Chapter XXIV.—GEAR-CUTTING MACHINES.

The Brainard automatic gear cutter, Figs. 2069, 2070, 2071 and 2072 is arranged to cut spur, bevel, and worm-wheels, and is of that class where the manipulations required in gear cutting are all performed by the machine itself, thus dispensing with the care of an attendant except to place the wheels in position and set the machine for the proper depth and length of cut. The manner in which these results are accomplished will be seen from the following description, reference being had to the engravings. The wheel to be cut (*a*, Fig. 2070) is held upon a mandrel *b* fitted to the spindle *c*, which is mounted in firm bearings upon a column or standard *d*. To the face of the standard is gibbed a sliding knee *e*. Upon this knee is placed the cutter slide *f*, which is arranged to be inclined for bevel-gear cutting, and to be swung aside in cutting worm-wheels. Rotary cutters are carried

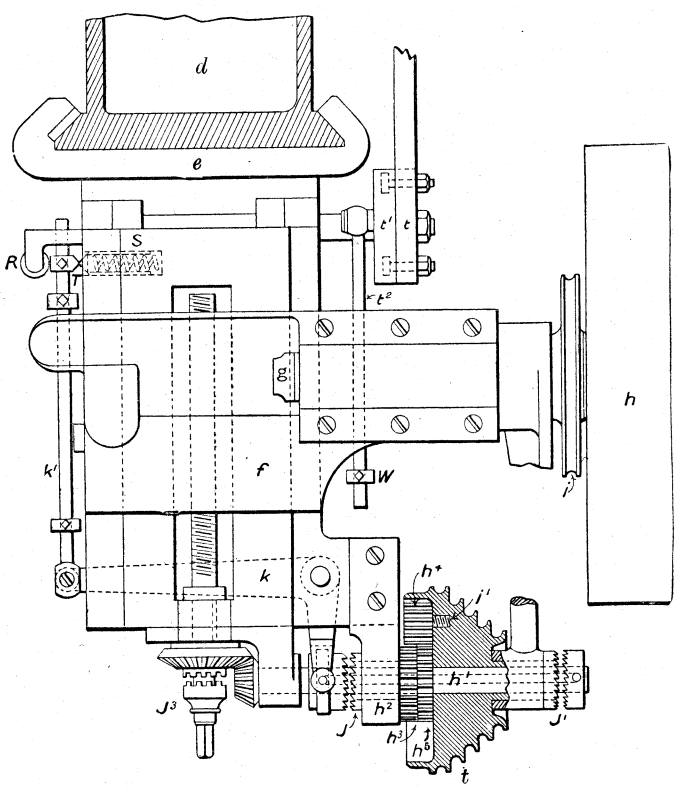

Fig. 2071.

on arbors fitted to the cutting spindle (*g*, Fig. 2071). Power for driving the cutter is applied to the pulley *h*, mounted upon the cutter spindle.

The cutter slide *f* is operated through the medium of a screw and bevel-gears from a shaft h^1, which is arranged to revolve alternately in opposite directions from a continuous motion of the driving cone pulley *t*, receiving motion from the feed pulley *i*, through the means of a swinging arm, carrying a receiving pulley and cone as is shown in Fig. 2069.

The method of obtaining these opposite motions of the shaft h^1 will be seen in Fig. 2071. To the block h^2 which supports the shaft h^1 is secured a gear h^3, which engages with a pinion h^4 mounted loosely on the cone pulley i^1. Side by side with this gear is placed a second gear h^5 also engaging with the pinion h^4 and having one tooth less than the gear h^3. This gear is mounted loosely on the shaft h^1 and is sleeved through the block h^2, and to it is secured a ratchet clutch *j*.

This arrangement produces a motion analogous to that of worm gearing; the revolution of the cone i^1 carrying the pinion h^4, causes the gear h^5 to be moved in the opposite direction to that of the cone i^1, and at a speed of one tooth for each revolution of the cone. The cone i^1 carries on its outer end a second clutch j^1. The shaft h^1 is made hollow, and two clutches are secured to a rod playing loosely on the hollow shaft, and arranged to be engaged alternately with the clutches *j* and j^1. This engagement is effected by means of a bell crank *k*, operated by a shipper rod k^1 on which adjustable dogs are placed, arranged to be operated by the cutter slide *f*.

This arrangement of feed shipping motion is very positive in its action, and allows of a very quick return of the cutter slide. The parts are so proportioned that the slide returns thirty-three times as fast as the forward motion, and yet on the very fastest speeds there is no perceptible jar of the parts. The entire mechanism can be disconnected from the feed screw, when desired, by disengaging the clutch j^3 on the feed screw. The means employed for spacing the wheel blank are shown in Figs. 2070 and 2072. At the rear end of the spindle *c* is secured a worm-wheel *l*. This worm-wheel is made in two parts screwed firmly together. By this construction the wheel is made very accurately. The screw holes in the ring l^1 are slightly elliptic. After the wheel has been hobbed out the position of the ring is changed and the wheel re-hobbed, and so on until the teeth will match perfectly in any position of the ring, when the ring is pinned and screwed on permanently. This wheel is driven by a worm *m* in connection with change gearing m^1, m^2, in such a way that one turn of the shaft m^3 serves for all divisions. To the shaft m^3 is secured a graduated plate *o*, to which is secured a latch plate o^1 by means of a **T**-slot and bolts. The latch plate o^1 is secured in this manner in order that the plate *o* may be turned any desired amount of "set over" in bevel-gear cutting, without disturbing the change gearing or latch. This dividing mechanism is driven by an independent belt from the countershaft to the pulley P, which is secured to a pinion P^1, running loose on a stud. The pinion P^1 engages with a gear P^2 mounted loosely on the shaft m^3. This gear is made to drive the latch plate o^1 at the proper time by means of friction plates, which are set to the required tension by check nuts. The latch plate o^1 is held by a spring latch *v*, which is secured to an arm v^1 mounted loosely on a stud. The arm v^1 is moved by a disk v^2 carrying a secondary latch v^3. This secondary latch v^3 has on one side a roll which engages with a fixed cam v^4, which trips the latch v^3 from its connection with the arm v^1, thus allowing the spring on the latch *v* to return it to its seat in the latch plate o^1.

The disk v^2 is moved by a steel ribbon (S, Fig. 2070) which is connected to a pair of plates, *t* t^1, held together by a **T**-slot and bolts, and mounted loosely upon the carriage which carries the cutter slide *f*. The object of the double plates is to take up the slack ribbon, in any required position of the carriage, on the knee *e*. To the inside plate t^1 is connected a shipper rod t^2, which carries a dog and is operated by the return motion of the cutter slide *f*. A spiral spring coiled on the stud supporting the disk v^2 returns the disk to its original position on the forward motion of the cutter slide *f*, and reseats the secondary latch v^3 in its seat in the arm v^1. This arrangement of dividing mechanism requiring but one turn of the shaft m^3 possesses some very decided advantages over the ordinary way of simple gearing and multiplied turns. The latch *v* is tripped immediately after leaving its seat in the plate o^1, and is returned by its spring against the periphery of the plate, and is surely seated by means of a lip on the upper side of the plate. Should it, however, fail by reason of any accident no harm will be done as the gear will be correctly spaced whenever the latch is seated, only one or more spaces will have been missed. Another advantage is that the feed gear can be disconnected and the latch withdrawn, thus allowing the gear to be revolved for the purpose of examination without any necessity for remembering the exact number of turns. When the latch is again seated the gear will be always properly spaced.

Fig. 2073 represents the same machine made half automatic, or in other words the feed is automatic, but when the cut is through, the worm that actuates the feed is thrown out of gear by a catch which lets the box or bearing at the left hand of the worm shaft drop vertically, this catch being operated by a stop on the side of the cutter slide. The method of arranging the feed mechanism so that it shall remain undisturbed, and require no alteration or adjustment at whatever height the knee carrying the cutter slide may be, is substantially the same as that already described with reference to the universal milling machine in Fig. 1893, while the dividing mechanism and other general features are the same as in the full automatic, with the exception of the mechanism for operating the cutter during the return stroke, and operating the dividing mechanism, both of which operations are done by hand in the half-automatic machine.

Fig. 2074 represents a Whitworth machine in which the cutter is carried in a vertical spindle carried in a sliding head. A is the driving pulley, B a pair of bevel-gears, and C a pinion driving the cutter spindle D, the cutter being at E. The cutter spindle has journal bearing at each end in arms upon the sliding head F, which is operated along the slideway of H by the gear-wheel G, receiving motion from the worm at C; at K is the index wheel, the wheel to be cut being carried on its shaft at M. The head N, carrying the index-wheel shaft, may be moved along the bed on which it slides by the handle P, which operates a screw within the bed, and engaging a nut on the under side of N. The worm for the worm-wheel K is carried beneath the wheel by a bracket from N, and being on a splined shaft moves with N. P is the handle for the divisions, the latter being obtained by means of change wheels at J, which connect with the worm shaft. By employing change gears the handle P makes a complete turn for any division, and is locked in a recess, which determines when an exact turn has been made. The range of a machine of this design is very great, because of the length of the bed on which the head N slides, which may be longer than would be practical if it stood upright.

Fig. 2075 represents a gear planing machine, shown with a bevel-gear in place. The main spindle is horizontal upon a fixed head, and has its dividing mechanism at the back of the machine. A single pointed tool is used in a slide rest, operated (by crank motion) upon the horizontal slideway shown, which may be set at any required angle for bevel-wheels. The cut is carried from the point to the flank of the tooth, and is put on by a rod and ratchet motion, the rod striking against the stop seen beneath the cross slide for the slide rest, and on the side of the horizontal slideway.

Figs. 2076, 2077, 2078, 2079, 2080, 2081, and 2082 represent different views of a gear-cutting machine, which consists of a bed plate A A, Figs. 2077, 2078, and 2079, having an extension at end A^2, to support the hollow cylindrical column A^3, which carries an overhead shaft a, at one end of which is a four-step cone a^3, for driving the cutter feed motions. At the other end are the tight and loose pulleys for driving this shaft, upon which is also a series of grooved pulleys a^5, arranged in the form of a cone. The object of this is to drive the cutter. At the base of the column A^3 is a corresponding series of grooved pulleys, also arranged in the form of a cone a^6. A round belt is employed. The shaft on which a^6 is placed extends through the column, and on its opposite end a grooved pulley is also placed. This serves to drive a belt which, passing over a series of idle pulleys, as will be seen by reference to Figs. 2076 and 2077, drives the rotary cutter.

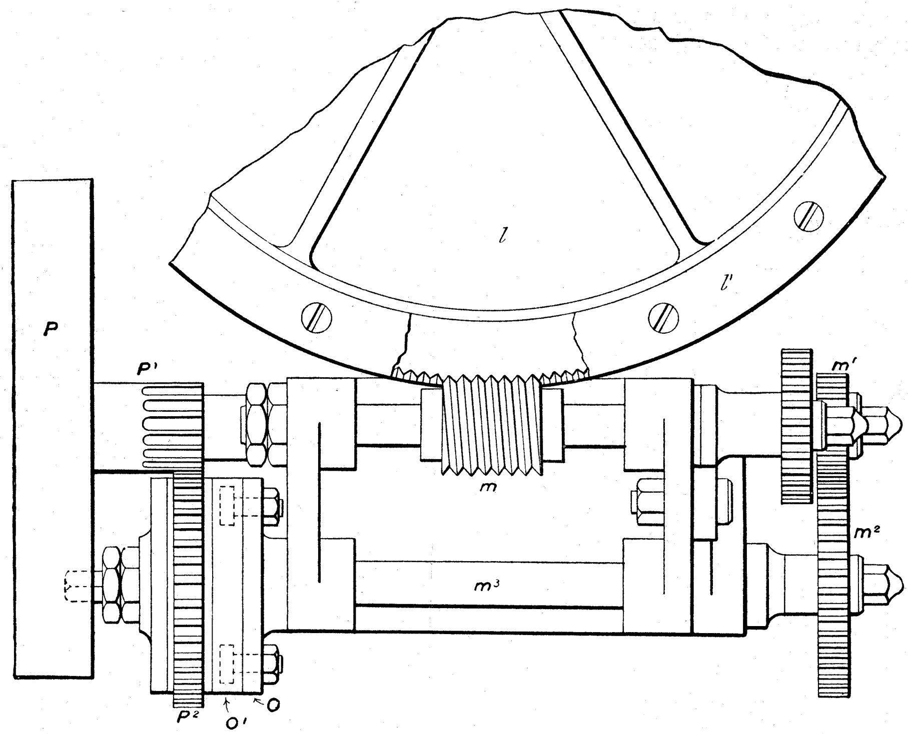

Fig. 2072.

The wheel to be cut is carried as follows: Upon the bed-plate of the machine is placed a head B, Fig. 2078, corresponding to the headstock of a lathe, opposite which is a head B', answering to the tailstock of a lathe. These two carry a mandrel D, to which is fastened a face-plate D' against which the work is chucked. At the end of D'' is fixed, in the usual manner, the worm-wheel for the dividing mechanism. The cutting arbor is held in a head that is carried in a cross slide C^2, Fig. 2077, this cross slide being a carriage that may be fed along the side extension of the bed, which is broken off in the plan view of the machine, Fig. 2078. The two slides thus provided in this machine form in effect a longitudinal and cross feed, answering to the feeds of a lathe carriage and tool rest.

The cutter head M, Fig. 2077, is composed of two parts, C and M. Provision is made to swing the head in two directions, one of

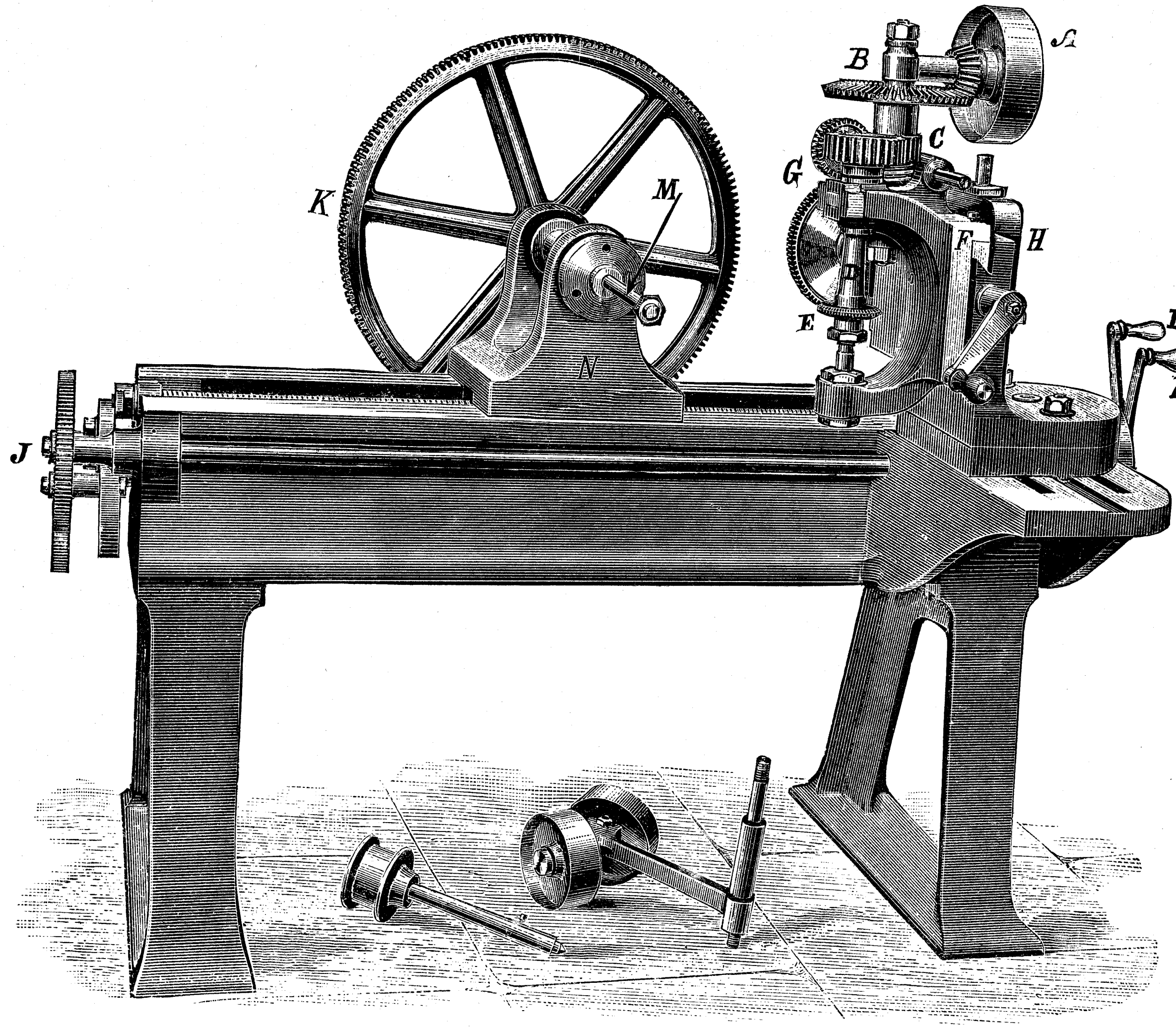

Fig. 2074.

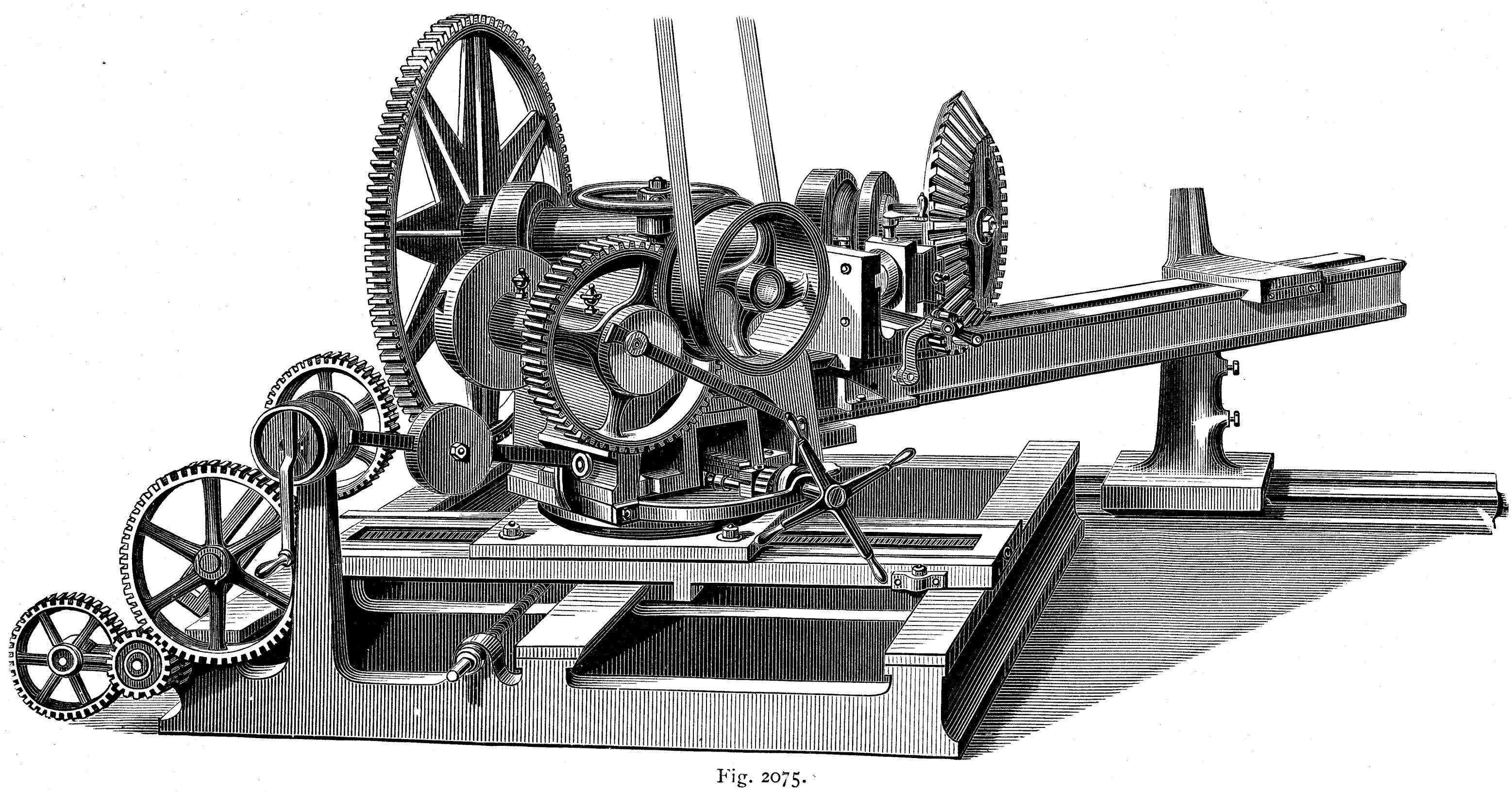

Fig. 2075.

which is noted by the plain arrow and the other by the feathered arrow in the engravings. Between the two the cutter arbor, it will be percived, may be set at an angle in whatever direction the nature of the work may require. Referring to Figs. 2076 and 2077, it will be seen that the cutter-driver mechanism operates as follows: The tight pulley a^1, driven in the direction noted by the arrow, turns the cone a^6 which drives the pulley b. The belt from b passes over grooved idlers, b^1, b^2, b^3, &c., to the grooved pulley b^8, which is fast on its shaft and drives a train of gearing that operates the cutter arbor, the train being best shown in Fig. 2077. The train of gearing thus driven is composed of gears c^1, c^2 and c^5, the latter being on the cutter arbor. The object of this arrangement is to obtain a high belt velocity. It will be seen that all these English planing machines. The clutch f is operated by a rod l', and drives the bevelled pinions d^2 d^4 by friction. The hub of the clutch is coned to fit a coned recess in the hubs of the two pinions. A pair of gears, d^6 d^7, transmit the motion of d^5 to the shaft d^1, on the end of which is the pinion e'. Motion is conveyed from this pinion to the feed-screw e, Fig. 2081, by the intermediate gears e^2, e^3, e^4 and e^5, and also by the helical pinions e^6 and e^7, the latter two being also shown in Fig. 2081.

Referring to the dividing mechanism, E, Fig. 2077, is an index-wheel operated by a worm. E^1 is an arm with a locking tongue. Motion from E is conveyed to the shaft g through a swing-frame, shown in dotted lines in Fig. 2077, and a train of gears g^2, g^3, g^4, g^5, g^6. On shaft g, Fig. 2078, is a pair of angular-toothed

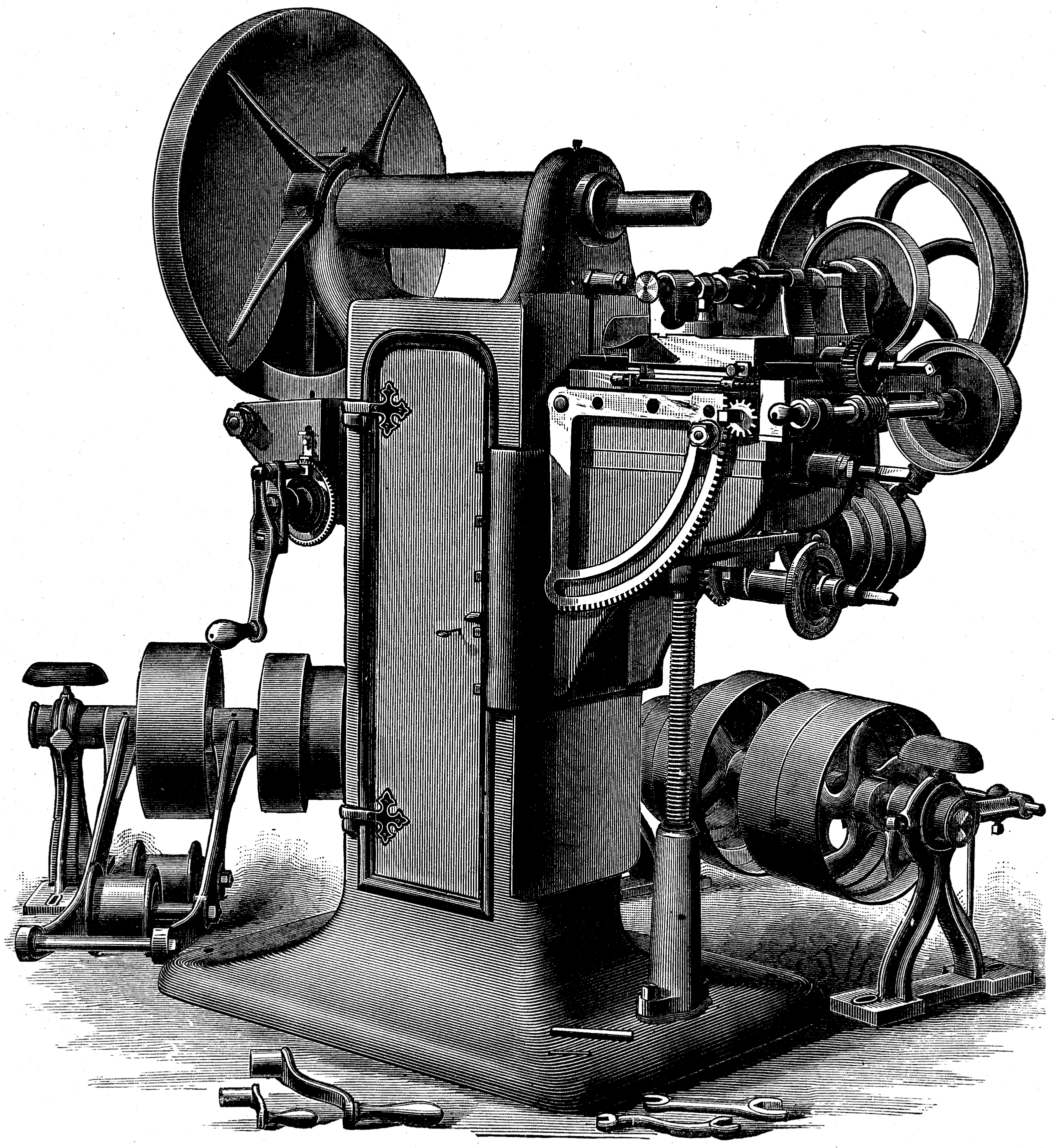

Fig. 2073.

gears have their teeth at an angle to their axes, a feature that has been introduced to obtain smoothness of action. To maintain equal tension of belt at whatever angle the cutter may be set, the idle pulley b^2 acts as a belt tightener, being carried by the rods t and t^1.

Referring now to the feed motions, the machine is provided with a quick return for the cutter, the mechanism of which is as follows: The cone pulley a^4, Fig. 2077, is mounted upon a driver shaft d, Fig. 2079. Upon this shaft are two loose bevelled pinions d^2 d^4, between which, and splined to the shaft, is a clutch f. For the feed traverse the clutch f is moved to engage with the pinion D^4, while for the quick return it engages with d^2. This device corresponds to the old-style quick-return motion used in some of the heavy beveled pinions, h^1 h^2, and on shaft h, Fig. 2080, is a pinion h^3, driving a pinion h^4, which in turn drives pinions i i^1. The latter drive the worm H′ which operates the wheel H. The two shafts carrying i i^1 are supported by a piece F, the arm of which appears in section. This is fixed on the large toothed wheel G, indicated by the dotted lines in the same figure. The piece F above referred to is not fully shown in the engraving, portions of it having been omitted in order to show the mechanism previously mentioned. The wheel H is mounted on shaft D″, and is used to revolve the face plate D′, all as shown in Fig. 2078. The wheels g^2 g^3 are change wheels, whose relative diameters determine the number of turns the wheel E must make for a given pitch. The arm E^1, Fig. 2077, is provided with a spring to hold the index pin into the notch of the index wheel. From this description it is obvious that when the number of the teeth of the wheel to be cut is a multiple of that of the wheel H, the number of turns to be given to the tangent screw H′, Fig. 2080, is exactly determined by the ratio existing between these two numbers. On the other hand, where the number of teeth required is not a multiple of the teeth in the wheel H, the number of turns to be given to the screw will be equal to *n* plus a fraction. In the first case, if all the intermediate gears between the dividing apparatus and the tangent screw are arranged to transmit to the former a number of definite turns, it will suffice to make the crank describe example, if it be supposed that a division corresponding to one turn of the tangent screw is to be made, if only one turn of the crank is made, the play unavoidable where easy movement is secured will be repeated and multiplied in the same way that an error is produced after a certain number of divisions. If, on the contrary, the mechanism be arranged so that the number of turns of the crank is multiplied in obtaining one turn of the tangent screw, the error will be appreciably reduced. It is therefore recommended by the designer of this machine to arrange the train of gears so as to give a certain number of full turns to the crank in all cases. If, after having cut the teeth in the blank, it is

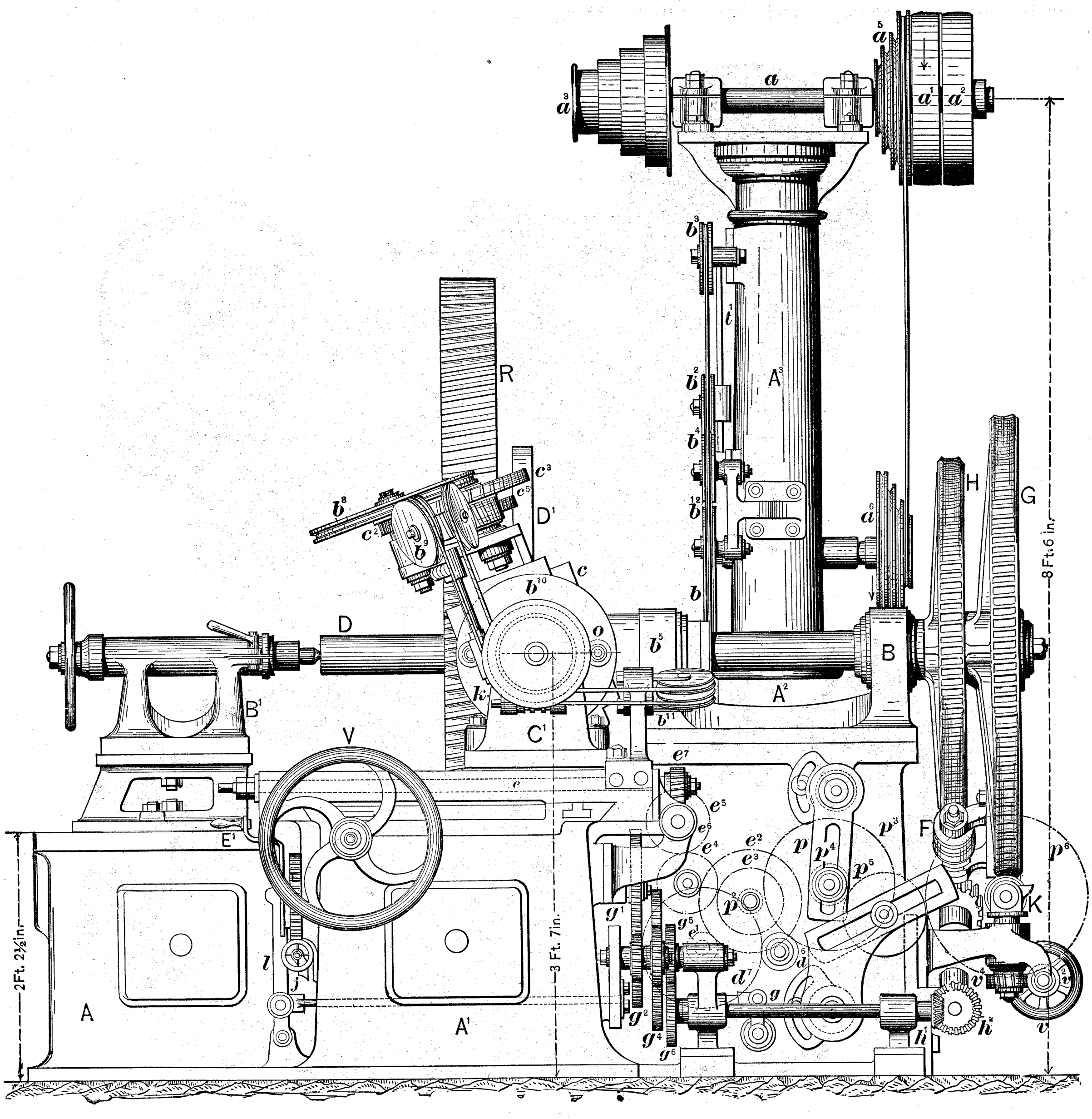

Fig. 2076.

the number of turns indicated by the ratio the wheel E bears to the worm-wheel. In the second case, in order to give the tangent screw *n* turns plus a fraction by giving the crank *n* + turns, it is necessary to employ several wheels, for which the ratio must be calculated. If the division so obtained is not an exact divisor of the number of teeth of the wheel H, it is necessary that one of the wheels forming the combination shall have a number of teeth which is a multiple of the division mentioned.

Another consideration with reference to the number of turns to be given to the crank of the dividing apparatus is mentioned in the inventor's description of this machine. The smaller the number the greater will be the chance of error in the result; for desirable to go over them again, it is simply necessary to turn the screw j which engages with the gear-wheel J^1.

The next feature to be described is the adjustment of the cutter. In some cases it is necessary to incline the cutter in such a way that the axis of the shaft carrying it forms a certain angle with the vertical. This is the case in cutting angle teeth, as shown in Fig. 2076. In order to produce the necessary angle for such teeth, it is only necessary to turn the worm *k* that engages with the worm-wheel *k*′, Fig. 2077. This wheel is fast on to the piece M, and the latter, when set to the desired inclination, is kept in place by means of bolts O, Figs. 2077 and 2081. In some cases it is necessary to incline the cutter in such a way that the axis of the shaft that carries it does not cease to be in a vertical plane perpendicular to the shaft D, this being the case as illustrated in Fig. 2082. In order to obtain this obliquity the small shaft m is turned, and the movement so obtained is transmitted by means of two small pinions m^2 m^3 to the shaft carrying at its extremity the screw n'. This screw gears with the segment n''. The latter is fixed to a piece J, furnished with bearings for the reception of the shaft that drives the cutter spindle, which is adjusted endways by means of the nuts shown.

If it is desired to produce a wheel with angle teeth it is necessary, after having arranged the cutter as shown in Fig. 2076, and not turn, nor does the second pinion h^4, which slides on the former. The screw H′ slightly turns the large wheel H, which, as previously mentioned, is mounted on the shaft D, Fig. 2078. When the special tooth operated upon is finished the movement is reversed by operating the lever l. The table and the wheel R, Fig. 2077, then move in the opposite direction. When the original position is reached by the cutter, the reversing lever is thrown out of gear; the handle E′ is then used so as to effect the proper division, and the machine is again started.

As has been shown, only a small portion of the circumference of the wheel G is subjected to wear. In this way it would be

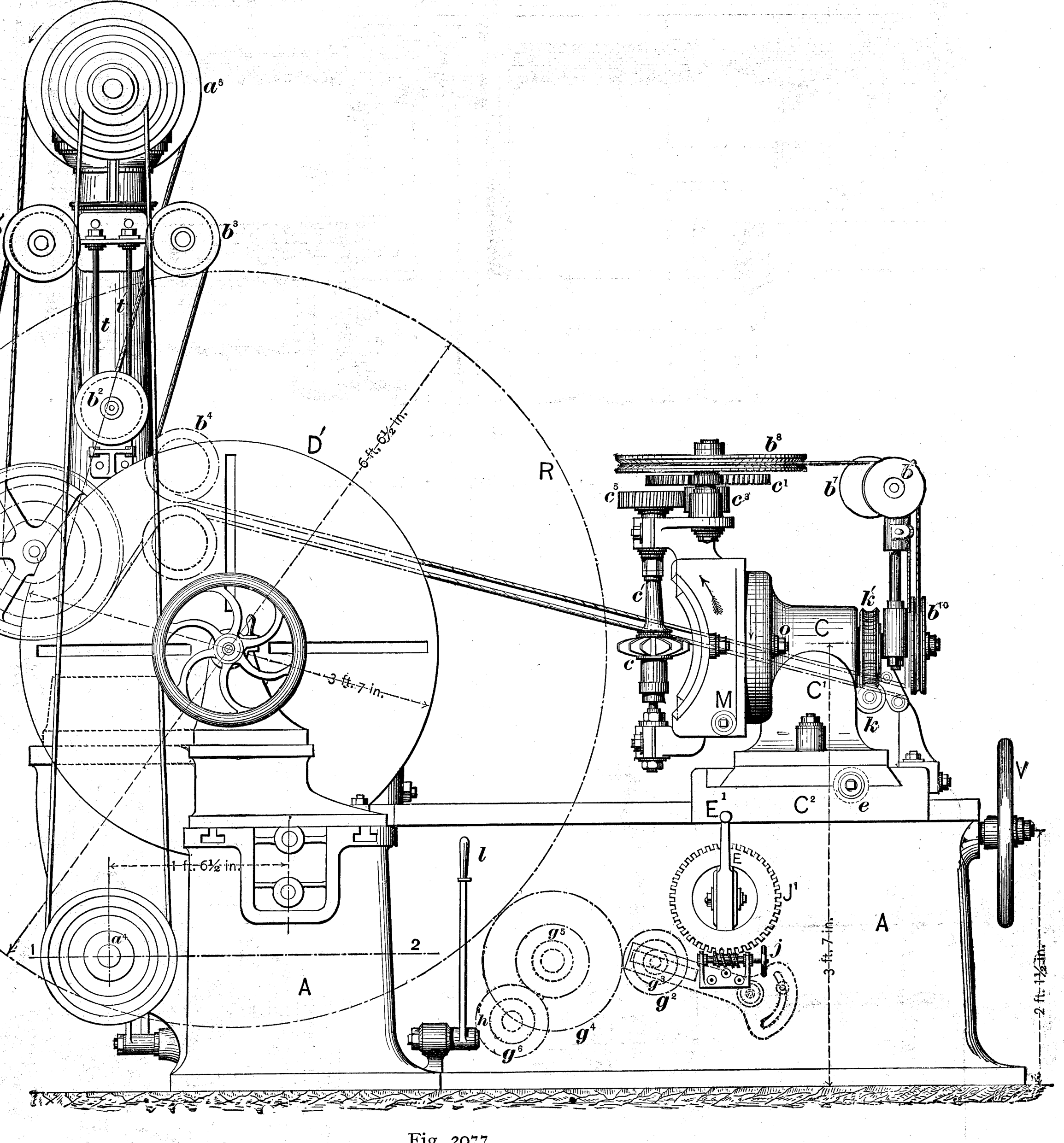

Fig. 2077.

while the forward motion of the carriage takes place, that the wheel R shall turn with a slow, regular movement until the tooth operated upon is finished. After this the tool retraces its path at a somewhat higher speed. This automatic motion is obtained from a shaft (Fig. 2076), on which are placed the pinions e^2 e^3. This shaft carries a third pinion p^2, which, by means of one or more pairs of wheels mounted two by two on a swinging frame p, as shown by p^3 p^4 p^5, turns the shaft p' (Fig. 2080), which carries at one of its extremities the wheel p^6 and at the other the screw h^3. This screw, by proper intermediates, operates the toothed wheel G, Fig 2080, which in its rotation carries along the piece F, with all the parts supported by it. In this movement the pinion h^3 does possible to limit the operation of cutting the teeth to a certain length of arc only. In that case, however, considerable wear would be produced; for this reason the constructor has preferred to provide the whole circumference with teeth, in order to change the working point from time to time, so as to distribute the wear. In order to permit this displacement it is necessary to disengage the worm K (Fig. 2076), which is accomplished by turning the hand wheel v, mounted on the shaft v', Fig. 2078. This shaft carries at each extremity small pinions, v^2, v^3, gearing with other pinions fixed at the extremity of each of the supports of the shaft p'.

In order to make the operation of this machine better understood, we will conclude our description by some practical examples of the calculations required in making helical teeth. It will be observed that the two small movements necessary in cutting an angle tooth in a given inclination are obtained first by the screw *e*, Fig. 2077, feeding the cutter head, and second by the tangent screw K, Fig. 2076, that governs the rotary motion of the wheel G,

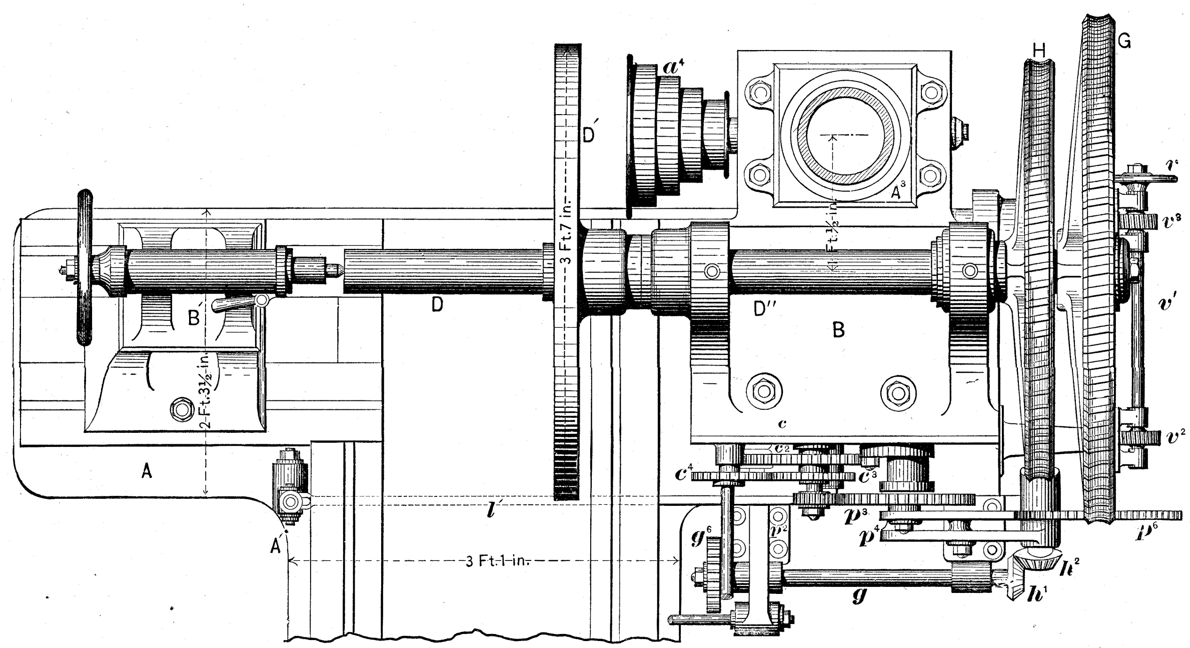

Fig. 2078.

and consequently of the shaft D, carrying the face plate and the blank to be cut. The second wheel H, mounted on this shaft, is driven by the endless screw H′, Fig 2080, the supports of which are fixed on the wheel G It will be observed at the same time that the speed of the screw *e* acting upon the tool holder is the same as that of the shaft carrying the wheels e^2 e^3 and p^2, since the wheels e^4 e^5 e^6 e^7 have the same number of teeth. It is obvious, therefore, that that ratio of speed which will exist between the tangent screw K and the shaft of wheels e^2 e^3 and p^2 will have to be the same as that between the driving screw *e* of the cutter head and the tangent screw K. Consequently, the combinations of wheels that connect

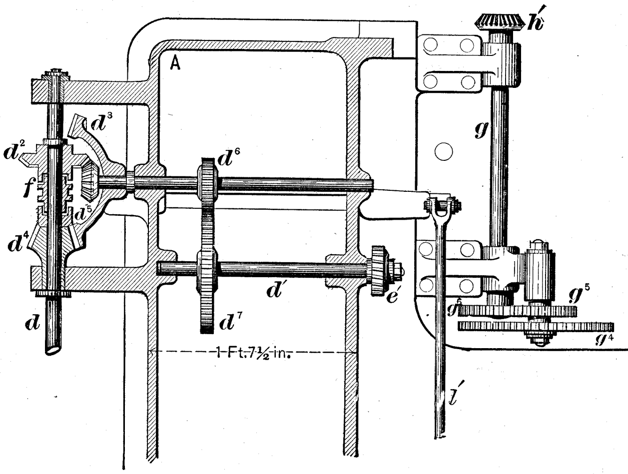

Fig. 2079.

this tangent screw K to the shaft e^2 e^3 and p^2 will produce the same effect as if they were connected directly with the feed screw *e*. This being established, the general formulæ determining the gearing to be employed in order to produce helical teeth inclined at a certain angle are obtained in the following manner: It should here be observed that the teeth produced will be what in the United States are called angle teeth, corresponding, however, so nearly to the helix as to be considered helical. Suppose that the number of teeth in the wheel G is 300, and that the pitch of the driving screw of the cutter head is 5 mm., using for convenience the French system of measurements. Let $\frac{x}{y}$ be the ratio of the four wheels that it is necessary to mount. Let M designate the degrees of inclination of the teeth. Let P equal the pitch of the desired helix, and D the diameter of the wheel to be operated upon. We then have cotan. $M = \frac{P}{D \times 3 \cdot 14}$, from which we find $P =$ cotan. $M \times D \times 3\ 14$, and in order to make the cutter head

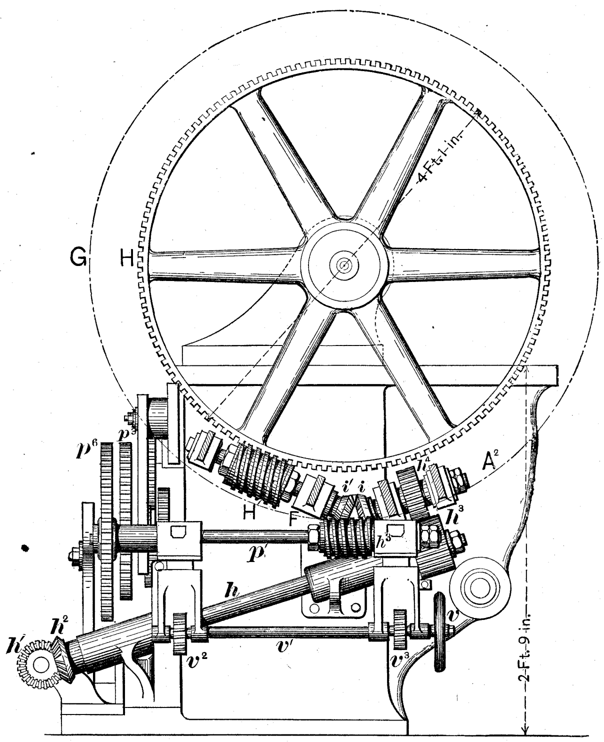

Fig. 2080.

run over a distance corresponding to this pitch, the driving screw *e* must make a number of turns equal to

$$\frac{\text{cotan. } M \times D \times 3 \cdot 141}{5}$$

But while the cutter head passes over a distance equal to the pitch, the wheel G makes one turn and the tangent screw 300 turns; consequently, the ratio to be established between the

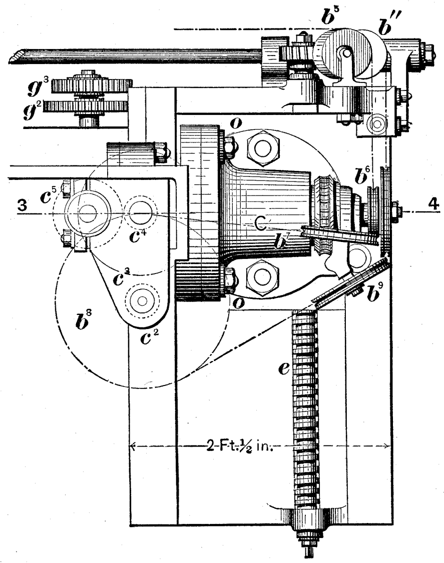

Fig. 2081.

speed of the tangent screw and between that of the screw driving the carriage will be represented by

$$\frac{x}{y} = \frac{1500}{\text{cotan. M} \times \text{D} \times 3 \cdot 141}$$

Thus, for a wheel with a diameter of 1·75 inches, the machine ought to have an inclination of 15° to the primitive circumference, and we would have, for the ratio to be established between the tangent screw and the driving screw,

$$\frac{x}{y} = \frac{1500}{\text{cotan. } 15° \times 1 \cdot 75 \times 3 \cdot 141} = \frac{1500}{20 \cdot 51778}$$

It should be remarked that, according as the angle should be either to right or to left, one or two intermediate pieces are placed

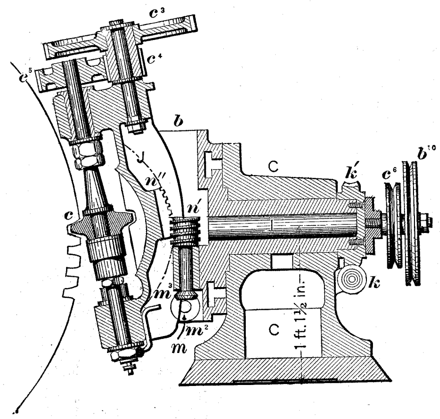

Fig. 2082.

on the swing-frame, the slide of which is nearly horizontal. The speed of the driving shaft, supported by the column mentioned in introductory remarks, is 120 revolutions; that of cutter equals from 20 to 30 revolutions; that of screw of cutter head, advance from 1 to 42 revolutions, return from 7 to 66 revolutions.