No. 627,310. Patented June 20, 1899.

C. DE LOS RICE.

GEAR CUTTING MACHINE.

(Application filed Nov. 12, 1898.)

(No Model.) 8 Sheets—Sheet 1.

Fig. 1.

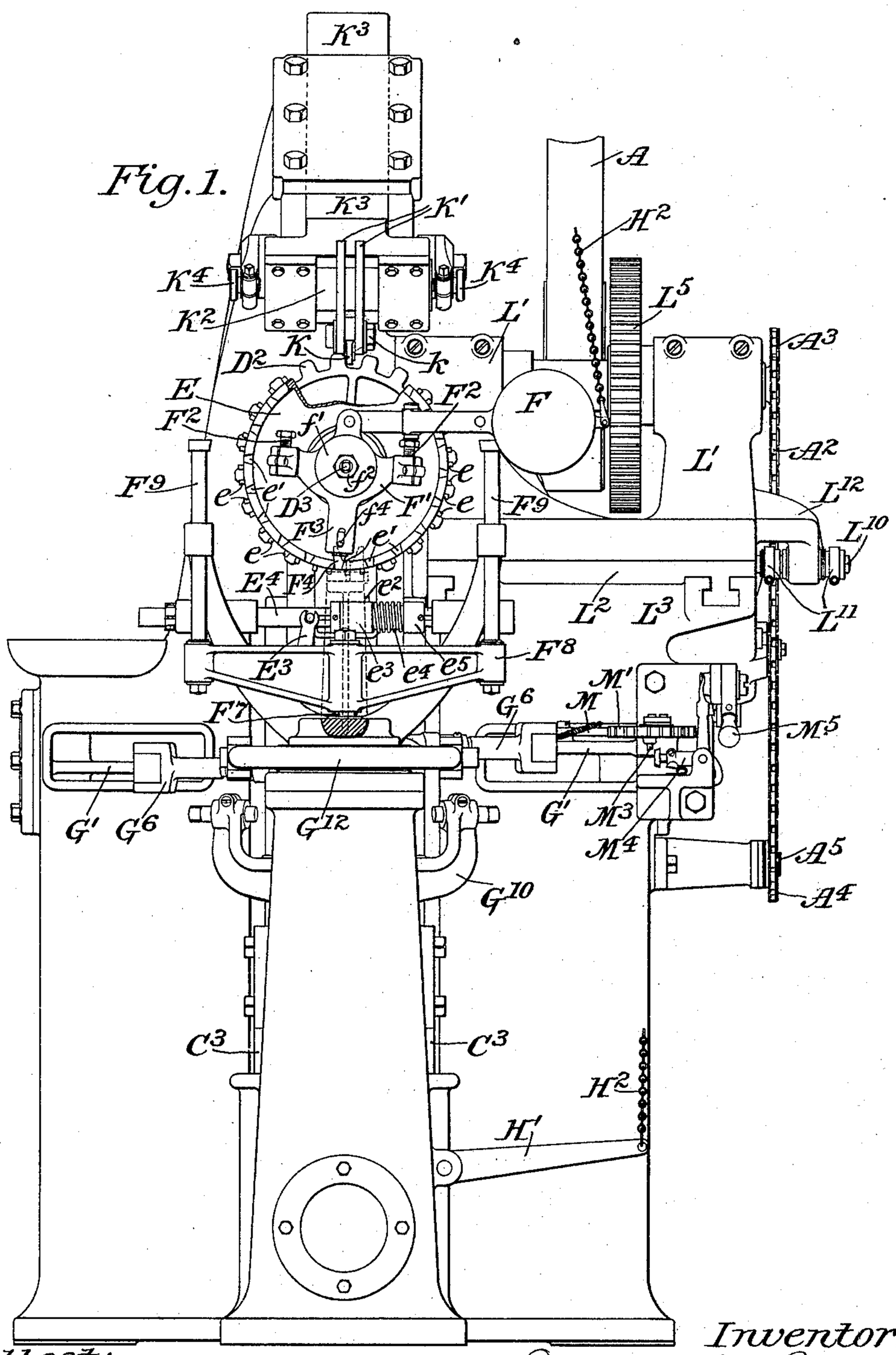

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Fig. 2.

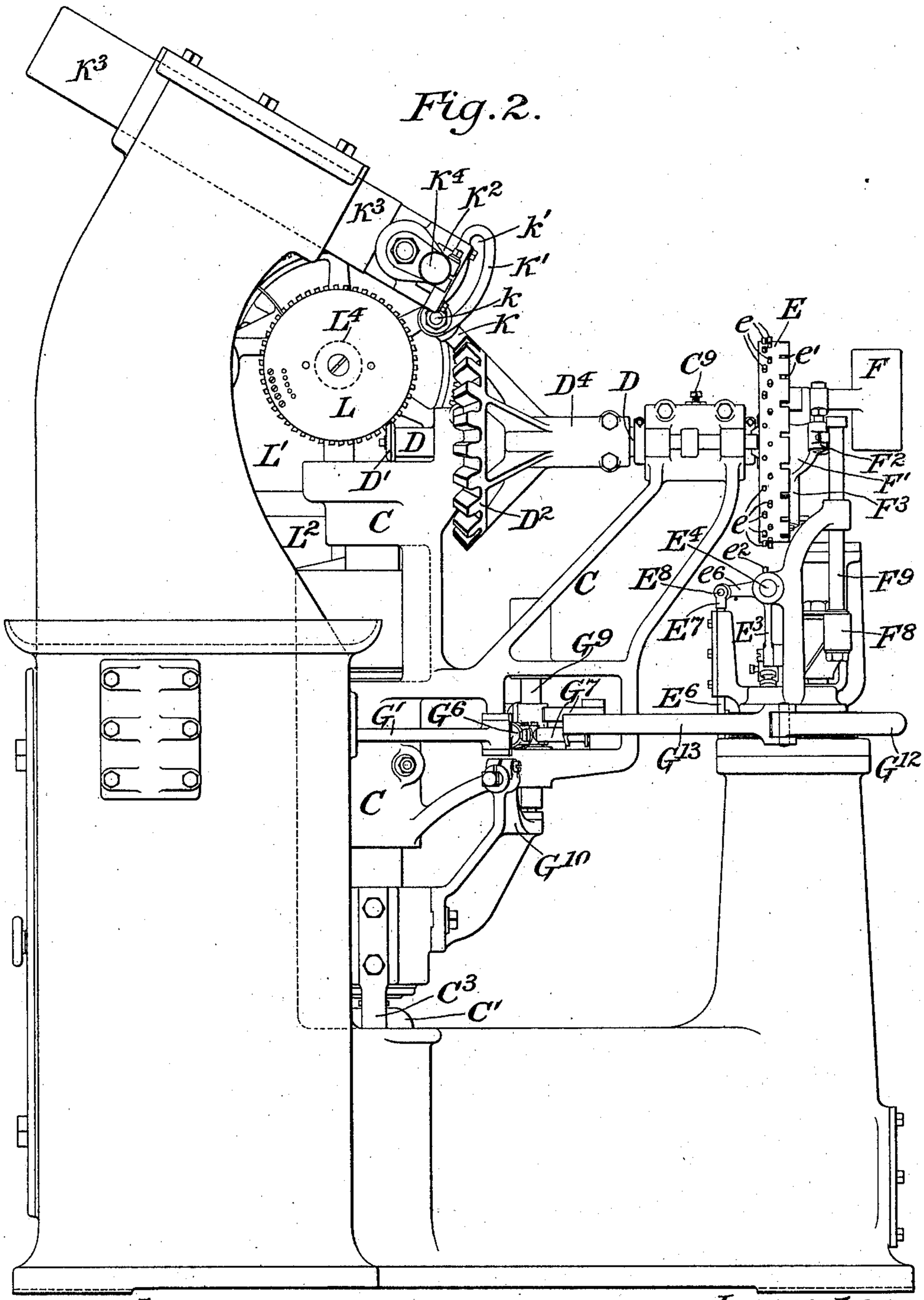

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Fig. 3.

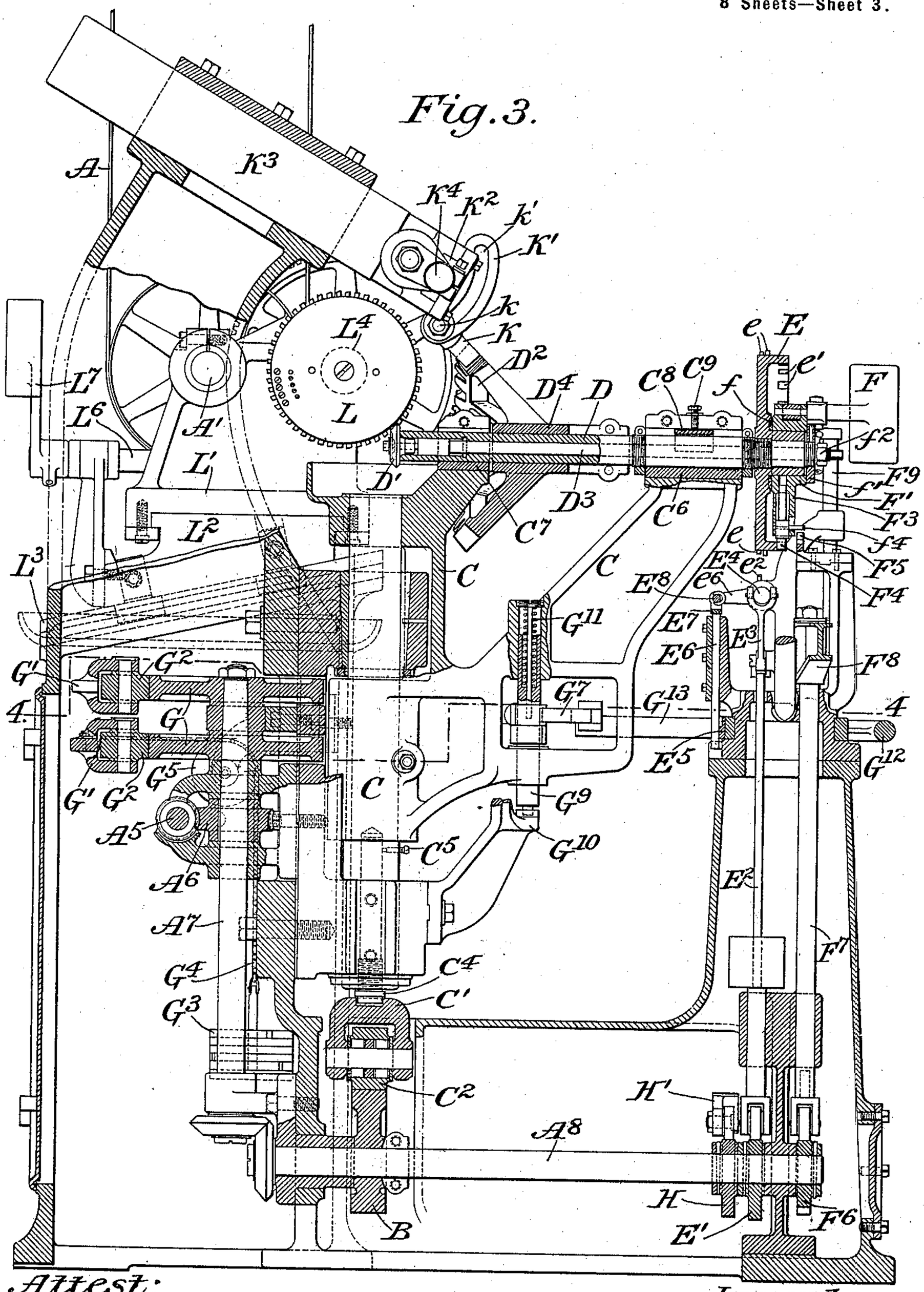

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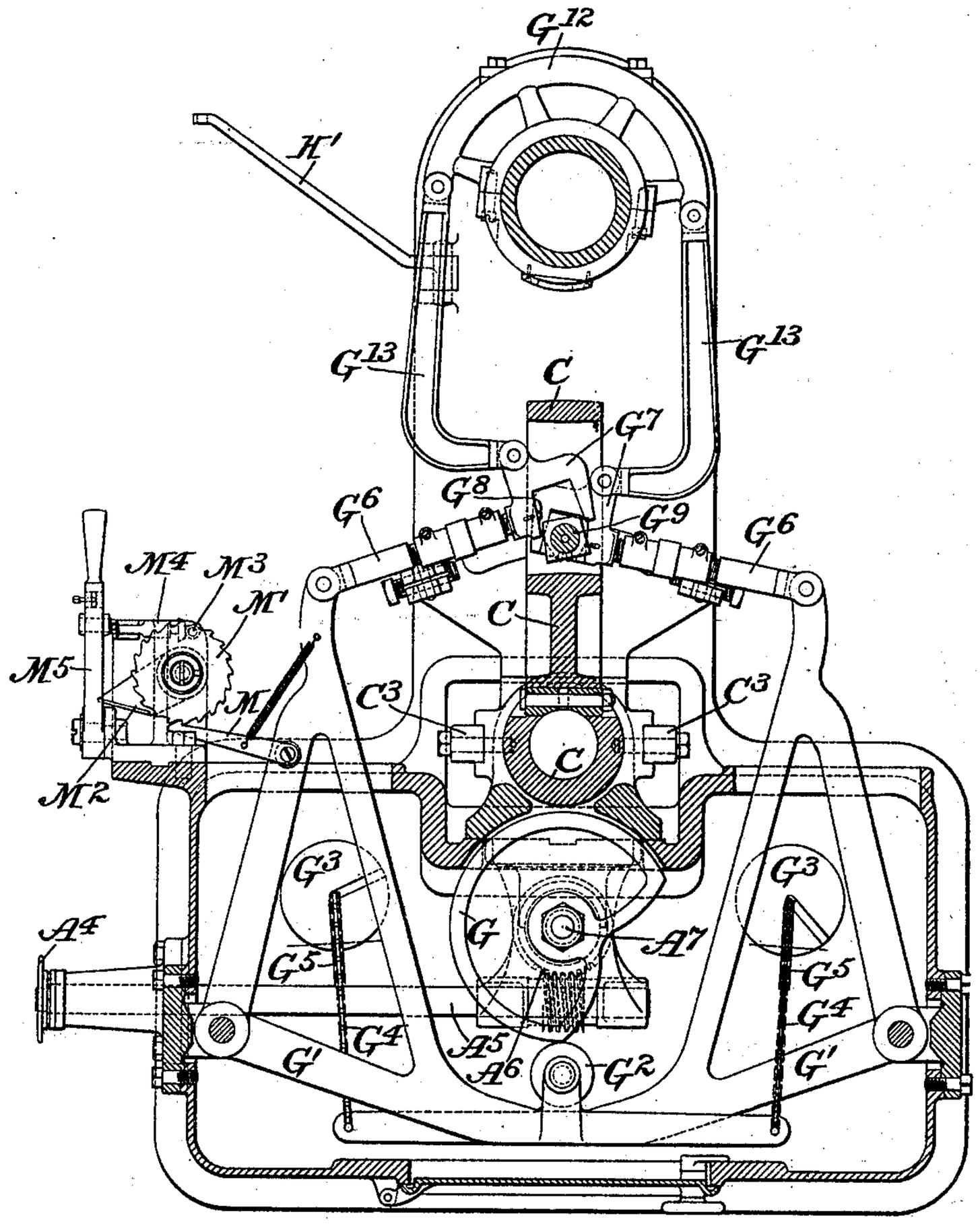
Fig. 4.



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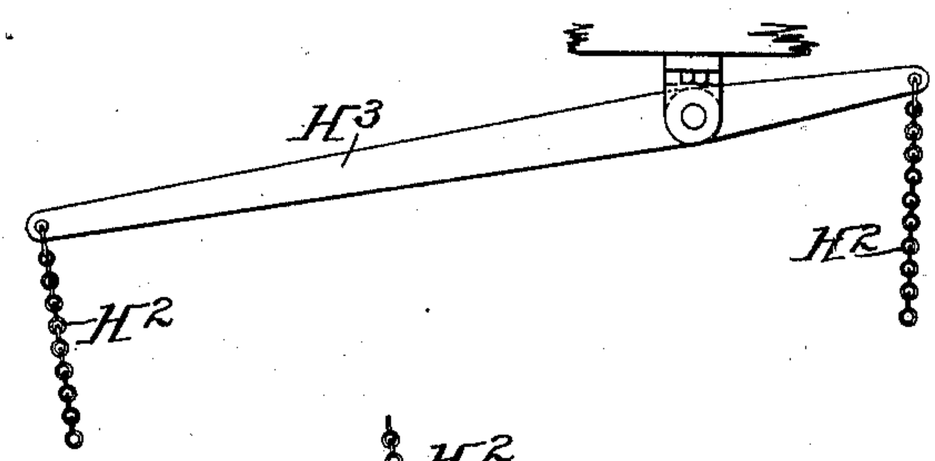


Fig. 5.

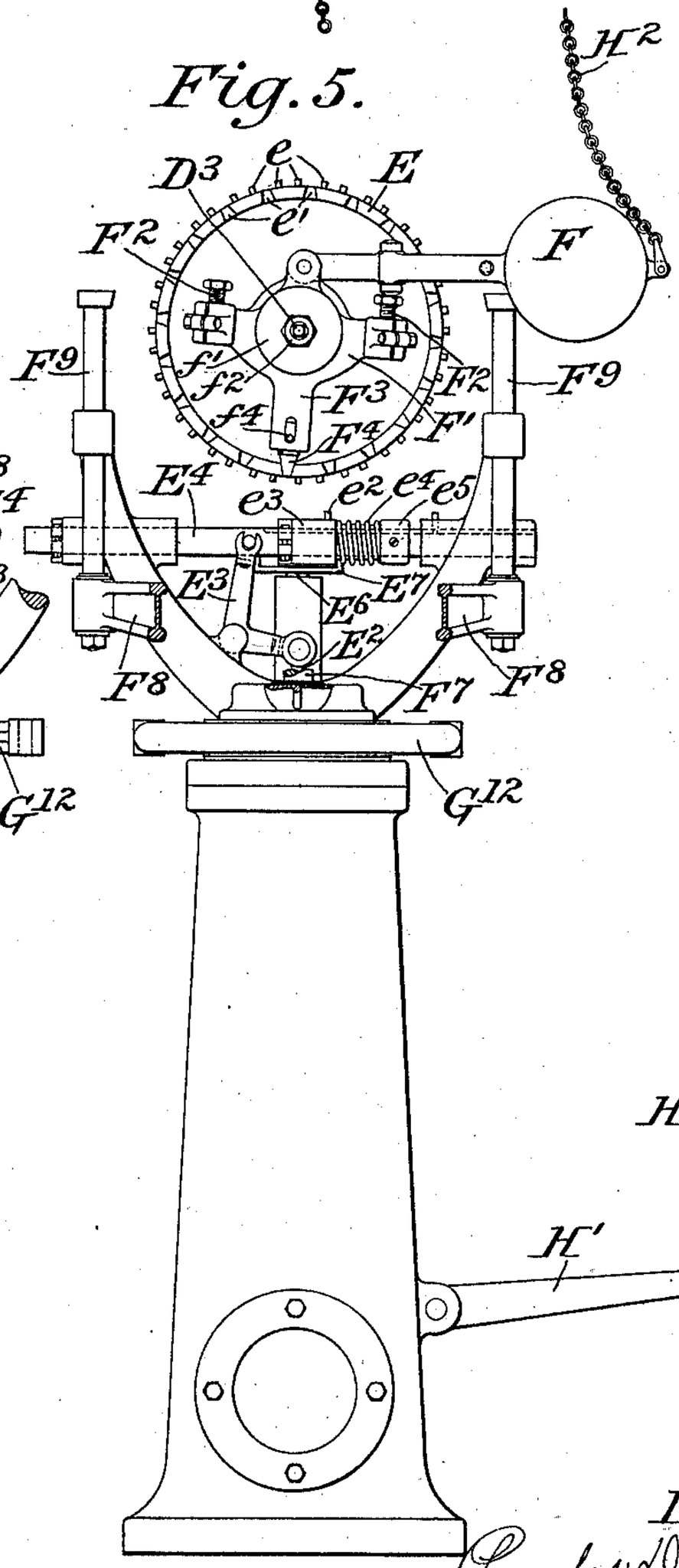
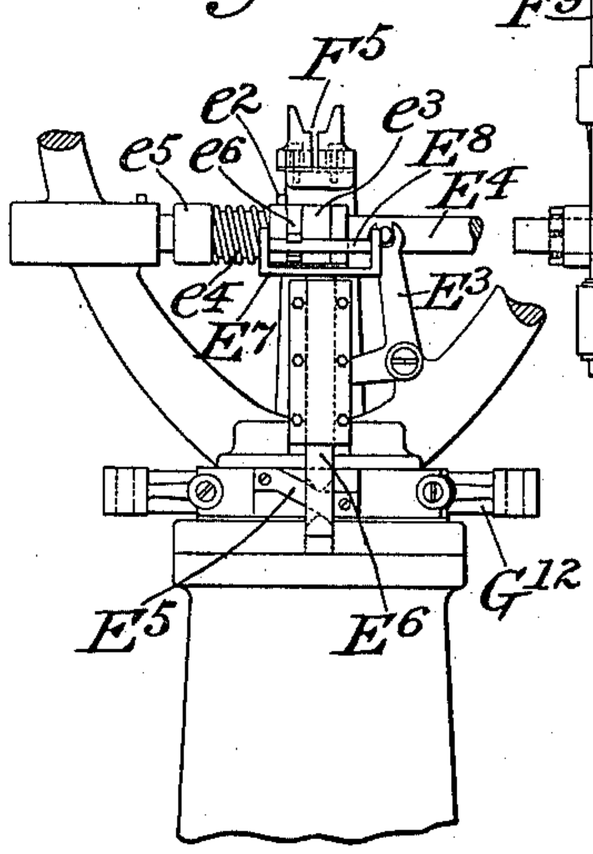


Fig. 6.



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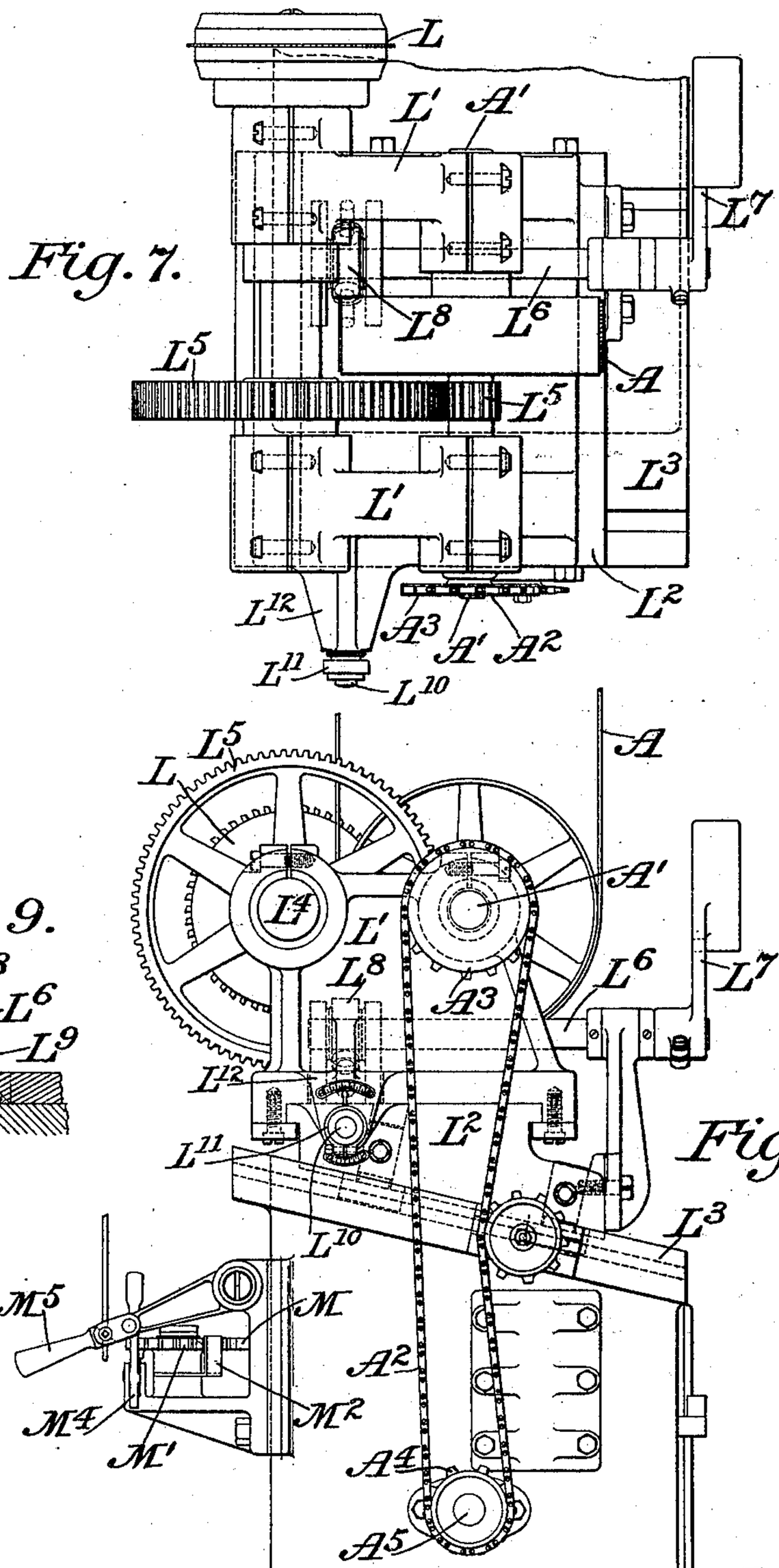

Fig. 7.

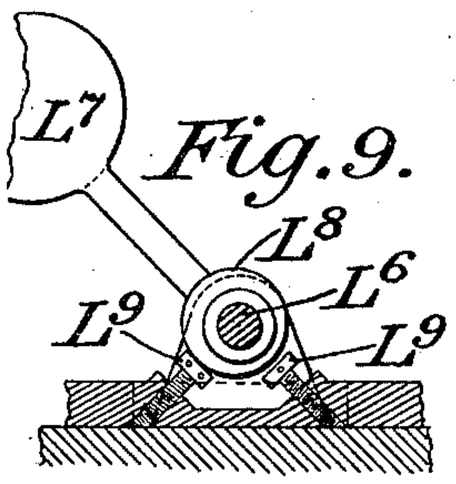

Fig. 9.

Fig. 8.

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Fig. 10.

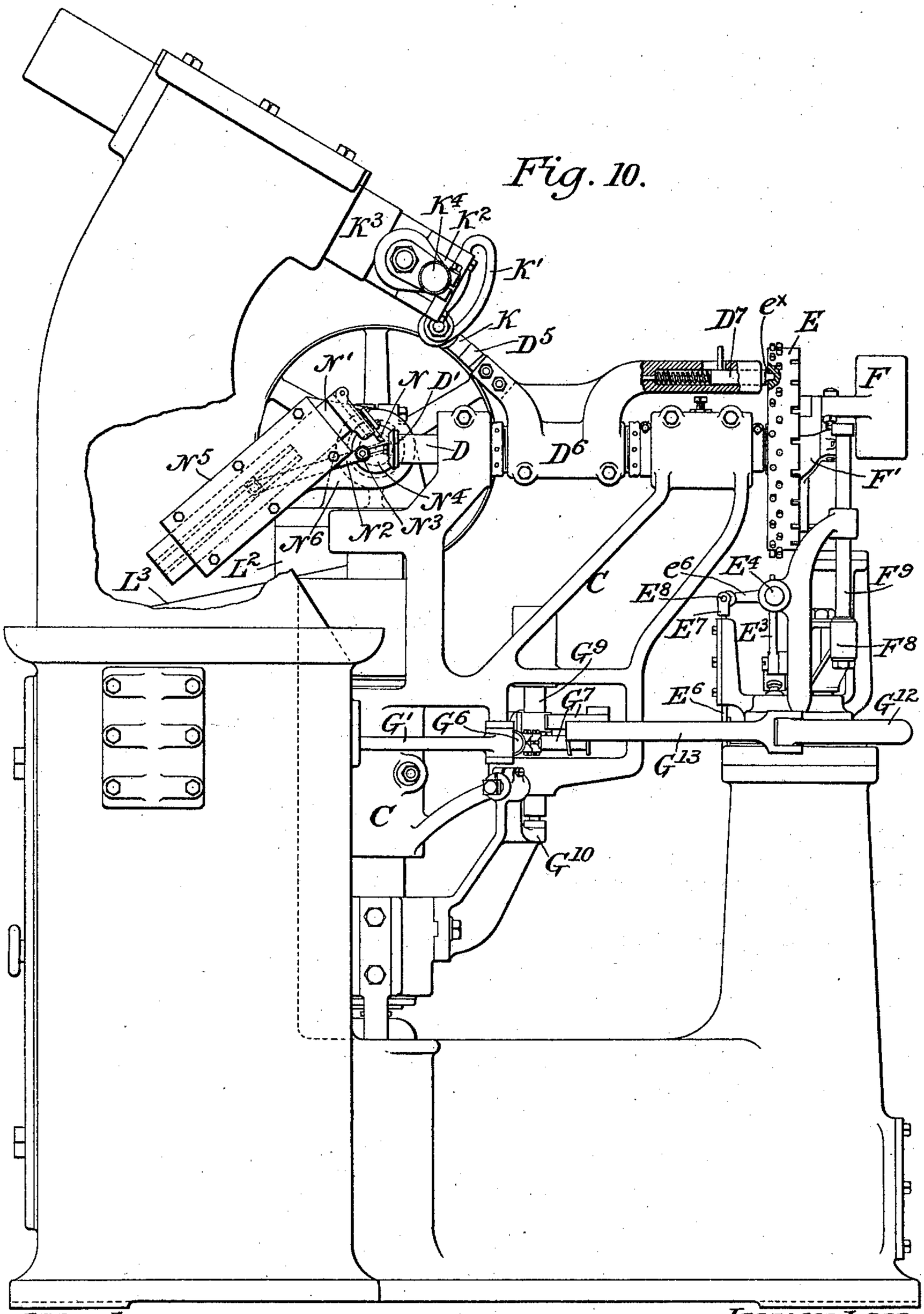

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Fig. 11

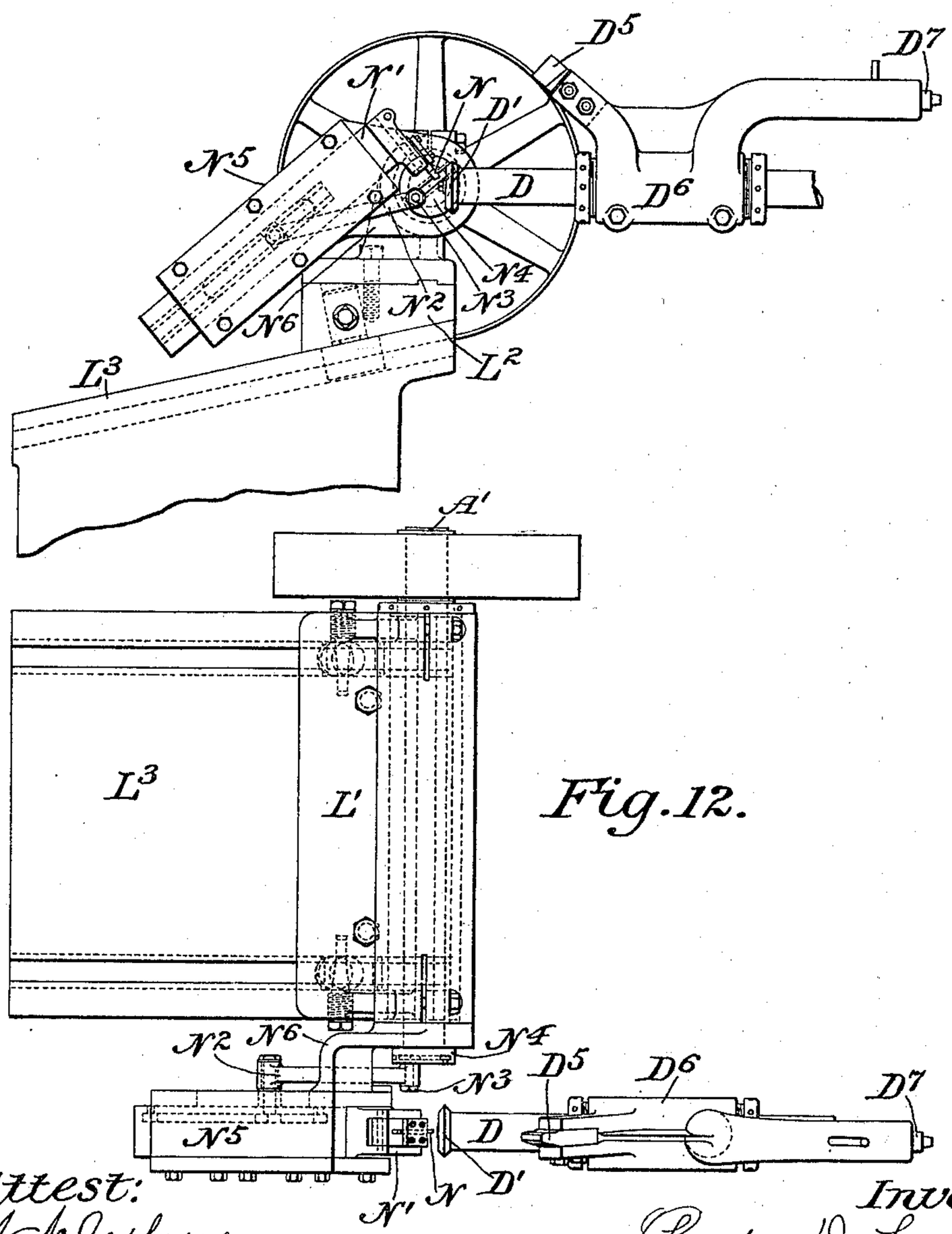

Fig. 12.

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UNITED STATES PATENT OFFICE.

CHARLES DE LOS RICE, OF HARTFORD, CONNECTICUT.

GEAR-CUTTING MACHINE.

SPECIFICATION forming part of Letters Patent No. 627,310, dated June 20, 1899.

Application filed November 12, 1898. Serial No. 696,196. (No model.)

To all whom it may concern:

Be it known that I, CHARLES DE LOS RICE, a citizen of the United States, residing in the city and county of Hartford, State of Connecticut, have invented certain new and useful Improvements in Gear-Cutting Machines, of which the following is a specification, reference being had to the accompanying drawings, forming a part thereof.

This invention relates in general to gear-cutting machines, and more especially to machines in which a templet or former or master gear or tooth is used in contradistinction to machines which are intended to generate a tooth in accordance with a theoretical form; but it will nevertheless be understood, particularly as this description proceeds, that various features of the invention are capable of general application and are not of necessity restricted to any particular type of machine.

For the purpose of enabling the nature of the invention to be clearly understood the same is illustrated in the accompanying drawings and described herein as applied to a machine for cutting bevel-gears. In that machine a master (either a complete gear or a single tooth) of the desired form and a blank of suitable size, which may or may not have been previously roughed out, are secured together upon a spindle, the blank being presented to a suitable cutting-tool and the master being pressed against a stationary guide. A work or master controlling weight is applied to the spindle, so that the master shall be pressed against the stationary guide with sufficient pressure, and the spindle is mounted upon a carrier, to which movement is imparted about an axis which intersects the axis of the spindle. The carrier also receives a vertical movement to bring the blank and the master into operative relation with the cutter and the stationary guide, respectively. A suitable indexing mechanism is also applied to the spindle above referred to. The various working parts above mentioned, with the exception of the cutter, receive their motion from or are controlled and checked in their motion by cams which rotate synchronously, but have their effective portions so arranged as to produce or permit the several movements at the proper time. The cutter or cutting-tool is shown both as a rotary cutter and as a reciprocating cutter, and in order to compensate for the thickness of the cutter and for the thickness of the guide when cutting opposite sides of a tooth the cutter is so supported as to be capable of a lateral displacement to the necessary extent. During the operation of the machine the work, starting from its initial and lowest position, first rises rapidly to approach the cutter and then continues to rise slowly during the cutting to the required depth. Then it receives a slight rotative movement about the axis of the blank for side cutting to the finish-line of the tooth and next a combined rotative and partially revolving or swinging movement about the vertical axis for the formation of the tooth-curves. This is followed by a quick return of the same motion and a quick drop to the lowest point. The last step is the indexing operation, which brings the corresponding side of the next tooth into position. When all of the teeth have been formed on one side, certain parts of the machine are reversed or shifted and the operations are repeated on the opposite side of each tooth. The details of construction and operation will be more fully explained hereinafter.

The machine here shown and described has been specially designed with especial reference to absolute accuracy in its work, the finished gear conforming exactly to the master and profiled therefrom, although on a different scale, and to efficiency as regards the quantity of work done. To this end devices are provided for securing the utmost exactness in adjustment of parts. Absolute immovability of those parts which should remain stationary during operation is provided for and the chance for wear between working parts is reduced to a minimum. The reliability of the cutter is also assured. The work and the templet or former or master gear or tooth are secured to the same member, so that there is no possibility of any wear or lost motion between the two. Finally, the moving parts have a very slow movement and a very limited action, making it possible to design them with such liberal proportions as to reduce both wear and elasticity to a minimum.

In the drawings, in which the machine above referred to and certain modifications

of some of its parts are illustrated, Figure 1 is a front view of the machine, a part of the indexing-wheel being broken away to show other parts beyond it. Fig. 2 is a side elevation of the machine viewed from the left in Fig. 1. Fig. 3 is a vertical section of the machine substantially in the plane of the axis of the lower cam-shaft. Fig. 4 is a horizontal section on the irregular plane indicated by the line 4 4 of Fig. 3. Fig. 5 is a detail view, in front elevation, illustrating the indexing mechanism and the connection of the work-controlling weight therewith. Fig. 6 is a rear elevation of some of the parts shown in Fig. 5 with the addition of the centering device. Fig. 7 is a plan view of the cutter and its driving, carrying, and shifting devices. Fig. 8 is a right-hand elevation of the upper rear portion of the machine, illustrating the devices shown in Fig. 7 and the belt-shipper-releasing mechanism. Fig. 9 is a detail view of the cutter-shifting weight and some of the parts with which it coöperates. Fig. 10 is a view similar to Fig. 2, but showing a machine having a single master-gear tooth in place of a complete master-gear and having a reciprocating cutter in place of a rotary cutter. Figs. 11 and 12 are detail side and plan views of some of the parts shown in Fig. 10.

The machine represented in the drawings Figs. 1 to 9, inclusive, receives power through a belt-wheel A on a short shaft A′, which rotates in suitable bearings on a carrier hereinafter referred to. From the shaft A′ power is transmitted by a chain A^2 and sprocket-wheels A^3 A^4 to a worm-shaft A^5, which is mounted in suitable bearings in the standard of the machine and engages a worm-wheel A^6 on a vertical shaft A^7. A second shaft A^8 is driven from the shaft A^7 at the same rate, the two shafts A^7 and A^8 bearing cams which actuate certain of the working parts hereinafter referred to.

Upon one of the cams B, secured to the lower cam-shaft A^8 and termed, with reference to its function, the "work-lifting" cam, rests a carrier C, which supports the blank to be cut, and the master gear or tooth or templet or former moves them to operative relation with the cutter or guide and permits them to have in cutting bevel-gears a partial revolution or, as it is hereinafter described, a swinging movement about an axis vertical to the axis of the blank and master-gear, as well as a rotative movement on the last-named axis. The carrier in the machine shown comprises a vertical shaft supported in suitable bearings and suitable bracket-arms to receive the bearings for the work-spindle. A block C′, carrying a roller C^2 to rest upon the cam B and prevented from rotative movement by a guide or guides C^3, forms a thrust-bearing to receive an adjustable step-bearing C^4, which is threaded into the lower part of the carrier, so as to permit of adjustment of the carrier with respect to the cam, and is secured in adjusted position by a set-screw C^5. In the arms of the carrier are rotatably mounted eccentrically-bored bushings C^6 C^7, which form the bearings for the work spindle or holder D. The eccentricity of the bushings is precisely the same, and they can be adjusted equally (being graduated, if necessary) in the split clamping-yokes in which they are mounted, so as to bring the axis of the work spindle or holder D exactly into the plane of the vertical axis about which the carrier swings. One of the bushings, as C^6, is cut away to receive a friction-shoe C^8, the pressure of which upon the work-spindle can be adjusted by a set-screw C^9. The object of this friction-shoe is to prevent too free rotation of the work-spindle, particularly during the cutting to depth and during the indexing operation.

The blank to be cut and the former are connected to move together during the cutting, and for this purpose the work spindle or holder is adapted to have securely fastened thereto the blank, which is represented at D′, and the master gear or tooth or templet or former, which is represented at D^2 as a full gear, although, as will be explained hereinafter, a single master-gear tooth may be substituted for the full gear if the character of the work renders it desirable. The relative positions of the blank and the "master," which term is used herein as a general term without regard to the particular character of the part, will depend upon the size which the gear to be cut is to have relative to the master. In the drawings the gear to be cut is represented at about one-fifth of the diameter of the master, being relatively nearer to the apex of the cone in which the blank and the master are contained—that is to say, the pitch-cone of the gear—the said apex lying in the axis about which the carrier swings. Obviously if the gear to be cut is to be larger than the master the blank will be placed farther away from this apex than the master. Any suitable means may be employed to secure the blank and the master to the work-spindle, so that there shall be no possibility of wear or lost motion between them, but that both shall move as one part during the cutting, although relative movement may be permitted between operations on successive teeth. As represented in the drawings, the blank may be held by a bolt D^3, which passes through the tubular spindle, and the master may have a split hub, as shown at D^4, adapted to be clamped upon the spindle.

At the outer end of the work spindle or holder D is secured rigidly the indexing-wheel E, which is provided about its periphery with a double row of projections *e*, which are staggered circumferentially for a purpose to be described, and is also provided in its peripheral flange with a series of notches *e*′.

Means are provided for imparting to the work-spindle a rotative tendency in order to press the working face of the master against the guide, and it is desirable that such means

shall have such an engagement with the work-spindle that the latter may be turned from time to time to bring a fresh surface of the blank to working position. The means shown for imparting to the work-spindle this rotative tendency comprise a work or master controlling weight or its equivalent or weighted arm F, which is pivotally secured to a sleeve or plate F′, which is mounted for convenience upon the hub of the indexing-wheel E, a friction-ring *f* being interposed between the indexing-wheel and the sleeve or plate, while a nut *f′* is applied to the work-spindle D to bear against said sleeve, being held by a lock-nut f^2. The master-controlling weight is pivoted to the sleeve F′ at a point substantially above the axis and is adapted to rest upon either one of two steps F^2, which are formed on the respective sides of the sleeve F′, each being provided with an adjustable bearing-stud. The weight is permitted to rest upon one or the other of these steps, according to the side of the tooth which is being finished. Connection between the master-controlling weight F and the work-spindle D or the master is effected through an arm F^3, extended from the sleeve F′ and carrying a plunger-latch F^4, which is adapted to engage the notches *e′* in the peripheral flange of the indexing-wheel E. The latch is released at the proper time during the descent of the carrier to permit the operation of the indexing mechanism by the collision of a laterally-projecting pin f^4 with a suitable stop carried on the fixed framework or standard of the machine. The stop, which is represented at F^5 in the drawings, is arranged to serve not only for the purpose of releasing the indexing-wheel from the work or master controlling weight, but before this release is actually effected to force the indexing mechanism to its true position, so as to insure the work being in exactly the correct position with respect to the cutter when it rises again, in which position it is held by the friction-shoe C^8, as already described, until the weight begins to turn the spindle. For this purpose the stop is formed of two laterally-adjustable blocks having their proximate sides inclined toward each other. The bottom of the V-notch formed by the two blocks serves as the seat against which the releasing-pin f^4 strikes as the carrier descends. Before the indexing mechanism is released, however, and while one side of the tooth is being finished the release-pin f^4 will be positioned on one side of the V seat or notch and on the opposite side while the other side of the tooth is being finished, thus throwing the center line of the arm F^3 and latch F^4 a little off from the perpendicular line in each case, but to the same distance. This distance corresponds to the distance of the center of the recess between two gear-teeth from the perpendicular plane which passes through the axis of the work spindle or holder, which distance is one-half the thickness of the cutter, and as this distance will vary inversely with the number of teeth of a given pitch in the gear to be cut the adjustability of the two parts of the stop F^5 permits the necessary variation of the distance of the release-pin f^4 from the vertical central plane to be effected.

The work-lifting cam B is so shaped as to cause the carrier to rise rapidly at first to cause the work to approach the cutter and then to rise slowly for a short distance while the cut is carried to the required depth. In order to prevent the work or master controlling weight F from imparting a rotative tendency to the work-spindle during the rise of the carrier and the cutting to the required depth, which would prevent the cutter-teeth from passing through the slot (if already roughed out) between the teeth equidistant from the center line of each tooth and might therefore result in the breaking of the cutter-teeth by premature contact with the work during its rapid rise, provision is made for lifting the work or master controlling weight or supporting it during the rise of the carrier, so that it shall not rest upon the step F^2, which is connected to the work-spindle F. The means referred to comprise a cam F^6 on the shaft A^8, which is timed exactly with the work-lifting cam B and, through a rod F^7, cross-arm F^8, and plungers F^9, one at each side of the axis of the work-spindle and in line with the corresponding position of the weight-arm, supports the weight or lifts it from the steps F^2 during the entire rise of the carrier. When the rise of the carrier has been completed, the weight-lifting cam F^6 permits the plungers F^9 to descend and the weight F to rest upon one or the other of the steps F^2, so that a rotative tendency shall be imparted to the work-spindle during the side cutting.

For the proper side-forming cut (in cutting bevel-gears) the work should have a lateral movement in the arc of a circle about the axis in which the apex of the cone of the work lies, and suitable mechanism, as will be presently described, may be provided for this purpose, as well as to prevent the master-controlling weight, which is no longer supported by the plunger F^9, from receding too rapidly, and thereby overburdening the cutter, although the weight alone, through the coöperation of the curved surface of the master with the guide, may produce the lateral as well as the rotative movement, in which case the mechanism to be described, if employed, merely checks the action of the weight. Two cams G are secured to the vertical shaft A^7, and motion is communicated from one cam or the other, according to the side of the teeth which is being finished, to the laterally movable or swinging carrier by transmitting devices, of which there are two sets, either one of which can be engaged with or disengaged from the carrier, as may be required. As the two sets of transmitting devices are precisely alike, the one lying slightly above the other, a description of one will suffice for both. A

bell-lever G′, carrying a roller G^2 to bear against the cam, is pivoted to the standard of the machine, the roller being held against the cam and the return movement of the connected parts effected by an adjustable weight G^3, connected to one arm of the lever by a chain G^4, which passes over a guide-pulley G^5. To the other arm of the bell-lever is connected a link G^6, which is made adjustable in length by ordinary means, such as are indicated in Fig. 4, and is formed at its free end with an open tapering slot or slotted jaw G^7, in one side of which is mounted a spring-pressed plunger-pin G^8 with a rounded head which protrudes slightly from the face of the side of the slot. In suitable bearings in the carrier is mounted a spindle G^9, which rests upon a segmental track G^{10}, carried by a suitable bracket secured to the fixed frame or standard of the machine. This spindle is rotatable and also movable longitudinally in its bearings and rests always on the segmental track G^{10} during the swinging of the carrier, being held down by a suitable spring G^{11}. In the plane of each of the links G^6 the spindle is made angular in cross-section to correspond with the slot of the corresponding link, so that when the link is made to engage the spindle its engagement shall be rendered certain. The bearing of the plunger-pin G^8 against the side of the spindle aids in retaining the engagement and preventing the link from working off during the movement of the parts. In order to provide for the convenient engagement of either link with the carrier, as described above, a segmental hand-wheel G^{12} is mounted horizontally on the standard of the machine and is connected on opposite sides of its vertical axis by links G^{13} with the links G^6, respectively, so that by a partial rotation of the hand-wheel in one direction or the other one of the links G^6 will be engaged with the carrier and the other disengaged therefrom. Although the weight and the cam mechanism when both are used as here shown produce, respectively, the rotative movement and the lateral movement, it will be obvious that their relations might be reversed, the cam mechanism in either case checking and controlling the action of the weight.

Reference has been made above to the indexing operation which follows the return of the laterally movable or swinging carrier to its central position, the object of such indexing operation, as is well understood, being to rotate the work, so as to bring a fresh surface into position to be operated upon. As already described, the indexing-wheel E is secured to the work-spindle and the work-controlling weight F is disconnected therefrom during the descent of the carrier C and just prior to the beginning of the indexing operation. The indexing-cam, as indicated at E′, is secured to the horizontal shaft A^8 and at the proper time raises a vertically-movable rod E^2, which is connected at its upper end to one end of a bell-lever E^3. The other end of said bell-lever engages a horizontal plunger E^4, which imparts motion by its reciprocation to the indexing-wheel E. In order to permit the engaging-pin e^2 of the horizontally-reciprocating plunger to be oscillated to one side or the other, in order that it may engage the pins or projections *e* of one row or the other on the indexing-wheel E, according to the side of the teeth which is being finished, said engaging-pin e^2 is carried on a sleeve e^3 on the plunger E^4. The sleeve reciprocates longitudinally with the plunger; but in order to prevent any hammering action of the plunger on the indexing-wheel, and consequent excessive movement thereof, the sleeve e^3 is mounted loosely on the plunger and a spring e^4 is interposed between the sleeve and one of the fixed abutments e^5. It is obvious that the oscillation of the sleeve e^3 to bring the pin e^2 into line with one or the other of the rows of projections *e* of the indexing-wheel E will be necessary only when a change is made from one side of the teeth to the other side of the teeth—that is, when one set of the carrier-swinging devices is disengaged from the carrier and the other set is engaged therewith. Consequently the movement of the shifting hand-wheel G^{12} may be taken advantage of to effect the required oscillation of the sleeve e^3. For this purpose the hub of the hand-wheel is provided with a cam E^5, (shown clearly in Fig. 6,) which actuates the vertically-movable bar E^6, sliding in a suitable guideway secured to the standard. At its upper end the bar carries a yoke E^7, between the members of which is a horizontal slide-bar E^8. The sleeve e^3 is formed with projections e^6, which straddle this slide-bar, so that the reciprocations of the sleeve are not interfered with, although the sleeve can be oscillated upon its axis at any time to cause the pin e^2 to engage with one or the other of the rows of projections on the periphery of the indexing-wheel E, whereby through the horizontal reciprocations of the plunger E^4 the required step-by-step rotation of the indexing-wheel, and consequently of the work-spindle and the blank secured thereto, is effected.

It is obviously unnecessary to have the work or master controlling weight exert a rotative tendency on the work-spindle during the return of the swinging carrier to its central position and during its drop to its lowest position. Means are therefore provided for lifting the work-controlling weight away from the steps on the work-spindle during these periods, so that the weight shall have no influence whatever upon the work-spindle at that time and the master shall be relieved of needless wear. The means shown comprise a cam H on the horizontal shaft A^8, which is positioned to act at the time referred to against a lever H′, pivoted on the standard of the machine. The outer or free end of this lever is connected by the chain H^2 with one end of an overhead lever H^3. The other end of this lever

is also connected by a chain with the work or master controlling weight or weighted lever F. The employment of flexible connections between the cam-lever and the weight permits the latter to be reversed for the cutting of the opposite sides of the gear-teeth. When the operations referred to have been completed, the cam H permits the work or master controlling weight F to descend until it again rests upon the plunger F^9, which is to support it.

The guide, which coöperates with the master during the operation of cutting, is mounted so as to be held rigidly during the cutting, to be capable of exact adjustment to the most effective position, and to be capable also of being shifted laterally when the change is made from one side of the teeth to the other in order that its second working face shall stand in precisely the same plane as did the first working face. The extent of this lateral shifting is obviously equal to the thickness of the guide. The guide is shown at K as a plate, the working surface of which is a true plane, with which the curved working surface of the master coöperates, the plane of the guide coinciding with the plane of the working face of the cutter, which in a bevel-gear machine passes through the axis about which the work swings. The plate is secured by a bolt *k* between two plates K′ having each a segmental slot *k*′, and both secured to or forming part of a laterally-movable carriage K^2. The segmental slots *k*′ permit the guide to be adjusted to the most favorable position as regards the master. The carriage K^2 is mounted in a suitable guideway formed at the end of a bar K^3, held rigidly to the frame or standard of the machine. At each end of the guideway is mounted a stop K^4, preferably in the form of a threaded stud capable of adjustment with great nicety.

In order that the work shall be performed with absolute accuracy, it is also necessary that the cutter shall be shifted laterally when the change is made from one side of the teeth to the other, so as to bring its second working surface exactly into the working plane. It is also necessary that the cutter shall be held firmly while it is at work in order to prevent vibratory action and chattering. The cutter shown in Figs. 2, 3, 7, and 8 of the drawings is a rotary cutter L and is mounted upon a cutter-head L′, which is laterally movable upon a saddle L^2, which in turn is adjustable on an inclined bed-plate L^3, formed on or supported by the frame or standard of the machine. The cutter-head is formed with bearings for the cutter-shaft L^4 and the short driving-shaft A′, with which the cutter-shaft is coupled by spur-gears L^5. Suitable means are provided for holding the cutter-head firmly to the saddle while permitting the necessary lateral movement. In bearings on the saddle L^2 is mounted a shaft L^6, transverse to the direction of movement of the cutter-head, said shaft having at one end a weighted arm or lever L^7 and at the other end a cam or eccentric L^8. The inner bearing-brackets for the shaft L^6 project upwardly through slots in the cutter-head L′, and the cam L^8 between them is adapted to bear against bearing-points on the cutter-head. These bearing-points are conveniently formed by adjustable screw-studs L^9, which are inclined toward each other at an angle of about forty-five degrees. The cam L^8 is positioned upon the shaft so that the weighted lever or arm L^7 when it has forced the cutter-head through the action of the cam L^8 to the limit of its movement in either direction shall stand at such an angle as to hold the cutter-head and the cutter without liability to vibration or chattering. At one end of the saddle is a screw-threaded stud L^{10}, which receives between nicely-adjustable nuts L^{11} an outwardly and downwardly extending ear L^{12}, secured to the cutter-head L′. The nuts L^{11} constitute adjustable stops to limit the movement of the cutter-head, and consequently of the cutter, in each direction. The saddle L^2 is also adjustably secured upon its inclined bed-plate, so that the cutter may be brought exactly to the position desired.

Means are provided for stopping the machine as soon as the work has been completed on one side of every tooth of the gear being cut, these means being shown in Figs. 1, 4, and 8. To one of the carrier-swinging levers G′, which, as now understood, makes a complete movement for each tooth in the master-gear or in the gear to be cut, is connected a spring-pressed pawl M, which engages a ratchet-wheel M′, mounted upon a vertical stud on a bracket secured to the standard of the machine. A shield M^2 is arranged so that the pawl shall engage only one tooth of the ratchet-wheel at each reciprocation and shall advance the ratchet-wheel only one space. At the proper point in the ratchet-wheel is secured a cam-pin M^3, which when the ratchet-wheel has advanced a number of spaces equal to the number of teeth in the gear operated upon shall operate suitable belt-shipper-releasing mechanism, such mechanism being shown in the drawings as comprising a bell-lever M^4 and a lever M^5, which is connected to the spring or weight actuated belt-shipper (not shown) and is normally held against the action of the weight or spring by its engagement with the bell-lever or latch M^4, but is released when such latch or bell-lever M^4 is tripped by the cam-pin M^3.

The operation of the machine thus far described will now be clearly understood. The master-gear D^2 and the blank D′ having been secured to the work-spindle and the several cams B, E′, F^6, G, and H being all at their initial or zero positions and the cutter and guide being adjusted for work upon one side of the teeth of the gear, while the work-controlling weight F is disposed on the corresponding side, the first action is that of the cam B, which first raises the carrier C rapidly to cause the work to approach the cutter L

and then more slowly while the cutter is working to the required depth at the root of the tooth. Meantime the cam F^6 raises the work or master controlling weight F, so that it shall impart no rotative tendency to the work-spindle until the carrier ceases to rise. Then the cam F^6 permits the work or master controlling weight F to descend and impart a rotative tendency to the work-spindle during the side cut, the tooth of the master-gear meanwhile bearing against the guide K. Next, while the work or master controlling weight continues to act upon the work-spindle the cam G regulates the movement of the carrier to finish the side cut. Meantime the weight-lifting cam H has begun to act, and as the work-lifting cam B permits the carrier C to descend the weight-lifting cam H takes all of the weight from the work-spindle. At the same time the cam G forces the carrier to swing back to its central position. As the carrier approaches its lowest position the indexing mechanism is disconnected from the work or master controlling weight, and finally the cam E′ actuates the indexing mechanism to bring a new portion of the blank to the line of work. These several operations are repeated until one side of every tooth has been completed, when the machine is stopped. To adjust the machine for work on the other side of every tooth of the gear, the guide K is shifted to bring its second working surface to the working plane, and the weighted cam-lever L^7 is thrown over to bring the other working surface of the cutter to the same plane. The segmental hand-wheel G^{12} is then shifted to bring the other swinging cam G into operative relation with the carrier C, and the work or mastsr controlling weight F is shifted to rest on the opposite plunger F^9. This shifting of the work or master controlling weight causes a slight rotative movement of the work-spindle, the extent of which is governed by the adjustment of the steps F^2 and their relation to the tops of the plungers F^9, which receive the weight. This slight rotative movement brings the work itself into the proper position with respect to the cutter and the master-gear into proper position with respect to the guide.

It will be readily understood that by substituting another master of the proper proportions and by properly adjusting the various parts of the machine according to the work to be performed it is possible to adapt the machine without other changes to the production of gears of any desired angle or shape and of any desired size within reasonable limits, the machine being universal. Moreover, by employing a rotary cutter of large diameter mounted upon relatively-fixed bearings it is possible to produce acceptable gear-teeth without the disadvantages incident to the use of a cutter of small diameter, which must be reciprocated in order to complete the cut. It will also be seen that the machine is a true profiling-machine, reproducing in the gear cut the exact shape of the master, so that it is possible to modify the shape of a theoretically correct master-gear tooth to such an extent—as by rounding off the point of the tooth, for example—as shall give the best results in practice. Furthermore, by substituting an emery-wheel, for example, for the steel cutter the machine can be used for grinding gears to remove tool-marks and to cure any distortion that may have been suffered by the gears during the hardening process to which they are usually subjected after being cut.

Although, especially for the cutting of small gears, it is preferable to employ a rotary cutter, as in the form of machine already described, on account of the greater speed with which the work can be performed, and it is also preferable to employ a complete master-gear rather than a single tooth, because a complete master-gear regulates the spacing of the teeth, which is an important consideration, as well as determining the tooth-curves, and also because the complete master-gear before being used can be mounted and run with its mating gear, and thereby proved to be of acceptable form, insuring absolutely correct results in the gears profiled from it, nevertheless it is easily possible to substitute a reciprocating cutter for the rotary cutter whenever the size of the gears or other considerations make such a change desirable, and it is equally possible to employ a single master-gear tooth or former in place of a complete master-gear if the character of the work to be performed renders this change desirable. A machine in which both of these substitutions have been made is shown in Figs. 10, 11, and 12 and will now be described so far as the parts just referred to are concerned. All other parts not more particularly mentioned hereinafter are represented as constructed, arranged, and operating in the same manner as in the machine already described, and therefore require no further explanation herein. As represented in the figures just referred to, the single master-gear tooth D^5 is securely clamped in an arm projecting from a sleeve D^6, which is journaled on the work-spindle D. The indexing-wheel E is secured rigidly, as before, to the work-spindle and is adapted for engagement with the sleeve which supports the master-gear tooth. As represented, it is provided on its inner face with a series of notches $e^\times$ for engagement with a spring-pressed plunger-latch D^7, which is mounted in another arm extended from the sleeve D^6. Obviously the notches $e^\times$ must be spaced with perfect accuracy. After the finishing of one side of a tooth the plunger D^7 is withdrawn by hand to permit of the indexing operation without the rotation of the master-gear tooth with the indexing-wheel. Otherwise the operations of the machine are the same as those already described. If the machine be used with a single master-gear tooth, it would evidently be feasible to create a steel tooth for the pur-

pose in a most refined form and to case-harden and burnish it, if necessary, so that its life would be very great, and this one tooth could be used for different gears, and in any case would insure the absolute similarity of all the teeth of a gear.

A reciprocating cutter may be arranged as shown in Figs. 10, 11, and 12, the tool itself, which is represented at N, having its sides parallel with each other and having a thickness great enough to insure strength, but not so thick as to interfere with the tooth next to that one being operated upon. It should also be so mounted as to have a capacity for lateral adjustment sufficient to bring either one cutting edge or the other into the plane of work, which in cutting bevel-gears must necessarily intersect the axis about which the work swings. The tool N is shown as mounted in a reciprocating carrier N′, which is connected by a rod N^2 with a crank-pin N^3, carried by a shaft N^4, the crank-pin and the connection of the rod to the reciprocating slide both being adjustable, so as to make it possible to control the action of the cutter. The slideway N^5 is carried by an arm N^6, which is swiveled upon the framework of the machine, the axis of the swivel being in a line with the apex of the pitch-cone, so that the movement of the cutter can be adjusted to be parallel with the base of the gear-tooth in a gear of any angle.

Although both forms of machine described herein are specially adapted for cutting bevel-gears, it will nevertheless be understood that the essential features of the machines are also capable of use in cutting spur-gears, the master, whether a complete gear or a single tooth, and the work having in such case a lateral movement in right lines instead of a lateral movement in curved lines. It will also be understood that various changes may be made in the construction and arrangement of the several parts of the machine without departing from the spirit of the invention, and that the invention, therefore, is not to be limited to the precise construction and arrangement of parts herein shown and described.

I claim as my invention—

1. A machine for cutting gear-teeth comprising means for supporting a master and a gear-blank to have a movement of rotation about a common axis and to have a lateral movement, a guide for contact with the master, and a weight connected to said master and gear-blank to press the master against the guide with a rotative tendency.

2. A machine for cutting gear-teeth comprising means for supporting a master and a gear-blank to have a movement of rotation about a common axis and to have a lateral movement, a guide for contact with the master, a weight operatively connected with the master to produce one of said movements, and a cam operatively connected with the master to produce the other of said movements.

3. A machine for cutting gear-teeth comprising means for supporting a master and a gear-blank to rotate about a common axis and to move laterally, a guide-plate the working surface of which is a true plane, and means to press the working surface of the master against the working surface of the guide-plate with a rotative tendency.

4. A machine for cutting gear-teeth comprising means for supporting a master and a gear-blank to rotate about a common axis and to move laterally, a guide-plate the working surface of which is a true plane, means to press the working surface of the master against the working surface of the guide-plate with a rotative tendency, and a cutter, the working surface of which is a true plane lying in the plane of the working surface of the guide-plate.

5. A machine for cutting bevel-gear teeth comprising means for supporting a master and a gear-blank to rotate about a common axis and to swing about an axis intersecting the first-named axis, a guide-plate the working surface of which is a true plane, lying in the plane of said intersecting axis, and means to press the working surface of the master against the working surface of the guide-plate with a rotative tendency.

6. A machine for cutting bevel-gear teeth comprising means for supporting a master and a gear-blank to rotate about a common axis and to swing about an axis intersecting the first-named axis, a guide-plate the working surface of which is a true plane lying in the plane of said intersecting axis, means to press the working surface of the master against the working surface of the guide-plate with a rotative tendency, and a cutter the working surface of which is a true plane lying in the plane of the working surface of the guide-plate.

7. A machine for cutting bevel-gear teeth comprising a holder for a master and gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, and a cutter.

8. A machine for cutting bevel-gear teeth comprising a holder for a master and gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, means to press the master against the guide, and a cutter.

9. A machine for cutting bevel-gear teeth comprising a holder for a master and gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, means to press the master in either direction against the guide, and a cutter.

10. A machine for cutting bevel-gear teeth comprising a spindle to which the master and

gear-blank are secured, a carrier for said spindle and with which it is movable about an axis intersecting the axis of the spindle, a stationary guide for contact with the master, and a cutter with its working face in the same plane with the working face of the guide and said intersecting axis.

11. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle, a stationary guide for contact with the master, a cutter with its working face in the same plane with the working face of the guide and said intersecting axis, and a weight operatively connected to said spindle to impart a rotative tendency thereto.

12. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle, a stationary guide for contact with the master, a cutter with its working face in the same plane with the working face of the guide and said intersecting axis, a step secured frictionally to said spindle, and a weight arranged to bear upon said step.

13. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle, a stationary guide for contact with the master, a cutter with its working face in the same plane with the working face of the guide and said intersecting axis, a plate secured to said spindle and having two steps, one on each side of the axis of the spindle, and a weighted arm pivoted between the steps and arranged to bear on either step.

14. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle, a stationary guide for contact with the master, a cutter with its working face in the same plane with the working face of the guide and said intersecting axis, a step secured to said spindle, a weight arranged to bear upon said step, and means to lift the weight from the step.

15. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle, a stationary guide for contact with the master, a cutter with its working face in the same plane with the working face of the guide and said intersecting axis, a step secured to said spindle, a weight arranged to bear upon said step, and a cam and intermediate devices to lift the weight from the step.

16. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier for said spindle, eccentric bushings for said spindle mounted rotatably on said carrier, a stationary guide for contact with the master, and a cutter.

17. A machine for cutting gear-teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle, an adjustable friction-shoe bearing on said spindle, a stationary guide for contact with the master, and a cutter.

18. A machine for cutting bevel-gear teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier movable about an axis intersecting the axis of the spindle and having bearings for said spindle, a stationary guide for contact with the master, and a cutter.

19. A machine for cutting bevel-gear teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier movable about an axis intersecting the axis of the spindle and having bearings for the spindle, a stationary guide for contact with the master, a weight arranged to bear upon said spindle at one side of its axis, and a cutter.

20. A machine for cutting bevel-gear teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier movable about an axis intersecting the axis of the spindle and having bearings for the spindle, a stationary guide for contact with the master, a weight arranged to bear upon said spindle at one side of its axis, means to lift said weight, and a cutter.

21. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, a work or master controlling weight connected to said holder, indexing mechanism connected to said holder, and a connection between said weight and said indexing mechanism.

22. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, a work or master controlling weight frictionally connected to said holder, indexing mechanism connected to said holder, and a connection between said weight and said indexing mechanism.

23. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, a plate secured to the holder and having a step and an arm, a weight to bear upon said step, and indexing mechanism engaged by said arm.

24. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, an indexing-wheel secured to said holder and having notches, a plate secured to the holder frictionally and having a step and an arm, a

latch carried by said arm to engage said notches and a weight to bear upon said step.

25. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, indexing mechanism connected to said holder, a radially-movable projection connected with the indexing mechanism, and a stationary V-notch for engagement with said projection.

26. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, indexing mechanism connected to said holder, a radially-movable projection connected with the indexing mechanism, and two stops forming between them a V-notch for engagement with said projection and adjustable upon a fixed support.

27. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, an indexing-wheel secured to the holder and having a series of notches, an arm secured frictionally to said holder, a radially-movable latch carried by said arm to engage said notches and having a laterally-projecting pin, and a stationary V-notch for engagement with said projecting pin.

28. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, an indexing-wheel secured to the holder, an actuator for said indexing-wheel, and means to shift said actuator to cause it to engage different points on said wheel, offset circumferentially whereby the thickness of the cutter is compensated for in working upon opposite sides of the gear-teeth.

29. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, an indexing-wheel secured to the holder and having two sets of teeth or projections offset circumferentially, a plunger having a pin or projection to engage one or the other of said sets of teeth, means to reciprocate said plunger, and means to oscillate said plunger in one direction or the other, to bring its pin or projection into engagement with one or the other of said sets of teeth.

30. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a stationary guide for contact with the master, a cutter, an indexing-wheel secured to the holder and having two sets of teeth or projections offset circumferentially, a plunger having a pin or projection to engage one or the other of said sets of teeth, a cam and connections to oscillate said plunger in one direction or the other to bring its pin or projection into engagement with one or the other of said sets of teeth and means to reciprocate said plunger.

31. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, and means to swing said carrier about said intersecting axis.

32. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, and a cam and intermediate connections to swing said carrier about said intersecting axis.

33. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, independent sets of devices to swing said carrier about its axis in opposite directions, and means to engage either of said sets of devices with said carrier.

34. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, a link to engage said carrier, a cam and operative connections between said link and cam, and means to engage and disengage said link with and from said carrier.

35. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, a link to engage said carrier, a cam and operative connections between said link and cam, a hand-wheel, and a link connecting the first-named link with the hand-wheel.

36. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, independent sets of devices to swing said carrier about its axis in opposite directions, a hand-wheel, and links connecting opposite sides of said hand-wheel with said independent sets of devices respectively.

37. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for

said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, a link having a slot to engage the carrier and a plunger-pin in one side thereof and means to actuate said link to swing the carrier, and means to engage and disengage said link with and from said carrier.

38. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, a link having a tapering slot to engage a correspondingly-shaped part of the carrier, means to actuate said link to swing the carrier, and means to engage and disengage said link with and from said carrier.

39. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder movable in a direction substantially perpendicular to the axis of the holder to bring the blank into operative relation with the cutter, a cutter, and a cam against the periphery of which said carrier rests.

40. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder movable in a direction substantially perpendicular to the axis of the holder to bring the blank into operative relation with the cutter, a cutter, a cam, and an adjustable step-bearing for said carrier upon said cam.

41. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder movable in a direction substantially perpendicular to the axis of the holder to bring the blank into operative relation with the cutter, a cutter, a cam, a roller-carrying block to bear upon said cam and having a thrust-bearing for said carrier, and a guide to prevent rotative movement of said block.

42. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter and means to move said carrier in a direction substantially perpendicular to the axis of the holder to bring the blank and the master-gear into operative relation with the cutter and the guide respectively.

43. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, means to press the master in either direction against the guide, a cutter, and means to move said carrier in a direction substantially perpendicular to the axis of the holder to bring the blank and the master into operative relation with the cutter and the guide respectively.

44. A machine for cutting bevel-gear teeth comprising a spindle to which the master and the gear-blank are secured and rotatable on its own axis, a carrier having bearings for said spindle and with which it is movable about an axis intersecting the axis of the spindle, a stationary guide for contact with the master, a cutter, and means to move said carrier in a direction substantially perpendicular to the axis of the spindle to bring the blank and the master into operative relation with the cutter and the guide respectively.

45. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a work-controlling weight connected to said holder, a cutter, and means to move said carrier in a direction substantially perpendicular to the axis of the holder to bring the blank and the master-gear into operative relation with the cutter and the guide respectively.

46. A machine for cutting bevel-gear teeth comprising a holder for the master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, means to swing said carrier about said intersecting axis, and means to move said carrier in a direction substantially perpendicular to the axis of the holder to bring the blank and the master into operative relation with the cutter and the guide respectively.

47. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, a cam and intermediate connections to swing said carrier about said intersecting axis, and means to move said carrier in a direction substantially perpendicular to the axis of the holder to bring the blank and the master into operative relation with the cutter and the guide respectively.

48. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, independent sets of devices to swing said carrier about its axis in opposite directions, means to engage either of said sets of devices with said carrier, and means to move said carrier in a direction substantially perpen-

dicular to the axis of the holder to bring the blank and the master into operative relation with the cutter and the guide respectively.

49. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, a cutter, a link to engage said carrier, a cam and operative connections between said link and cam, means to engage and disengage said link with and from said carrier, and means to move said carrier in a direction substantially perpendicular to the axis of the holder to bring the blank and the master-gear into operative relation with the cutter and the guide respectively.

50. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, means to swing said carrier about said intersecting axis, and a belt-shipper-releasing device in operative relation with said means and progressively actuated thereby with a step-by-step movement whereby the belt-shipper is released after the carrier has been swung a predetermined number of times.

51. A machine for cutting bevel-gear teeth comprising a holder for a master and a gear-blank rotatable on its own axis, a carrier for said holder and with which it is movable about an axis intersecting the axis of the holder, a stationary guide for contact with the master, means to swing said carrier about said intersecting axis, a belt-shipper-releasing device including a ratchet, and a pawl engaging said ratchet and operatively connected with said means.

52. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank, a stationary guide for contact with the master on either side of the master-tooth, means to press the master against the guide, a cutter, and means to shift the cutter sidewise in either direction to bring its working face into the same plane with the working face of the guide.

53. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank, a stationary guide for contact with the master on either side of the master-tooth, means to press the master against the guide, a cutter, a cutter-head upon which the cutter is mounted and with which it is movable sidewise, and means to shift the cutter-head to bring the working face of the cutter into the same plane with the working face of the guide.

54. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank, a stationary guide for contact with the master on either side of the master-gear tooth, means to press the master against the guide, a cutter, a cutter-head upon which the cutter is mounted, and with which it is movable sidewise, and a weighted lever having a cam-surface for coöperation with bearing-points on the cutter-head.

55. A machine for cutting gear-teeth comprising a holder for a master and a gear-blank, a stationary guide for contact with the master on either side of the master-tooth, means to press the master against the guide, a cutter, a cutter-head upon which the cutter is mounted and with which it is movable sidewise, a weighted lever having a cam-surface, and adjustable studs carried by the cutter-head and inclined in opposite directions toward said cam-surface to furnish bearing-points therefor.

56. A machine for cutting gear-teeth, comprising a holder for a master and a gear-blank, a stationary guide for contact with the master on either side of the master-tooth, means to press the master against the guide, a cutter, a cutter-head upon which the cutter is mounted and with which it is movable sidewise, adjustable stops to limit the movement of the cutter-head, and means to shift the cutter-head to bring the working face of the cutter into the same plane with the working face of the guide.

57. A machine for cutting gear-teeth comprising a rotary cutter, a support for said cutter, a stationary guide, a movable master connected with the blank to be cut and engaging said guide, and an inclined bed-plate upon which the cutter-support is adjustable in a plane inclined to the axis of the blank and master.

This specification signed and witnessed this 9th day of November, A. D. 1898.

CHARLES DE LOS RICE.

In presence of—
FELTON PARKER,
HERMANN F. CUNTZ.