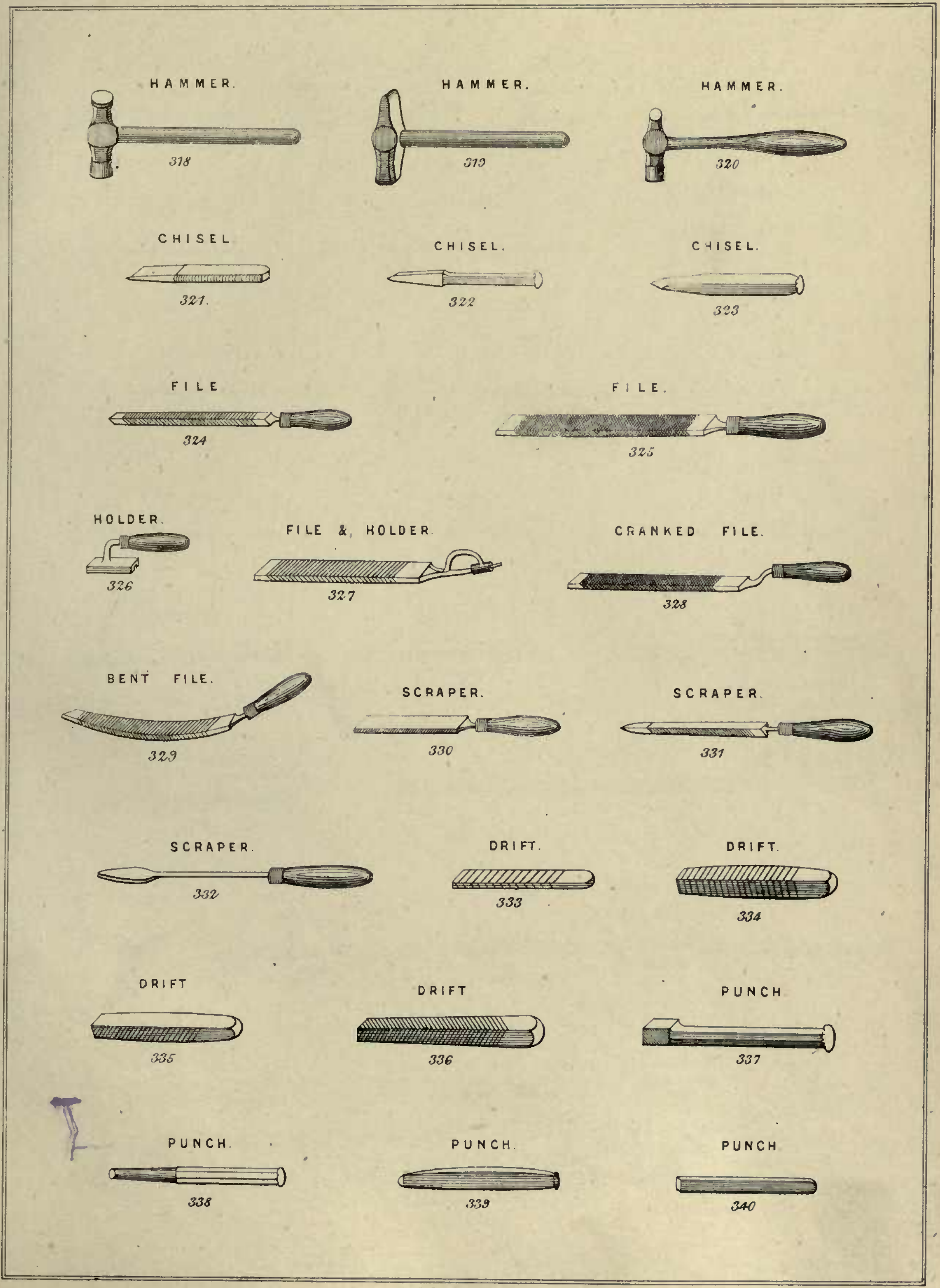
E. & F. N. Spon. 48, Charing Cross, London.



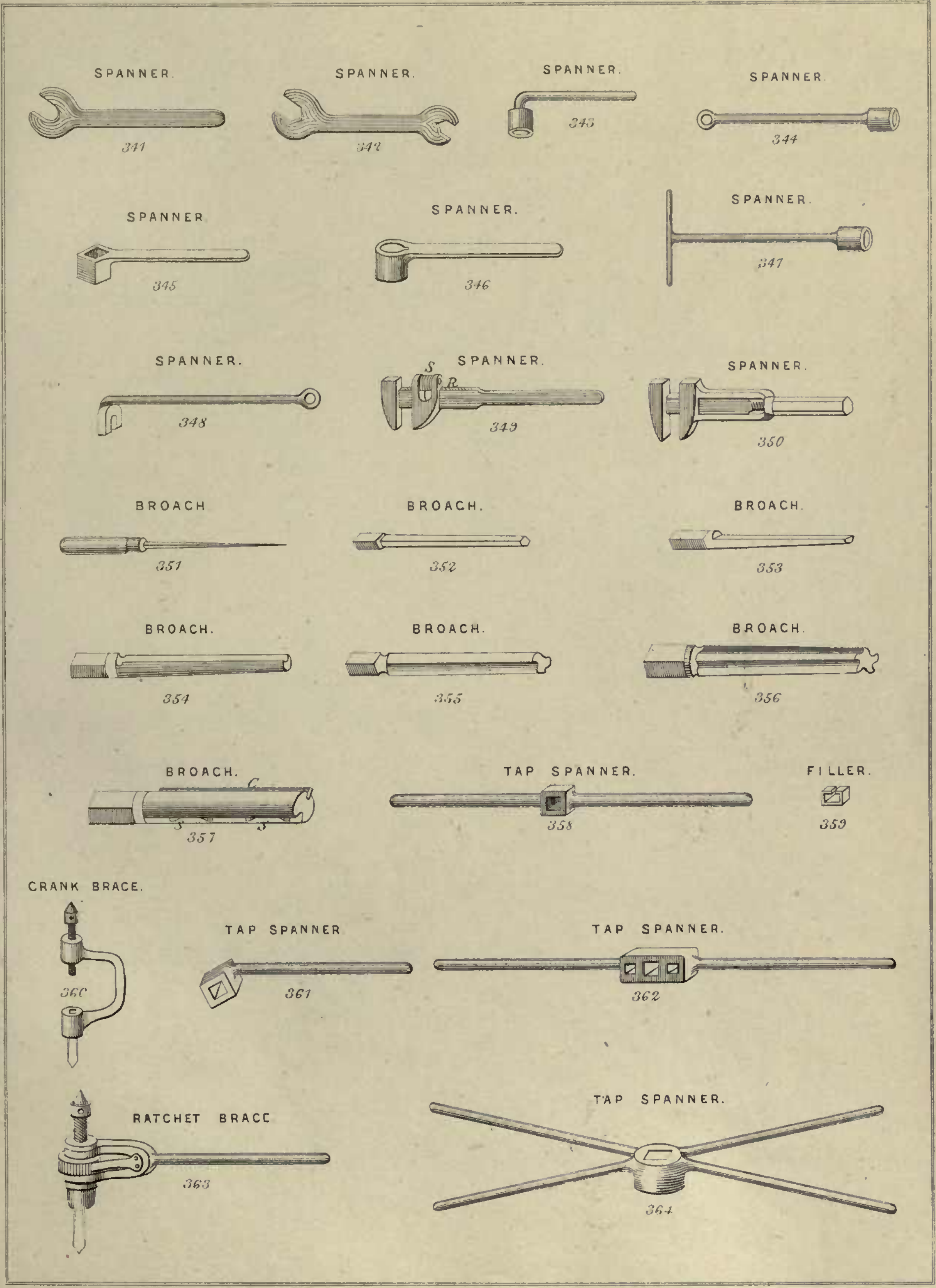
E. & F. N. Spon. 48, Charing Cross, London.



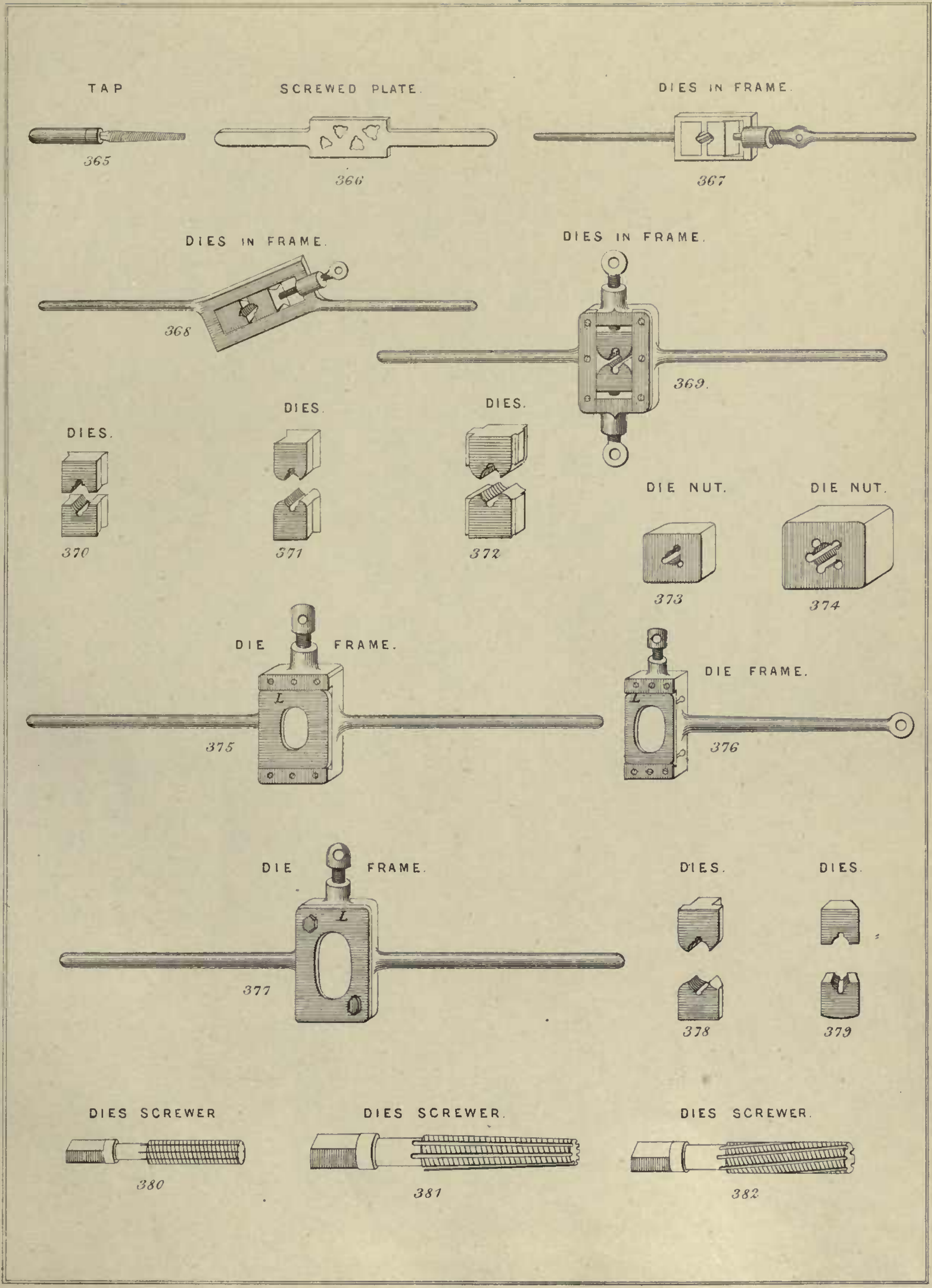
E. & F.N. Spon. 48, Charing Cross, London.



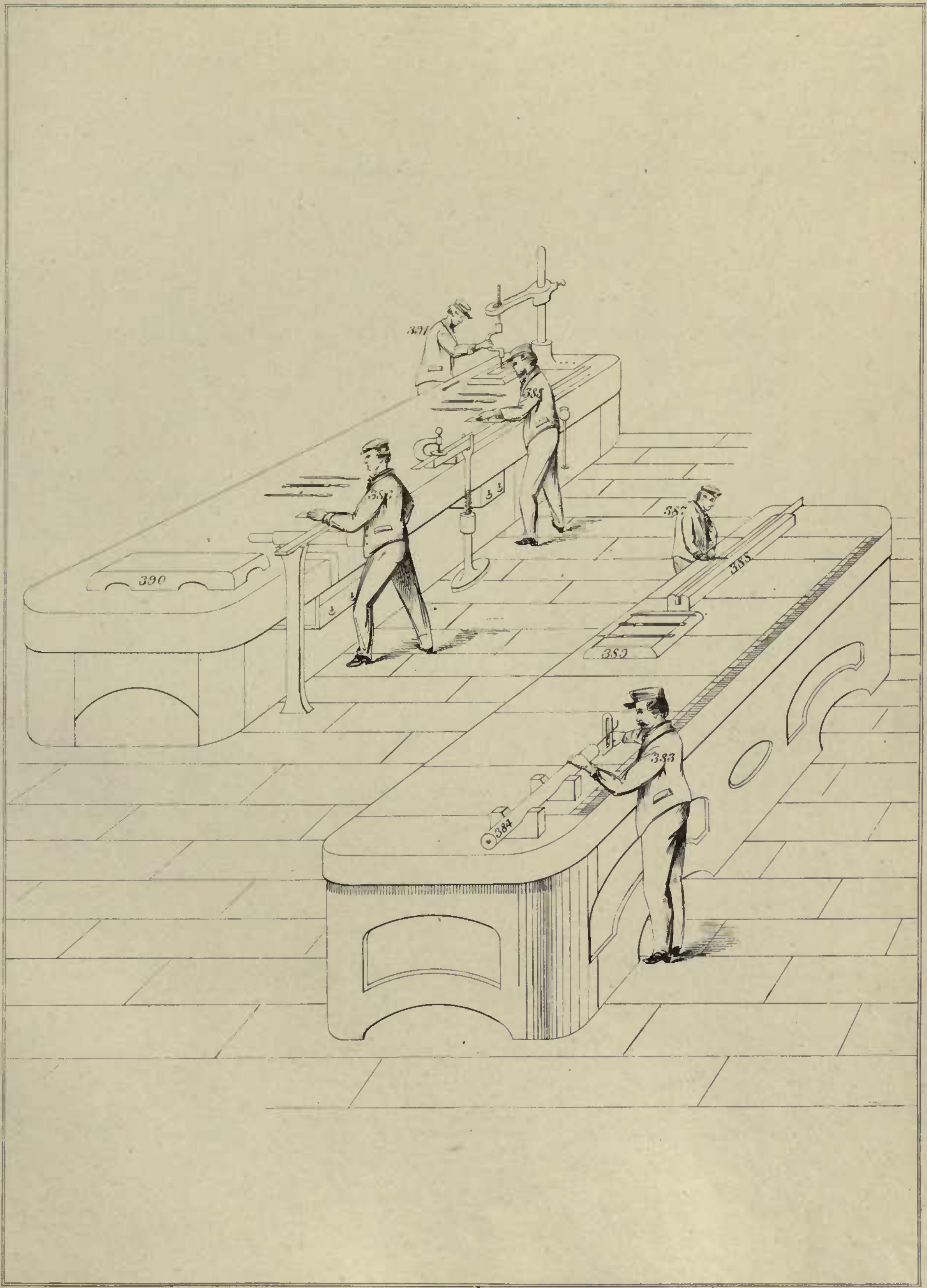
E. & F. N. Spon 48, Charing Cross, London.



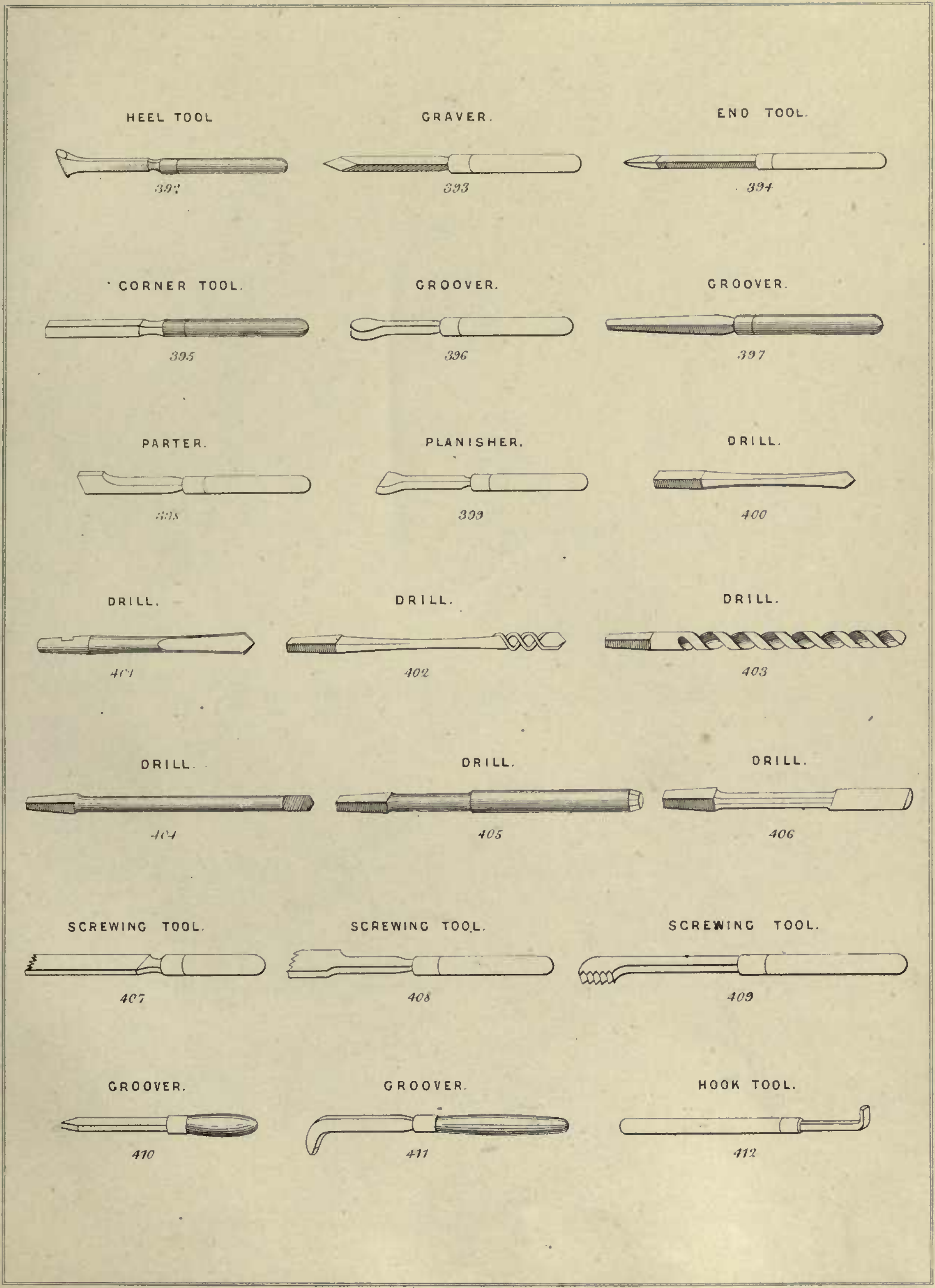
E & F. N. Spon. 48 Charing Cross. London.



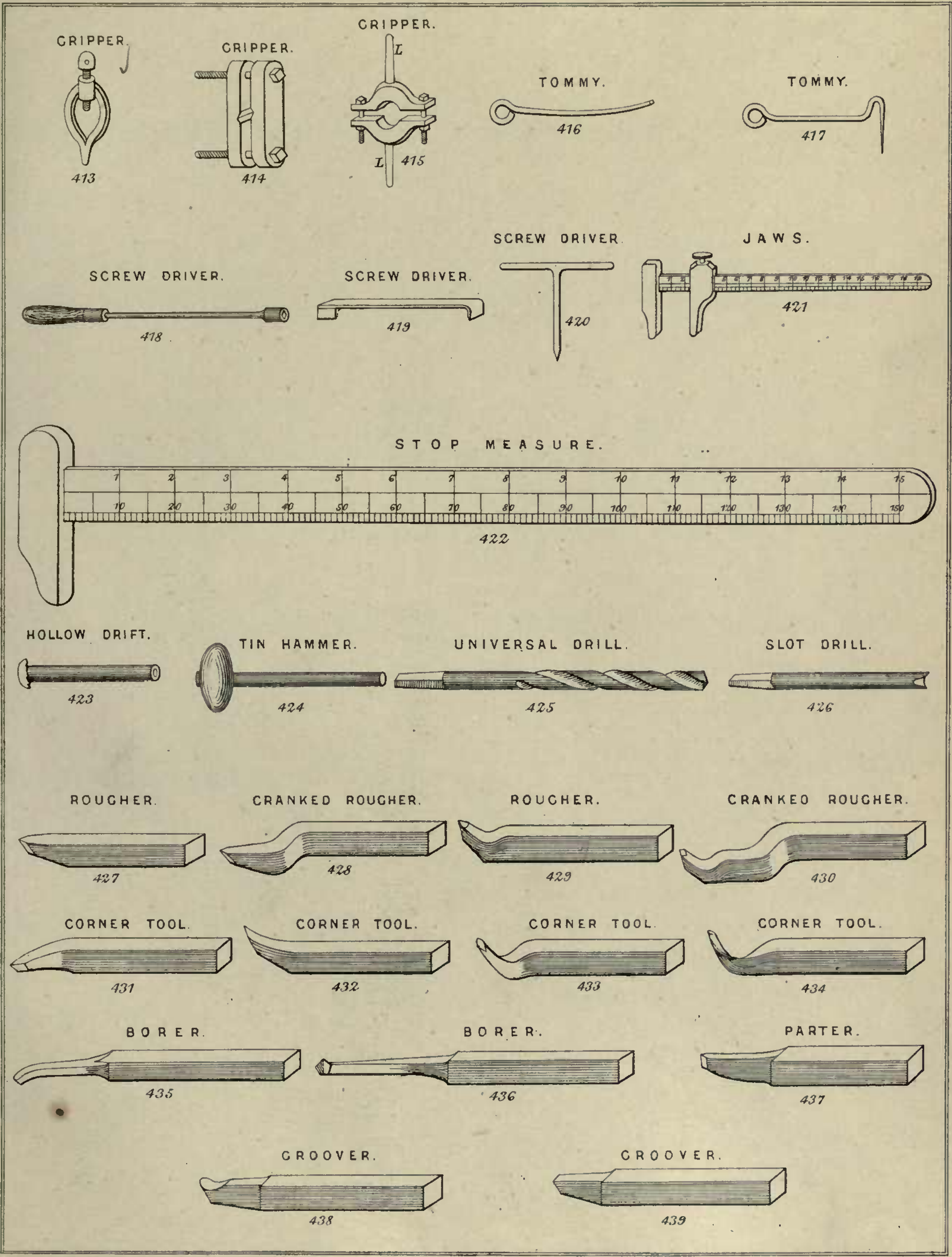
E & F N. Spon. 48, Charing Cross. London.



E.&F.N. Spon. 48. Charing Cross. London.



E & F.N. Spon. 48, Charing Cross. London.


GRIPPER.
413
GRIPPER.
414
GRIPPER.
L
L
415
TOMMY.
416
TOMMY.
417
SCREW DRIVER.
418
SCREW DRIVER.
419
SCREW DRIVER.
420
JAWS.
421
STOP MEASURE.
422
HOLLOW DRIFT.
423
TIN HAMMER.
424
UNIVERSAL DRILL.
425
SLOT DRILL.
426
ROUCHER.
427
CRANKED ROUGHER.
428
ROUCHER.
429
CRANKED ROUGHER.
430
CORNER TOOL.
431
CORNER TOOL.
432
CORNER TOOL.
433
CORNER TOOL.
434
BORER.
435
BORER.
436
PARTER.
437
GROOVER.
438
GROOVER.
439

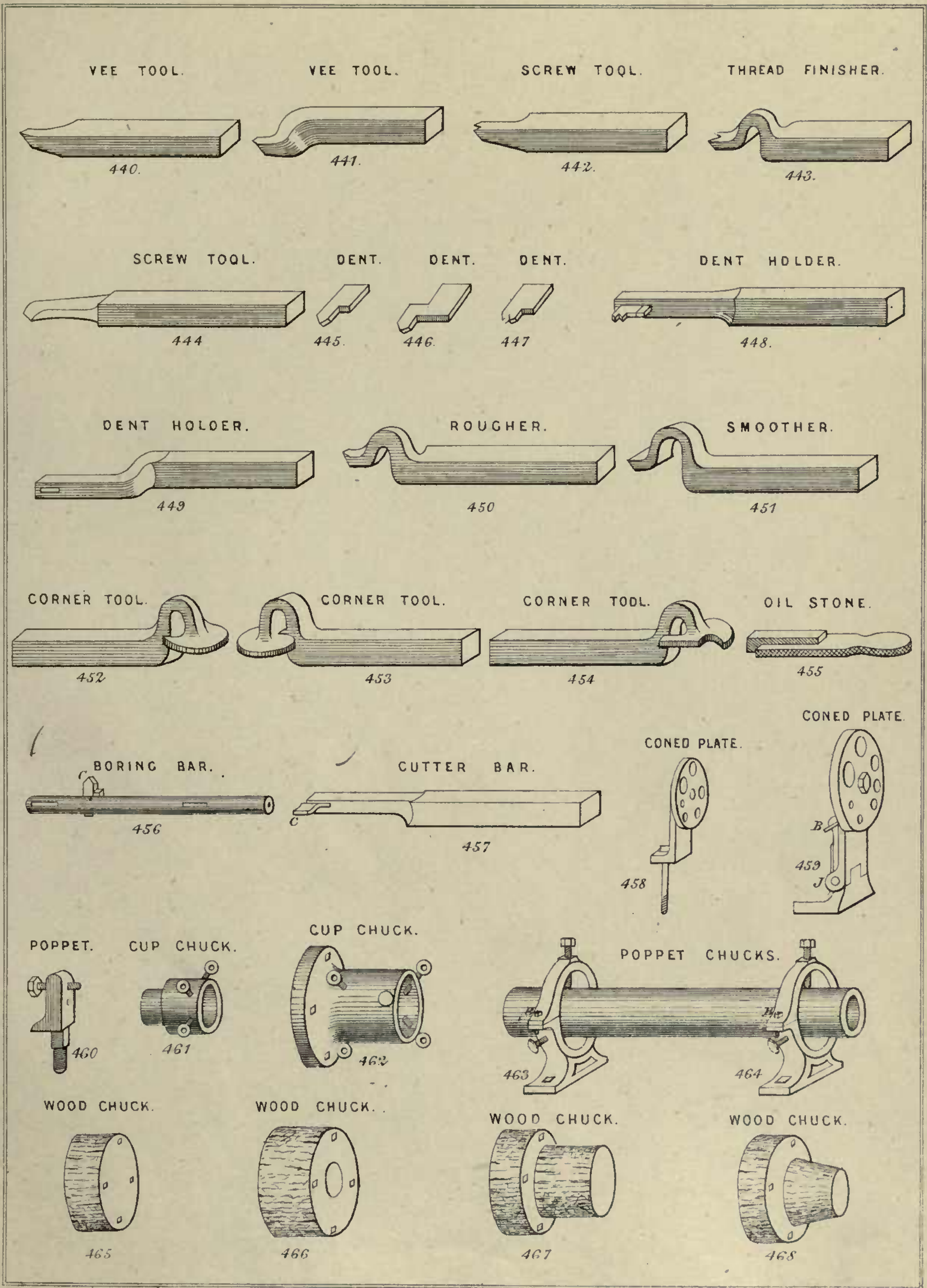
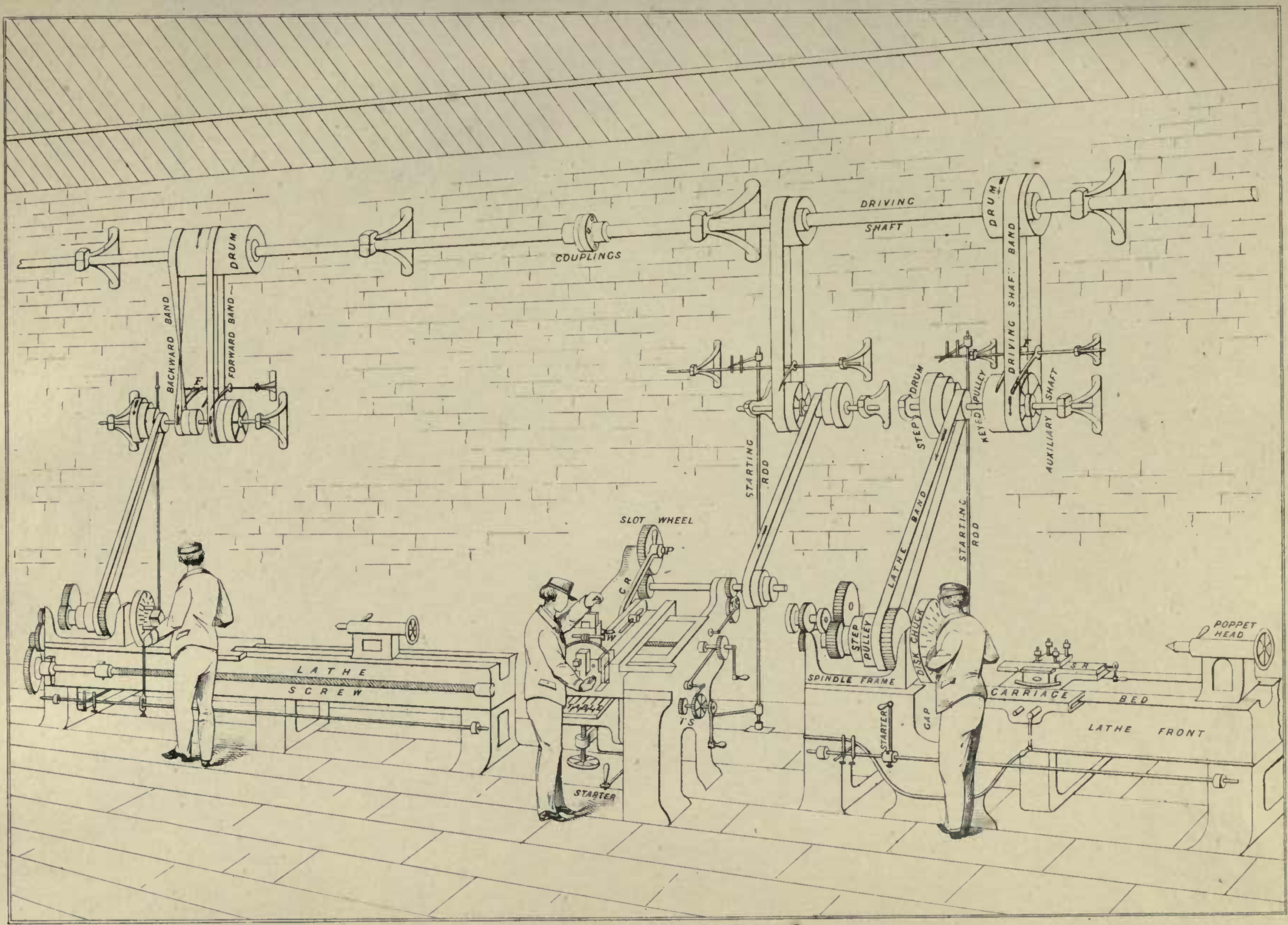

VEE TOOL.
440.
VEE TOOL.
441.
SCREW TOQL.
442.
THREAD FINISHER.
443.
SCREW TOQL.
444
DENT.
445.
DENT.
446.
DENT.
447
DENT HOLDER.
448.
DENT HOLOER.
449
ROUGHER.
450
SMOOTHER.
451
CORNER TOOL.
452
CORNER TOOL.
453
CORNER TOOL.
454
OIL STONE.
455
BORING BAR.
C
456
CUTTER BAR.
C
457
CONED PLATE.
458
CONED PLATE.
B
459
J
POPPET.
460
CUP CHUCK.
461
CUP CHUCK.
462
POPPET CHUCKS.
B
463
B
464
WOOD CHUCK.
465
WOOD CHUCK.
466
WOOD CHUCK.
467
WOOD CHUCK.
468

Plate 35



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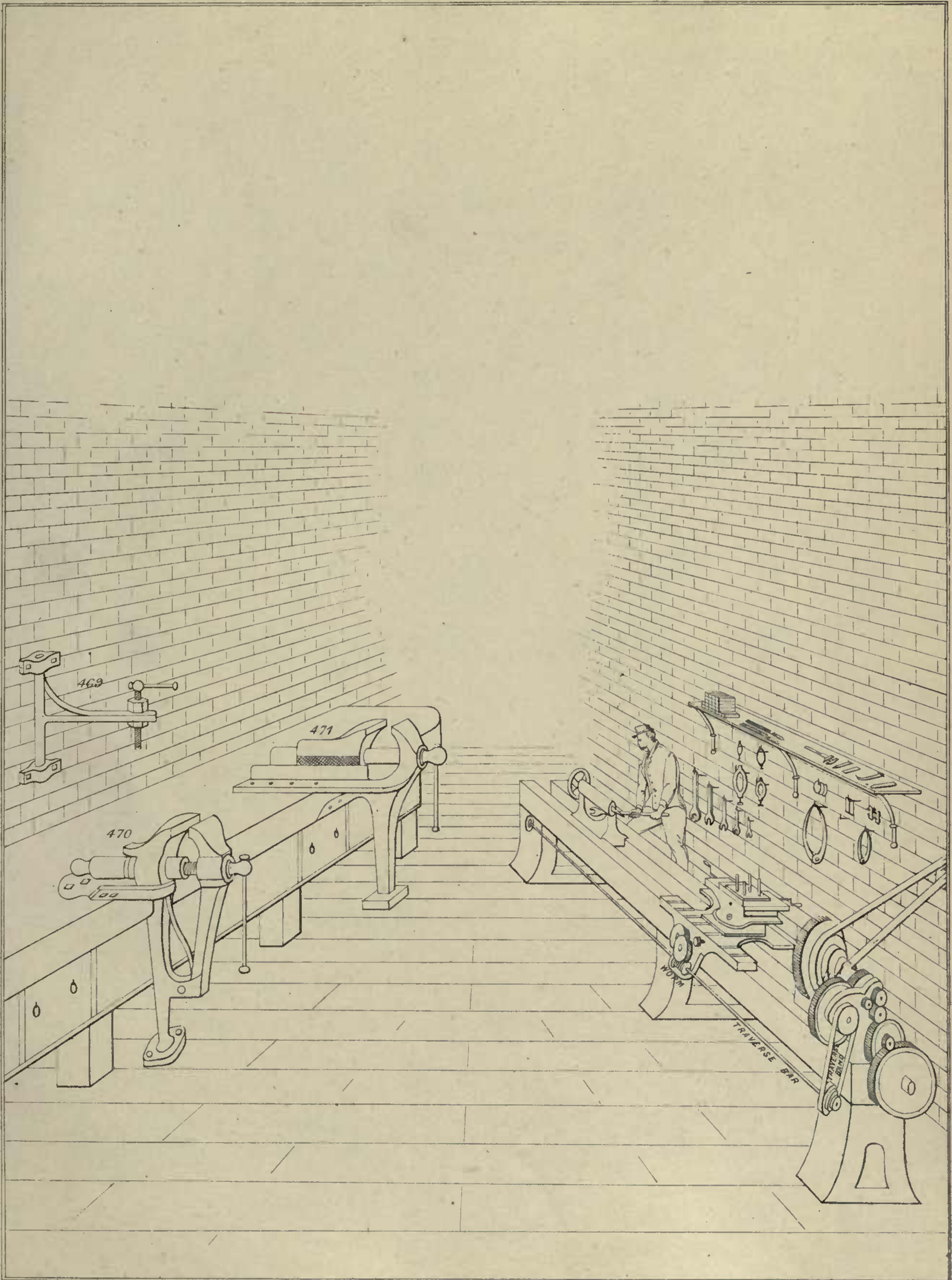
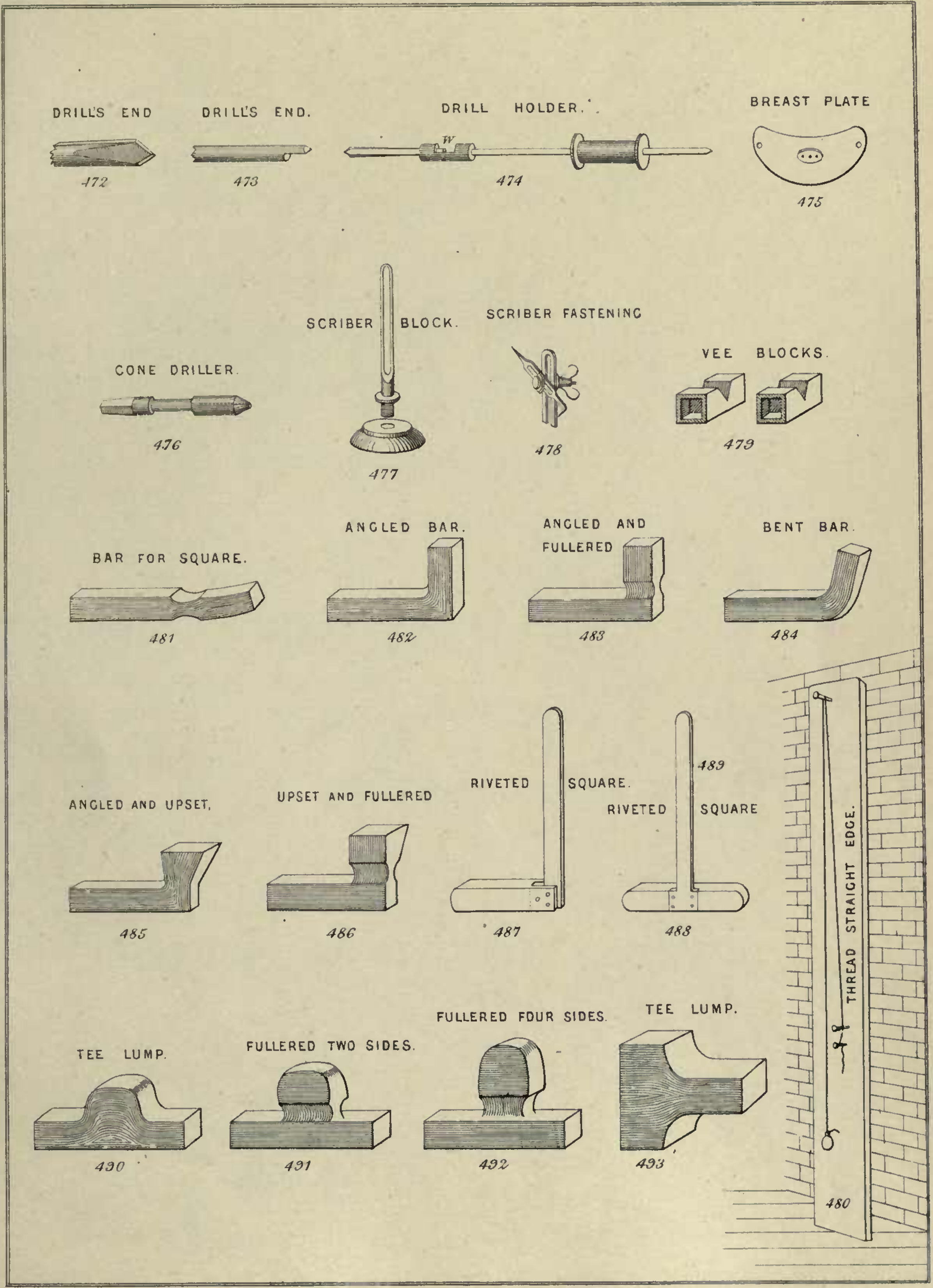
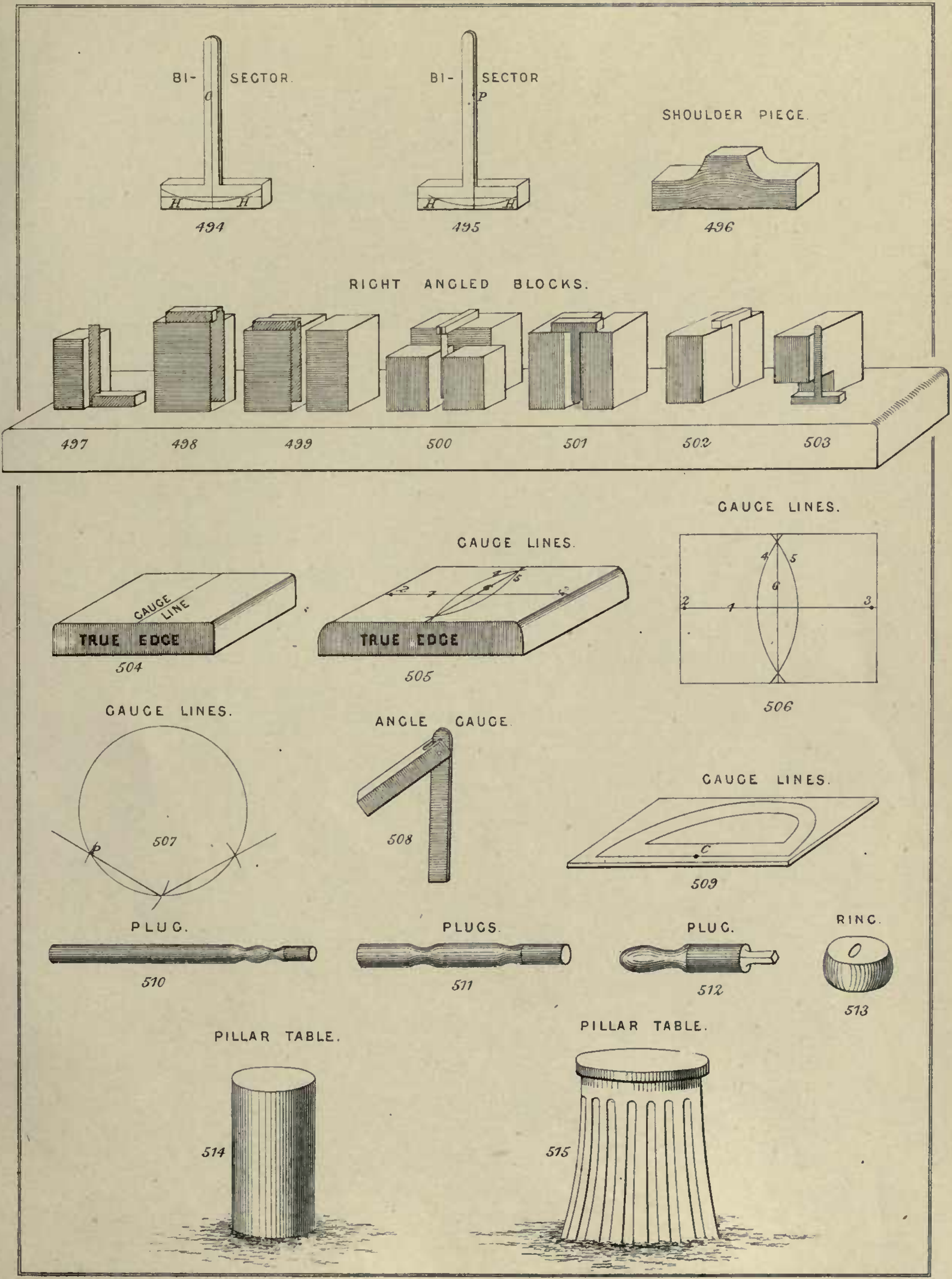


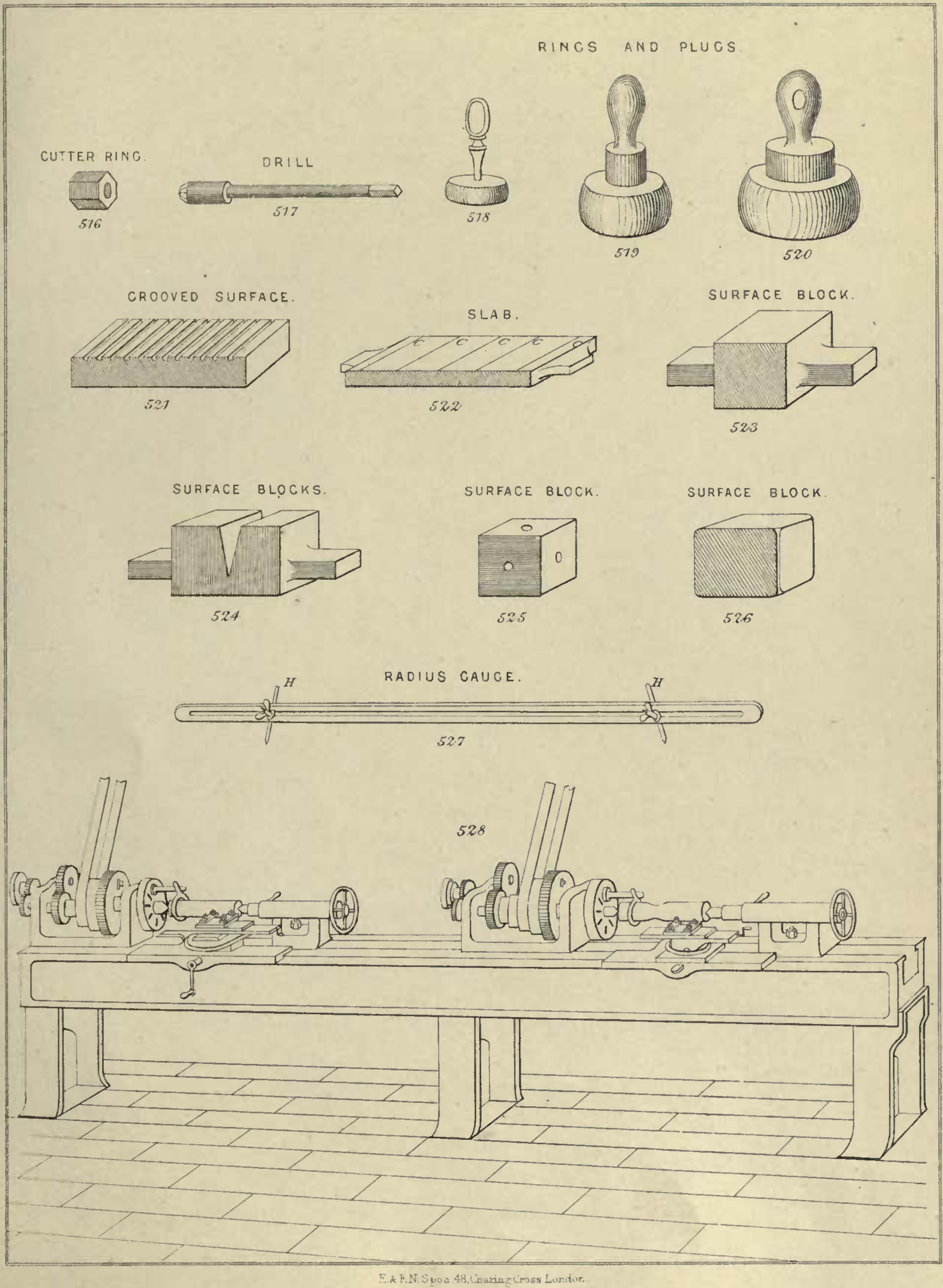
E & F N. Spon. 48, Charing Cross. London.



E. & F. N. Spon 48 Charing Cross. London.



E.& F.N. Spon. 48, Charing Cross. London



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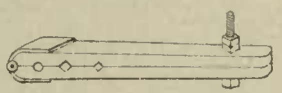
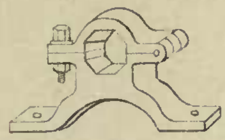
GRINDER.



529

GRINDER FRAME.



530

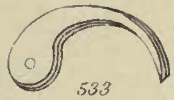
CALLIPER LEGS.

531

CALLIPER LEGS.

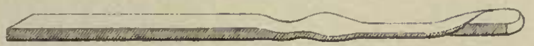
532

LEGS.



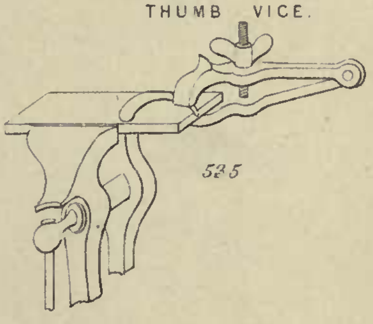
533

END LUMP.



534

THUMB VICE.



535

HAND TAP.

536

HAND TAP.

537

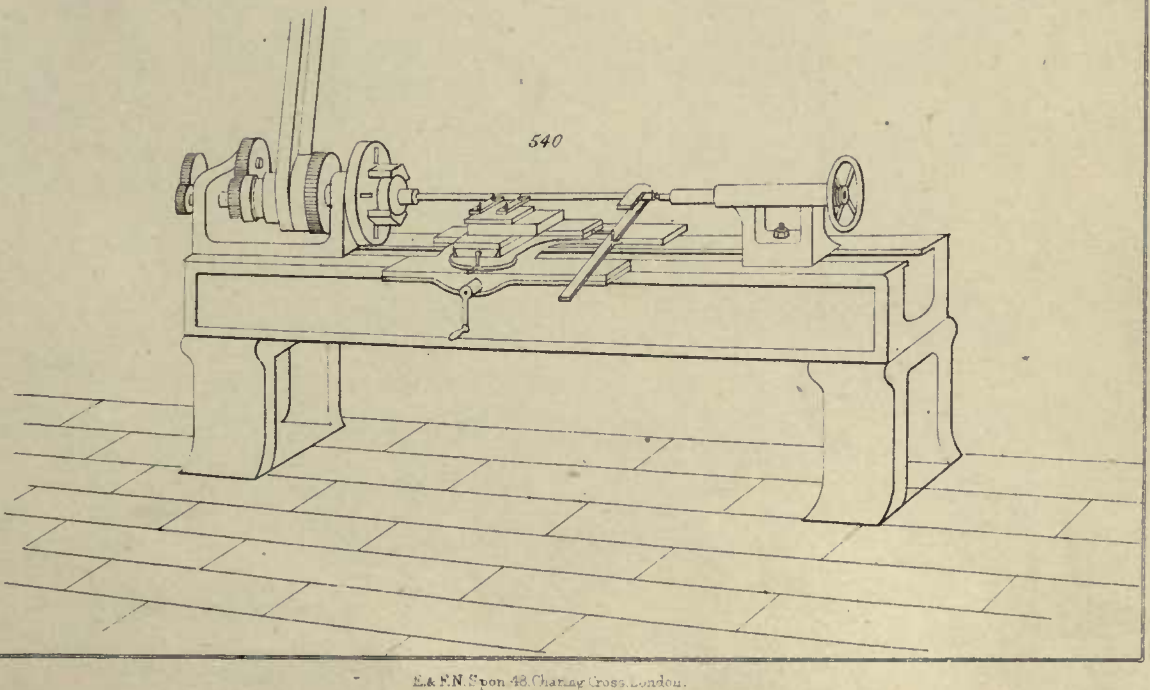
HAND TAP.

538

LONG TAPER TAP.

539

540



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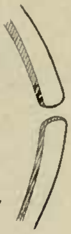
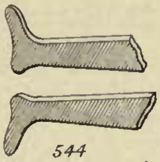
CALLIPER ENDS



541

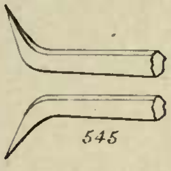
542

543



544

CALLIPER ENDS.

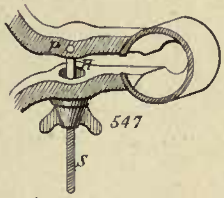


545

CONVEX WASHERS.

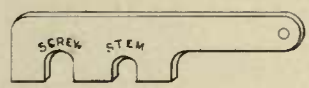
546

ADJUSTING SCREW.



547

HOB GAUGE.



548

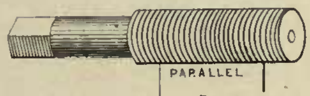
TAP GAUGE.

549

POPPET PIVOT.

550

HOB.

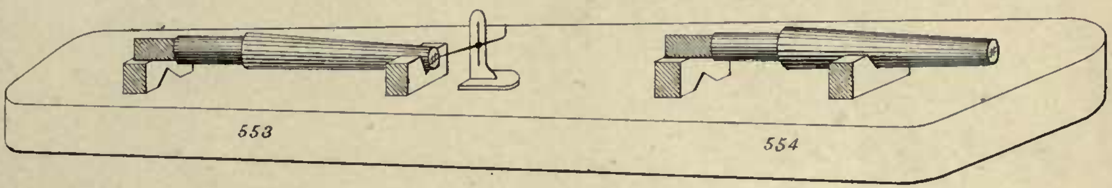


551

TAP.

552

TAP SCRIBING.



553

554

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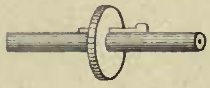
TWO EDGED KNIFE FILE.

555

ROUND FILE.

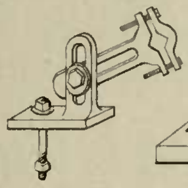
556

KEYED CUTTER.



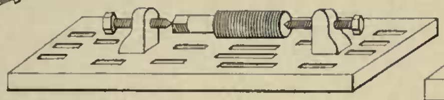
557

SLOTTED HOLDFAST.



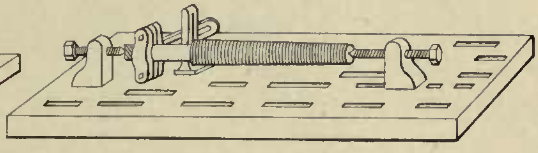
558

CHUCK.



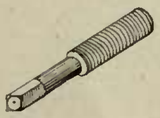
559

CHUCK.



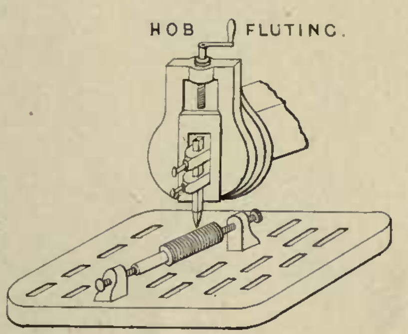
560

HOB.



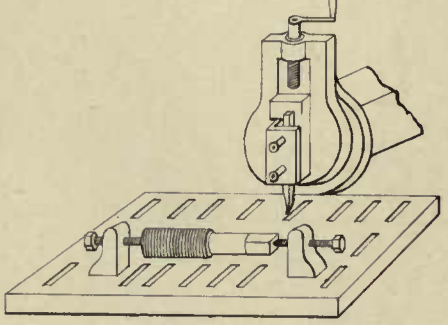
561

HOB FLUTING.



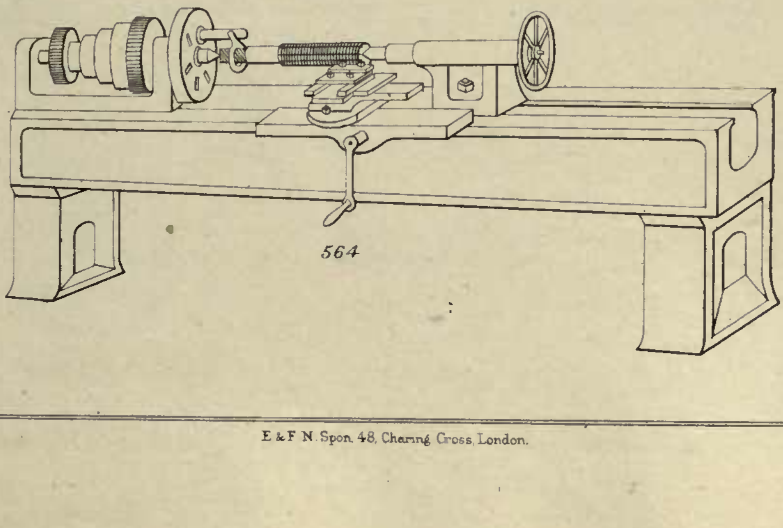
562

HEAD SHAPING.



563

HOB FLUTING



564

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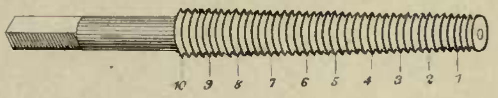
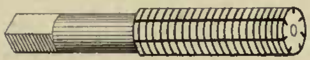
NUMBERED TAP SCREW



565

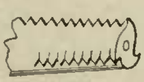
HOB FLUTES



566

567

TAP FLUTES



568

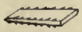
569

570

HANDLE HOLE

571

WEDGE



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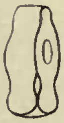
SLEDGE HAMMER



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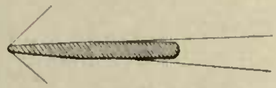
SIDE OF CHISEL



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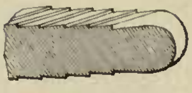
DRIFT TEETH



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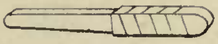
HANDLE DRIFT



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HANDLE DRIFT

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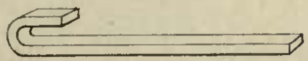
GAP SPANNER



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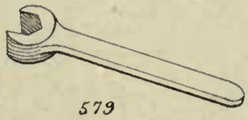
SPANNER



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SPANNER LUMP

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SOCKET

581

STEM

582

SOCKET AND FILLER

583

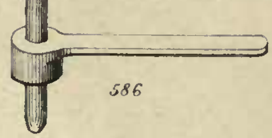
BAR FOR SPANNER

584

TAPER DRIFT

585

PARALLEL DRIFT



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E & F N Spon 48, Charing Cross London.

SPANNER BOSS

587

SPANNER

588

SPANNER BOSS

589

TONGUE JOINTED SPANNER

590

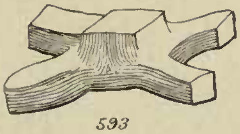
BOSS PIECE

591

BOSS PIECE

592

BOSS WITH FOUR ARMS



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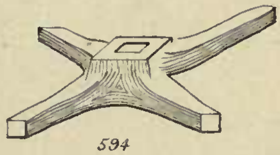
BOSS WITH FOUR ARMS



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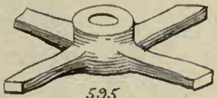
CIRCULAR BOSS



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LATHE BROACH

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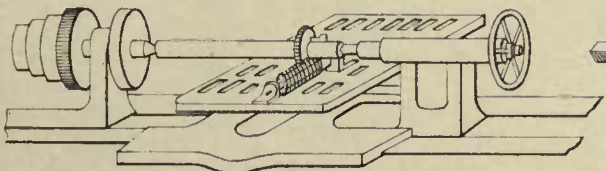
HOB FLUTING



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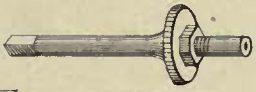
CUTTER SPINDLES



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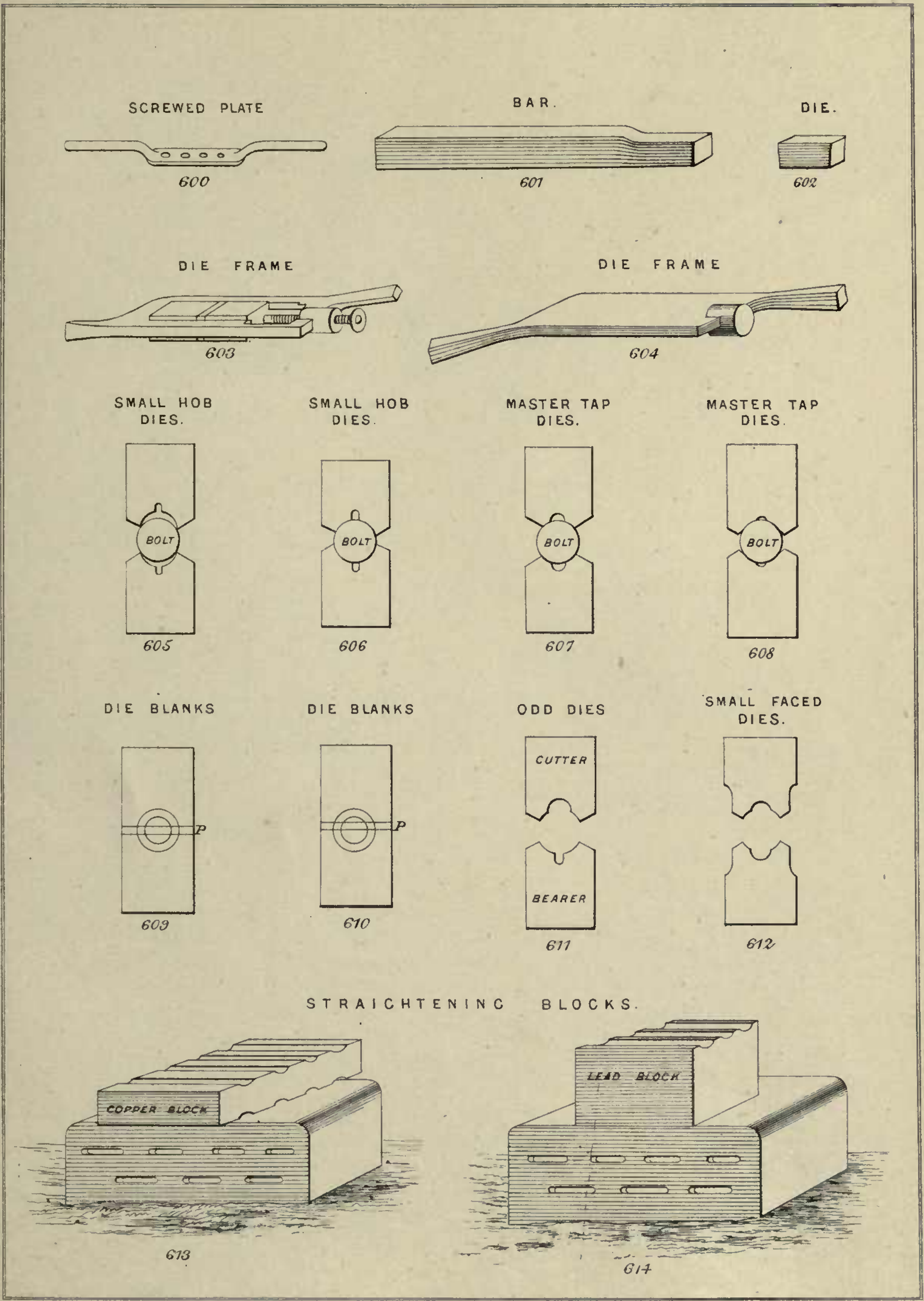
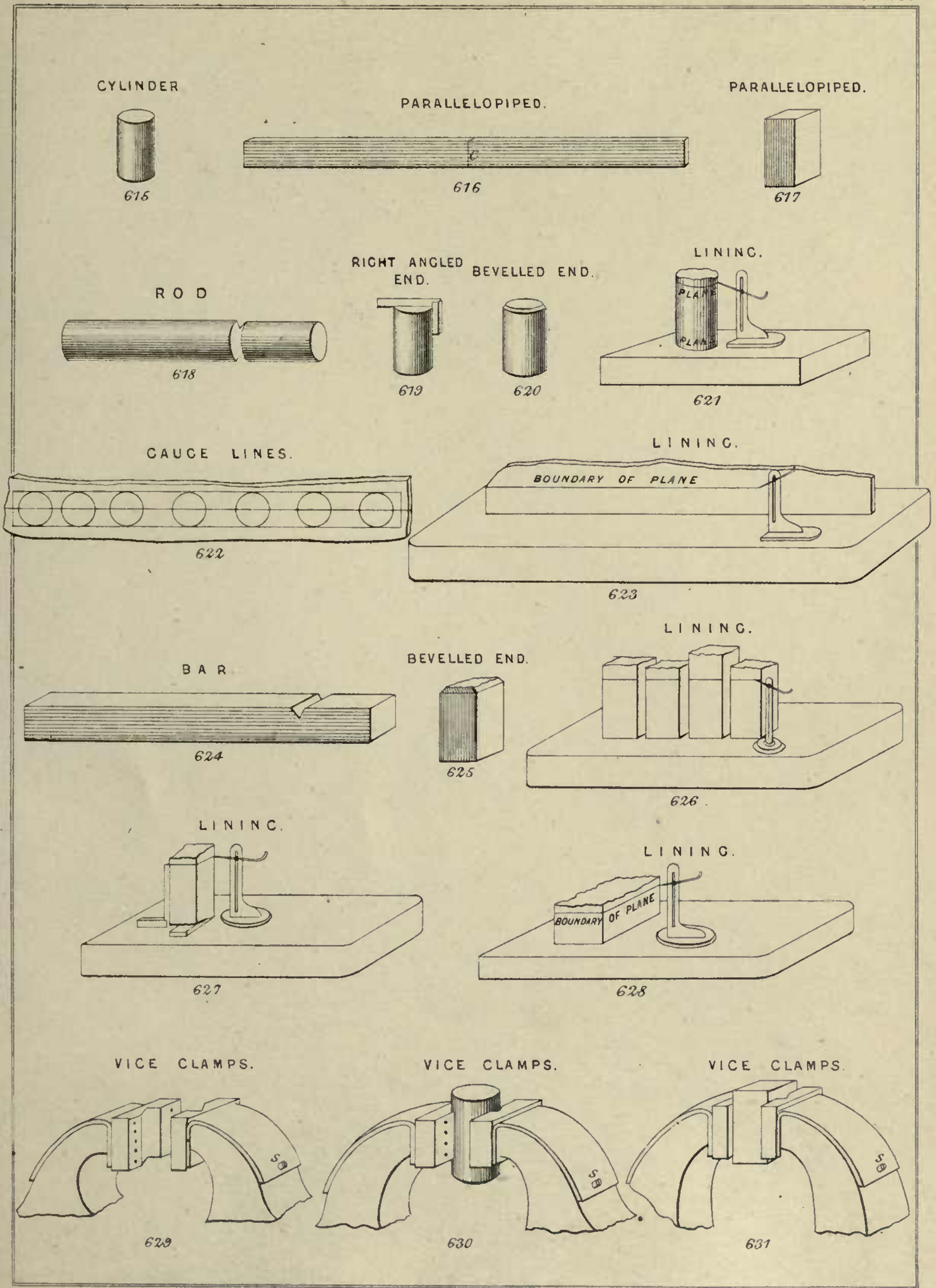
599

E & F N. Spon. 48, Charing Cross London.



E. & F. N. Spon, 48, Charing Cross, London.



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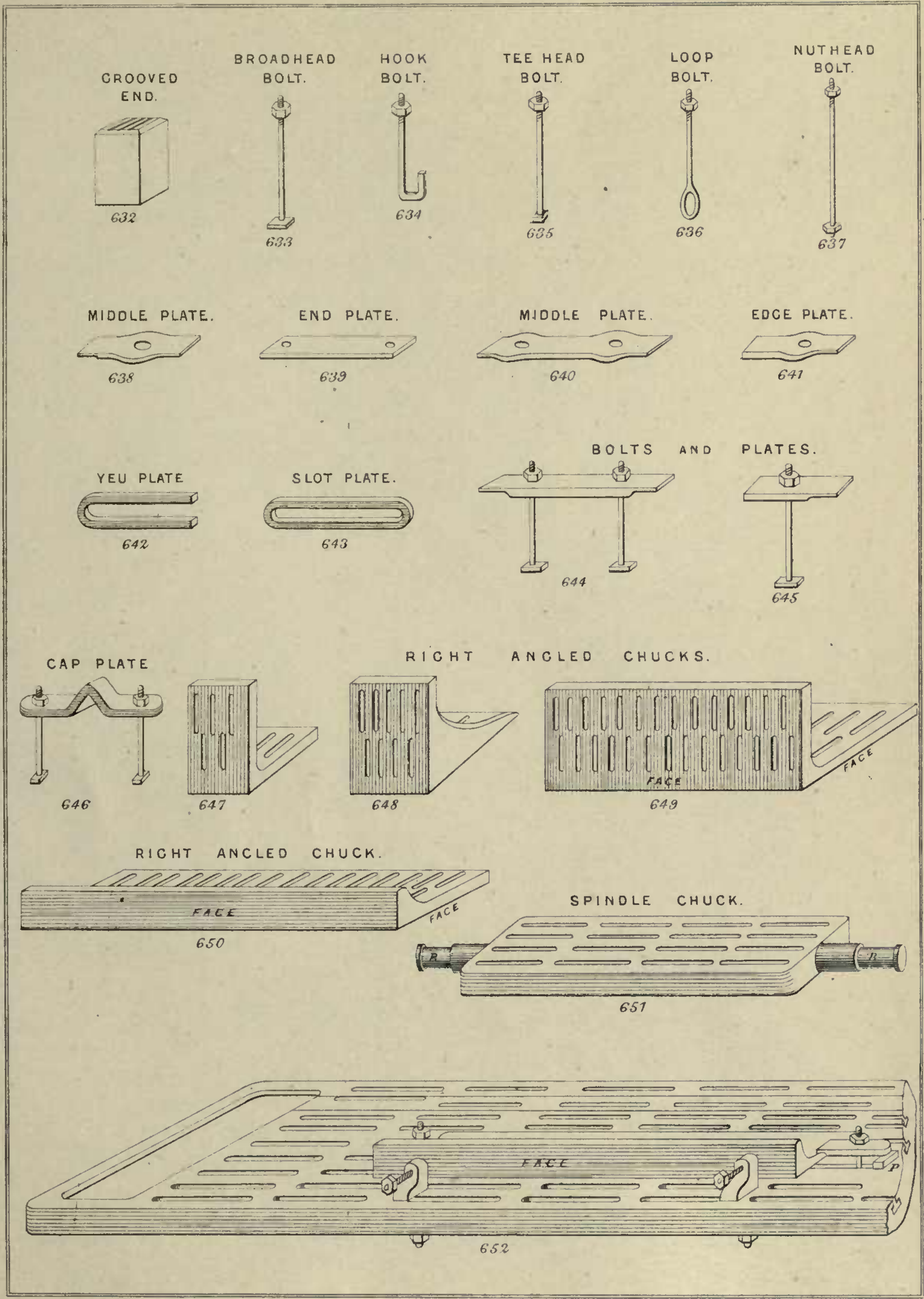

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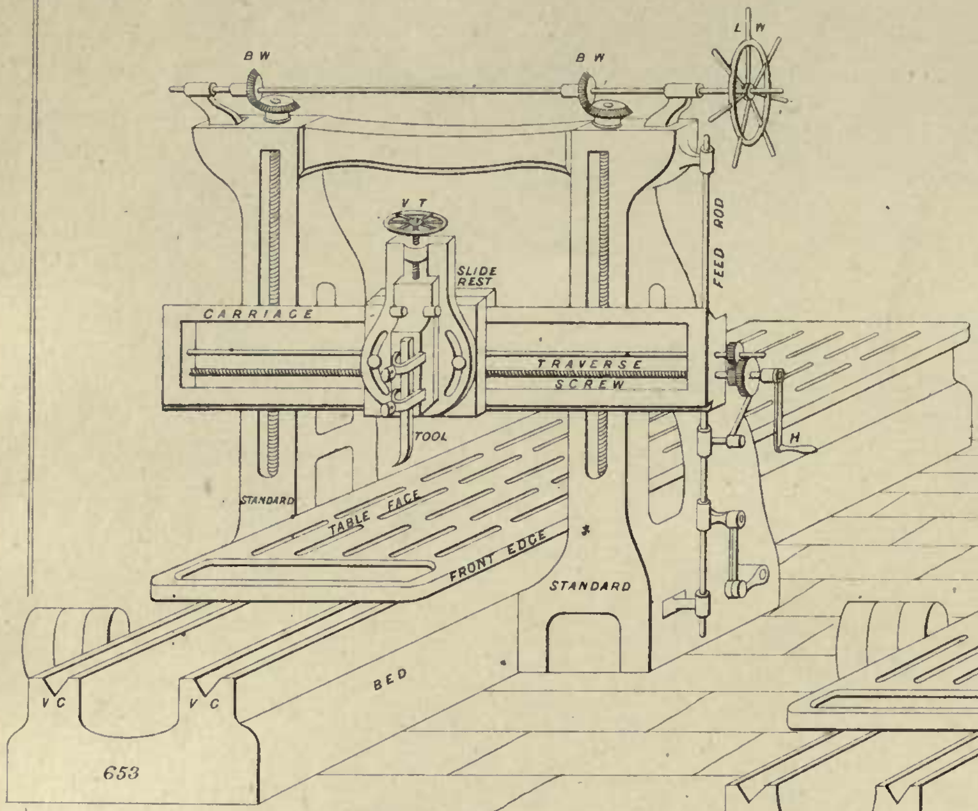

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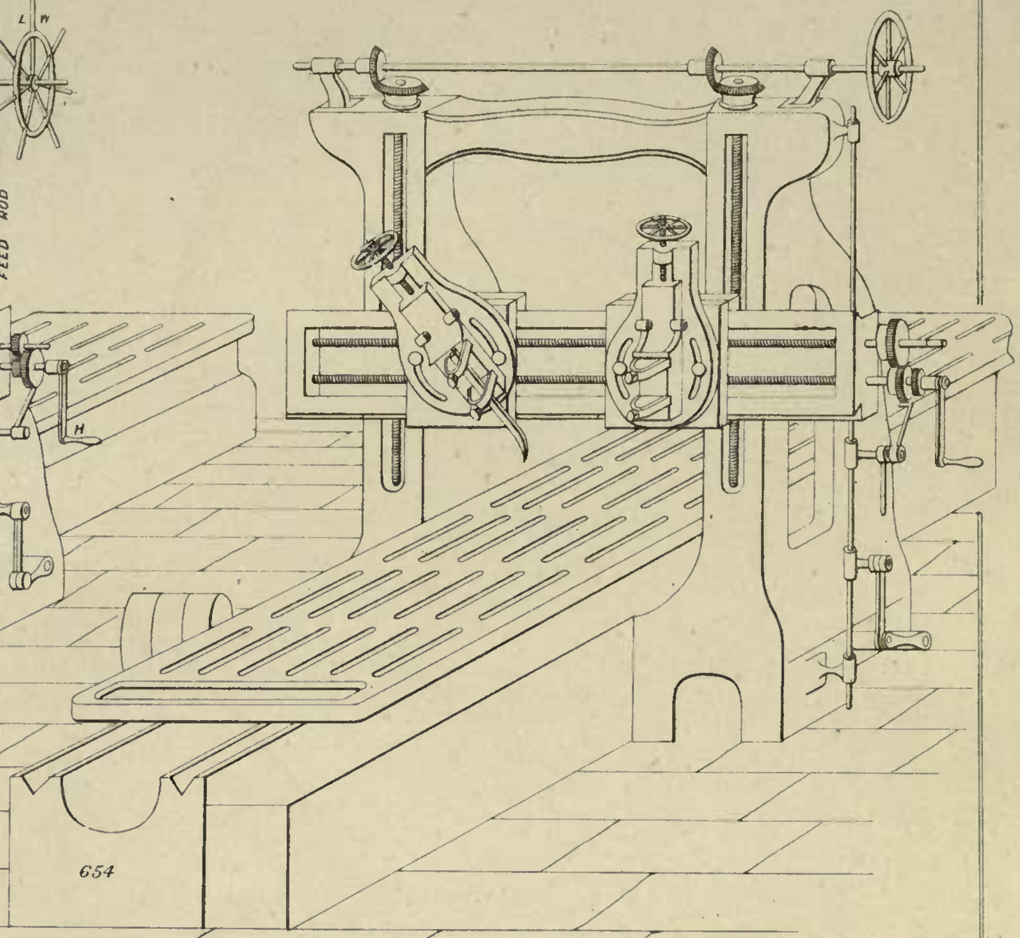

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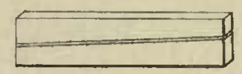
THE LINING OF KEYS, BOSSES, ETC.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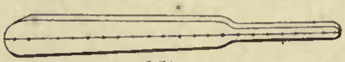
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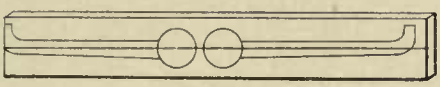
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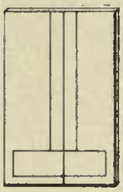
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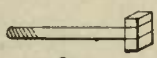
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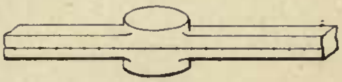
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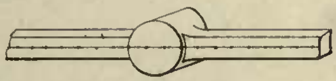
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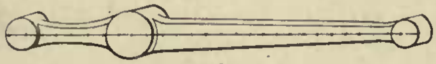
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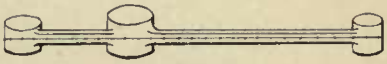
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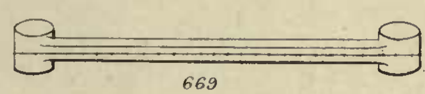
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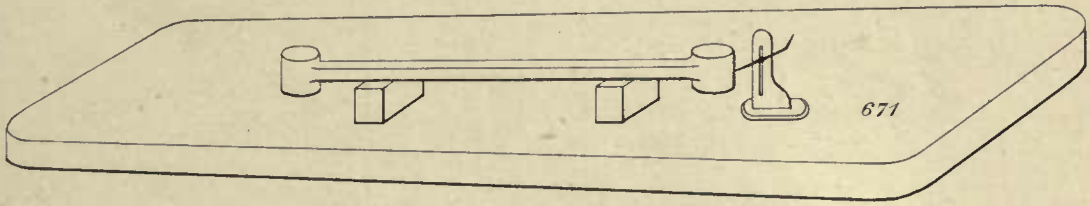
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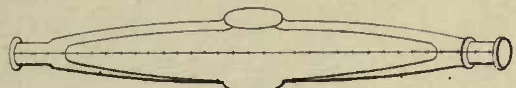
LINING OF CROSSHEADS, LINKS, ETC.



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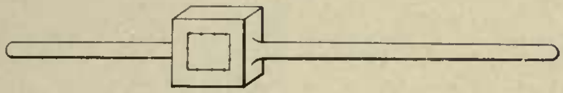

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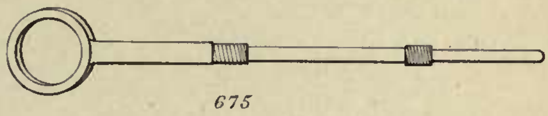

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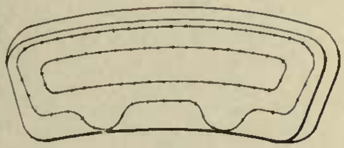

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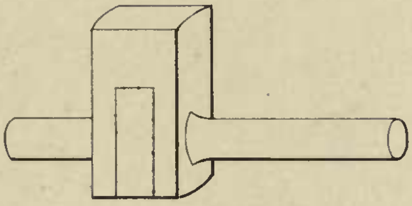

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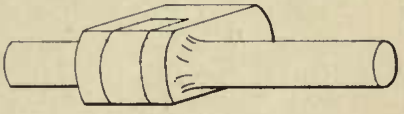

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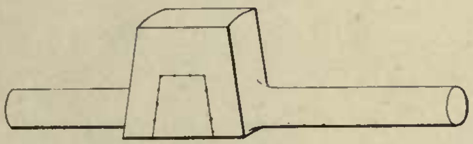

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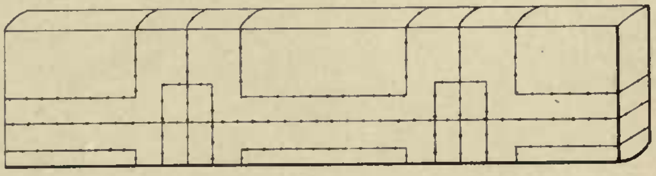

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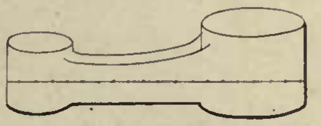

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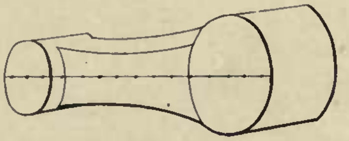

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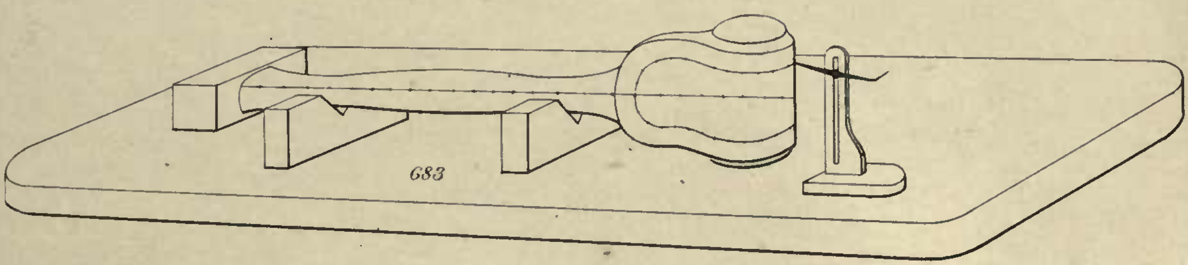

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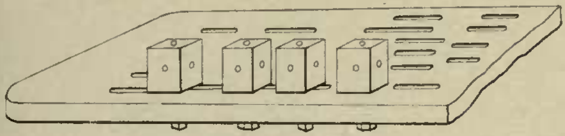
MODES OF FIXING FOR PLANING.



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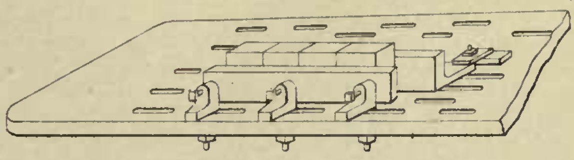

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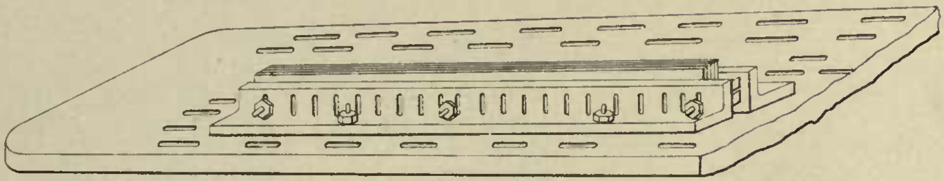

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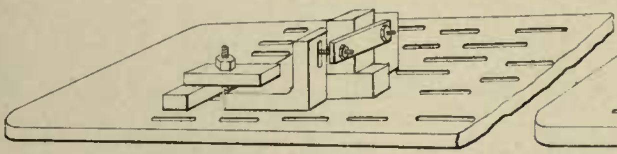

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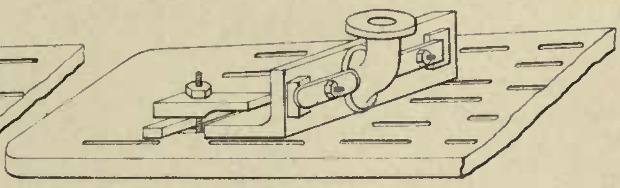

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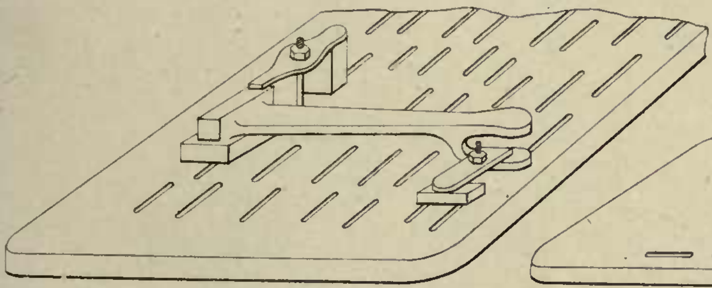

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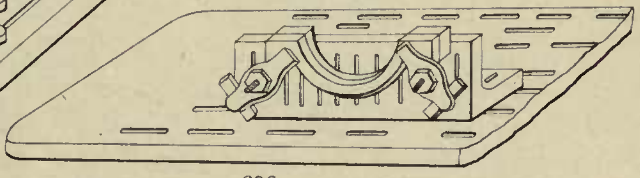

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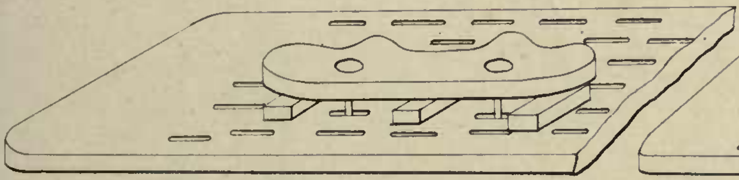

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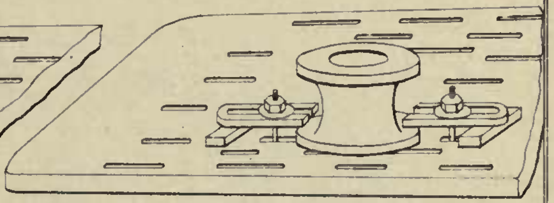

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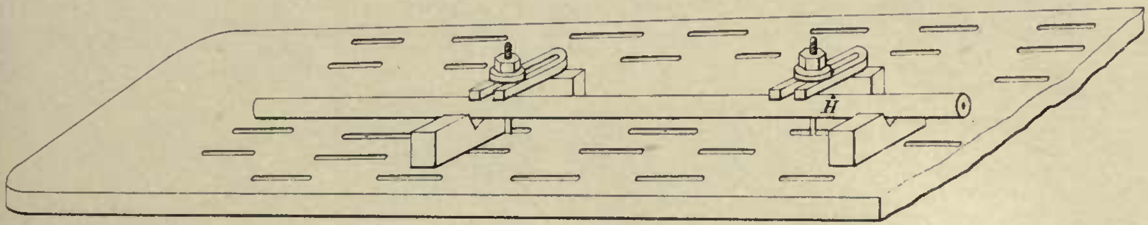

693

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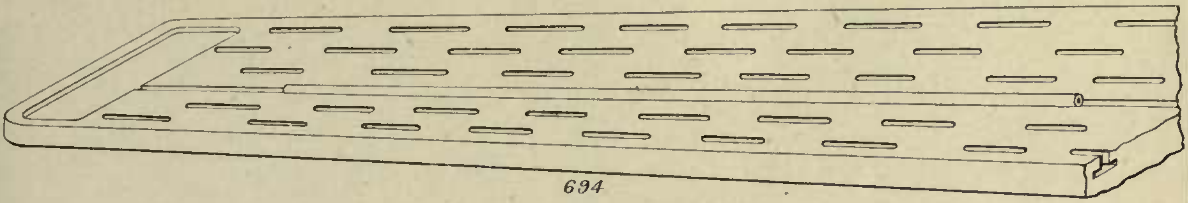
SPINDLE IN A VEE-GROOVE.



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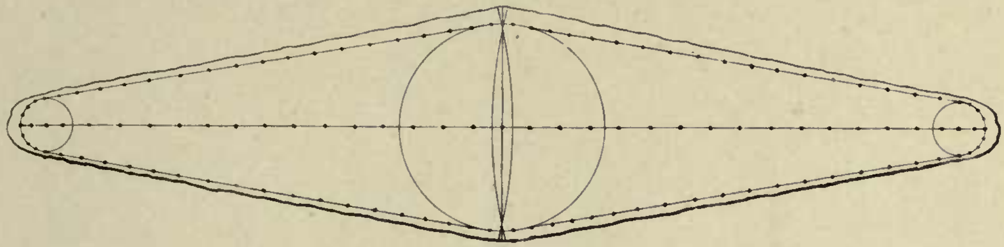
SIDE OF A SLAB.



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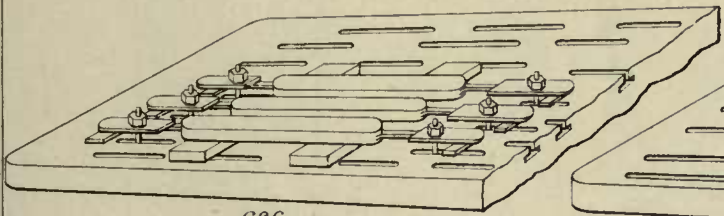
USE OF HOLDERS.



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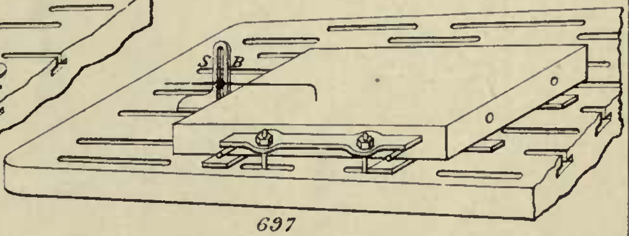
ADJUSTING A PLATE.



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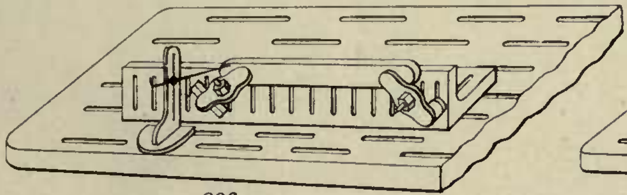
ADJUSTING KEYS TO SCRIBER-POINTS.



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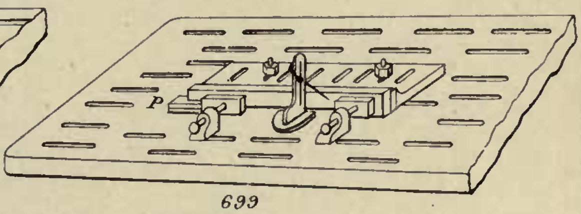

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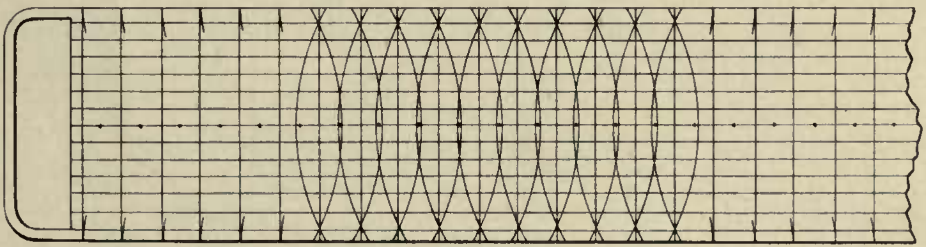
LINES ON A TABLE'S FACE.



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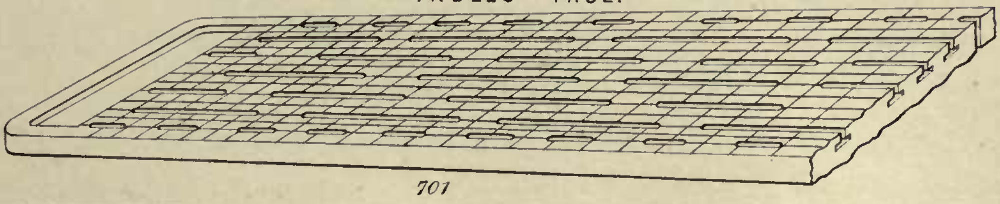
TABLE'S FACE.



701

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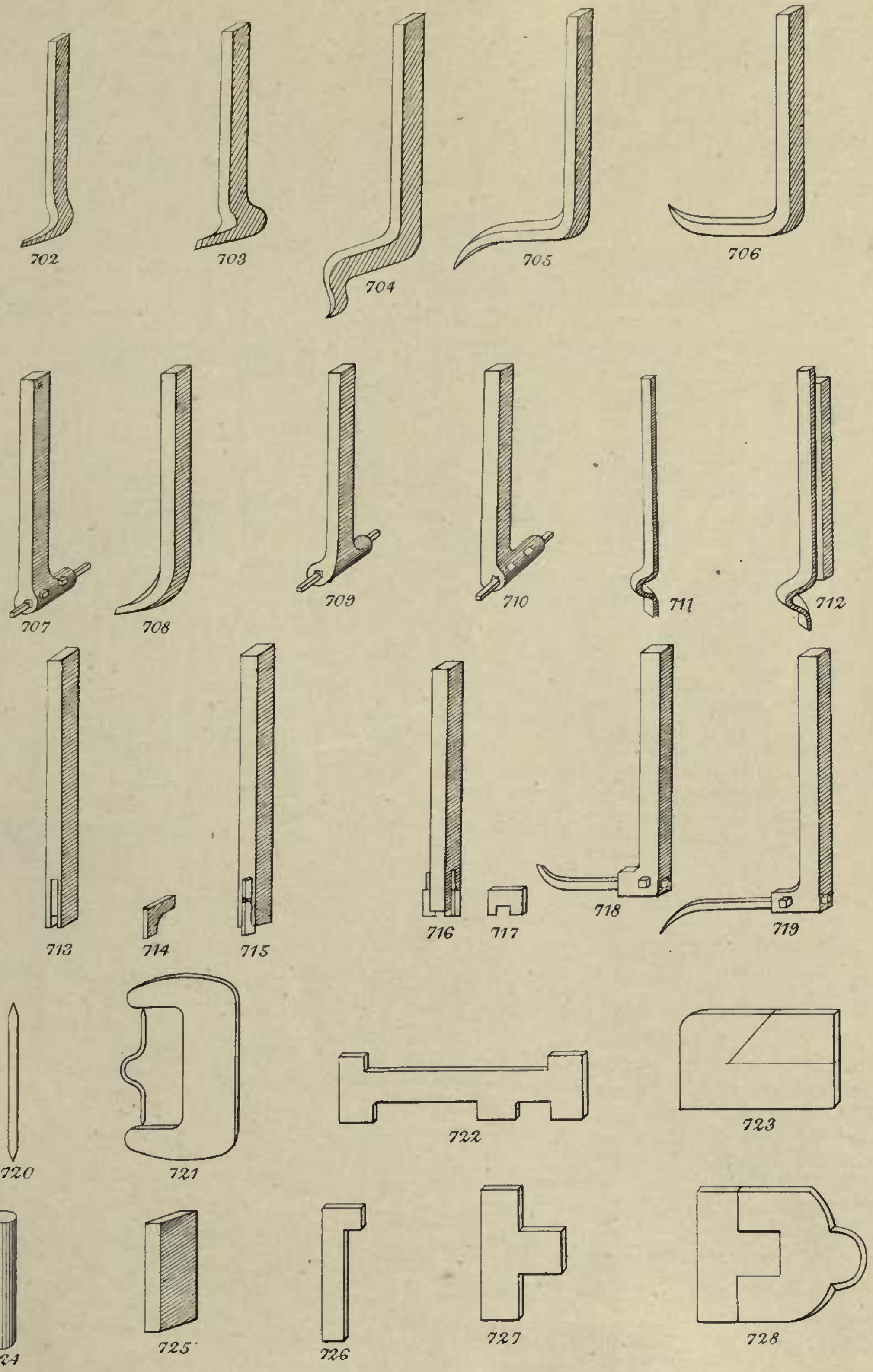
TOOLS FOR PLANING-MACHINES.



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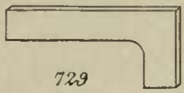

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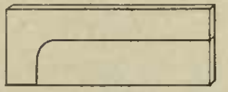

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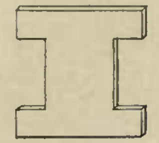

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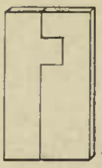

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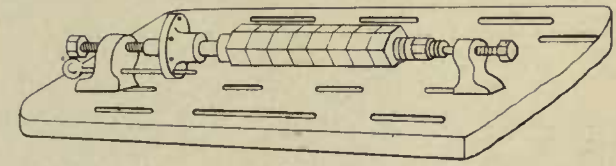

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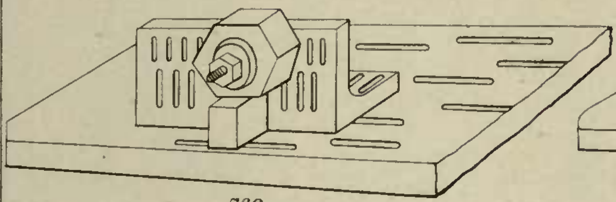

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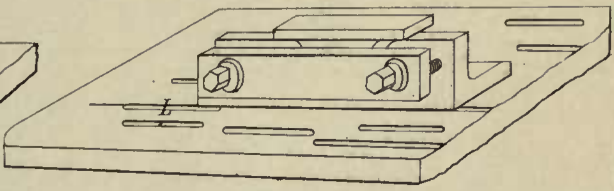

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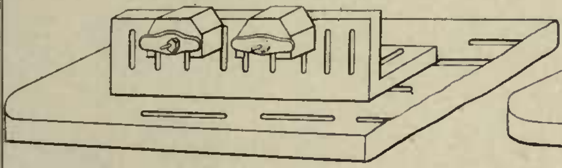

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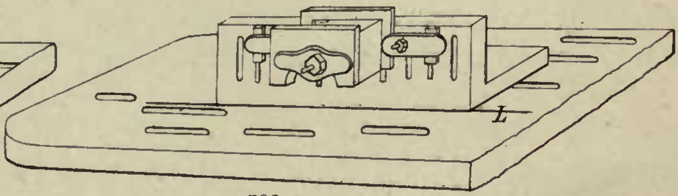

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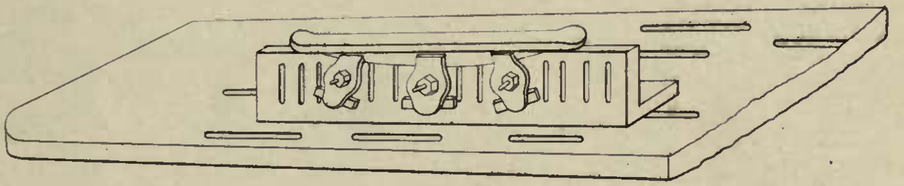

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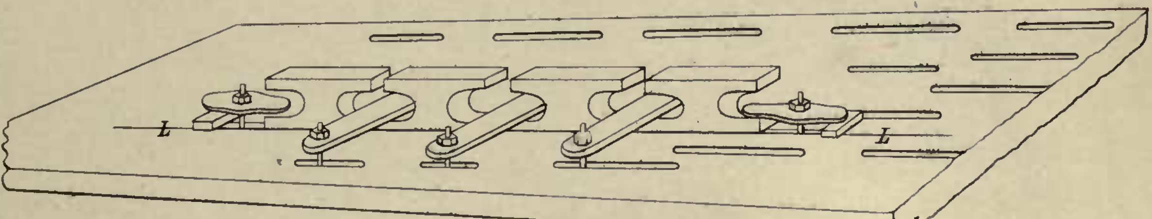

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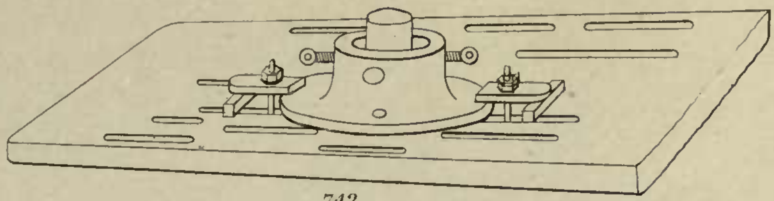

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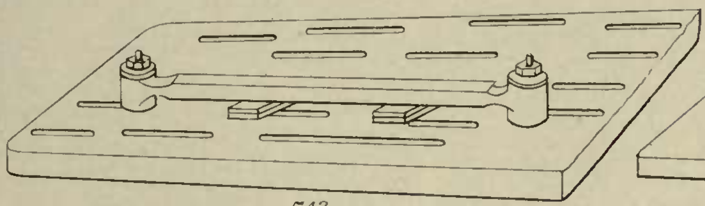

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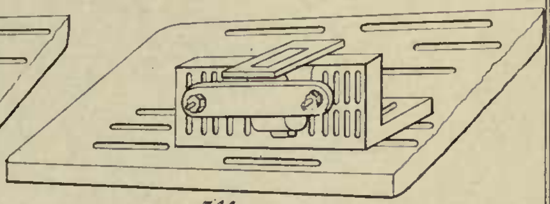

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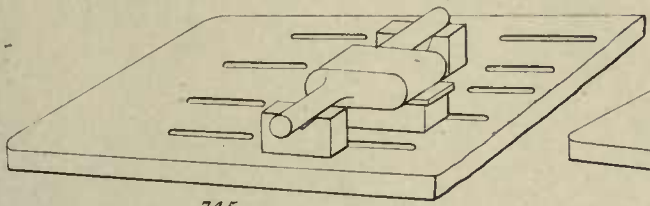

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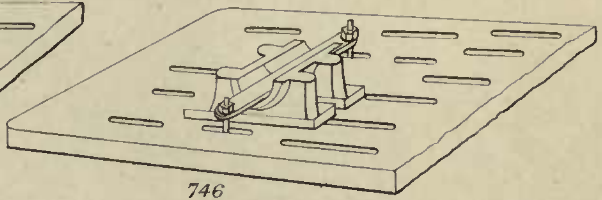

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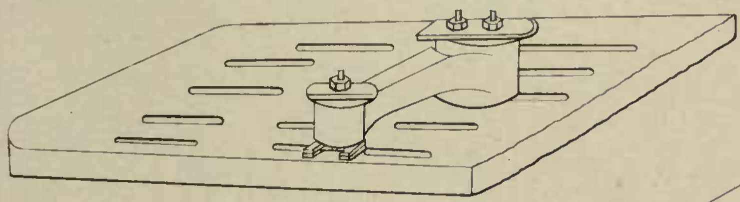

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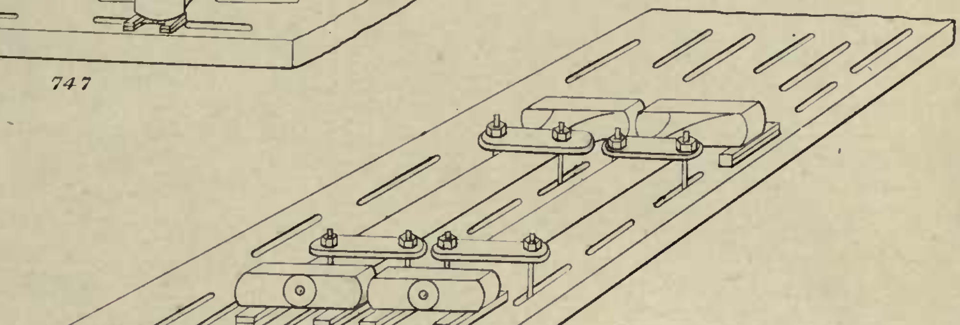

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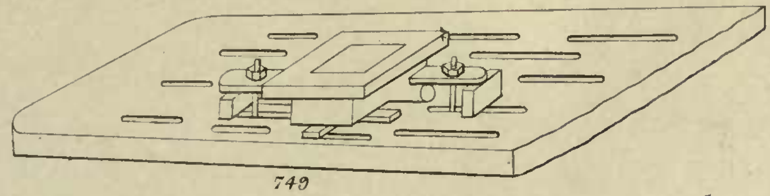
E & F. N Spon, 48, Charing Cross, London.



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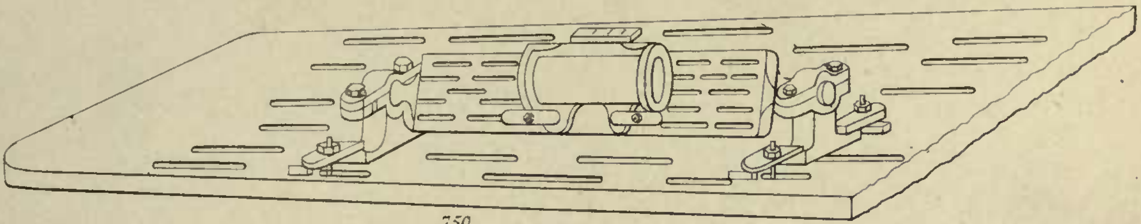

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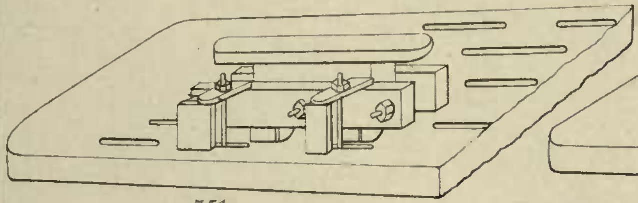

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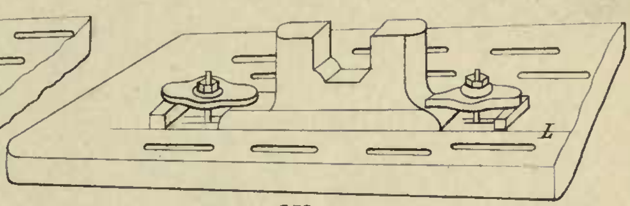

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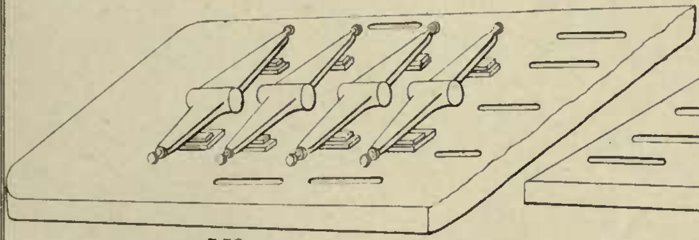

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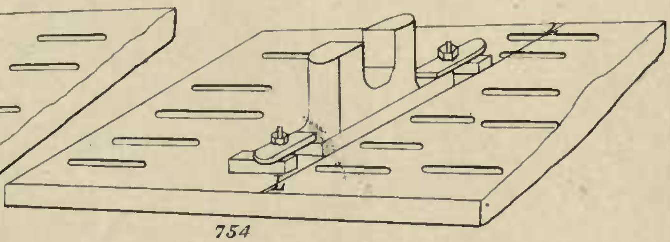

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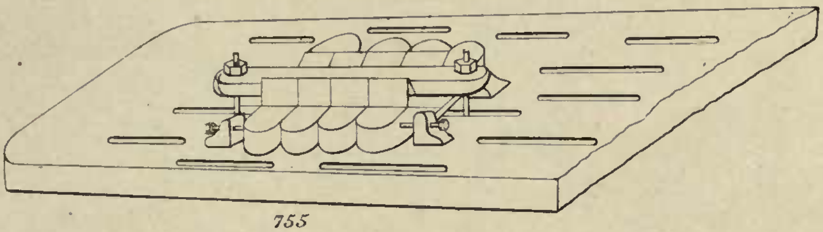

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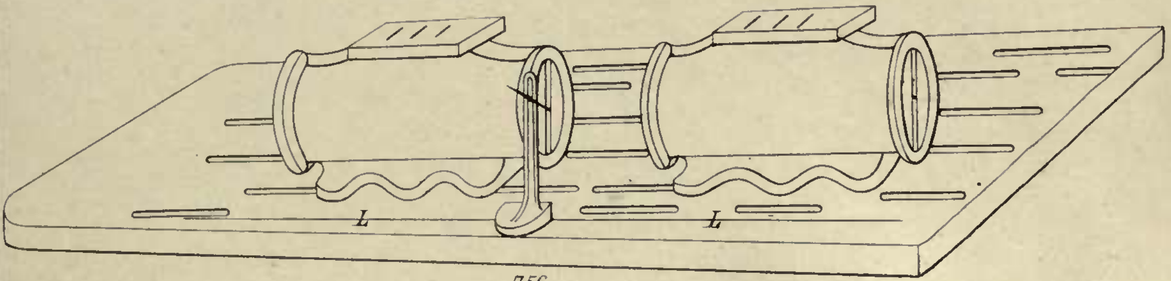

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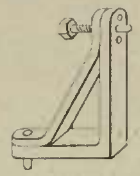
E & F.N Spon 48, Charing Cross, London

757



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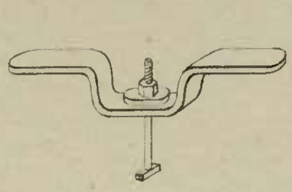

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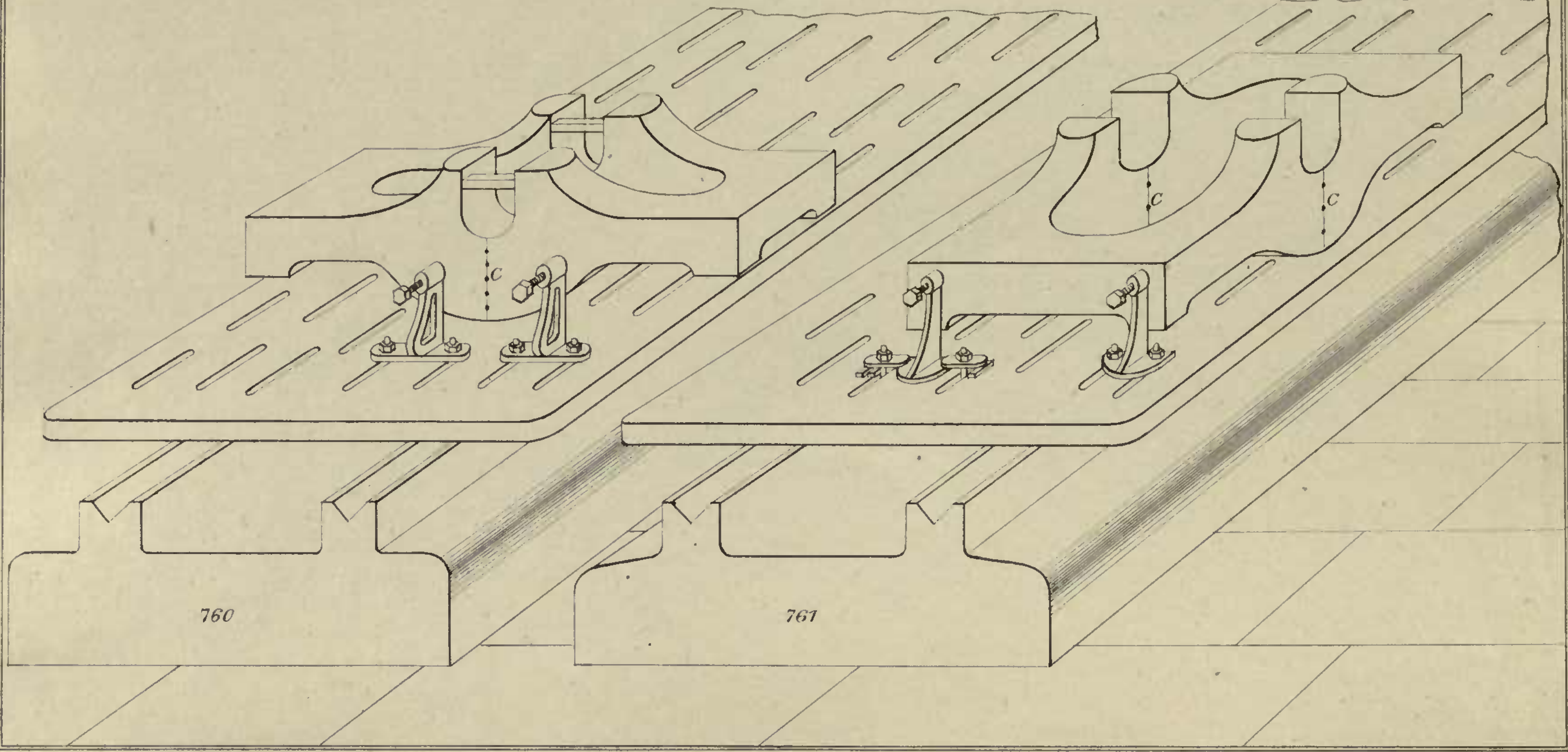

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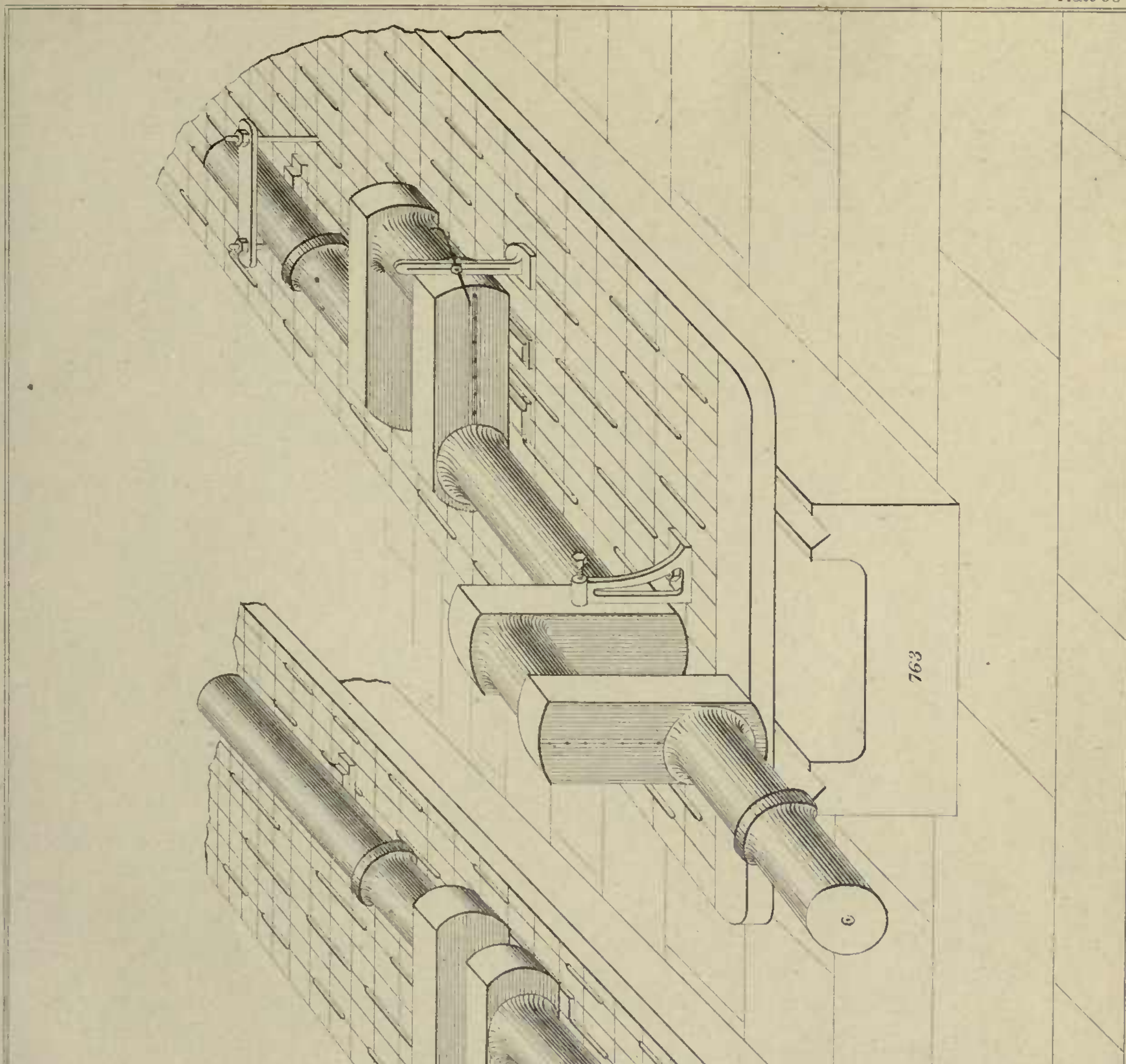
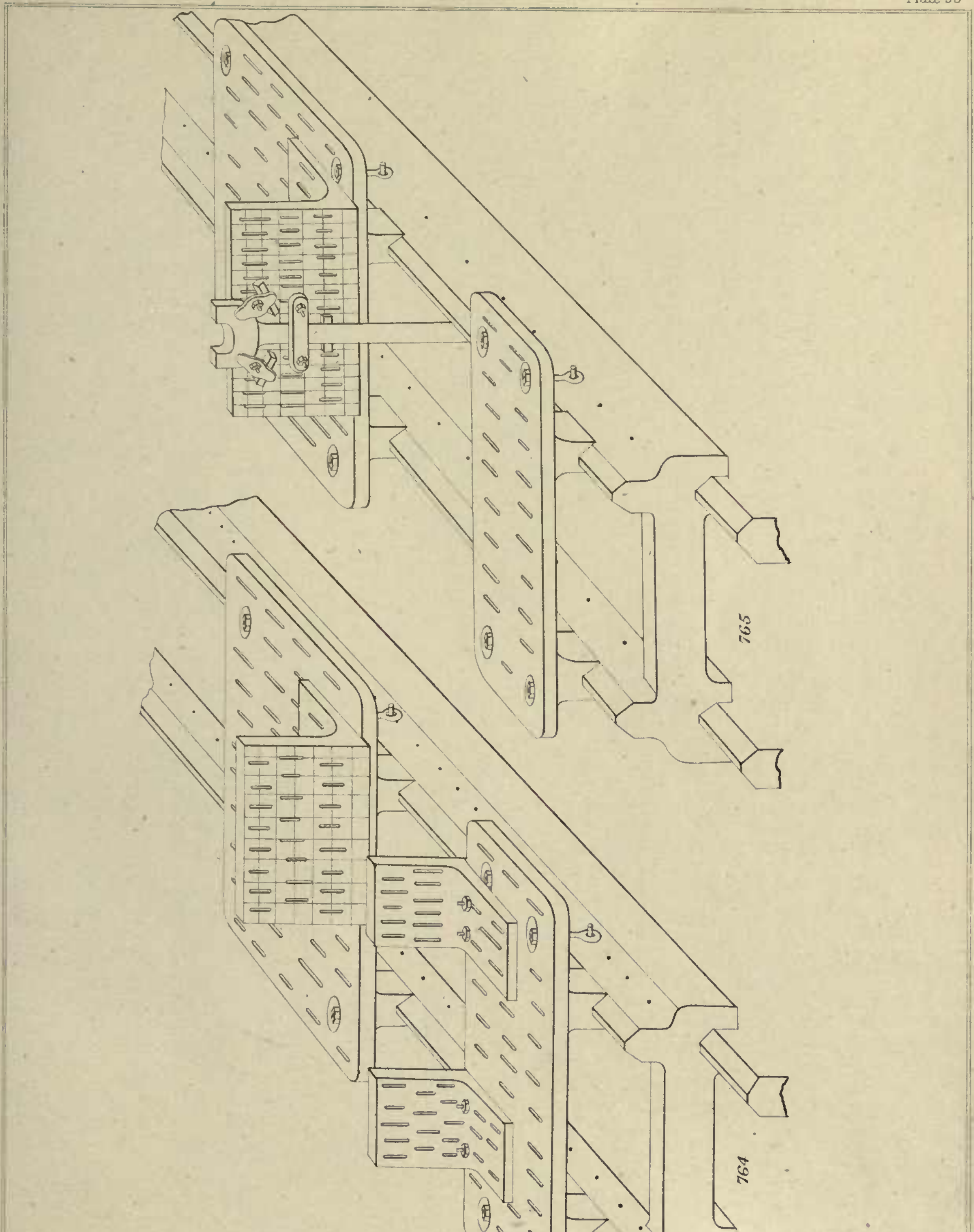
761

E & F N Spon. 48, Charing Cross London.

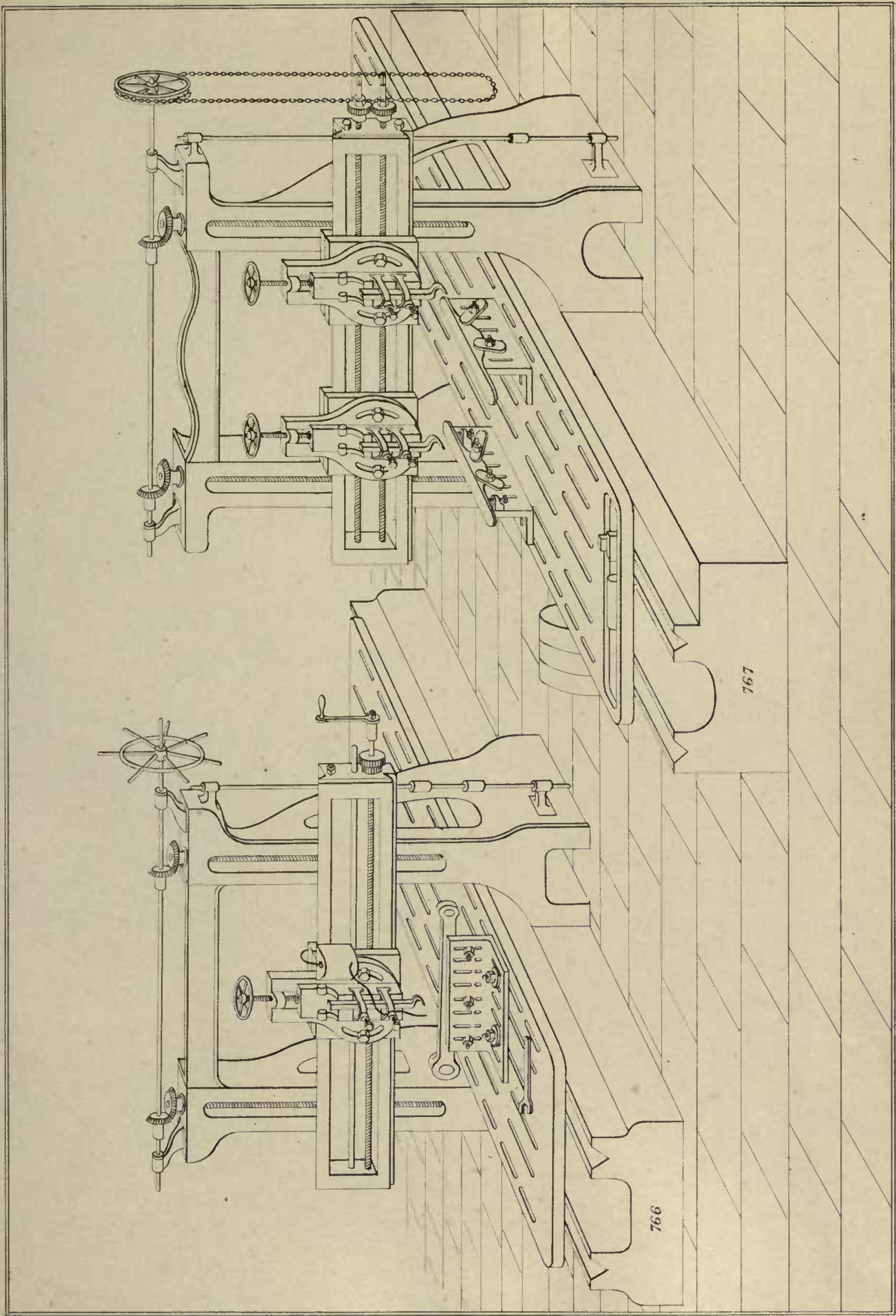
Plate 58



E & F N Spon. 48 Charing Cross. London.



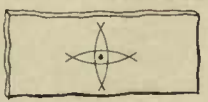
E & F N Spon 48 Charing Cross London



E & F.N Spon, 48, Charing Cross, London


768


769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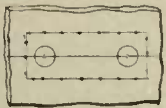
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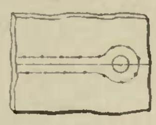
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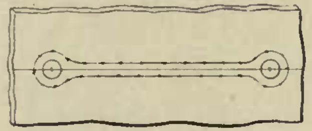
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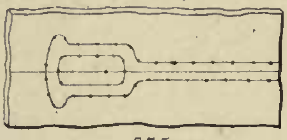
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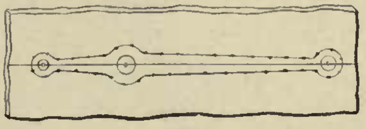
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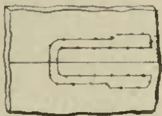
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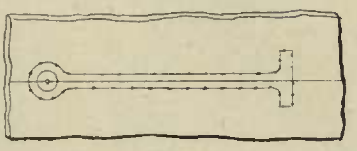
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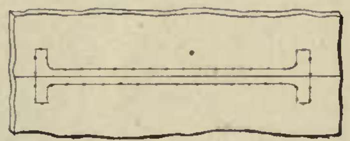
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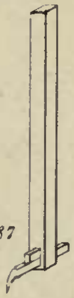
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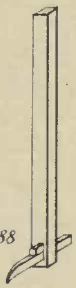
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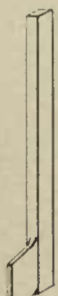
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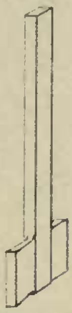
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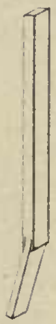
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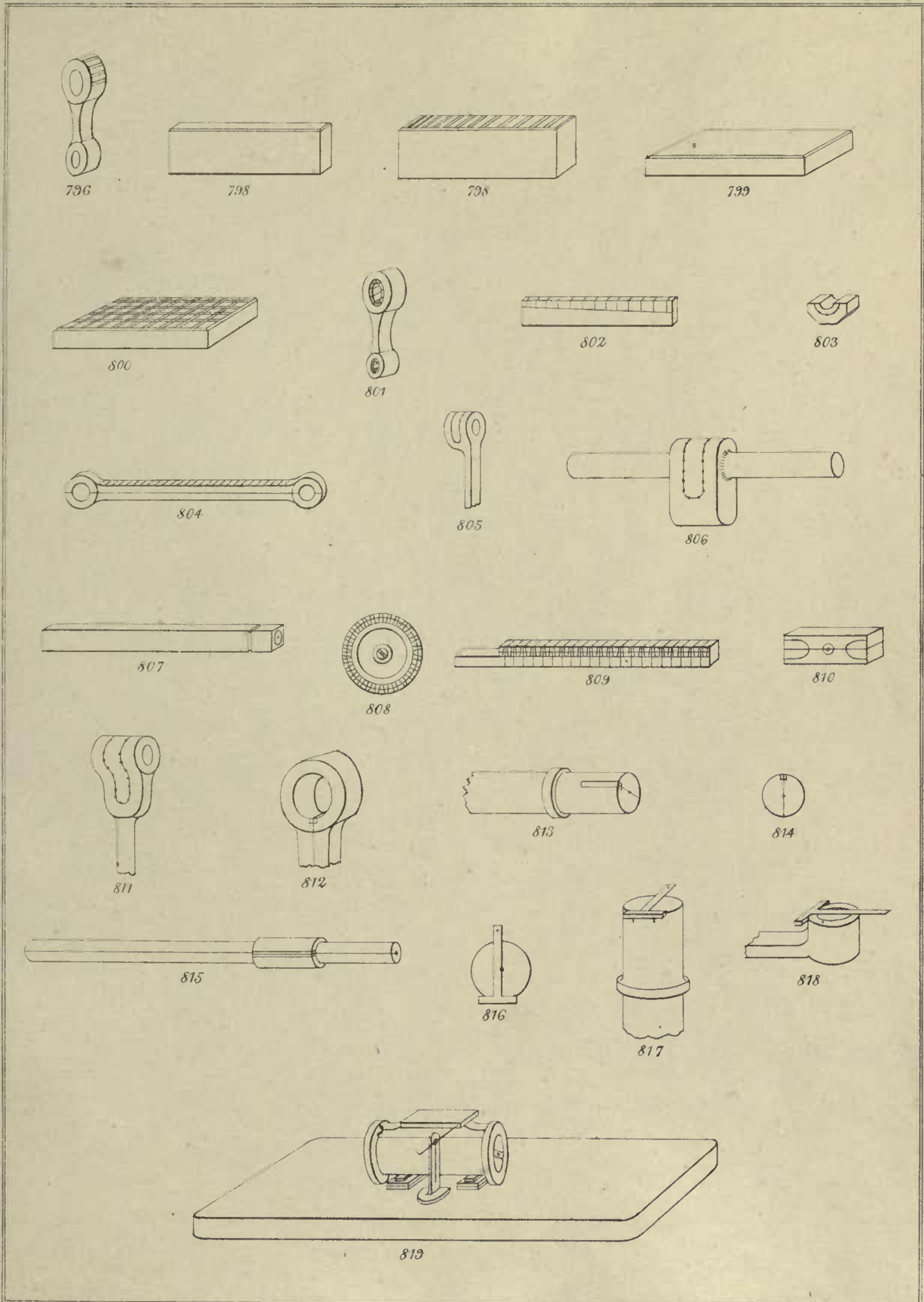
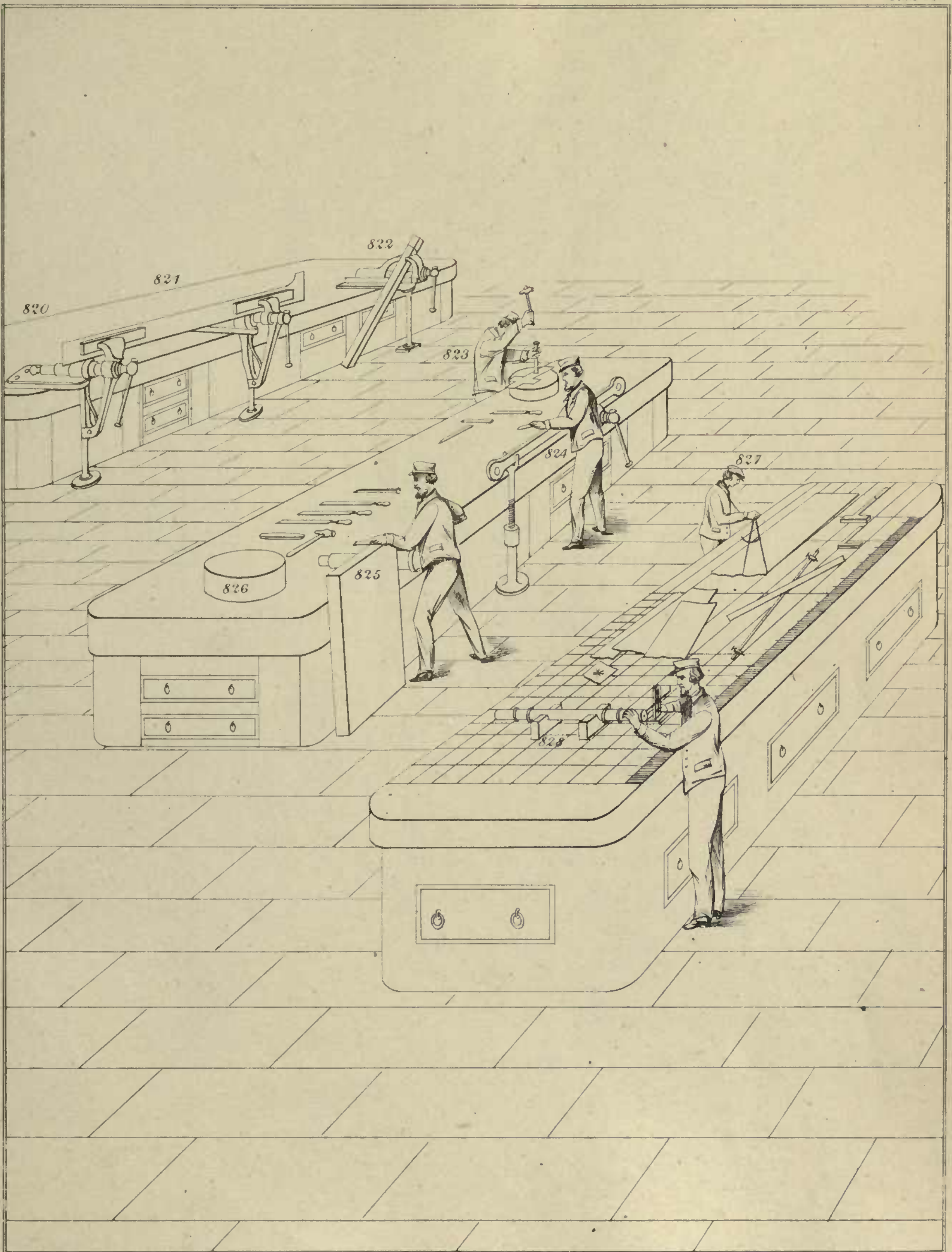
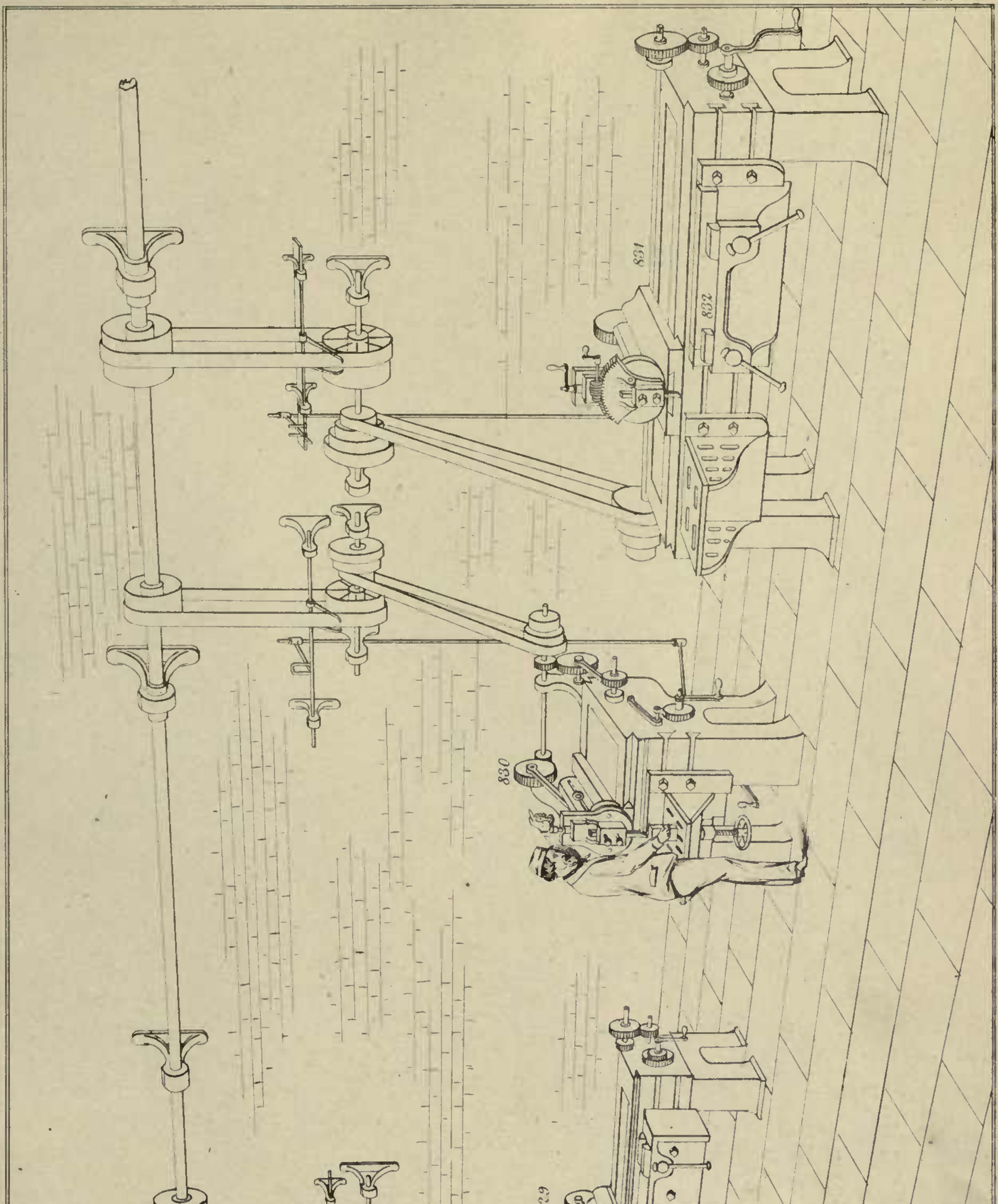
E & F N Spon, 48, Charing Cross London



E & F N Spon, 48 Charing Cross, London



E & F N Spon 48, Charing Cross, London.



E. & F. N Spon, 48, Charing Cross London

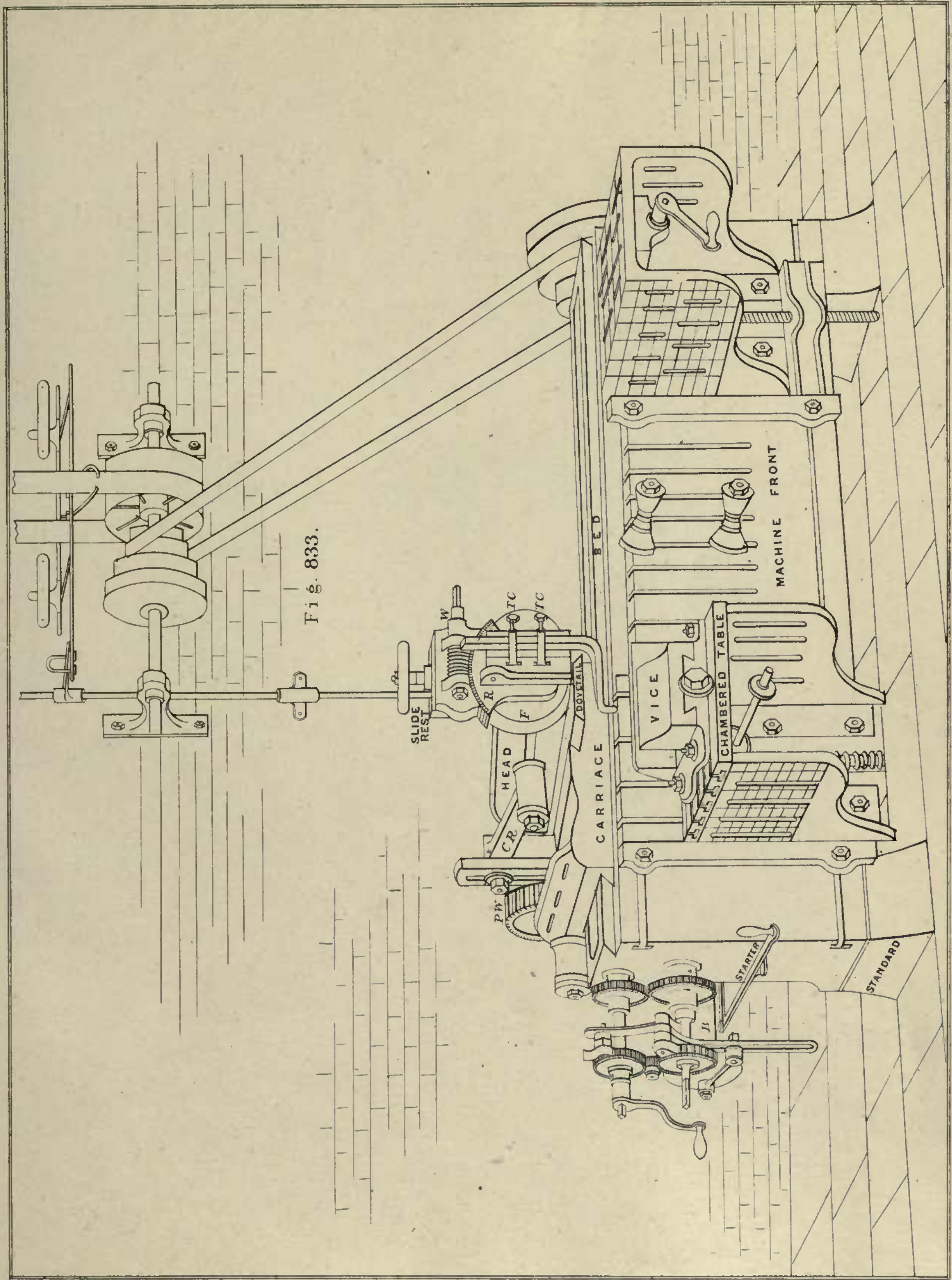


Fig. 833.

E & F N Spon, 48, Charing Cross, London.

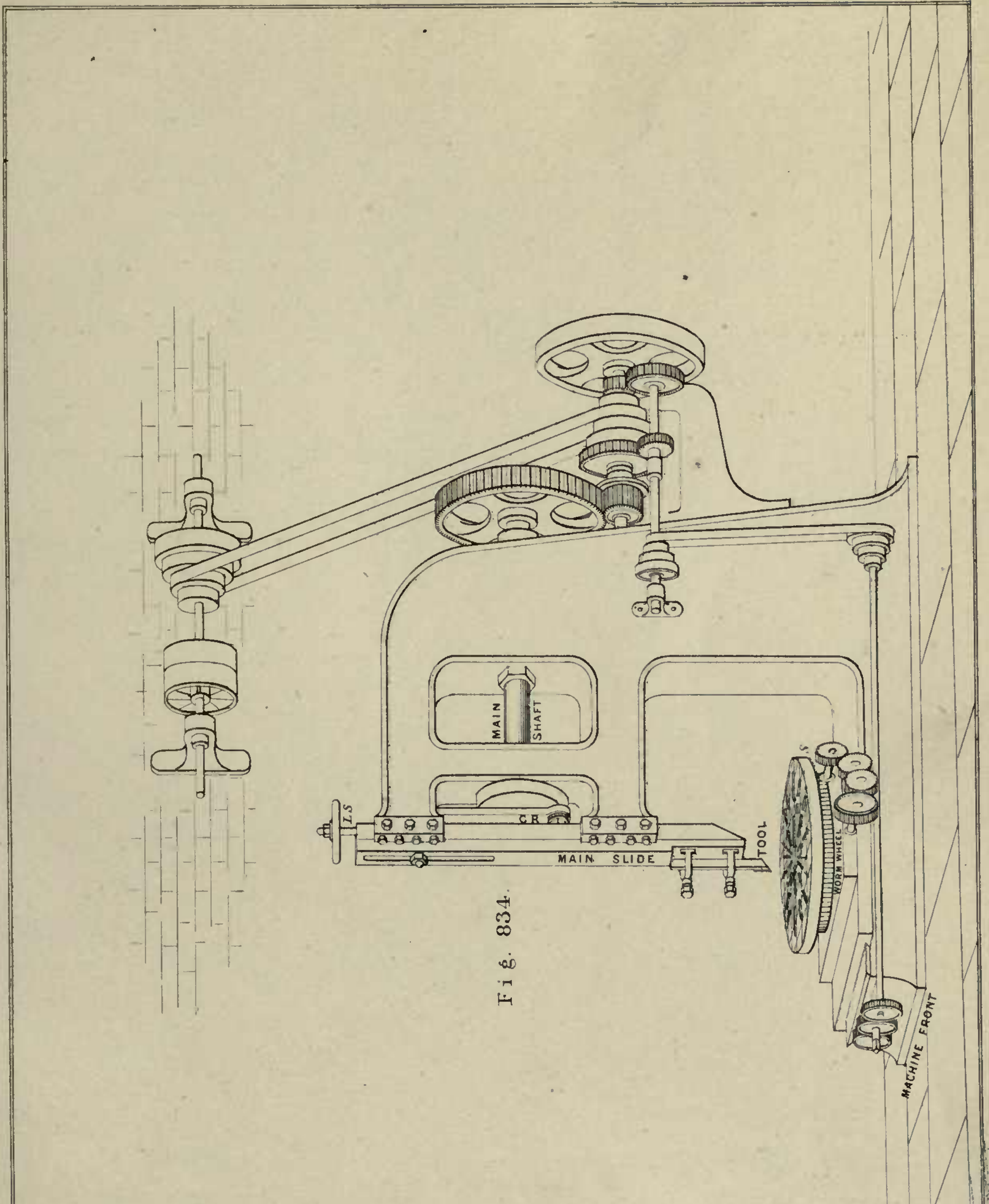
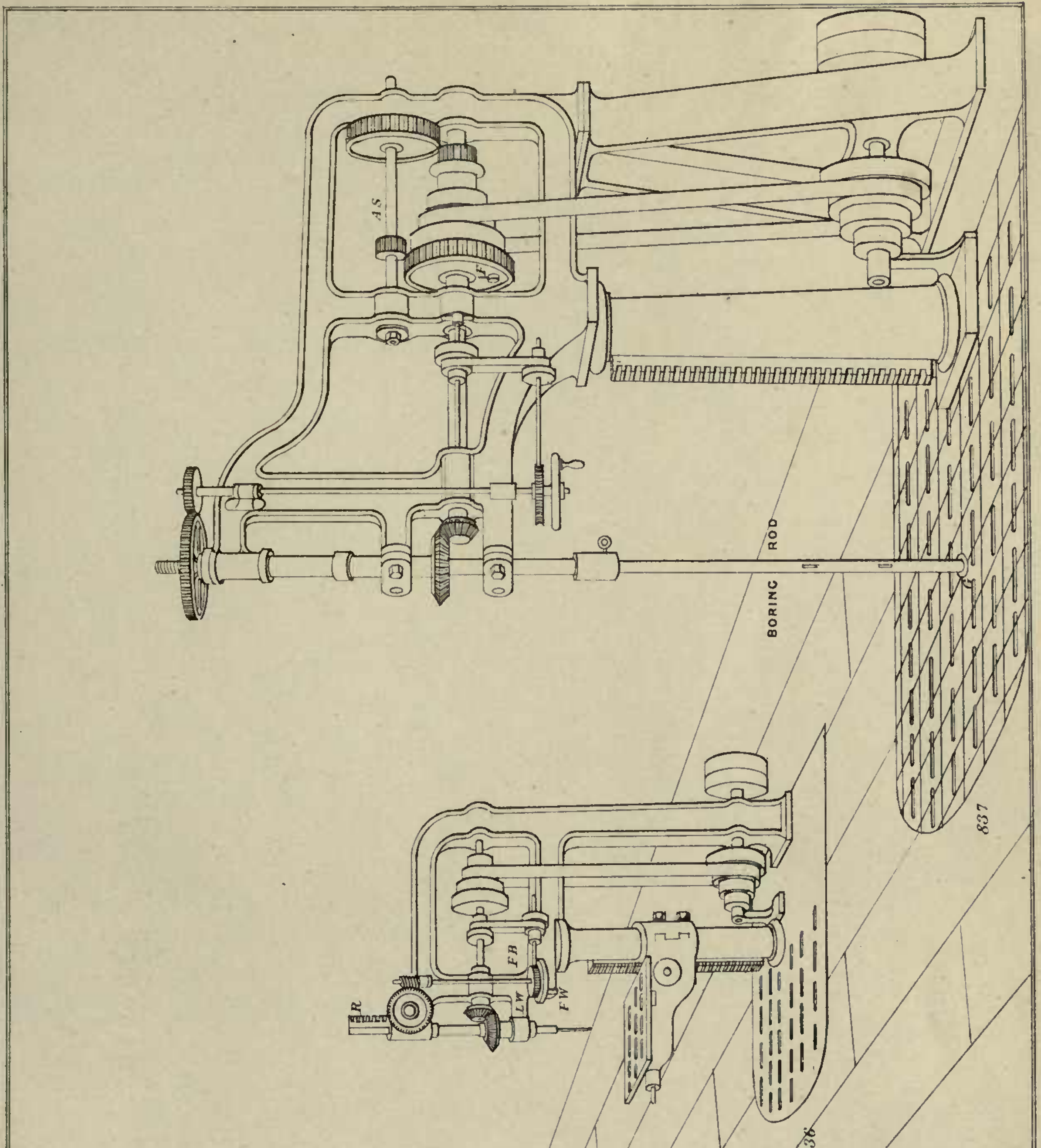
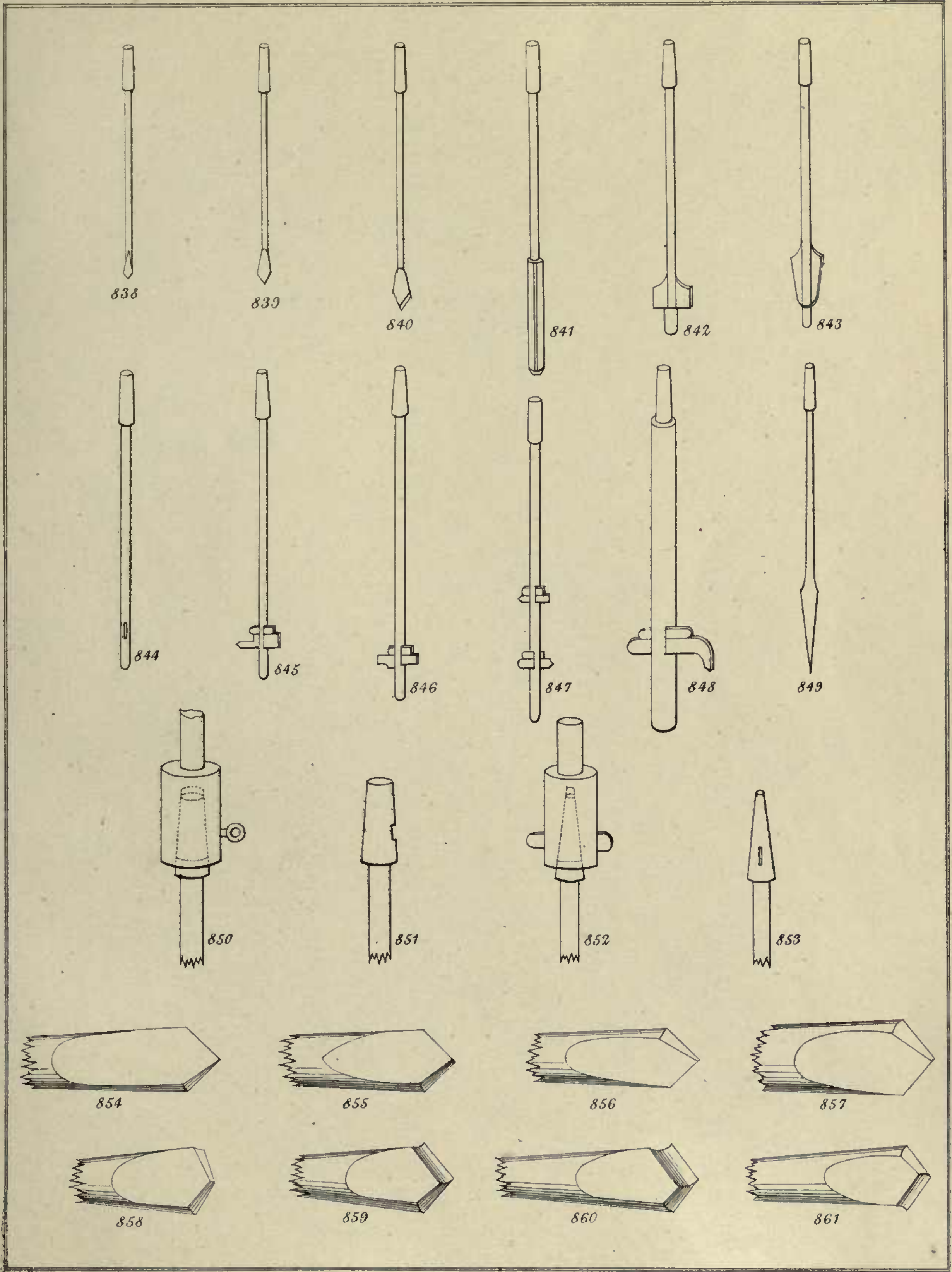


Fig. 834.

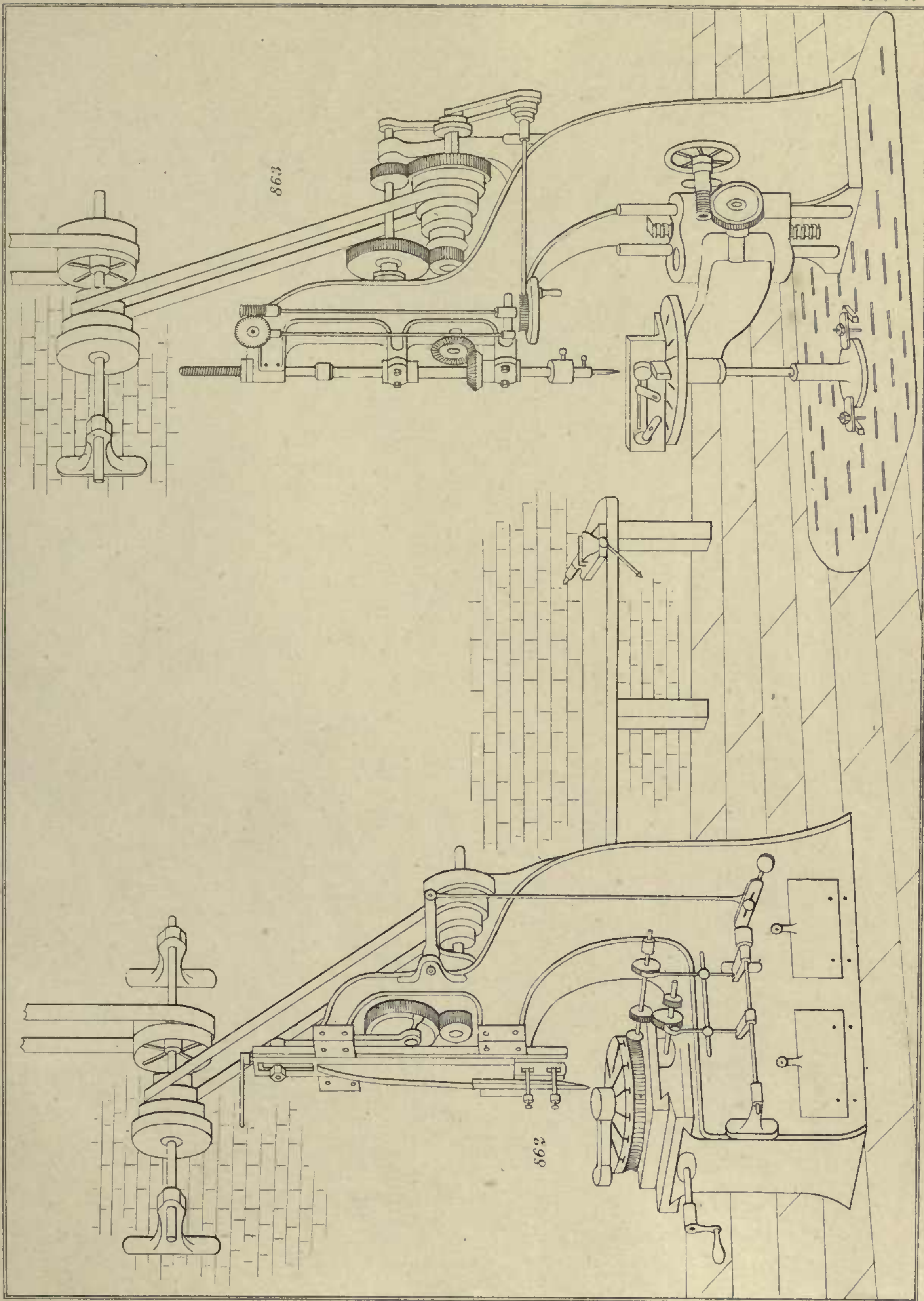
E & F N Spon 48, Charing Cross, London



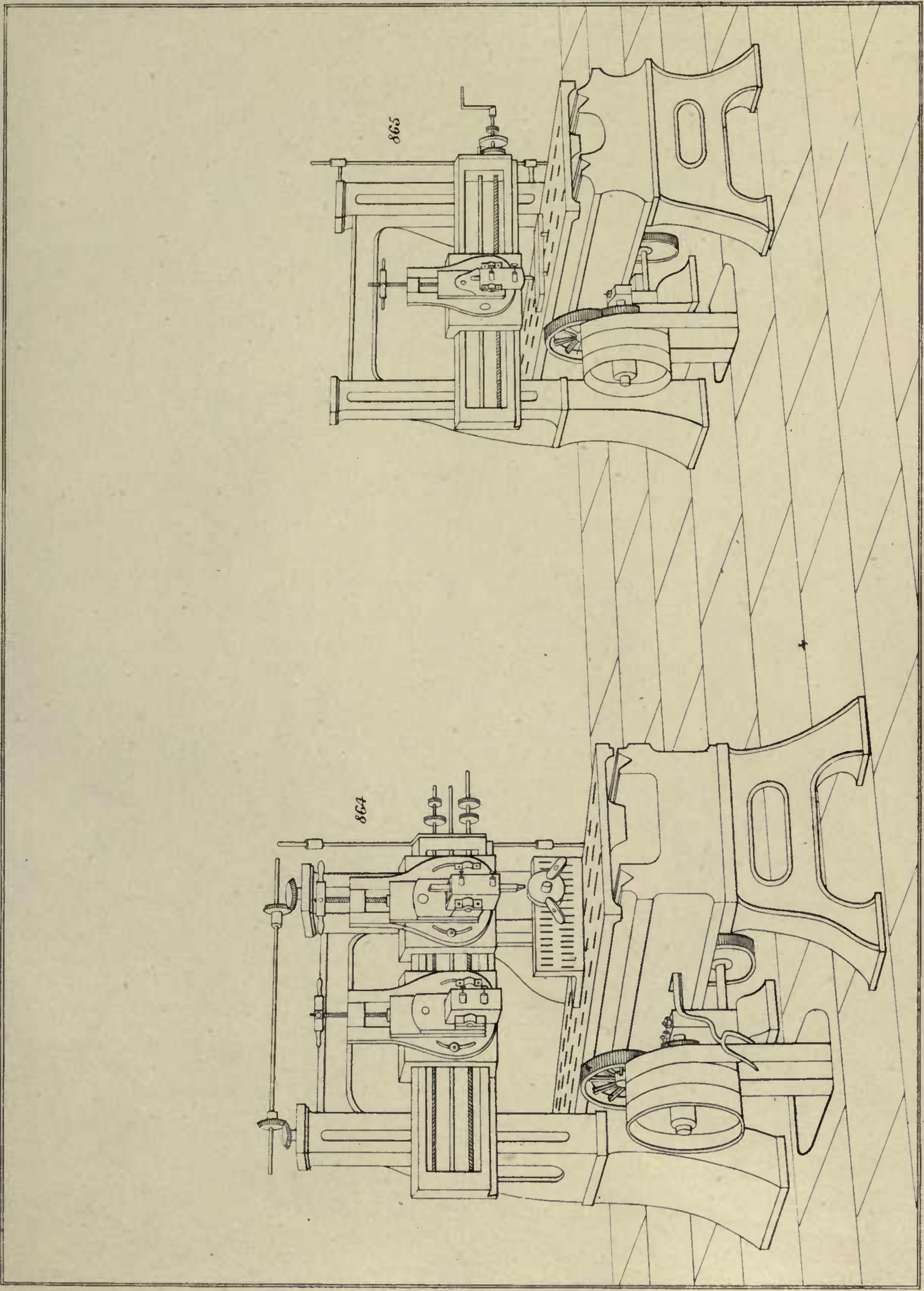
E & F N Spon, 48, Charing Cross, London



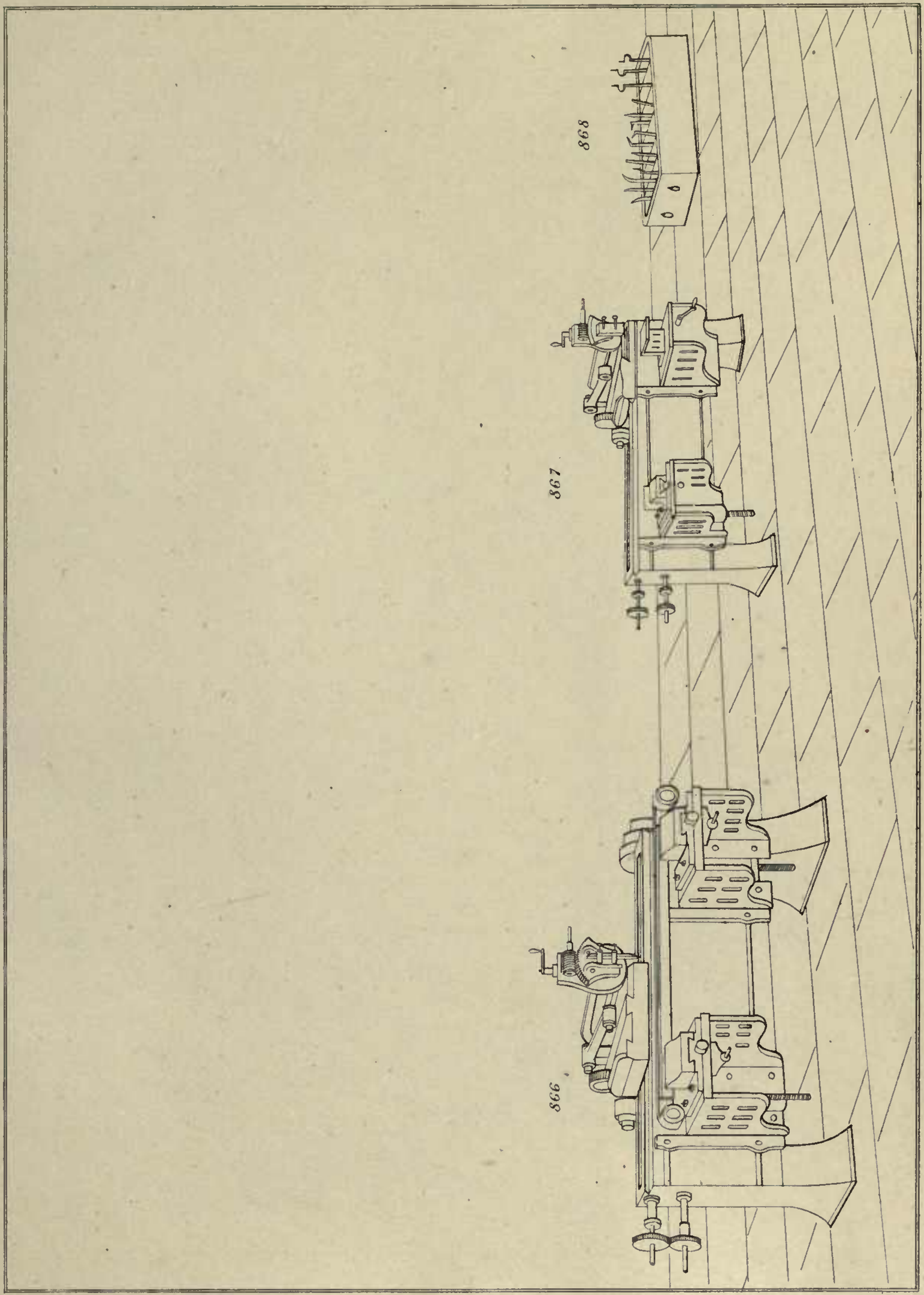
E & F. N. Spon, 48, Charing Cross, London



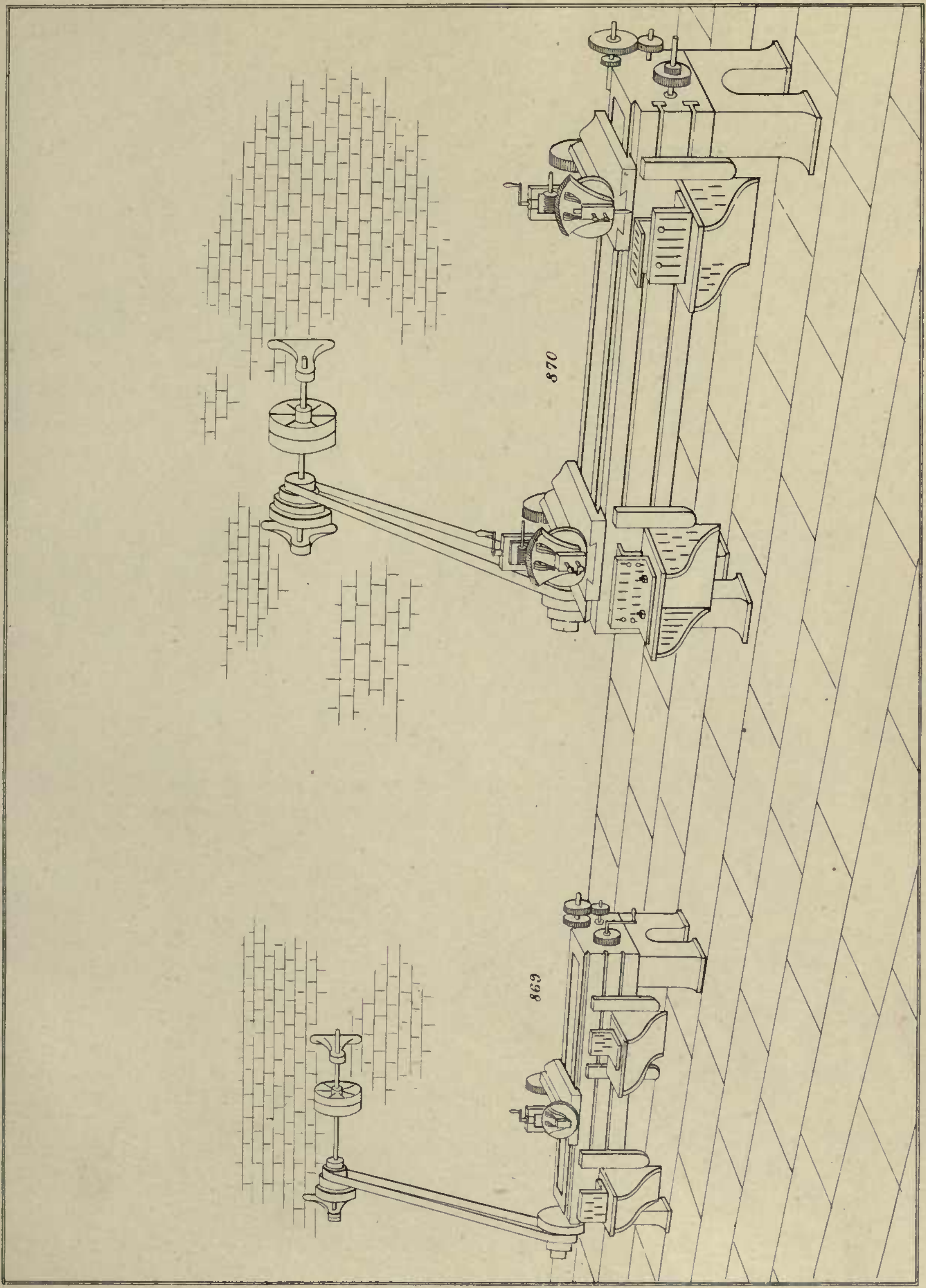
E & F N Spon, 48, Charing Cross, London.



E & F N Spon. 48, Charing Cross, London.



E. & F. N. Spon, 48, Charing Cross, London.



E. & F. N. Spon, 48, Charing Cross, London.

ARBOR CHUCK.

871

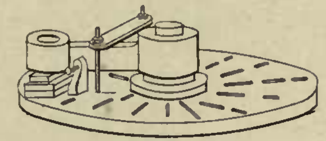
STEPPED ARBOR CHUCK.

872

ARBOR CHUCK.

873

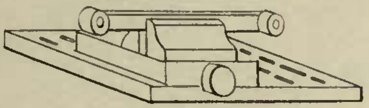
LEVER ON AN ARBOR.



874

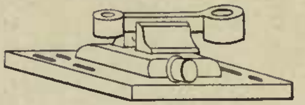
BAR ON SHAPING TABLE.

BAR IN A VICE.



875

LEVER IN A VICE.



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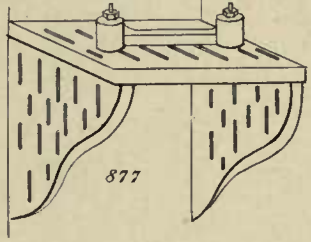
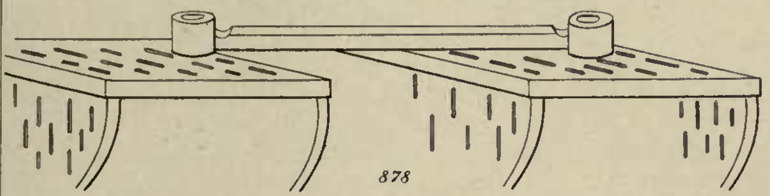


877

CONNECTING-BAR HELD BY AN EL-CHUCK.

BAR ON TWO TABLES.



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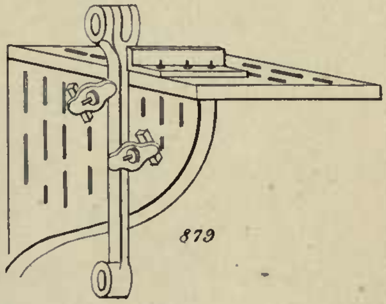
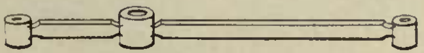


879

BAR TO BE SLOTTED.

LEVER WITH FINISHED JUNCTIONS.



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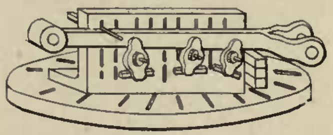
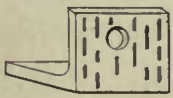


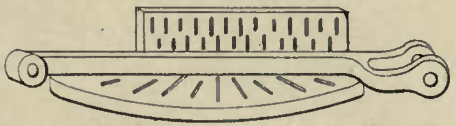
881

EL-CHUCK FOR BOSSES.



882

BAR TO BE SLOTTED.



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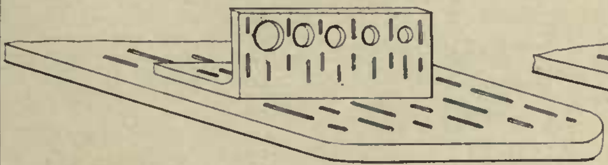
EL-CHUCK FOR GAP-ENDS.

EL-CHUCK FOR BOSSES.



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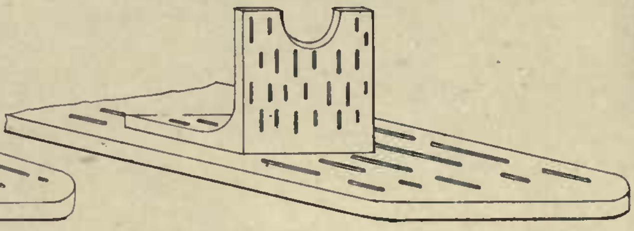

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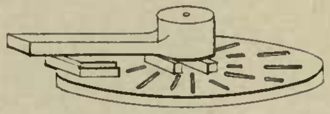
E. & F. N. Spon, 48, Charing Cross London

BOSS ON PARALLEL BLOCKS.

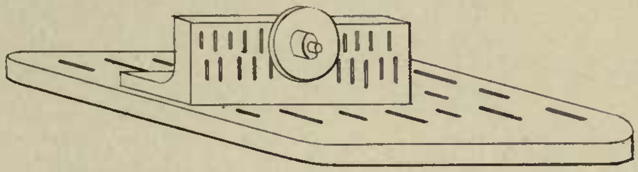


886

BOSS ON A PARALLEL RING.

887

WHEEL ON AN ARBOR-CHUCK.

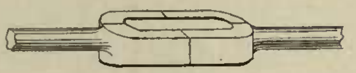


888

ARBOR CHUCK ON AN EL-CHUCK.

889

MIDDLE BOSS.



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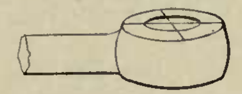
END-BOSS.



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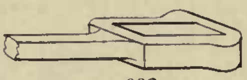
END-BOSS.



892

BROAD SIDE OF BOSS.

892

NARROW SIDE OF BOSS.

894

BROAD SIDE OF BOSS.

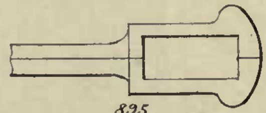


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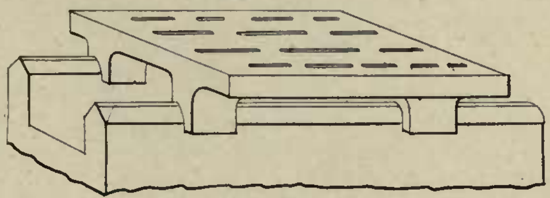
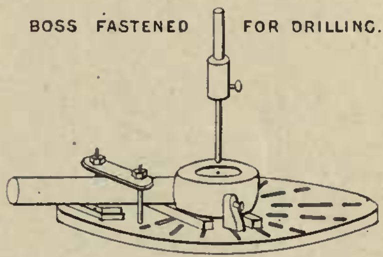
TABLE.



896

BOSS FASTENED FOR DRILLING.



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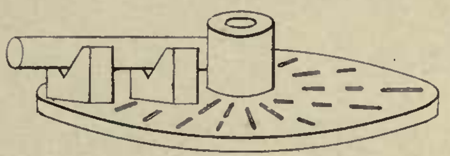
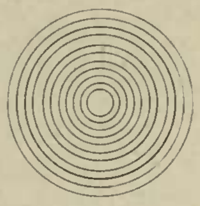
BOSS FOR ROTATION ON VEE-BLOCKS.



898

E. & F. N. Spon, 48, Charing Cross. London.

CONCENTRIC LINES ON A TABLE.



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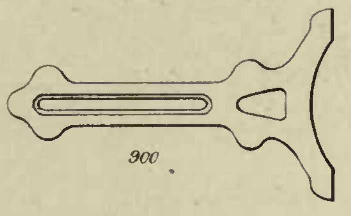
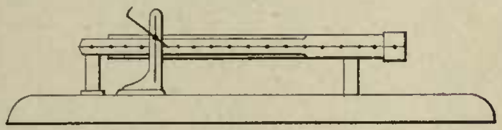
GUIDE'S BROAD SIDE.



900

LINING A NARROW SIDE OF GUIDE.



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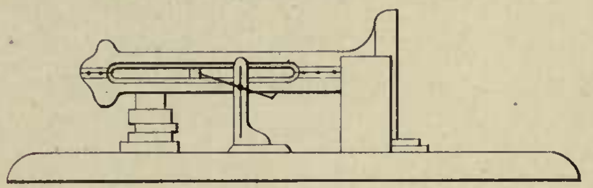
LINING A BROAD SIDE OF GUIDE.



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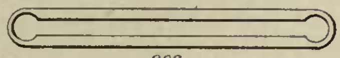
CLEARANCE SPACES OF A GUIDE-SLOT.



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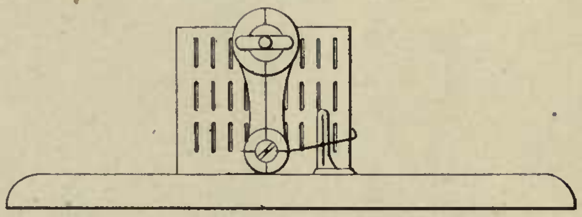
LINING A BOSS FOR A KEY-SLOT.



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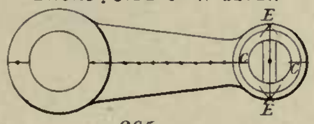
BROAD SIDE OF A LEVER.



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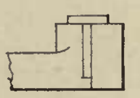

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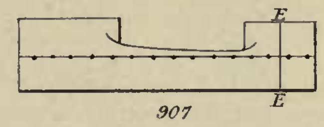
NARROW SIDE OF LEVER.



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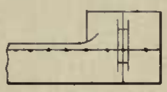
LINES FOR KEY-SLOT.



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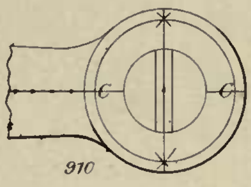

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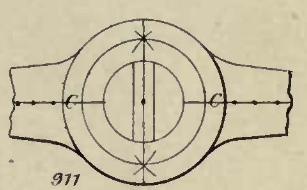

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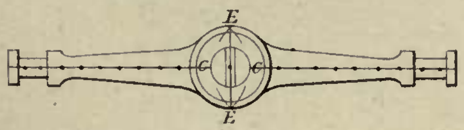
NARROW SIDE OF CROSSHEAD.



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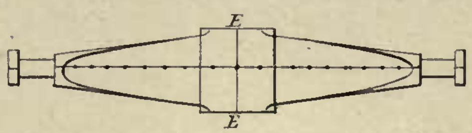
BROAD SIDE OF CROSSHEAD.



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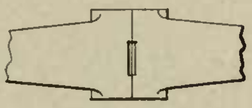
E & F N Spon, 48, Charing Cross, London.

LINES FOR KEY-SLOT.



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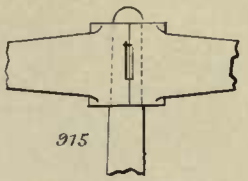
BOSS & ROD'S END.



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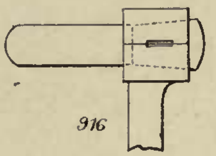
BOSS & CRANK-PIN.



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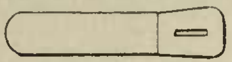
LINES FOR KEY-SLOT.



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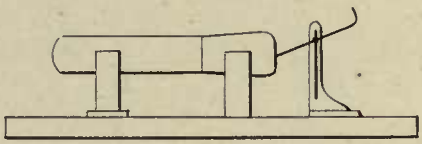
PIN ON VEE-BLOCKS.



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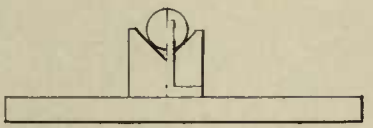

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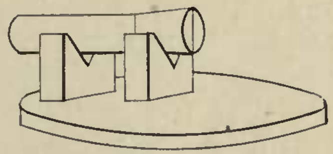

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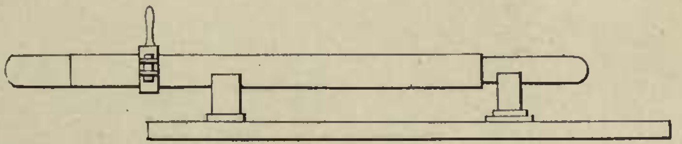
ROD WITH ROTATOR.



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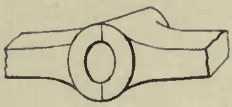

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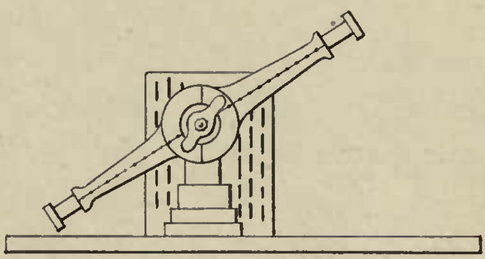

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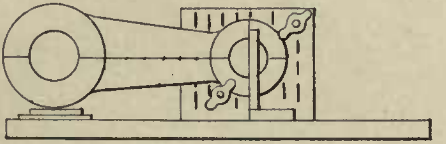

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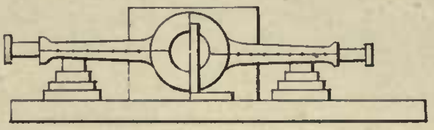

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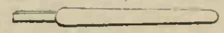
E & F. N. Spon, 48, Charing Cross London.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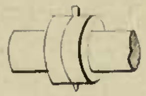
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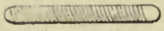
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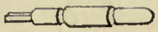
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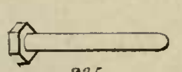
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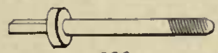
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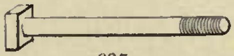
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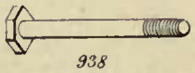
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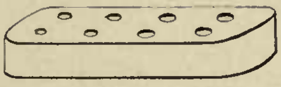
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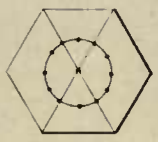
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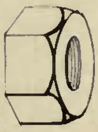
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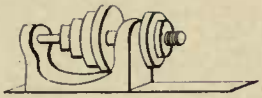
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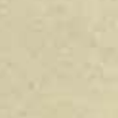
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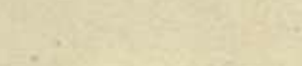
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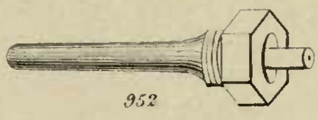
E & F N Spon. 48, Charing Cross, London.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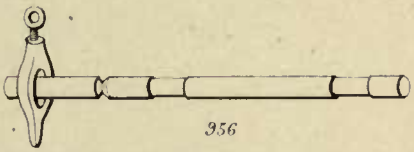
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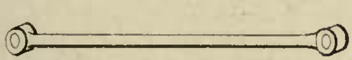
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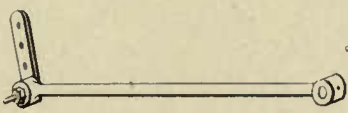
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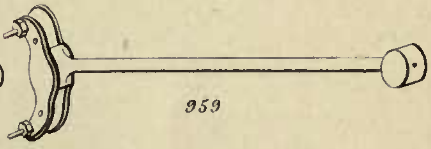
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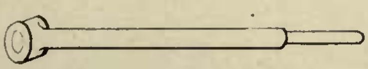
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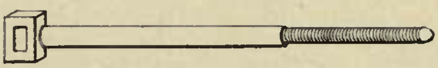
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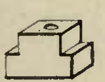
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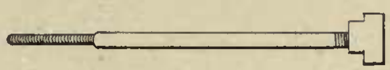
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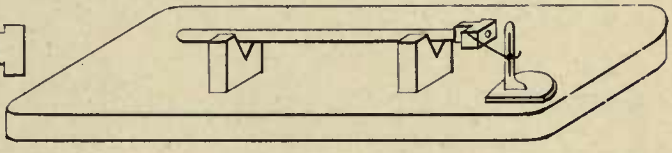
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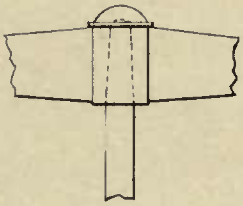
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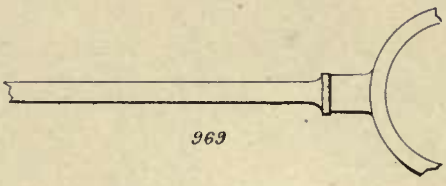
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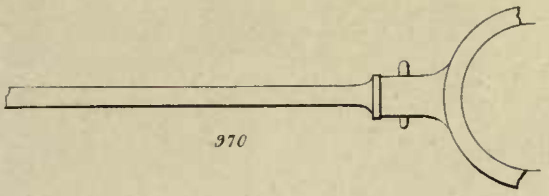

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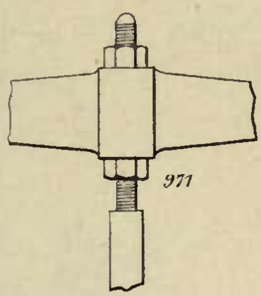

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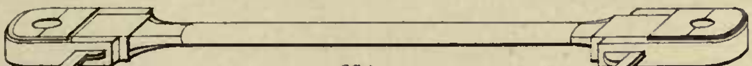

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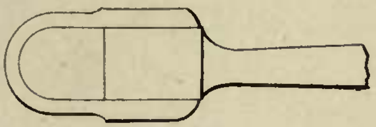

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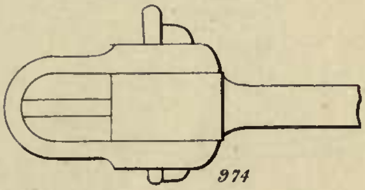

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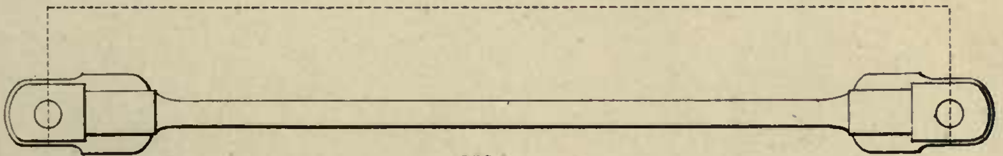

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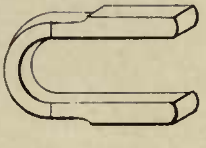

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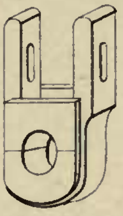

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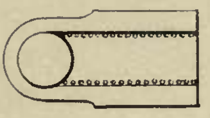

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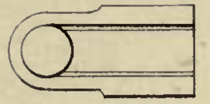

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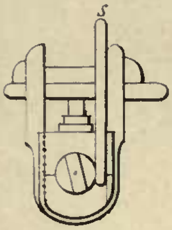

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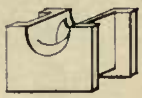

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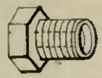
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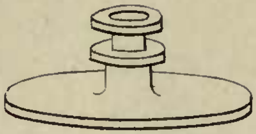
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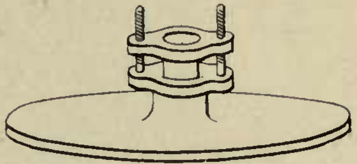
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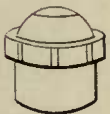
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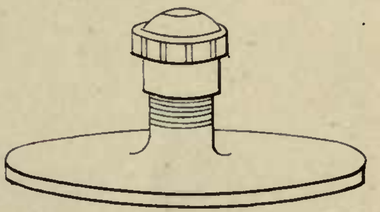
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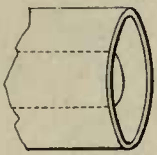
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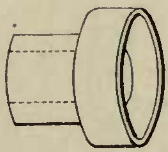
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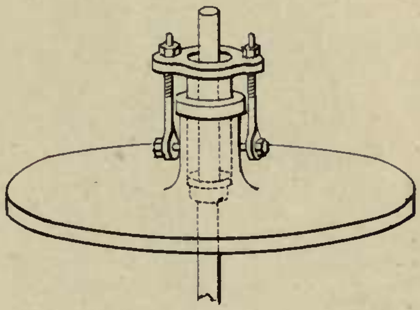
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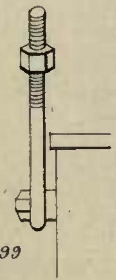
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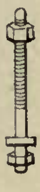
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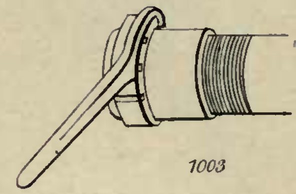
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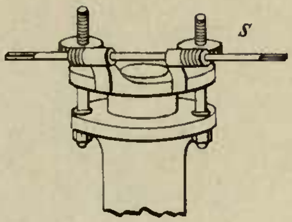
E & F N Spon, 48, Charing Cross, London.



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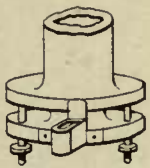

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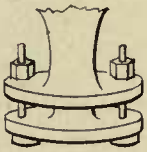

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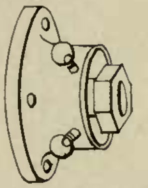

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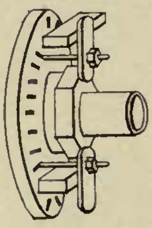

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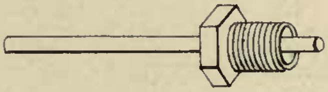

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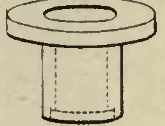

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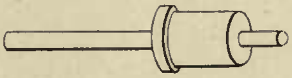

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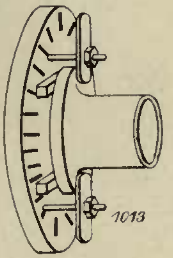

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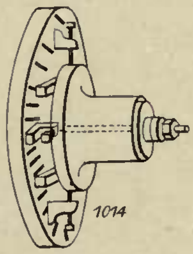

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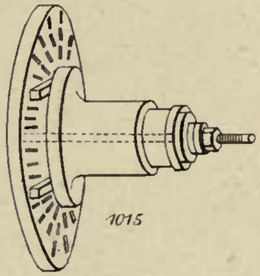

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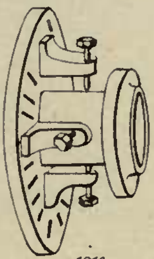

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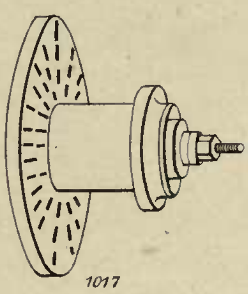

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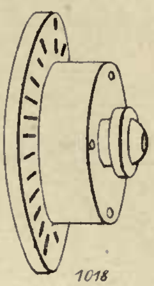

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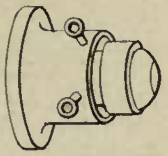

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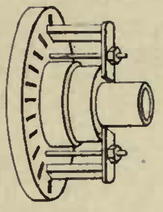

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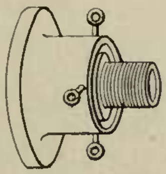

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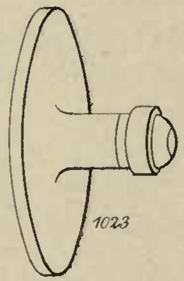

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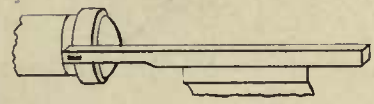

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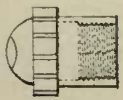

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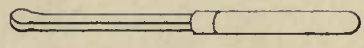

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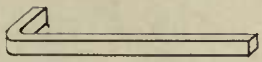

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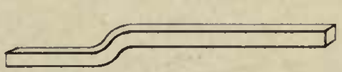

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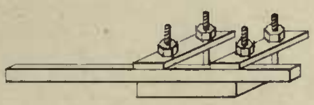

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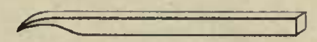

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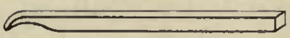

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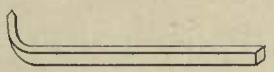

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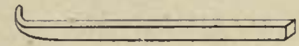

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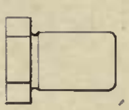

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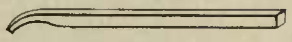

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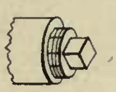

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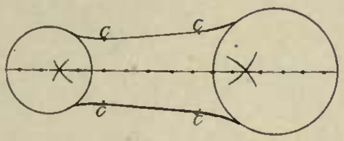

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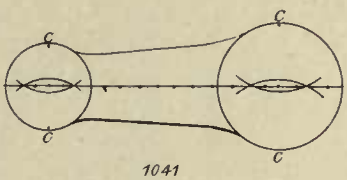

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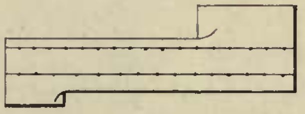

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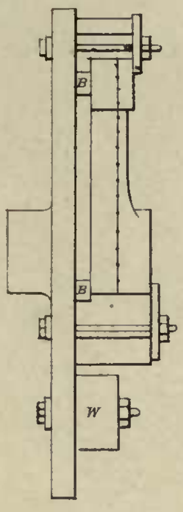

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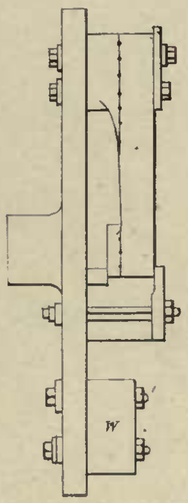

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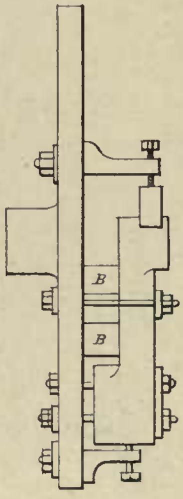

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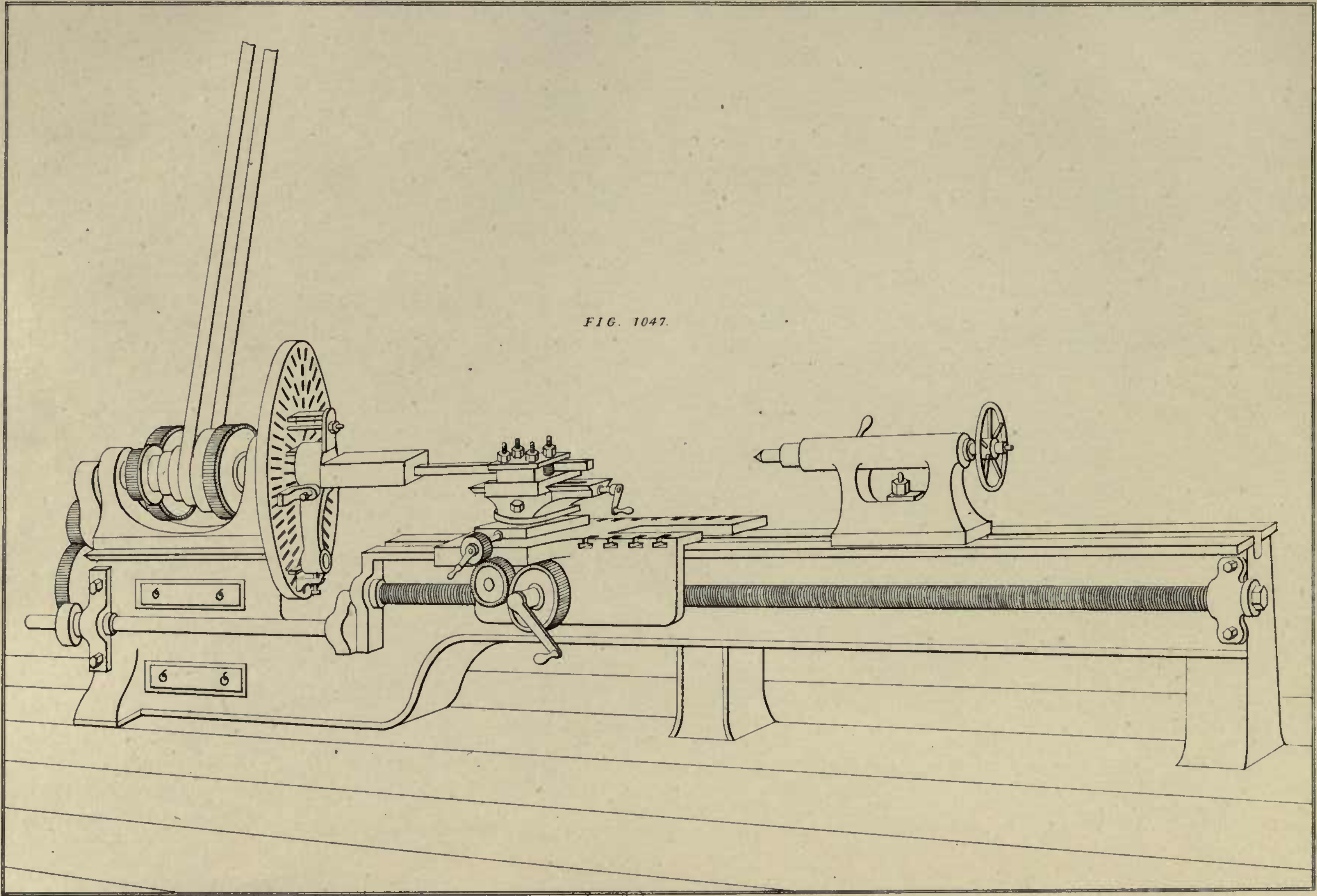
FIG. 1047.



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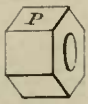
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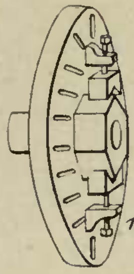
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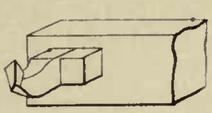
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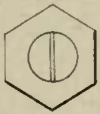
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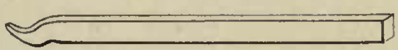
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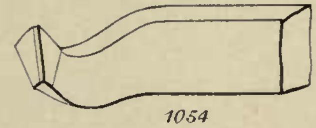
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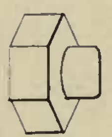
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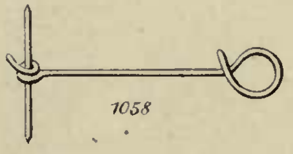
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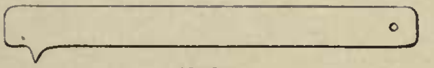
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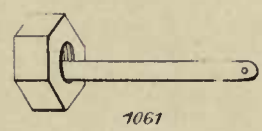
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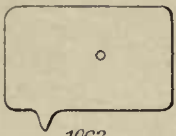
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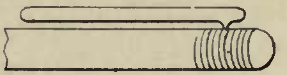
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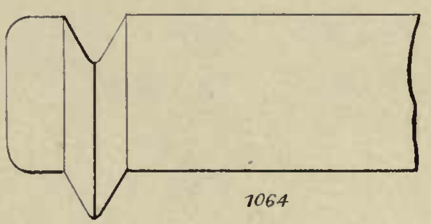
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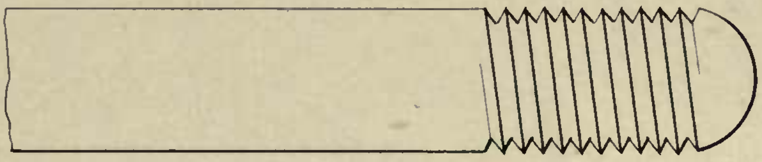
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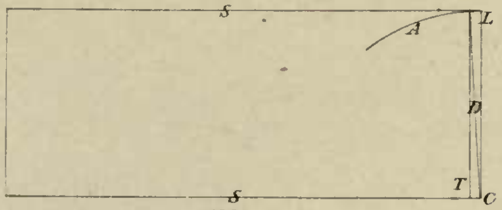

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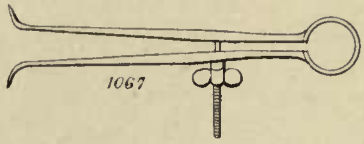
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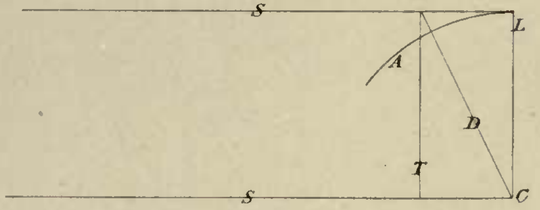

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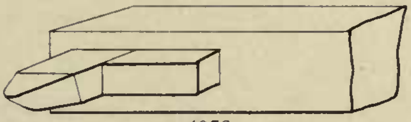
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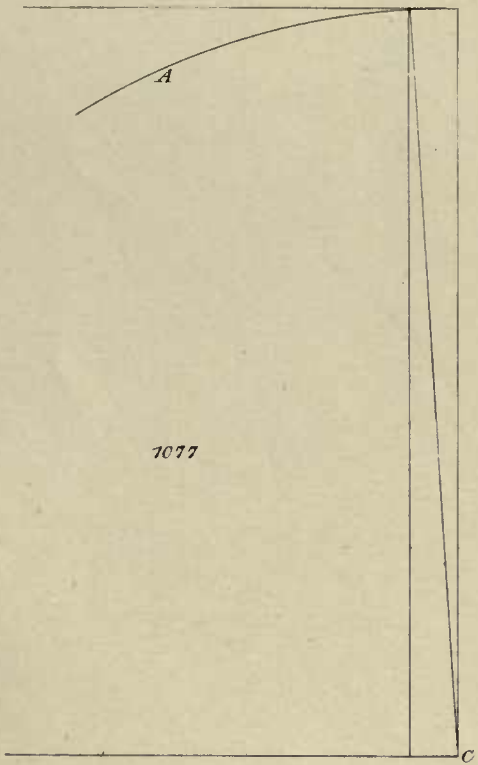

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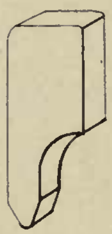
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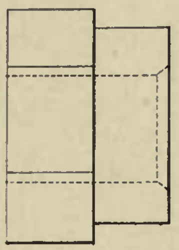
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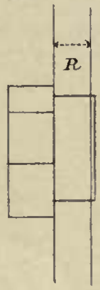

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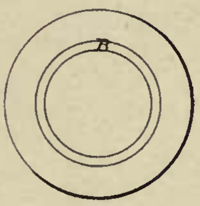

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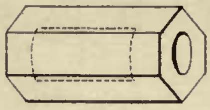
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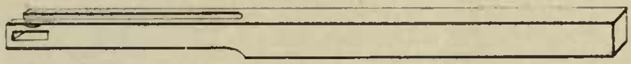

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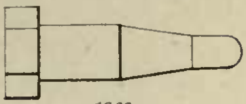

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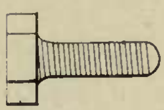

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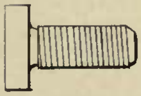

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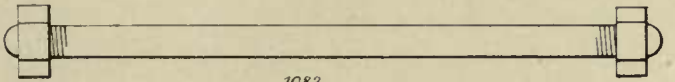

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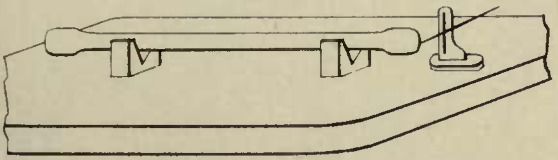

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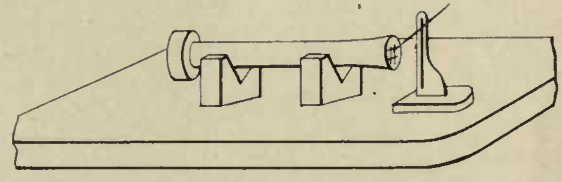

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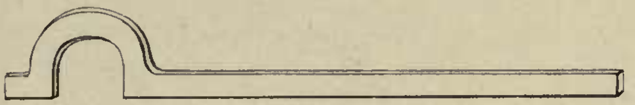

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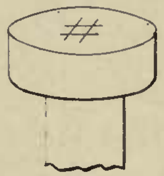

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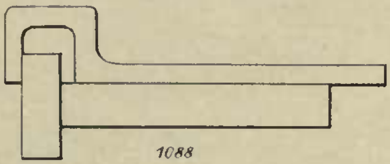

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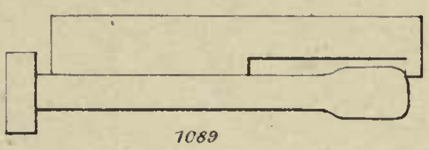

1089

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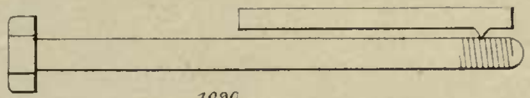

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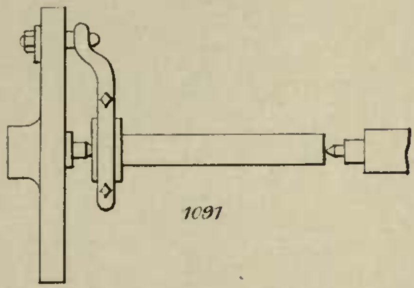

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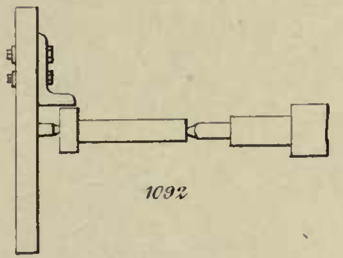

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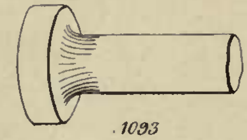

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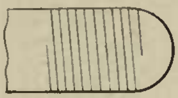

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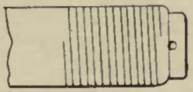

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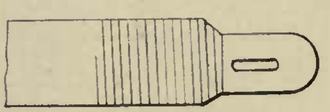

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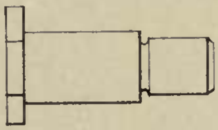

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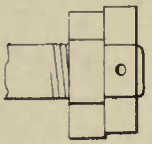

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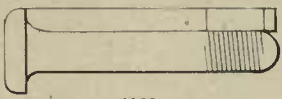

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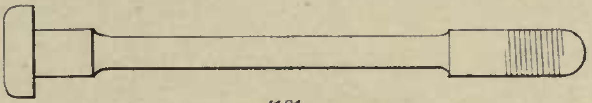

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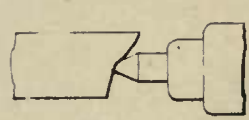

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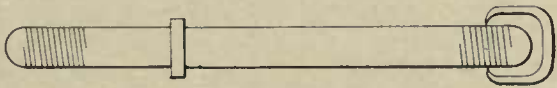

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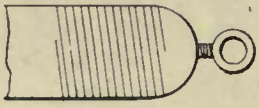

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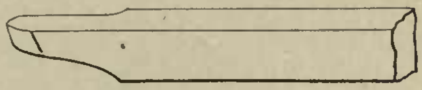
E & F N Spon 48, Charing Cross, London



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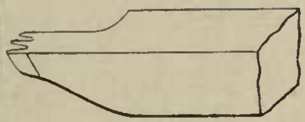

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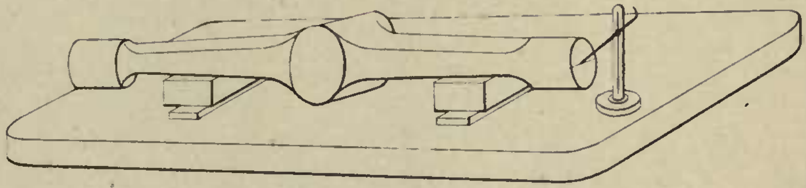

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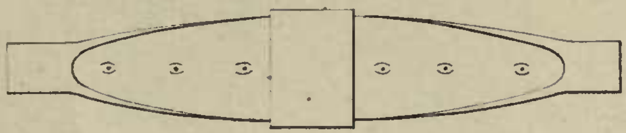

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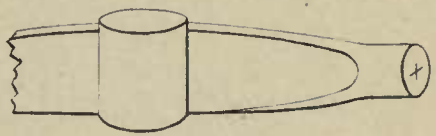

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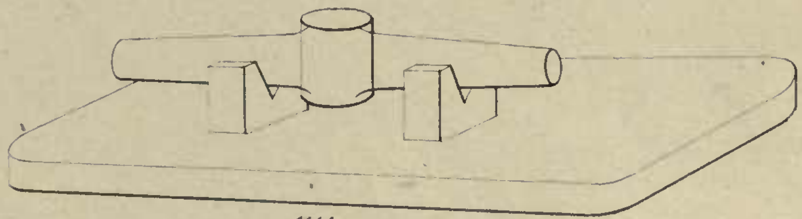
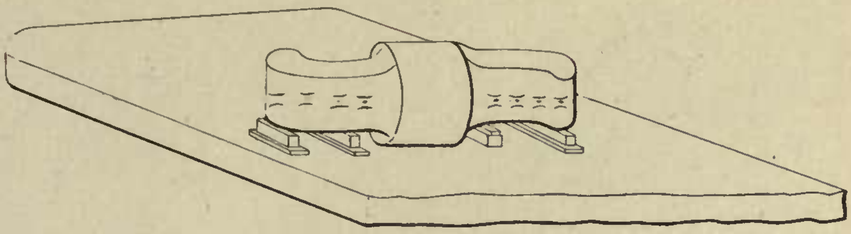


1114

E & F N Spon 48 Charing Cross London



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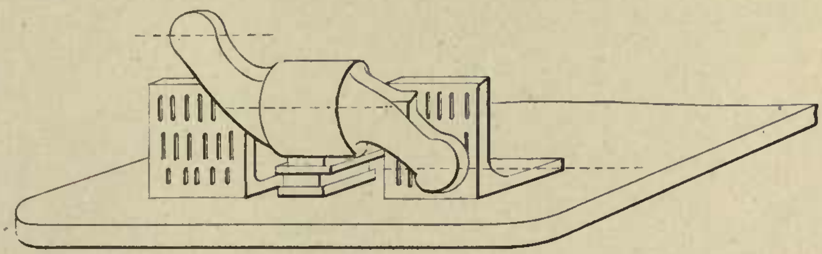

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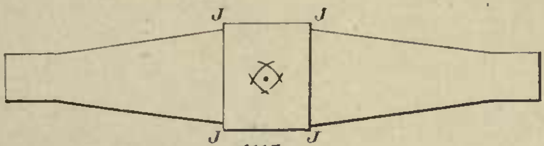

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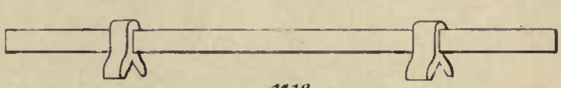

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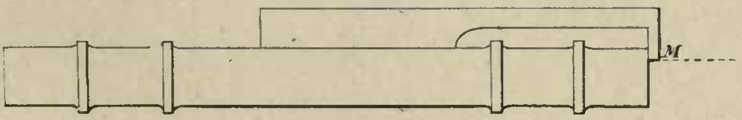

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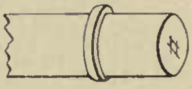

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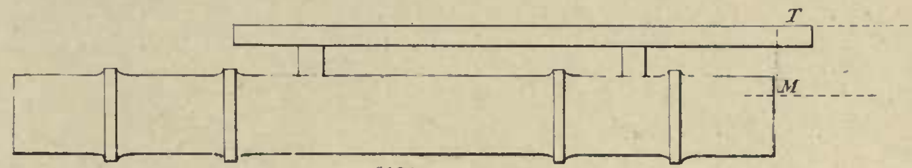

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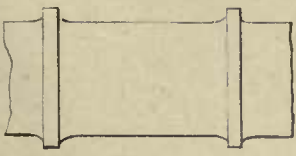

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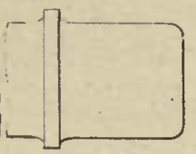

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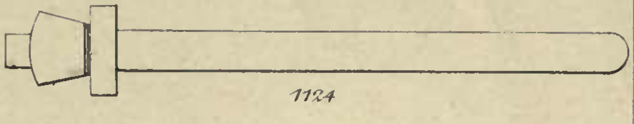


1124

E. & F. N. Spon, 48, Charing Cross, London.

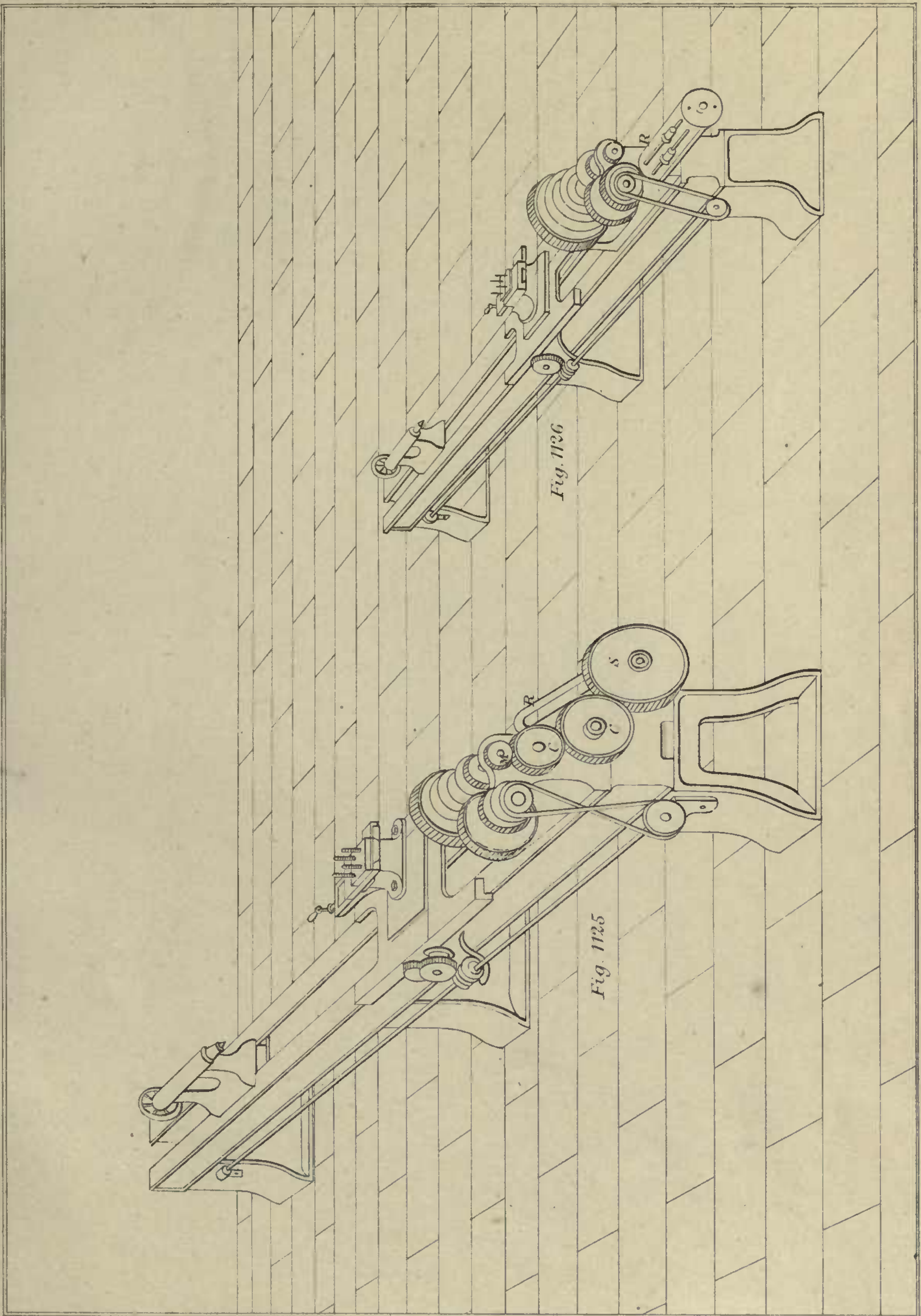


Fig. 1126

Fig. 1125

E. & F. N. Spon, 48, Charing Cross, London.

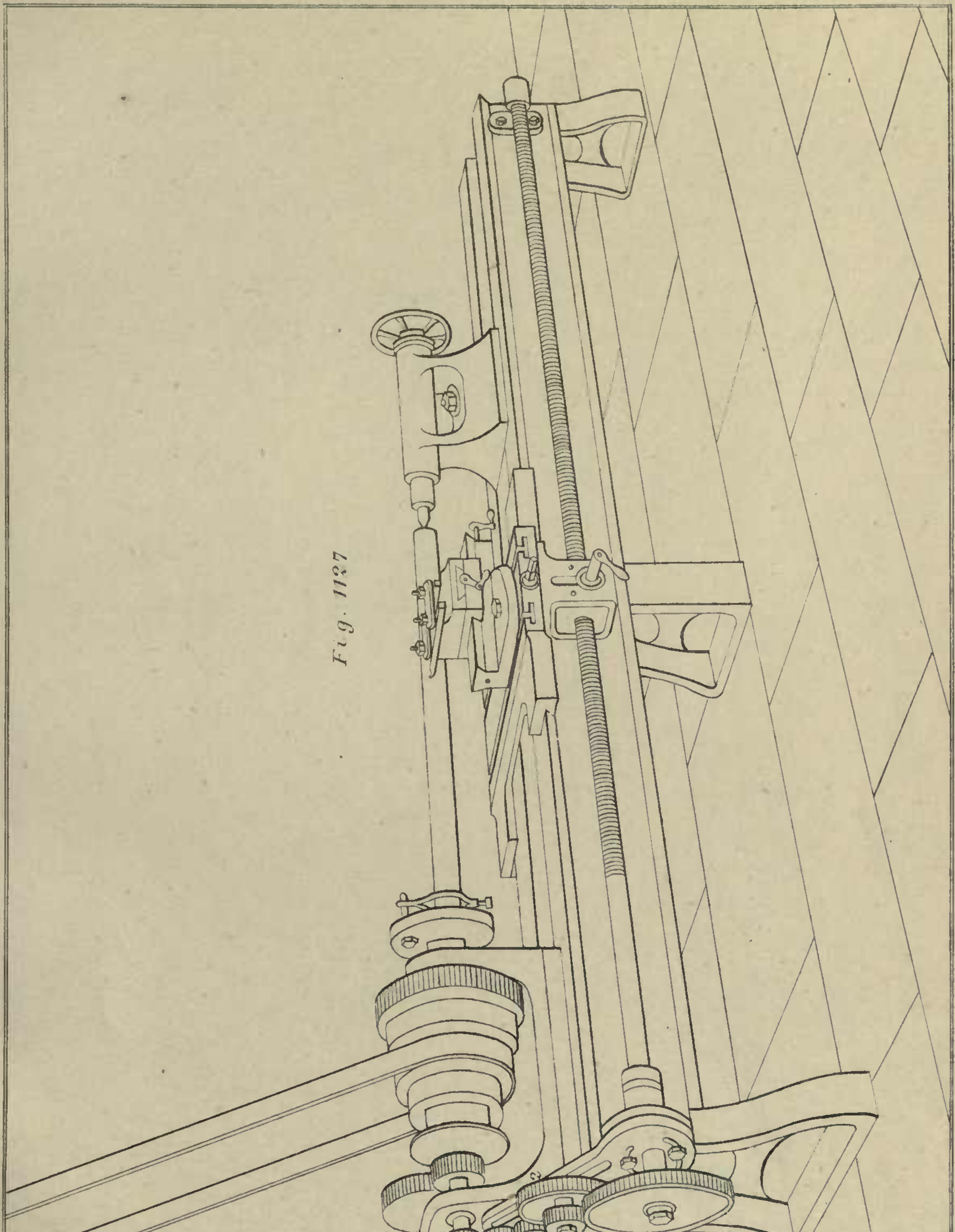
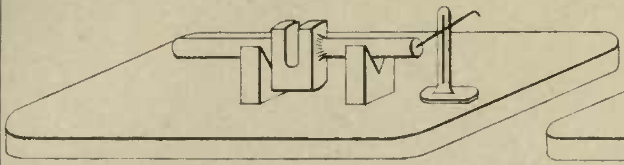


Fig. 1127

E & F. N Spon, 48, Charing Cross London



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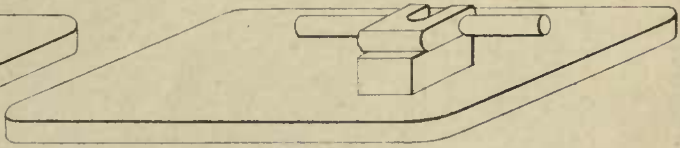

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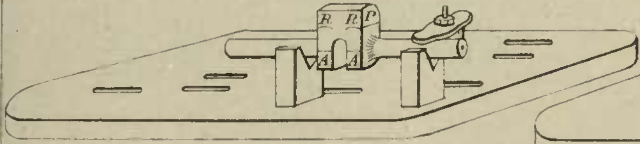

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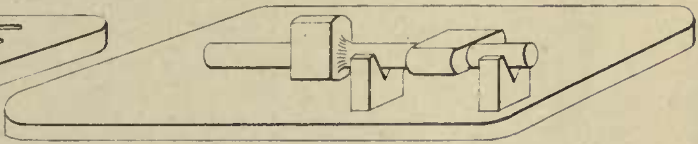

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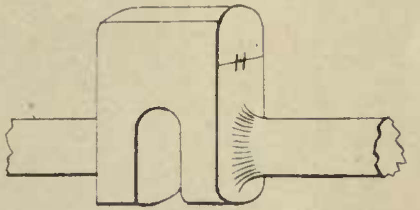

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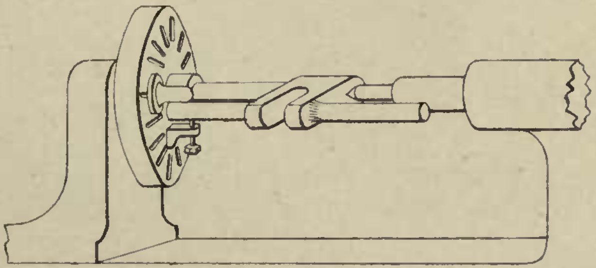

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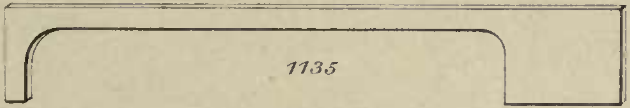

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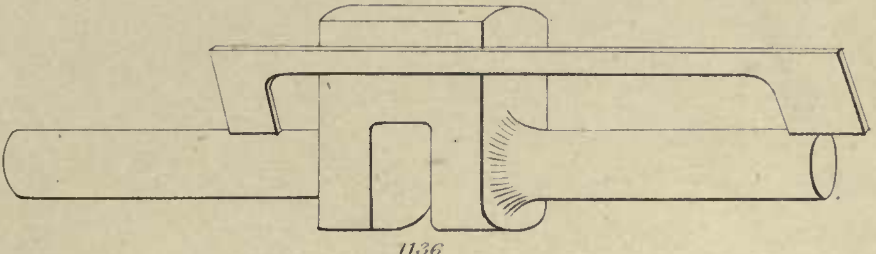
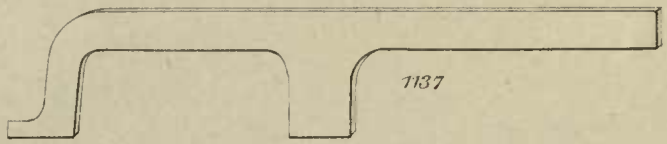


1136

E & F N Spon, 48, Charing Cross London



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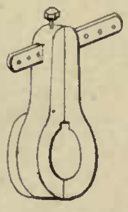

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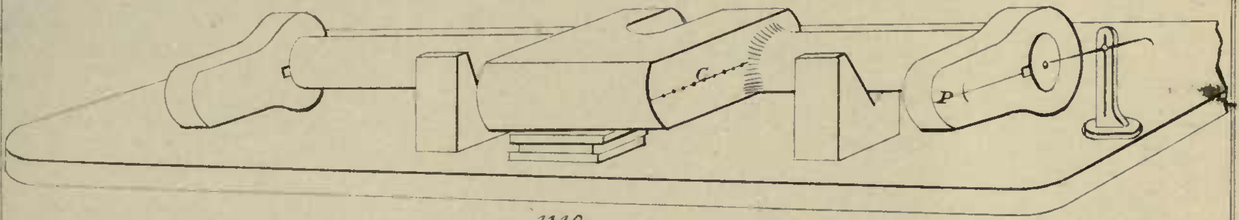

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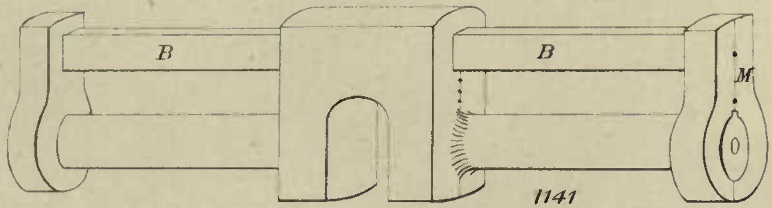

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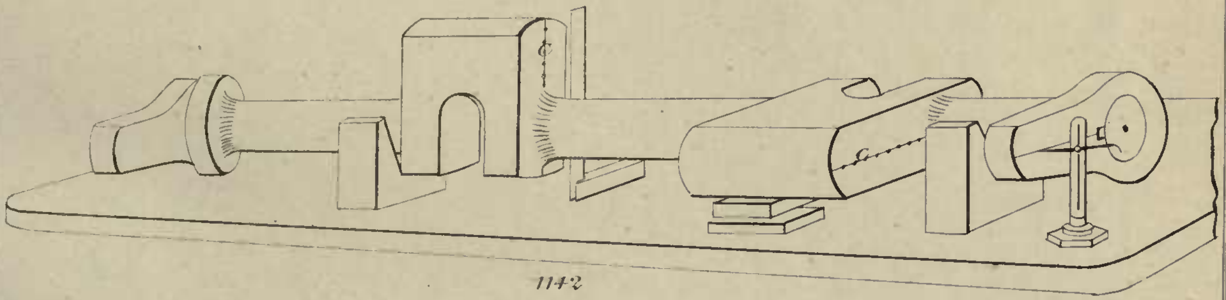

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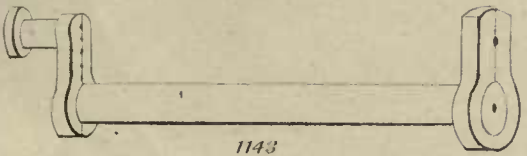

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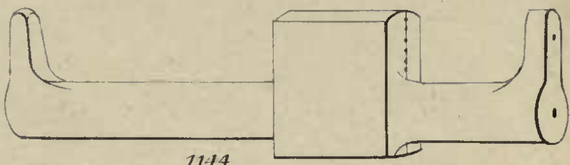

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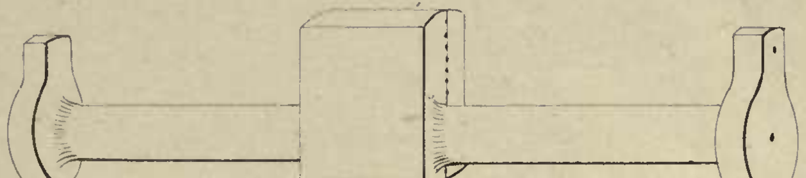

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E. & F. N. Spon. 48, Charing Cross London.

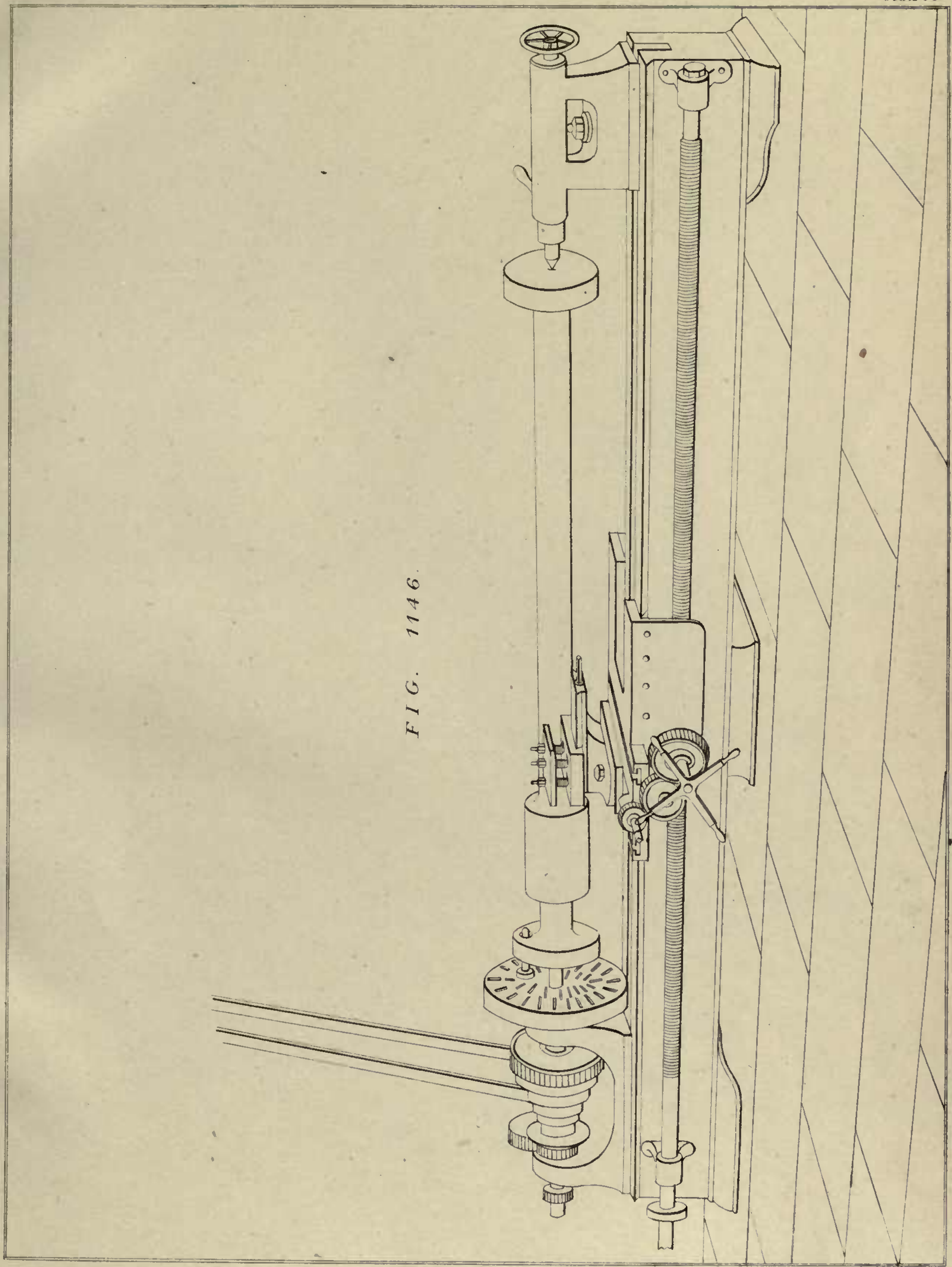

FIG. 1146.

E. & F. N. Spon, 48, Charing Cross, London

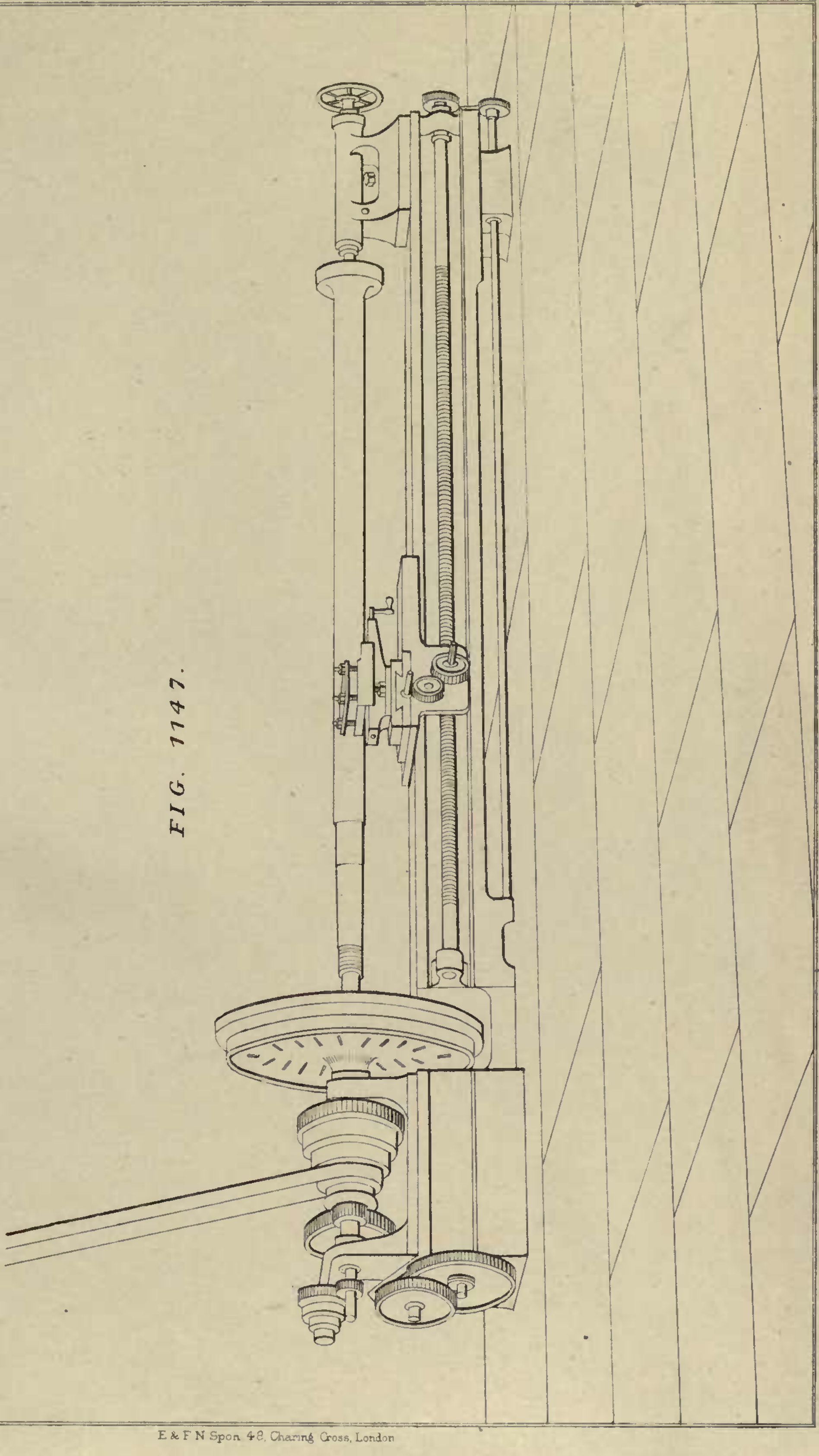

FIG. 1147.

E & F N Spon. 48, Charing Cross, London