(No Model.)

6 Sheets—Sheet 1.

H. C. WARREN.

MACHINE FOR GENERATING GEAR TEETH.

No. 559,011.

Patented Apr. 28, 1896.

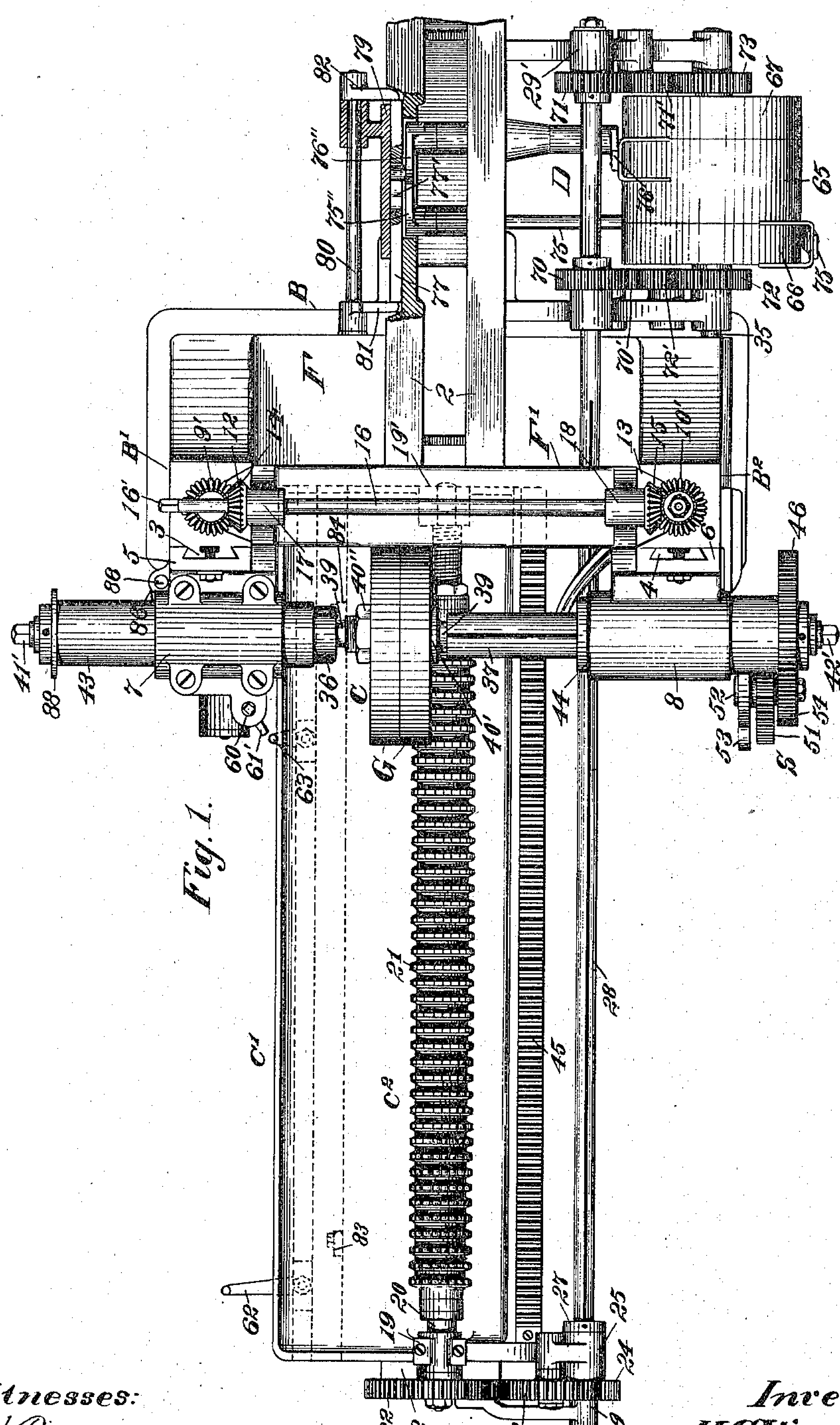

Fig. 1.

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6 Sheets—Sheet 2.

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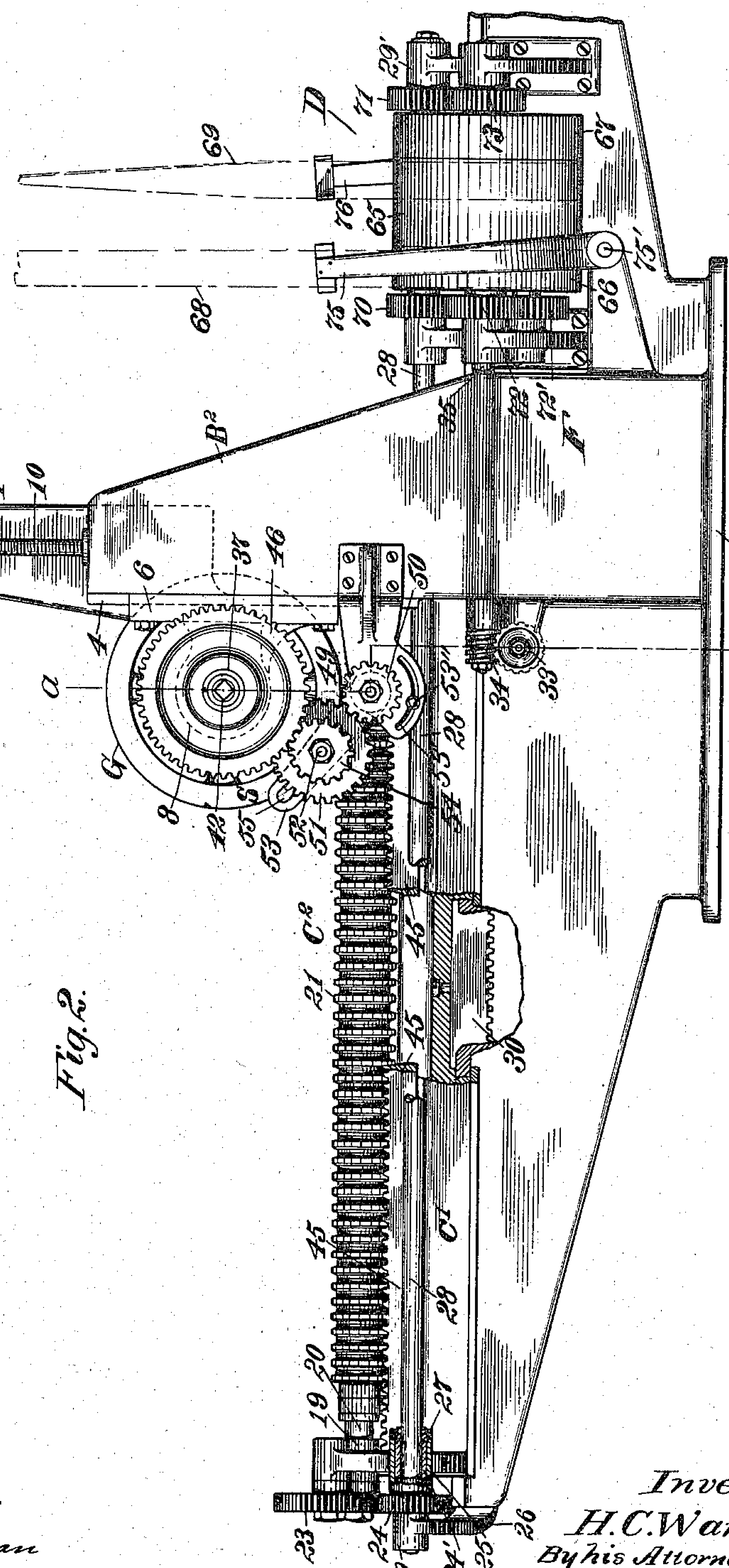

Fig. 2.

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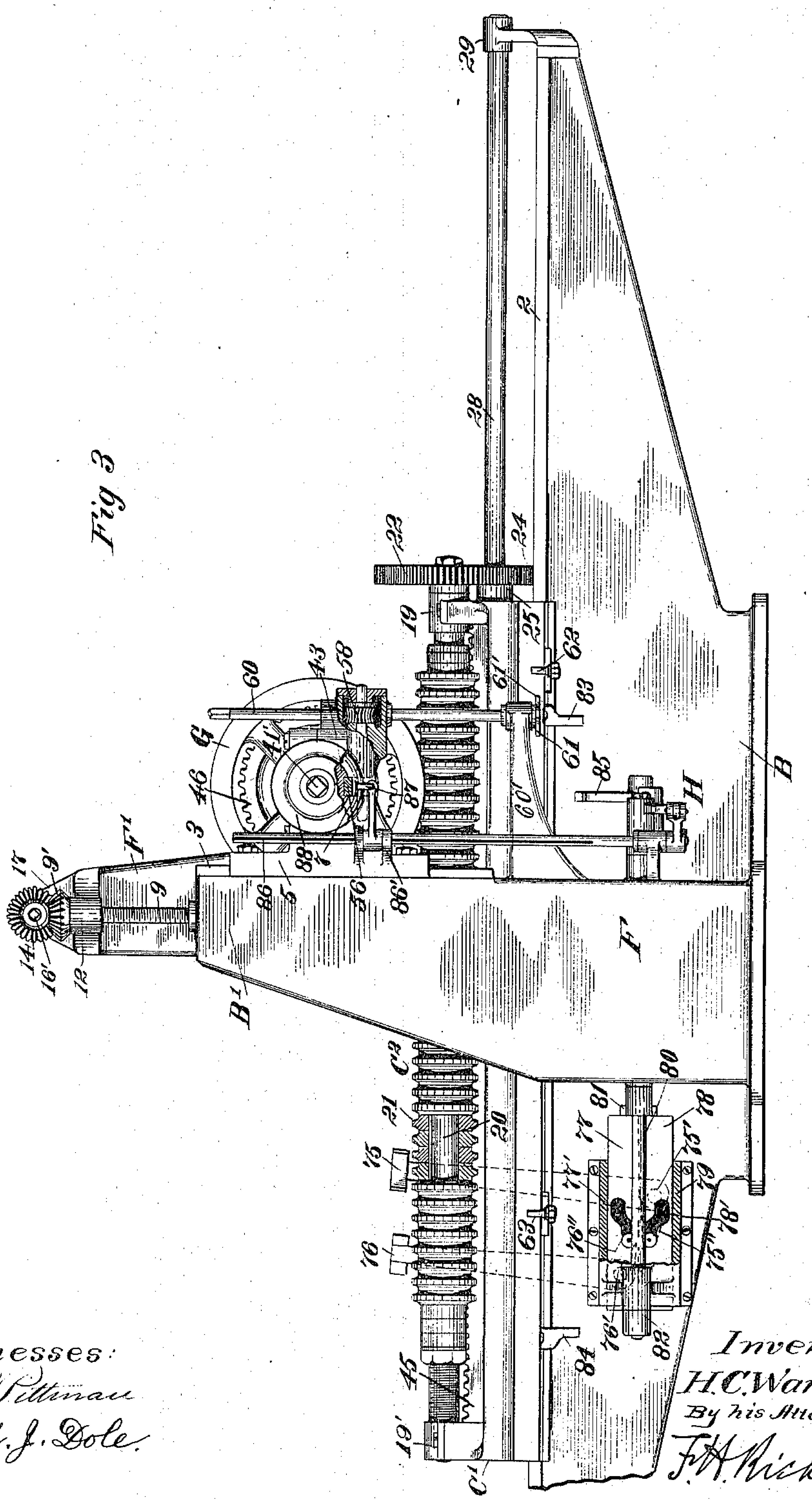
Fig 3



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6 Sheets—Sheet 4.

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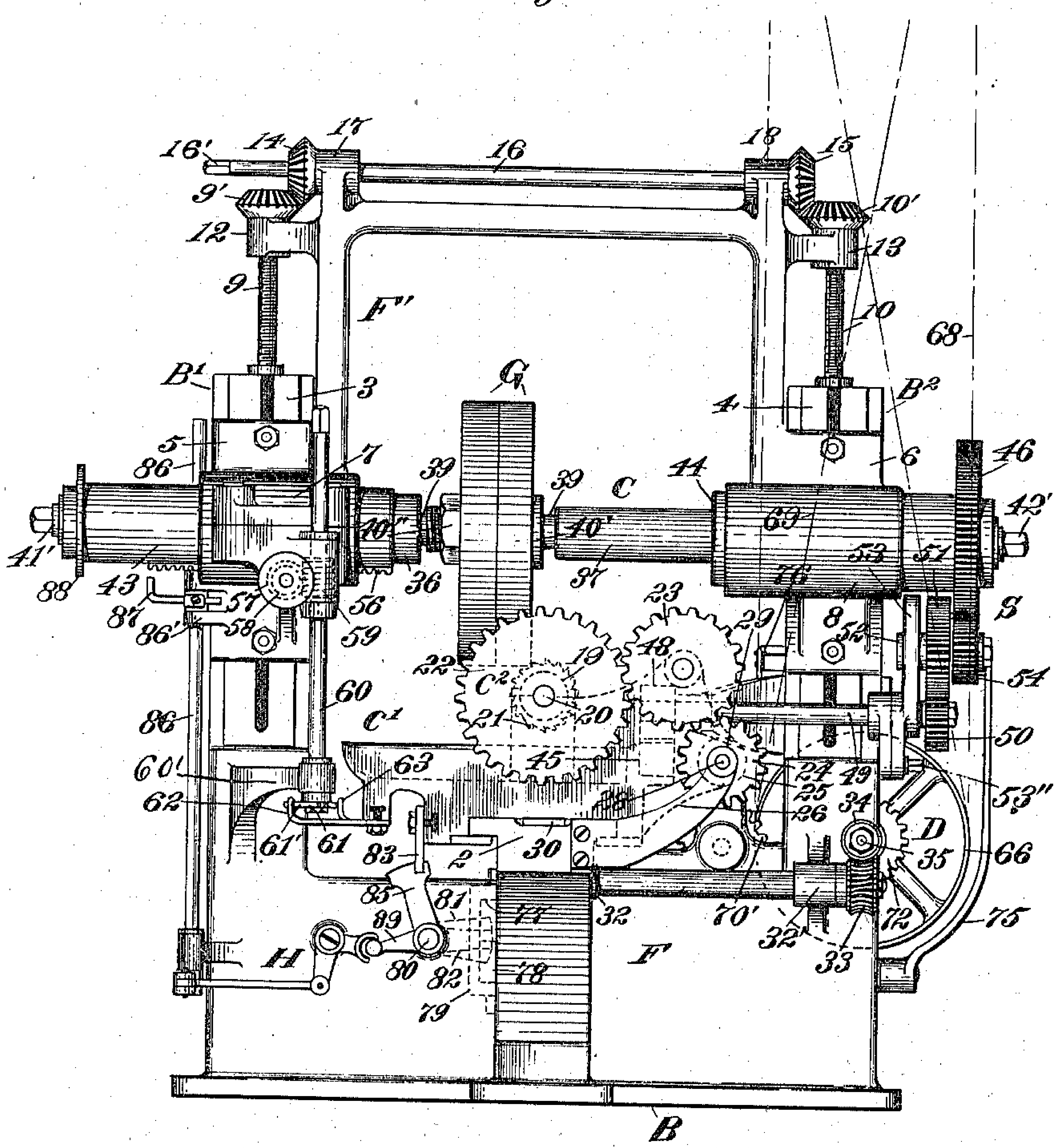
Fig. 4.



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(No Model.) 6 Sheets—Sheet 5.

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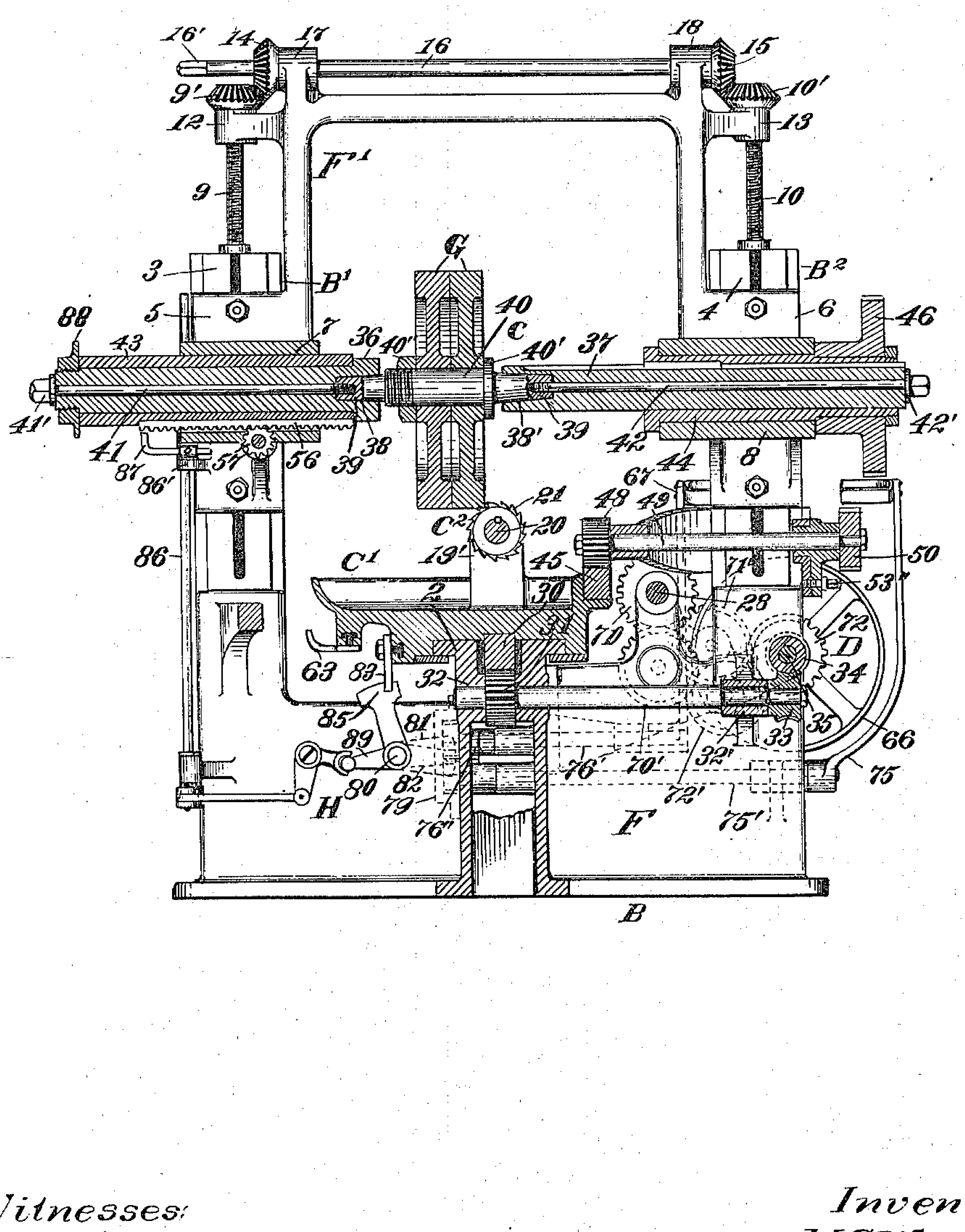
Fig. 5.



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6 Sheets—Sheet 6.

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MACHINE FOR GENERATING GEAR TEETH.

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Fig. 6.

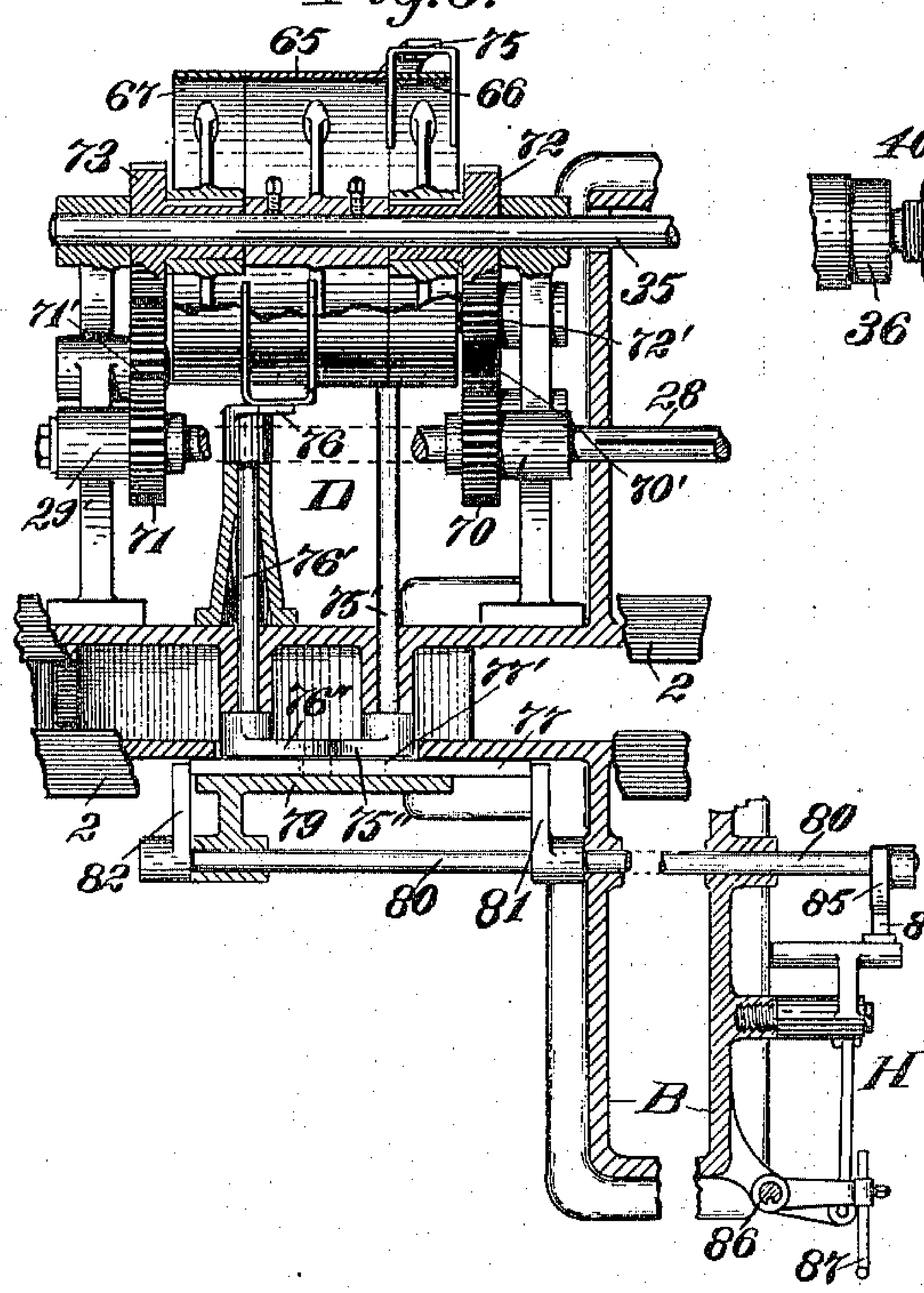


Fig. 9.

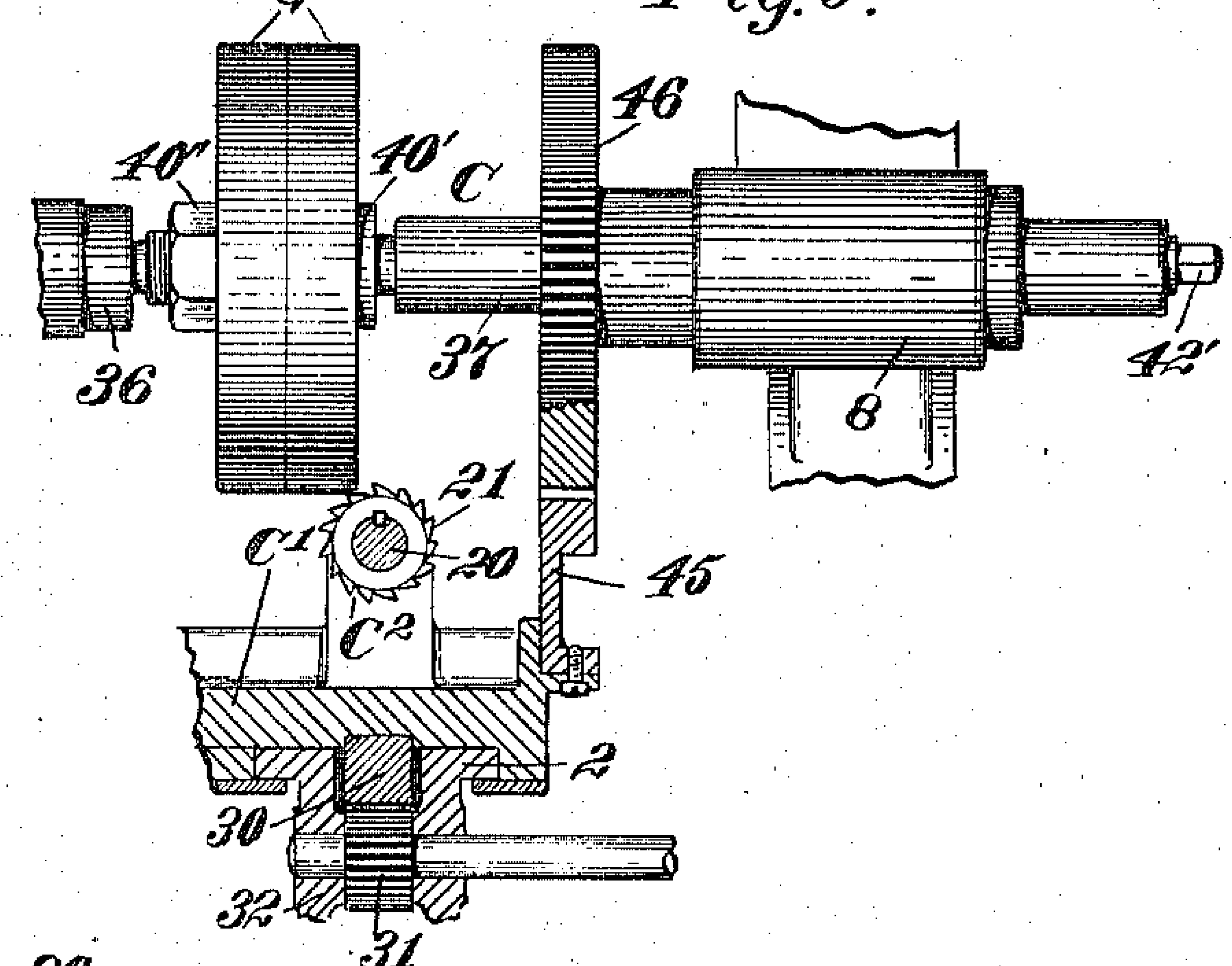


Fig. 7.

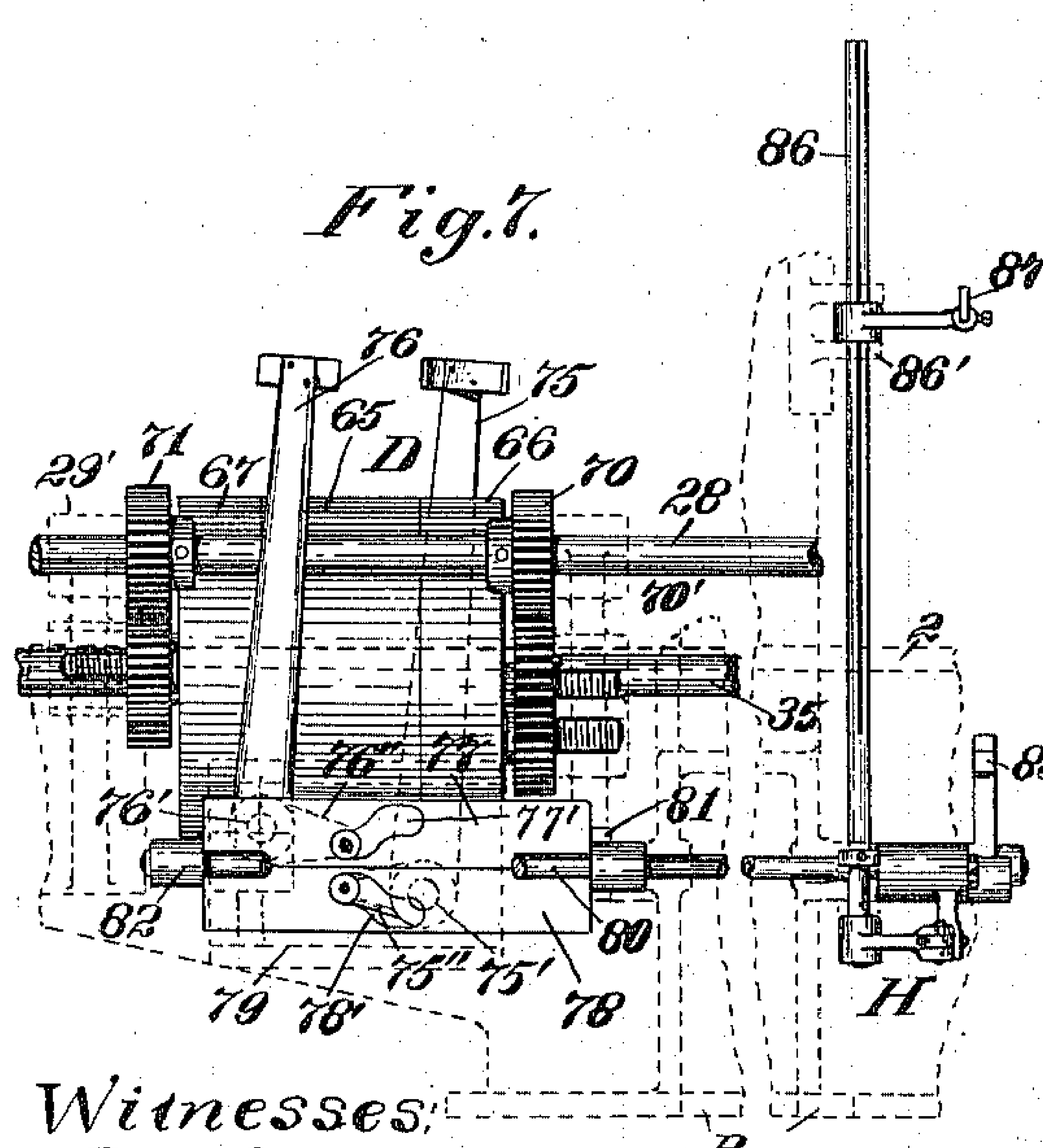
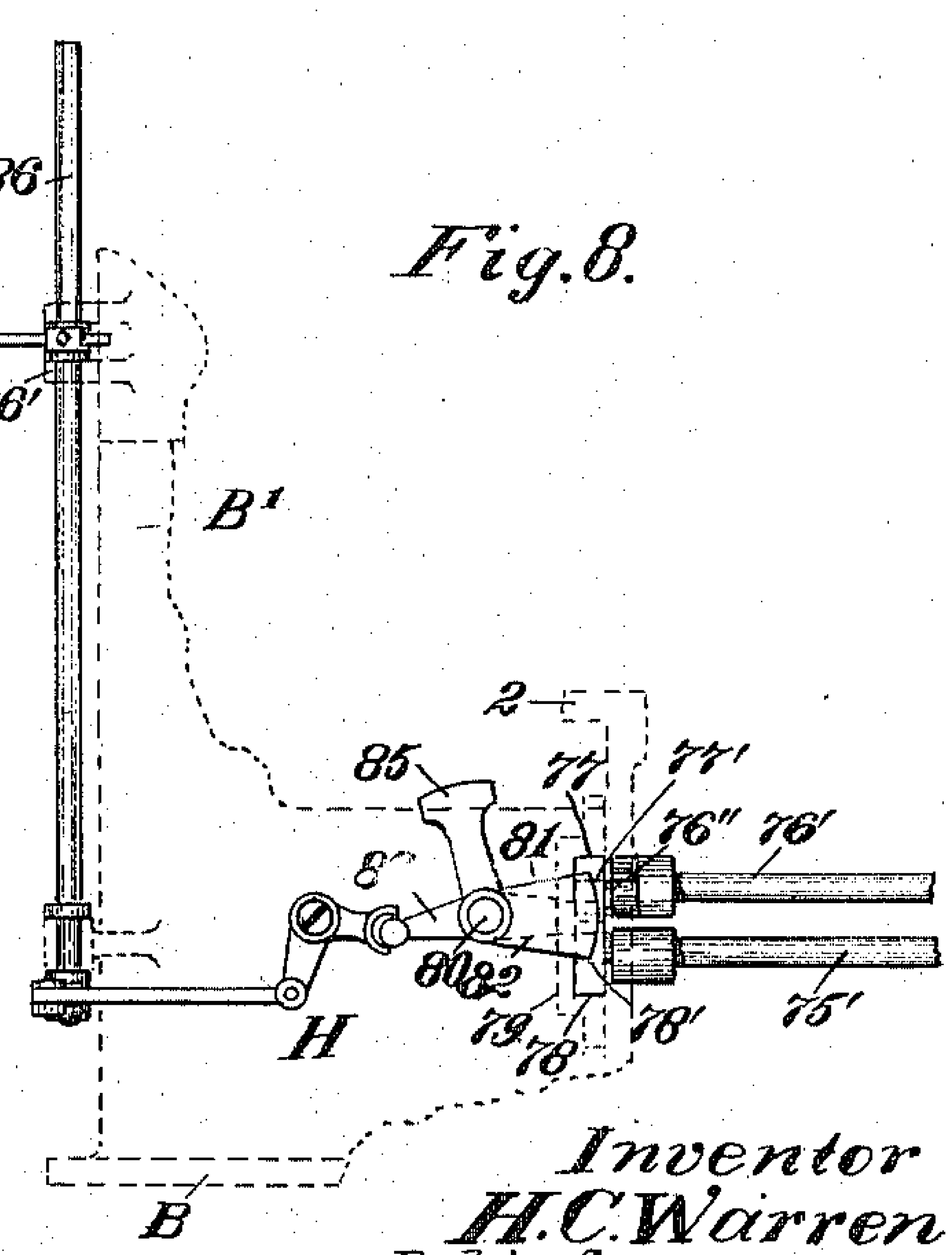


Fig. 8.



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UNITED STATES PATENT OFFICE.

HERBERT C. WARREN, OF HARTFORD, CONNECTICUT.

MACHINE FOR GENERATING GEAR-TEETH.

SPECIFICATION forming part of Letters Patent No. 559,011, dated April 28, 1896.

Application filed November 5, 1895. Serial No. 567,982. (No model.)

To all whom it may concern:

Be it known that I, HERBERT C. WARREN, a citizen of the United States, residing at Hartford, in the county of Hartford and State of Connecticut, have invented certain new and useful Improvements in Machines for Generating Gear-Teeth, of which the following is a specification.

My invention appertains to machines for generating gear-teeth, and it relates more particularly to that class of machines especially designed for cutting the teeth of spur-wheels.

One object of my present invention is to furnish a machine of the class specified of improved and simplified construction and organization and which is especially adapted for generating the teeth of spur-wheels with rapidity, precision, and economy.

Another object of my invention is to furnish an improved gear-tooth-generating machine comprehending a reversibly-revoluble gear-blank carrier and a continuously-rotative and longitudinally-reciprocative cylindrical or polygonal tooth-cutting rack or multiplex cutter, and to provide, in operative connection with the gear-blank carrier and tooth-cutting rack, actuating mechanism in position and adapted for continuously rotating the cutting-rack, and at the same time imparting a rotary movement to the gear-blank carried by the carrier and a longitudinal movement to the cutting-rack simultaneously in coinciding directions and at the same peripheral velocities, and also adapted for simultaneously reversing the direction of movement of the gear-blank and cutting-rack at predetermined points in the movement of the cutting-rack, and also for changing the relative transverse positions of the gear-blank and cutting-rack at predetermined points in the movement of said cutting-rack, whereby the operation of the cutting of the teeth in the gear-blank will be continuous, and whereby the cutting-rack will act upon the entire circuit of the tooth-forming portion of the gear-blank at every complete stroke of said rack.

Another object of my present invention is to provide, in coöperative relation with a continuously-rotative gear-blank carrier, in a machine of the class specified, an elongated multiplex cutter of a length not less than the peripheral length of the gear-blank carried by the carrier, and supported with its longitudinal axis substantially at right angles to the axis of the gear-blank carrier and adapted for rotation and for longitudinal reciprocation, and means for continuously rotating the cutter and for simultaneously imparting a rotary movement to the gear-blank and a longitudinal movement to the cutter in the same direction and at corresponding peripheral velocities and for effecting one complete rotation of the gear-blank carrier to every complete stroke of the cutter, as will be hereinafter more fully described.

In the accompanying drawings, forming a part of this specification, Figure 1 is a plan view of a gear-tooth-generating machine embodying my present invention, portions thereof being broken away to more clearly illustrate the construction and organization of certain of the details, the tooth-generating rack or elongated cylindrical cutter being shown in its extreme retracted position—the position it occupies during its first operation in cutting a blank. Fig. 2 is a side elevation of the gear-tooth-generating machine, seen from the under side in Fig. 1, a portion of the bed of the machine being broken off and the gear-blank and cutter being shown in the same position illustrated in Fig. 1. Fig. 3 is a side elevation of the gear-generating machine, seen from the opposite side to that shown in Fig. 2, the gear-tooth-generating rack being shown in this figure near the end of the forward movement. Fig. 4 is an end elevation of the gear-generating machine, seen from the left hand in Fig. 1. Fig. 5 is a vertical sectional view of the machine, taken in dotted lines *a a*, Fig. 2, looking toward the right hand in Fig. 3. Fig. 6 is a plan view of a portion of one end of the machine, partially in section, and showing the general construction and organization of the reversing driving mechanism and subsidiary elements. Fig. 7 is a side elevation of the mechanism shown in Fig. 6, seen from the under side in said figure, a portion of the framework being shown in dotted lines. Fig. 8 is an end view of a portion of the mechanism which actuates the belt-shipper cam, seen from the right hand in Fig. 7, a portion of the framework being shown in dotted lines. Fig. 9 is a sectional end view of a portion of the gear-tooth-generating machine, showing a slightly-modified form of synchronizing actuating mechanism between the gear-blank carrier and cutter-carrier.

By the term "multiplex cutter," as herein applied, is meant a rotative elongated rack-like cutter, of cylindrical or polygonal cross-section, comprehending a multiplicity of circumferentially-disposed tooth-cutters, each of a cross-sectional shape—in the the plane of its axis of rotation—similar to a truncated wedge, and which cutters are separated from each other by a distance substantially equal to the width of the teeth it is desired to generate. This tooth-cutter may in practice consist of a toothed ring, disk, or flange, of a shape suitable for generating the required form of gear-tooth.

To generate the teeth of spur-gears in accordance with my present invention, it is desirable that the gear-blank shall have a continuous uninterrupted rotative movement for a distance not less than the peripheral length of said blank, and that a multiplex cutter, comprehending a multiplicity of continuously-rotative cutters, be moved into contact and along with the gear-blank in the same direction and uninterruptedly for a distance equal to the peripheral length of the gear-blank and with the same peripheral velocity, to thereby generate a portion of each tooth of the entire circuit of teeth at one cutting operation; and it is further desirable that the direction of movement of the gear-blank and multiplex cutter be reversed at the end of each and every complete rotation of the gear-blank, and that the multiplex cutter shall be operable for performing its cutting function in both directions of its reciprocatory movement, which may be accomplished by changing the relative transverse positions of the gear-blank and cutter at predetermined points in the length of the working stroke of the cutter.

As an instrumentality for generating the teeth of spur-gears in accordance with my present invention I have shown in the drawings a theoretical adaptation of mechanism for supporting the gear-blank and multiplex cutter in proper coöperative relation and for automatically effecting the requisite movements of the gear-blank and cutter, to form in said gear-blank theoretically-correct gear-teeth by progressive and uninterrupted backward and forward cutting operations of said cutter.

In the preferred organization thereof herein shown and described my improved machine for generating gear-teeth comprehends, in part, a continuously-rotative gear-blank carrier, (designated in a general way by C,) which is supported for movement transversely of the axis of a rotative tooth-generating cutter, and which is also supported for adjustment in a direction transversely to its own axis, a cutter-carrier, (designated in a general way by C',) which is supported for reciprocatory movement in a plane parallel to a line tangent to the periphery of a gear-blank, as G, carried by the gear-blank carrier, a multiplex tooth-generating cutter (designated in a general way by C^2) supported for rotation about an axis substantially at right angles to the axis of the gear-blank carrier, and comprehending a series of peripherally-disposed tooth-cutters separated transversely, or in the plane of their axes, by intervening tooth-formative spaces, actuating mechanism for the gear-blank carrier, cutter, and cutter-carrier, comprehending means for continuously rotating the multiplex cutter, also for simultaneously imparting a rotative movement to the gear-blank and a longitudinal movement to the cutter in coinciding directions and with corresponding peripheral velocities, also for effecting one complete rotation of the gear-blank carrier to every complete stroke of the cutter, and also for simultaneously reversing the direction of movements of the gear-blank and the cutter and feed mechanism controlled by the movements of the cutter-carrier, and for automatically effecting a change in the relative transverse positions of the gear-blank and cutter, all of which will be hereinafter more fully described.

The framework of my improved gear-tooth-generating machine, which framework may be of any suitable general construction for carrying the operative parts, consists, in the preferred form thereof herein shown, of a main frame, (designated in a general way by F,) which frame supports the cutter-carrier and certain elements of its subsidiary mechanism, and an overhanging auxiliary frame, (designated in a general way by F',) which is supported for vertical adjustment on the main frame and supports the gear-blank carrier and certain elements of its subsidiary mechanism.

The main frame F, or "cutter-carrier frame," as it may be hereinafter termed, is shown in the drawings somewhat similar to an ordinary planer-frame, it consisting of the base B, having the usual longitudinal guide-way 2 midway of its width, and having the uprights B' and B^2, located at opposite sides of the bed and approximately midway between the opposite ends of said bed, which uprights B' and B^2 have vertical slideways 3 and 4 thereon to receive the slides 5 and 6 on the supplemental frame F', or "gear-blank-carrier frame," as it may be hereinafter termed.

The blank-carrier frame F', which is shown as a **U**-shaped frame overreaching the base of the machine, has slides 5 and 6, preferably formed integral with the ends thereof. These slides are carried for vertical adjustment on the slideways 3 and 4, respectively, on the uprights B' and B^2, and are shown in the nature of sliding brackets having horizontal bearings 7 and 8, formed, respectively, therein, the axes of which bearings are coincident and are transversely disposed relatively to the longitudinal axis of the base B of the machine, as will be understood by reference to

Figs. 1 to 5, inclusive, of the drawings. These bearings are intended to receive the rotative gear-blank carrier, (designated in a general way by C,) the construction and organization of which gear-blank carrier will be hereinafter more fully described.

As a convenient means for adjusting the blank-carrier frame F′ vertically of the cutter-carrier frame F to raise or lower the gear-blank carrier C, as hereinafter more fully described, I have provided, in connection with the blank-carrier frame, a suitable blank-carrier-adjusting mechanism, which, in the form thereof herein shown, consists of two adjusting-screws 9 and 10, journaled in bearings at their upper ends 12 and 13 at opposite sides of the frame F′, and having screw-threaded bearings at their lower ends in the upper ends of the uprights B′ and B^2, respectively, said adjusting-screws 9 and 10 being shown provided at their upper ends with bevel-gears 9′ and 10′, respectively, which mesh with similar bevel-gears 14 and 15 at opposite ends of a screw-actuating shaft 16, journaled in horizontal bearings 17 and 18 upon the upper end of the blank-carrier frame at opposite sides thereof. This shaft 16 has a cross-sectionally angular end 16′, extended beyond the intermeshing gears and adapted to receive a crank or other suitable tool, by means of which this shaft and the connected adjusting-screws may be rotated to raise or lower the blank-carrier frame, as will be understood by reference to Figs. 1 to 5, inclusive, of the drawings.

The cutter-carrier C′ (shown somewhat similar, in a general way, to an ordinary planer-bed) is supported for reciprocatory movement on the guideway 2, and is shown having at opposite ends thereof bearings 19 and 19′ to receive the ends of the multiplex tooth-generating cutter C^2, the extended core or shaft of which is journaled at opposite ends for rotation in said bearings.

In the preferred form thereof shown in the drawings the multiplex tooth-generating cutter C^2 comprises a multiplicity of transversely-equidistant tooth-milling cutters 21, detachably fixed to a shaft 20, which, as before stated, is journaled at opposite ends thereof for rotation in the bearings 19 and 19′ of the cutter-carrier C′.

It is desired to state in the above connection that while it is preferable to employ a multiplicity of independent milling-cutters and to practically secure them upon a shaft, as 20, extending centrally the entire series of cutters, this construction and arrangement might be modified somewhat without departure from my invention. For convenience the shaft 20 and the milling-cutters 21 thereon, irrespective of the fact that the cutters may be separate from or form an integral part of the shaft 20, will be hereinafter referred to as "the multiplex cutter," said multiplex cutter being somewhat in the nature of a rotative cylindrical rack, the teeth of which have cutting-faces of a shape adapted for generating a tooth-space in a gear-blank.

In practice the multiplex tooth-generating cutter C^2 will have its cutting-faces of an aggregate length, longitudinally of the axis thereof, not less than the peripheral length of the gear-blank to be operated upon, and it will be adapted for generating a portion of each tooth of the entire circuit of teeth to be generated in the gear-blank at each complete forward and backward movement of said multiplex cutter.

As a means for continuously rotating the multiplex tooth-generating cutter during and throughout the reciprocatory movements of said cutter I have shown the shaft or core 20 of said cutter furnished with a spur-wheel 22, which is geared with a pinion 24 through the medium of the intermediate idle-wheel 23, and this pinion 24 has a hub 24′, journaled in a bearing 25 upon an outwardly-extending arm or bracket 26 on the cutter-carrier C′, and is held in place so as to move with the cutter-carrier and bracket, preferably by means of an internally-screw-threaded collar 27, screwed onto the end of said hub, as shown most clearly in Fig. 2 of the drawings. This pinion 24 is splined upon and is adapted to be moved longitudinally of a cutter-rotating driven shaft 28, which is supported at opposite ends in bearings 29 and 29′ upon the side of a cutter-carrier frame F of the machine, said shaft 28 being continuously driven in one direction through the medium of suitable driving mechanism (designated in a general way by D) and in a manner hereinafter more fully described.

As a convenient means for imparting a longitudinal reciprocatory movement to the cutter-carrier said carrier is shown provided on its under side with a longitudinally-disposed rack 30, the teeth of which are in mesh with a driving-pinion 31 on a driven shaft journaled in transverse bearings 32 and 32′ on a cutter-carrier frame F, which shaft is furnished at its outer end with a worm-wheel 33, which is driven by a worm 34 upon a driving-shaft 35, journaled in suitable bearings upon the side of said frame, and which shaft is rotated, first in one direction and then in an opposite direction, to advance and retract the cutter-carrier by means of the driving mechanism D, which also actuates the cutter-rotating shaft, which driving mechanism is herein shown in the nature of reversing driving mechanism, and will be hereinafter more fully described.

The gear-blank carrier C, in the preferred construction and organization herein shown and described, comprehends, in part, two axially-coincident longitudinally-separable members 36 and 37, adjustably connected together, as hereinafter more fully described, for movement together in the plane of their longitudinal axes and transversely of the multiplex cutter C^2. These members are shown conically recessed, as at 38 and 38′, at their inner adjacent ends, to receive the conical ends 39 of an arbor 40, which supports the gear-blank G, said arbor practically constituting a connector between the two carrier members 36 and 37, and being held in place by means of clamp-rods 41 and 42, which extend through axial bores in the two members 36 and 37, respectively, of the carriers. These rods are in the nature of elongated bolts having screw-threaded bearings at their inner ends in the opposite ends of the arbor, and having the heads 41′ and 42′ thereof in bearing engagement with the outer ends of the rotative carrier members 36 and 37, respectively.

One of the carrier members, as 36, is shown journaled for rotation in a rack-like sleeve 43, supported for reciprocatory movement in a horizontal bearing, as 7, at the lower end of the blank-carrier frame F′, whereas the other carrier member, as 37, is shown splined for longitudinal movement in a rotative sleeve 44, journaled in a horizontal bearing, as 8, located at the lower end of the blank-carrier frame F′, in axial alinement with the bearing 7 before referred to. This last-mentioned sleeve 44 is held against reciprocatory movement in the bearing by suitable flanges at the ends thereof, as shown in the drawings.

For the purpose of rotating the gear-blank carrier in synchronism with the reciprocatory movement of the multiplex cutter said gear-blank carrier will be actuated directly from and controlled in its movements by the cutter-carrier, and as a means for effecting the requisite synchronous movements of the gear-blank carrier and cutter-carrier said gear-blank carrier is shown operatively connected with the cutter-carrier by means of synchronizing actuating mechanism, (designated in a general way by S.) This synchronizing actuating mechanism S, which practically constitutes an actuating-connector between the gear-blank carrier C and cutter-carrier C′, may, in the simplified form thereof shown in Fig. 9, consist of a rack 45, fixed to the upper face and extending longitudinally of the cutter-carrier at one side the axis thereof, and a spur-wheel 46, removably fixed to a rotative member of the sleeve 44 of the gear-blank carrier and meshing with the rack 45 of the cutter-carrier. In this form of synchronizing mechanism the spur-wheel 46, which practically constitutes a pattern-wheel for securing, in connection with the rack 45, the requisite ratio of movement between the gear-blank carrier and the cutter-carrier, will in practice be of the same diameter and have the same number and form of teeth as the gear-wheel having its teeth generated.

In the form thereof shown in Figs. 1 to 5, inclusive, the synchronizing actuating mechanism between the gear-blank carrier and cutter-carrier is of more complex character, the rack 45 on the cutter-carrier and the spur-wheel on the gear-blank carrier being shown, in this instance, separated and operatively connected together by means of suitable intermediate gearing (herein shown as a pinion 48) carried at the inner end of the driven shaft 49 and meshing with the rack 45, this shaft 49 being journaled in suitable bearings with the main frame and carrying a pinion 50 at the outer end thereof, which meshes with an idle-wheel 51 of relatively large diameter, mounted on a stud 52, adjustably fixed to an arm 53, which in turn is shiftably supported on the shaft 49 and is adapted for adjustment in a plane concentric to the axis of said shaft, an idle-wheel 54, of relatively small diameter, also being carried on the stud 52 and meshing with the spur-wheel 46.

In the organization of synchronizing actuating mechanism described in the last preceding paragraph it is necessary to substitute different sizes of idle-wheels 51 and 54 when it is desired to adapt the machine for cutting and generating gear teeth and blanks of different diameters, so as to maintain the requisite ratio of velocity between the gear-blank carrier and cutter-carrier, whereas with the modified form of synchronizing actuating mechanism shown in Fig. 9 it is necessary to apply a different rack 45 and a different spur-wheel 46 for every different-sized gear-blank to be cut.

As a means for adjusting the arm 53, which carries the idle-wheels 51 and 54, so as to permit larger or smaller idle-wheels to be placed in operative relation with the spur-wheel 46 and the pinion 50, said arm 53 has a slot 53′ at one end thereof, which is concentric to the axis of movement of said bracket, through which slot is extended a clamping-bolt 53″, which has a screw-threaded bearing in a fixture of the main frame of the machine, as will be readily understood by reference to Figs. 2 and 5 of the drawings, and as a means for facilitating the adjustment of the idle-wheels longitudinally of the arm 53 said arm has a longitudinal slot 55, through which the stud 52, on which the idle-wheels are mounted, is extended, said stud being screw-threaded at one end and furnished with a nut, by means of which said stud is held adjusted in position on the arm 53.

In the drawings (see Figs. 1, 2, 4, 5, and 9) I have shown two separate gear-blanks G G, carried upon the arbor 40 in position to be operated upon by the multiplex cutter C^2, and as a means for tightly clamping said blanks in position upon the arbor 40 said arbor is shown peripherally flanged, as at 40′, at one end to form an abutment for the outer face of the hub of one of the gear-blanks, and is externally screw-threaded at the opposite end to receive the clamp-nut 40″, which bears against the outer face of the hubs of the other of said gear-blanks, as shown most clearly in Figs. 4 and 5.

As a convenient means for automatically feeding the blank or blanks G, together with the blank-carrier C, transversely of the multiplex cutter C^2 at the requisite point in the advancing or retracting movement of the cutter, the sleeve 7, in which the carrier member 36 is journaled for rotation, is shown furnished with a rack 56 at the lower face thereof and longitudinally disposed relatively to the axis of said sleeve, which rack meshes with a pinion 57, fixed to a horizontally-disposed shaft journaled in suitable bearings in a bracket on the blank-carrier frame F′, said shaft being provided at its outer end with a worm-wheel 58, which meshes with and is actuated by a worm 59, splined for longitudinal movement on a feed-shaft 60, which is journaled at its lower end in a bearing on a bracket 60′, constituting a fixture on the cutter-carrier frame F, and is held against longitudinal movement by suitable collars. At the lower end thereof the feed-shaft 60 is provided with a feed-wheel 61, (herein shown as a "star-wheel,") having a series of radially-disposed arms 61′, in position to be engaged by abutments on the cutter-carrier during the forward and backward movements of said cutter-carrier. These feed-shaft-actuating abutments or stops (designated by 62 and 63, respectively) are adjustably secured to the side of the cutter-carrier, preferably in the manner shown in Figs. 3 to 5, inclusive, and at a distance apart substantially equal to the length of the requisite effective stroke of the cutter-carrier. One of said feed-wheel-actuating abutments or stops, as 62, is shown located near the rear end of the cutter-carrier, and is adapted for engaging and for partially rotating the feed-wheel near the end of the advancing movement, or preferably at the end of the effective advancing stroke, of the cutter-carrier, to thereby feed the gear-blank inward relatively to the multiplex cutter and bring another portion of the gear-blank into position to be operated upon by the cutter upon the retractive stroke of said cutter, and the other of said abutments or stops, as 63, is located near the forward end of said cutter-carrier, and is adapted for engaging and for partially rotating the feed-wheel at the end of the retractive movement of the cutter-carrier to bring another portion of the gear-blank into the position to be operated upon by said cutter during the next advancing movement of said cutter, as will be readily understood by reference to Figs. 3 to 5, inclusive, before referred to.

The driving mechanism (designated in a general way by D) for effecting a continuous rotation of the multiplex cutter C^2 in one direction and for effecting an advancing and retracting movement alternately of the cutter-carrier C′ simultaneously with the rotation of the cutter C^2, and without effecting a change in the direction of said cutter, may consist of any suitable reversing driving mechanism in operative connection with the cutter-rotating shaft 28, which controls the rotation of the cutter, and with the worm or driving shaft 35, which controls the reciprocation of the cutter-carrier, and which mechanism comprehends means for continuously rotating the cutter actuating and controlling shaft 28 in one direction and for alternately rotating the worm or driving shaft 35 in opposite directions. In the form thereof herein shown this driving mechanism D comprises a fast pulley 65 on the worm-shaft 35, two loose pulleys 66 and 67, one at each side of said fast pulley and two driving-belts, a straight belt and a twist-belt 68 and 69, respectively, (shown in dotted lines in Figs. 2 and 4,) which may lead to the usual driving-pulley on the main shaft, (not shown,) and which belts are adapted for rotating the fast pulley 65 alternately in opposite directions when said belts are shifted alternately on and off said fast pulley 65, which may be automatically effected by means controlled by the movement of the cutter-carrier, as will be hereinafter more fully described.

As a means for continuously rotating the cutter-actuating shaft 28 constantly in one direction and in synchronism with the rotation of the cutter-carrier-actuating shaft 35, irrespective of the direction of movement of said shaft 35, the shaft 28 has fixed thereon two pinions 70 and 71, located one adjacent to the outer face of each loose pulley 66 and 67, as clearly shown in Figs. 1, 2, 6, and 7, and said loose pulleys have pinions 72 and 73, fixed concentrically thereto, respectively, the one 72, fixed to the loose pulley 66, being geared to the pinion 70 by means of two intermediate idle-wheels 70′ and 72′, and the one 73 on the loose pulley 67 being geared to the pinion 71 by means of one intermediate idle-wheel 71′. Thus it will be seen that the loose pulley 66 is in geared connection with the cutter-actuating shaft 28 by a train of gears adapted for rotating said shaft in the same direction that the pulley 66 rotates, whereas the loose pulley 67 is in geared connection with this shaft 28 by a train of gears adapted for rotating said shaft in a reverse direction from that in which said pulley 67 rotates. Therefore, notwithstanding the fact that the loose pulleys 66 and 67 are rotated by the belts 68 and 69, respectively, alternately in reverse directions, the direction of rotation of the cutter-actuating shaft, which is directly controlled by said loose pulleys, remains unchanged. Normally the belts 68 and 69 are so disposed relatively to each other and to the three pulleys 65, 66, and 67 that one of said belts extends over the tight pulley 65 and the other of said belts extends over one or the other of the loose pulleys 66 and 67, and as a means for automatically shifting said belts 68 and 69 together or separately, as required for reversing the direction of rotation of the cutter-carrier-actuating shaft, or for stopping the rotation of said shaft, I have provided a belt-shifting mechanism, which, in the preferred form thereof herein shown, comprises suitable shipper-levers 75 and 76, which engage the belts 68 and 69, respectively, and are carried at their lower ends upon rock-shafts 75′ and 76′, journaled in suitable bearings transversely of the main frame of the machine, and having cranks 75″ and 76″ at the opposite ends thereof with projections engaging in cam-slots 77′ and 78′, formed in shipper-cams 77 and 78, which are supported for sliding movement in a suitable slideway 79 on the side of the main frame F′ of the machine.

The instrumentality preferably employed for operating the shipper-cams 77 and 78 is shown consisting of an actuating-rod 80, journaled for sliding and rotative movements in suitable bearings in the frame F in parallelism with the path of longitudinal movement of the cutter-carrier, said actuating-rod being provided with two transverse cam-actuating arms 81 and 82, one adjacent to each end of the two cams, and one of said arms being adapted, when in the position shown in Figs. 4 and 5 of the drawings, for engaging both cams and for shifting said cams together in one direction when the actuating-rod is moved longitudinally in that direction, and the other of said arms, when in this position, being adapted, when the shaft is moved in the opposite direction, for shifting both cams in a reverse direction. The cam-actuating rod will be automatically operated, preferably, at or near the extreme ends of the longitudinal movement of the cutter-carrier by means of stops 83 and 84, adjustably secured to and near the opposite ends, respectively, of the cutter-carrier, which stops are in the position for engaging, near the opposite ends of the strokes of the cutter-carrier, an abutment 85 on the cam-actuating rod 80 and for moving said rod longitudinally in opposite directions alternately, to thereby shift the shipper-cams 77 and 78 together first in one and then in the opposite direction, thus actuating the rock-shafts and throwing the belts 68 and 69 alternately onto the tight pulley 65, and thereby alternately rotate the carrier-actuating shaft 35 in opposite directions, and effect an automatic reversal in the direction of movement of the cutter-carrier, without effecting a change in the direction of rotation of the multiplex cutter C².

As it is sometimes desirable to stop the longitudinal movement of the cutter-carrier, as when the generation of the teeth in the gear-blank has been completed, I have provided, in connection with the shipper-cam-actuating rod, an automatic stopping device controlled by the movement of the gear-blank carrier C transversely of the cutter C². This means, in the form thereof herein shown, consists of a rock-shaft 86, having a sliding fit in a journal 86′ on the blank-carrier frame F′ and having its lower end journaled in a bearing on the cutter-carrier frame F, as shown most clearly in Figs. 3, 4, and 5, and an actuating-arm 87, splined to the shaft 86 between abutments on the frame F′ and having its outer free end located in the path of movement of a projection 88 on the gear-blank carrier C′. This rock-shaft 86 is operatively connected at its lower end with an arm 89 on the cam-actuating rod 80 by a crank connection, (designated in a general way by H,) which may be of any suitable construction for partially rotating the cam-actuating rod upon a partial rotation of the rock-shaft 86, as will be understood by reference to Fig. 4 and also to Figs. 6, 7, and 8. This crank connection is so arranged as to rotate the rod 80 in a direction required for throwing the cam-actuating arms 81 and 82 downward, so as to engage only the lower cam upon the longitudinal movement of the cam-actuating rod 80, as is required for shifting one of the belts, as 68, independently of the other belt onto the loose pulley, and thereby stop the rotation of the cutter-carrier-actuating shaft 35 immediately upon the operation of the automatic stopping device by the gear-blank carrier.

It is desired to state in the above connection that the mechanism employed for actuating the cutter and cutter-carrier and the mechanism employed for automatically reversing the direction of movement of the cutter-carrier and for automatically stopping the cutter-carrier may be variously modified within the scope and limits of my invention, and also that the means for effecting the requisite ratio of movement between the gear-blank carrier and cutter-carrier may be variously modified without departure from my invention.

The invention is obviously not limited to a cutter-carrier reciprocating in a right line, but comprehends any movable cutter-carrier capable of connection with the gear-blank carrier for the purpose stated.

Having thus described my invention, what I claim is—

1. The combination of a reversibly-rotative gear-blank carrier; a reciprocative cutter-carrier; and actuating mechanism for synchronously moving the gear-blank carrier and cutter-carrier, first in one and the same direction, and then in the opposite and the same direction, at comparative velocities of a predetermined ratio.

2. The combination of a rotative gear-blank carrier; actuating mechanism for rotating the gear-blank carried by the gear-blank carrier, first in one, and then in the opposite, direction; a rotative, multiplex, tooth-generating cutter in operative relation with the gear-blank carrier; means for continuously rotating the multiplex cutter; and means for moving the cutter endwise at substantially the same speed as the pitch-line of the revolving blank in which the teeth are to be cut, and first in one, and then in the opposite, direction, corresponding to the directions of movement of the gear-blank.

3. In a machine for generating gear-teeth, carrying and rotating means for a gear-blank, in combination with a multiplex cutter of a length not less than the peripheral length of

the blank to be cut; a movable cutter-carrier; and means actuated by the cutter-carrier for rotating the blank-carrier.

4. The combination of a rotative gear-blank carrier; a reciprocative cutter-carrier supported in operative relation with the gear-blank carrier; a rotative, multiplex cutter carried by said carrier, and having its effective stroke of a length not less than the peripheral length of the gear-blank in which the teeth are to be generated; and synchronizing actuating mechanism for rotating the gear-blank carrier and cutter, and for imparting to the cutter an endwise-working stroke of a length not less than the peripheral length of the gear-blank in which the teeth are to be generated, at each complete rotation of the gear-blank carrier, and in the direction of rotation of the gear-blank carrier, and at right angles to the axis of said carrier.

5. The combination of a reversibly-rotative gear-blank carrier; a reciprocative cutter-carrier; a rotative, multiplex cutter carried by said cutter-carrier; actuating mechanism for synchronously rotating the gear-blank carrier, first in one direction and then in the opposite direction, and for simultaneously rotating the multiplex cutter and at the same time moving the same longitudinally at a velocity corresponding substantially with the pitch-line velocity of the blank in which the teeth are to be generated, and first in one and then in the opposite direction, coinciding with the directions of movements of the blank-carrier; and means controlled by the movements of the cutter-carrier for automatically changing the relative transverse relations of the gear-blank carrier and cutter-carrier.

6. A machine for generating gear-teeth, comprehending a multiplex cutter, of a length not less than the peripheral length of the gear-blank in which the teeth are to be generated; a carrier for the gear-blank; actuating mechanism for imparting to the cutter and gear-blank a motion corresponding to the motion of a rack and an intermeshing, rotating pinion, and for moving said cutter a distance not less than the peripheral length of the gear-blank at each stroke of the cutter and at each complete rotation of the gear-blank; means for continuously rotating the multiplex cutter; and feeding mechanism for automatically changing the relative transverse relation of the gear-blank and cutter intermediate to successive cutting strokes of said cutter.

7. In a machine of the class specified, a rotative gear-blank carrier and a reciprocative cutter-carrier, supported, one above the other, with their axes of movement in planes intersecting each other; in combination with means for reciprocating the cutter-carrier; and an actuating-connector between, and operatively connecting, the gear-blank and cutter-carrier and adapted for rotating the gear-blank carrier in synchronism with the movements of the cutter-carrier, and for establishing a predetermined ratio of movement between said cutter-carrier and gear-blank carrier.

8. A machine for generating gear-teeth, comprehending an axially-rotative cutter of a length not less than the peripheral length of the blank to be cut, a rotative gear-blank-carrying member and a reciprocative cutter-carrying member, one of which carrying members is in operative connection with, and is directly actuated by, the other in the same direction and at comparative velocities of a predetermined ratio; and means for actuating one of said members.

9. A machine for generating gear-teeth, comprehending a reversibly-rotative blank-carrying member; a reciprocative cutter-carrying member in direct geared connection with the blank-carrying member, and having the plane of its movements transverse to the axis of rotation of the blank-carrying member and a rotative multiplex cutter carried by the cutter-carrying member; actuating means for reciprocating the cutter-carrying member; and means for rotating the cutter simultaneously with the reciprocatory movement of the cutter-carrying member, substantially as described.

10. In a machine for generating gear-teeth, a rotative gear-blank-carrying member and a reciprocative cutter-carrying member, one of which is in operative connection with, and is directly actuated by, the other; means for actuating one of said members; and means controlled by one of said members for changing the relative transverse relations of the two members, substantially as described, and for the purpose set forth.

11. In a machine for generating gear-teeth, a rotative carrier for the gear-blank; a cutter-carrier supported for longitudinal movement in a plane transverse to the axis of the gear-blank carrier; a longitudinally-disposed rack on the cutter-carrier; a spur-wheel on the gear-blank carrier in geared connection with the rack on the cutter-carrier; and actuating mechanism for imparting longitudinal movements to the cutter-carrier, substantially as described, and for the purpose set forth.

12. In a machine for generating gear-teeth, a rotative gear-blank carrier and a longitudinally-movable cutter-carrier supported with their axes of movement in relative transverse planes; a rack on the cutter-carrier; a pinion on the gear-blank carrier in geared connection with the rack on the cutter-carrier; a rotative multiplex cutter carried by the cutter-carrier with its axis of rotation transverse to the axis of the gear-blank carrier; actuating mechanism for imparting longitudinal movements to the cutter-carrier; rotating mechanism in connection with the cutter; and feeding mechanism for effecting a change in

the transverse relations of the gear-blank carrier and cutter, substantially as described, and for the purpose set forth.

13. In a machine for generating gear-teeth, a rotative gear-blank carrier; a multiplex cutter supported for rotation in longitudinal movement below, and with its axis in a plane at right angles to, the axis of the gear-blank; reversing driving mechanism for rotating the cutter continuously in one direction, and for moving the same longitudinally, first in one, and then in the opposite, direction; and actuating mechanism for rotating the gear-blank carrier, first in one direction and then in the opposite direction, in synchronism and coinciding with the directions of movement of the cutter, to establish a uniform peripheral velocity between the cutter and the gear-teeth in which the teeth are to be generated.

14. In a machine for generating gear-teeth, a rotative gear-blank carrier; a reciprocative cutter-carrier having its plane of movement transverse to the axis of the gear-blank carrier and a rotative multiplex cutter; in combination with reversing driving mechanism in connection with, and adapted for moving, the cutter-carrier longitudinally, first in one, and then in the opposite direction; cutter-rotating mechanism in connection with, and adapted for continuously rotating, the cutter; gearing intermediate to, and operatively connecting, the reversing driving mechanism and the cutter-rotating mechanism; synchronizing actuating mechanism intermediate to, and operatively connecting, the gear-blank carrier and cutter-carrier, and adapted for establishing a predetermined ratio of movement between the gear-blank carrier and the cutter-carrier; and feeding mechanism controlled by the longitudinal movements of the cutter-carrier for effecting a change in the transverse relation of the gear-blank carrier and cutter-carrier, substantially as described, and for the purpose set forth.

15. In a machine of the class specified, the combination of a cutter-carrier frame; a cutter-carrier supported for longitudinal movement on said frame; a rotative multiplex cutter carried on said cutter-carrier with its axis in the plane of longitudinal movement of the cutter-carrier; a gear-blank-carrier frame supported on the cutter-carrier frame for adjustment vertically thereof; adjusting means for said blank-carrier frame; a rotative gear-blank carrier supported on the blank-carrier frame with its axis transverse of the path of movement of the cutter-carrier; and actuating mechanism for synchronously moving the gear-blank carrier and cutter-carrier, the first rotatively and the other longitudinally in the same direction and at comparative velocities of a predetermined ratio.

16. In a machine of the class specified, the combination of a cutter-carrier frame; a horizontally-disposed cutter-carrier supported for longitudinal movement upon said frame; a multiplex cutter rotatively carried on the cutter-carrier with its axis in the plane of the longitudinal movement of the cutter-carrier and transversely of a gear-blank carrier; a gear-blank-carrier frame supported on the cutter-carrier frame for adjustment vertically thereof; adjusting means for said blank-carrier frame; a rotative gear-blank carrier supported on the blank-carrier frame with its axis transverse of the path of movement of the cutter-carrier, and for adjustment transversely of the multiplex cutter; synchronizing actuating mechanism operatively connecting the gear-blank carrier and cutter-carrier, and controlled by the movements of the cutter-carrier for establishing a predetermined ratio of movement between the gear-blank carrier and cutter-carrier; actuating mechanism in connection with, and adapted for moving, the cutter-carrier and the cutter thereon transversely of the plane of the axis of the gear-blank carrier; rotative mechanism for the cutter; and means controlled by the movement of the cutter-carrier for intermittently feeding the gear-blank carrier transversely of the cutter.

17. In a machine for generating gear-teeth, a rotative gear-blank carrier, and a longitudinally-movable multiplex cutter supported with their axes in a plane transversely of each other; in combination with actuating mechanism for rotating the cutter, and for simultaneously moving the cutter longitudinally, and the gear-blank carrier rotatively, in the same direction at comparative velocities of a predetermined ratio; reversing mechanism for intermittently reversing together the longitudinal and rotative directions of movements of the cutter and gear-blank carrier, respectively; feeding mechanism controlled by the longitudinal movements of the cutter for automatically and intermittently moving the cutter-carrier transversely of said cutter; and a stopping mechanism controlled by the movement of the cutter-carrier transversely of the cutter for automatically stopping the longitudinal movement of the cutter at a predetermined point in said relatively transverse movement of the gear-blank carrier.

18. In a machine for generating gear-teeth, the combination with a rotative gear-blank carrier adapted for carrying the gear-blank in which the teeth are to be generated; of a rotative, multiplex cutter supported for movement in the plane of its longitudinal axis and transversely of the axis of the gear-blank carrier, and comprehending a multiplicity of relatively transversely-separated polygonal cutters, in axial alinement and of an aggregate cutting length, longitudinally of said axis, not less than the peripheral length of the gear-blank in which the teeth are to be generated; a cutter-carrier; and means connecting said carriers, substantially as described.

19. A rotative multiplex cutter of a length not less than the peripheral length of the blank to be cut, and a movable cutter-carrier in

combination with a gear-blank carrier; and mechanism connecting said carriers.

20. A rotative multiplex cutter of a length not less than the peripheral length of the blank to be cut, and a movable cutter-carrier in combination with a gear-blank carrier; mechanism connecting said carriers; and means for moving one of said carriers transversely.

21. An axially-rotative cutter of a length not less than the peripheral length of the blank to be cut, and a carrier on which said cutter is supported; in combination with a gear-blank carrier; and means for moving the gear-blank carrier transversely.

22. A gear-tooth-generating machine, comprehending an axially-rotative multiplex cutter of a length not less than the peripheral length of the blank to be cut; a carrier by which said cutter is supported; a gear-blank carrier; and intervening means connecting the two carriers and by which one carrier is actuated by the other carrier.

23. A reciprocative carrier, and an axially-rotative cutter journaled thereon; in combination with a gear-blank carrier an actuator connecting said carriers; means for moving one carrier beneath the other carrier; and means for reversing the direction of movement of one of said carriers.

24. A movable carrier and a multiplex cutter of a length not less than the peripheral length of the blank to be cut, carried thereby; in combination with a gear-blank carrier; means for moving one carrier transversely with relation to the other; and gearing connecting said carriers.

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Witnesses:
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