Fig. 272 shows a tool upon the dividing line between the slotters and the milling-machines. It is for cutting key-seats and similar work. The cutter reciprocates with a quick-return motion from the crank and slotted lever.

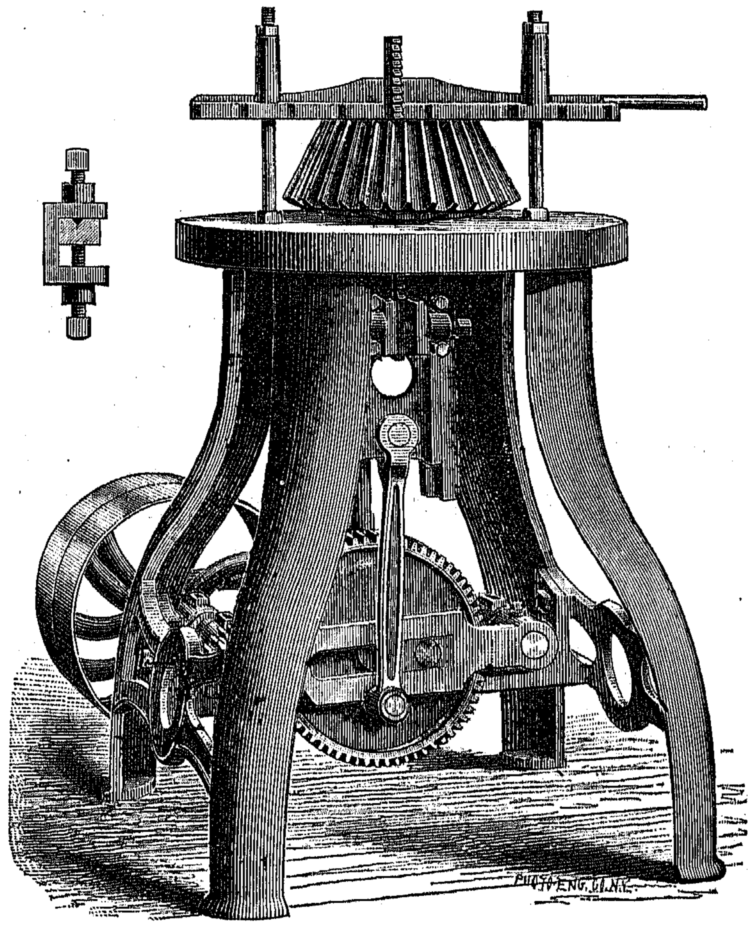

Fig. 272.

The cutting is done by the teeth on the point of a bar which resembles a developed milling-cutter. It can, of course, pass through a hole of quite small diameter.

§ 30.

D.—MILLING-MACHINES.

The term milling-machine may be applied generally to all metal-working tools operating with serrated rotary cutters. Where the cutter is very thin, the machine becomes a metal saw; where especially adapted for one operation, it is often known by a special name; but it still retains enough fundamental features to justify its classification with the typical machine.

The use of the milling-machine is attended with certain conspicuous advantages. These are the result of the revolving cutter, and the resulting elimination of spring in the tool. A great saving of time results from the continuous action of the cutters. There is no return or inactive stroke as in the reciprocating tools. The cutting-edges are very near to their points of support. Therefore exactness of dimensions may be insured and uniformity in duplication of irregular shapes. Again, the cutting-edges of the rotary cutter compel an outline of the work whose form accords with that of the cutter. Hence, if a pattern of cutter be fixed upon by a skilled mechanic, the reproduction of duplicate forms can be intrusted to a less skilled operative. Provided only the cutters are maintained in shape, and the work is properly chucked, the machine can be worked to stop-gauges without the repeated application of standards. For these reasons, the milling-machine in its various forms has become an essential in the manufacture of exact machinery. Operators become easily accustomed to working to a thousandth of an inch, and for fire-arm, electric, and sewing-machine work they have revolutionized the practice of earlier days.

One of the earliest forms of milling-machine for gun-work is illustrated by Figs. 273 and 274. In both the machines shown great improvements have been made over the original machine as made many years ago. The driving-spindle rises and falls in the uprights, controlled either by two screws geared (Fig. 273) or by one screw, equalized between the two boxes by a cross-head and stiff plungers (Fig. 274). Lost motion is prevented by the

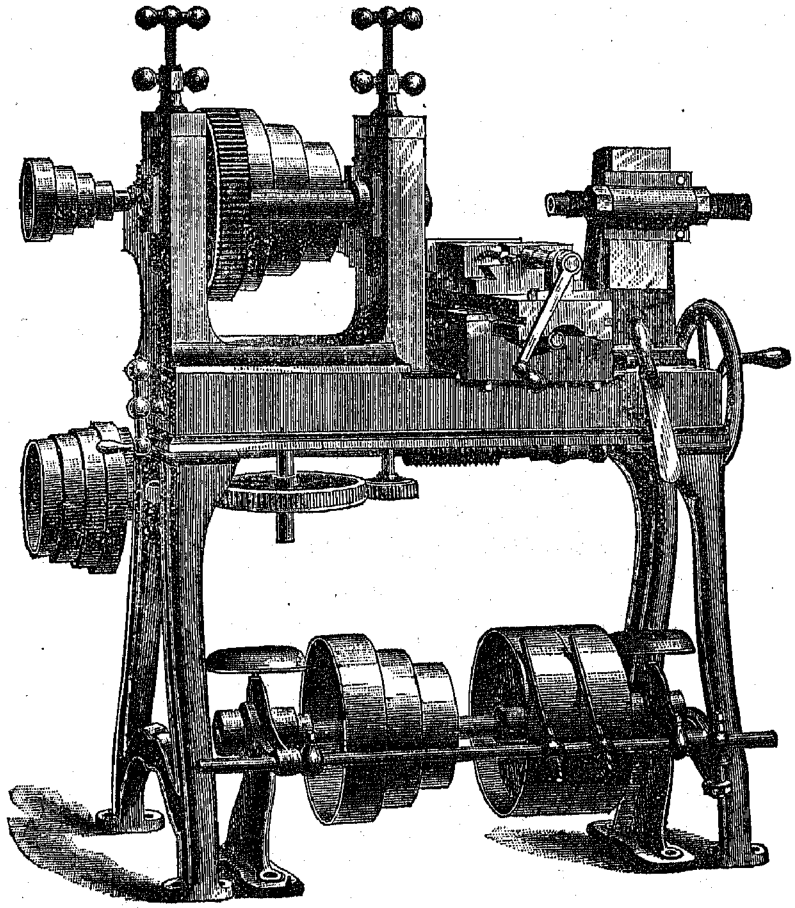

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Fig. 273.

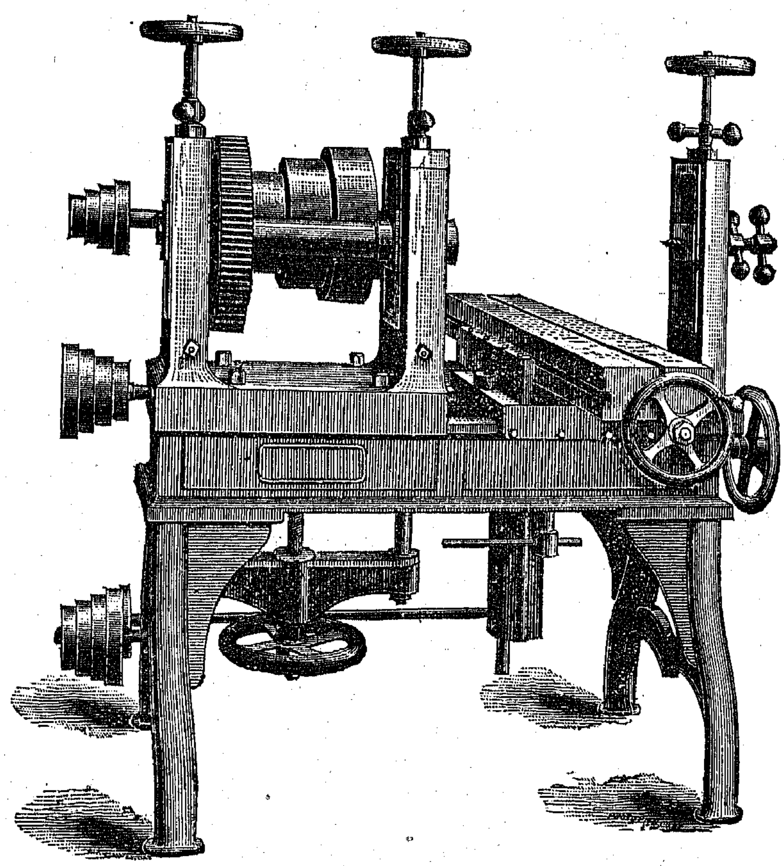

Fig. 274

jam-nuts on the top screws. The cutters are held on a mandrel, which fits into the end of the spindle, the outer end being borne by an adjustable center. This has a motion independent of that of the spindle, for convenience of taper work. The spindle is geared to a pulley-shaft, the latter shaft being adjustable laterally for various elevations of the spindle. There will be three or four grades on the cone-pulley. The piece to be operated upon is clamped in a vise or chucked to a table, which may have two motions. The motion along the axis of the cutter-mandrel is quite short, and is usually by hand only, for adjustment. The motion at right angles to this line and against the cutters is much longer and is automatic. A worm-shaft is driven by small cone-pulleys, and turns a worm-wheel,

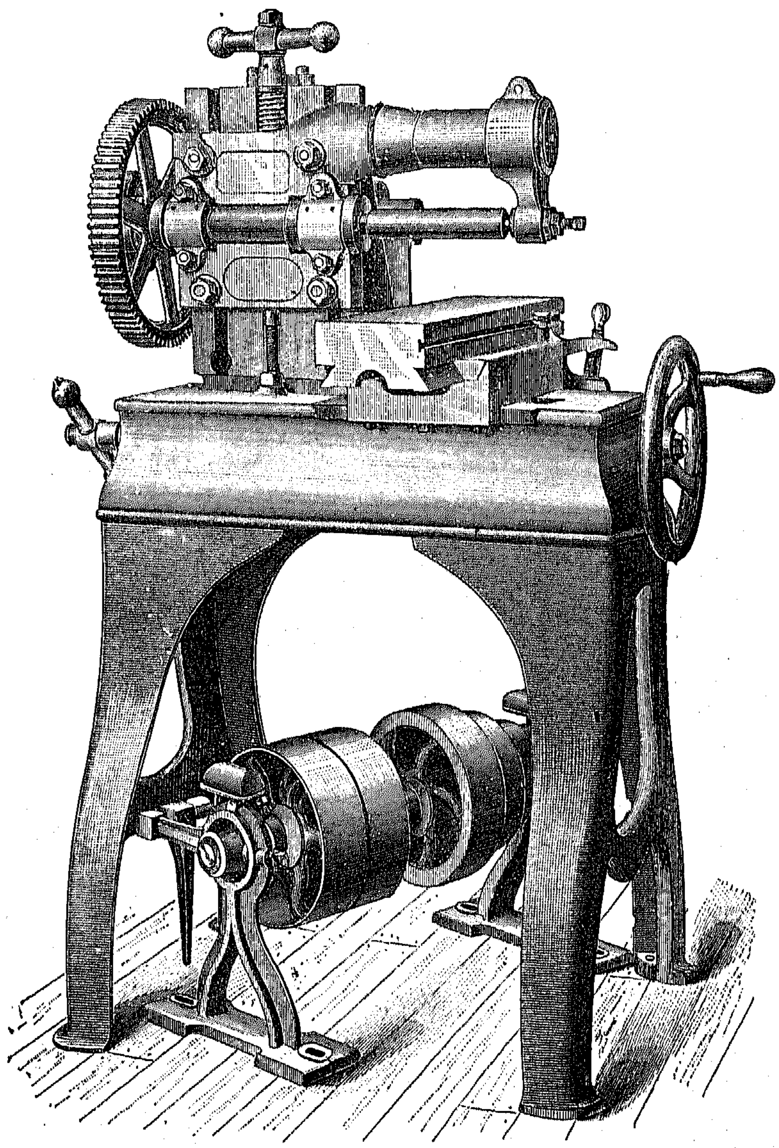

Fig. 275.

which meshes into a gear on the cross-feed screw. The worm-shaft is carried on a swivel-bearing at the head-stock, and the further bearing is connected to a pivoted lever. When this lever is latched up the worm turns the wheel. The release of the latch, either by an automatic stop or by hand, permits the worm to drop out of gear with the wheel, and stops the feed. The worm is made long so as to operate wherever the table may be in its longitudinal traverse.

Fig. 275 shows the construction of a machine, which is in some respects an improvement on the earlier forms. The spindle is held on a flat plate sliding in slots to which it may be clamped by bolts. It is adjusted by one large screw, and has a stop-screw below. The pulley-spindle swings on a yoke and is linked to the main spindle, rendering the lateral adjustment of its bearings automatic. The heavy slide insures parallelism of the main spindle at all times, which the unequal wear of the gears and screws of the earlier form was liable to vitiate. The feed-motions of the table are as before. Instead of a back-carrier stand, adjustable for mandrels of different lengths, an outside center support is attachable on an arm from the carrier. These will all move together and can be adjusted while the machine is in motion. A similar design is shown by Fig. 276. Milling-machines of this type are known as

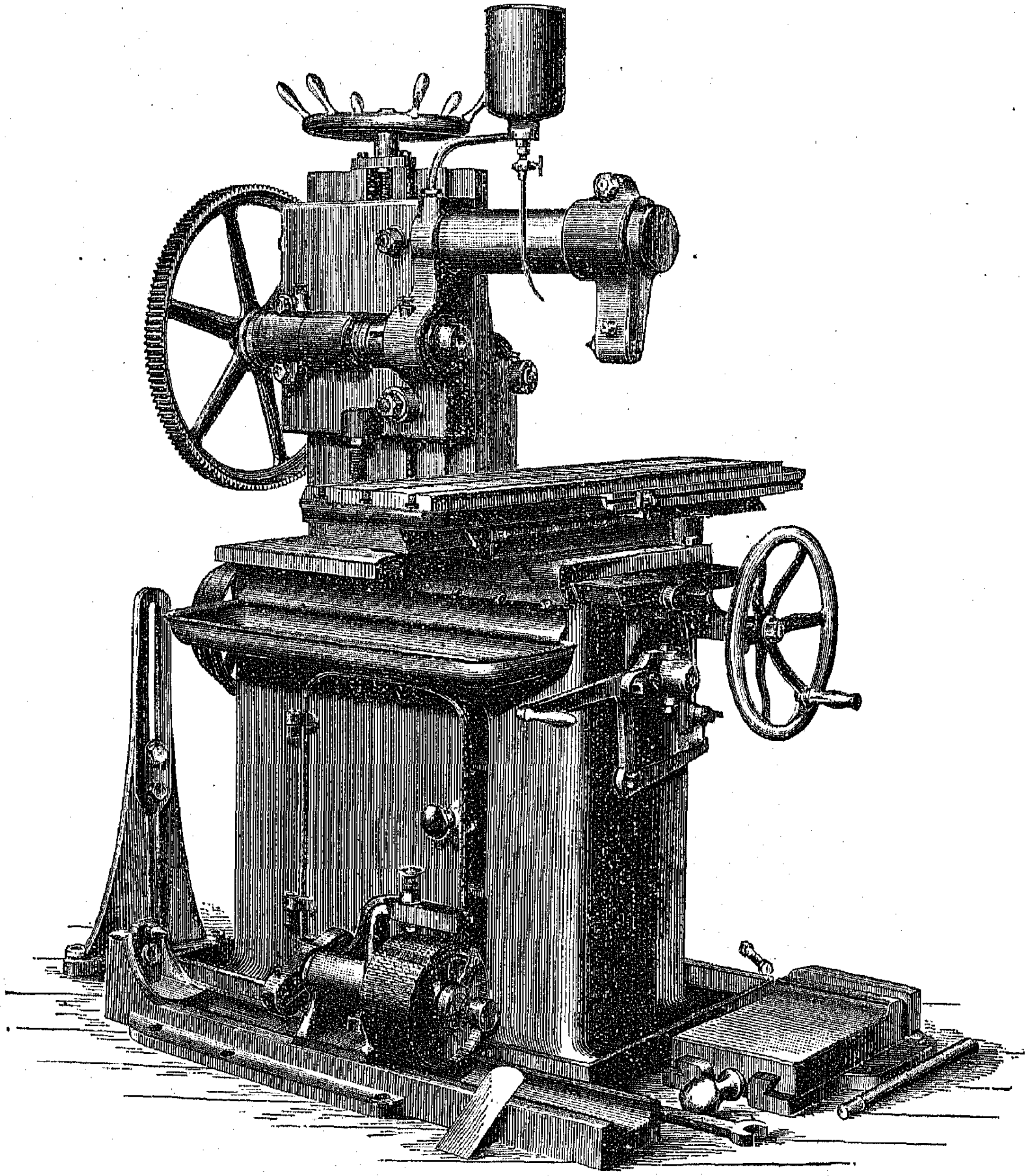

Fig. 276.

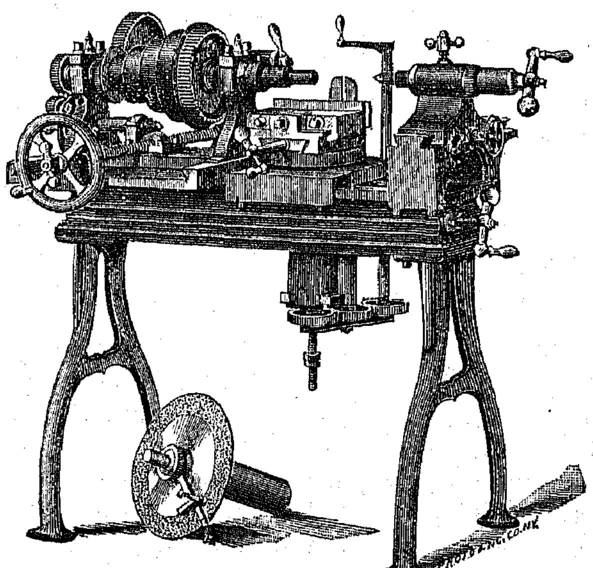

Fig. 277.

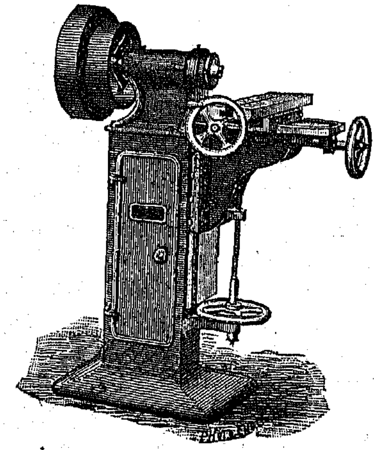

Fig. 278.

D.—MILLING-MACHINES.

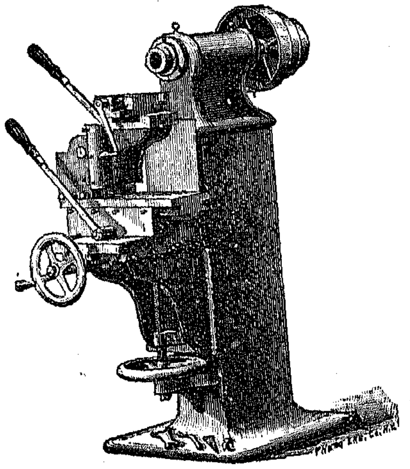

Fig. 279.

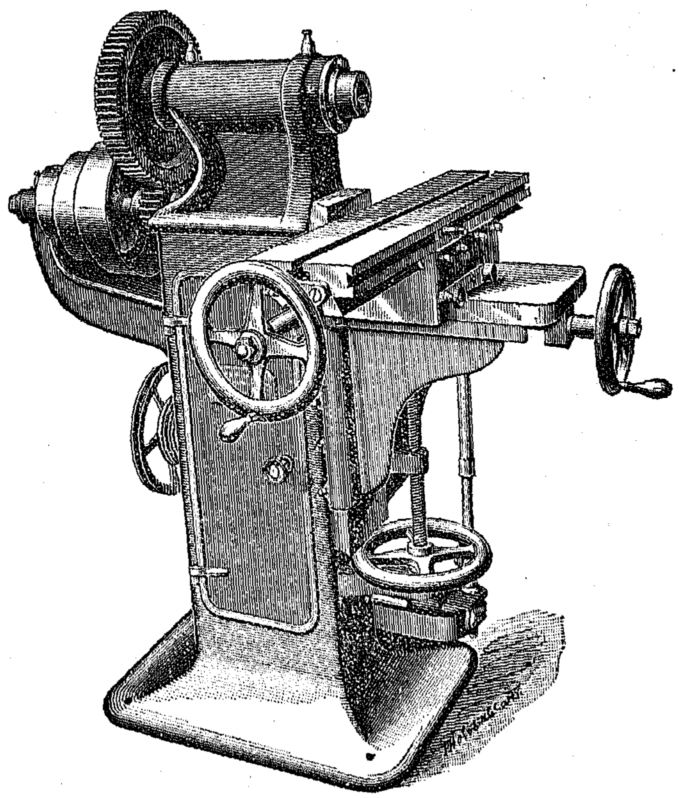

Fig. 280.

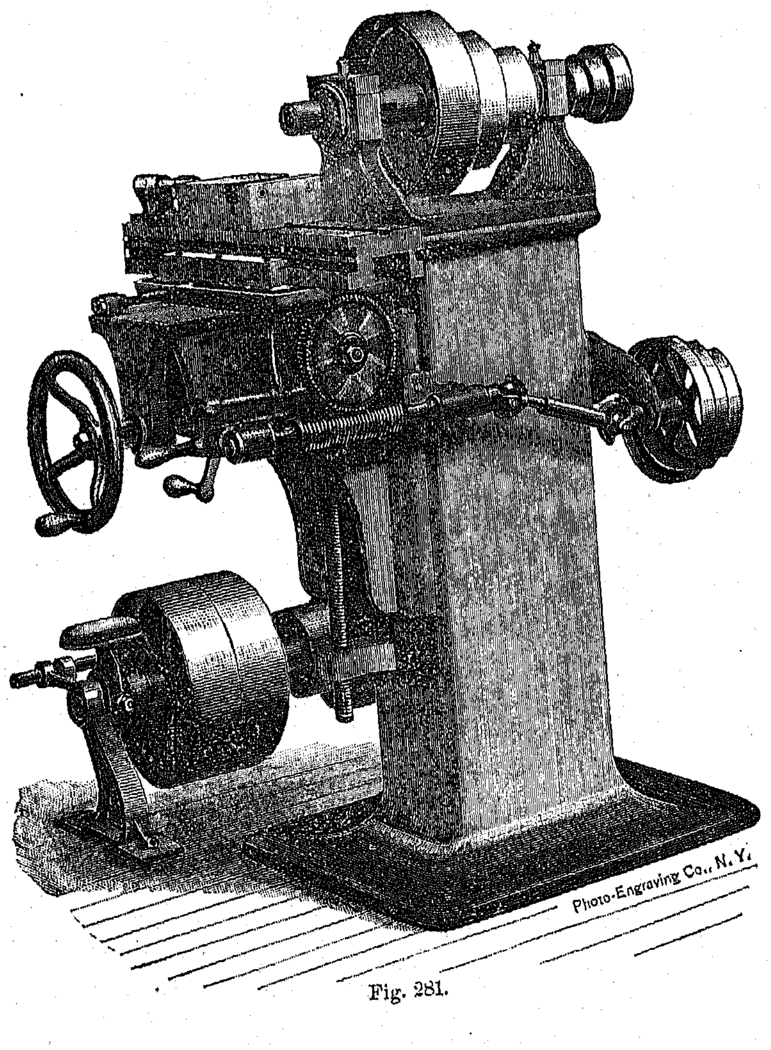

Fig. 281.

"plain" milling-machines. A milling-machine of a slightly different construction, but similar in principle, is shown by *Fig.* 277. The vise receives the vertical feed, and both the main and tail spindles have set-over motions. The tool illustrates the application of the lathe principle to milling purposes.

The second form of milling-machine is what is known as the "standard" machine. The working parts are borne upon a column or standard, which in many designs makes a convenient tool-closet for the attachments.

Figs. 278 and 279 illustrate types of the hand-machines. The spindle is driven directly by belt and the knee-table gives a vertical adjustment while the back-and-forth and right-and-left motions are given to the compound table. These are adapted for work with small cutters only, which turn at high speed, and the feeds are by screw or by rack and pinion by the levers.

Fig. 280 illustrates a larger design of standard miller with power-feed across the front. The screw on the hand-wheel shaft is turned by bevel-gear from the vertical telescopic shaft in front, which is driven from a worm-shaft at the base of the tool, as shown by Fig. 284.

Fig. 281 shows another way of producing the feed-motion by a long worm which may be disengaged by hand-lever in front. To compensate for rise and fall, the cone-pulleys are connected to the worm by two universal joints and a telescopic shaft. The double joint also prevents the irregularity of feed from being as noticeable as it would be with but one. There is an automatic stop-motion for the feed, adjustable to any position. There is also a stop by jam-nuts upon the in-and-out hand traverse.

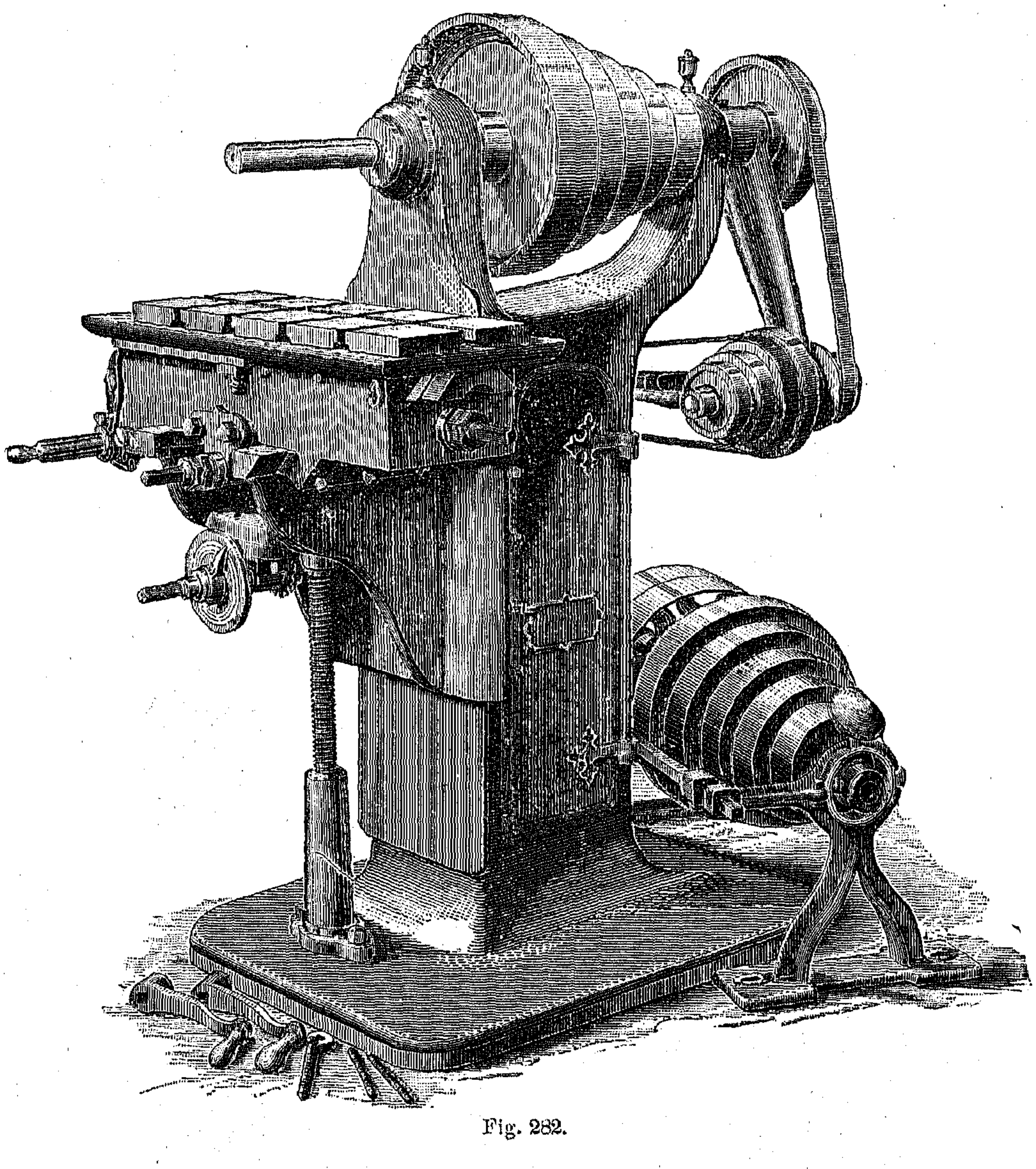

Fig. 282.

Fig. 282 shows the feed-worm driven by belts through a floating cone-pulley shaft. The stiff link swings around the box of the spindle, and an extensible link swings round the worm-shaft. The worm-shaft can thus be more accurately fitted to the adjustable table, and the tension of the driving-belt may be varied at will. The extensible link is forked and bears at both ends of the arbor. The spring latch at the left is acted upon by the adjustable stop under the oil-pan in front. The elevating-screw is turned by bevel-gear and is fitted with a graduated circle

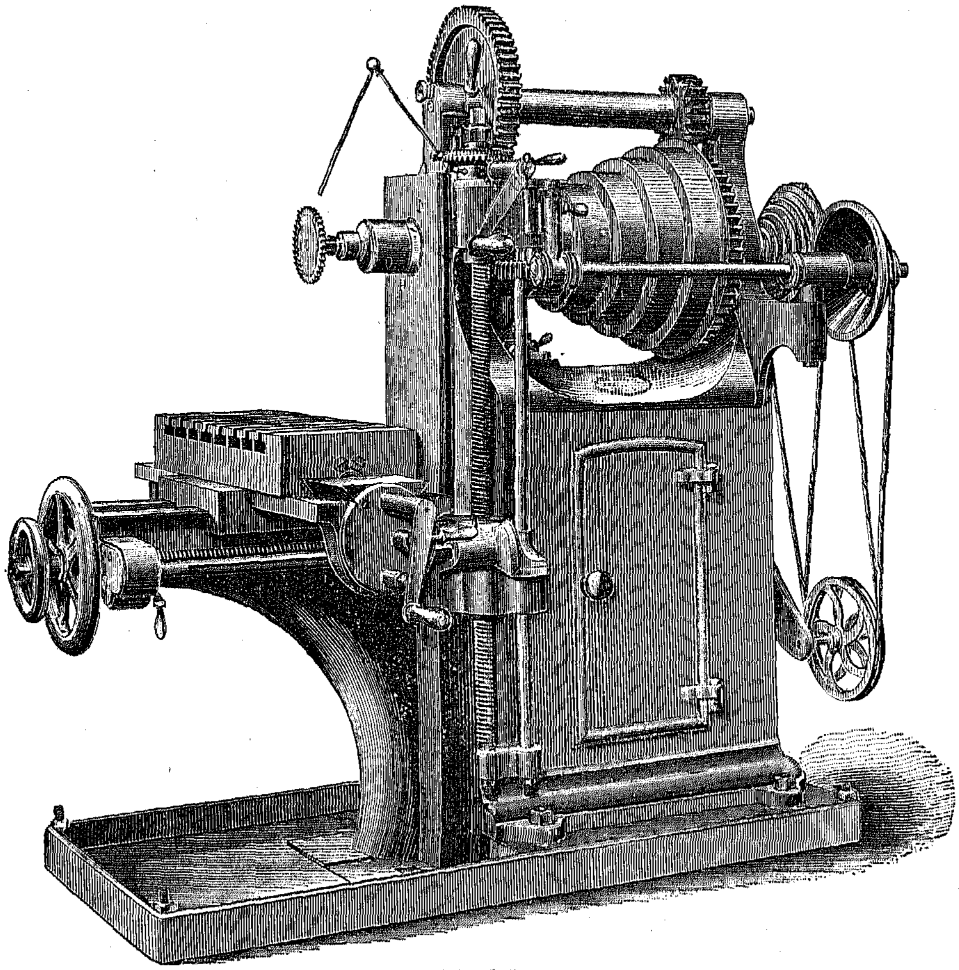

Fig. 283.

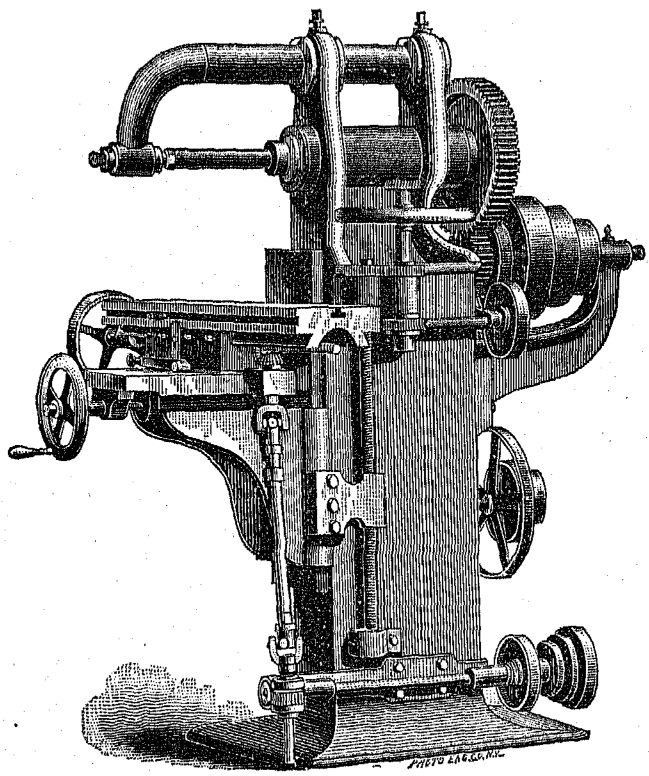

Fig. 284.

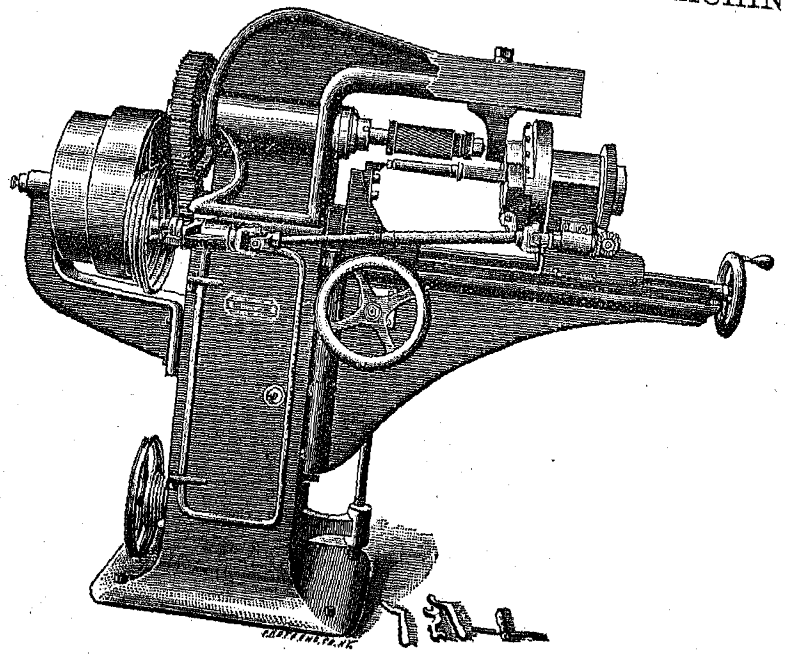

Fig. 285.

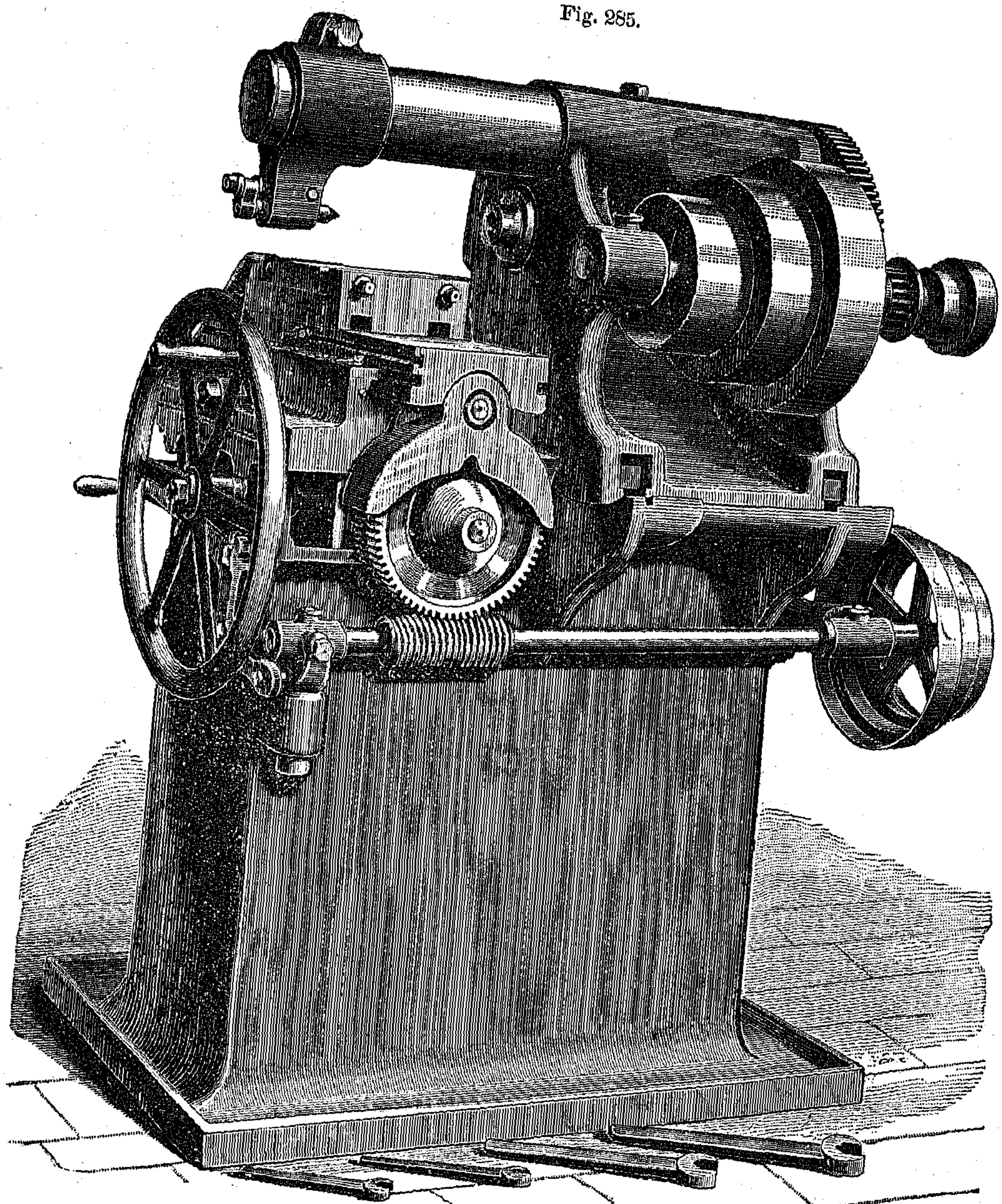

Fig. 286.

D.—MILLING-MACHINES.

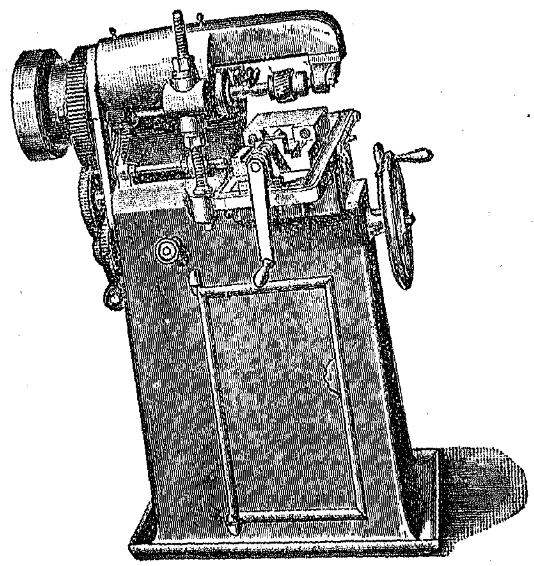

Fig. 287.

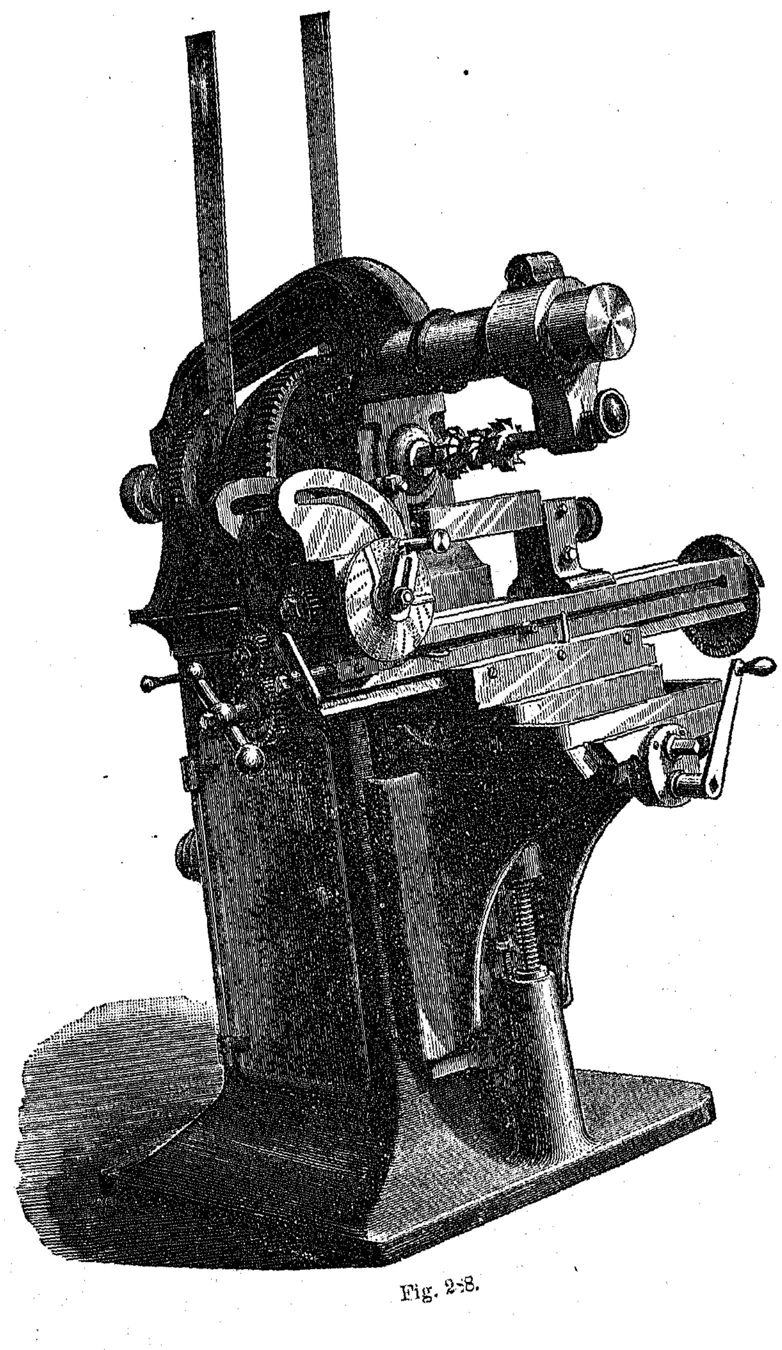

Fig. 2-8.

and index. By dividing the circle into 125 parts and using a screw of one-eighth of an inch pitch, the table may be raised by one-thousandth of an inch, or by one-half of that by ocular bisection of the graduations. The traverse in line with the spindle is by hand over 5 inches only.

Fig. 283 shows a type of back-geared milling-machine, with feed in all directions to the compound table. A twisted round belt transmits motion through a floating stud to a shaft with short worms, right and left. These may be engaged at will with a worm-wheel on a splined shaft which transmits motion by bevel-gears to a second splined shaft at the side of the knee-table. From this the motion is taken off by gears to the cross-feed screw at the end, and for the longitudinal feed. The feeds are disengaged by the short hand-levers shown near the screws. The knee-table is lifted by the screw at the side, the bearing being very long to resist twisting.

For larger tools it is necessary to have an outside center support for the mill-arbor. The strain of the cut might deflect the arbor and cause untruth in the work.

Fig. 284 illustrates an unusual way of accomplishing this result. The arm passes through rings and is set in place by screws, so as to uphold the mandrel by a center. The table has vertical and transverse hand- and power-feed by narrow belts to worm-shafts.

In Fig. 285 the arm for the center is cast with the head, and is not detachable, as is customary. The hanging arm bolts the center through a slot, by which arbors of different lengths may be accommodated. The cut illustrates a tool of this class applied for the special duty of milling out the profile of a carriage-axle at one operation. The square of the axle receives feed-motion by a tangent-screw to the special-holder vise. A type of solid arm, with adjustment vertically, is shown by Figs. 286 and 287. In both figures the compound table has no vertical adjustment for differing thicknesses. This gives steadiness to the table and for its motions, and simplifies the feed connections. In Fig. 286 the casting which carries the arm and spindle is fitted to a concave arc on the standard. The center of the two arcs is the center of the cone-pulley shaft. The movable casting slides on tenons in the arc of the standard, as governed by a screw at the rear, moving tangent to the arc. By this means a vertical adjustment of 6 inches is possible, without interfering with the driving-belt. In Fig. 287 the arm and spindle-casting is hinged at the right, and a pillar-screw and jam-nuts secure the swinging arm in the proper adjustment. The motion takes place around the center of the gear-axis as before.

The most familiar types of the universal standard milling-machine are shown by Figs. 288 and 290. They embody the highest refinements of construction for exactness and finish, many of which are applied in the smaller machines as well, or may be omitted or replaced in designs of less elaboration. In Fig. 289, which shows part of

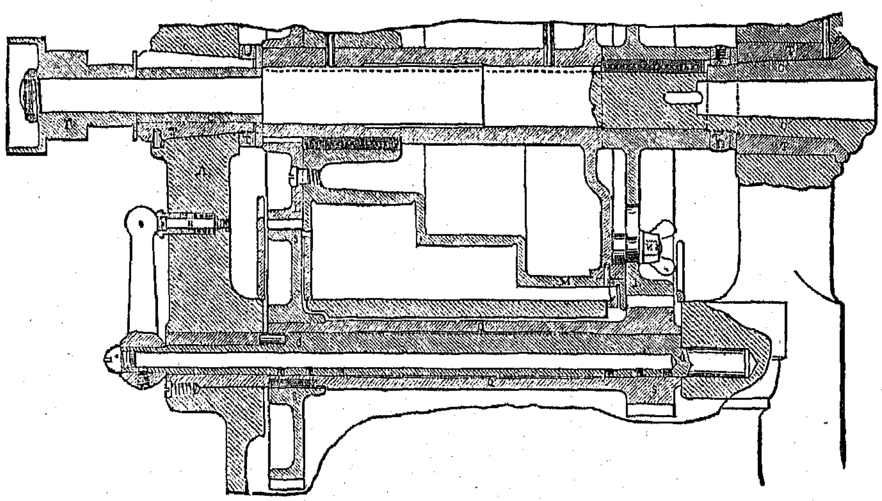

Fig. 289.

the detail of the head of the machine, the spindle C C′ is of hammered steel, hardened and turning in hardened boxes. The spindle is ground at front of box to tangents to the Schiele curve to receive the thrust on the end. A long taper socket is made in the spindle to receive the ends of mandrels. The front box is solid, forced into the supporting casting. A capstan-nut with set-screws on the spindle can take up any lost motion from wear, by drawing inward the conical bearing. The rear box is split, and wear is taken up by a capstan-nut which compresses the box upon the journal as it draws inward the cone of the outside of the box into the casting. Back-gearing is applied below the main spindle, a spring catch holding the engaging-arm in place. The outside center support is bolted to the top of the uprights of the spindle-bearings, and the center clasps the finished arm by a bolt, which closes the split. The dead-center has also a fine adjustment by a milled head on a screw, this having also a split clamp. The vertical and back and forth feeds are by hand. The transverse feed is from the cone-pulleys on the spindle to a complementary nest at the side of the standard. By two universal joints and a telescopic shaft motion is transmitted through a jaw-clutch to the bevel-wheel on the end of the feed-screw. This jaw-clutch can be disengaged by an adjustable stop on the table. It has all the usual and necessary attachments, to be alluded to in the sequel.

Fig. 290 shows a universal standard milling-machine differing from the preceding in several points. The bearings for the spindle are cylindrical, and the thrust of the mills is borne by composition washers on a step-screw at the tail. The journals are of bronze split at one point, and wear is taken up by capstan nuts on each side of the castings of the standard. The arm for outside center has a long cylindrical fit in the cap casting, with about

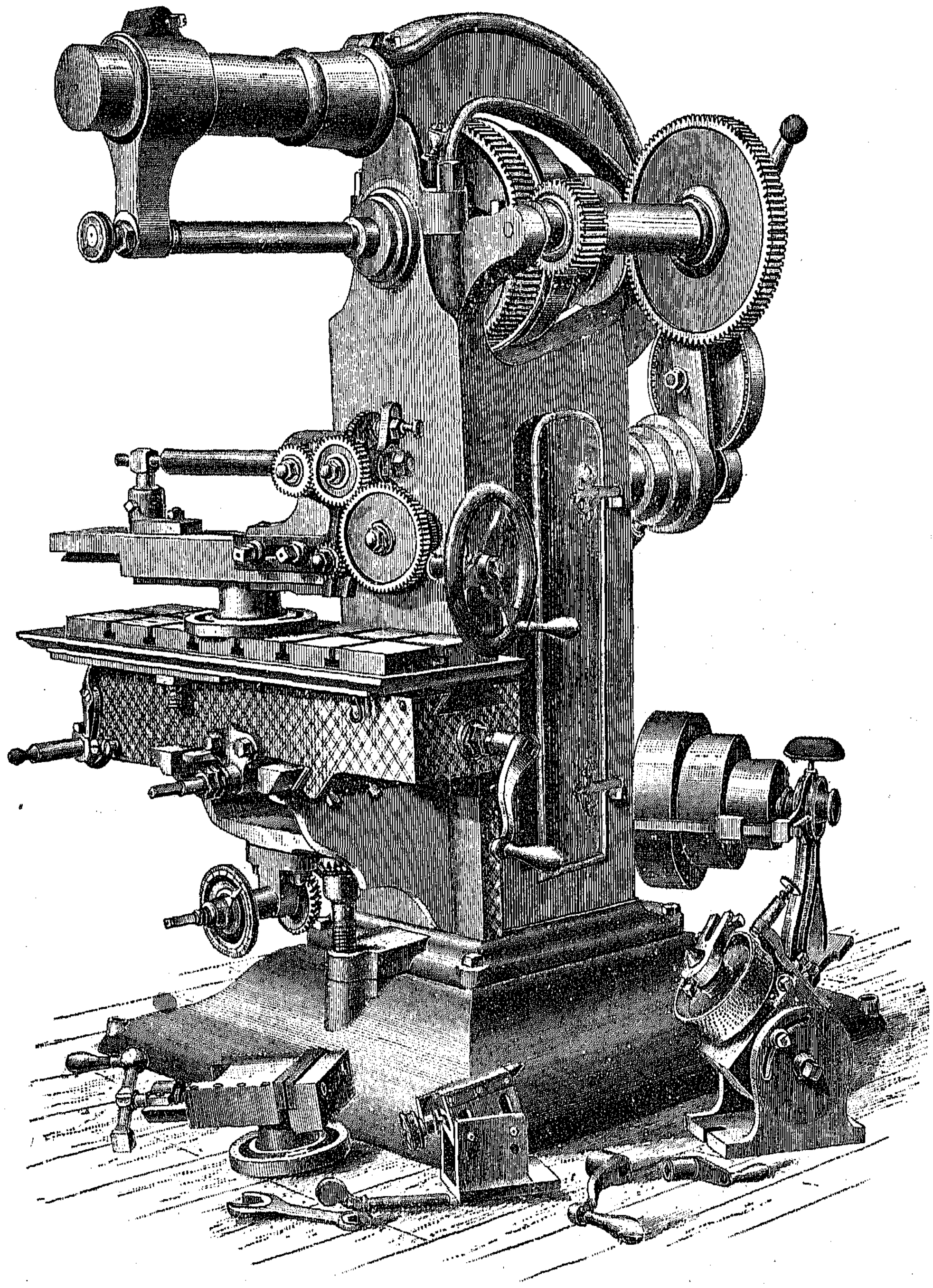

Fig. 290.

1 inch of thread. When screwed home to refusal the split is tightened to prevent the arm from jarring itself loose. The back-gears are at the side, and the feed-shaft is driven by shielded gear and belt through a floating cone-pulley shaft linked to driver and follower. Wear in the feed-screws can be taken up by double nuts. The same fine graduated motion to the table is obtained as in Fig. 282. The main spindle is hollow for convenience of driving out mandrels. In these tools of this class the workmanship is of the best and most accurate. The surfaces are scraped with the greatest care and regard for truth, and so accurately is the work fitted to gauges that in the T-slots in the tables a tenon gauge may be pressed in by hand, but must not fall in easily. From this exactitude in the machine it follows that its work can be correspondingly exact. Units which were formerly thought so small as to be rather in the field of the physicist are now of frequent occurrence in our workshops.

Fully to entitle these milling-machines to the term "universal" certain attachments are required to go with them. These will bolt to the top of the table in the **T**-slots, of which there will probably be one longitudinal and four or six transverse. The first of these will be a vise, which can swivel to any horizontal angle (Figs. 291 and

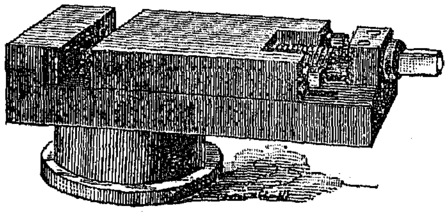

Fig. 291.

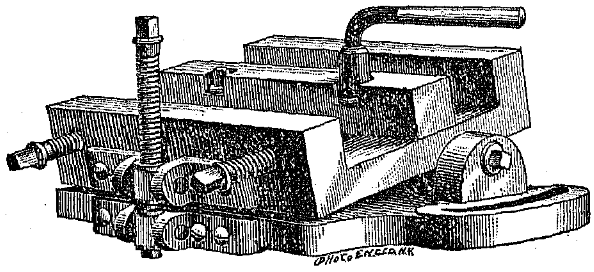

Fig. 292.

292), and one design permits vertical swiveling also. Any form of holder may be designed for any especial shape or process.

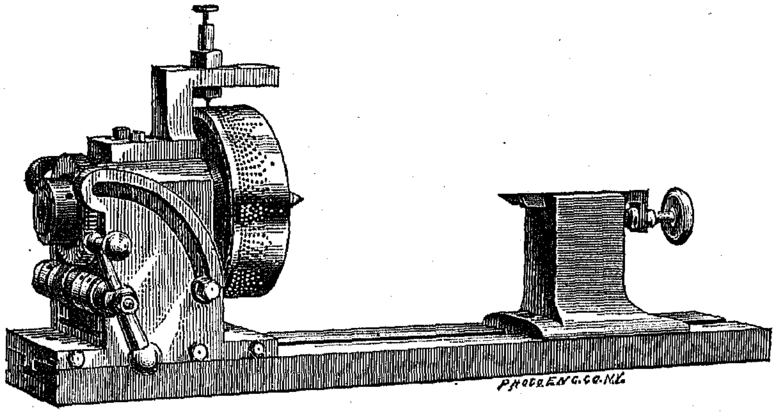

Fig. 293.

The second attachment is a universal head, which can also be used as a simple pair of centers. Fig. 293 illustrates a usual form. The head center is hollow, for rods of any length, and is fitted with a screw in front to hold a chuck or dog-jaw. The spindle may be revolved through any number of degrees by the tangent gearing, the divided cylinder in front serving as index and stop-gear. The whole center has a motion around the axis of the worm, by which an elevation may be given to it for working out tapers with a straight parallel mill. The stationary center has a short pin adjustment when clamped in place.

Fig. 294 shows a similar head with patent back center. The upright is faced on the inside, and fits the inner

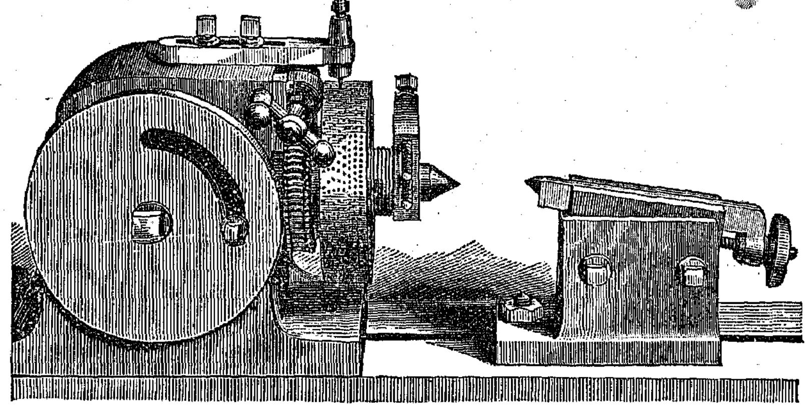

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Fig. 294.

block, which carries the spindle proper. The two parts bolt together by bolts through the curved slots of the inner block. The center is therefore capable of elevation and depression, but can also be set at an angle, so that tapered work can be finished without danger of throwing the point out of the center line of the countersink and wearing both surfaces unduly. These heads will permit gear-cutting, both spur and bevel. The index-dial will divide in an average size of head all numbers to 25, all even numbers to 50, and several others up to 120. One large head has been made by these builders which will divide a circle into eighteen thousand parts with the highest limit of accuracy, and it will divide it even into fifty-four thousand parts. The worm-wheel is made with sharp **V**-threads, and contains 180 teeth. The wheel is in two parts, and no matter how the two disks may be screwed together any two half-teeth form one without perceptible error. A graduated disk receives a spring pawl, by which exact record can be kept of the turns of the worm. There are arrangements to take up wear longitudinally by check-capstan nuts and vertically by hollow capstan-nuts on the block with through clamp-nuts.

The other attachment for the milling-machine table is a spiral cutter. While the work is fed longitudinally by a screw against the cutter, it receives also a motion around its own axis (Fig. 295). This second motion is derived from a worm on the screw by a train of change-wheels, and spirals may be originated and cut with pitches varying between 2 and 72 inches. The spiral may be cut upon a cone as well as upon a cylinder by a special device.

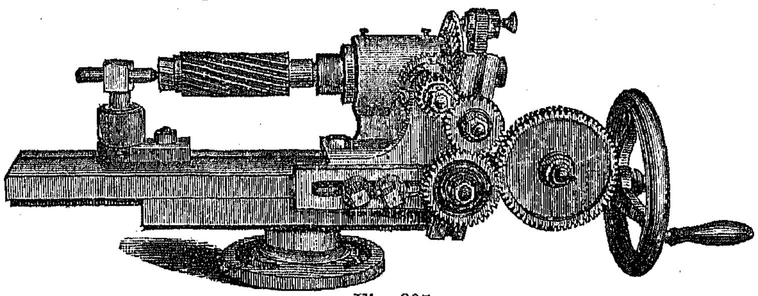

Fig. 295.

Of course for any special manufacture special appliances may supplement these standard attachments. With such devices the application of the machine to all kinds of work becomes most simple. Its use is extending, and is having a most important bearing upon exact manufacture.

§ 31.

SPECIAL FORMS.

For the use of drop-forging apparatus it is necessary that the steel dies be carved out to the exact shape desired. This manufacture of dies is called "die-sinking", and has given rise to a special form of milling-machine. Fig. 296

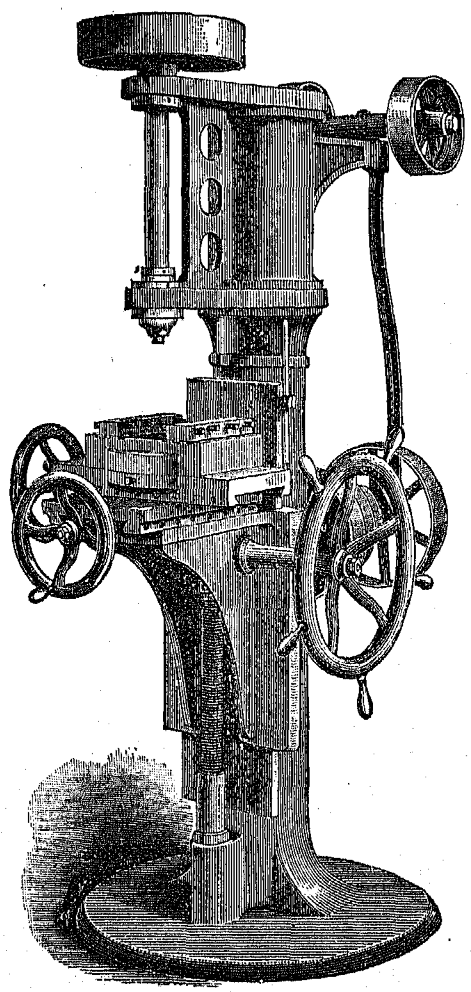

Fig. 296.

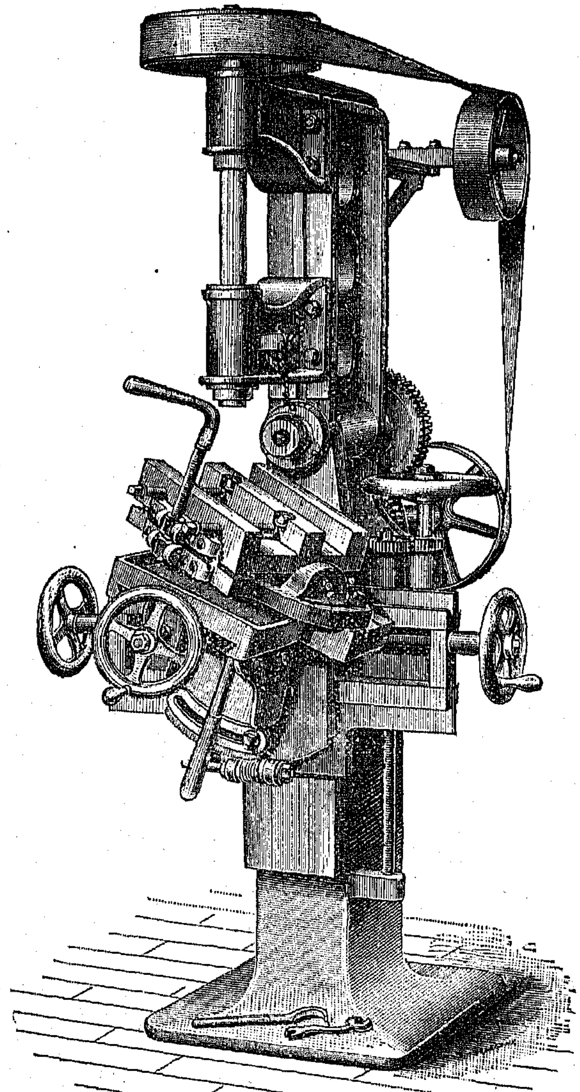

Fig. 297.

illustrates a type. The cutter is vertical, driven by a belt over guide-pulleys. The mill usually cuts on both face and side. The vise has compound motion by hand, and the knee-table can be raised and lowered. There are special devices for taking up thrust and lost motion at the bearings. Very often the motions to the table and vise are given by levers.

Fig. 297 shows a machine with both horizontal and vertical spindles and universal motion to the vise. A saddle has two motions in a vertical plane, and a swivel table, controllable by a worm, holds the slide which receives the vise. All the motions are controlled by hand-wheels within convenient reach of the operator. Such a machine, of course, can be used for any of the small work of miscellaneous milling.

For edge-milling or profiling the irregular shapes of several classes of manufacture the type of machine shown in Fig. 298 is approved. The pieces to be dressed are clamped to the table, which receives a backward and forward

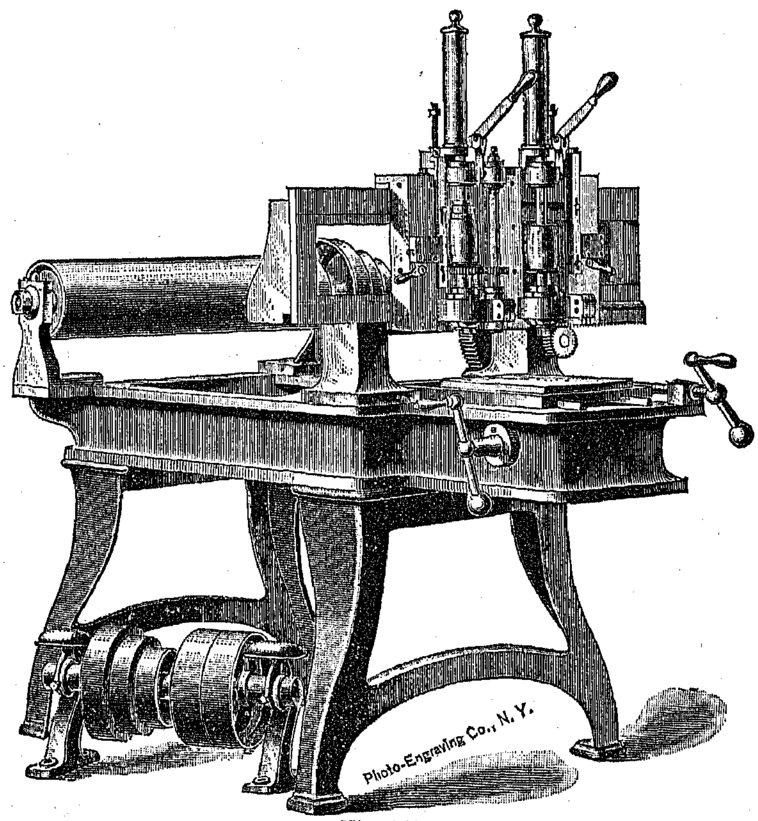

Fig. 298.

feed by rack and pinion from the ball-handle. The mills are carried in the vertical spindles, which are borne on a saddle, which receives transverse motion by a pinion on its under side through the ball-handle on the right. A former is secured to the table, and the operator controls his two feeds by that. The spindles have vertical motion by the hand-levers between adjustable stops for depth, and are driven from the long drum at the rear. This machine has a patent device for cutting formers without reversing the fixtures. The guiding-pin may be driven by gear from one spindle, and the cutter and pin exchange places, while the model is secured to the place which the work is to occupy in the future. The cutter on the guide-pin cuts the forming pattern in the exact position it will retain in use. The gearing and rack are made double, so as to be adjustable to prevent any back-lash in the feeds. This is essential for accuracy of irregular work, and especially in turning corners. Such a machine can also be used as a jigging and die-sinking machine. There may also be three spindles. A rotary cutter has been mounted upon an arbor transverse and parallel to a planer bed, and is used to mill out the flats of locomotive-rods. It is then known as a slabbing-machine, and will take a 4-inch cutter the full width of the rod. For cast iron a larger cutter may be used with advantage. Where, however, heavy work is to be done, the use of inserted cutters is expedient. The work done will then be proportional to the number of cutters, as compared with reciprocating tools.

An example of the economic application of this principle is shown by Figs. 299 and 300. The tool (Fig. 299) is designed to face off the ends of bridge and other girders to exact dimensions. The work is bolted to a stationary table, and the mill traverses in front of it. Several may be secured at once, and each is held independently by a set-screw through the clamp. The mill consists of a solid wrought-iron disk of tough and homogeneous metal. It is 2 inches thick and weighs 400 pounds. Eighty-four teeth are inserted in the rim, on edge and face alternately, and since the disk is 28 inches in diameter the alternate system permits a tooth upon every inch of circumference. The teeth are of steel, $1\frac{1}{8}$ inches face by $\frac{7}{8}$ of an inch thick, and are fitted in milled grooves. The milling-disk is driven by a large steel worm on a splined shaft, by which a vertical adjustment of the slide is possible. The whole head is fed along by a screw either by hand or by power, through a worm-gear from cone-pulleys, and the feed can

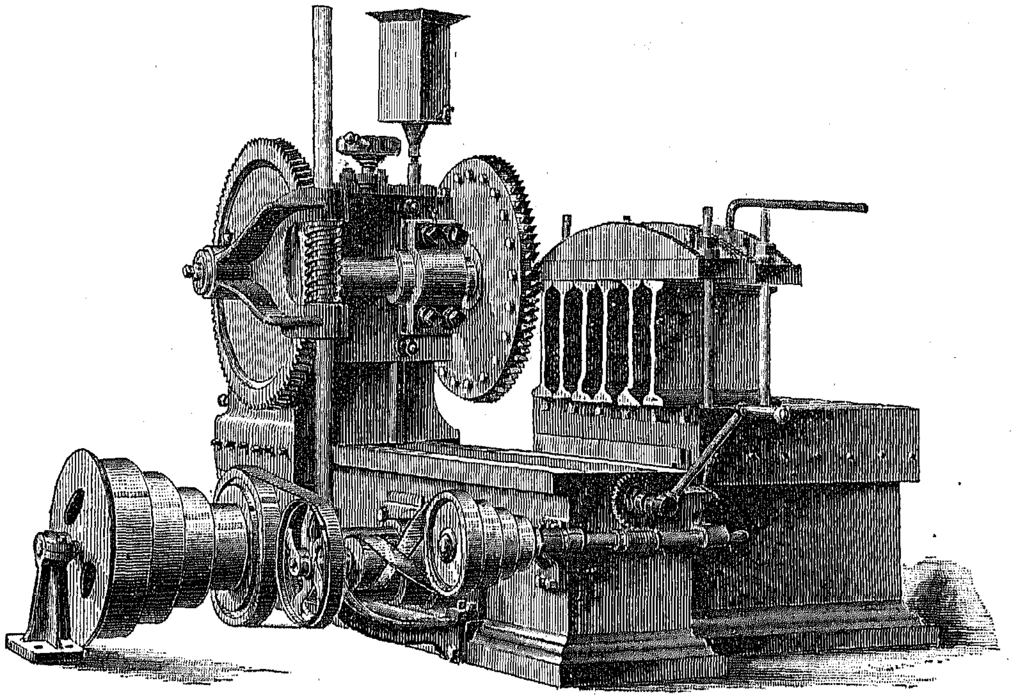

Fig. 299.

be varied from $\frac{1}{8}$ of an inch to 1 inch per revolution. Such a machine can square and finish six 15-inch beams per hour, allowing $\frac{1}{2}$ inch of metal to be cut from each end. If less is taken off the feed may be more rapid. In Fig.

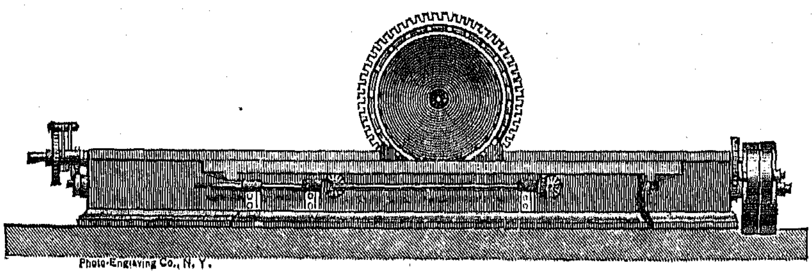

Fig. 300.

300 the cutters are twenty-eight in number, on a 25-inch plate wheel, which is banded with wrought iron. The wheel is driven as in the other tool by worm-gear, and the whole head is made to travel by an automatic variable feed.

§ 32.

GEAR-CUTTERS.

Any of the universal millers can be used as gear-cutters by means of a universal head, with worm-wheel and index. They can usually cut both spurs and bevels. There are certain tools, however, which are built for that especial purpose, and may properly be discussed by themselves.

Fig. 301 illustrates the type which has been in very general use. The blank from which the spaces between the teeth are to be cut is held firmly upon the end of a vertical arbor. Upon this arbor is secured the index-plate, with its stop-pin, adjustable legs, and clamp. The cutter is borne upon a slide which has a power-feed across the face of the blank, and the whole upright has adjustment for different diameters of blank. To compensate for the motion of the cutter-arbor the belt passes over a hinged binder-frame overhead, which is weighted to maintain a constant tension on the belt.

Fig. 302 illustrates a standard type of machine. The cutter-carriage is swung from a fulcrum on the standard, and may be set to cut bevels of any angle. The cutter is fed automatically across the face of the blank, and has a stop-gear. The mandrel for the blank may be adjusted for different radii of wheels. The wheels are divided by a worm-wheel.

To increase the adaptability of the milling-machine for bevel-wheels such machines as Figs. 303 and 304 have been produced. In Fig. 303 the index-plate is attached to the bottom of a hollow spindle, which swivels around a

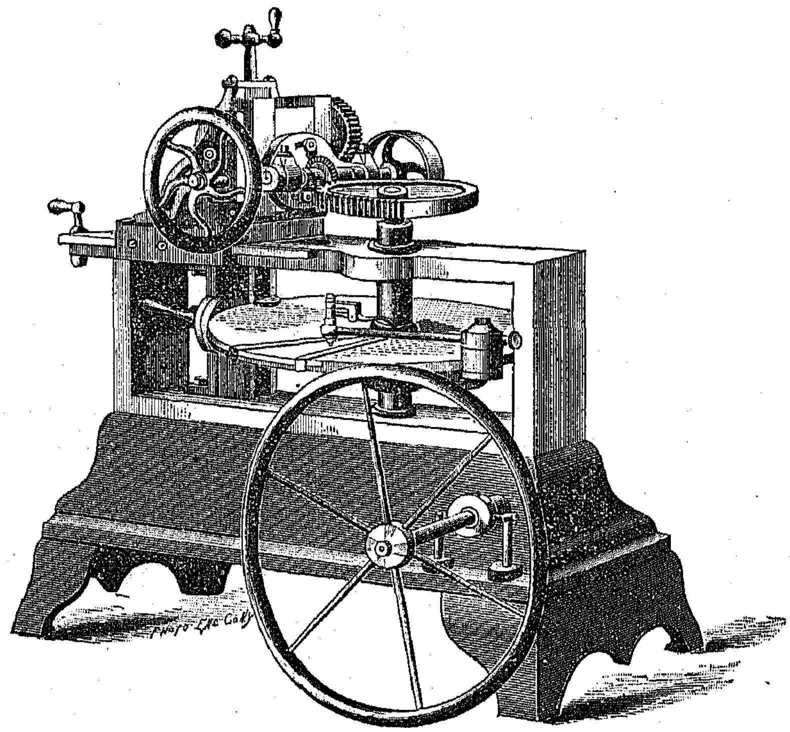

Fig. 301.

center on a vertical slide. The spindle can take a vise or centers or any attachment, and can be set at any angle between 0° and 180°. The vertical slide has a perpendicular traverse of 2 inches and a horizontal adjustment between stops for different diameters. The machine can therefore cut spurs and bevels and worm-teeth. The cone-spindle has a horizontal movement by hand-lever limited between check-nuts.

In Fig. 304 the mill-arbor is driven by bevel-gear from the splined shaft to avoid the necessity for the binder-frame. The vertical spindle has the same motions and adjustments as in the previous machine. As this is designed for general work also, the vertical spindle is arranged to clamp so as to relieve the index-plate from strain, as in the preceding type.

Fig. 305 illustrates a machine specially adapted for racks. The cutter is borne on a horizontal slide driven by gears from the cone-pulley, and more than one cutter may be used at once. The cutters are fed forward by power automatically, and the pitch for the rack is given by a spring stop into the teeth of a change-wheel. The train can be so arranged relative to the pitch of the traverse screw as to have the two pitches commensurable, and the pin should pass over always the same number of teeth.

In the best practice for larger wheel-work the drilled index-plate is replaced by a large worm-wheel, and motion to the worm is transmitted from a crank by a train of change-wheels, as in Fig. 302. The crank is arranged to lock with a spring latch or by a jaw of some sort, so that any number of entire revolutions of the crank may be so multiplied or divided as to effect any subdivision of the circumference of the worm-wheel. By this means the errors of fractional subdivisions are avoided, and also possible inaccuracies from the division or wear of the index plate. Moreover, when the worm-wheel is large, any errors in it are reduced in cutting-wheels of smaller diameter than itself, which will always be most numerous. The only source of error is from the danger of making the wrong number of turns of the crank-shaft. The combinations and numbers of turns can all be worked out and tabulated in advance.

The most advanced types of gear-cutters are those which are automatic. They are made by several of the best builders, and after adjustment of the blank and the combinations they will operate without supervision from the attendant. It is therefore possible to keep four machines full and earning their own interest, with the cost of the labor of but one operator to be divided among the four. Beside, the automatic machine is likely to work more rapidly than a similar machine worked in part by hand. There is a general resemblance in the mechanical devices for securing automatism, though the machines differ widely in outward form and appearance and differ in their adaptedness for large and small work.

A Providence machine for wheels up to 18 inches diameter, with 3-inch face, is shown by Fig. 306. It will cut wheels of any angle by the sector adjustment of the cutter-slide, which carries a graduated arc and index. The cutter-mandrel is driven by belt, with idle-pulley, for equality of tension. The wheel is secured on the horizontal

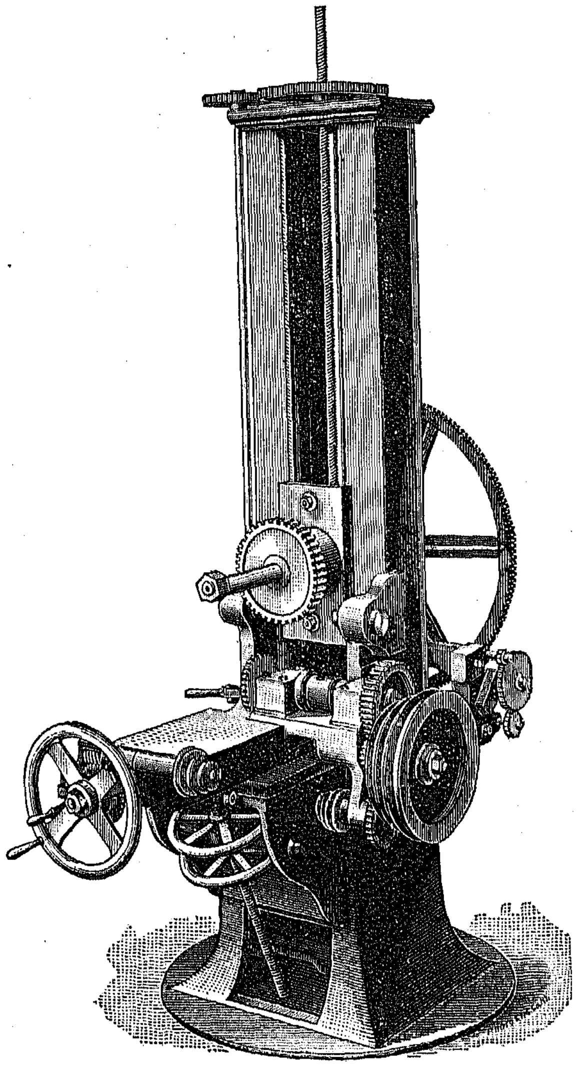

Fig. 302.

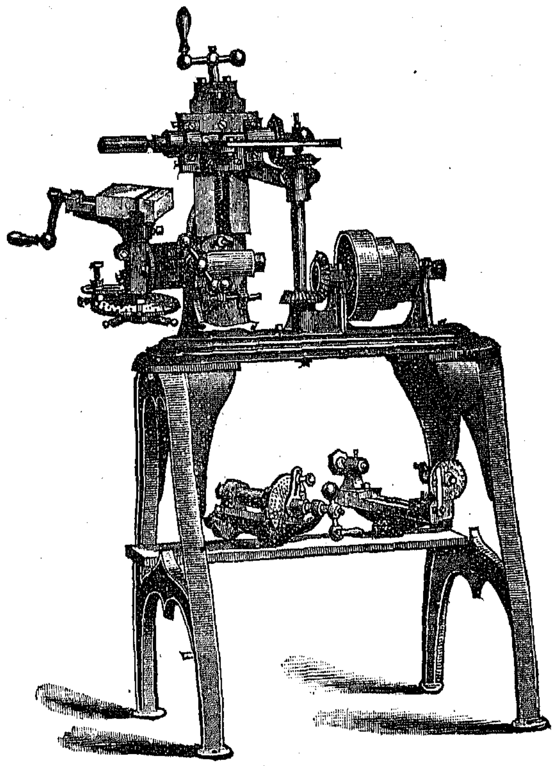

Fig. 304.

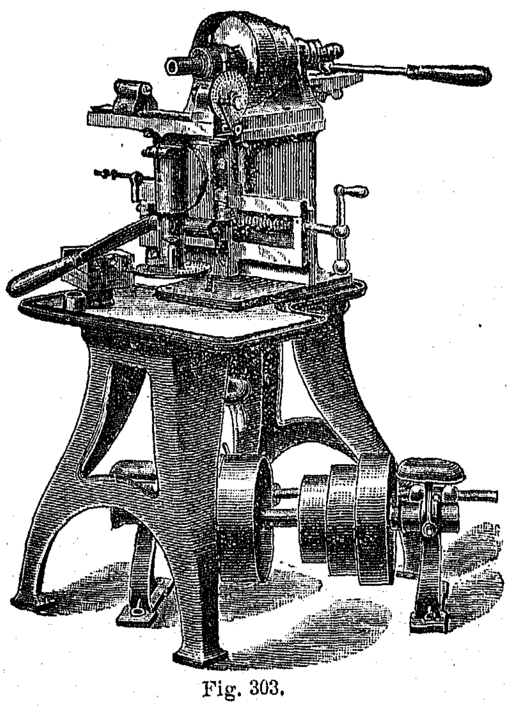

Fig. 303.

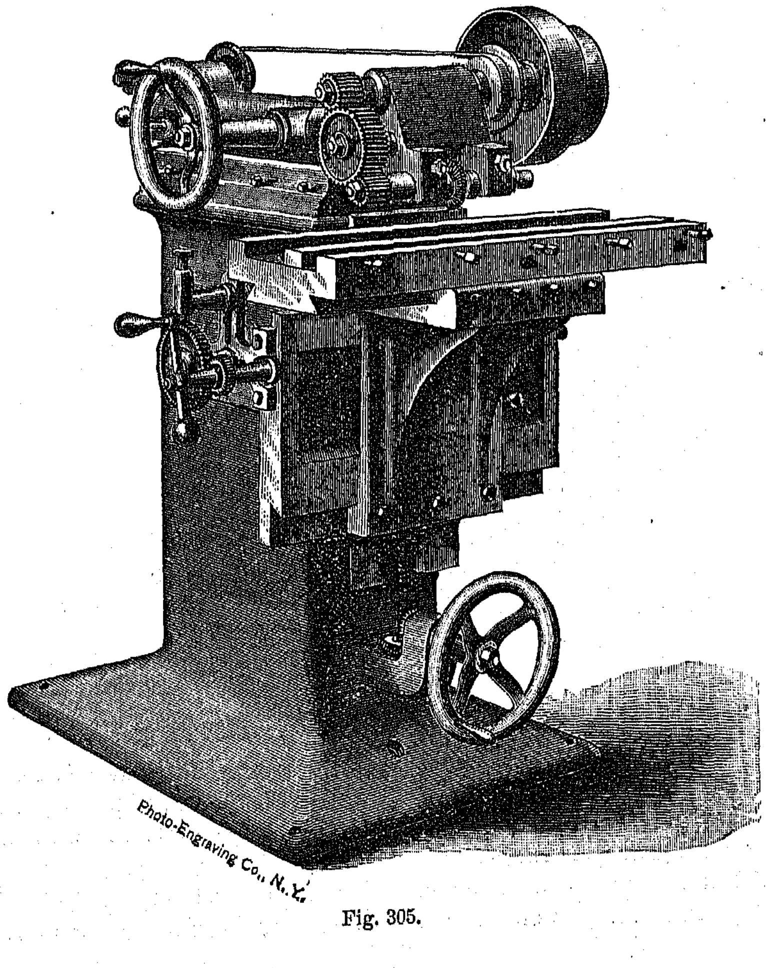

Fig. 305.

arbor, and the latter is adjusted by a scale graduated to thousandths of an inch for exactly the proper depth of tooth. The cutter-slide is fed forward by a screw at the proper speed, cutting through across the face, and when the cut is made the slide returns at quick speed. This is effected by a clutch between bevel-gears on opposite sides of the driving-shaft, and of different diameters. The shifting device is prevented from stalling by wedge-points, one on the clutch-lever and one on a movable stud pressed forward by a spring. As the two wedges cannot hold by their sharp edges, the compressed spring will certainly throw the clutch to one side or the other. To give the proper rotation to the blank, that the next cut may be properly made, the mandrel carries a worm-wheel. The worm which drives it is borne upon a splined vertical shaft, driven from below by change-wheels. The spline permits adjustment for wheels of differing diameters, and the worm is turned and locked by a special device. When the cutter-slide has retreated it engages a clutch, which puts a train in motion, turning the worm. On this clutch-shaft are two wheels, side by side, with their faces plain, except a notch in each. One wheel is fast on the shaft; the other is loose, and is driven in the direction opposite to that of its mate by internal gearing from an idle shaft. It is obvious that a detent can only fall into the notch of either wheel when that of each shall coincide under it. This detent can be so shaped as to lock both wheels and to disengage the clutch which is driving them. Since the wheels are driven in opposite directions, it is simply necessary so to arrange a train of change-wheels that the two notches shall coincide only when the proper number of revolutions of the worm shall have been made. When the shaft has gone round the standard number of times, the notches coincide, the detent falls into them and locks the worm-wheel and blank, and disengages the driving-gear. The detent is loosened by the return of the cutter-slide.

In one of the Philadelphia designs the worm-shaft is driven by a train of change-gears, which must change the speed of the driving-arbor by proper alteration of the six revolutions which the latter always makes when engaged by the return of the cutter-slide. This series of six revolutions is secured by the action of dogs upon two equal wheels with different numbers of teeth.

Fig. 307 shows a special automatic pair of machines, one for spur-wheels and the other for bevel-wheels of small dimensions for light machinery.

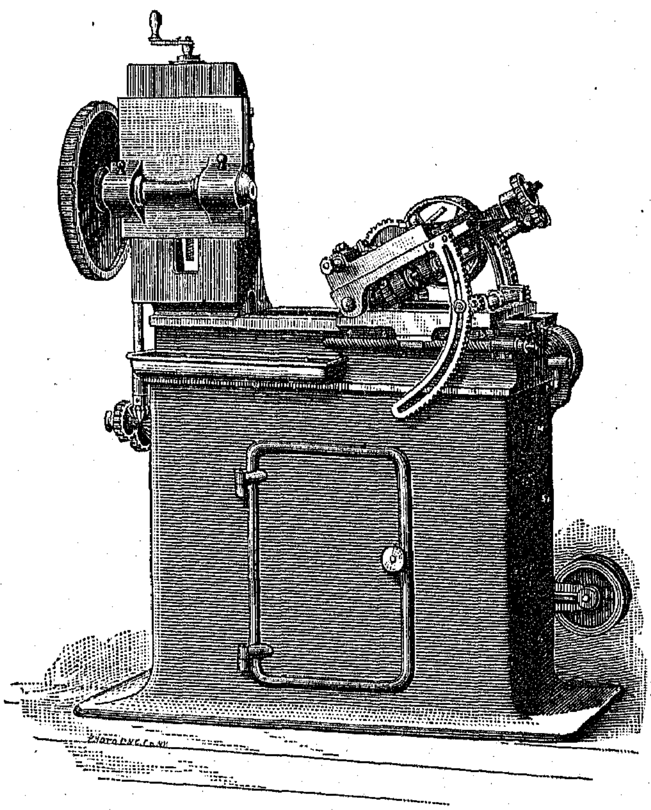

Fig. 306.

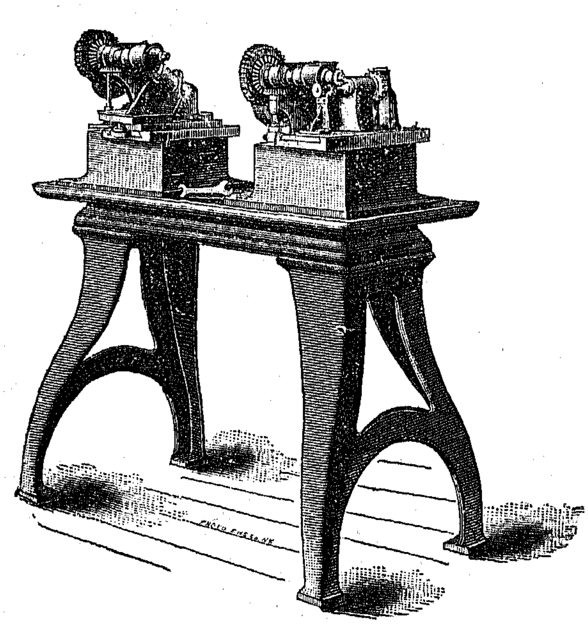

Fig. 307.

Figs. 308 and 309 *a* and *b* illustrate a large automatic machine for bevel- and spur-wheels up to 4½ feet in diameter and of 12 inches face. It will divide the circumference of wheels containing from ten up to three hundred and sixty teeth. The cutter is borne upon a horizontal slide, with variable traverse and return motion. It is driven by bevel-gear from the cone of belt-pulleys, the belt passing over a counter-weighted tightener-frame. The feeding and dividing motions are obtained from the central vertical shaft. By supporting the outer end of the mandrel for the blanks a large number of thin wheels may be cut at one cross-traverse.

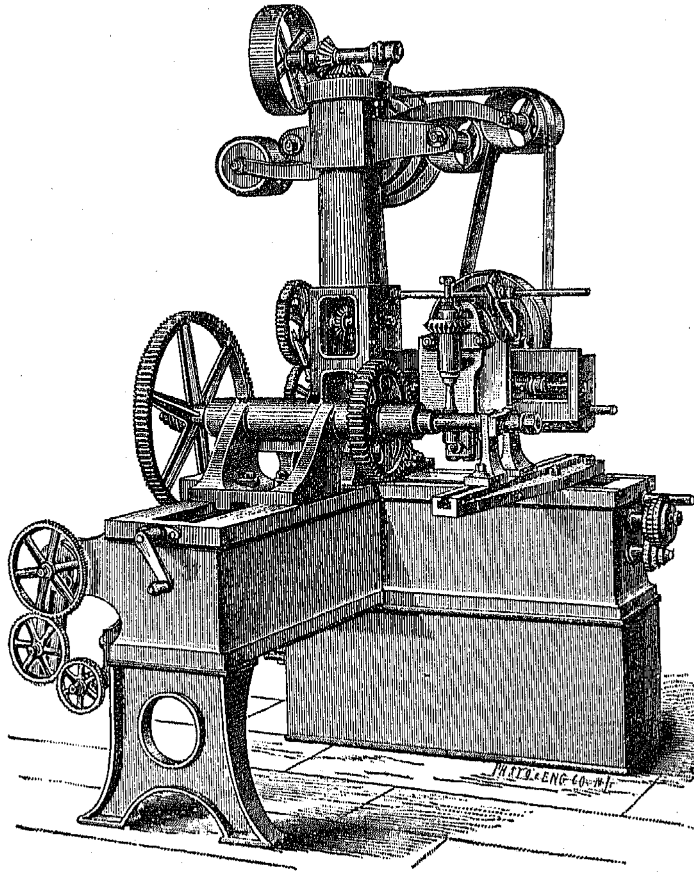

Fig. 308.

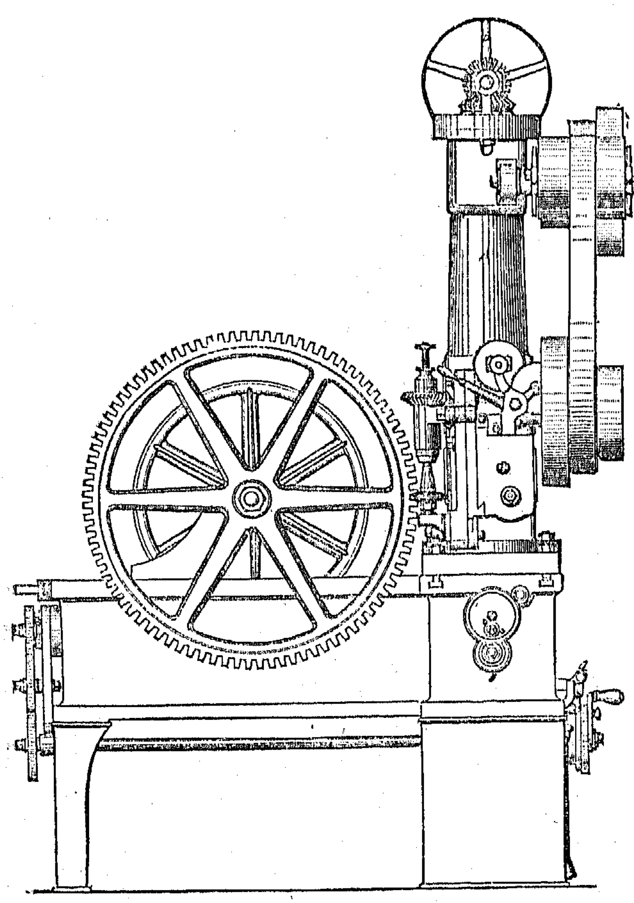

Fig. 309 a.

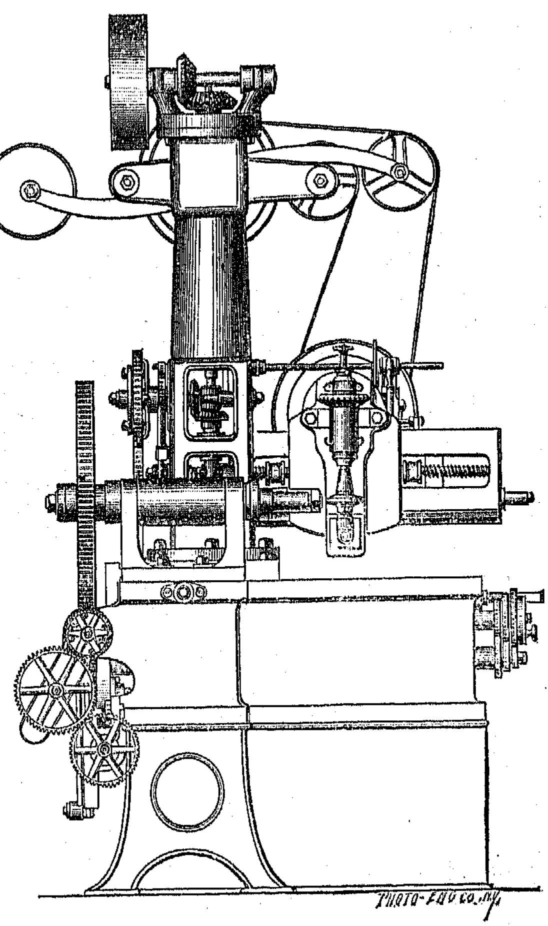

Fig. 309 b.

For the rotating cutters for these machines a very general type of patent cutter is shown by Fig. 310. Such cutters are so constructed that they can be sharpened by grinding upon the flat front face without spoiling the profiles of the side edges. The relief necessary for the top of the cutting-face obliges the profile to retreat toward the center. If only the top retreated, each successive grinding would make the space cut in the blank more and more shallow. To avoid this, each cutter is turned in a relieving lathe. The forming-tool receives a special forward motion from the tip to the root of each cutting-tooth as the mill being shaped revolves on a mandrel. This forward motion is imparted by a cam under the former-slide, which revolves once for each cutting-tooth of the mill (Fig. 311). To make the forming-tool, the true profile is worked out and a male chisel is made from it. By this male tool a female tool is planed out, and this latter is used to turn the spiral profiles of the mill itself. By distributing the numbers of teeth in each circular pitch among eight cutters the errors from inexact profile are made quite small.

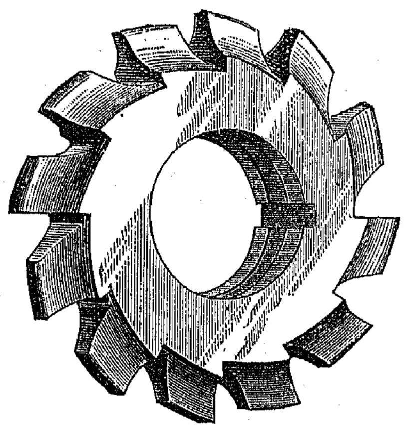

Fig. 310.

In another system (Pratt & Whitney, Hartford, Connecticut) an especial tool is used for producing an exact epicycloidal profile in the templet from which the mill is to be shaped. Fig. 312 shows a side view, and Fig. 313 gives a view in oblique plan. By this means is eliminated the variableness of profile of hand-made equivalents. From this templet, mechanically exact, as a former, the profile of the mill proper is reproduced. If the edge of a templet,

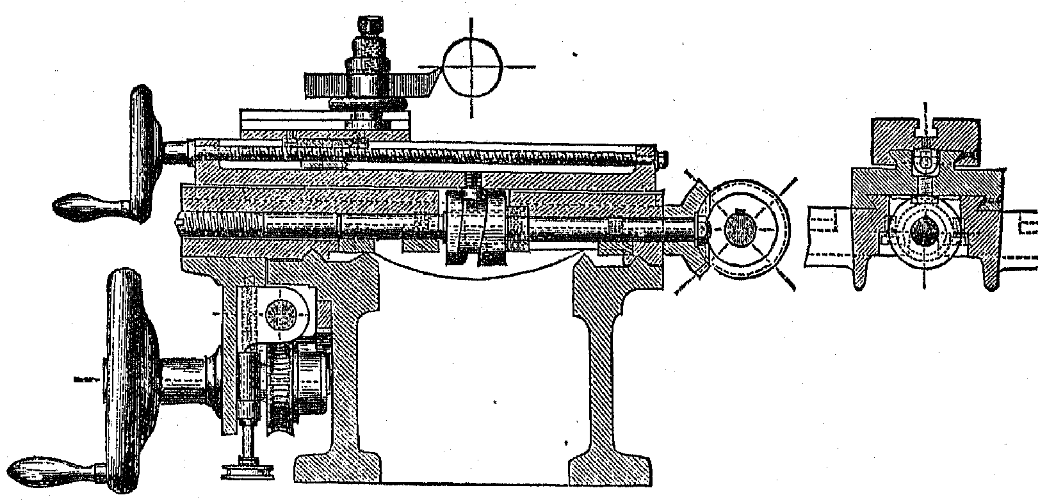

Fig. 311.

T T (Fig. 314), has been shaped by a cutter traveling on a true epicycloidal curve, a roller, P, running along the profile of T T, will make another cutter, N, on the axis of P, reproduce a profile, R S, which has a constant

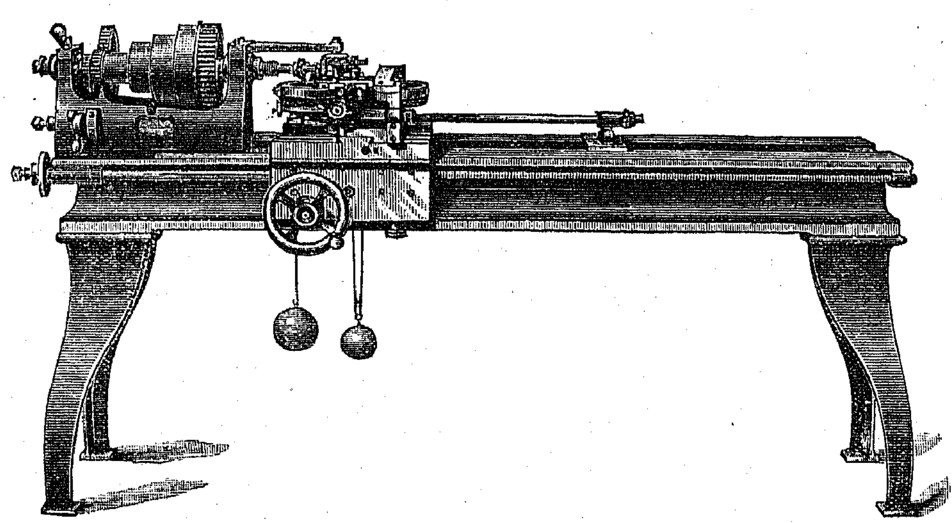

Fig. 312.

normal distance from T T. The reproduction of such curves for cutters is done by turning the cutter nearly to the required form and notching it for the cutting-edges. It is then put upon the pantographic cutter engine (Fig. 315), by which the exact profiles are produced for any other pitch by reduction with a simple device. The pantographic engine will reproduce any type of tooth profile other than the epicycloidal, if supplied with the corresponding templets. This method gives exceedingly satisfactory results. It is open to the theoretical objection that even a roller of the same size as the original milling-cutter will not retrace completely the cycloidal path in which the

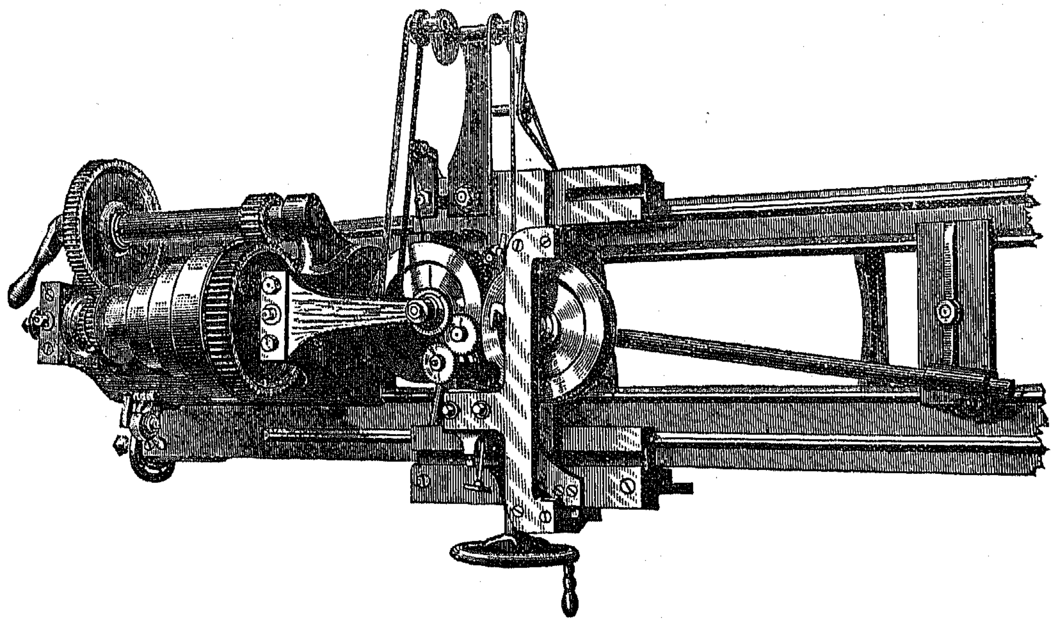

Fig. 313.

latter moved. But this objection is found to cause an inaccuracy of profile in practice so small as to defy detection. Very large wheels are always cut from a former, which guides the cutter. It becomes impossible to use a cutter which shall fully fill the spaces and reproduce itself in large pitches. Hence a cutter is used which dresses the profile by acting upon successive elements, with frequent traverses, and which is controlled by working up to a suitable former.

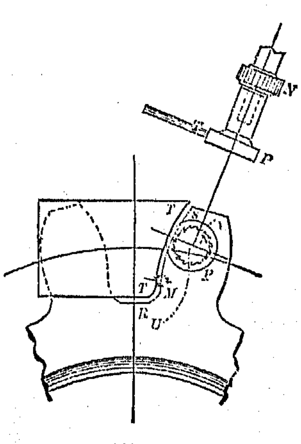

Fig. 314.

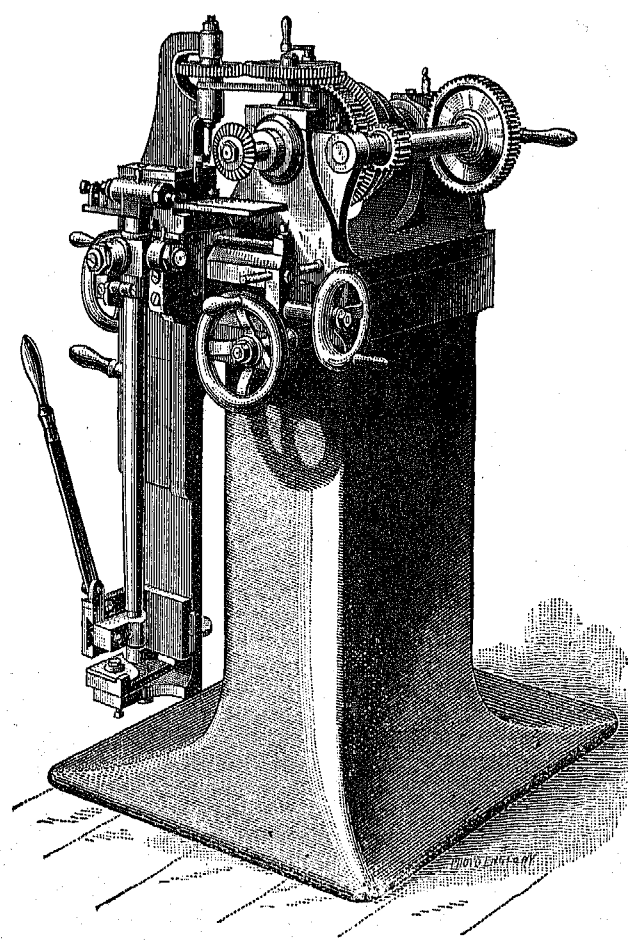

Fig. 315.

For bevel-gear the largest type of machine is that (Fig. 316) of Mr. Corliss, of Providence, Rhode Island. The blank is held upon a horizontal mandrel, on the end of which is an index-wheel of 15 feet diameter. By the use of such a large wheel any errors in it are reduced in the work. The blank is so secured that the apex of its conical surfaces shall coincide with the point through which the path of the tool-point always passes. By guiding the tool-slide by a large former, against which the rear of the slide shall be held, the path of the cutting-point at each

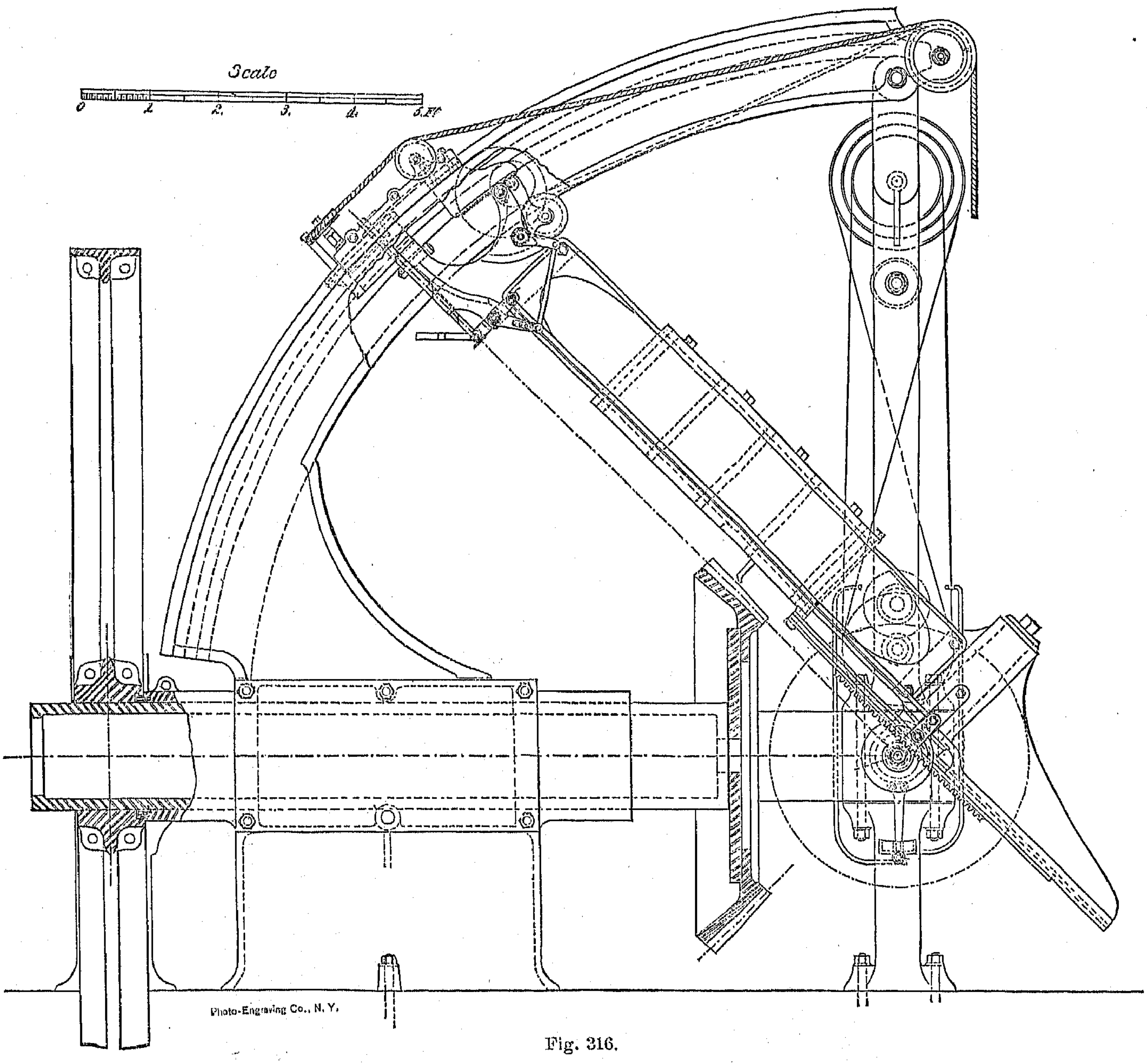

Fig. 316.

element of every tooth will pass through the apex and be tangent to an exact profile at the base of the cone of which the blank forms a short frustum. Profiles of great accuracy will thus result. A smaller machine on similar principle is built by the same makers.

Fig. 317 shows a gear-dressing machine by Gleason, of Rochester, New York. It will act on both spur- and bevel-wheels up to 100 inches in diameter. The wheel to be cut is mounted on the horizontal mandrel, which carries the worm-wheel and train from a crank. For iron wheels the tool-slide is driven by a crank from the central shaft in the upright post, whose center is the center of all cones in bevel-wheels. The end of the radial bar is laid off in degrees for convenience in this work. The tooth-former is put under the tool-holder, and the latter is fed over it. To dress wooden teeth inserted in rims or for patterns a thick circular saw is held in the tool-post, and is driven by belt over guide-pulleys from a radial drum overhead. The radial bar will swing to any angle with the mandrel between 0° for spur-wheels to 90° for crown-wheels. It is also hinged, to permit a vertical movement for bevel-wheels. With greater capacity than the preceding design, it is much less bulky and more rigid vertically.

Fig. 318 shows the Holmes machine working upon a similar principle.

While these latter machines scarcely belong to the class of milling-machines, yet they attach themselves so closely to the milling gear-cutters as to be presented at this point.

The milling-machine in its larger sizes, for locomotive, pump, and engine shops, is becoming increasingly popular. While at present practical considerations often overweigh the theoretical advantages which the tool possesses, and which would lead to its introduction, yet the tendency is toward higher appreciation of the value of

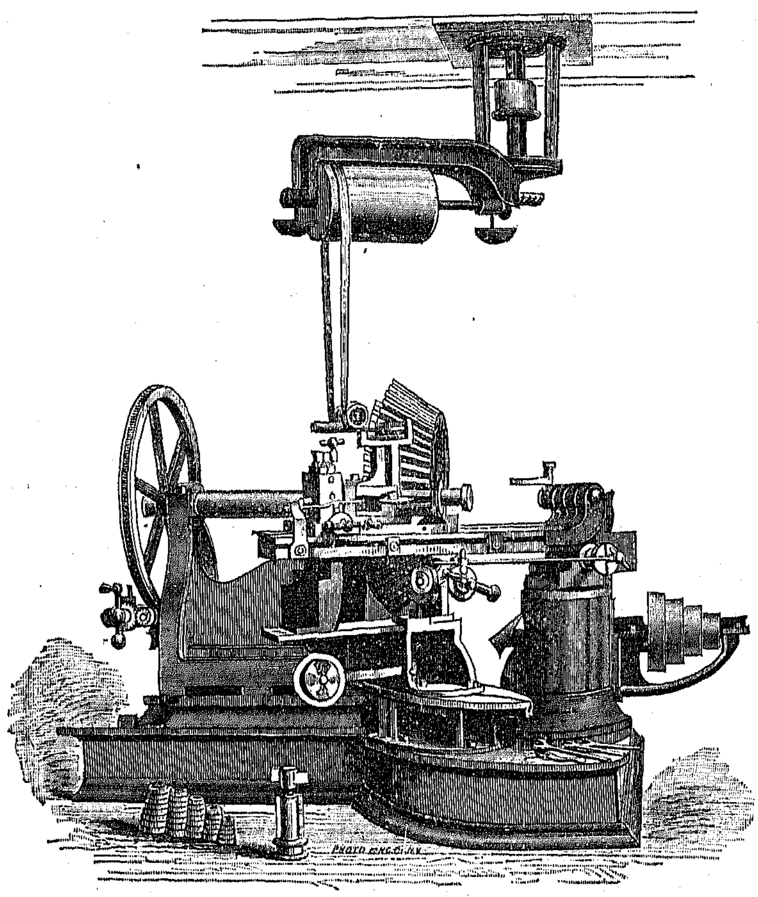

Fig. 317.

the tool. It may also by comparison be called a distinctively American tool in the forms in which it is most frequently met, because the greatest improvements in it have originated in the genius and necessities of this country. By its means production of certain specialties has been cheapened to a degree which would at one time have seemed entirely impossible with the existing high prices of skilled labor.

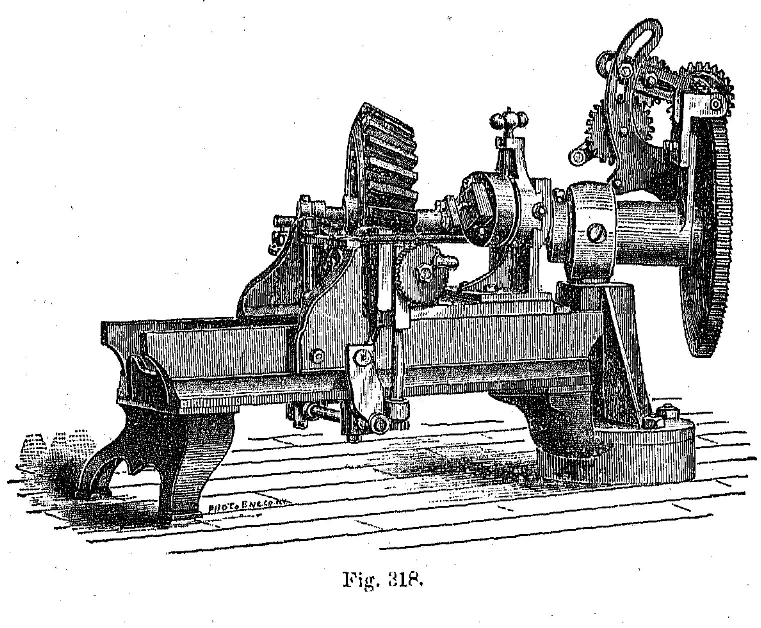

Fig. 318.

§ 33.

E.—TOOLS ACTING BY ABRADING OR GRINDING.

To this class belong the machines in which the conversion of material is not effected by cutting-edges of hardened steel, but by the attrition of revolving mineral. The work is presented to it, and the sharp particles of the stone abrade its surface. The abrading mineral is either the grindstone grit, emery, or corundum, and it may act to produce an especial shape of work or simply to produce a finish or polish on work already shaped.

A very large part of the duty of these grinding-tools is the production of cutting-edges upon hardened steel, that the softer metals may be cut by them. This shaping of the edges or sharpening of tools is the especial function of the grindstone. It is employed to smooth and polish in but few industries. The sharpening grindstone is held between flanges by a nut on a mandrel. The wedges around the mandrel should be just sufficient to keep the stone from throwing, while the flanges serve to hold it in place. The stone should have a speed at the periphery, varying with the class of tool to be ground upon it, from 200 to 500 feet per minute. Where hard tools for wood are to be ground with light pressures, the stone should go faster than for metal-working tools, which will be held more firmly. To compensate for the reduction of diameter as the stone wears, by which the speed at the periphery will become too low, the belt-pulley on the mandrel should be changed for one of smaller diameter at proper intervals. To prevent the annoyance and danger from flying grit and abraded particles, as well as to keep the steel cool, grindstones are run with water. The stone stands in a trough, which holds the excess of water and receives the particles thrown off. It is not wise to let the stone stand or run in water, on account of the softening action of water on the surface. The water is usually delivered from a pipe upon the stone when needed, the supply being controllable by a faucet.

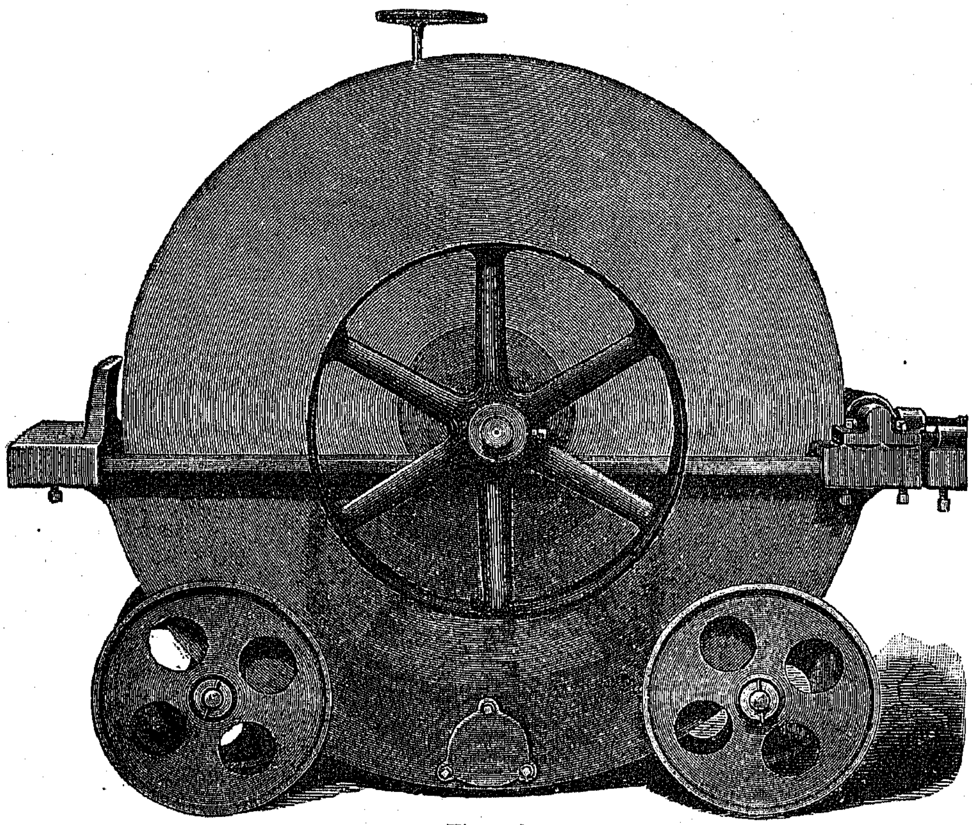

Fig. 319.

Fig. 319 shows a form of trough-mounting for a shop-stone. The stone is hung on a squared arbor, with long bearings, which are self-oiling and shielded to keep out grit. The boxes can be moved a few inches on the flat top of the trough, so that when the smaller pulley is put on after the stone has worn the belt need not be cut and re-adjusted. The rest is secured to the ledge of the trough by set-screws, and an adjustable self-turning attachment on the farther face keeps the stone round and its face true. This turning device consists of a steel screw, driven by the stone itself and pressed against it with any desired pressure by screws.

Fig. 320 shows a different design of mounting, the screw being linked to a hinge, so that the hand-wheel pressure easily engages or disengages it without special adjustment for equality of pressure upon the face. The water-can stands upon an upright at the side.

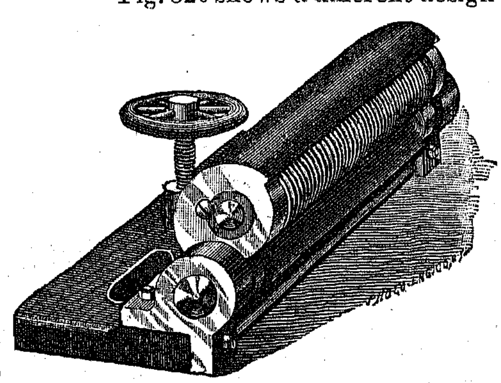

Fig. 320.

The modern grindstone-frames are mounted upon wheels. This has several advantages. The stand can be wheeled under a convenient crane or hoist, and the stone may be mounted or changed with ease. Secondly, when sufficient grit has gathered in the trough it can be wheeled to a convenient door or platform and there be hosed out through the hand-hole openings. By this expedient is avoided the overflow of gritty water, which may do harm, and is certainly untidy. In one design there are three wheels, the single one being swivel- or caster-mounted, in order that it may be turned at right angles to the others and may resist the pull of the driving-belt. The wheel system further renders the maintenance of one belt possible with mandrel-pulleys of diminishing diameters as the stones wear.

Most of the grindstones in use come from Ohio or Michigan, or are imported from Great Britain or its colonies. They are of all grades of grit and hardness, which fact adapts them for the various purposes for which they are to be used. The fine, sharp grits are used for tool sharpening in shops.

Emery is used for tool sharpening in the form of the so-called solid emery wheels. These are molded disks of convenient size, made by cementing the ground emery to some vehicle which shall suitably carry it. These disks are mounted upon a mandrel and rotated at a high velocity. A usual velocity for average diameters is a speed at the circumference of 3,500 feet per minute. Small wheels often have a speed of less than 2,500 feet; larger ones are run at 5,000 feet or higher. While a large grindstone will remove a given quantity of metal in less time than an emery wheel, yet the emery-wheel can be made of a small thickness and of a shape which would be impossible in a stone. For milling-tools and for small machinery a wheel of small face will resist a lateral pressure which would crack a stone of same size and shape. The harder emery-wheel revolving at its high speed will do truer work also than the grindstone. This is independent entirely of the manufacturing capabilities of the emery-wheel, as in stove-plate work, wrought-plate work, fettling castings, small hardware, cutlery, etc.

The solid emery-wheel is an American invention. The special differences in the different makes arise from the qualities and defects of the cementing vehicle. This cement should possess certain properties. It must be strong enough in its cohesion to resist the centrifugal force due to the high speed of revolution. It must not soften, warp, split, or crack under heat or pressure, nor should it become brittle by cold. It must not dilute the emery too much by forming too large a percentage of the wheel mixture, and must permit such an intimate mixture with the emery as to produce a wheel of uniform density throughout with the same strength and texture. If it fails in this quality, the wheel will run out of balance in service, which is fatal to its usefulness and safety and durability. The cement must not glaze by fusion or combination with the cuttings, nor must it be so resistant as to make the work heat unduly from the necessity of wearing away the cement in order to get at the particles of emery. It would seem that an ideal cement to prevent these two latter difficulties would be one which wore away as fast as the crystals of emery lost their sharpness, so that the latter should be thrown off when their cutting qualities were lost. It will be seen, therefore, that the two conditions of free cutting and durability in a wheel are in a sense antagonistic, and the most that can be done is to effect a compromise. While, therefore, all should attain safety in use, durability and permanent sharpness cannot both be attained at once in any make of wheel.

Of the various cementing materials hard rubber or vulcanite was one of the earliest. Other makers use the gum from old leather acted on by acid, japan, and linseed oil, glue, silica with calcined chloride of magnesia, or "bittern" water, oil, and litharge, calcined chloride of zinc, celluloid and vitrified feldspar, or quartzose material. Most of these require the use of high hydraulic pressure in molds, a 12-inch wheel receiving a pressure of from 150 to 250 tons. One maker puts a circle of brass-wire netting in the center of the wheel to prevent accident in case of rupture. The same maker obtains the pressure for the mixture by the application of heat to the solidly-bolted molds. The hardness of the resulting wheel may be varied by the amount, by weight, of the mixture which is put in a mold of given capacity. The material undergoes a partial vitrefaction in the process of heating, by which the volume tends to increase. To secure balance in one make the four quadrants of the disk are filled separately, and are put in the mold in Russia-iron cells. Each of these is carefully weighed, so as to contain exactly the same weight of mixture when the cells are withdrawn. In the vitrified wheels the formed disk is exposed to a high heat in a kiln, by which the feldspar or its equivalent is partly fused and the wheel becomes as nearly like what a natural one would be as artificial means will admit. In one of these wheels the calcining makes the wheel porous, so that it is lighter in weight than when mixed. This permits the wheel to receive water at its axis and deliver it at its circumference, keeping the cutting-surface moist and cool without throwing an excess. Many of the wheels are fitted with a brass or lead bushing at the center, in order that a possible high temperature may not break the wheel by its expansion against a tightly-fitting mandrel. The wheels are held between flanges when at service, screwed up by a nut. It is often judicious to pad the flanges with leather, but is not essential with many makes. These vitrified wheels may also be run in oil for buffing or polishing work. More usually, however, this is done by wooden wheels, which are covered with leather on their face. The leather is coated with glue, and the emery is dusted on, or else the wheel is rolled in the emery. There are many of the cements which will not permit the use of water, and oil cannot be used on others. The glue wheels are likely to give off an odor in service.

To turn the emery-wheels to true cylindrical surfaces and to effect a complete balance the black diamond or bort is used. The wheel is chucked on a mandrel, and is faced on the periphery and on the ends. Any defect in balance is corrected by lightening the flat face. The wheels are graded by numbers. The lowest numbers, 8 to 10, give a duty about equal to that of a wood rasp; number 40 is about equivalent to a bastard file; number 80 corresponds to a smooth file; and 120 about equals a dead-smooth file. Flour emery gives a fine finish, without any especial sharpness of cut. The wheels may be molded and turned of any especial profile, as called for by varying classes of work. Some of these will be alluded to in the sequel.

Figs. 321 and 322 illustrate the ordinary form of emery grinder for general shop use. One carries two wheels, often of differing grades or profiles, with separate rests. One of the rests at least is arranged to act at the side of

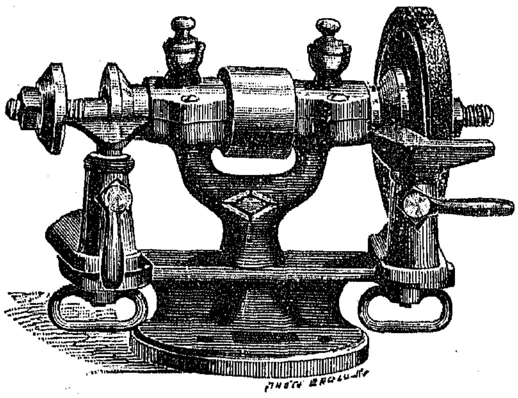

Fig. 321.

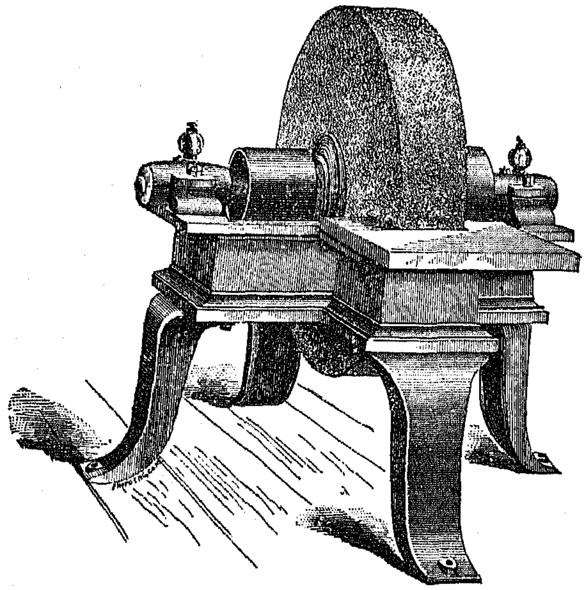

Fig. 322.

the wheel as well as at its face. One of the essential features of such machines is the proper protection of the bearing from the dust and grit which fly when the wheels are in use. In one design a ring outside the bearing is covered by a chamber in the long box, in which the grit will be caught.

Fig. 323 illustrates a compact standard grinder, with the self-lubricating boxes shielded by the cap. One of the wheels is plain, and the other is beveled for milling-gear cutters. A special attachment for cylindrical mills may be added.

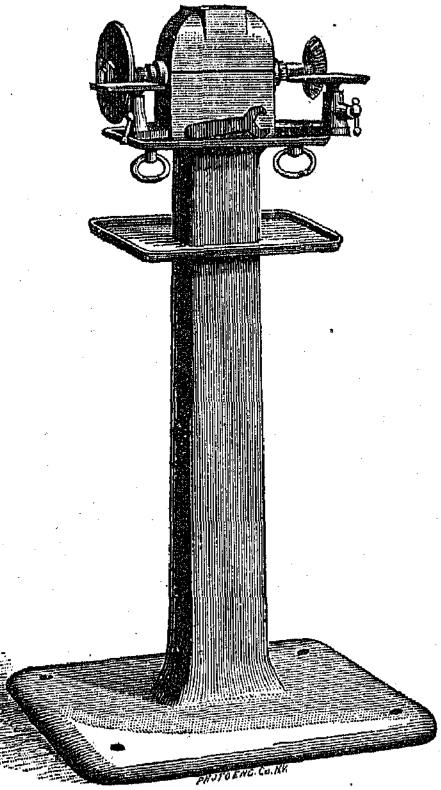

Fig. 323.

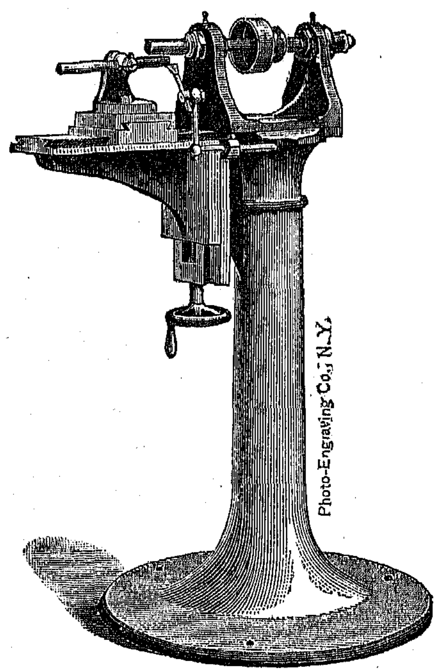

Fig. 324.

In Fig. 324 the grinder is especially designed for milling-cutters. A mandrel has a universal adjustment, vertical, lateral, and angular. An adjustable guide rests against the tooth which is being ground, by which the work may be gauged perfectly. Straight, taper, or spiral cutters may be ground with this machine, and it may use grindstones as well as emery-wheels.

Fig. 325 illustrates a double emery grinder, with universal milling-cutter attachment. The bracket swings to any angle and may be clamped, and a guide secures accuracy. Work may also be held on centers or in a vise.

A convenient form of bench machine, holding the cutter on a mandrel between centers which are adjustable, is shown by Fig. 326.

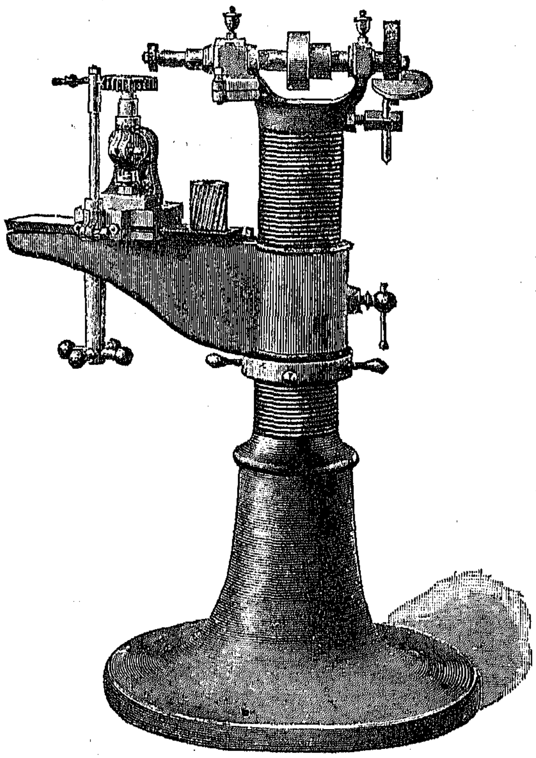

Fig. 325.

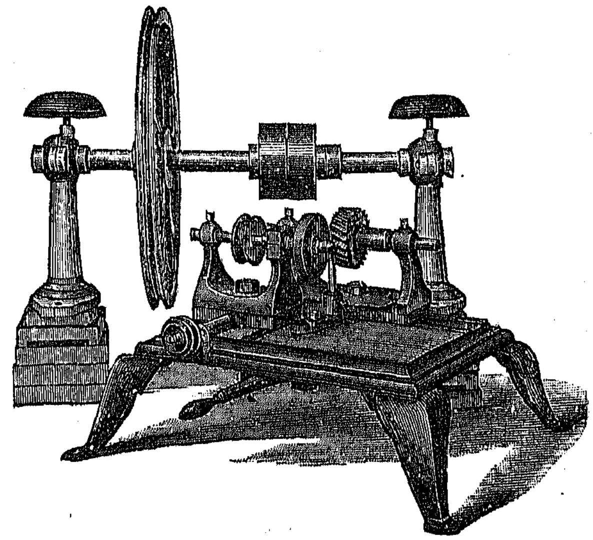

Fig. 326.

Of the special emery grinders perhaps one of the most important is the grinder for twist-drills. These should insure equal cutting duty on both edges and a proper relief or clearance while retaining them at a proper angle. Fig. 327 illustrates one form with the drill in position. The bar which guides the socket of the drill is placed at an angle with the horizontal traverse of the emery-wheel. This angle is experimental, and does not vary in the

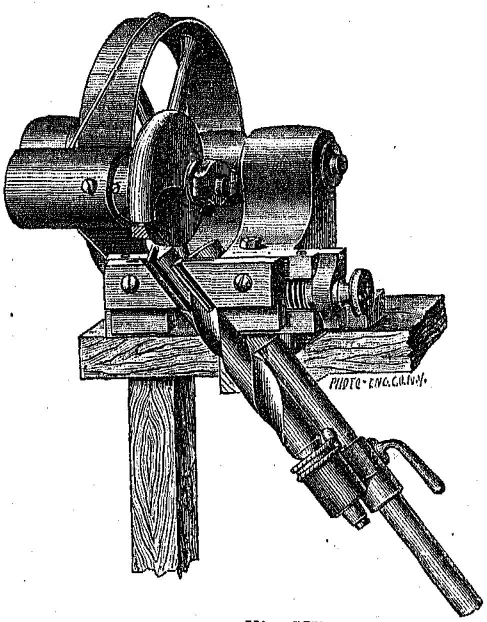

Fig. 327.

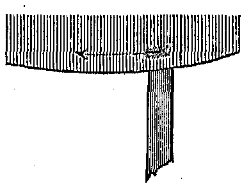

Fig. 328 *a*.

Fig. 328 *b*.

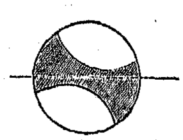

Fig. 328 *c*.

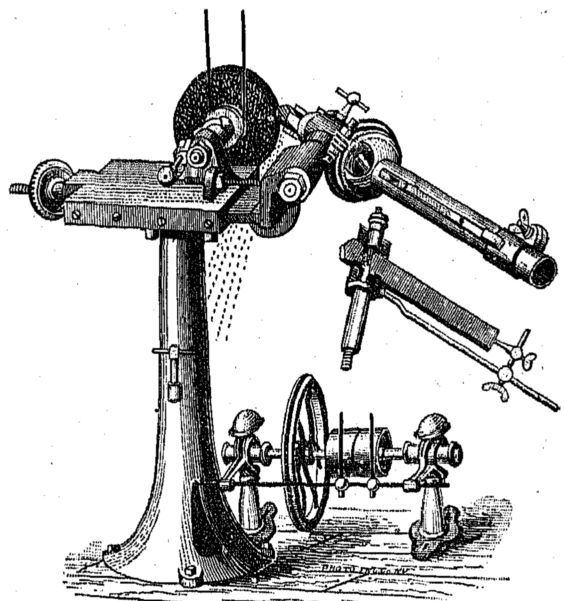

Fig. 329.

different makes very far from 45°. The drill is placed with its edge parallel to the path of the emery-wheel across the face, and receives clearance for its cut near the edge only. When one edge has been dressed to a true line the drill is turned on its axis through 180° by an index on the clamp for the socket. The vise at the lip is tightened anew, and the wheel makes its traverse.

For flat drills this tool gives all the clearance necessary (Fig. 328 *b*). Twist-drills require that the increasing clearance for the longer heel be given by hand, by backing off from the ground surface upon a second stone (Fig. 328 *c*).

In the machine shown in Fig. 329 the drill is held by a hollow spindle, which terminates in four jaws. These jaws are tightened upon the drill by worm and wheel. This spindle is attached to an horizontal arm which is not in its plane, making a projected angle of about 45° with it. This horizontal arm serves as center of motion for the spindle and the drill which it holds. As the lower end of the spindle is revolved upward the lip of the drill comes against the stone first. As the spindle is lifted further the heel of the edge is swung closer to the stone, and thus the relief is given. To secure equality in the two edges an adjustable stop abuts against the lower end of the drill, and the forward traverse of the emery-wheel may be controlled by stop-nuts upon a screw on the slide. The slide is moved by a hand-wheel. By this machine the lips of the drill will be of the same angle and length, will center in the axis of the tool, and will have clearance or relief increasing away from cutting-edge. This secures a durable edge to the drill, and the holes bored by it are more likely to be of the same diameter as the drill.

In the grinder shown in Fig. 330 the emery-wheel is a tub-wheel, which is a cylindrical wheel hollow in the

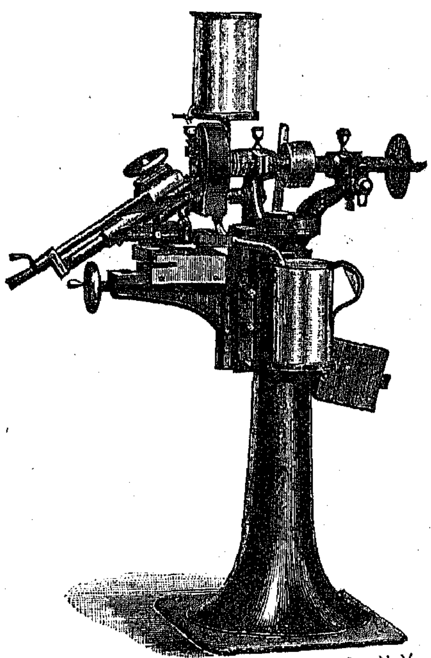

Fig. 330.

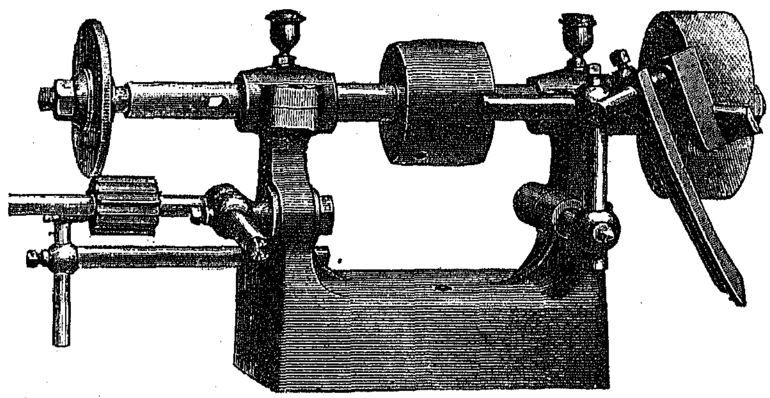
Fig. 331.

center, and which grinds upon the edge only. The builders prefer a vitrified wheel, which receives water in the middle of the hollow and delivers it to a drain below. The spindle is swung on a similar arm not in its plane at the proper projected angle. This arm is vertical. The drill is clamped by right-and-left screws, and the table which carries the vertical arm is moved toward the wheel by a feed-screw against stops for equal prominence of lip. The knee-table rises and falls by lever and counter-weight, so as to wear the face of the wheel equally. The edge is put vertical by a guide on the jam of the holder, and the amount of relief may be varied by loosening a large central screw. A similar machine with mill- or shell-reamer attachment is shown by Fig. 331. The articles to be ground are properly supported, and are presented to the stones by hand only.

Emery-wheels are also successfully applied for grinding the knives of wood-working planers and saws. Such a machine is shown by Fig. 332. The wheel used is known as a tub-wheel, which grinds upon the end only. By the use of this form the concave edge is avoided, which will be caused by the use of the face of a disk-wheel. Stop-gauges compel the knives always to stand at the same angle so as to receive the same bevel at every grinding, so that no unnecessary metal is successively ground away. The knife-carriage is fed back and forth by power. For sharpening saws the face of the further wheel is beveled and the saw is held upon a mandrel on a slide. The usual profiles for these "saw-gummers" are shown by Fig. 333, which also illustrates forms which may be required if the second wheel be intended for the cutters of wood-molding machines. Fig. 334 shows a gummer mounted upon universal joints, by which it can easily be presented to its work.

But in addition to its uses as a tool-sharpener the emery-wheel and grinder may be applied as a shaping-machine for general or for special manufacture. It can only be used with economy upon surfaces which are *nearly* correct, or upon those for which the reciprocating or milling cutter are not applicable. To this class belong the tools for acting on hardened steel, and for shaping and removing the fins from sandy castings. Fig. 335 illustrates a special machine for this latter duty, where beveled surfaces may occur frequently. In place of the conical wheel any other shape may be used, or a pot-wheel may be put on for dressing the inside of hollow ironware. The table can be tilted for any degree of bevel, and the spindle is carried in boxes upon a guided cross-head, which may be lifted by the hand-lever. By the use of false tops with centers and clamps stove plates may be turned and beveled with great rapidity, and the machine may be applied to a variety of miscellaneous work. Horizontal grinders are also applied very generally for this type of duty.

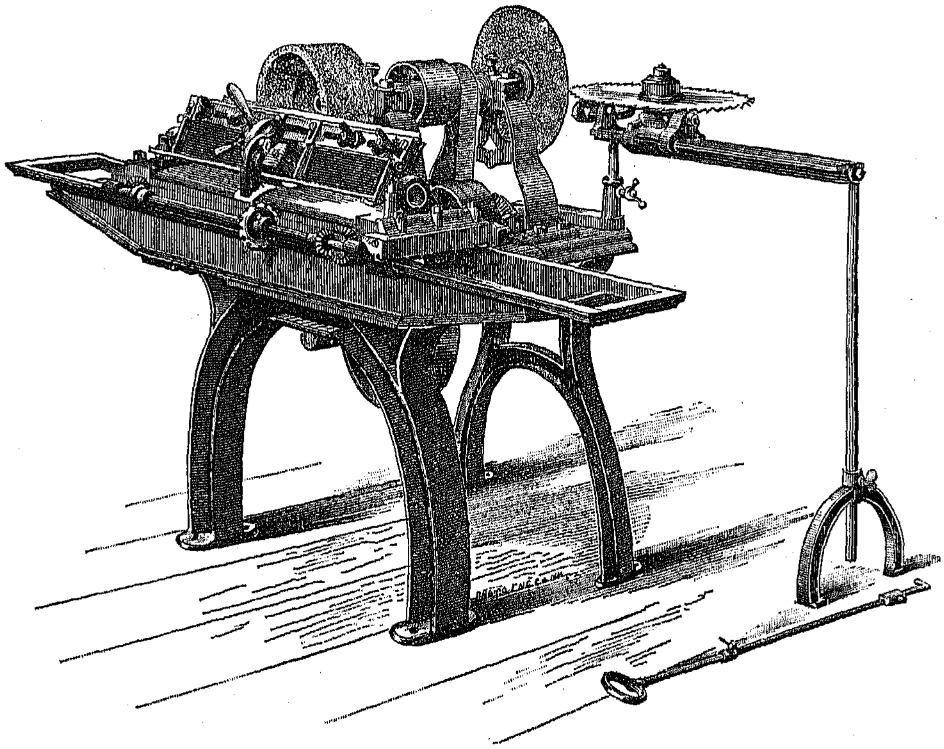

Fig. 332.

For work upon hardened-steel surfaces of revolution the lathe shown by Fig. 120 has been alluded to, with the emery-wheel mounted on the carriage and receiving a traverse motion automatically from the driving-head. A tool of similar principle is also used for grinding into approximate truth the treads of chilled car-wheels. Both wheels may be trued at once as they revolve with their axle held between centers. The emery-wheels are fed by a slide-rest mounting. For grinding taper work, straight or curved, as well as cylindrical pieces for arbors, cutters, etc., the machine of Fig. 336 has been designed. There is a movable table on the top of the primary, which may be swung around its center by a tangent-screw and graduated arc, so that the centers are always truly in line. The longitudinal feed is by rack driven from open and crossed belts, which are clutched to the train by appropriate stops on the table. The clutch cannot stall, because the device of a spring wedge is applied to it. By this machine straight and taper holes may be ground, such as hardened boxes and standard ring gauges. The

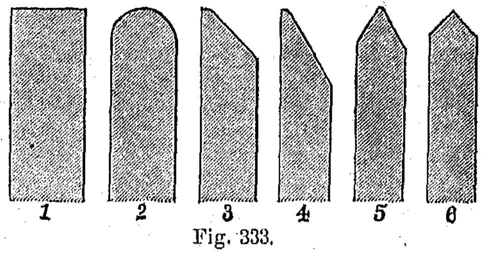

Fig. 333.

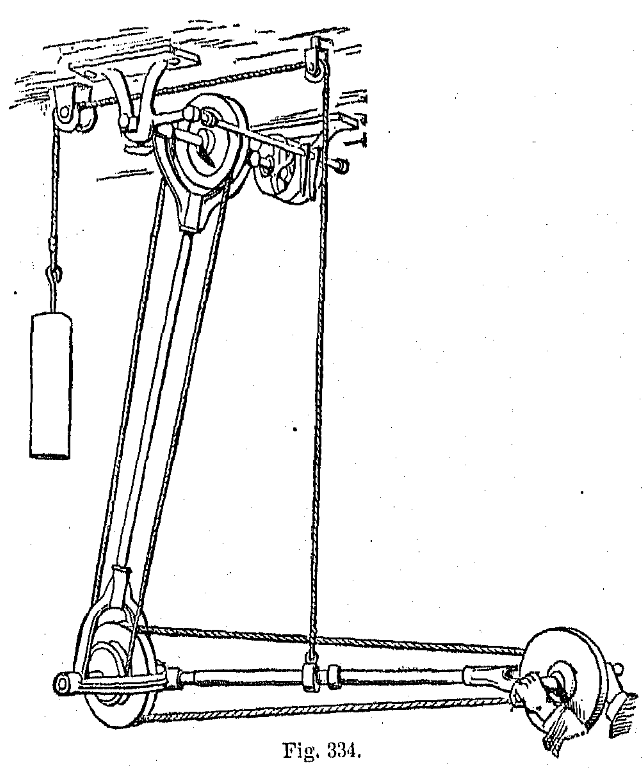

Fig. 334.

wheels may be used with or without water, and all the working surfaces and slides are protected. Wheels from one-fourth of an inch to 12 inches in diameter may be used. Graduated arcs assist in setting the work for taper grinding either external or internal.

Figs. 337 and 338 show similar machines.

For flat and true surface grinding and finishing of hardened or soft work the machine of Fig. 339 has been designed. It is to act as an effective substitute for filing, scraping, and stoning. An emery-wheel is hung from

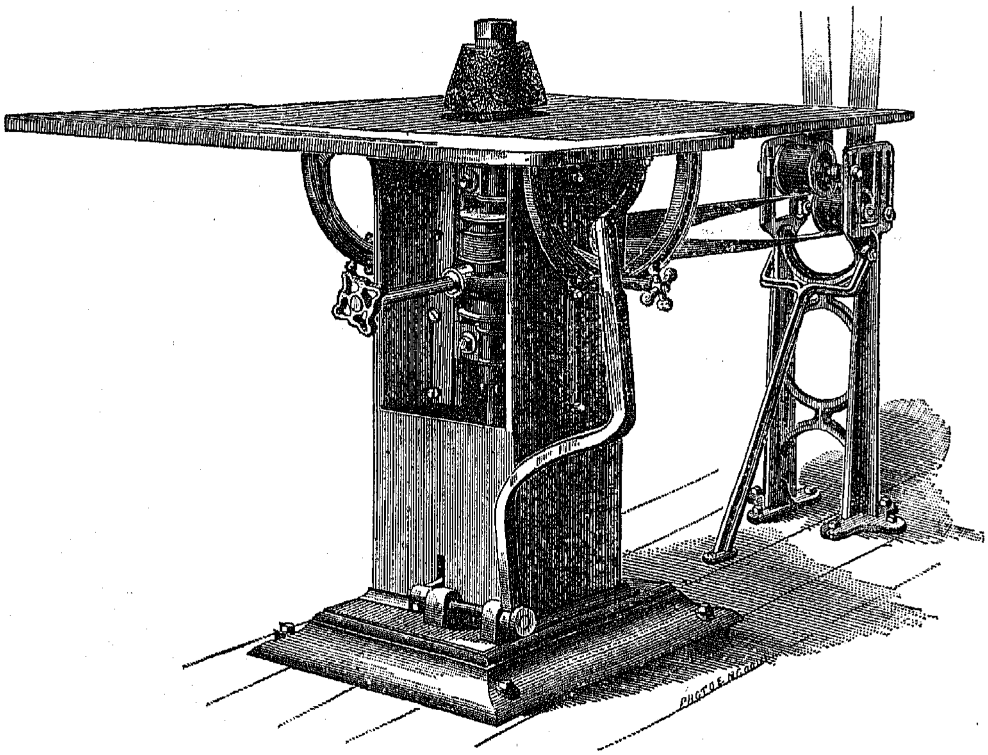

Fig. 335.

the cross-head, and is driven from the long drum at the back. The adjustment of the cross-head takes place around the axis of the drum as a center. The table is fed by a planer-gear with open and crossed belts, and the wheel-saddle receives a feed from a friction device through sector and ratchet. For punches, dies, flattening-dies,

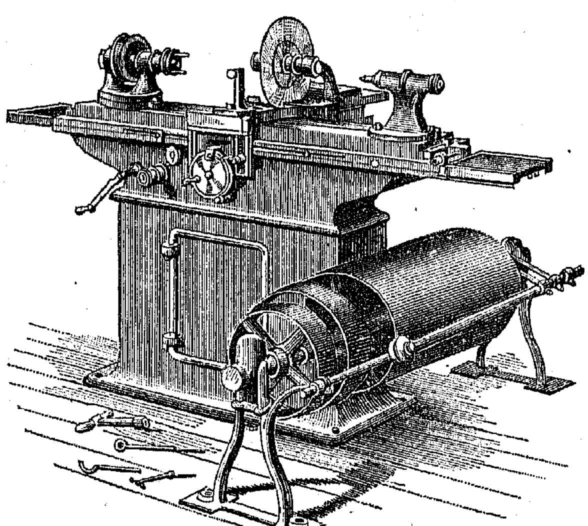

Fig. 336.

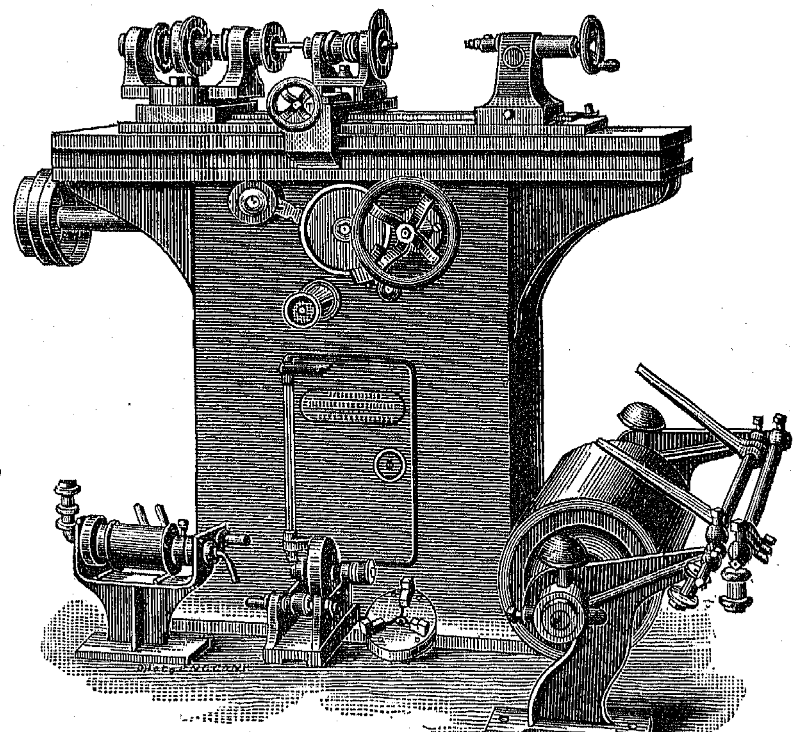

Fig. 337.

straight-edges, and work of that class, this machine is claimed to save three-quarters of the labor usually expended, and to replace the cost of files by that of the more lasting wheel. It is a machine which is a symptom of the demand for a higher grade of workmanship in many branches of shop-work.

For polishing purposes, the solid wheels are not much used, because a polishing-wheel should glaze, while a cutting-wheel should not. A few which can be run with oil may be used for polishing. More usually, however, for

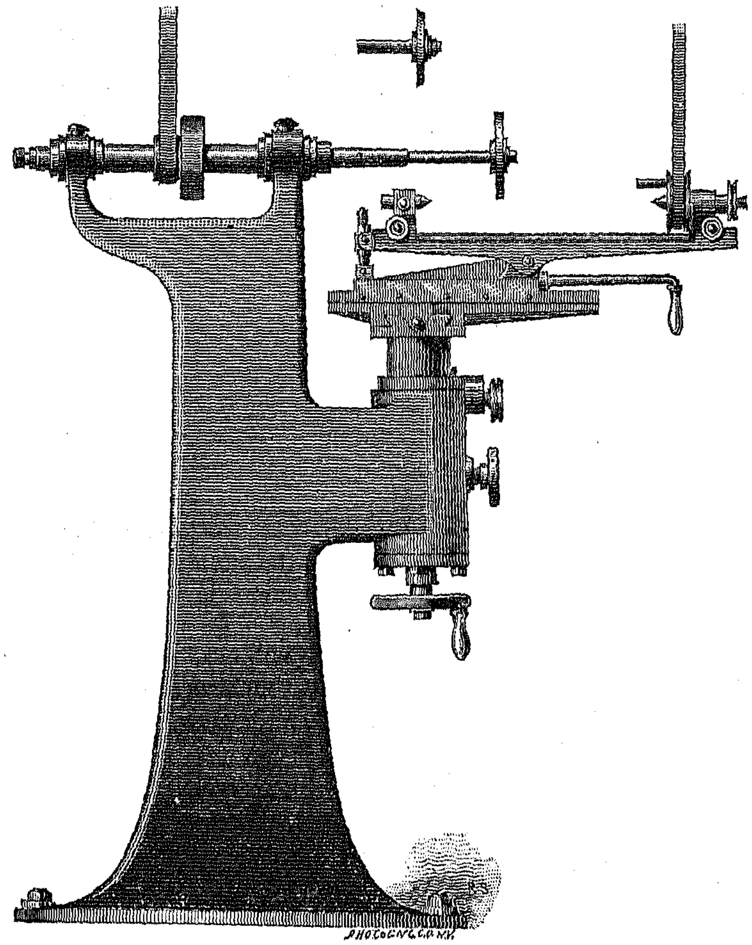

Fig. 338.

this service, as already stated, emery is used upon a leather face glued to a wooden wheel. This wheel is built of overlapping sectors, breaking joints, of selected wood which will not warp. These can scarcely be called emery-wheels, however.

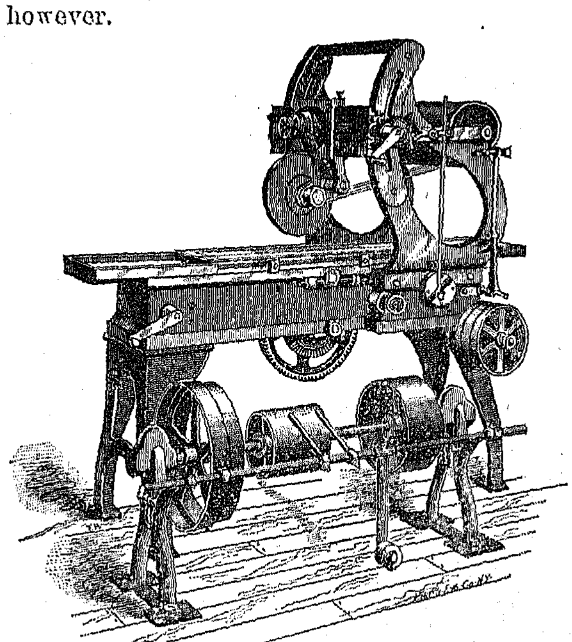

Fig. 339.

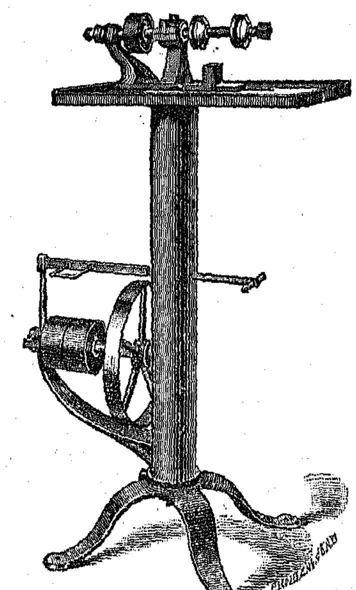

Fig. 340.

For fine buffing a leather-covered wheel is used, upon which the successive grades of emery may be used loose, from the coarsest to the finest required for the finish in question. For the most brilliant luster on brass-work a felt or cloth wheel is used, often known as a "rag wheel". Disks of the flexible fabric are secured between flanges, and centrifugal force gives them the necessary stiffness when revolved at high speed. Crocus-powder is used for the last polishing with wheels of this class. Their great difficulty is the jarring and chattering, due to lack of proper balance, which is increased by the leverage due to the usual overhang. The journals are apt to give trouble. In the machine of Fig. 340 the long central journal is tapering, and the other is cylindrical, with a tail-screw. By this means any vibration can be taken up. This machine is also adapted for light tool-grinding, with solid wheels. Its avoidance of end-play gives it special advantages for certain classes of such work. Special patterns of simple machinery for grinding hardened-steel rings on their faces are in use. The ring revolves by friction of a pair of cast-iron rings, the pitch lines of the steel and iron rings intersecting each other. The pair of iron rings may be made to compress the steel ring between them with any desired pressure, and the grinding is done with powdered emery and oil.

§ 34.

TOOL-ROOM.

A discussion of the machine-shop tools driven by power would be incomplete without a supplementary allusion to the contents of the tool-room. Every large establishment has a space devoted to the storage and repair of those hand-tools which need not necessarily form a part of the outfit of each operator, but which may be common property, accessible when needed. Every machinist either owns his own hammers, wrenches, scales, callipers, and the special gauges needed for his machine, or else they belong to the shop, which holds him responsible for their safety in his kit. Files and chisels which wear rapidly often come through the supply-room, and are kept separate from the more permanent tools. In some shops these two divisions are combined.

In shops which do any outside repairs or large erecting hand-drills will be required. For very small holes, where but little pressure can be put on the feed, the breast-drill will be of service. For heavier work the ratchet-drill is best (Fig. 341). The conical step at the top abuts against an arm clamped to the work. For very heavy drilling the ratchet-arm may be extended by slipping a piece of pipe on it.

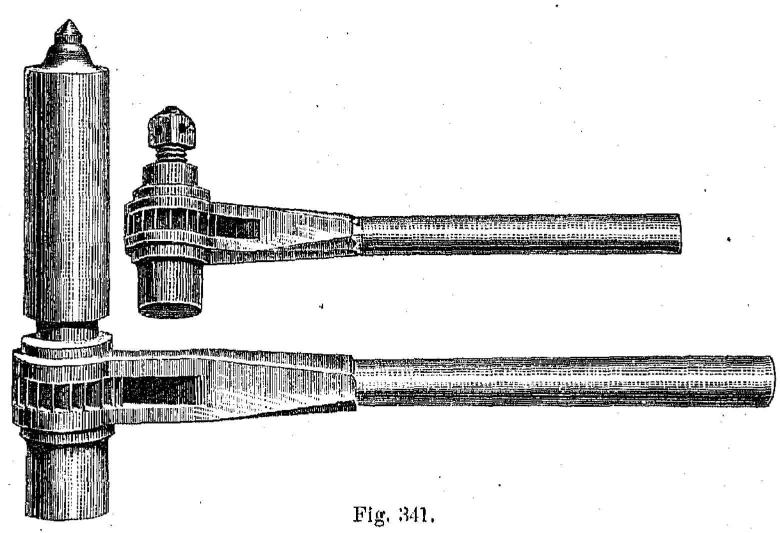

Fig. 341.

Fig. 342 illustrates an improved device by which the pawl on the arm may be either right or left handed, or may be disengaged entirely. The cut also shows how sockets may be introduced to accommodate drills with shanks of different shape.

The tool-room usually contains a full complement of drills of the usual sizes, and often those of unusual sizes. Those in most frequent use are often racked upon the drills themselves, the tool-room having duplicates. These drills consist to-day of a majority of flat or fly drills, which are gradually being displaced by twist-drills (Fig. 343). This displacement is in some shops complete. It will probably be so in all before long. Twist-drills are made with the taper shank as shown, or straight. The taper largely predominates. The newer ones are scribed with a grinding line on the hollows of each side. By working to this always the cutting-point will always be in the axis of the drill, and the hole drilled will be no larger than the drill. The drill-presses are fitted to receive a socket in a taper hole in the end of the spindle. This socket may either be keyed in the spindle by a steel key through a slot in both (Fig. 344) or the fit may be by friction. Sockets of different sizes will be used for larger or smaller drills. Those not in use will be in the tool-room, as well as special sockets for odd sizes. The milled tail of the shank prevents the butt of the drill from getting marred, so as to spoil the fit in the socket, and also permits of light keying in the slot. If pin-drills are called for by the requirements of the shop service, they will be kept here. They will be used for boring out a large hole, for which a small hole has been made in the axis as a guide.

For accurate cylindrical holes the simple drill will not answer. It will not necessarily produce a hole either straight or round. It is necessary, therefore, to bore the hole a little small with the drill and bring it to standard size by a reamer. The solid reamer (Fig. 345) enters the hole by a short taper, and enlarges it to the size desired. For very rapid work, as in bridge-plate, and especially for punched steel plate, the self-feeding reamer is approved. The short thread carries the tool rapidly forward (Fig. 346). For certain metals the reverse of this is desirable,

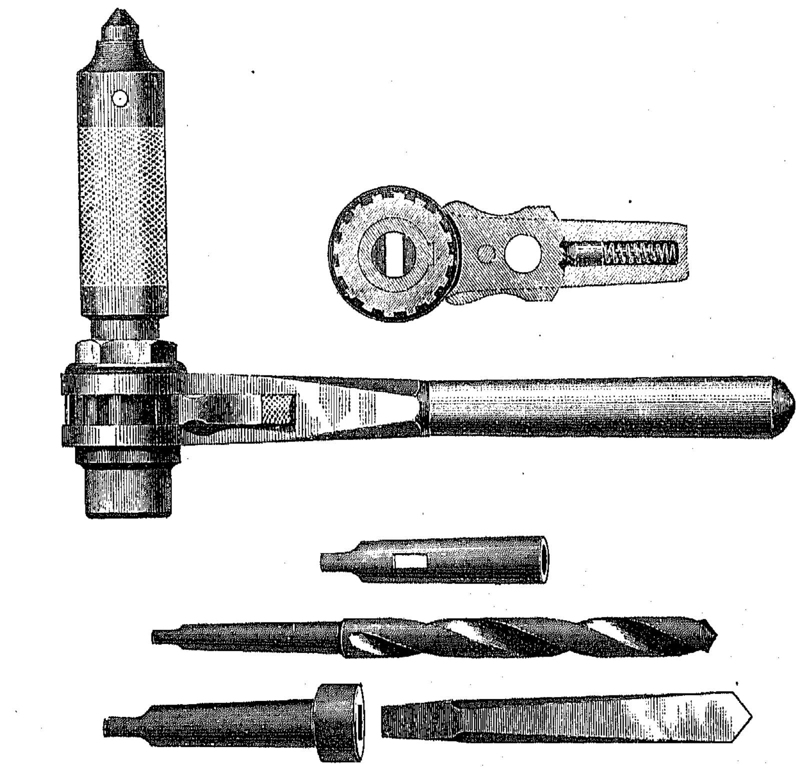

Fig. 342.

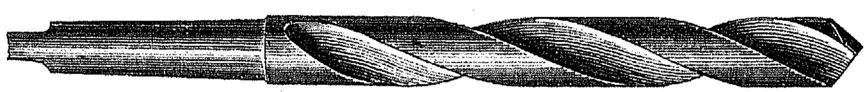

Fig. 343.

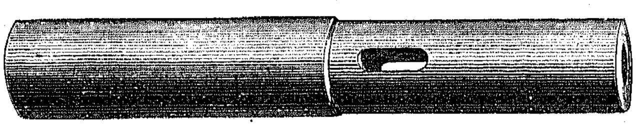

Fig. 344.

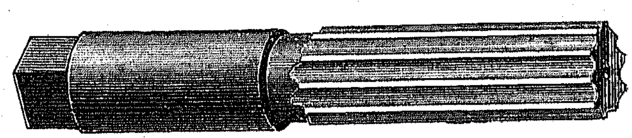

Fig. 345.

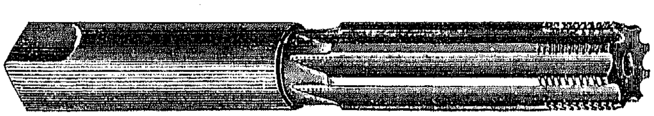

Fig. 346.

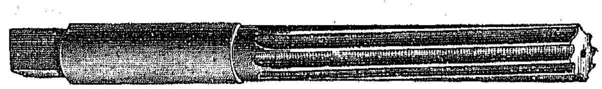

Fig. 347.

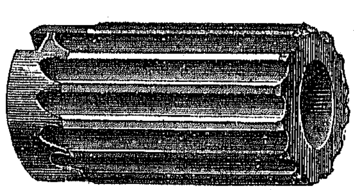

Fig. 348.

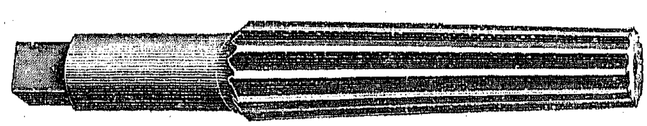

Fig. 349.

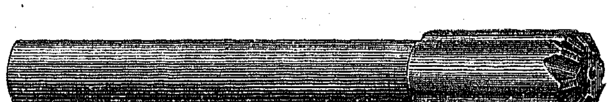

Fig. 350.

and even the plain reamer may feed itself too rapidly. To meet this case the relief reamer has the flutes inclined backward, so that a dragging cut is produced (Fig. 347). The shell reamer works upon a central guiding-spindle (Fig. 348), and the taper reamer (Fig. 349) acts simply to enlarge a hole without exact regard to its truth. The rose reamer (Fig. 350) is usually arranged to be chucked in a taper socket, for producing countersinks and similar duty.

After the production of the holes will be the cutting of screw-threads upon them if they require it. Fig. 351 illustrates the usual forms of taps for bolt- and nut-work. Fig. 352 is the long tap for threading the two surfaces of stayed work so that the screws may fit both.

Fig. 353 illustrates the usual form of pipe-tap, with the standard threads for gas and steam fitting. Fig. 354 illustrates a larger size, with inserted cutters in grooves in the body of the tap.

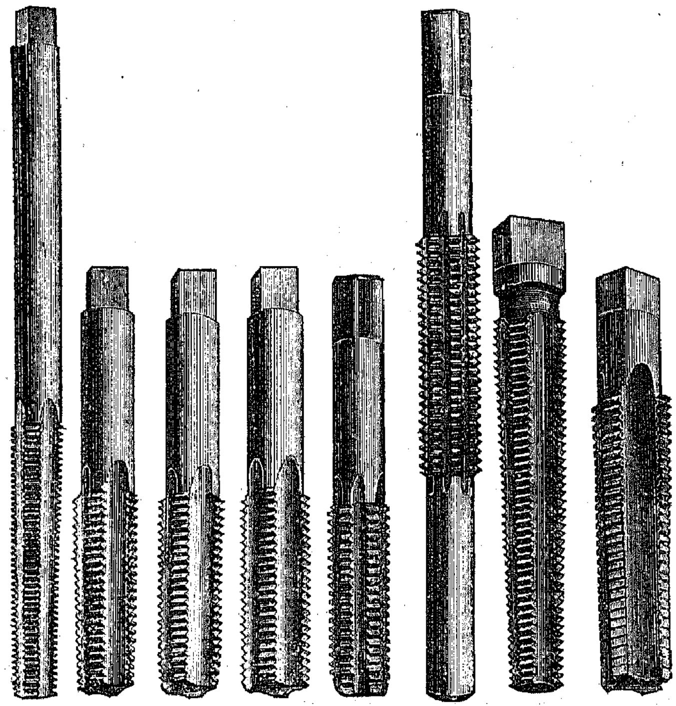

Fig. 351.

Fig. 352.

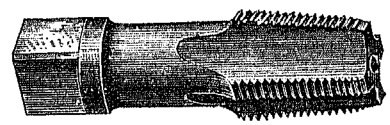

Fig. 353.

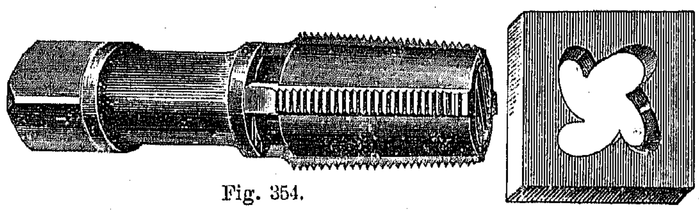

Fig. 354.

For turning these taps a special form of two-handed wrench is used. Fig. 355 shows one form, where the two halves of the square are closed by screwing in one handle. In the other form (Fig. 356) the two halves are brought together by a milled scroll disk and held by a latch.

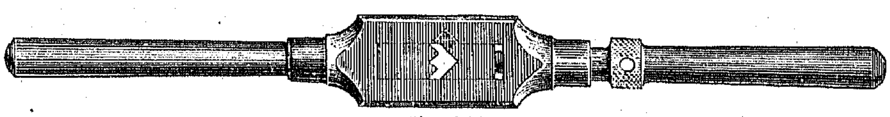

Fig. 355.

For cutting the threads upon bolts and studs by hand a stock with open dies is mostly used. The dies are either milled to fit tenons in the sides of the opening of the stock, with a blank distance-key in the bottom, so that the dies may be changed, or some improved device is used.

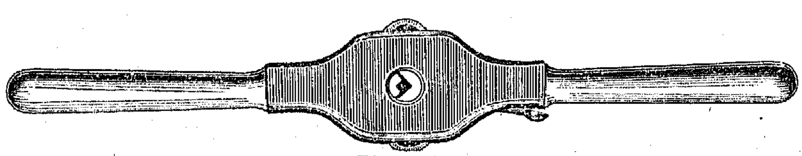

Fig. 356.

Fig. 357 illustrates a convenient one, in which the dies are held by the long arms of the bent levers, which are tightened in sidewise by the pressure of the adjusting binding-screw. When this latter is released, pressure on the stud releases the dies. So simple an arrangement is this that it may be wise to use the stock as a tap-wrench by replacing the dies by blanks.

Figs. 358 and 359 show details of stocks and solid adjustable dies which cut a thread with one going over. The details for taking up wear will be visible from the cuts. For pipe-dies solid dies are most usual of the form shown by Fig. 354. These are held in a stock of the shape of Fig. 361, which has a leader-screw for securing the proper starting of a large thread. This will be used only for sizes over one inch. Bushings serve to guide the die straight. For small work not infrequently the combined stock is used (Fig. 362), the dies being laid in and covered with the cap-plate as in the larger sizes. Above 3-inch pipe the stock must have sockets for removable arms, because otherwise the vises would not be high enough to let the longer arms clear the floor. There are usually

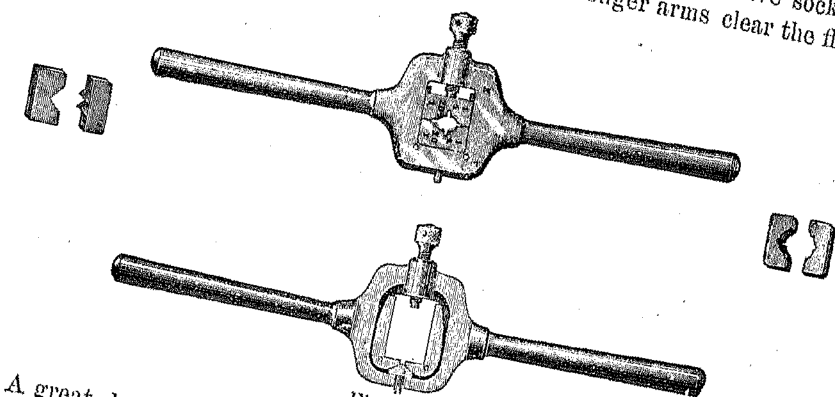

Fig. 357.

sockets for four arms. A great deal of shop-work on pipes is now done by machine. Su an outfit will be for job-work only. Cutters and tongs for the different sizes complete the set. Fig. 363 illustrates an open die-stock. The compression and adjustment is effected by the screw, which is capped over by the hollow handle.

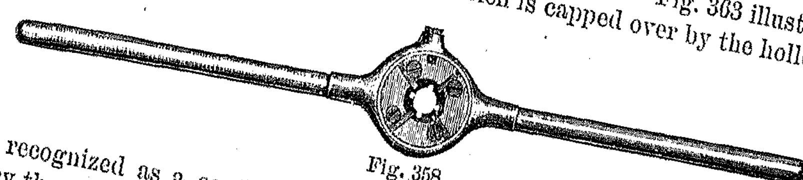

Fig. 358.

It has long been recognized as a corollary to the system of the division of labor that greater accuracy of calibration is necessary than the ordinary scales and calipers will admit. When a number of different men are working at different parts of a job which is finally to be assembled it is only possible to economize time in the

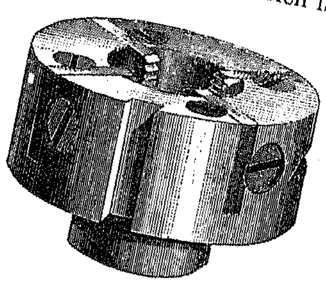

Fig. 359.

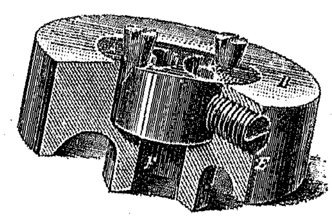

Fig. 360.

fitting operations by securing very great accuracy of dimension. To secure this end many of our best establishments have in their tool-rooms a set of standard gauges, external and internal (Figs. 364, 365, and 367), which are of hardened steel, and are used to set the common calipers, instead of graduated scales. Were they used as

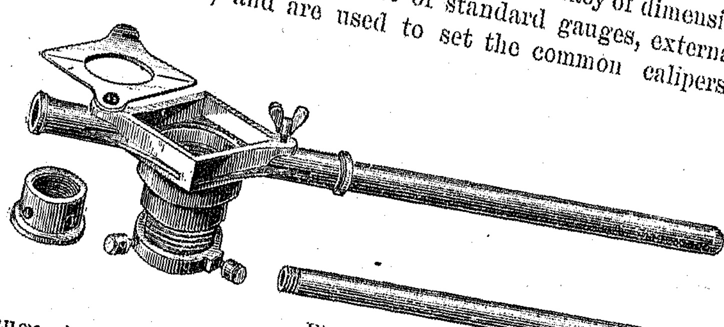

Fig. 361.

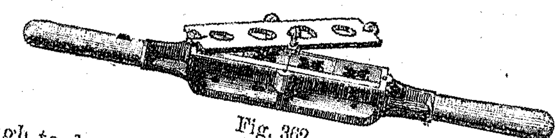

Fig. 362.

gauges in the shop, the wear on the hardened steel would be enough to destroy their accuracy. They may be used to test a set of shop standards, which may be thrown away as they lose their truth. For general shop use several of the exact-tool makers are making the type of gauge shown by Fig. 366 for external and internal calibration. They may be of steel, or one builder is using wrought iron, case-hardened, as preferable. The form of screw-thread gauge is shown by Fig. 365. For fine calibration and adjustment of special tools a tool-room often requires vernier calipers. Figs. 368 and 369 illustrate two forms of differing capacities. These will both read by the vernier down

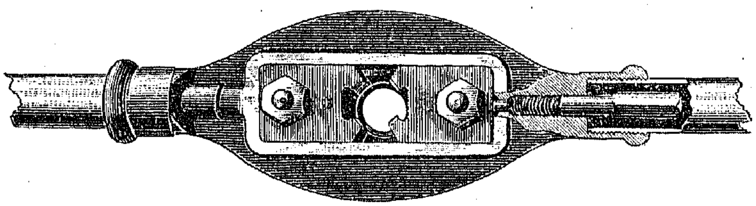

Fig. 363.

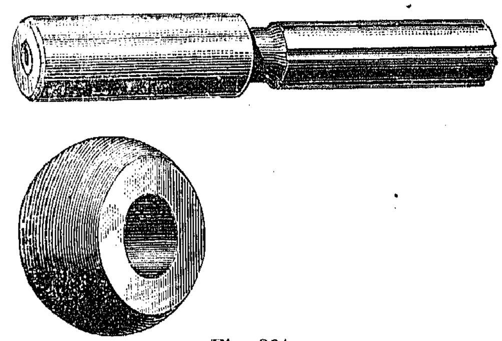

Fig. 364.

to one-thousandth of an inch. The smaller one has an adjustment to secure accuracy after wear. These are not in general shop use as yet for larger types of work. Special gauges, scales, straight-edges, surface-plates, angles, rules, and standards may be called for over and above these for special branches of manufacture. A very few of the shops are provided with an especial machine for exact measurement. By micrometric devices these will read to a high limit of exactness. It is not within the scope of this discussion to describe them more fully.

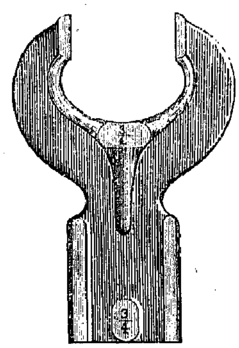

Fig. 366.

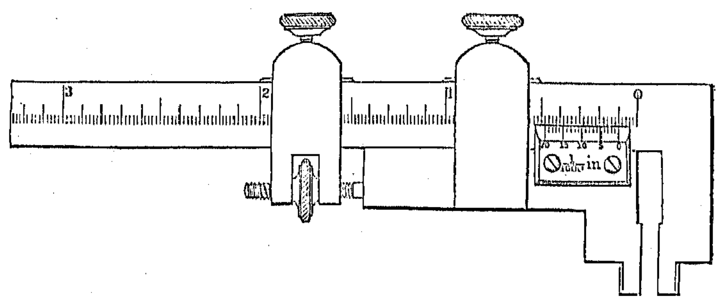

Fig. 368.

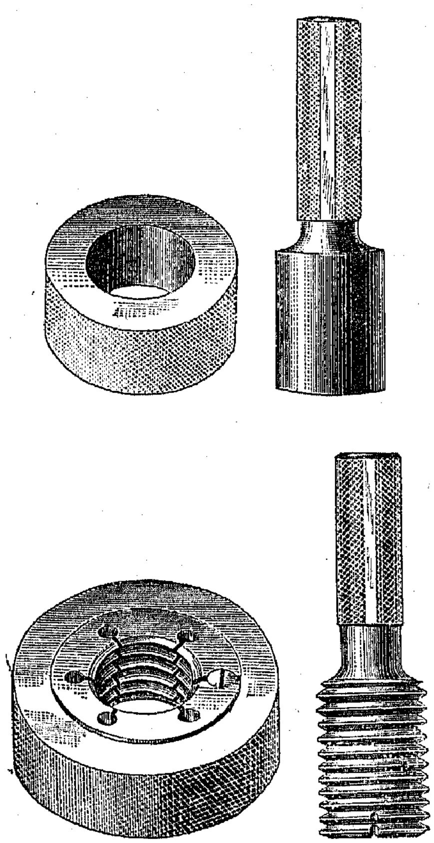

Fig. 365.

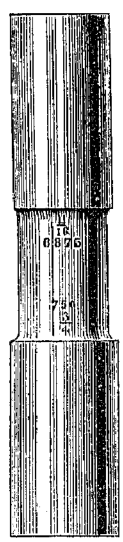

Fig. 367.

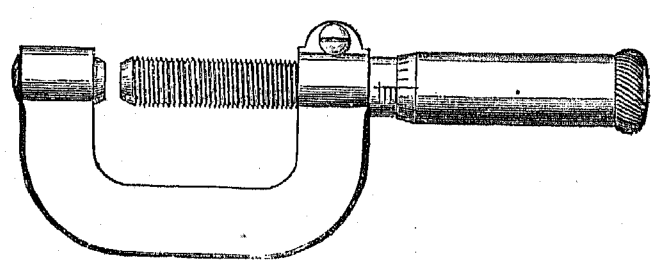

Fig. 369.

Where milling-cutters are used in any variety the tool-room furnishes them and usually keeps them in order also. For all the work on tools in the tool-room, both general and special, the machine-tools characterized by their universality and exactness are best adapted. It is for such uses that the milling-machine and the emery grinders are very frequently applied.

§ 35.

It has not been thought necessary to enter largely into the subject of the linear capacity of the tools discussed. Such information is easily accessible to those who wish it. Neither has special commendation been awarded. Those who are expert in such matters will detect from the descriptions those features which deserve it. But it may not be amiss to call attention to two points which have had a great influence in raising the standard of machine-tool manufacture in this country. The first is the increasing respect for the small decimal subdivisions of the inch and a more complete understanding of their significance. This is manifested in the prevalence of the use of exact standard gauges, and by the increased strength and stiffness of the designs of the newer tools. It is understood that properly distributed weight of metal is necessary and desirable, and a heavy tool will do light work far more accurately than a light one can do heavy work. By proper resistance to the strains of the cut the tool is *expected* to do exact work, and its designer and its maker do not and should not rest till it accomplishes that end. The second point is the increasing prevalence of hand-scraped surfaces, tooled with a hook-scraper and worked up to true planes. The use of the file and emery-cloth to produce a finish pleasing to the eye only, while the surface was mechanically untrue, is a thing of the past in our best shops. By this advance every bearing surface bears all over, and not at a few points only. Wear is diminished, and the motions take place in true straight lines.

A third point might be the extended use of hardened steel, ground and lapped. The truth of the fit originally made by the maker remains for a long time to benefit the user.

It is for these reasons, and for others which might be adduced, coupled with the mechanical genius of their designers, that American machine-tools have reached the degree of excellence which characterizes the best of them.

PART II.—WOOD-WORKING MACHINERY.

§ 36.

It is proposed to discuss the class of wood-working machinery between the limits which are parallel to those established for the machine-tools. The forest-sawing of the lumber will be considered as preliminary to the tools in question. This is the limit parallel to the metallurgical tools and processes for the metals. It is equally out of the aim of this section to enter on the subject of the special tools which have an important bearing in one or two lines only of special manufacture, such as chair, barrel, sash and blind, wheel machinery, and the like. This limit corresponds to the further limit of the previous discussion. Between these two limits lies a large class of those general tools which are of universal or extended application in house- and car-building and in the pattern- and carpenter-shops of engineering establishments. These are of primary importance, and will be brought under notice.

The differences between the metals and the woods give rise to very marked differences in the structure and in the action of the tools for the two classes of material. On account of the softness of the woods relative to the cutting-edges, wood-workers permit and demand that the conversion into the required shape should be rapid. Revolving cutters will therefore predominate, and they will be driven at the highest speeds. The high speed is also necessary on account of the fibrous character of the woods. At slow speeds, the surface would be more likely to be torn than to be cut by the shaping-edges. It is the existence of the fiber or grain of the woods which gives rise to the different methods by which wood-working tools operate. These are:

F.—By scission.

G.—By paring.

H.—By combinations of these two.

I.—By abrading.

The tools acting by scission are those which act to sever the fibers of the woods across the grain. This class includes the numerous varieties of saws. They might also be called tools acting by disintegration, since they penetrate and shape by reducing the material in their path to a fine dust. The second class, which acts by paring, would include those which produce shavings or chips by acting upon the fibers in the direction of their length. Such would be the surfacers, planers, matchers, friezers, and molders. The tools of the third class would be those which act upon the fibers both lengthwise and crosswise. They must therefore partake of the capacities of both the others. Such are the lathes, boring-machines, the mortisers, rotary and reciprocating, and the gaining-machines. In these tools there must be a spur or saw-segment to sever the fibers before the chisel-edge can pare away neatly the material to be removed. The class of machines acting by abrasion or grinding includes the sand-paperers and the like. These, however, are rather for ornamenting or finishing the work of other tools, and are therefore secondary. It is the saw and the chisel of the handicraftsman which furnish the basis of all the wood-working machinery. The plane, the gouge, and the bit are themselves deductions from the primary two. The sand-paper and the file are the originals of the abrading-machines.

§ 37

F.—SAWS.

RESAWING-MACHINES.

There are several reasons why the forest-sawing of lumber to small dimensions is impolitic. It is best to make the logs up into squared stock only, and thus to transport them to the purchaser. Among these reasons are that the thin green lumber will warp and dampness and sun will check the ends. There will be great loss of lumber from the wide kerfs of the log-saws, and the grit, which will adhere to the great surface exposed, will induce the surfacers to take a heavy chip to get under the grit, so as to avoid ruining their knives. For these reasons, and for others connected with the storage of the lumber in yards, machinery for resawing squared stock, either seasoned or kiln-dried, has become of increasing importance as lumber becomes more valuable.

Resawing machinery is of three classes. The first includes the vertical reciprocating saws, the second includes the circular resaws, and the third embraces the band resaws. There are certain features which are, or should be, common to all. The planks are presented vertically to the saws by the means of four vertical rolls, which are driven by power. These may be arranged to center equally upon the saw, so that it shall bisect any plank presented to it, or one pair may be clamped at one side, so as to act as a guide to insure that equal thicknesses shall be cut for every board. In this case the other pair yields slightly, to compensate for varying thicknesses of the rough stock. For bevel-siding, for clap-boards and similar work, the whole roll-mounting may be swung so as to present the lumber obliquely to the plane of the saw. Their other functions must not be interfered with in this case. Several special features will be alluded to in the sequel.

Fig. 370 illustrates a simple open type of vertical resaw. The saw is strained in a sash or gate of wood, driven by two pitmen from the balance-wheels overhead. Wood is used for the sake of lightness. The feed is given by

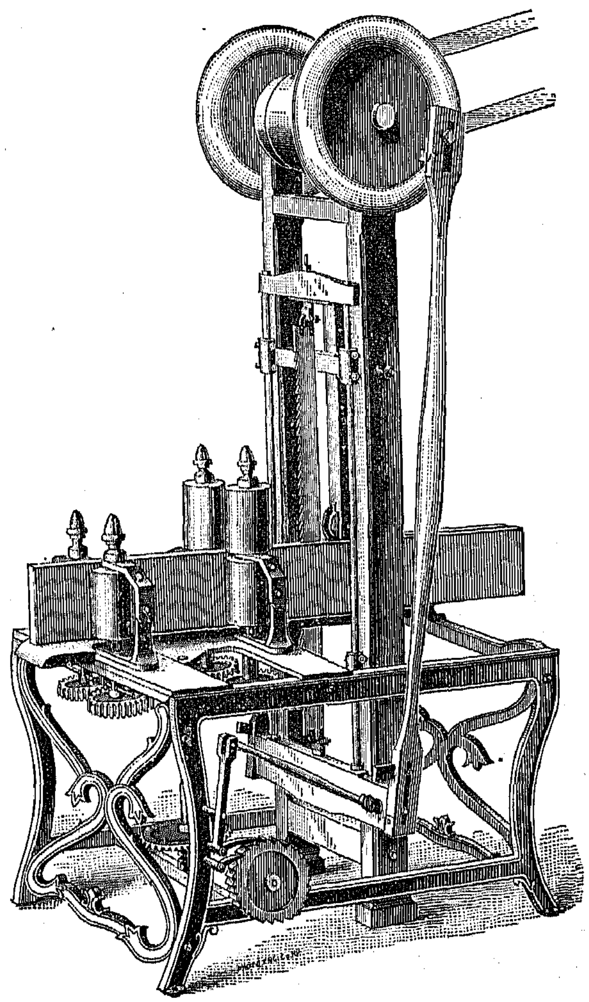

Fig. 370.

lever and dog from the gate to the gears on the roll-spindles. The stock is kept from rising by an adjustable roller, which carries a flange, and acts to wedge open the cut. The rolls have their secondary bearings adjustable. The intermittence of the feed relieves the saw in part on the up-stroke.

Fig. 371 shows a larger and heavier type, with the balance-wheels below. The pitmen have adjustable stub-ends, to take up wear and to insure equality of length. The rolls are driven from a separate belt-wheel, and are adjusted laterally by the levers and links from in front. A spiral spring controls the feeding pressure, and the feed is continuous. An adjustable weighted device keeps the plank from rising with the lift of the saw, which tendency is increased by the continuous feed. A still larger type is shown by Fig. 372, where the gate is of iron and the pit below accommodates the pitmen and wrist-plates. The gang-saw, with several plates in one gate, does not seem to have been generally applied for fine resawing. It has been approved for heavier work more extensively.

The strained vertical saw has the advantage of economy of kerf. A very thin blade may be used, and made wedge-shaped in section. To be opposed to this is the slow speed of feed—from 4 to 6 feet per minute, according to the width of the board. This is due to the necessarily slow speed of reciprocation, and to the fact that the saw is cutting during only one-half of the time.

The circular resaw is in most general use at this date. It has the advantage of continuous cutting action and high cutting speed. Its disadvantage is the wide kerf which must be cut. The saw-plate must be thick enough to retain its stiffness when at work and under the action of centrifugal forces, and to attain this, greater thickness is demanded than in strained saws. Various devices to secure stiffness with small kerf-losses are exhibited in the various designs.

To compensate for the wear of the saw most of the designs have the mandrel-boxes adjustable, so that the saw may be kept close to the guiding-rolls. A smaller saw can also be thus admitted. The front rolls must be very close to the saw, inasmuch as the top part only cuts when the stock is over the mandrel. The front rolls are often made longer than the back ones.

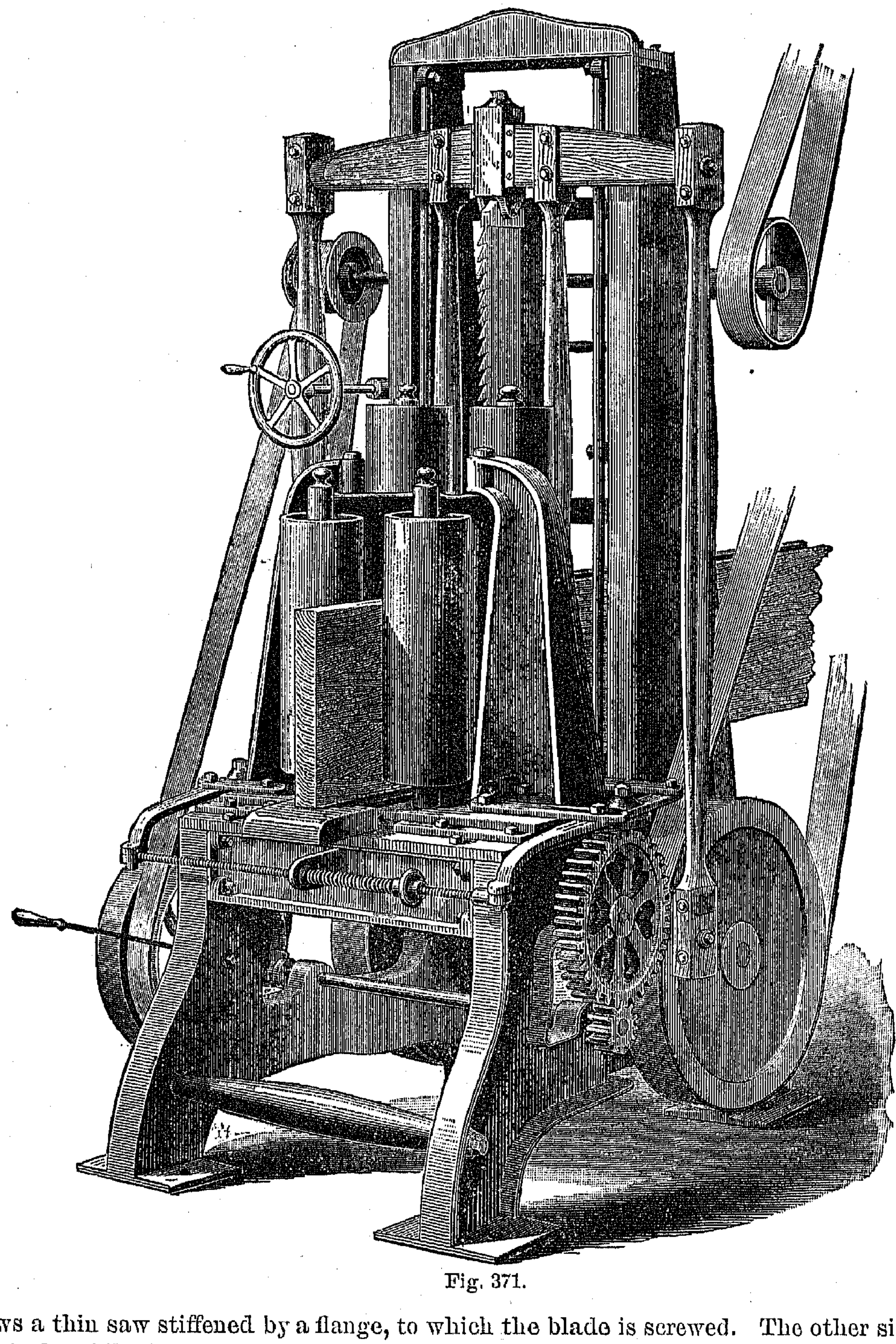

Fig. 371.

Fig. 373 shows a thin saw stiffened by a flange, to which the blade is screwed. The other side is flat, working against the stiff stock, while the flexible board is wedged away so as to prevent the plate from heating. The feed is given by reducing-gear from the arbor, but is still at high speed. The pairs are connected together by gearing on top, and receive their motion from the bevel-gears on the splined shaft below. The gears slip on the shaft laterally to permit the adjustment for varying thickness of stock. The bent lever and weight act upon a double wrist-plate to center the rolls upon the saw. The rolls are supported in long bearings in saddles upon a slide below. This is a very usual arrangement. The slide casting may rock upon a central pin for bevel-sawing. It is adjusted by a screw, and further clamped by the hand-nuts in the slots of the arc.

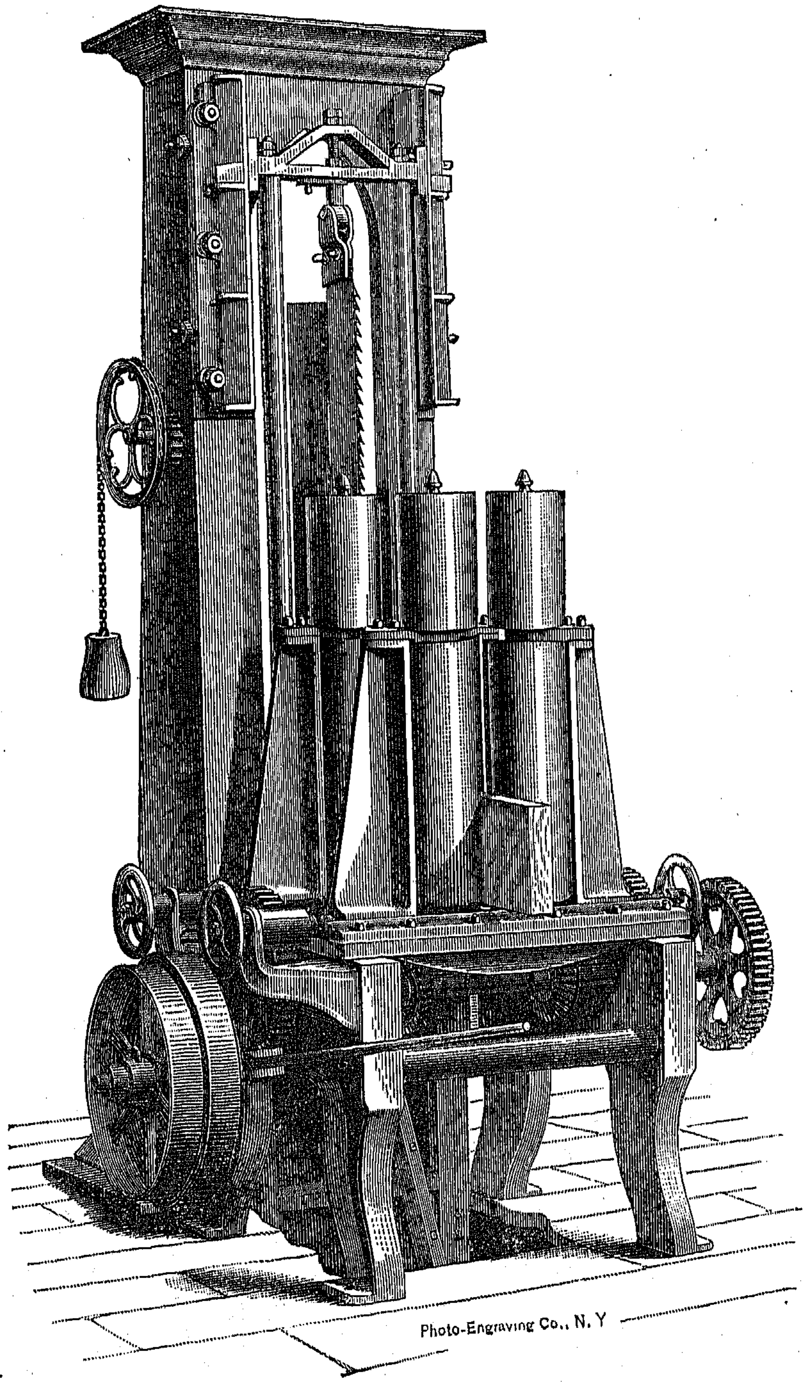

Fig. 372.

Fig. 374 shows a machine with taper-ground flanges on the saw, permitting the use of thin saws. A pair of friction-rolls project well over the plate to guide wide stuff near the cut. The weighted lever acts by equalization,

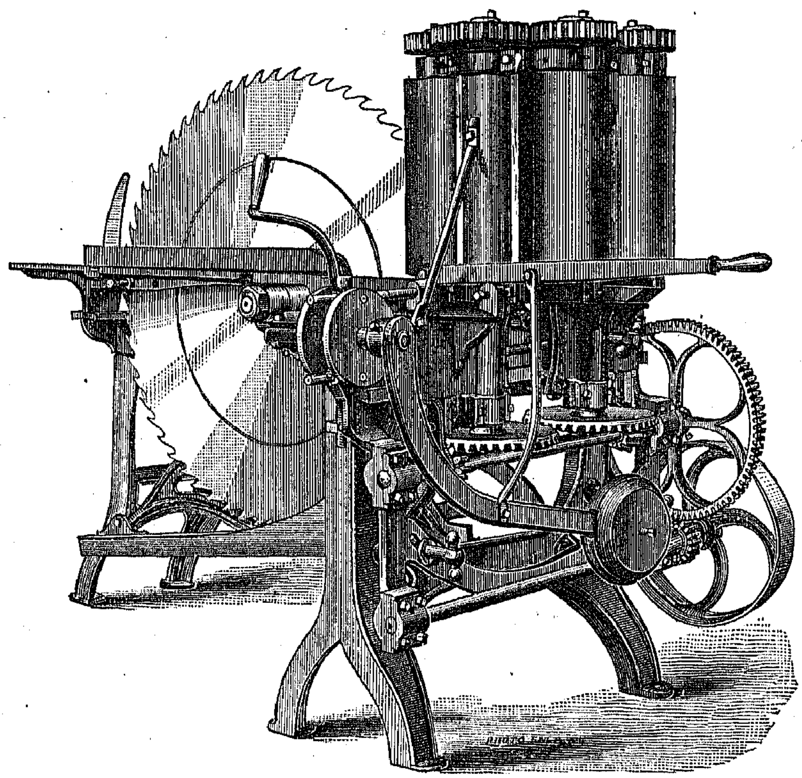

Fig. 373.

so that either center or side cuts may be made. The whole feed apparatus will swing for bevel-sawing, and the feed may be arrested by a clutch at the right. Dust is caught in a trough, which also shields the bottom of the saw.

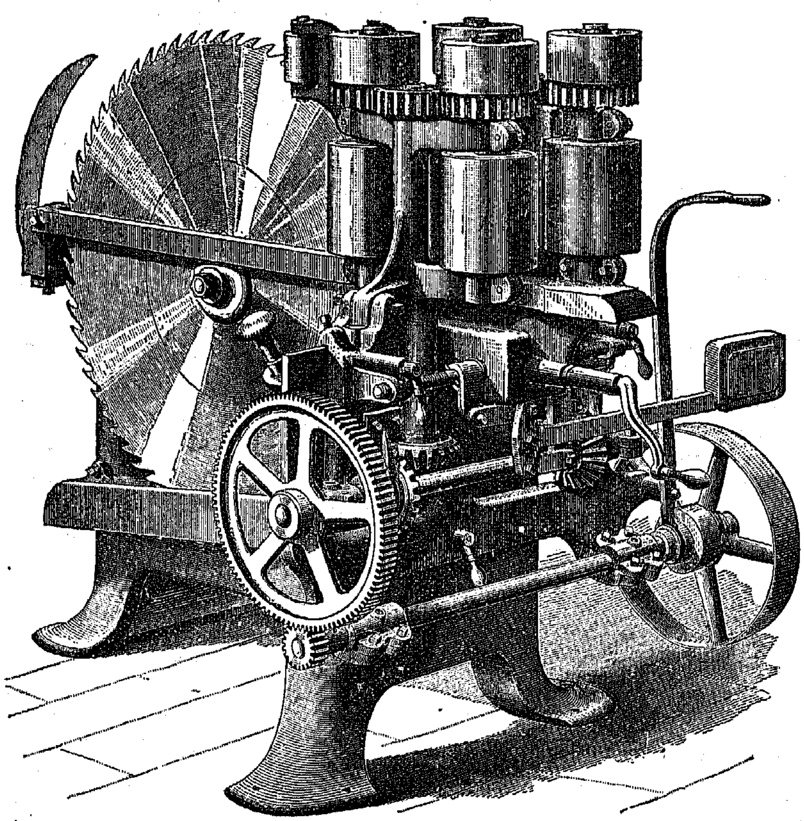

Fig. 374.

Fig. 375 shows a saw with inserted teeth. By the incidental use of softer plate this system also gives a thin kerf of less than one-eighth of an inch with a 50-inch saw. The rolls are mounted on separate slides, which are inclined so as to be normal to the resultant of the weight of rolls and stock and to the push against the latter, due to the cut. The rolls are steadied by adjustable ring-bearings, by which inclination of their axes is permitted. There are three changes of feeding speed and a disengaging-clutch. All adjustment of the rolls, from center to side cutting, is effected from the feeding end by hand-wheel.

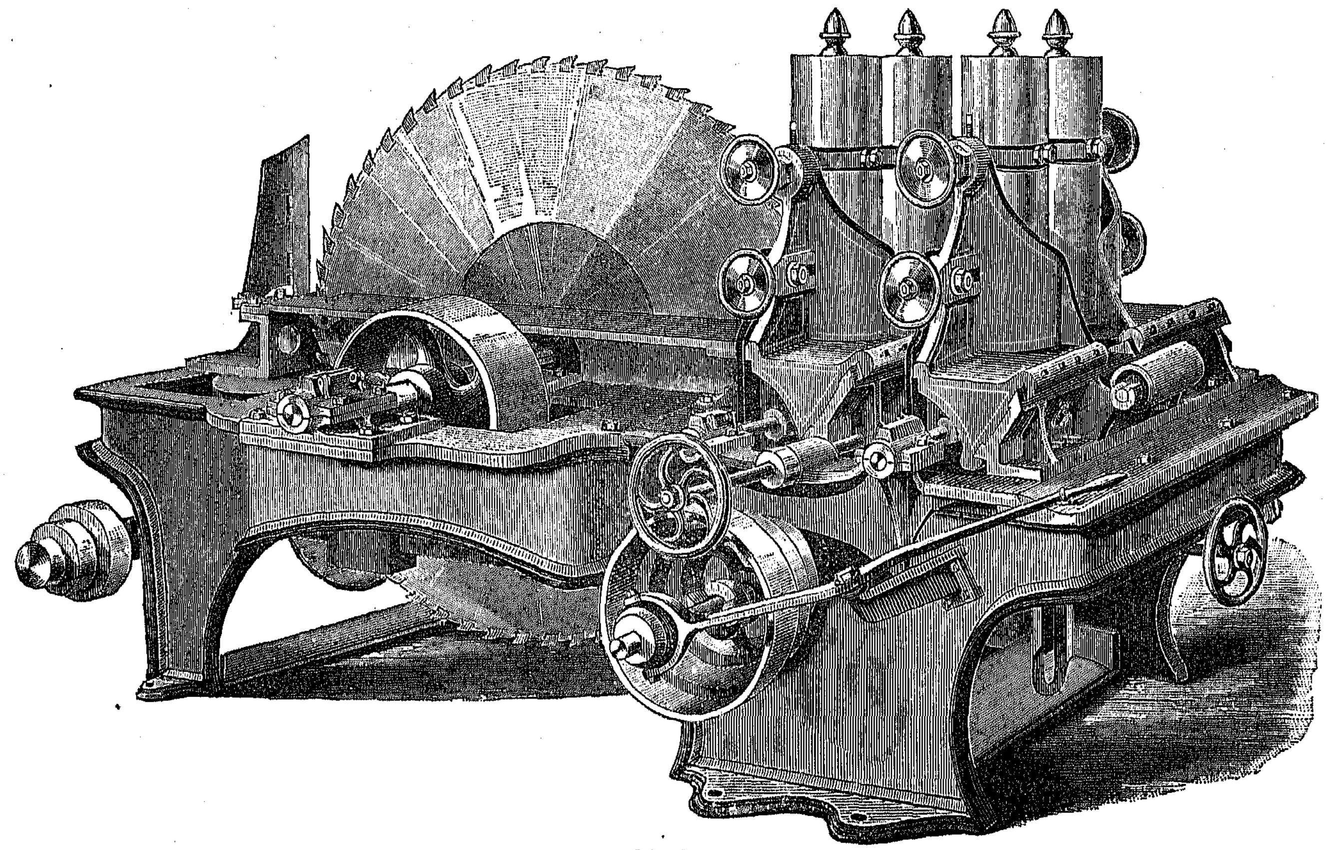

Fig. 375.

Fig. 376 illustrates a type which has some special features. The saw is guided by end-wood adjustable guides at both ends of the horizontal diameter and at the top. By this principle of guiding a great reduction is possible

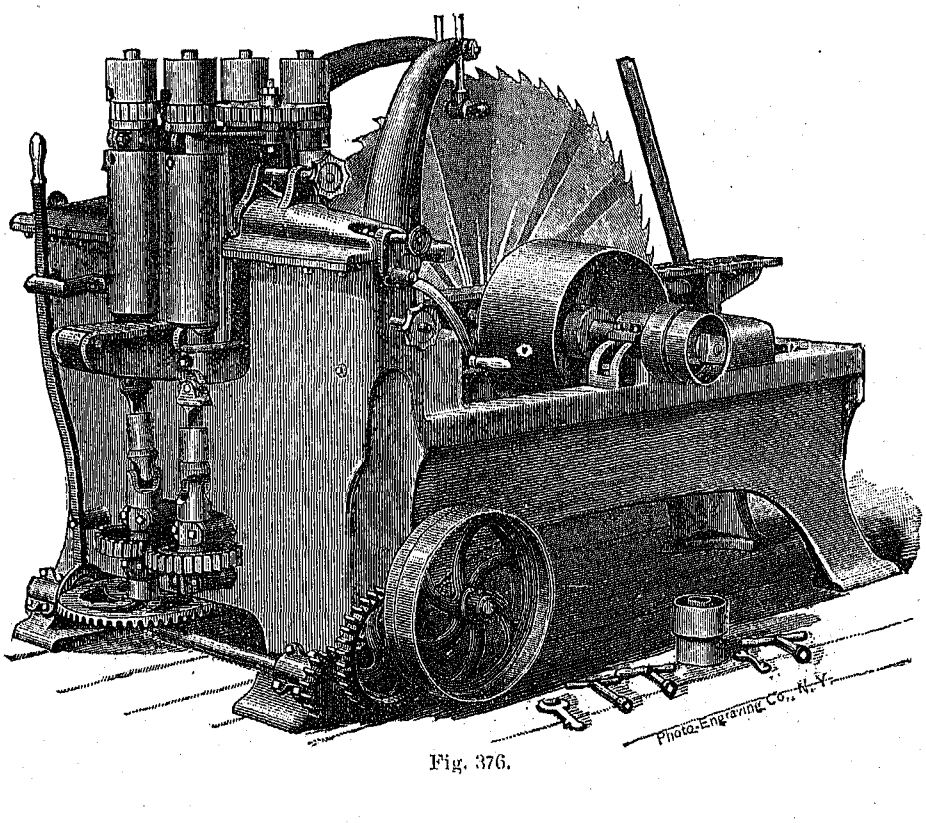

Fig. 376.

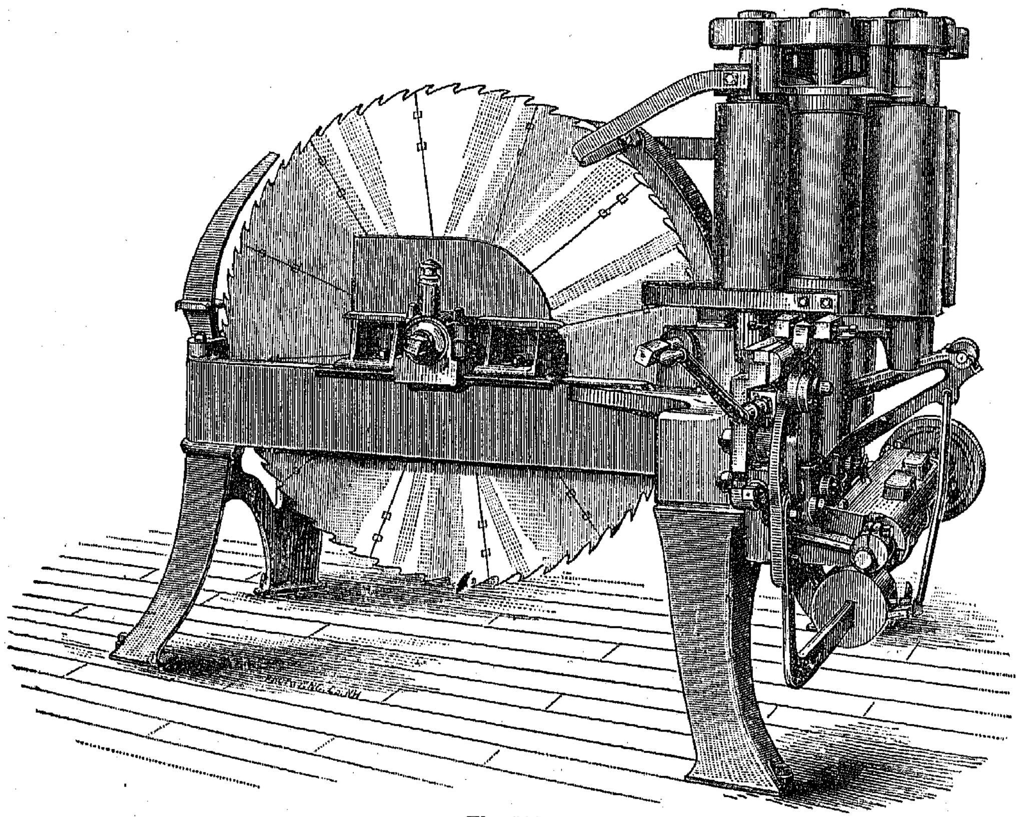

Fig. 377.

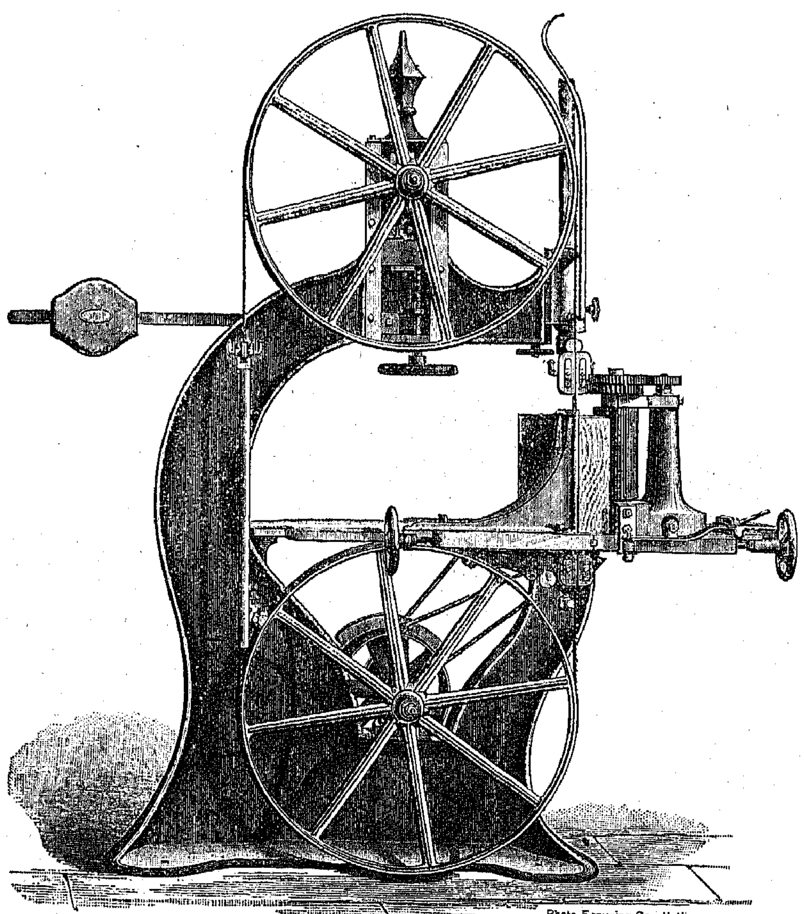

Fig. 378.

in the gauge of the saw-plate, and hence in the width of the kerf. The circular saw at high speeds yields very easily to lateral pressure, and will not cut to true lines when thin unless guided near the cut. Moreover, the guides upon which the rolls yield are placed near their middle points. By this means the pressure upon the stock does not cause a binding upon the slides and guides, which will be caused when the slides are vertical and below the working level. The rolls can easily be set to any required bevel. Instead of being driven from a splined shaft with sliding bevel-gears, the pairs of rolls are driven from fixed spur-gears by universal joints and telescopic shafts. This avoids the wear on the splined shaft due to the leverage which the rolls exert. There are two changes of feed which may be disengaged by the lever at the left if necessary to withdraw the stock for any cause. The arbors are made hollow, to prevent springing.

Fig. 377 shows a segment-saw. The segments are connected together by copper dovetails. While the gauge at the circumference is 16, at the center it is 5. The feed is given to the rolls from a long gun-metal worm, which is driven by round belt from the arbor. The worm-wheels will roll upon the screw for any adjustment laterally, and

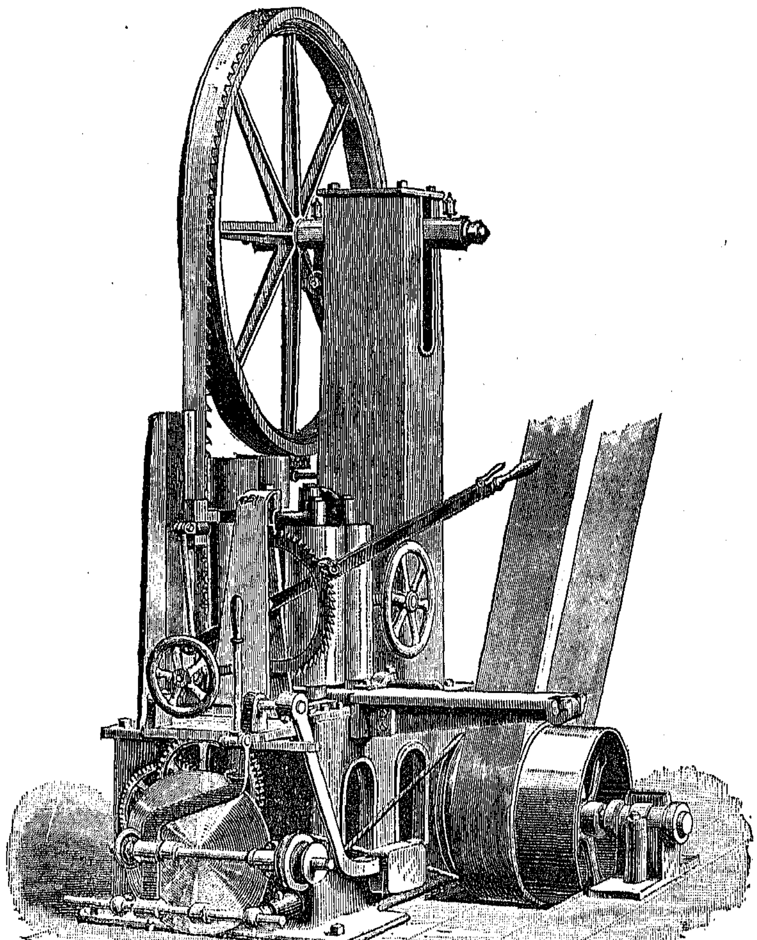

Fig. 379 *a*.

the whole feed works will swivel for bevel sawing. The weighted lever bears upon an equalizer, and the rolls are geared together at the top. The use of the worm simplifies the feed-gear very satisfactorily. Other builders use the segmental saw for their larger sizes, or when preferred by their customers. By the use of the circular saw the feeding speed may vary from 25 or 30 feet to the minute up to 90 feet on narrow lumber. Forty feet per minute would be perhaps an average. A notable economy results from this increase of velocity.

The manifest advantages of the band-saw for other classes of sawing has led some of our advanced builders to adapt it for resawing. These advantages are its great thinness, its variable tension, its linear and continuous motion at the cutting-point, its high speed, the simplicity and rotary motion of its machinery, the easy delivery of dust, the coolness of the blade, and its taper- or wedge-shape.

Fig. 378 shows one of the lighter types of the band resaw. The lumber is pressed against a guide-plate and driven by fluted rolls. For the feed-gear of these resaws the brush-wheel combination is nearly universal. It permits any variation of speed of feed, and reversal is possible. The saw has all the usual attachments of belt-shifter and brake, brush to dust the lower wheel, roller-guide for the passage of the blade to the upper wheel,

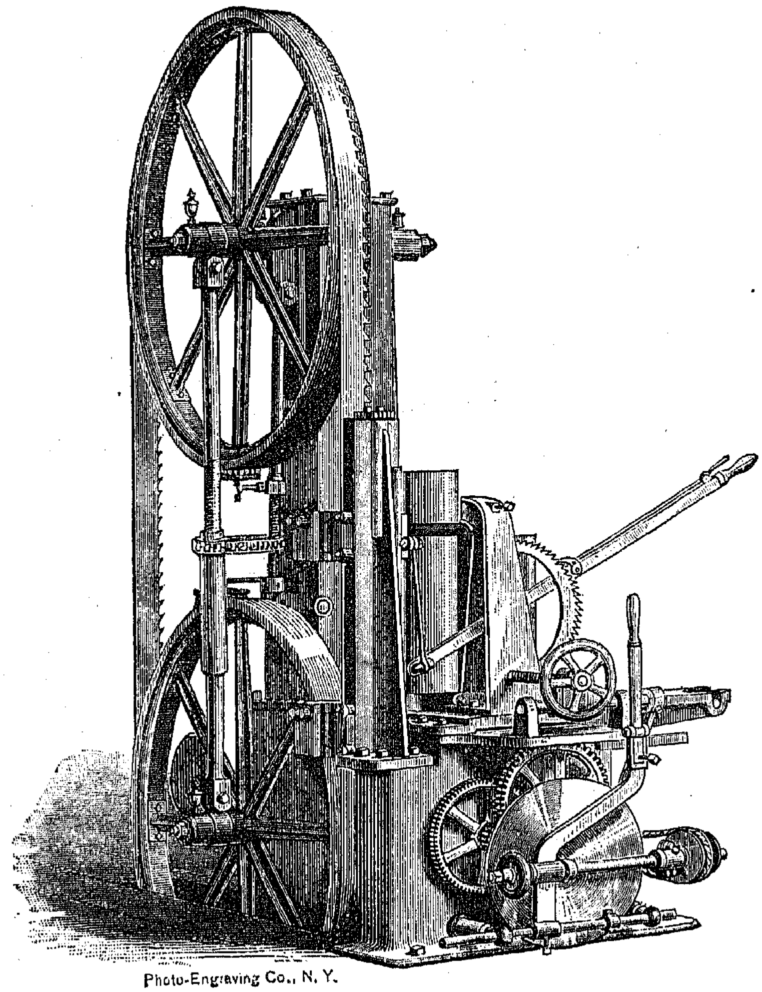

Fig. 379 *b.*

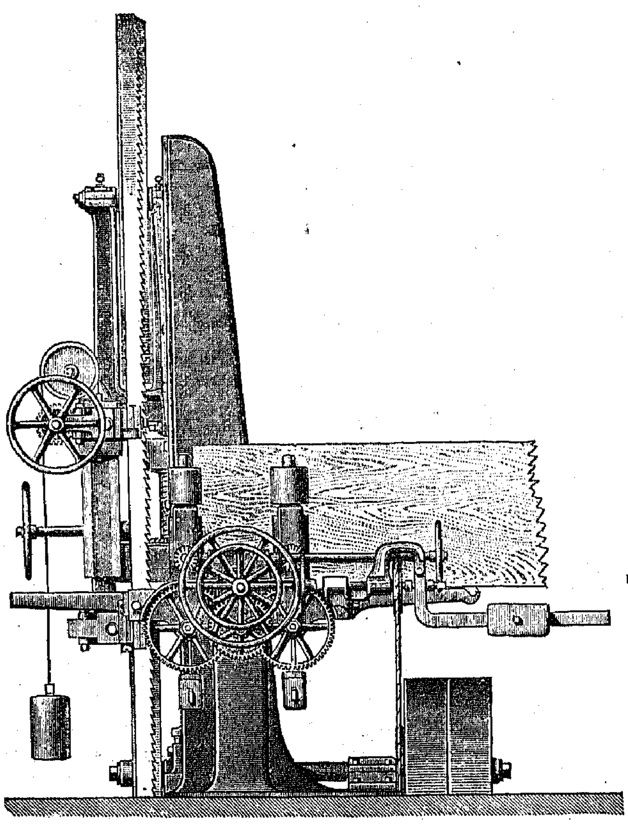

Fig. 380 *a.*

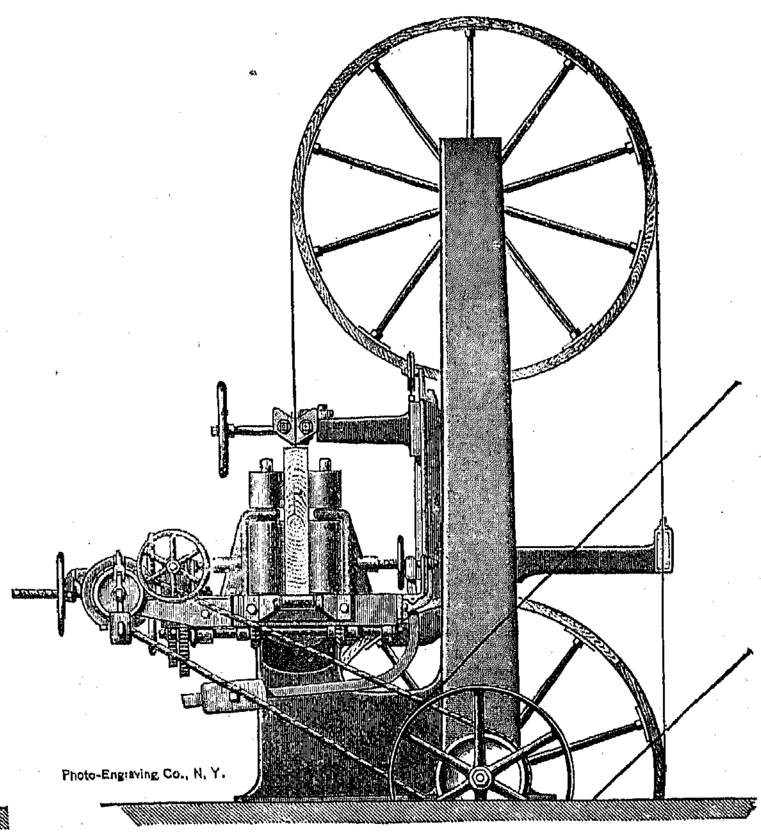

Fig. 380 *b.*

thrust device and lateral guides above and below the cut, and straining device by weight and screw. The upper bearing slides in guided ways, and the arbor of the wheel has a screw adjustment to direct the course of the blade on the upper wheel. In a larger size, carrying a wide blade (Figs. 379 *a* and *b*), the saw-arbor cannot overhang. Therefore a telescopic link, adjustable by screw and chain-gearing, effects the adjustment of the arbor and maintains the tension of the saw. The outer pair of rollers yields by a weighted lever, the feed, as before, being by brush-wheels in front, which are adjustable by the hand-lever. The saw-wheels are of iron, with wooden rims covered with rubber. Special roller devices for the thrust are provided on these larger sizes.

Figs. 380 *a* and *b* show a similar type with the brush-wheels controllable from in front by a screw of steep pitch. The upper guide and thrust-bracket are counter-weighted and adjustable by hand-wheel. The brush-wheel pressure is adjustable by the weighted bent lever. The upper wheel-arbor is supported on both sides of the wheel. The rear feed-rolls yield with a weight to maintain the desired pressure. The band resaw has a variation of speed of feed up to 25 feet per minute. This makes it possible to do over four times as much work as with a reciprocating saw. The band-saw has a capacity for 10,000 feet per day, while the up-and-down saw will finish 2,500. The manifest advantage over the circular resaw is the use of thin blades of 14 or 18 gauge. It is possible to get two boards, sawed and planed, three-eighths of an inch wide, from a 1-inch board. The kerf and planer-chips all come out of one-fourth of an inch. For valuable lumber this is an important consideration, and it is for such materials that the band resaw has found its special application.

§ 38.

DIMENSION-SAWS.

After the lumber has been resawed to the desired thickness the next sawing operation upon it will be its reduction to the desired dimensions, either of width or length. For this purpose two saws will be used, known as the ripping- or slitting-saw, for sawing with the grain, and the cross-cut or cut-off saw for severing the fibers across the grain. For sawing with the grain, the teeth cut upon their front edges. Cross-cut saw teeth cut upon their sides. In ripping, the boards have to be fed against the saw; in cutting off they may be fed to the saw, or the saw may be moved across the work. The choice of these two latter methods will be governed usually by the size and weight of the piece to be sawed.

The usual bench-saw is a solid steel disk, with proper teeth in the circumference and a central hole for the driving-mandrel.

Fig. 381 shows forms of teeth of the two classes of saw. Inserted teeth are not extensively in use for this class of saw. The usual type of mandrel has the pulley at one end and the flange and nut for the saw at the other, the two journal-boxes lying between them and close to the points of strain.

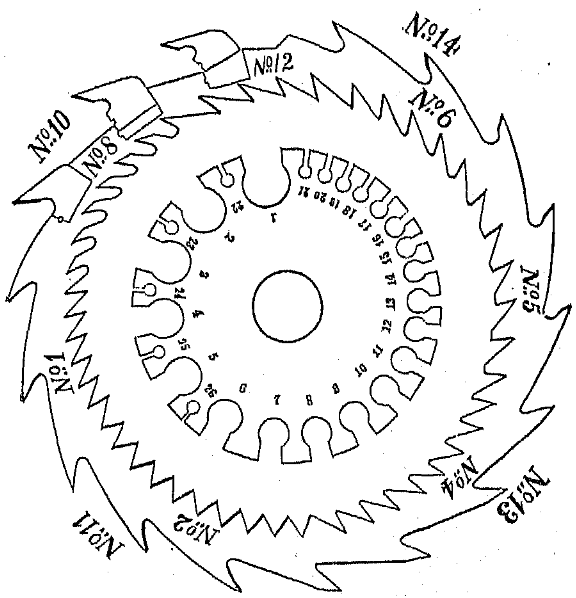

Fig. 381.

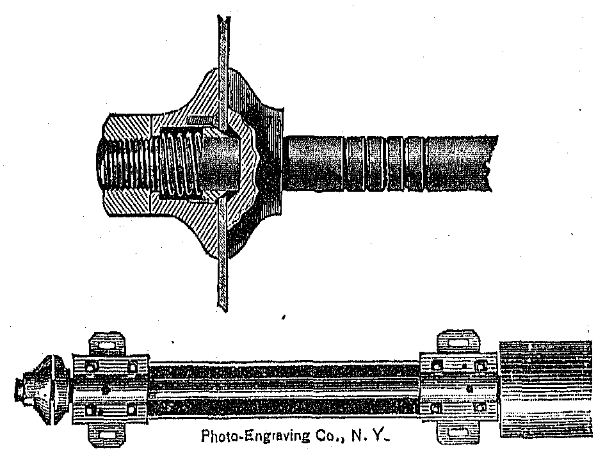

Fig. 382.

Fig. 382 shows a usual type. Most of the boxes are self-oiling to a certain extent, although the wisdom of intermitting the attention of the operator to his boxes has been questioned. A general type of these boxes would show an oil-cellar below the bearing, in which some fibrous material is put, which may hold the oil (Fig. 383). A diagonal groove in the bottom of the box carries the oil upward and to the ends, whence any excess flows back. The chambers at the ends of the box prevent any loss endwise, and a great saving is claimed and effected. The mandrel shown prevents end-play by a series of rings turned in the journal, into which fit ridges in the babbitt of the box. The same figure illustrates a special cone-bushing, to simplify the centering of a saw whose hole is larger than the mandrel. The spiral spring in a hollow in the outer flange takes up all the play and the flange holds all from moving. A western builder tightens in a cone by a screw in the axis of the arbor. The pulley on the mandrel is made highly crowning to diminish the tendency of the belt to curl up and run off when bending so rapidly over so small a pulley. The pulleys must be small in cross-cut saws especially, in order that the work may pass over them. For this reason, too, the counter-shafts must be below or on the floor. For ripping-saws they may be overhead. The pulley must also be relatively wide. Its face is usually made equal to its diameter.

The saw-tables or saw-benches of to-day are of wood or of iron. The wood tables are made by several builders to supply a demand for a cheap article. The iron frames, however, are standard, as they should be.

Fig. 384 shows a type of wooden bench in which the top is made to lift by means of the cams under the front end. These are worked and held by a worm and wheel.

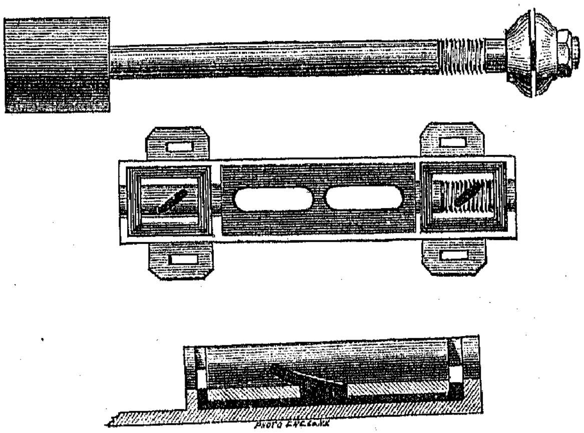

Fig. 383.

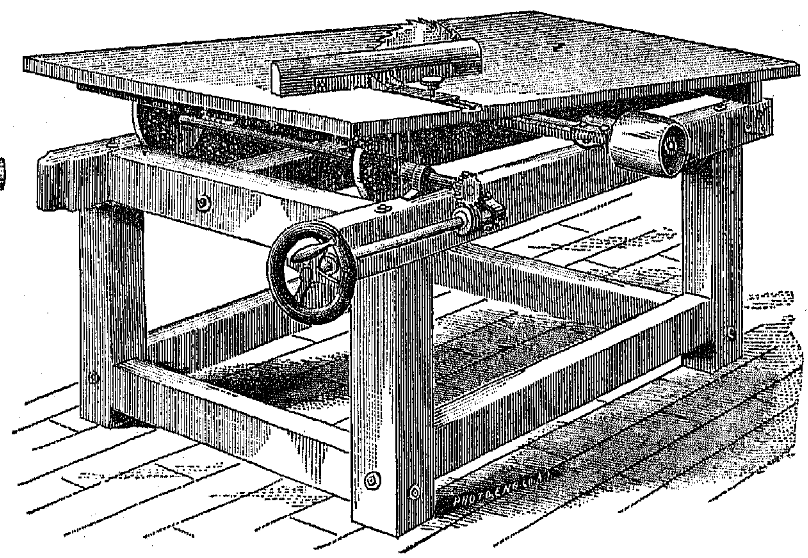

Fig. 384.

Fig. 385 shows an iron bench in which the whole table lifts bodily upon guides by a screw worked by the hand-wheel. One is for heavier and the other for lighter work. The object in varying the projection of the saw above

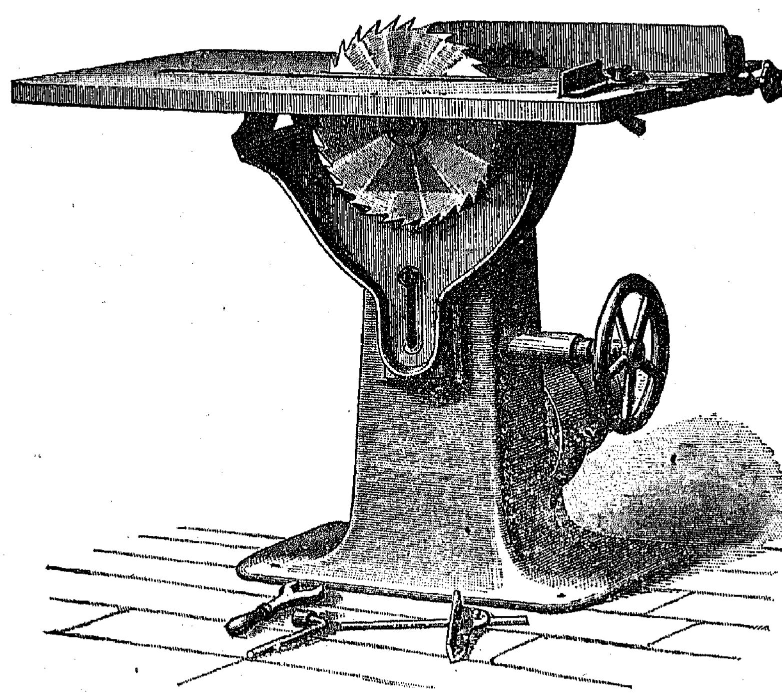

Fig. 385.

the table is to enable it to cut rabbets and tenons, or to make the cuts for gains. The wood is passed over it, and the saw cuts to the gauge mark. Round grooves may be cut in the face of work by passing it obliquely over the

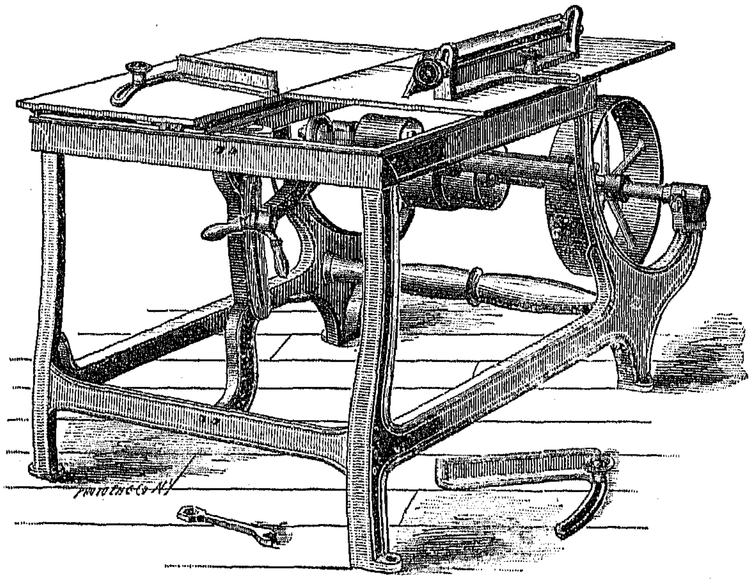

Fig. 386.

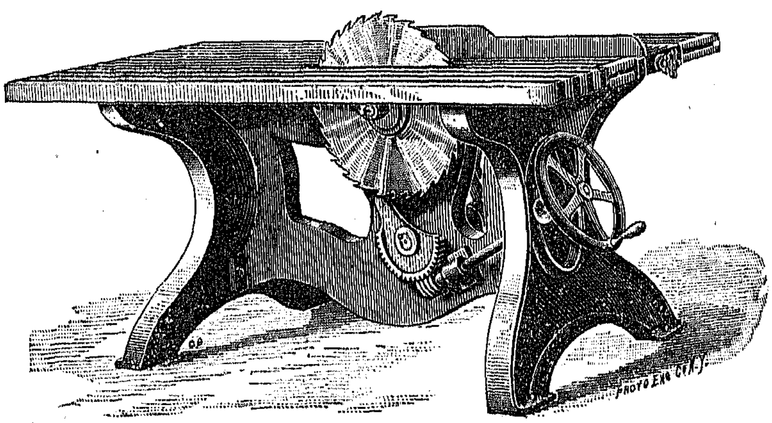

Fig. 387.

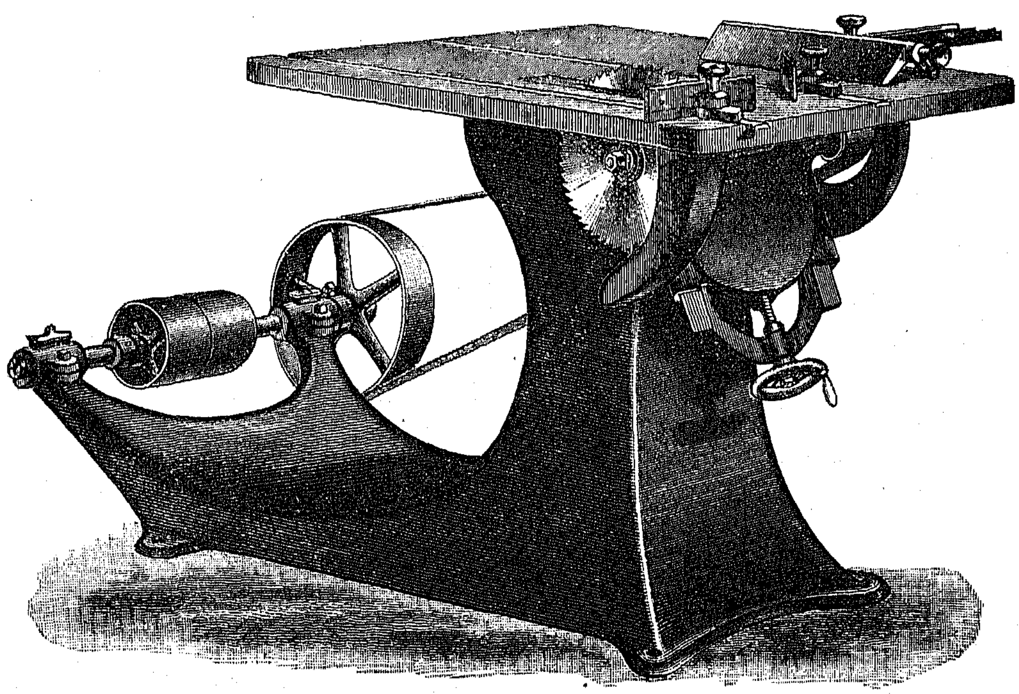

Fig. 388.

top of the slightly-projecting saw. All the best benches, therefore, of to-day have this adjustment, either lifting the table as above or by raising the saw-mandrel. In Fig. 386 the mandrel boxes are carried on a frame whose center of oscillation is the center of the counter-shaft. The arm and handle which raises and lowers the frame is clamped at any point of the slotted sector. In Fig. 387 the mandrel is controlled by the worm- and segment-wheel, and in Fig. 388 by the screw directly. These also illustrate the differences in design. The most modern practice approves the use of one single casting, by which stiffness is secured, and fewer joints in the frame.

For guiding work to the saw various arrangements of fence or rest are used. For iron tables a form such as shown in Fig. 389 has been used for splitting. The fence proper slides in the grooves of the rear part, which may

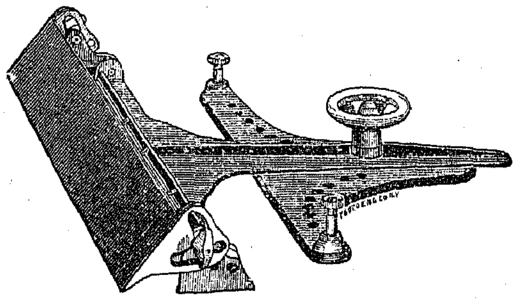

Fig. 389.

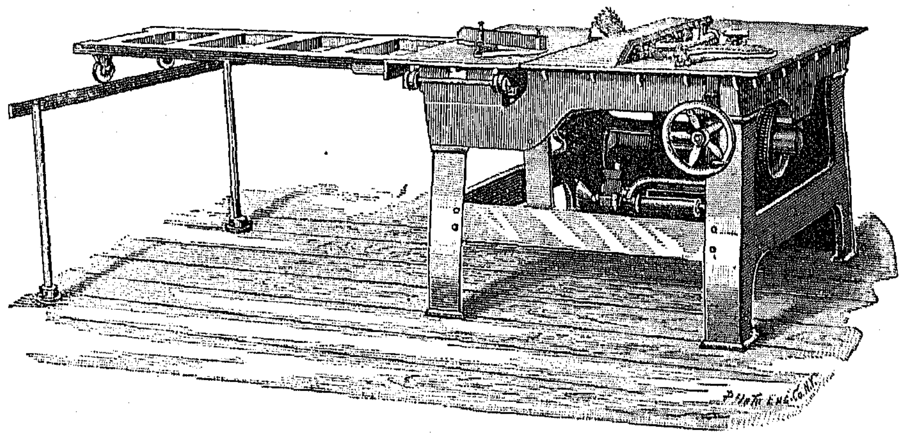

Fig. 390.

be pinned in holes in the table, so as to be parallel to the saw and at any desired distance from it. The fence can be clamped at any vertical angle with the plane of the saw for sawing bevels. In order to feed for cross-cutting a guide will be clamped at the desired horizontal angle with the saw and moved forward against the saw. The

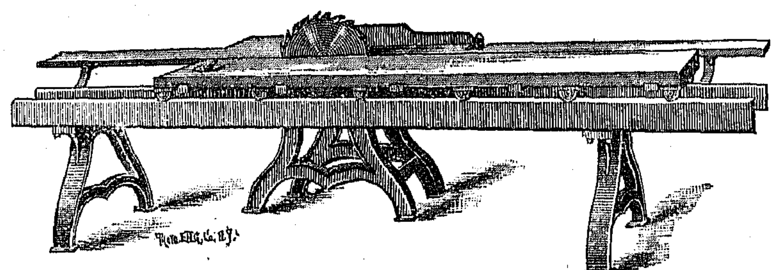

Fig. 391.

motion of the guide will be made parallel to the plane of the saw by a groove in the top of the table, in which fits a tenon on the bottom of the guide, or else (Fig. 390) the half of the table is made to slide upon ways with the guide

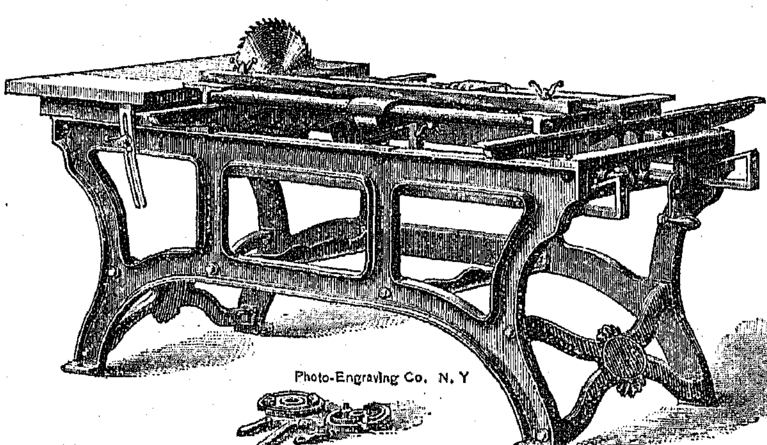

Fig. 392.

clamped upon it. The former method is usual upon tables with wood top, an iron groove being let into the top for the purpose.

Fig. 391 illustrates a roller-table for slitting-benches, designed for heavy plank, and Fig. 392 shows a table for

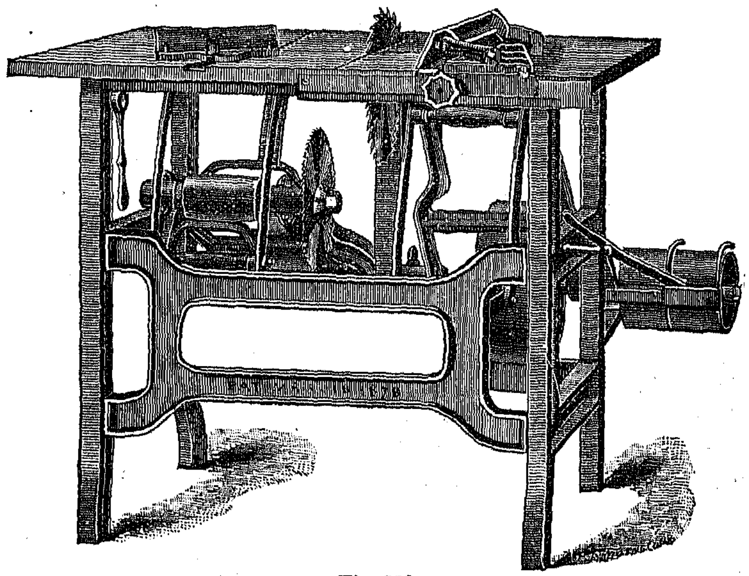

Fig. 393.

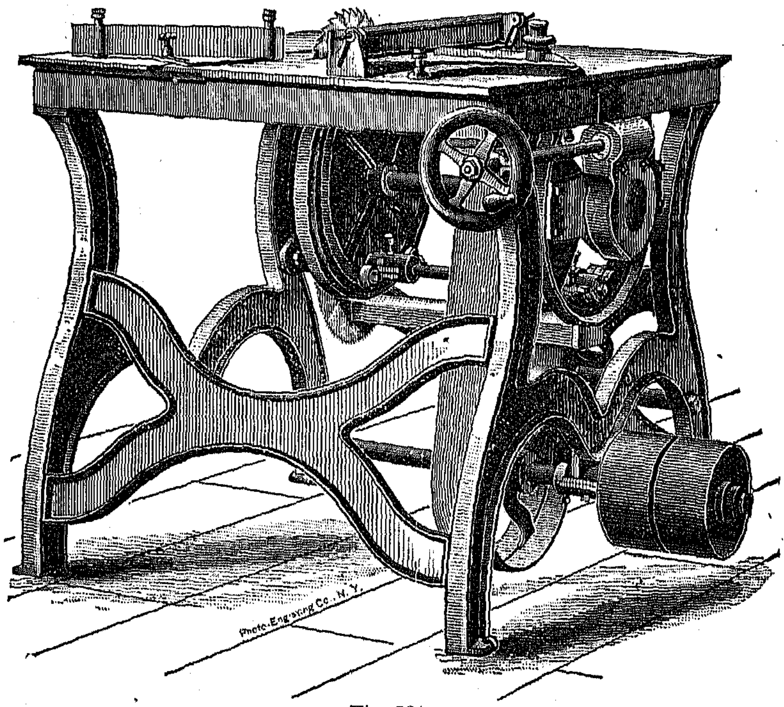

Fig. 394.

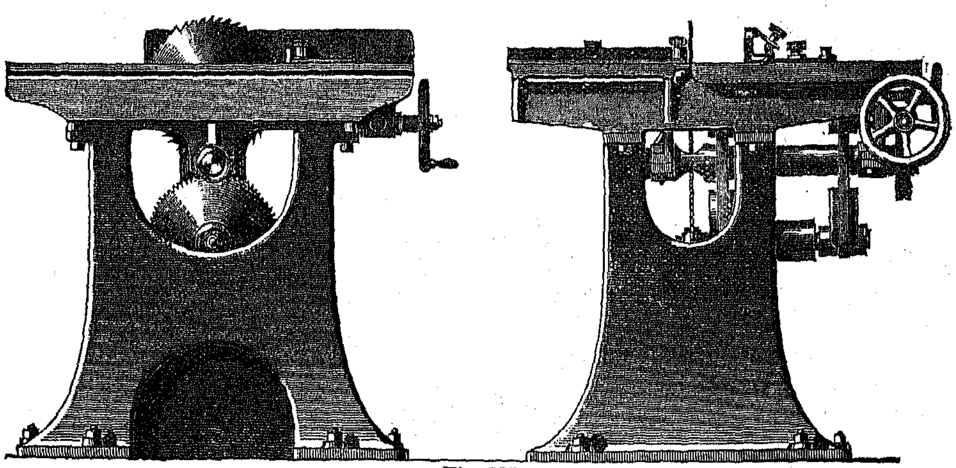

Fig. 395.

cutting off only. In this form the fixed half of the table may be inclined for bevels and the ways for the carriage may be lifted together by inclined planes for cutting across for tenons and gains. The crank at the right controls the inclines.

A very great part of the saw-benches for job or miscellaneous shops is made double, to accommodate at once a ripping and a cut-off saw.

Fig. 393 shows a double bench with adjustable saws, swinging in separate frames around the counter-shaft. There is a device to prevent both saws from being above the table at once, which is an element of danger. Its action can be suspended, however, if necessary. A more usual type of double table is illustrated by Fig. 394. The two mandrels are borne on opposite ends of a diameter in a frame, which receives a motion for adjustment around its center by a worm and wheel. Either saw may, therefore, be lifted up through the slit in the table and to any desired amount. It is a specialty of one or two to have the boxes of the mandrels remain right side up in all positions of either to avoid loss of oil. The driving-belt is made extra wide, and is guided so as to be in contact with that pulley which is in use in its every position.

Fig. 390 shows a similar design, and Fig. 395 illustrates a high-grade machine, built with great care and exactness for pattern-shops and the similar grades of service. The ripping-fence is adjusted by screw- and hand-wheel, and the other side of the table slides upon V's. The counter-shaft is at the base of the machine, so that the top is entirely free.

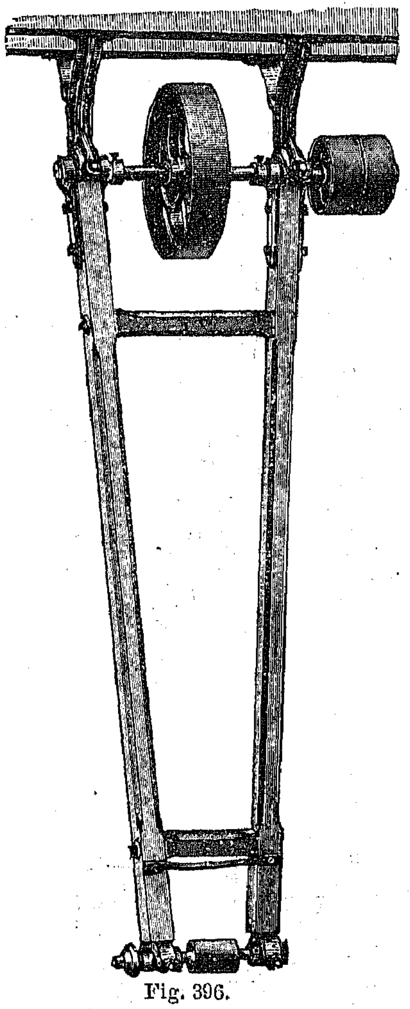

Fig. 396.

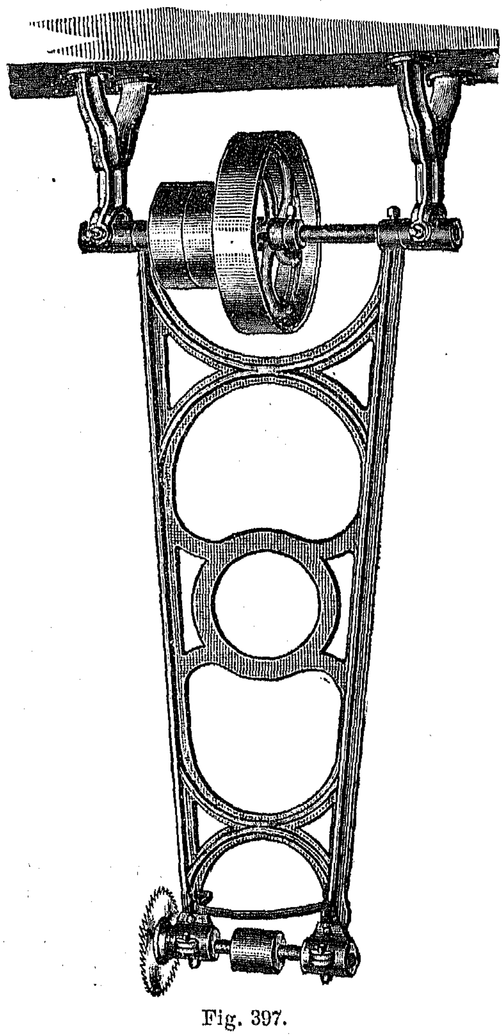

Fig. 397.

The other class of cross-cut saw-benches, where the work is stationary and the saw is fed toward it, is especially adapted for heavy work, or for work which, from its shape, would not rest stably against guides if the latter were in motion. The table for this class of saw is entirely separate from the frame of the tool itself. These saws appear in two forms. The cheaper and less exact is known as the swing cut-off saw, and appears in Figs. 396, 397, and 398. Fig. 396 shows the older form of wood frame, Fig. 397 is the improved iron frame, and Fig. 398 illustrates a shielded saw of neat design. The saw is borne on what is often called a yoke mandrel, receiving its motion from the counter-shaft, round which the frame swings. In the best practice the frame swings around the outside of the boxes of the hangers, so as not to bind the shaft. These may be arranged to hang from overhead or to come up through the table from below.

The better class of traveling saws is known as the railway cutting-off saw (Fig. 399). The saw-mandrel is borne on a carriage, gibbed upon ways. The belt passes over guide-pulleys on a frame centered on the counter-shaft. This frame is linked to the carriage, and they move forward together. The driving is done by the under belt, and

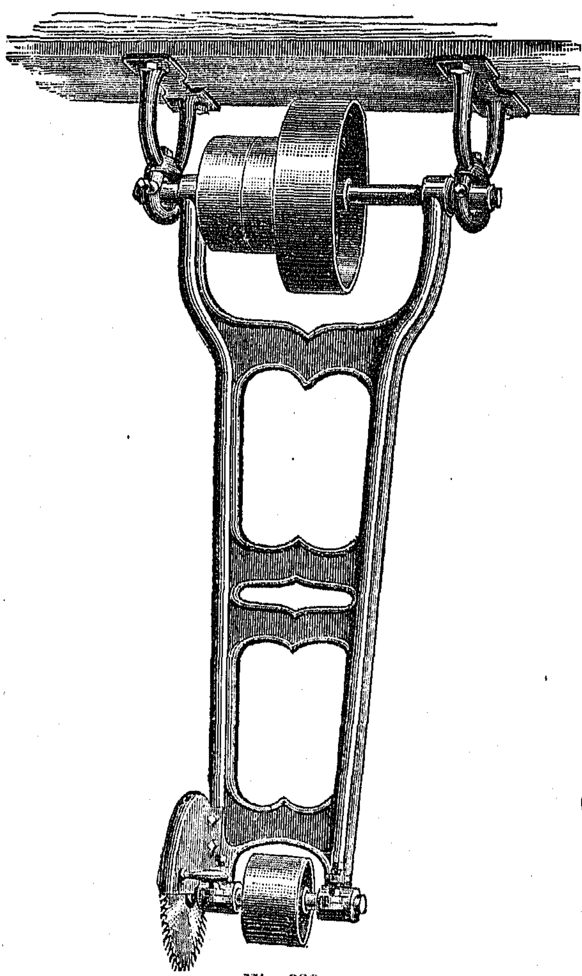

Fig. 398.

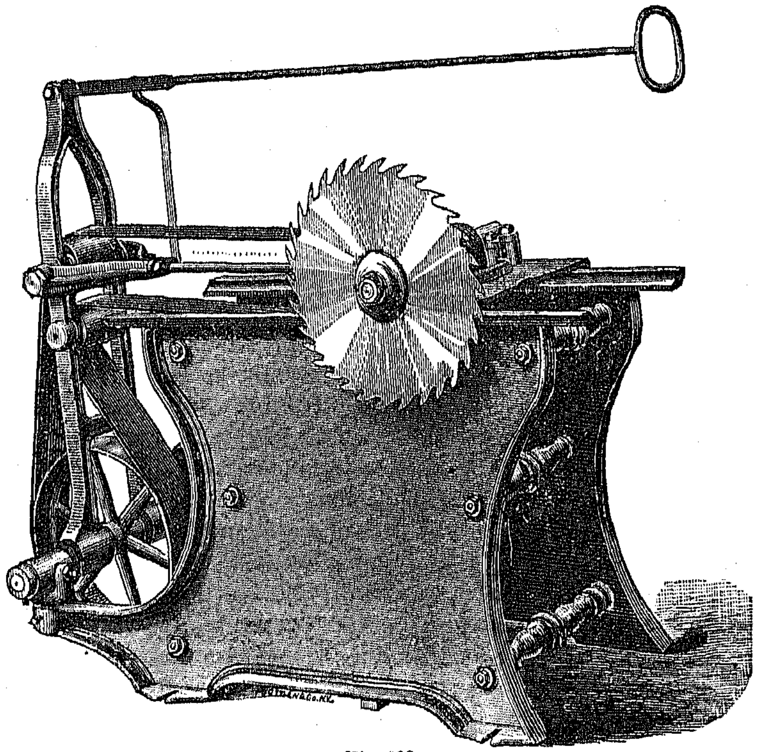

Fig. 399.

no difference is made in the strain of the belt within the limits of the travel of the saw. One maker links the frame to a pendulum in the way-frame, whose bob acts to retract the saw when the handle is released. The handle is always kept horizontal by the short link.

Fig. 400 shows a bracket railway-saw hung from a wall. The counter-shaft is overhead, over the center of the traverse of the saw. The bracket is mounted on a true plate, permitting adjustment for diminished diameter of

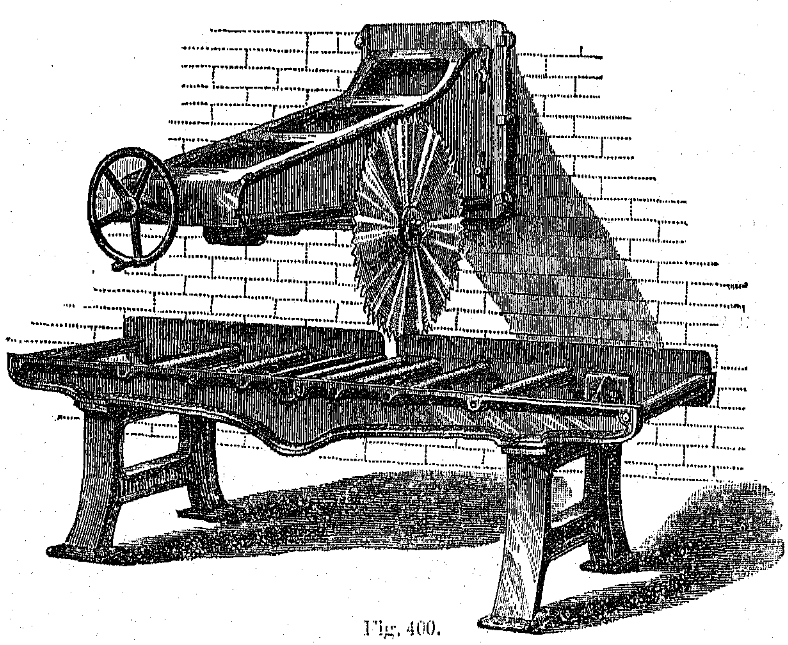

Fig. 400.

saw. The table has friction-rolls for the easy motion of heavy timbers. Not infrequently the tables are fitted with a scale of length from the saw-kerf as a zero-point, for convenience in cutting to dimensions.

There are devices upon the tables of several builders by which the adjustment of the ways of sliding tops is possible. This renders it easy to adjust to parallelism with the saw. Moreover, a tonguing or grooving head can be placed upon the saw-mandrel, where it may not be convenient to perform that operation on a special machine. Again, some table tops are arranged to tilt sidewise as a whole, for sawing bevels, and there may be minor modifications which are not of sufficient prominence to rank the table as a special machine.

§ 39

SPECIAL FORMS.

The circular-saw table may be adapted for one line of manufacture by very simple additions. It may be applied for cutting shingles from one or several blocks by adding a carriage, which shall reciprocate and give alternately unequal feeds to the ends of the blocks. It may be used for sawing to the center of small logs for clap-boards or to prepare the stock for ax-handle lathes and the like. The log is held on centers and rotated by an index-plate after each cut. A small core will be left, which can be used for other purposes. For cutting up cord-wood for railroad purposes a saw with a long mandrel is used, with a heavy solid balance-wheel near the pulley end. This is to store up work in the intermissions of cutting, so as to relieve the driving-power, which is very often a horse-tread power. For lath, fence, or flooring manufacture, or for general edging, a gang of saws may be used. For smaller work of standard thickness the saws may be spaced by distance-collars. These should be of a diameter sufficient to support the work at the level of the table. For miscellaneous edging, the saws are often upon grooved sleeves, which can be adjusted laterally on the splined or squared mandrel from the feeding-end. Very often these gang-edgers are arranged to be self-feeding. A serrated roller drives the solid wood in front of the saw, and a smooth pressure-bar holds the pieces from flying behind the cut. This may be also applied to a single slitting-saw. Two saws may be run on a single mandrel, for cutting off all pieces to a standard length, or the two saws may be on mandrels at an angle with each other, for producing a standard bevel at both ends of work. For sawing circular arcs from the plank two dished saws suitably spaced may be used. For sawing staves for barrels, either with or without bilge, cylinder saws are used. The block is fed and retracted from the saw on the proper lines automatically, while the staves are cut to the proper curvature. By setting a plain circular saw, of thick gauge, obliquely on its mandrel, it may be made to produce square grooves with considerable range of width.

Fig. 401 shows the use of oblique washers for this purpose, and Fig. 402 shows a different device. The latter may be adjusted very rapidly while the saw is in motion. The circular saw may also act as cutter for producing

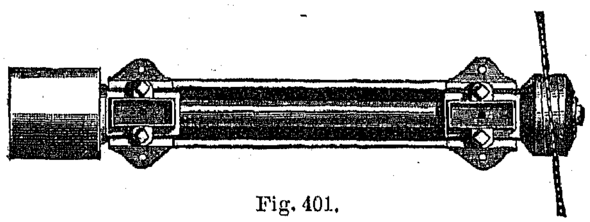

Fig. 401.

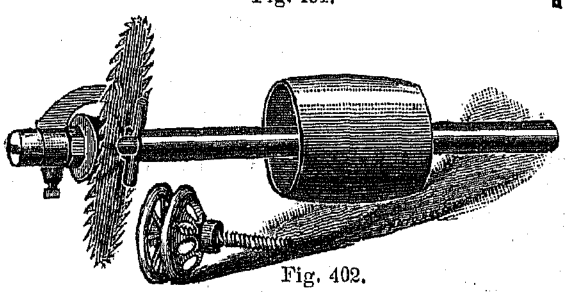

Fig. 402.

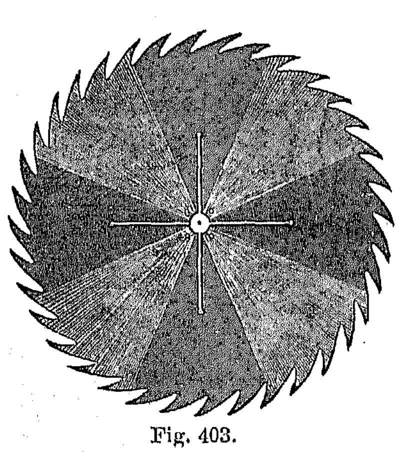

Fig. 403.

surfaces of revolution upon work revolved in front of it. When thickened or made of especial profile it may be applied as a kind of milling-cutter, for such duties as crozing barrel-staves and similar service. The great number of cutting-edges permits the saw to work very rapidly.

With regard to the manufacture of saws, the majority are made by the old process. The teeth are punched from the disks of soft steel, which are then hardened and tempered, and are then peined true with hammer on anvil. There is a New England manufacturer who claims advantages from his process of bringing the saws to form by pressure and heat under patented machinery. A western builder aims to avoid the difficulties of expansion and contraction by heat in service by radial slots in the plate (Fig. 403). These slots close when the blade tends to expand, and thereby the buckling and "wobbling" of the plate is asserted to be diminished. Bench-saws rarely use inserted teeth. They are employed more for forest practice.

§ 40.

BAND-SAWS.

The band-saw in its smaller sizes is not much used for dimension-sawing. While it can be so applied, it is for curved sawing that it meets its widest adaptation. Log-sawing and resawing are done with wide blades; scroll-sawing requires the use of narrow and thin blades. Of course the advantage of the band-saw over the jig or reciprocating saw is its continuous motion. This makes the presentation of work more easy and accurate, and the dust is carried down away from the lines of the marking. The advantages of the principle of the band-saw have already been noted.

The frame for the shop band-saw is now most frequently in one piece, cast in the form of a letter G, with cored or hollow section. In a few the arm carrying the upper guide is bolted on. The belt-wheels are of cast iron, or are built up of wrought-iron spokes and wooden rim, or are of composite design. Very often the two wheels are of different designs. The lower wheel is the driving-wheel, and may be made heavy, since its inertia can do no harm to the saw. The upper wheel, however, is an idle-wheel for maintaining the tension of the saw, and should be as

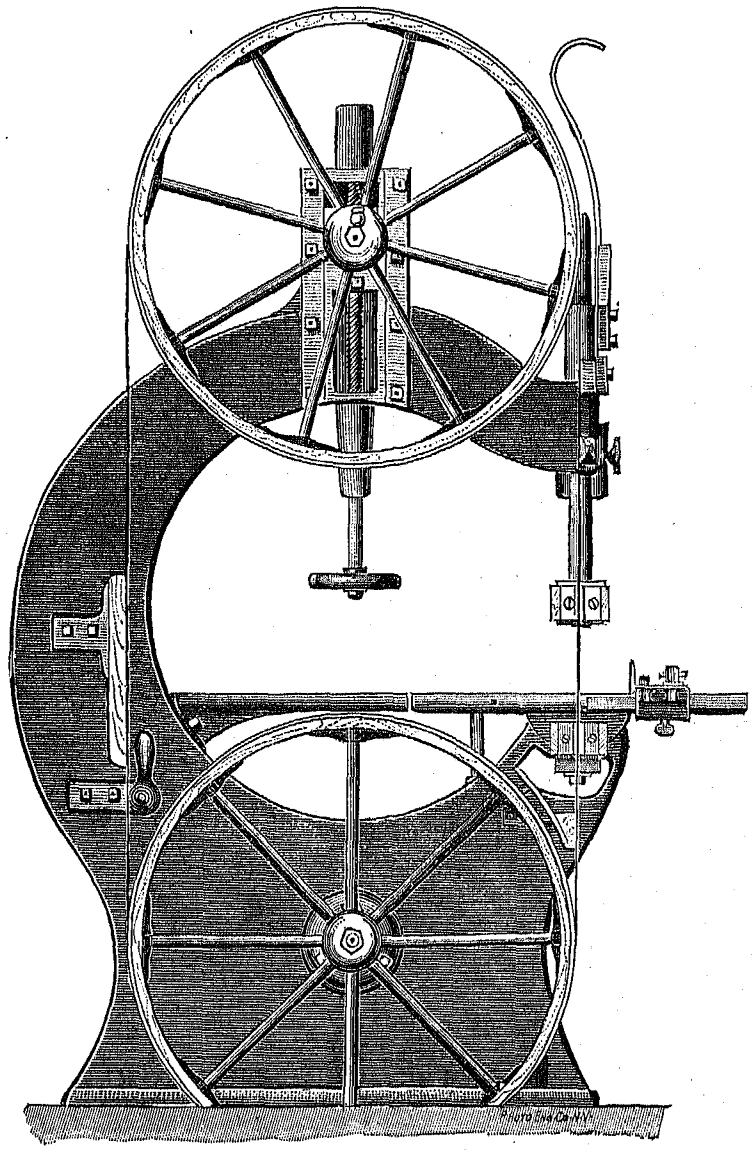

Fig. 404 *a*.

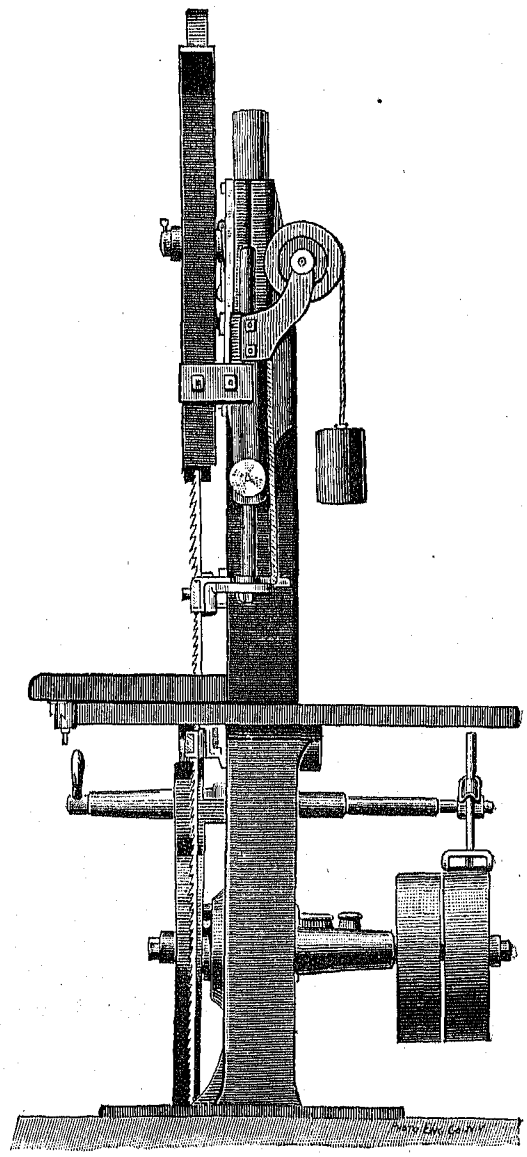

Fig. 404 *b*.

light as possible. The reason for this lessening of inertia and living force in the upper wheel is very obvious. When the lower wheel is started by shifting the belt upon the fast pulley the saw at once tends to start at full speed with it. In putting the upper wheel in motion the saw will be stretched and will slip over the upper wheel till its inertia is overcome. The greater its dead weight the more the slip. When the belt is shifted off the fast pulley, the friction on the lower shaft, due to the strain of the belt on the loose pulley, will arrest the motion. The upper wheel having less friction would be likely to overrun the saw, straining it or slipping under it. The tendency to overrun would also occur when the work of the saw grew harder and it moved more slowly for a time. The slipping of the saw or wheel tends to heat the saw and ultimately to deteriorate it or to wear the covering of the wheels. For these reasons special features of upper wheel will be noted. The saw is strained by the adjustment of the upper wheel. Its bearings are borne in a slide which rises and falls on a screw. This permits a variation in length of the saw of several inches. For maintaining the tension of the saw under slight variations of length, due to stretch or temperature, a weight or spring is applied to the adjusting-screw. The weighted lever is most approved, being easily adjustable and positive. Rubber springs are apt to become stiff by cold and by long service. To guide the saw upon any part of the face of the upper wheel the mandrel is made to tilt. This is usually done by a hinging apron lifted by a set-screw. Some of those in which the plane of the guides is at right angles to the way in which they stand in Fig. 404 had the adjustment for the plane of the wheel in a horizontal plane. The former is approved, however. The wheels are covered with leather or rubber, to preserve the set of the teeth of the saw. Another very essential feature in the shop band-saw is the guide and thrust device at the cut. This must prevent the saw from twisting on curves and from yielding to the pressure of the cut.

Figs. 404 *a* and *b* show a saw strained by screw and spring. The top guide is counter-weighted and clamped close to the cut. The lower guide is just below the table. In this tool the thrust is taken by a steel washer set forward by a cylinder of cast iron for blades of different widths. The washer may be rotated as it wears. The side guides are adjustable for different thicknesses and confine the washer.

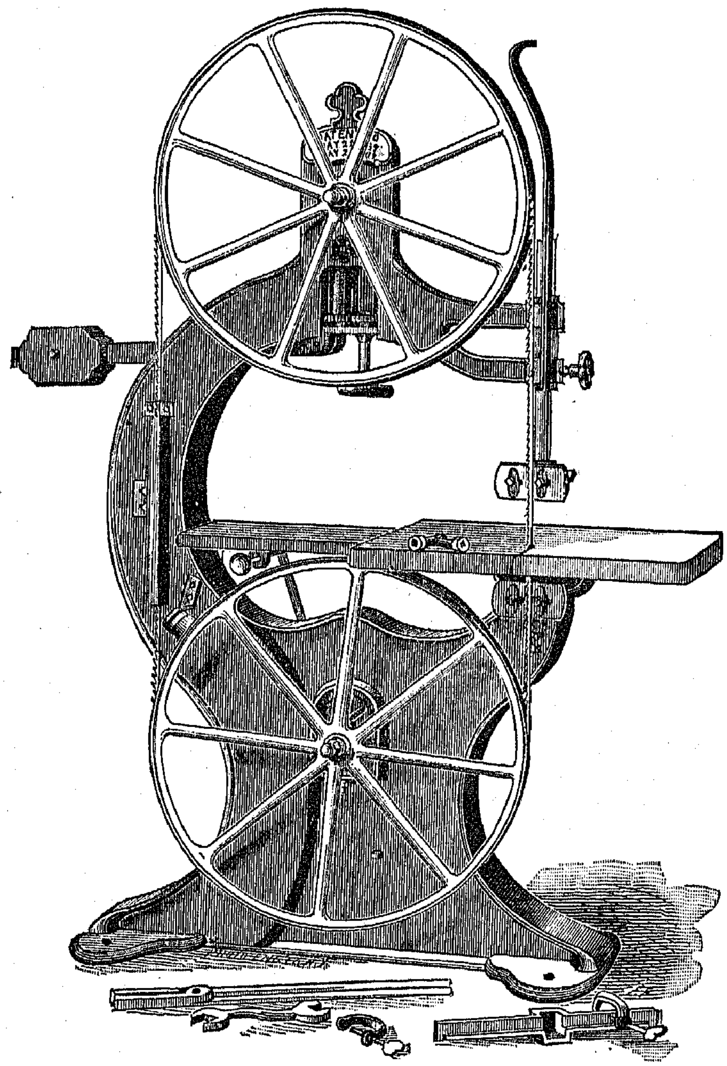

Fig. 405.

Fig. 405 shows the arrangement for straining the saw by a weight. The thrust is here borne by a steel plate, which is adjusted by four set-screws, so as to have a true bearing against the blade. The side guides are of wood. A brush keeps the sawdust from adhering to the rubber tire.

Fig. 406 has a weighted lever to strain the saw, which has a stop so that the tension may be taken off when not required. The thrust is here taken by a steel rod in place endwise behind the saw. It is adjusted by a milled head behind the guide bar. Side guides are of wood. This tool has a guard, C, below the table to carry off blocks and dust from the saw.

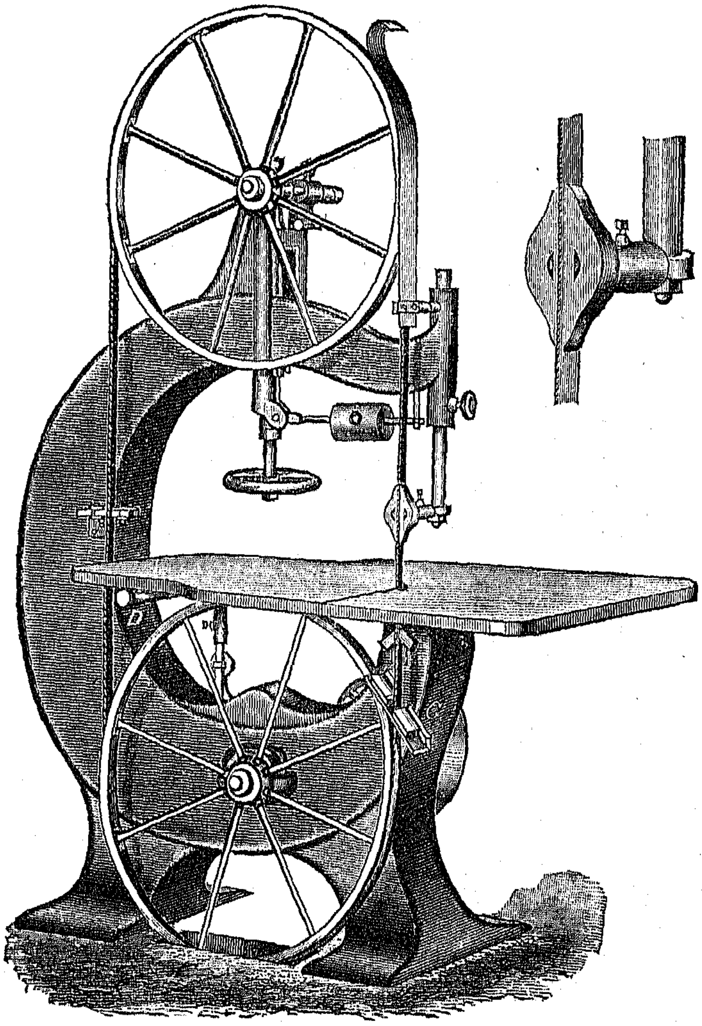

Fig. 406.

Fig. 407 illustrates a design with cast-iron driving-wheel below and an elastic steel wheel of very light construction above. A similar weighted lever takes up and compensates for any buckling or stretch of the blade, and the thrust is borne upon a steel roller with wooden side guides. The roller device diminishes the tendency for the back of the saw to upset or harden. The objections to it are its high speed of rotation, and that the support to the blade must be at a point above the cut distant at least the radius of the roller. This roller is also apt to "ring" or become cut into grooves. There is a roller at the rear to guide the blade to the upper wheel, and the ascending part of the blade is shielded. The guard in front of the upper wheel is universal in order to prevent injury in case of accident. The roller thrusts are lubricated by self-oilers. There is a brake connected to the shipping device to arrest the motion quickly. The rubber tire of the wheel is ground true in-place.

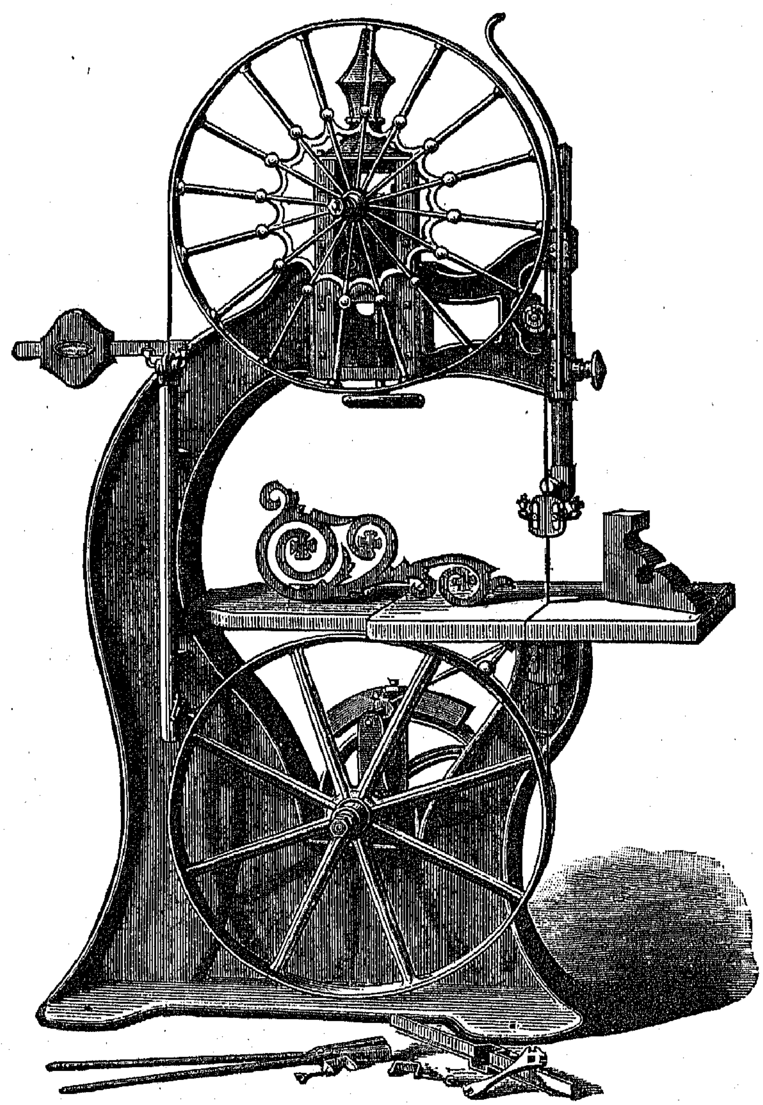

Fig. 407.

Fig. 408 has the mandrels supported in boxes upon their ends, instead of permitting the wheels to overhang. The counter-weight acts directly in the plane of the saw, so that its action does not bind the slide, and therefore it is more sensitive. The thrust is taken by a hardened steel disk whose center is out of the plane of the pressure against the saw. The grooves cut by the back of the saw do not intersect at one point, and the washer can be turned to present a fresh surface until it is all used up. The rotation is by a worm-thread cut on the edge of the disk.

Fig. 409 illustrates a type of slightly different shape of frame. The adjusting-apron swings laterally by set-screws to produce vertical adjustment of the upper wheel. The geared tension-screw is counter-weighted. The lateral guides are of wood. The thrust of the cut is taken upon a series of balls of hardened steel. These rest in a drilled vertical cylinder, and are kept from contact with each other by steel-drilled washers of the same diameter. The balls are set up against the saw back by set-screws, whose points bear against the balls a little at one side of the line of saw pressure. As the balls are turned by the saw a compound motion is caused by the bearing of the screws, and therefore the balls are prevented from "ringing". This ball system distributes the pressure against

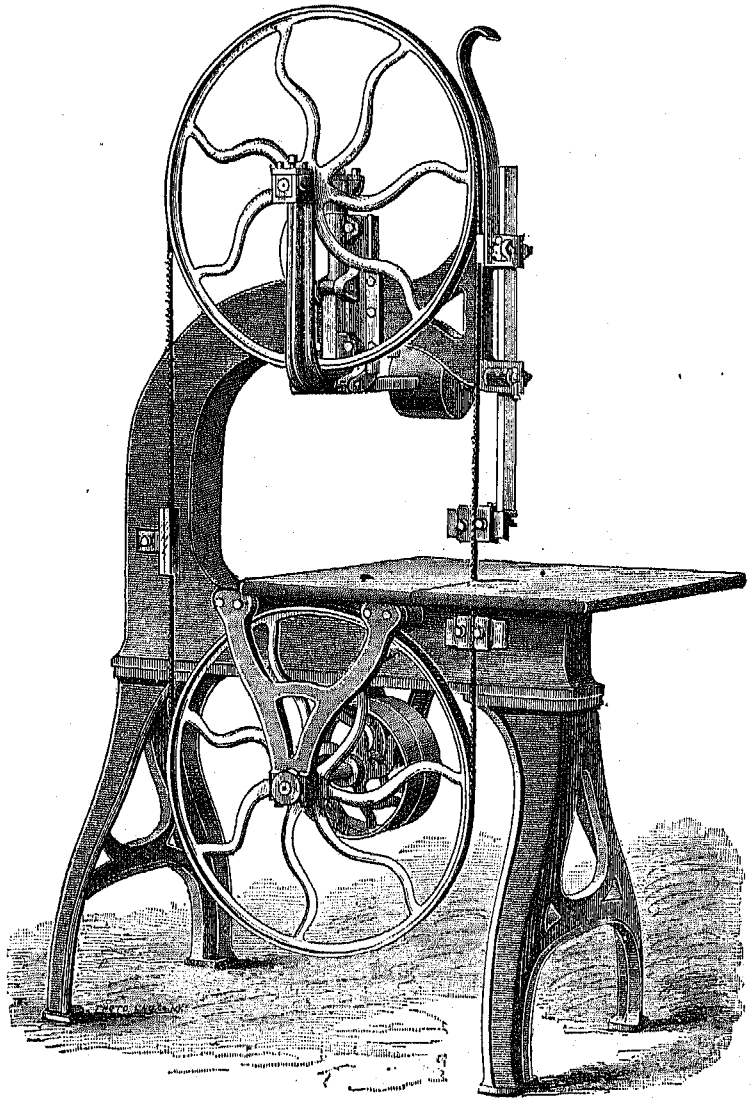

Fig. 408.

the blade over a large area and brings the first resistance close to the cut. To counteract the strains on the saw, due to starting the upper wheel and to its overrunning when the lower wheel is stopped by a friction-brake, this machine has a special device. The rim of the upper wheel is flanged, and pockets of anti-friction alloy are formed in recesses in it. In the groove thus formed a steel ring covered with leather is accurately fitted. The saw lies upon this ring, the leather serving to protect the set of the saw. This light ring will slip in the groove at the start

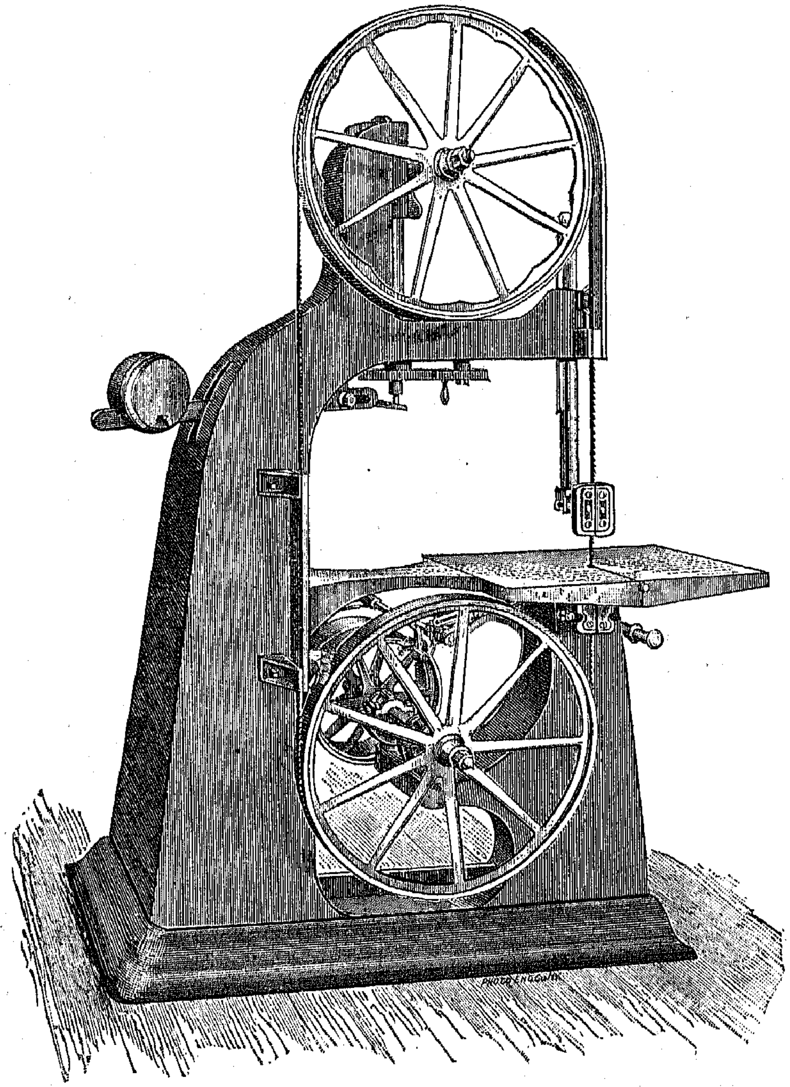

Fig. 409.

or the arrest of motion and distribute the shock of change over several inches of circumference and between smooth surfaces. Otherwise the saw-teeth must rough up the covering of the wheels. The centrifugal expansion of the ring gives elasticity to the bedding of the saw. The friction-brake clasps the pulley-face on both sides and stops rotation rapidly without forcing the wheel out of line. The links to the brake from the shifter-lever are so arranged that the saw is not liable to be freed accidentally and to be started while the operator is handling it. The brake-lever will have passed its dead-point, and will be so held locked by the bearing of the shifter-rod when the brake is acting and the belt is on the loose pulley. The chattering of the shifter-fork cannot disengage either shifter or brake.

There is a variety of cheaper designs with omission of the special features of excellence in the larger patterns. The strain on the saw may be by screw only, without spring or weight; the thrust may be by wood only; the table may be fixed without arrangements for bevel sawing, and less care may be taken in fitting. These are in answer to a demand for low-priced goods, where durability and accuracy are thought of less moment.

§ 41.

RECIPROCATING SCROLL- OR JIG-SAWS.

A continuous saw is not adapted for fret-work, in which internal patterns are to be cut out. It becomes necessary to have a saw of which one end may be inserted within the area to be removed. The band-saw must therefore be supplemented or replaced by a reciprocating saw, which shall have one end which may be freed from the driving mechanism. These saws appear in three forms: Gate-saws, strained saws, and unstrained saws. The gate-saws are adapted for scroll-work upon heavy plank. The saw is strained positively by a screw between an upper and lower frame, which receives motion from a wrist-plate shaft. There may be one saw, as in Fig. 410, in the center of a wide table, or the post-gate system of Fig. 411 may be duplicated upon the other side of the post. Each saw in this case resists the strain of the other. The thrust and twist of the cut is resisted by an adjustable guide, hung from the stationary frame. This also holds down the work on the up-strokes. A reciprocating air-pump blows the lifted dust from the lines in Fig. 410. Centrifugal blowers are more usual.

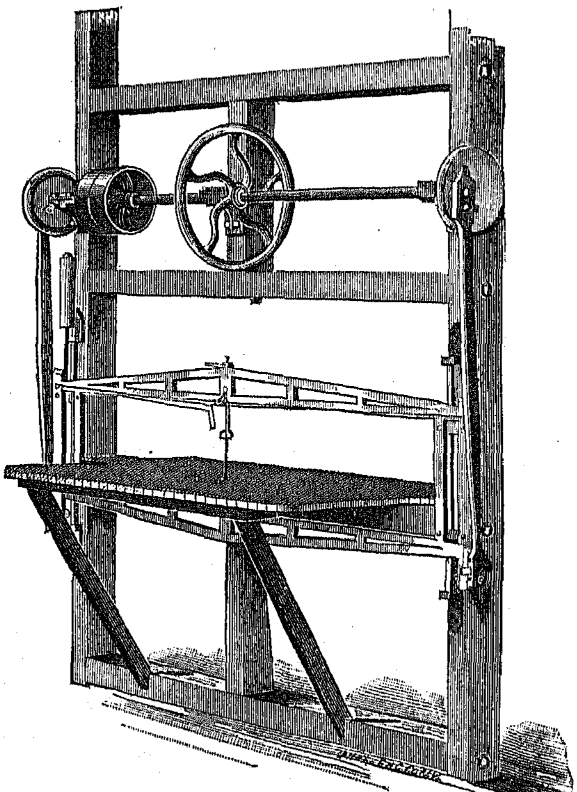

Fig. 410.

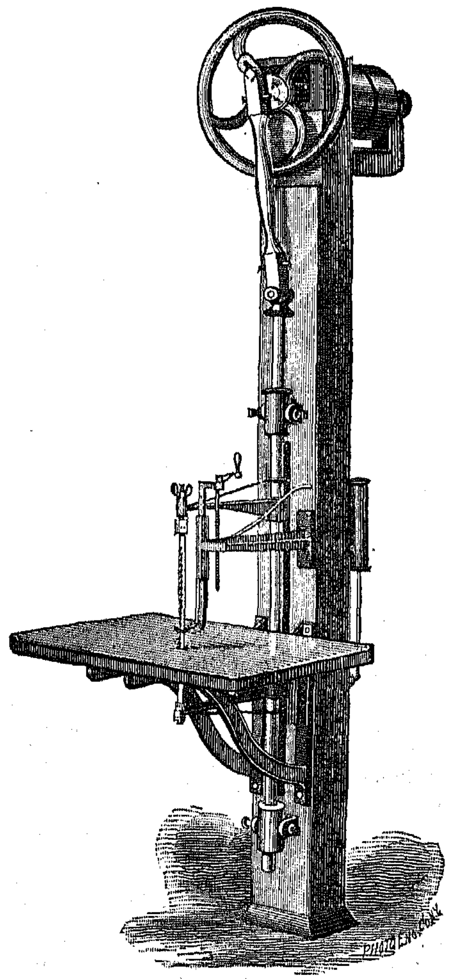

Fig. 411.

In Fig. 410 the trussed frame is so long as to require light lateral bracing. In the post-gate system the central connection makes this unnecessary. In the form shown the slide is of gas-pipe, for the sake of the lightness. The fly-wheel equalizes the work upon the two strokes.

The saws strained with a spring are by far the most numerous. Since they cannot be forced to heavy cuts as in the gate-saws, they must acquire their capacity by very high speeds. The reciprocating parts are therefore made very light, and the spring is made strong enough to carry up the saw, which cuts on the down-stroke only. The great advantage which this type has over the gate-saws is its wide swing. The upper works above the saw are attached to a hanging post, braced by rods to the ceiling. These tie-rods are usually made adjustable by turn-buckles or right-and-left sleeves, which may make the post entirely rigid and insure that the saw is perpendicular to the table. The lower end of the saw is guided by a cross-head, which is driven by a light wooden pitman from a wrist-plate shaft near the floor. This shaft carries a fast-and-loose pulley, the shifter, in many modern designs, being worked by the foot of the operator. Almost universally the shifter device applies and releases a brake upon the edge of the wrist-plate. A great saving of time results from this. The wrist-plate is made heavy to serve as balance-wheel.

The old form of spring to lift the saw was a bar of ash secured at the end farthest from the saw. This wood spring, when used to-day, is either made duplex or else acts on the saw through leverages. Either system reduces the length and inertia of the spring and permits a higher speed of reciprocation. The problem of straining devices of to-day is to secure equal tension of the saw at all points of its stroke. A large number of designs use the fusee principle, by which the leverage of the saw diminishes as the strain on the spring grows greater. The leather strap to the saw or to the spring is wrapped and unwrapped spirally upon a cone or an eccentric-wheel or arc. Very many are content to attain this object, and permit very high speeds by permitting but small motion to the spring.

In Fig. 412 a spiral spring acts upon the pivoted arc, upon whose face is stretched the flexible band to which the saw is hooked. The arc keeps the pull on the upper cross-head vertical.

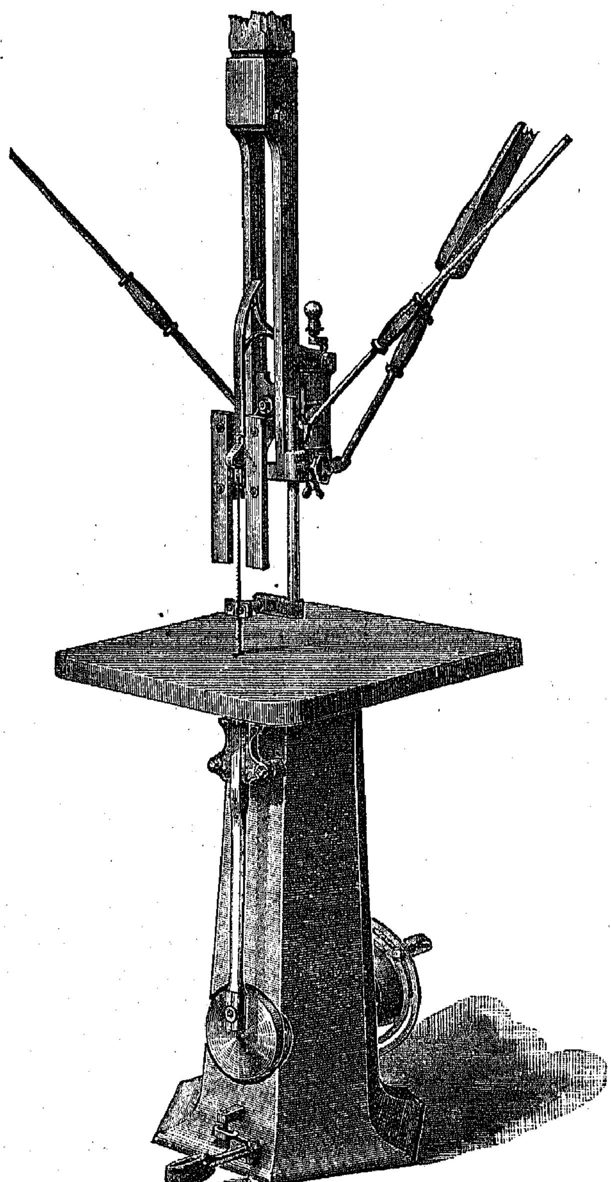

Fig. 412.

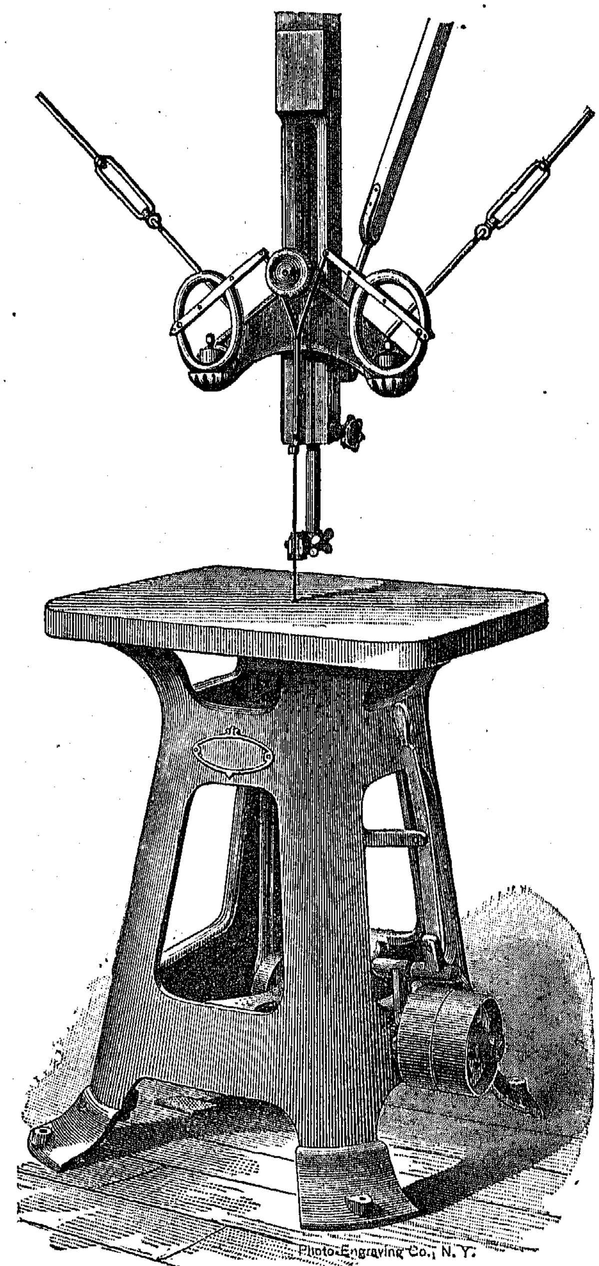

Fig. 413.

In Fig. 413 of a tool by the same builders, the springs are open ovals of thick steel, strained by the levers shown. Their varying leverage equates the varying strain on the springs. Differences of tension are secured by the position of the ovals under the clamping set-screws, and the whole upper casting is also movable for further adjustment. Direct torsion of steel bars is also applied by some designers. The form of table is also adapted to absorb its own vibrations instead of transmitting them to the flooring. So important a consideration is this of absorbing vibrations properly, that some of the older forms should not be put on the upper floors of high buildings.

In Fig. 414 the strain is maintained by leaf springs acting on a differential-wheel device within the shield. The springs may be equalized by the milled-head screws. The shifter-brake acts by an incline and is very powerful. Such a machine may be run at from 1,600 to 1,800 revolutions per minute.

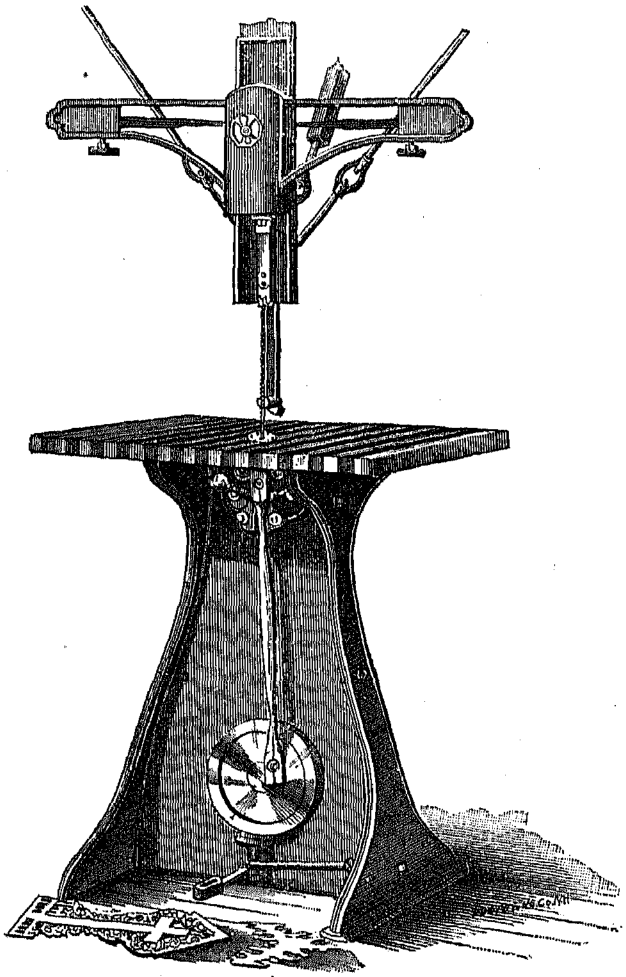

Fig. 414.

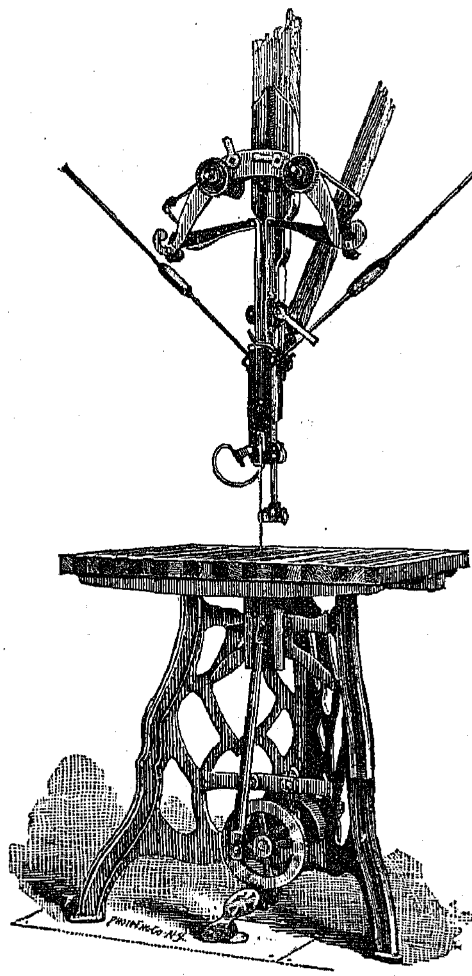

Fig. 415.

Fig. 415 shows a coiled-spring lever-strain, with the strain on the saw adjustable between the limits of 10 to 75 pounds. All the upper works are carried by the pipe E, and they are balanced by the spiral spring O above them. The shaft E is clamped at will by the cam-lever F. The air-pump is within E. The lower cross-head has special devices to prevent jamming or rattling from heat or contraction, and the friction devices for the crank-shaft permit the machine to be stopped, the saw to be removed, replaced and in operation within four seconds. The tilting of the table of a larger size is sometimes convenient for sawing patterns with draught.

Fig. 416 shows a saw in which the straining-lever floats upon the links to the two straining-springs. The relative variation in the leverages of the two springs keeps a uniform tension on the blade. The degree of strain is controlled by the thumb-screw.

Fig. 417 shows a form of unstrained saw on the mulay principle. The slide below is octagonal and hollow, and the saw is pinned to it by spring cotters. The upper end is free, and the thrust is received and the blade is guided just above the work. The guide also acts as a "hold-down" for the work. The fan-blower is above the foot-socket of the hanging post. Such saws may run very rapidly, and avoid the inconvenience of the overhead springs and their wear and fracture. Perforated work is also done very rapidly where no disconnection is required. They will cut quite heavy pieces for carriage, wagon, and miscellaneous work. The strained fret-saws of the same builder are so arranged that the rake of the cut may be varied by throwing forward the cross-head guides. Wooden tops are often fitted with an iron plate around the saw, that a hollow place may not be worn there. Wooden tables are often made of ash and walnut or cherry glued in alternate strips, to prevent a tendency to warp. Most builders have patterns for tables which may tilt for bevels.

There is an infinity of jig-saw attachments to be put upon lathes. These are for amateurs entirely, and for pleasure rather than for profit. They do not come within the scope of this discussion. Neither do the reciprocating saws for forest sawing. They are discussed elsewhere.

In concluding the subject of the reciprocating saws, it may be said that their importance has been waning since the introduction of the band-saw for outside work and of friezing or shaping cutters for inside ornamentation. The latter finish the surface as well as shape it, and for many classes of work are superseding the scroll- and fret-saw. The latter must, however, be still employed until the type of ornamentation for certain work shall undergo a considerable change.

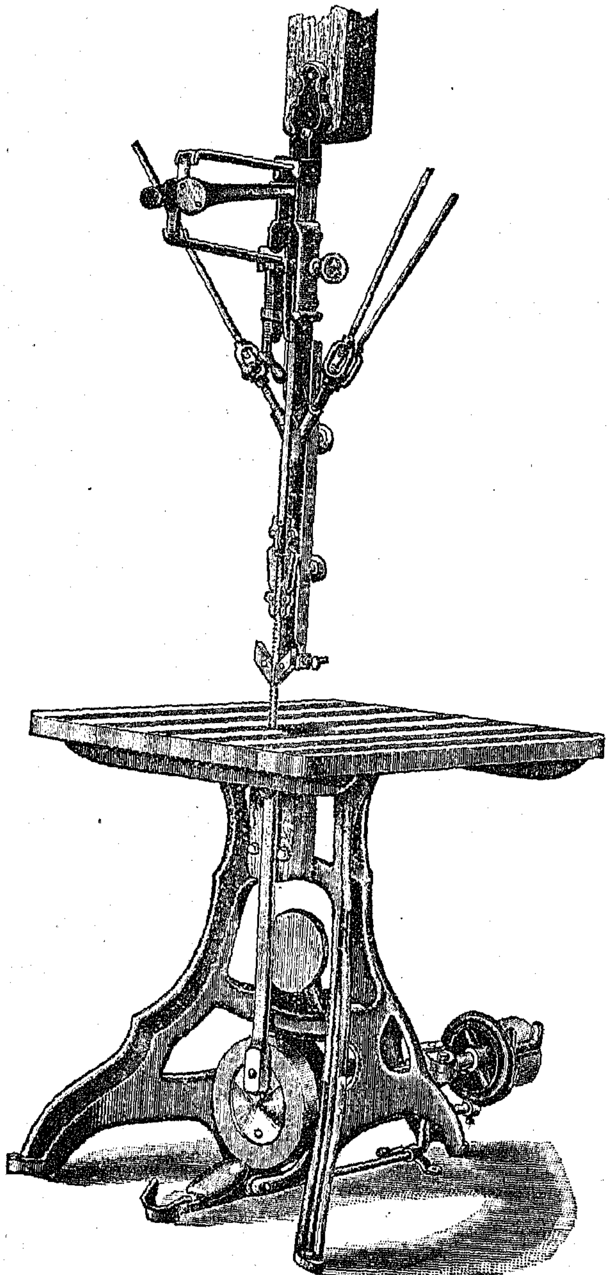

Fig. 416.

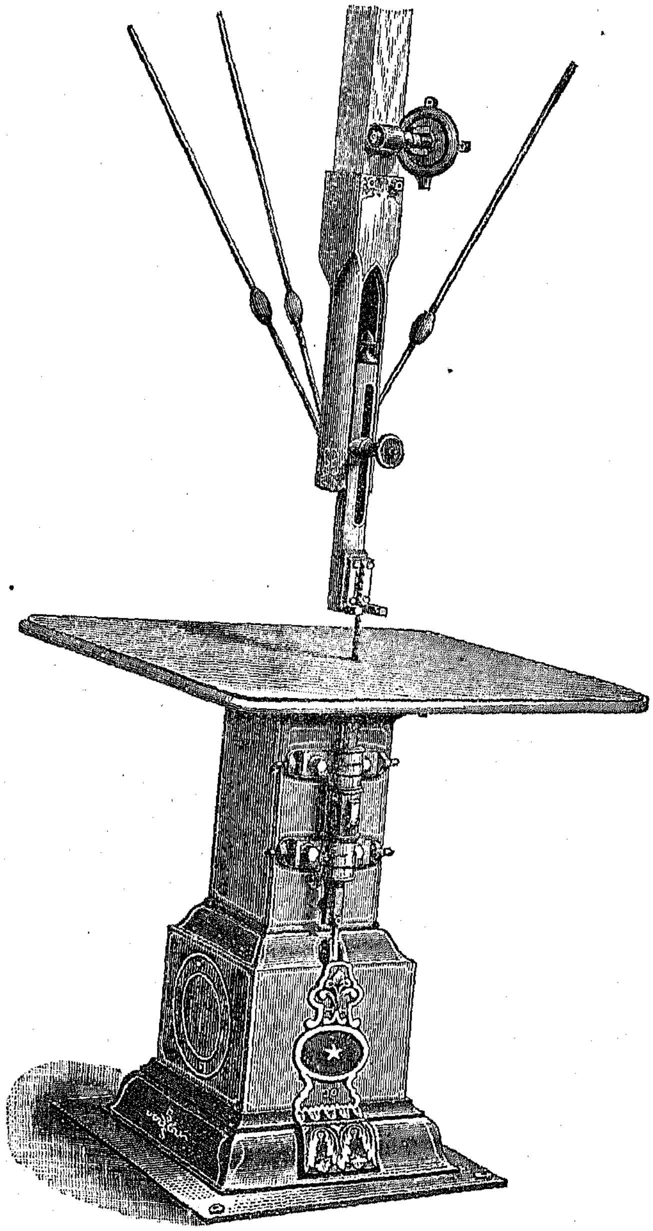

Fig. 417.

Sawing machinery as a class is fundamental to the other processes. Considerable thought has been expended in improving it, and the results are to be seen in the types illustrated. The improvement since the earlier days is very marked, and is daily advancing.

§ 42.

G.—TOOLS ACTING BY PARING.

SURFACERS, PLANERS, AND MATCHERS.

After the wood has come from the resaws, or from the forest-saws, its surface is rough. It will have the marks of the saws upon it, it may be gritty and disfigured, and it may be in wind or out of truth. It is therefore passed through a machine, in which cutters act upon it in the direction of its fibers or grain. The edges act to pare away the surfaces, taking off chips, and not dust. A class of machinery, therefore, very different from the