No. 801,097. PATENTED OCT. 3, 1905.

C. M. MANLY.

VARIABLE SPEED GEAR.

APPLICATION FILED MAR. 17, 1904.

5 SHEETS—SHEET 1.

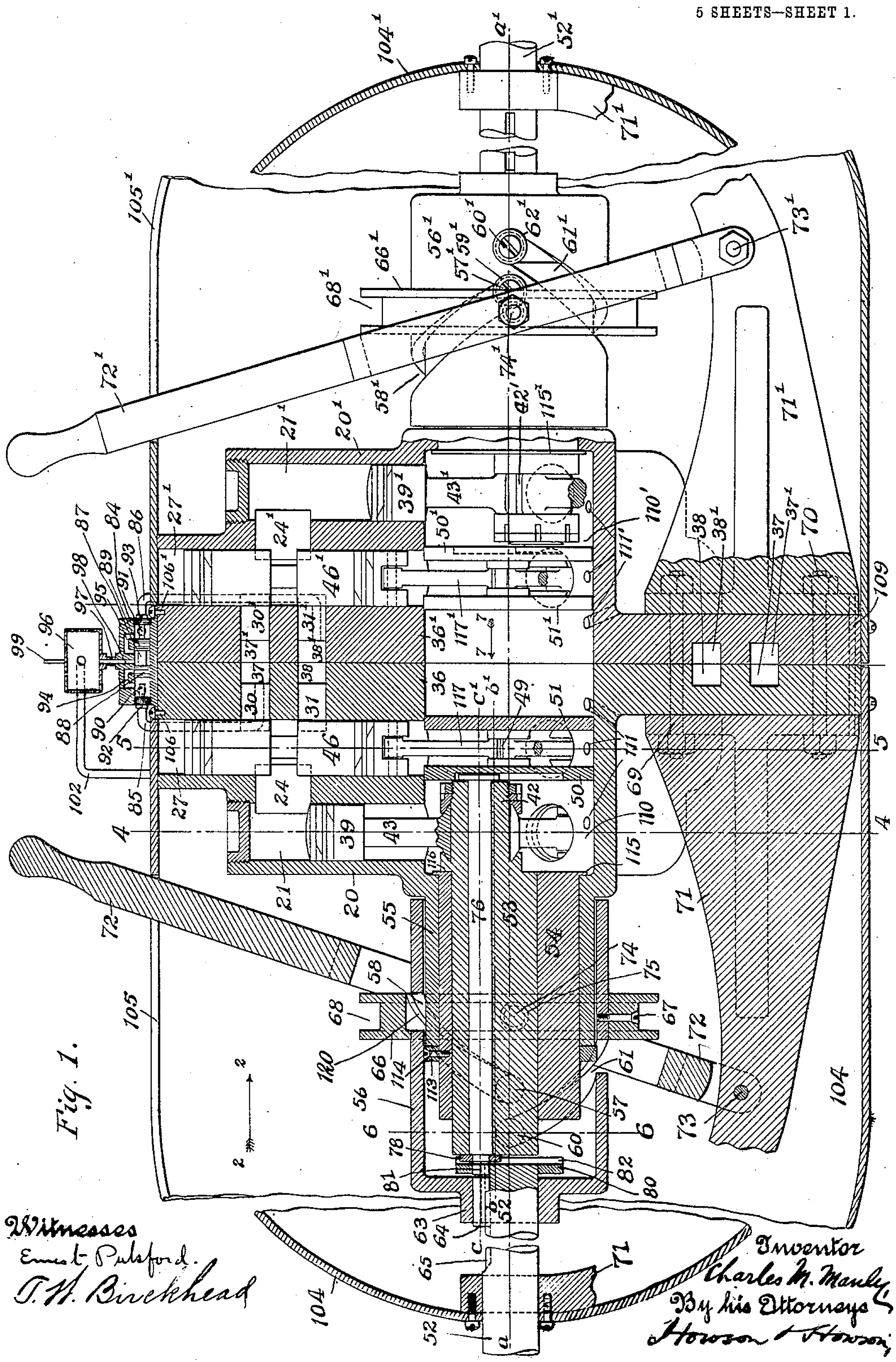

Fig. 1.

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5 SHEETS—SHEET 2.

Fig. 6.

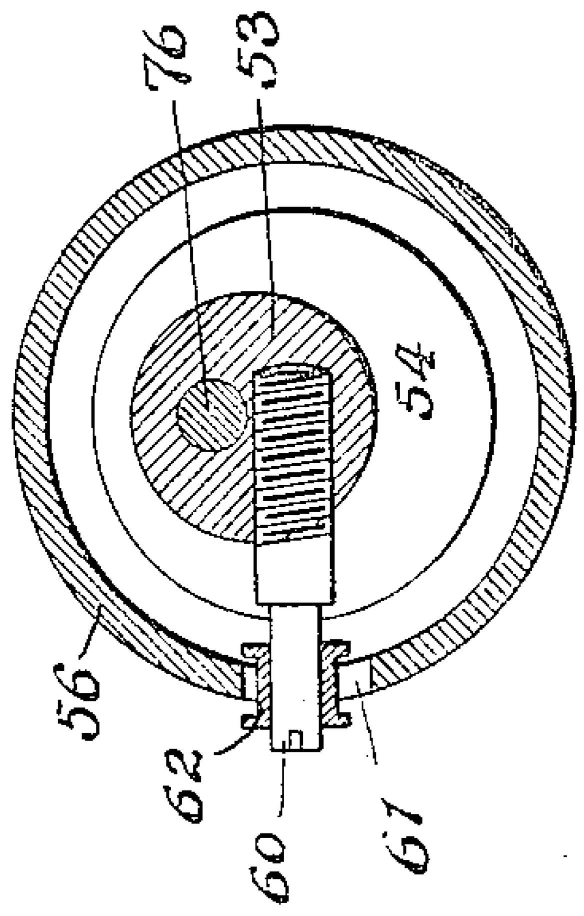


Fig. 9.

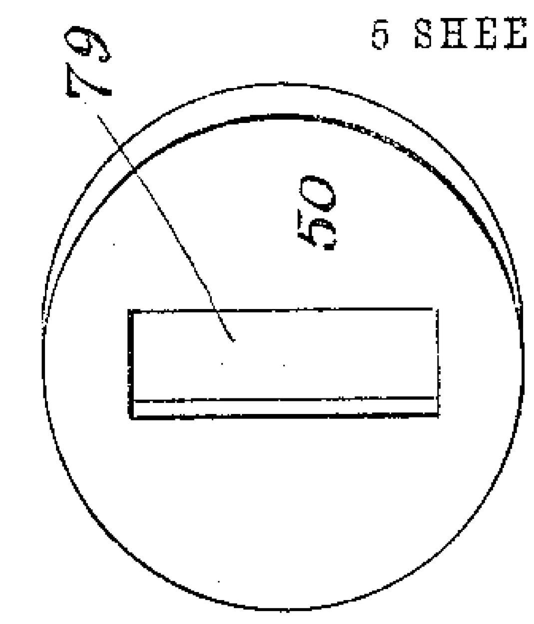


Fig. 8.

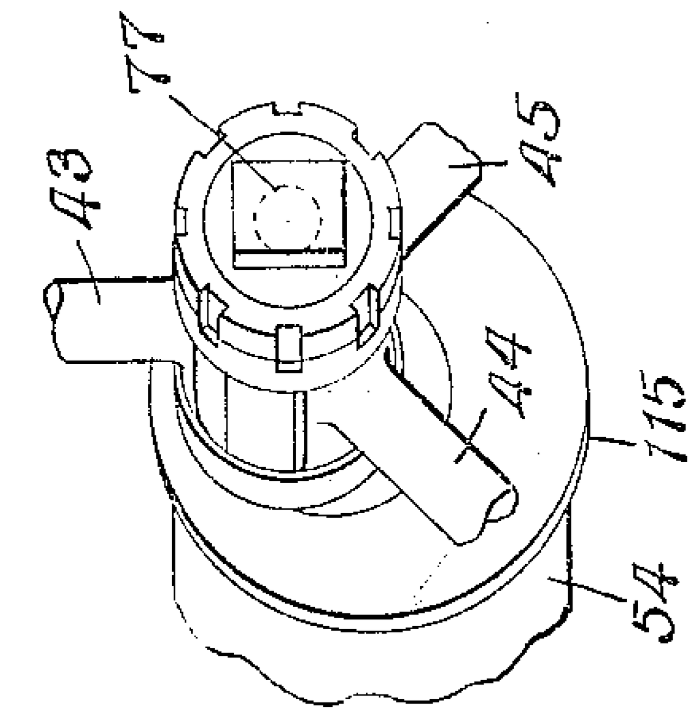
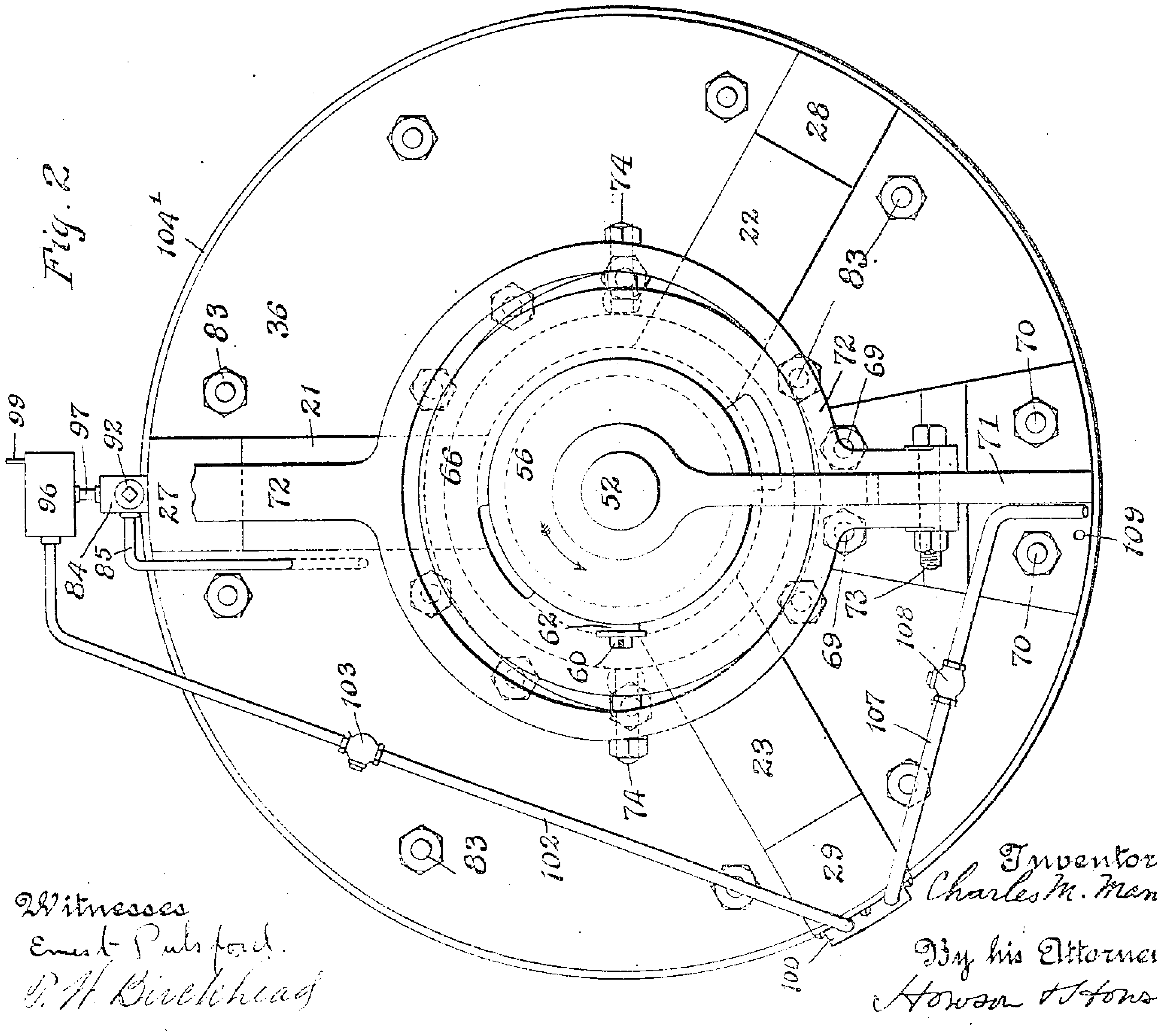


Fig. 2



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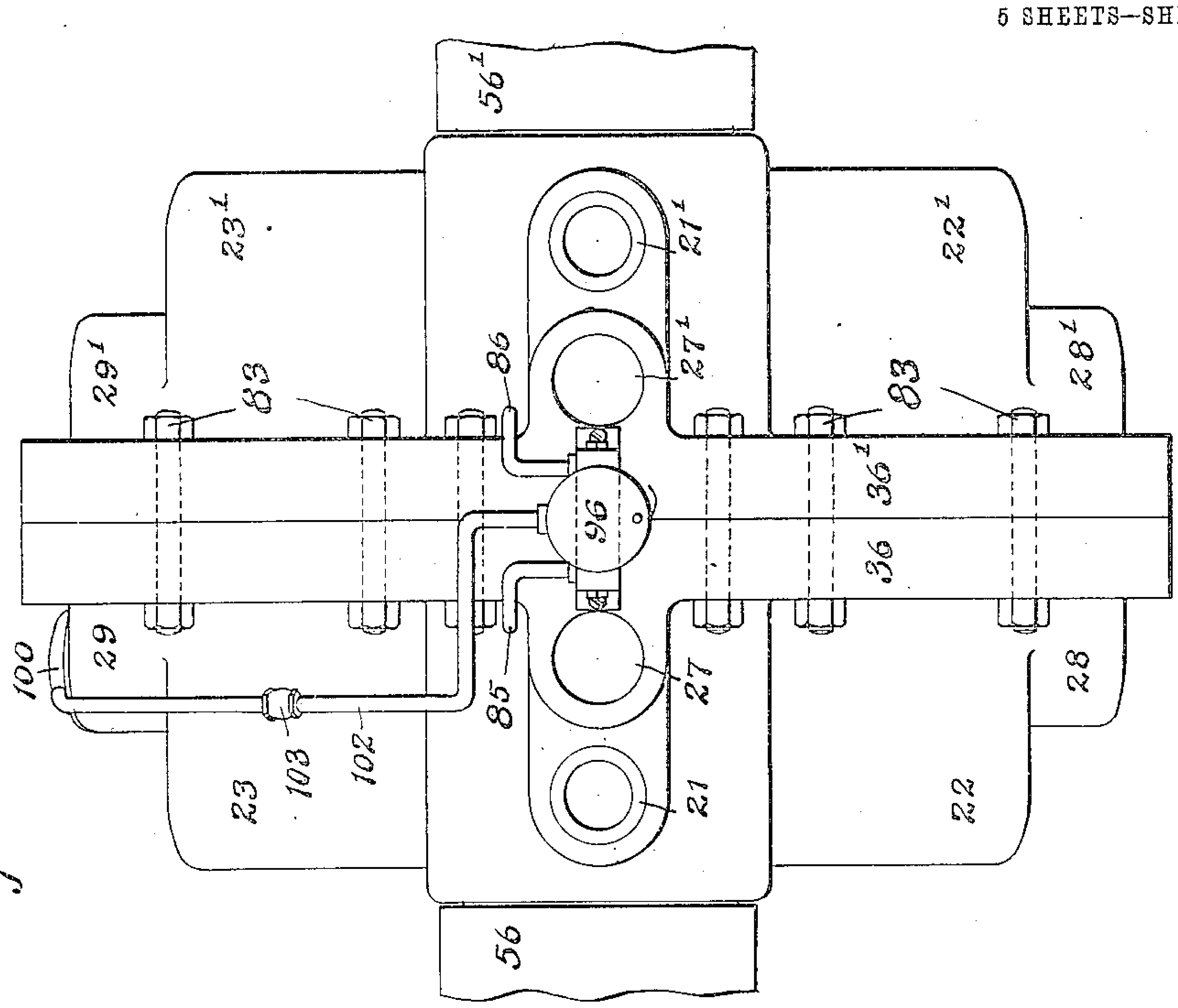

Fig. 3.

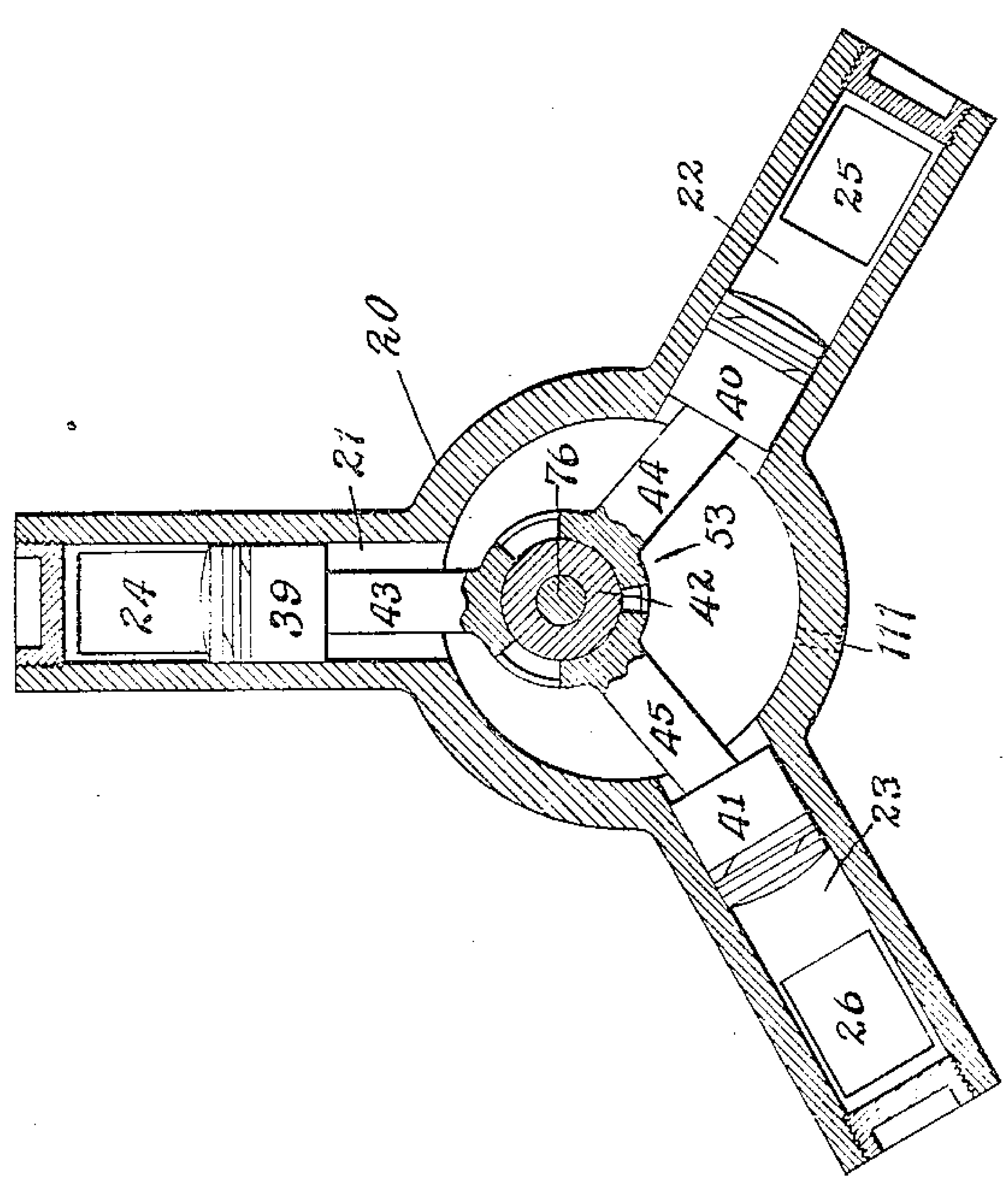

Fig. 4.

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5 SHEETS—SHEET 4.

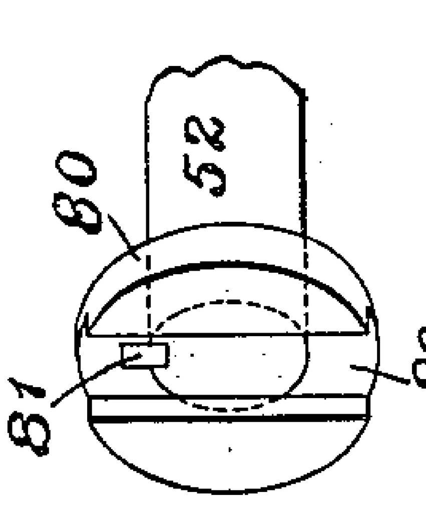

Fig. 11.

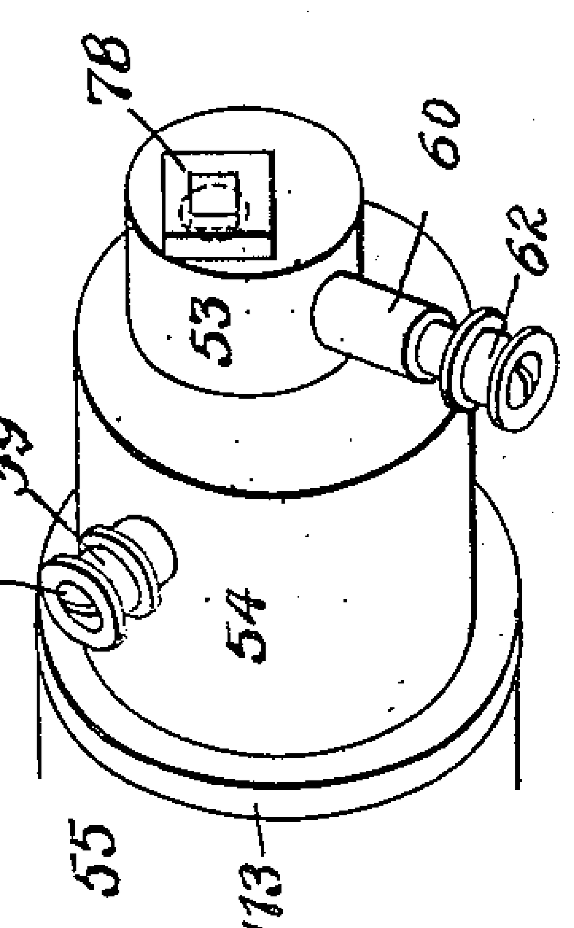

Fig. 10.

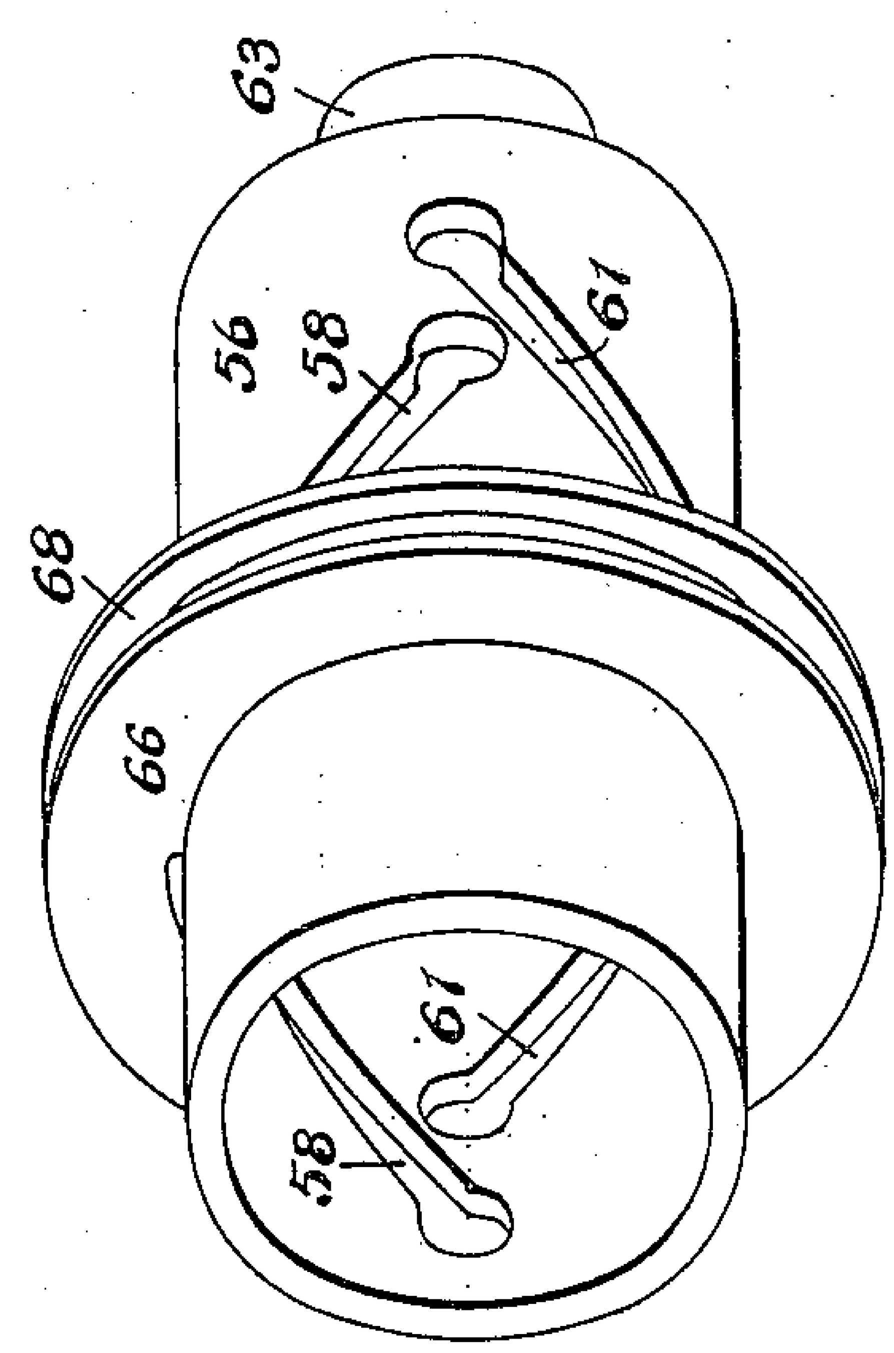

Fig. 12.

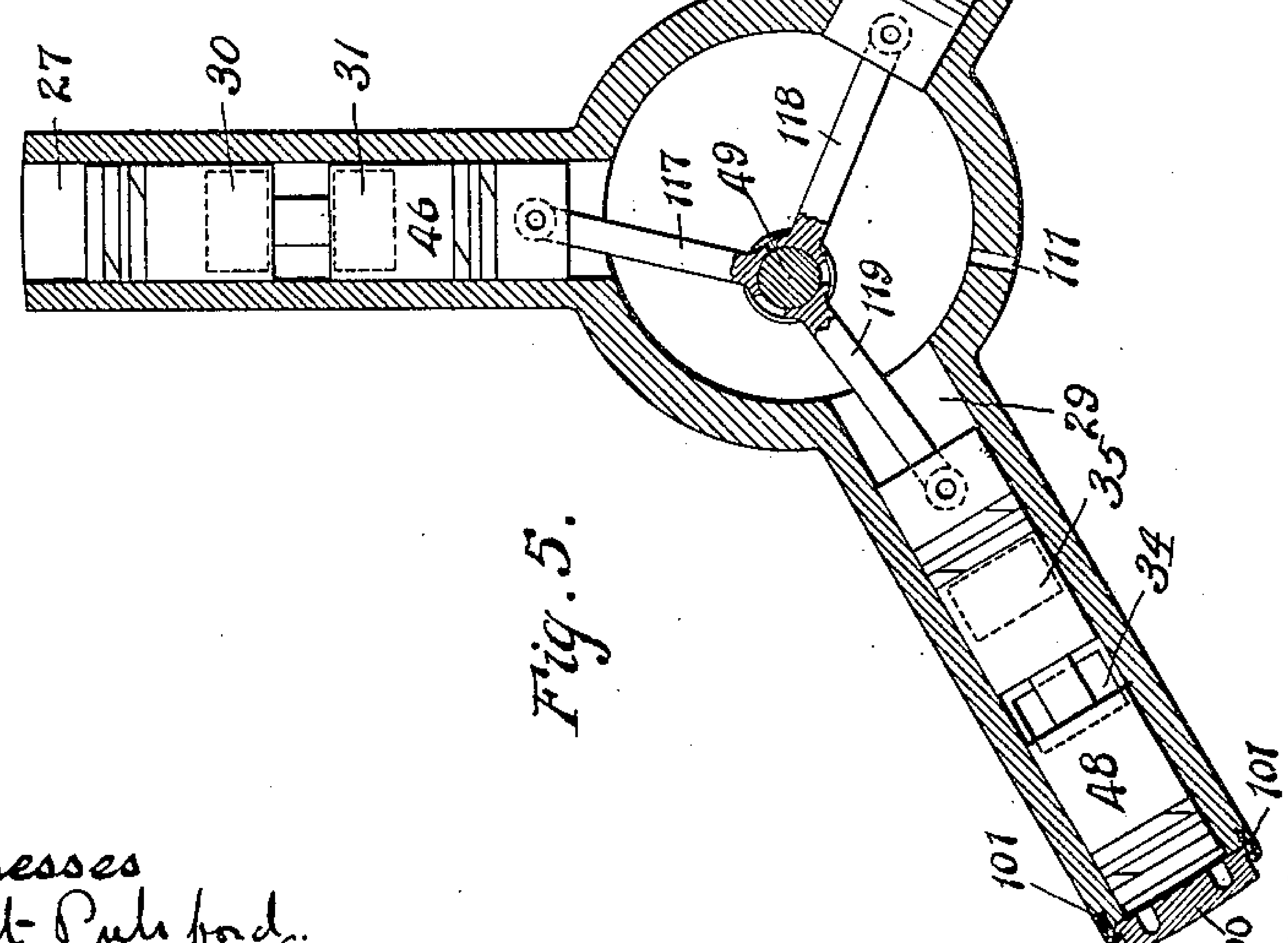

Fig. 5.

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APPLICATION FILED MAR. 17, 1904.

5 SHEETS—SHEET 5.

Fig. 13.

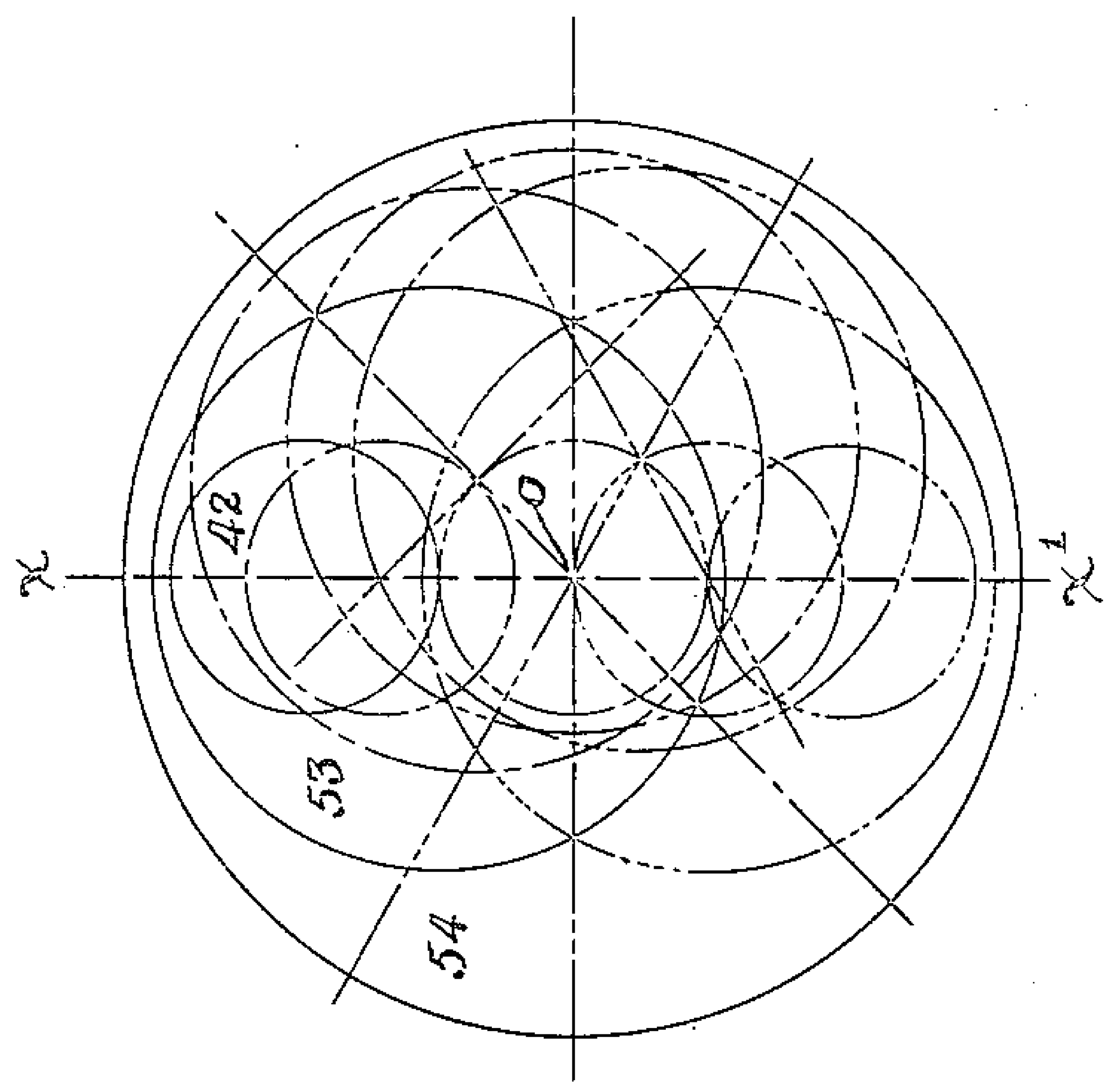
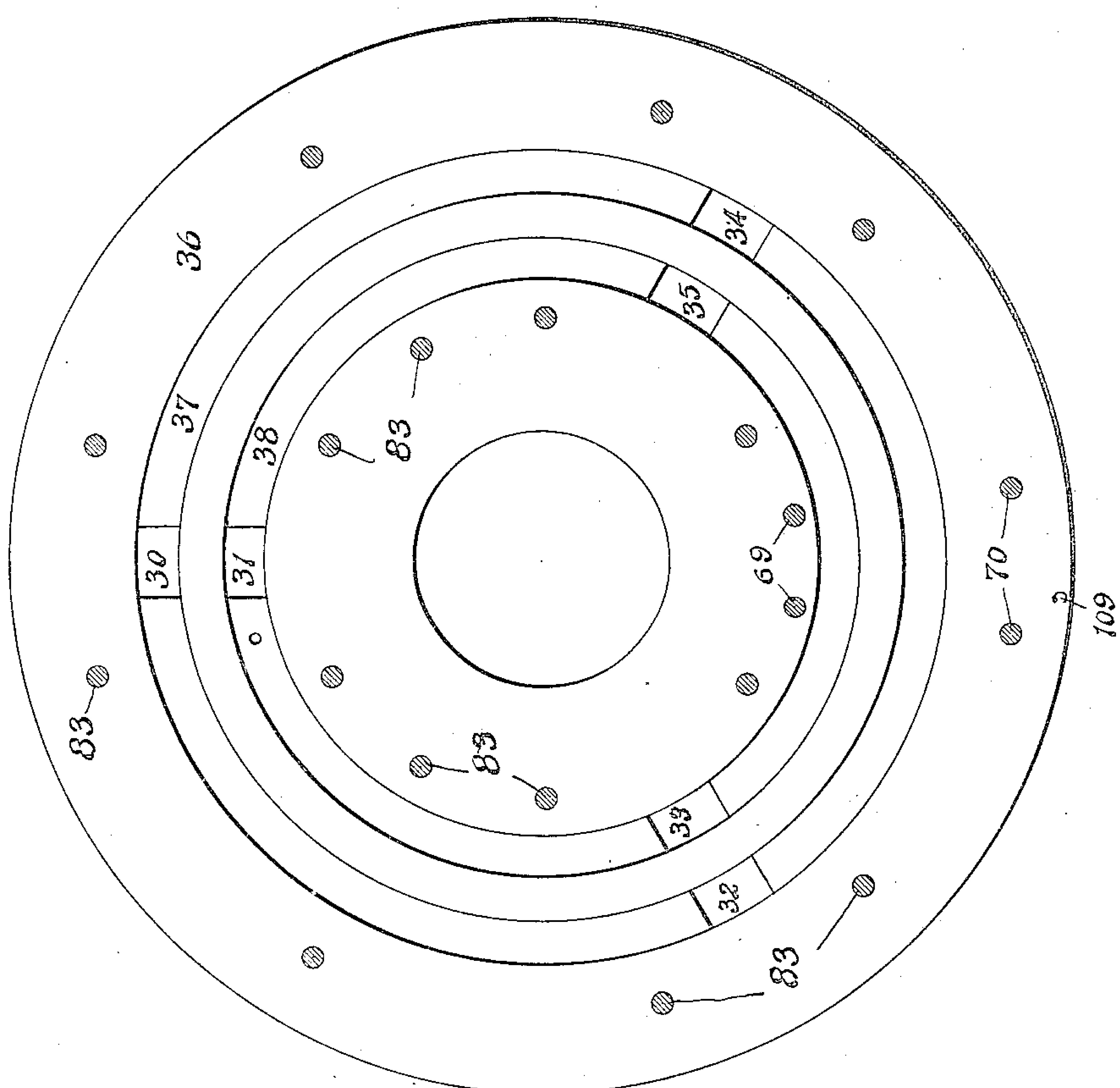


Fig. 7.



Witnesses
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P. H. Birckhead.

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UNITED STATES PATENT OFFICE.

CHARLES M. MANLY, OF WASHINGTON, DISTRICT OF COLUMBIA.

VARIABLE-SPEED GEAR.

No. 801,097. Specification of Letters Patent. Patented Oct. 3, 1905.

Application filed March 17, 1904. Serial No. 198,616.

To all whom it may concern:

Be it known that I, CHARLES M. MANLY, a citizen of the United States, and a resident of Washington, District of Columbia, have invented certain new and useful Improvements in Variable-Speed Gears, of which the following is a specification.

My invention relates to variable-speed-transmitting mechanisms in which a pumping device and a motor operated by a fluid, preferably oil or water, delivered from the pump are interposed between a prime mover and a driven device, such fluid circulating through the pump and motor as a fluid connection, as disclosed in the type forming the subject of my Letters Patent numbered 710,485, dated October 7, 1902.

My object is to provide improved, simple, and effective means in such mechanisms as that designated for varying at will the velocity ratio of the driven device to the prime mover from any predetermined positive value through zero to any other predetermined negative value, whereby the prime mover may be run at a constant speed and the driven device caused to operate at any desired speed between the maximum speed in one direction, represented by the predetermined positive value, to a maximum speed in the reverse direction, represented by the predetermined negative value.

My further object is to accomplish this desirable result in such a manner that any fluctuations in the velocity of the driven device relative to that of the driving device or prime mover shall be so small at any speed as to be practically negligible, and, finally, my object is to provide a variable-speed gear of the character specified which shall be applicable to any situation where it is desirable or necessary to transmit varying speeds from a driving device to a driven device, and which shall be especially adapted for use on motor-vehicles and other structures where the load or resistance varies within wide limits.

With these objects in view my invention consists of an improved speed-transmitting mechanism embodying a pump driven from any suitable external source of power, a motor connected to the pump by a fluid and adapted to be connected to a driven device, and means for adjusting the relative capacities of the pump and the motor, as hereinafter more particularly pointed out in the claims; and it further consists in a variable-speed gear of the type indicated wherein stationary cylinders and a rotating crank, adjustable while in motion, are employed, and, finally, in the novel construction and details thereof with reference to the accompanying drawings, as hereinafter described, and more particularly pointed out in the claims.

In the drawings, which illustrate a preferred form in which my invention may be carried out, Figure 1 is a central longitudinal sectional view. Fig. 2 is an end elevation with the front half of the inclosing case removed looking in the direction of the arrow 2 2 in Fig. 1. Fig. 3 is a partial plan view of Fig. 1 with the inclosing case removed. Fig. 4 is a sectional view on the line 4 4 of Fig. 1. Fig. 5 is a sectional view on the line 5 5 of Fig. 1. Fig. 6 is a sectional view on the line 6 6 of Fig. 1. Fig. 7 is a detached end view of one of the main castings, showing the ports and connecting-channels and looking in the direction of the arrow 7 7 in Fig. 1. Fig. 8 is a detached perspective view of the crank of the pump. Fig. 9 is a detached perspective view of the valve-crank disk of the pump. Fig. 10 is a detached partial perspective view of the arrangement for adjusting the pump and valve cranks. Fig. 11 is a detail perspective view of one of the adjusting elements for preserving the angular relation between the pump or motor crank and the valves. Fig. 12 is a detached perspective view of the sleeve for adjusting the crank, and Fig. 13 is a diagrammatic view hereinafter referred to.

In Fig. 1 I have shown the pump structure on the left of the vertical medial line and the motor structure on the right, and as the construction of both is here shown as similar a detailed description of one—for example, the pump—will be sufficient to clearly set forth the manner in which both are to be made, these two elements of the device here shown as differing from each other only in the functions performed, as hereinafter described.

Referring now to the drawings, in which the same reference characters relate to the same or corresponding parts in all the views, the numeral 20 indicates the pump-casting embodying a plurality of cylindrical chambers 21, 22, and 23, constituting the pump-cylinders, which may be formed in the main casting or in any suitable manner and are radially disposed around the axial line *a a'* of the structure, such axial line passing centrally through the pump and motor structures. The cylinders 21, 22, and 23 are provided with suitable ports 24, 25, and 26, communicating, respectively, with the cylindrical chambers 27, 28, and 29, formed in the casting 20 and constituting the valve-chambers of the pump. Formed in the side of the valve-chambers opposite the ports 24, 25, and 26 are outer and inner ports 30 and 31, 32 and 33, 34 and 35, respectively, which pass at a uniform radial distance from each other through the web 36, in which the pump-casting terminates on the one side, the outer ports communicating with a circular groove 37, which connects all of said outer ports together, and the inner ports communicating with a circular groove 38, which connects all of the inner ports together. Pistons 39, 40, and 41 are slidably mounted in the pump-cylinders 21, 22, and 23, respectively, and are connected to a radially-adjustable crank-pin 42 by means of connecting-rods 43, 44, and 45, having a rocking connection with their respective pistons and adapted to cause said pistons to reciprocate in their respective cylinders when the crank-pin rotates. Piston-valves 46, 47, and 48 are slidably mounted in the valve-chambers 27, 28, and 29, respectively. Each piston-valve is composed of an outer head and an inner head spaced apart a distance equal to the distance separating the outer port of the valve-chambers from the inner port thereof and joined together by a stem. These valves are connected by rods 117, 118, and 119, respectively, to a crank-pin 49, carried by the valve-crank disks 50 and 51, rotatably mounted in and bearing against the walls of the crank-chamber 110, whereby said disks are held at right angles to the center of rotation, the connecting-rods 117, &c., preventing lateral movement of said disks. The eccentricity of said crank-pin 49 with respect to the center around which it is adapted to rotate is equal to the distance which separates the outer and inner ports of the valve-chambers, said crank-pin 49 being adapted to rotate in unison with the pump crank-pin 42, and thereby cause the piston-valves to reciprocate in their respective chambers. The crank-pin 42 is adapted to be rotated by means of the primary driving-shaft 52, as hereinafter described, and is here shown in its upper position of dead-center with respect to the cylinder 21. The crank-pin 42, in the position shown in Fig. 1, is eccentrically disposed with reference to the central axial line $a\ a'$ and is carried by a shaft 53, mounted in the eccentric bore of a bush 54, the outer or peripheral surface of which is concentric with respect to the hub 55, in which the pump-casting terminates on one side and in which said bush is rotatably mounted. The bush 54 is connected to a sleeve 56 by means of a pin 57, screwed into said bush, and provided with a roller 59, operating in a spiral slot or groove 58 in said sleeve 56. The crank-shaft 53 is also connected to the sleeve 56 by means of a pin 60, screwed into said crank-shaft and having a roller 62 rotatably and slidably mounted thereon and operating in a spiral slot or groove 61, also formed in the sleeve 56. The slot or groove 58 is, as here shown, a right-hand spiral and the slot or groove 61 a left-hand spiral.

The eccentricity of the bore in the bush 54 is preferably made equal to the eccentricity of the crank-pin 42 with reference to its shaft 53, because when such is the case the crank-pin 42 may be caused to move radially in a straight line with respect to the sleeve 56 toward and through the central axis $a\ a'$ by such proper relative motions of the shaft 53 and the bush 54 in opposite directions as will give to the bush 54 one-half of the angular displacement around the central line $a\ a'$, and referred to a fixed diameter of the sleeve 56 that is given to the shaft 53 around its central line $b\ b'$, and referred to the line connecting the center of said bush 54 and the center of said shaft 53. The rotary adjustment of the crank-shaft 53 and the bush 54 at their proper relative rates, as here defined, can be effected through the medium of the spiral slot-and-pin connections above described by means adapted to slide the sleeve 56 back and forth, as below described. The outer left-hand end of the sleeve 56 terminates in a hub 63, adapted to receive the primary driving-shaft 52 and which is connected thereto by means of a key 64, engaging a keyway 65, formed in the primary shaft. On the outer surface of the sleeve 56 is a ring 66, fastened thereto by means of screws 67, said ring having formed in it a circumferential groove 68. Fastened to the web 36 of the pump structure, by means of bolts 69 and 70, is a projecting arm 71, extending up to form a bearing for the primary driving-shaft 52. Fastened to the projecting arm 71 is a lever 72, consisting of a ring large enough to allow the ring 66 to pass through it and terminating in the upper end in a handle and in the lower end in a yoke straddling the projecting arm 71 and fulcrumed thereto by means of a bolt 73. Fastened to the ring of the lever and on opposite sides are the two pins 74, on which are mounted rollers 75, fitting in the groove 68 of the ring 66. For convenience I have shown the primary driving-shaft 52 as broken across the keyway 65, said keyway 65 being of a sufficient length to allow the key 64, which is fastened to the sleeve 56, to slide back and forth in it to the extent permitted by the limits to the motions of the sleeve, as hereinafter described. By moving the lever 72 the pin 74, carrying the roller 75, working in the groove 68 of the ring 66, will cause the sleeve 56 to slide back and forth on the primary driving-shaft 52, and the spiral grooves 58 and 61, engaging the rollers 59 and 62, respectively, mounted on the pins 57 and 60, will impart rotary movement to the bush 54 and crank-shaft 53 around their respective centers, the relative adjustments of said bush and said shaft being dependent upon the pitch of their respective spiral grooves 58 and 61. In order to prevent the bush 54 from slipping longitudinally in its bearing in the hub 55 and at the same time allow it to turn freely in said bearing, a collar 113 is secured by screws 114 on said bush and bears against the outer face of the hub, and a shoulder 115 is formed on the inner end of the bush and bears against the inner face of the hub 55. Furthermore, it is evident that the crank-shaft 53 is prevented from moving longitudinally in the eccentric bore of the bush 54 by the pin 60, which bears against the outer end of said bush, and the shoulder 116 of the crank-shaft, which bears against the inner end of said bush.

Referring now to Fig. 6 and the diagram in Fig. 13, it will readily be seen that if the relative pitches of the spiral grooves 58 and 61 be such as to cause the bush 54 to be rotatably adjusted around its axial line *a a'* at one-half the angular rate and in the opposite direction referred to a fixed diameter of the sleeve 56 the shaft 53 is rotatably adjusted around its axial line *b b'* and referred to the line connecting the center of the bush 54 to the center of the shaft 53, the crank-pin may be adjusted in such a way that its center will always be on the straight line *x x'*, varying from the maximum position represented by the full-line circle through all positions on the same side of the center O, through the center O, and through all positions to an equal maximum one on the opposite side of the center O. As the outer surface of the bush 54 and the sleeve 56 are concentric, the roller 59, operating in the spiral groove 58, has no tendency to slide on the pin 57; but since the shaft 53 is not concentric with the sleeve 56 the roller 62, being prevented from sliding radially in its groove 61 by confining-flanges, must be capable of sliding on the said pin 60, for when the shaft 53 is rotatably adjusted in the eccentric bore of the bush 54 the point of the shaft 53 at which the pin 60 enters it is at times closer to the sleeve 56 and at times farther away. It is, furthermore, evident that the edges of the spiral groove 58 will always be parallel to radial lines with respect to the sleeve 56, whereas the edges of the spiral groove 61 are not always parallel to radial lines, since the pin 60 is not always radial with reference to the sleeve 56, the amount that it is not radial being dependent on the position of the shaft 53 in its rotary adjustment. The edges of the groove 61 have a twist which is zero at one end of the groove and varies up to the other end of the groove, when it again becomes zero, or, in other words, the edges become parallel to radial lines. With the position of the pin 60 located with reference to the shaft 53, as shown in the drawings, the maximum amount of non-radiality of the pin 60 with reference to the sleeve 56 occurs when the crank-pin is adjusted to the axis *a a'* and equals the maximum eccentricity of the crank-pin with reference to the axis *a a'*. Furthermore, in order to permit the outer flange of the roller 59 to pass under the adjusting-ring 66 a small shallow slot 120 is cut in the inner circumference of the said ring where it comes directly over the spiral groove, allowing the flange of the roller to clear the ring, and in order to allow the outer flange of the roller 62 to also clear the adjusting-ring the said adjusting-ring also has a similar slot cut in it where it passes directly over the said spiral groove 61, the latter slot being deepened for a sufficient width and to a depth equal to the eccentricity of the crank-shaft 53 with respect to the axial line *a a'* in order to allow the said pin 60 to pass under the said adjusting-ring 66 when it is moved along in the spiral groove, and in such movement is caused to project an amount at this point equal to the said eccentricity. At the two points, practically one-fourth the length from either end of the spiral groove 61, the pin 60 will project beyond the sleeve 56 an amount equal to double the said eccentricity. Said spiral grooves then being made of such a pitch as to cause the shaft 53 and the bush 54 to be rotatably adjusted around their respective axes at their proper relative rates, it is readily seen that said shaft and said bush may be adjusted while they are revolving under the action of the primary driving-shaft 52, to which they are connected through their respective pins, rollers, and spiral grooves in the sleeve 56, since if in Fig. 1 the lever 72 be moved from the right toward the left the sleeve 56 will also move from right to left, and in so moving will push the pins and rollers in their respective grooves around in opposite directions.

In Fig. 13 the full lines represent the first relative positions of the crank-pin 42, shaft 53, and bush 54, while the dotted lines represent four separate relative positions of the several parts, the single-dotted lines indicating the first position, the double-dotted lines the second position, the treble-dotted lines the third position, and the quadruple-dotted lines the fourth position, from which it is evident that the angular displacement of the shaft 53 around its central line *b b'*, and referred to the line joining the center of the bush 54 to the center of the shaft 53 of twice the angular displacement of the bush 54 around its central line *a a'* and referred to a fixed diameter of the sleeve 56, will preserve the same angular relation of the crank-pin 42 on the shaft 53 with respect to the sleeve 56. Furthermore, it will be seen that the length of stroke of the pistons 43, 44, and 45 may be varied from maximum to *nil* by rotating the shaft 53 around its central line *b b'* through one hundred and eighty degrees, and during such movement to obviate any angular displacements of the crank-pin

42 with respect to the sleeve 56 at intermediate points the said crank-pin 42 must move radially from the maximum to the position where the stroke is *nil*, which result is effected, as hereinbefore indicated, by rotating the bush 54 at the proper rate of speed in the opposite direction with respect to the rotation of the shaft 53.

The shaft 53 is provided with a hole extending from end to end on the line c c', passing through the center of the crank-pin, in which hole is a rod 73, one end of which terminates in a square shoe 77 and the other end being provided with a square shoe 78, fitted thereon. One of the valve-crank disks, as 50, is provided with a diametrical slot 79 of the same width as the shoe 77 and of sufficient length to permit said shoe to slide therein from its maximum upper position to its maximum lower position, said disk 50 being maintained in engagement with the shoe 77 by the connecting-rods 117. A disk 80 is secured to the end of the shaft 52 by means of a suitable key 81, in which disk is formed a diametrical slot 82, parallel to the slot 79 in the disk 50, in which slot 82 the shoe 78 is fitted and adapted to slide. The shaft 52 projects through the boss 63 a sufficient distance when the sleeve 56 is at its innermost position, as shown in Fig. 1, to prevent the disk 80 from contact therewith. It will be readily seen from Figs. 1, 8, 9, 10, 11, and 13 that since the crank-pin 42 is caused to move in a straight line with reference to a fixed diameter of the sleeve 56, said straight line passing through the axial line a a', if the slot 82 in the disk 80 be parallel to this straight line the shoe 78 on the end of the rod 76 will move up and down in the slot 82 as the crank-pin is adjusted, and that consequently the shoe 77, moving in the slot 79 in the valve-crank disk 50, will cause said valve-disk to always remain in a fixed position with reference to the sleeve 56, and that therefore the valve-crank 49, carried by said disk, will always maintain its same position with reference to the sleeve 56, and the cycle of motions of the pistons and valves will therefore also be constant. It will be seen that there is no torsional effect on the shaft 76 or the shoe 77, which is the sole means for driving the crank-disk 50, except when said shaft 76 is adjusted to a position concentric with the axis of rotation, which is the case when the crank-pin is adjusted to its position of no stroke. Assuming the shaft 52 to be rotating in the direction of the arrow in Fig. 2, I have shown the valve-crank 49 as ninety degrees in advance of the pump-crank 42, and therefore as the piston 39 moves down in its cylinder 21 the piston-valve 46 will move down in its valve-chamber 27; but since the valve-crank and the pump-crank must rotate at the same speed and the valve-crank pin being ninety degrees in advance of the pump-crank pin it is evident that the piston-valve 46 will have moved down and allowed the port 31 to communicate with the cylinder 21 and will have returned to its initial position (shown in Fig. 1) just as the pump-crank pin 42 reached its lower dead-center, and that as the pump-crank continues its rotation from the lower dead-center to the upper the piston-valve 46 will move up in the valve-chamber 27, allowing the port 30 to communicate with the cylinder 21, and that the said valve 46 will have again returned to its initial position (shown in Fig. 1) just as the crank-pin 42 reached its upper dead-center from which it started. It is therefore evident that as the pump-crank pin 42 revolves, drawing the piston 39 down in the cylinder 21, any fluid which might be in the port 31 will be drawn into the cylinder 21 until the piston 39 reaches the lower limit of its stroke, at which same time the piston-valve 46 will have returned to its initial position and that on the further rotation of the crank the fluid which had passed from the port 31 into the cylinder 21 will be forced out through the port 30 until the piston 39 reaches the upper limit of its stroke, at which time the piston-valve will have again returned to its initial position and shut off the port 30, and similarly for all the other cylinders, pistons, coöperating valves, &c., of the pump. It is furthermore evident that the piston-valves will always remain constant in this cycle of operations and that as the crank-pin 42 is adjusted and passes through the axial line a a' to the opposite side thereof, the piston-valves still continuing through a constant cycle of operations, the pump-pistons will now be moving toward the center when the piston-valves are moving away from the center, and vice versa, thereby reversing the ports 30 and 31, the port 30 now becoming the suction-port and the port 31 the pressure-port and the other cylinders and ports following a similar cycle of operations and the outer ports being connected together by the circular groove 37 and the inner ports by the circular groove 38, the said groove 37 will have now become the suction-groove and the inner groove 38 the pressure-groove.

Supposing then the shaft 52 to be revolved in the direction shown by the arrow in Fig. 2 and the crank-pin to have its maximum positive adjustment, as shown in Fig. 1, and the groove 38 to be supplied with the fluid to pass away, the pistons 39, 40, and 41 would suck in fluid through the ports 31, 33, and 35 while they were moving through their inward strokes and would force this fluid out through the ports 30, 32, and 34 and into the groove 37 while they were making their outward strokes, and therefore cause the structure, as described, to act as a pump, fluid being drawn into one half of the cylinders while fluid is being forced out of the other half through the suction and exhaust or pressure ports and grooves, and in order to cause said fluid to be circulated in a closed circuit and constitute a fluid or liquid connection between the driving element of a power-transmitting device connected to a prime mover and the driven element thereof I provide for the utilization of the delivery from the pump as a means for operating a motor-shaft independently movable with respect to the pump-shaft and connected to the driven part of the device, so that the connection between the pump and said motor may be varied in such a way as to vary the relative speeds of the two elements of the transmitting device, and I preferably effect this object by means of a motor here shown as similar in all respects to the pump and on the right-hand side of the pump structure in Fig. 1. In Fig. 1, however, I have shown the motor only partly in section in order to give on the same drawing an exterior view of the adjusting lever, ring, sleeve, grooves, rollers, &c., thus permitting the disposition of these parts to be more readily understood, the sleeve on the motor side, however, having been shortened up for convenience in the drawing. All of the parts of the motor are designated by numerals similar to their duplicate parts in the pump, the numerals in the motor being designated by an accent—as, for example, the crank-pin of the pump is designated by the numeral 42 and the crank-pin of the motor by the numeral 42′, and so on for all the parts. The face of the web 36 of the pump structure fits the face of the web 36′ of the motor structure, and they are firmly bolted together by the bolts 83, thus joining together the outer circular channels or grooves 37 and 37′ and the inner channels 38 and 38′, and thus providing a closed fluid-circuit between the pump and motor. Mounted on top of the webs 36 and 36′ is a supply-chamber 84, said supply-chamber 84 being connected to the channels 37 37′ and 38 38′, respectively, through the pipes 85 and 86. This supply-chamber is bored to receive a piston-valve 87, composed of a stem connecting two pistons 88 and 89 and adapted to move back and forth in the said supply-chamber, but which is limited in its extent of motion by the stops 90 and 91, formed on the inner ends of the plugs 92 and 93 closing the bore of said supply-chamber 84. On the upper side of the supply-chamber are formed channels 94 and 95, and mounted on top of the supply-chamber is a reservoir 96, connected to the supply-chamber by means of a pipe 97, connected to the port 98. Mounted on top of the reservoir 96 is a pipe 99, which serves as an air-vent for said reservoir.

Referring to Figs. 2 and 5, it is seen that I have covered the end of the pump valve-chamber 29 with a cap 100, fastened to said chamber by screws 101. Connected to this cap 100 is a pipe 102, which connects the outer end of the valve-chamber 29 with the reservoir 96 and is provided with a check-valve 103, which permits fluid to pass from the outer end of the valve-chamber 29 to the reservoir 96, but does not allow the fluid to pass in the opposite direction from the reservoir to the valve-chamber. Inclosing the pump side of the gear is a shell or casing 104, extending to the junction between the pump and motor structures and provided with a slot 105, in which the lever 72 plays. A small part of this casing is cut away at the top to allow the supply-chamber 84 to be fastened to the web of the pump structure by means of the screws 106. The motor side of the gear is similarly inclosed by a shell or casing 104′, having a slot 105′, in which the lever 72′ plays. Connected to the cap 100 is a pipe 107, which passes to a point near the bottom of the casing, and this pipe 107 is provided with a check-valve 108, which allows fluid to pass from the interior of the casing up through the cap 100 into the valve-chamber 29, but does not allow the fluid to pass in the opposite direction.

The pump and motor cylinders, the connecting ports and channels, and the reservoir are intended to be supplied with fluid, preferably oil or water, in order to provide the fluid connection heretofore referred to, and the supply-chamber 84, with its ports and passages, and the valve 87 serve to keep the proper amount of fluid in the said fluid connection, any deficit arising, due to leakage, being made up by fluid in the reservoir 96 passing down through the pipe 97, the port 98, and into the suction-channel of the gear, and to accomplish this the said piston-valve 87 automatically acts in the supply-chamber 84 in such a way as to keep the reservoir 96 always connected to the suction-channel of the gear, no matter which channel happens to be the suction one, and to keep the pressure-channel always cut off from the reservoir 96, no matter which channel happens to be the pressure one. To accomplish such automatic action of the valve 87, the distance between the two piston-heads 88 and 89 and the length of the stops 90 and 91 on the plugs 92 and 93, respectively, are such that when one head—say 88—of the valve 87 covers the inner end of the channel 94 the other head 89 of the valve 87 will rest in the position shown, thus allowing fluid to pass from the reservoir 96 through the pipe 97 and the port 98 into the supply-chamber 84 between the heads 88 and 89 of the piston-valve 87 and from there through the channel 95 into the outer right-hand end (in Fig. 1) of the supply-chamber, and from there through the pipe 86 into the channels 38′ and 38, should there be any deficit of fluids in said channels, while the fluid which is under pressure in the channels 37 and 37′, acting through the pipe 85 and in the outer left-hand end (in Fig. 1) of the supply-chamber 84, will press against the outer end of the head 88 of the piston-valve 87 and will keep said valve forced against the stop 91 of the plug 93, which in turn will cause the head 88 to close the inner end of the channel 94, which, as is readily seen, will prevent any direct communication between the pressure-channels 37 and 37′ and the reservoir 96. It will thus be seen that the piston-valve 87 normally closes the pressure or delivery channel from the reservoir 96 and normally opens the suction-channel thereof to said reservoir. Similarly, it will be seen that should the pressure on the head 89 of the piston-valve 87 be greater than the pressure on the head 88 said piston-valve will be forced over against the projection 90 of the plug 92, which will permit the channels 37 and 37′ to communicate, through the pipe 85, the channel 94, the port 98, and the pipe 97, with the reservoir 96, but will shut off communication between the channels 38 and 38′ and said reservoir 96. Such an automatic change, however, in the position of the valve 87 can only occur when the channels 37 37′ and 38 38′ change functions, and thus this change in the position of the piston-valve 87 automatically connects the reservoir 96 with the suction-channels of the gear.

It should be observed that the channels 94 and 95 are made slightly less in cross-sectional area than the pipes 85 and 86, so that the pressure of the fluid passing through the pipes 85 and 86 at the proper times will accumulate behind that piston-head which is in contact with its stop, and thus readily effect the automatic shifting of the piston-valve 87 from one side to the other. It is furthermore evident that should any leakage occur around the pistons of the pump and motor or their respective piston-valves such leakage will finally settle to the lower portion of the inclosing casings, and I have provided for returning this fluid to the reservoir and from this to the fluid connection by means of the cap 100, fitting over the outer end of the valve-chamber 29, and which, as previously described, has connected to it the pipe 107 and the pipe 102, the former having a check-valve allowing the fluid to pass from the interior of the casing into the valve-chamber 29 and the latter having a check-valve in it allowing the fluid to pass from the valve-chamber 29 to the reservoir 96, and said outer end of the valve-chamber 29, with the piston-valve 48 reciprocating therein, tends to cause any fluid in the bottom of said casing to be sucked up into the valve-chamber and forced from there up into the reservoir 96, and any air being sucked up is allowed to pass out of the reservoir through the air-vent 99. In order to permit any fluid which has leaked in the motor side to pass to the pump side of the casing, I having provided the small passage 109, which is drilled through the webs 36 and 36′ and the flanges of the projecting arms 71 and 71′, near the bottom of the casing, as shown in Fig. 2, and in order to permit fluid leaking in the crank-chambers of the gear to pass out into the casings I have provided the passages 111, drilled slightly above the bottom of the crank-chamber 110, to insure the retention of a small amount of fluid in the bottom of the crank-chamber, so that it may be thrown around by the valve-disks, and thereby lubricate the working parts situated therein.

The operation of the device is as follows: Suppose the parts to be in the positions shown in Fig. 1, where the crank-pin 42 of the pump is at its point of maximum throw, the piston 39 at its upper dead-center in its cylinder 21, and the other pistons of the pump occupying relative positions corresponding with their angular displacement around the crank-pin, and the corresponding crank-pin 42′ of the motor being at its point of maximum throw and at its lower dead-center and the other pistons of the motor being in their corresponding relative positions around the crank-pin 42′. The cylinders, channels, valve-chambers, ports, &c., of both the pump and motor having been supplied with oil or water and a reserve amount being supplied to the reservoir 96, the pump crank-pin is caused to rotate through the medium of the primary driving shaft 52, supposed to be connected to some prime mover, by which operation the pistons are caused to reciprocate in the pump-cylinders as the said crank-pin rotates around the central axial line *a a′*, thus acting upon the fluid in the cylinders to force the same through the respective ports 24, 25, and 26 into the valve-chambers 27, 28, and 29, respectively, and from said valve-chambers through the ports 30, 32, and 34 into the channel 37 and to suck fluid from the channel 38 through the ports 31, 33, and 35 into the valve-chambers 27, 28, and 29, respectively, and from said valve-chambers through the ports 24, 25, and 26 into the cylinders 21, 22, and 23, respectively. As the direction of rotation of the pump-crank is supposed to be fixed, the relative angular position of the valve crank-pin with respect to the pump crank-pin will determine which of the circular channels is the pressure one and which is the suction one, the outer circular channel being the pressure-channel and the inner circular channel the suction-channel when the pump-valve crank-pin is ninety degrees in advance of the pump crank-pin and the outer channel being the suction-channel and the inner one the pressure-channel when the valve crank-pin is ninety degrees behind the pump crank-pin. It is furthermore seen that both the position of the pressure-channel, whether it be the inner or outer one, and the position of the motor-valve crank-pin will determine the direction of rotation of the driven shaft, since if the outer channel be the pressure-channel the motor-crank will revolve in such a direction that the motor-valve crank-pin is ninety degrees behind the motor crank-pin, whereas if the inner channel is the pressure-channel the motor-crank will revolve in such a direction that the motor-valve crank-pin is ninety degrees in advance of the motor crank-pin, and since it is possible in assembling the device to put the motor-valve crank-disks in such a position as to cause the motor crank-pin to revolve in either direction when either channel is the pressure-channel, and since it is also possible in assembling the device to put the pump crank-disks in so that either channel will be the pressure or suction channel, the normal relative directions of rotations of the driving and driven shafts when the adjusting-sleeves are in their extreme inner positions will be determined by the relative positions of the pump and motor valve crank-pins, respectively. In Fig. 1 I have shown the device as so assembled that when the adjusting-sleeves are both at their extreme inner positions the motor operates to drive the driven shaft in the opposite direction from the direction of rotation of the driving-shaft, and, furthermore, as heretofore mentioned, the pump parts are so assembled that when the direction of rotation of the driving-shaft is as is shown by the arrow in Fig. 2 and the adjusting-sleeve is at its inner extreme position the outer channels 37 37′ will be the pressure-channels and the inner channels 38 38′ will be the suction-channels. It is now evident that if the number of cylinders, the bore of the cylinders, and the stroke of the cranks are the same in both the motor and the pump, and the parts are in the relative positions shown in Fig. 1, and the driving-shaft be rotated in either direction the driven shaft will be revolved by the motor in the opposite direction to that of the driving-shaft and at the same speed, since the motor will receive fluid under pressure and return it back to the pump without pressure as fast as the pump furnishes the fluid under pressure to the motor and receives it without pressure from the motor. It is furthermore evident that if the stroke of the pump be decreased anywhere between its positive maximum and zero and the stroke of the motor remains the same the motor, and consequently the driven shaft, will revolve at a decreased speed, the amount of decrease in the speed being exactly proportional to the decrease in length of stroke in the pump, since the capacity of the motor remaining the same the pump will have to make a proportionately larger number of strokes of decreased length in order to supply the motor with the decreased number of strokes of the original length, and it is furthermore evident that since as the length of stroke of the pump is decreased a uniform torque on the driving-shaft will be able to force the fluid over to the motor at a proportionately-increased pressure, and since the proportionately-increased pressure acting on the original length of stroke of the motor will be able to correspondingly increase the torque of said motor that the torque on the driven shaft will increase in a ratio corresponding with its decrease in speed. It is furthermore evident that when the pump crank-pin is adjusted to its zero position, or where it has no stroke, that no fluid will be furnished to the motor and that, therefore, the motor-shaft will not revolve, and consequently the driven shaft will not revolve. It is again evident that if the adjustment of the pump-crank be still further continued, so that the crank-pin passes beyond its zero position to a position on the side of the axial line opposite to that which it formerly occupied, that the pump-valve crank-pin will now be ninety degrees behind the pump-crank instead of ninety degrees in advance, as it first was, and that, therefore, the channels which were formerly the pressure-channels will become the suction-channels, and the channels which were formerly the suction-channels will become the pressure-channels, and consequently the motor will revolve in the opposite direction, thereby causing the driven shaft to revolve in the opposite direction, and the speed and torque of the driven shaft will depend on the amount that the pump crank-pin is adjusted beyond its center or zero position. It is furthermore evident that since the adjusting-sleeve may be moved through all positions between its extreme inner and outer positions that the pump crank-pin may be caused to assume all possible lengths of stroke between a positive maximum represented by its limit of adjustment on one side of its zero position to a negative maximum represented by its extreme limit of motion on the opposite side of its zero position, provided the adjusting-sleeve is of such a length and the spiral grooves of such a pitch and length as to allow for such adjustment, said grooves needing for such adjustment from a positive maximum to a negative maximum to be of such a length as to cover one hundred and eighty degrees each of the circumference of the adjusting-sleeve, and therefore, to prevent the spiral grooves from running into each other or from cutting the sleeve in two, one groove is placed in a position longitudinally in advance of the other.

The above description of the device is based on the supposition that the adjustment of the motor crank-pin has been kept constant and to its maximum position, as shown in Fig. 1. In this position of the adjustment of the motor crank-pin the motor exerts its maximum torque.

Now suppose the driven device while requiring some predetermined speed also requires very little torque. It will be seen that by adjusting the crank-pin of the pump nearer to its position of no stroke than would be required to give the desired speed to the driven device when the crank-pin of the motor is at its maximum adjustment from the center line $a\,a'$ we may by also adjusting the motor crank-pin nearer to the center line or axis $a\ a'$ by its device similar to that employed for adjusting the pump crank-pin obtain the desired speed and torque and at the same time obviate any excessive travel of the pistons in their respective cylinders. It is also apparent that by having the crank-pin of the pump and the crank-pin of the motor both adjustable it is possible to secure a greater range of velocity ratio between the motor and the pump, and consequently between the driven device and the prime mover, than if they were not both adjustable. It is furthermore seen that by having both the pump and motor crank-pins adjustable either side of the device may be used as the pump side and either side as the motor side.

It is also possible to use my device as a brake, since with a practically non-compressible fluid connection, if the pump crank-pin is adjusted to zero, it is impossible for the motor crank-pin, and therefore for the driven shaft, to revolve, since in the driven device any revolving would revolve the motor crank-pin, which would create a pressure in the cylinders of the motor; but since the fluid so received into the fluid-circuit under pressure would have no opportunity for exit it would be impossible for the crank-pin of the motor to revolve or therefore for the driven device to revolve, and it is therefore also evident that by the adjustment of the pump crank-pin it is possible to allow the motor to revolve at any speed that is desired. It is also evident that if the primary driving-shaft be caused to cease revolving and the motor crank-pin be adjusted to its zero position that the motor crank-pin, and consequently the driven shaft, may be allowed to revolve freely at any speed whatsoever.

It is furthermore evident that if it is not desired to adjust the motor crank-pin that the crank, eccentric-bush, adjusting-sleeve, lever, &c., of the motor may be replaced by a crank of the usual form having a pin projecting from the crank-pin into the slot in the motor-valve disk to drive the motor-valves, and that such a crank-shaft in said motor may be extended beyond the casing to connect to any driven device or shaft.

From the foregoing description it will be seen that by my invention I provide means for varying the relative speeds of the driven member of a power-transmitting device with respect to the driving member thereof which is susceptible of wide application and in which the velocity ratio can be readily decreased from a maximum to *nil*, and vice versa, by infinitely small amounts and the direction of rotation of the driven device reversed and its velocity ratio in such reverse direction increased by infinitely small amounts from *nil* to maximum, and vice versa. Furthermore, my construction with such wide range of variations in the relative speeds of the prime mover or driving device and the driven device is such that the various changes of speed from a maximum through reversal to a maximum in the reverse direction may be effected by the simplest movements of the controlling device, for it is obvious that such controlling device need be moved in one direction only to effect the various changes incident to the change from a predetermined positive value to a predetermined negative value.

While I have shown three cylinders in the pump and three in the motor, it will be understood that a greater or less number may be used, if desired, and that the number of cylinders of the pump may be greater or less than the number of cylinders of the motor without departing from the scope of my invention, and it is to be further understood that the normal capacity of the pump or motor cylinders may be either the same or different and that the individual cylinders may be of the same or different normal capacities, according to the nature of the device to which my invention is applied.

It will of course be understood that wherever necessary the joints will be suitably packed by any of the means well known to the art.

I claim as my invention—

1. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor, substantially as described.

2. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, relatively movable valves controlling the passage of fluid between said pump and motor, and means for altering the relative capacities of the pump and motor, substantially as described.

3. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor and adapted to change the direction of rotation of the motor, substantially as described.

4. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank

acting as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, relatively movable valves controlling the passage of fluid between said pump and motor, and means for altering the relative capacities of the pump and motor and adapted to change the direction of rotation of the motor, substantially as described.

5. A variable-speed gear comprising a driving element, consisting of a multiple stationary radial cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary radial cylinder-motor, the crank shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, and means for varying the capacity of the pump, substantially as described.

6. A variable-speed gear comprising a driving element, consisting of a multiple stationary radial cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary radial cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, and means for varying the capacity of the motor, substantially as described.

7. A variable-speed gear comprising a driving element, consisting of a multiple stationary radial cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary radial cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, and means for varying the relative capacities of the pump and motor, substantially as described.

8. A variable-speed gear comprising a driving element, consisting of a multiple stationary radial cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary radial cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, and means for varying the capacity of both the pump and motor, substantially as described.

9. A variable-speed gear comprising a driving element, consisting of multiple stationary radial cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary radial cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor, substantially as described.

10. A variable-speed gear comprising a driving element, consisting of multiple stationary radial cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary radial cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor and adapted to change the direction of rotation of the motor, substantially as described.

11. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the capacity of the pump, substantially as described.

12. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the capacity of the motor, substantially as described.

13. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the relative capacities of the pump and motor, substantially as described.

14. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the capacity of both the pump and motor, substantially as described.

15. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank act-

ing as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for altering the relative capacities of the pump and motor, substantially as described.

16. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a member slidable with reference to the bush and crank-shaft and connected thereto to cause the bush and crank-pin to be adjusted with reference to each other as said member is moved, substantially as described.

17. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, reciprocating valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the capacity of the pump, substantially as described.

18. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, reciprocating valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the capacity of the motor, substantially as described.

19. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, reciprocating valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the relative capacities of the pump and motor, substantially as described.

20. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, reciprocating valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for varying the capacity of both the pump and motor, substantially as described.

21. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, reciprocating valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for altering the relative capacities of the pump and motor, substantially as described.

22. A variable-speed gear comprising a driving element, consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a pump, a driven element consisting of multiple stationary cylinders, coöperating pistons and a crank acting as a motor, a fluid connection between the pump and motor, reciprocating valves interposed between the pump and motor and by which a fluid may pass to connect said pump and motor, and means for altering the relative capacities of the pump and motor and adapted to change the direction of rotation of the motor, substantially as described.

23. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, and means for adjusting either of said crank-shafts, whereby the relative capacities of the pump and motor may be varied, substantially as described.

24. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its center of rotation and connected to the pistons, a driven element consisting of a stationary cylinder-motor having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its axis of rotation, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor, substantially as described.

25. A variable-speed gear comprising a driv-

ing element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its center of rotation and connected to the pistons, a driven element consisting of a stationary cylinder-motor having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its axis of rotation, a fluid connection between the pump and motor, and means for altering the eccentricity of either crank-pin, substantially as described.

26. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its center of rotation and connected to the pistons, a driven element consisting of a stationary cylinder-motor having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its axis of rotation, a fluid connection between the pump and motor, and means for altering the eccentricity of the crank-pin of the pump, substantially as described.

27. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its center of rotation and connected to the pistons, a driven element consisting of a stationary cylinder-motor having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its axis of rotation, a fluid connection between the pump and motor, and means for altering the eccentricity of the crank-pin of the motor, substantially as described.

28. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its center of rotation and connected to the pistons, a driven element consisting of a stationary cylinder-motor having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its axis of rotation, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor while either crank-pin is in motion, substantially as described.

29. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its center of rotation and connected to the pistons, a driven element consisting of a stationary cylinder-motor having a plurality of cylinders, coöperating pistons in said cylinders, and a crank-pin eccentrically disposed with reference to its axis of rotation, a fluid connection between the pump and motor, and means for altering the relative capacities of the pump and motor while either crank-pin is in motion, and adapted to change the direction of rotation of the motor, substantially as described.

30. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, and means for varying the relative capacities of the pump and the motor from a maximum through zero, substantially as described.

31. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor, means for automatically returning to the fluid connection any fluid that has leaked therefrom, and means for varying the relative capacities of the pump and motor, substantially as described.

32. A variable-speed gear comprising a driving element, consisting of a multiple stationary cylinder-pump, the crank-shaft of which is adapted to be connected to a driving device, a driven element consisting of a multiple stationary cylinder-motor, the crank-shaft of which is adapted to be connected to a driven device, a fluid connection between the pump and motor and having pressure and suction sides thereof, a reserve-fluid reservoir, means for connecting said fluid in said reservoir to the suction side of said fluid connection, and means for altering the relative capacities of the pump and motor, substantially as described.

33. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a crank-shaft adapted to be connected to a driving device, a driven element consisting of a stationary cylinder-motor and having a crank-shaft adapted to be connected to a driven device, a fluid connection having pressure and suction sides between the pump and motor, means for varying the relative capacities of the pump and motor, and adapted to change the direction of rotation of the motor, a reserve-fluid reservoir, and means for automatically maintaining communication between the suction side of said fluid connection and said reserve-fluid reservoir, substantially as described

34. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a crank-shaft adapted to be connected to a driving device, a driven element consisting of a stationary cylinder-motor and having a crank-shaft adapted to be connected to a driven device, a fluid connection having pressure and suction sides between the pump and motor, means for varying the relative capacities of the pump and motor and adapted to change the direction of rotation of the motor, a reserve-fluid reservoir, means for automatically maintaining communication between the suction side of said fluid connection and said reserve-fluid reservoir, and means for automatically returning to the fluid connection any leakage therefrom, substantially as described.

35. A variable-speed gear comprising a driving element consisting of a pump having a plurality of cylinders, coöperating pistons in said cylinders, and a crank to which the pistons are connected, a driven element similarly constructed, a fluid connection between the pump and motor, valves for controlling the passage of fluid between the pump and motor, means for causing one of said valves to operate as a pump, means for causing any fluid leaking from said fluid connection to be pumped back thereto by the operation of said valve as a pump, and means for varying the relative capacities of the pump and motor, substantially as described.

36. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons therein, a crank-pin to which said pistons are connected, a crank-shaft eccentrically disposed with reference to the axis around which it is adapted to revolve and on which said crank-pin is mounted, a bush the outer peripheral surface of which is concentric with the axis around which it is adapted to revolve and having the said crank-shaft eccentrically mounted therein, means for simultaneously adjusting said crank-shaft and said bush in opposite directions and for causing the eccentricity of said crank-pin to be thereby adjusted, a motor similarly constructed, means for enabling rotations of the pump crank-pin to cause the motor crank-pin to rotate, substantially as described.

37. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons therein, a crank-pin to which said pistons are connected, a crank-shaft eccentrically disposed with reference to the axis around which it is adapted to revolve and on which said crank-pin is eccentrically mounted, a bush the outer peripheral surface of which is concentric with the axis around which it is adapted to revolve having said crank-shaft eccentrically mounted therein, the eccentricity of said crank-shaft with respect to said bush being equal to the eccentricity of said crank-pin with respect to said crank-shaft, means for simultaneously adjusting said crank-shaft and said bush around their respective centers, means for adjusting said bush around its center in a direction opposite to the direction of adjustment of said crank-shaft and at one-half the speed of the adjustment of said crank-shaft around its center thereby causing the eccentricity of the crank-pin to be adjusted, a motor similarly constructed, means for enabling rotations of the pump crank-pin to cause the motor crank-pin to rotate, substantially as described.

38. A variable-speed gear comprising a driving element, consisting of a stationary cylinder-pump having a plurality of cylinders, coöperating pistons therein, a crank-pin to which said pistons are connected, a crank-shaft eccentrically disposed with reference to the axis around which it is adapted to revolve and on which said crank-pin is eccentrically mounted, a bush the outer peripheral surface of which is concentric with the axis around which it is adapted to revolve and having the said crank-shaft eccentrically mounted therein, means for simultaneously adjusting said crank-shaft and said bush in opposite directions and for causing the eccentricity of said crank-pin to be thereby adjusted, a motor having a plurality of cylinders, coöperating pistons therein, a crank-shaft having a crank-pin eccentrically mounted thereon and to which said pistons are connected, means for enabling rotations of said pump crank-pin to cause rotations of said motor crank-pin, substantially as described.

39. A variable-speed gear comprising a stationary cylinder-pump structure, a stationary cylinder-motor structure, a web interposed between the two provided with annular passages, ports in the cylinders of the pump and motor structures, valve-chambers having ports connected with said annular passages, and valves in said chambers controlling the passage of fluid between the pump and motor structures and operating to connect one of the annular passages with the pressure-ports of the pump structure and the other with the suction-ports thereof, substantially as described.

40. A variable-speed gear comprising a driving element consisting of a pump, a coöperating crank-pin, a driven element consisting of a motor, an adjusting element having grooves or slots therein, devices coacting with said grooves or slots constructed and arranged, as said adjusting element is moved, to adjust the eccentricity of the said pin while in motion, substantially as described.

41. In a variable-speed gear, the combination with a pump or motor structure comprising cylinders and coöperating pistons therein, a rotating crank-pin to which said pistons are connected, means for adjusting said crank-pin to vary the capacity of the pump or motor,

valves governing the admission and exhaust of fluid to and from the cylinders, connections between the crank-pin and the valves for operating the latter and comprising a member movable with the crank-pin, said connections being constructed and arranged to preserve the angular relation between the valves and crank-pin when the latter is adjusted, substantially as described.

42. In a variable-speed gear, the combination with a pump or motor structure comprising cylinders and coöperating pistons therein, a rotating crank-pin, means for adjusting said crank-pin to vary the capacity of the pump or motor, reciprocating valves controlling the admission and exhaust of fluid to and from the cylinders, a disk carrying a valve-crank having a constant angular relation to the crank-pin, a slidable connection between said crank-disk and the adjustable crank-pin, said connection being constructed and arranged to preserve the constant angular relation between the said crank-pin and valve-crank, substantially as described.

43. A variable-speed gear comprising a stationary cylinder pump and motor structure, reciprocating pistons, passages between the pump and motor, valves controlling the said passages, and a single adjusting means controlling the variations of speed between the motor and pump between a maximum in one direction through zero to a maximum in the reverse direction, substantially as described.

44. A variable-speed gear, comprising a pump structure, a motor structure, passages for fluid between the two, valves controlling said passages the functions of which passages change from pressure to suction, a fluid-reservoir, means for pumping leakage to the reservoir, and a supplementary valve automatically acting to supply deficit of fluid to the suction-passage, substantially as described.

45. In a variable-speed gear, the combination with a pump and a motor having a fluid connection between them, means for collecting leakage of an auxiliary pump adapted to return to the fluid connection such leakage, substantially as described.

46. In a variable-speed gear, the combination with a pump and a motor having a fluid connection between them, of a pump automatically operating to return to the fluid connection any leakage therefrom, substantially as described.

47. In a variable-speed gear, the combination with a pump structure and a motor structure comprising cylinders and coöperating pistons, passages between the pump and motor, valves controlling the passage of fluid between the pump and motor, a fluid-reservoir for supplying fluid to the suction side of the pump, and means for causing one of the valves to act as a pump to return to the fluid connection any leakage therefrom, substantially as described.

48. In a variable speed-gear, the combination with a pump structure and a motor structure comprising cylinders and coöperating pistons, passages between the pump and motor, valve-chambers having valves controlling the passage of fluid between the pump and motor, a fluid-reservoir for supplying fluid to the suction side of the pump, and a cover for one of the valve-chambers with conduits provided with check-valves connecting the reservoir with said chamber and with leakage-space of the structure, thereby causing said valve to act as a pump to return leakage to the fluid connection, substantially as described.

49. A variable-speed gear, comprising a pump and a motor, a fluid connection between them, means for collecting leakage, a fluid-reservoir, an auxiliary pump for pumping such leakage from the fluid connection to the said reservoir, and a supplementary valve automatically acting to supply from said reservoir any deficit of fluid to the fluid connection, substantially as described.

50. The combination with a cylinder structure and a coöperating crank-pin, of means for adjusting said crank-pin while in motion to change its eccentricity, including an element movable longitudinally with respect to said crank-pin and having pin-and-slot connections therewith coacting to adjust said pin, substantially as described.

51. The combination with stationary cylinders, and coöperating pistons therein, and a rotating crank-pin to which the pistons are connected, of means comprising a pin-and-slot connection for adjusting the crank-pin to vary the capacity of the cylinders while the crank-pin is in motion, substantially as described.

52. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which the pistons are connected, of a bush in which said crank-pin is eccentrically mounted, and means comprising a pin-and-slot connection for rotating said bush with reference to said crank-pin while the crank-pin is in motion to vary the eccentricity of the crank-pin, substantially as described.

53. The combination with stationary cylinders, coöperating pistons therein, and a rotating crank-pin, of a bush having an eccentric bore, a shaft mounted in said bore on which the crank-pin is eccentrically disposed, and means comprising a pin-and-slot connection for rotating the shaft while the crank-pin is in motion to vary the eccentricity of the crank-pin, substantially as described.

54. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin, of a bush having an eccentric bore, a shaft on which the crank-pin is eccentrically disposed mounted in said bore, and means comprising a pin-and-slot connection for rotating the bush and shaft in opposite directions while the crank-pin is in motion to vary

the eccentricity of the crank-pin, substantially as described.

55. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin carried by a shaft and to which said pistons are connected, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a member slidable with reference to the bush, and a pin-and-slot connection between the bush and crank-shaft and slidable member adapted to rotate the bush as said member is moved, substantially as described.

56. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin carried by a shaft and to which said pistons are connected, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a member slidable with reference to the shaft, and a pin-and-slot connection between the crank-pin shaft and slidable member adapted to rotate the shaft as said member is moved, substantially as described.

57. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a member slidable with reference to the bush, having a pin-and-slot connection with the bush and crank-pin adapted to cause the bush and crank-pin to be adjusted in opposite directions as said member is moved, substantially as described.

58. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a sleeve having a spiral slot therein slidably mounted with reference to the bush, a pin on the bush engaging said spiral slot and a pin-and-slot connection between the crank-pin shaft and the said sleeve, substantially as described.

59. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a sleeve having two spiral slots therein slidably mounted with reference to said bush, a pin on the crank-pin shaft and on the bush respectively engaging said slots, substantially as described.

60. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a sleeve slidably mounted with reference to said bush having right and left hand spiral slots therein, a pin on the crank-pin shaft and on the bush each engaging one of said slots, substantially as described.

61. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a sleeve having right and left hand spiral slots therein slidably mounted with reference to said bush, one longitudinally in advance of the other, each extending one hundred and eighty degrees around the bush, a pin on the crank-pin shaft and on the bush each of which pins engages one of the slots, substantially as described.

62. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a sleeve having two spiral slots therein slidably mounted with reference to said bush, a pin on the crank-pin shaft and on the bush respectively engaging said slots, a grooved ring on said sleeve, and a lever having a pin engaging said groove, substantially as described.

63. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin to which said pistons are connected carried by a shaft, of a bush having an eccentric bore in which the crank-pin shaft is mounted, a bearing for the bush concentric with the axis of rotation of the crank-pin, a sleeve having two spiral slots therein slidably mounted with reference to said bush, a pin on the crank-pin shaft and on the bush respectively engaging said slots, a grooved ring on said sleeve having a spiral groove in its inner surface where it crosses either slot, substantially as described.

64. The combination with cylinders, coöperating pistons therein, and a rotating crank-shaft having an eccentrically-disposed crank-pin thereon, of a bush in which said shaft is eccentrically mounted, the outer surface of the bush being concentric with the axis around which it is adapted to revolve and the eccentricity of the crank-shaft with respect to the bush being equal to the eccentricity of the crank-pin with reference to the crank-shaft, and means comprising a pin-and-slot connection for adjusting the bush and shaft in opposite directions, substantially as described.

65. The combination with cylinders, coöperating pistons therein, and a crank-shaft hav-

ing an eccentrically-disposed crank-pin thereon, of a bush in which said shaft is eccentrically mounted, the outer surface of the bush being concentric with the axis around which it is adapted to revolve and the eccentricity of the crank-shaft with respect to the bush being equal to the eccentricity of the crank-pin with reference to the crank-shaft, and a sleeve slidably mounted with reference to the bush having a pin-and-slot connection with the shaft and bush adapted to adjusting the two said parts in opposite directions as the sleeve is moved, substantially as described.

66. The combination with cylinders, coöperating pistons therein, and a crank-shaft having an eccentrically-disposed crank-pin thereon, of a bush in which said shaft is eccentrically mounted, the outer surface of the bush being concentric with the axis around which it is adapted to revolve and the eccentricity of the crank-shaft with respect to the bush being equal to the eccentricity of the crank-pin with reference to the crank-shaft, and a sleeve slidably mounted with reference to the bush and having right and left hand spiral slots therein, pins on the bush and crank-shaft respectively engaging said slots, and means for moving the sleeve, whereby the bush and shaft are adjusted in opposite directions, substantially as described.

67. The combination with cylinders, coöperating pistons therein, and a rotating crank-pin, of a bush mounted in a bearing concentric with the axis of rotation of the crank-pin and having an eccentric bore, a crank-shaft on which the crank-pin is eccentrically disposed mounted in said bore, a sleeve slidable longitudinally with respect to the bush and having opposite spiral slots therein, a pin on the shaft having a roller slidably and rotatably mounted thereon and engaging one of the spiral slots, a pin on the bush engaging the other spiral slot, and means for moving the sleeve, substantially as described.

68. The combination with a cylinder structure, coöperating pistons therein and a crank-pin to which the pistons are connected, of means for changing the eccentricity of the crank-pin while in motion including a controlling element longitudinally movable with respect to the crank-pin, and pin-and-slot connections between said element and the crank-pin, adapted to vary the eccentricity of the crank-pin as said element is moved, substantially as described.

69. The combination with a cylinder structure, coöperating pistons therein, and a rotating crank-pin to which the pistons are connected, of a bush having an eccentric bore and rotatably mounted in a bearing concentric with the axis of rotation of the crank-pin, a shaft by which the crank-pin is carried rotatably mounted in the said eccentric bore of the bush, and means comprising a pin-and-slot connection for rotating the bush with reference to said shaft to adjust the crank-pin, substantially as described.

70. The combination with a cylinder structure having coöperating pistons therein, of valves controlling the passage of fluid to and from the cylinders, a rotating crank-pin to which the pistons are connected, means interposed between said crank-pin and valves for causing the movements of the latter, means for adjusting the crank-pin to vary its eccentricity, comprising elements having pin-and-slot connections therewith, said adjusting means and valve-actuating means comprising provision adapted to preserve the angular relation between the valves and the crank-pin as the latter is adjusted, substantially as described.

71. The combination with a stationary cylinder structure having coöperating pistons therein, of a rotating crank-pin to which the pistons are connected, valves controlling the passage of fluid to and from the cylinders, connections between the crank-pin and the valves for operating the latter, means comprising a pin-and-slot connection for adjusting the crank-pin to vary its eccentricity, said adjusting means and valve-operating means comprising provision adapted to preserve the angular relation between the valves and the crank-pin as the latter is adjusted, substantially as described.

72. The combination with a stationary cylinder structure having coöperating pistons therein, a rotating crank-pin to which the pistons are connected, valves controlling the passage of fluid to and from the cylinders, connections between the crank-pin and the valves for operating the latter, means slidably connected to the crank for adjusting the crank-pin to vary its eccentricity between a maximum in one direction through zero and a maximum in the reverse direction, said adjusting means and valve-operating means comprising provision adapted to preserve the angular relation between the valves and the crank-pin as the latter is adjusted, substantially as described.

73. The combination with a stationary cylinder structure having coöperating pistons therein, a rotating crank-pin to which the pistons are connected, valves controlling the passage of fluid to and from the cylinders, connections between the crank-pin and the valves for operating the latter, and means slidably connected to the crank for adjusting the crank-pin to vary its eccentricity between a maximum in one direction and a maximum in the reverse direction, said adjusting means and valve-operating means comprising provision adapted to preserve the angular relation between the valves and the crank-pin as the latter is adjusted, and to change the lead of the valves as the crank-pin is adjusted through zero, substantially as described.

74. The combination with a cylinder struc-

ture, coöperating pistons therein, valves for controlling the passage of fluid to and from the cylinders, and a rotating crank-shaft mounted in a bush having a bearing concentric with the axis of the cylinder structure and having a crank-pin to which the pistons are connected, of a disk having a bearing concentric with the axis of the cylinder structure, an eccentrically-disposed pin thereon connected to the valves, a groove extending diametrically of said disk, a rod passing centrally through the crank-pin having a squared end engaging said groove, and means for adjusting the crank-pin to different eccentricities, substantially as described.

75. The combination with a cylinder structure, coöperating pistons therein, valves for controlling the passage of fluid to and from the cylinders, of a hub on said cylinder structure concentric with the axial line thereof, a main shaft, a sleeve slidably mounted with reference to the hub and having a sliding connection with the said shaft, a bush rotatably mounted in the hub, a crank-shaft eccentrically mounted in the bush and having an eccentrically-disposed crank-pin to which the pistons are connected, a disk on the main shaft having a groove therein, a disk rotatably mounted in the cylinder structure having a pin eccentrically disposed thereon to which the valves are connected and provided with a groove therein, a rod passing through the crank-pin and engaging the said grooves at each end, said sleeve having a pin-and-slot connection with the bush and the crank-shaft whereby as the sleeve is moved longitudinally of the bush the latter is rotated to vary the eccentricity of the crank-pin, substantially as described.

76. The combination with a cylinder structure, coöperating pistons therein, valves for controlling the passage of fluid to and from the cylinders, of a hub on said cylinder structure concentric with the axial line thereof, a main shaft, a sleeve slidably mounted with reference to the hub and having a sliding connection with the said shaft, a bush rotatably mounted in the hub, a crank-shaft eccentrically mounted in the bush and having an eccentrically-disposed crank-pin to which the pistons are connected, a disk on the main shaft having a groove therein, a disk rotatably mounted in the cylinder structure having a pin eccentrically disposed thereon to which the valves are connected and provided with a groove therein, a rod passing through the crank-pin and engaging the said grooves at each end, and connections between the sleeve, bush and crank-pin whereby as the sleeve is moved the eccentricity of the crank-pin is varied and the angular relation between the latter and the valves is preserved, substantially as described.

77. The combination with a cylinder structure, coöperating pistons therein, and valves for controlling the passage of fluid to and from the cylinders, of a hub on said cylinder structure concentric with the axial line thereof, a main shaft, a sleeve slidably mounted with reference to the hub and having a sliding connection with the said shaft, a bush rotatably mounted in the hub, a crank-shaft eccentrically mounted in the bush and having an eccentrically-disposed crank-pin to which the pistons are connected, a disk on the main shaft having a diametrical groove therein, a disk rotatably mounted in the cylinder structure having a pin eccentrically disposed thereon to which the valves are connected and provided with a diametrical groove therein, a rod passing through the crank-pin and having squared ends engaging the said grooves at each end, and connections between the sleeve, bush and crank-pin whereby as the sleeve is moved the eccentricity of the crank-pin is varied and the angular relation between the latter and the valves is preserved, substantially as described.

78. The combination with a cylinder structure, coöperating pistons therein, valves for controlling the passage of fluid to and from the cylinders, of a hub on said cylinder structure concentric with the axial line thereof, a main shaft, a sleeve slidably mounted with reference to the hub and having a sliding connection with the said shaft, a bush rotatably mounted in the hub, a crank-shaft eccentrically mounted in the bush and having an eccentrically-disposed crank-pin to which the pistons are connected, a disk on the main shaft having a groove therein, a disk rotatably mounted in the cylinder structure having a pin eccentrically disposed thereon to which the valves are connected and provided with a diametrical groove therein, a rod passing through the crank-pin and engaging the said grooves at each end, said sleeve having a pin-and-slot connection with the bush and said crank-shaft whereby as the sleeve is moved longitudinally of the bush the latter and said shaft are rotated to vary the eccentricity of the crank-pin, substantially as described.

79. The combination with a cylinder structure, coöperating pistons therein, and valves for controlling the passage of fluid to and from the cylinders, of a hub on said cylinder structure concentric with the axial line thereof, and a main shaft, a sleeve slidably mounted with reference to the hub and having a sliding connection with the said shaft, a bush rotatably mounted in the hub, a crank-shaft eccentrically mounted in the bush and having an eccentrically-disposed crank-pin to which the pistons are connected, a disk rotatably mounted in the cylinder structure having a pin eccentrically disposed thereon to which the valves are connected and provided with a diametrical groove therein, a disk fixed to the main shaft having a diametrical groove therein, a rod passing through the crank-pin and engaging the said grooves at each end, said sleeve having spiral slots therein, pins on the crank-shaft and bush engaging said

slots whereby as the sleeve is moved longitudinally of the bush the eccentricity of the crank-pin is varied, substantially as described.

80. The combination with a cylinder structure, coöperating pistons therein, valves for controlling the passage of fluid to and from the cylinders, of a hub on said cylinder structure concentric with the axial line thereof, and a main shaft, a sleeve slidably mounted with reference to the hub and having a sliding connection with the said shaft, a bush rotatably mounted in the hub, a crank-shaft eccentrically mounted in the bush and having an eccentrically-disposed crank-pin to which the pistons are connected, a disk on the main shaft having a diametrical groove therein, a disk rotatably mounted in the cylinder structure having a pin eccentrically disposed thereon to which the valves are connected and provided with a diametrical groove therein, a rod passing through the crank-pin and having squared ends engaging the said grooves at each end, said sleeve having spiral slots therein, and pins on the bush and sleeve engaging said slots, whereby as the sleeve is moved longitudinally of the bush the eccentricity of the crank-pin is varied, substantially as described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

CHARLES M. MANLY.

Witnesses:
C. W. FOWLER,
R. T. FRAZIER.