No. 758,854. PATENTED MAY 3, 1904.

E. L. RUSSELL.

MULTIPLE CYLINDER HYDROCARBON ENGINE.

APPLICATION FILED MAY 22, 1901.

NO MODEL. 6 SHEETS—SHEET 1.

Fig. 1.

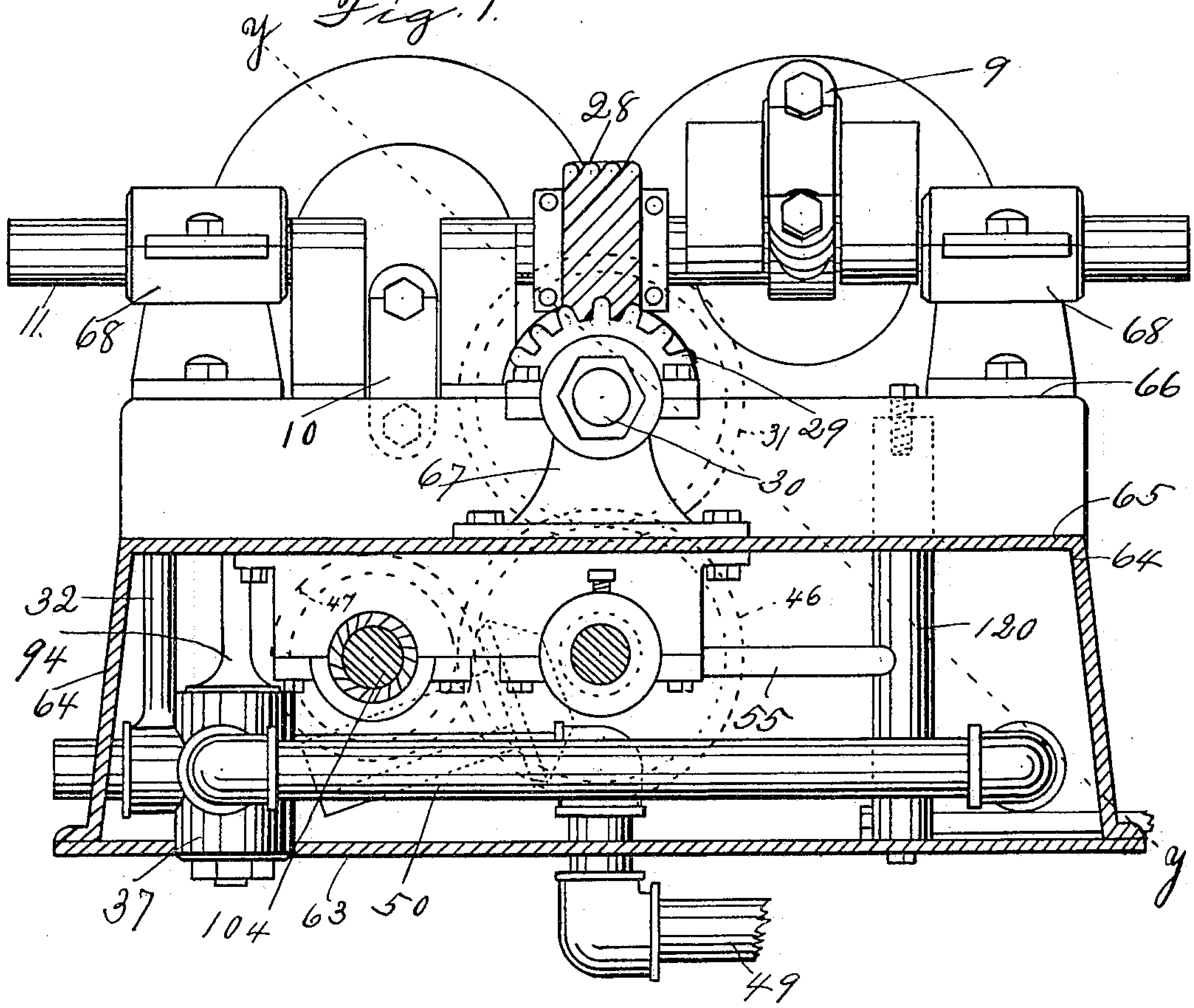
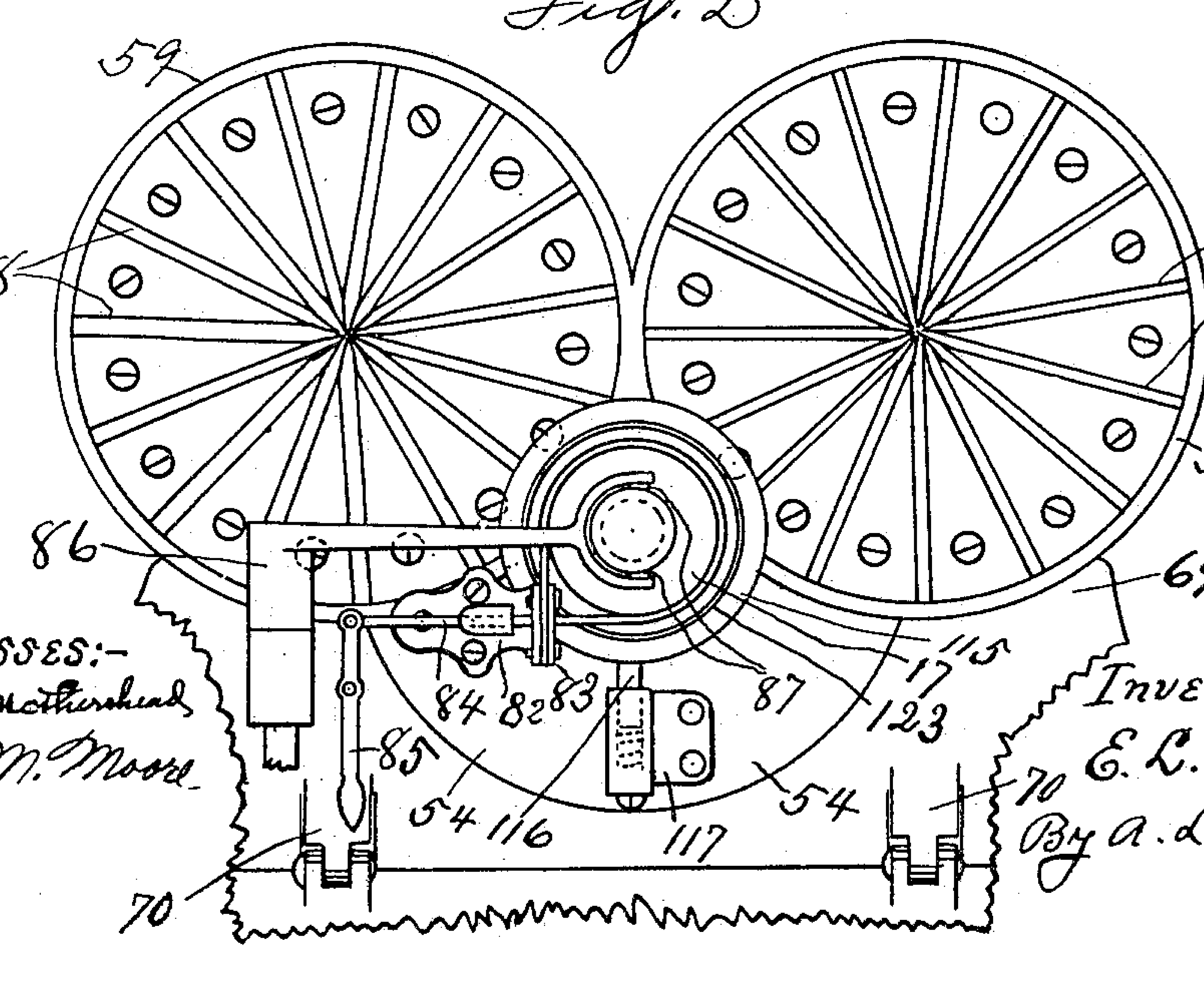


Fig. 2



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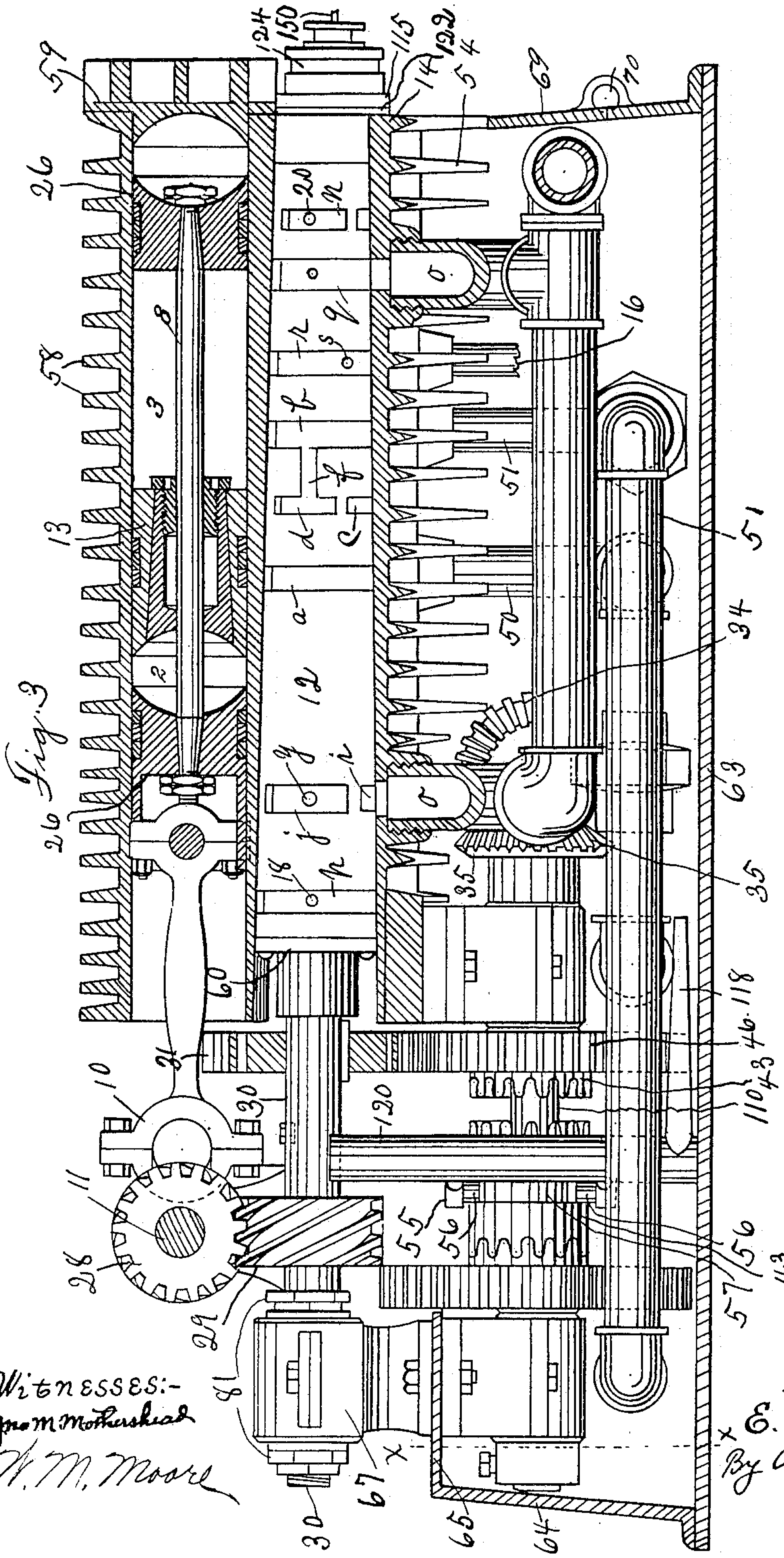

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NO MODEL. 6 SHEETS—SHEET 3.

Fig. 4

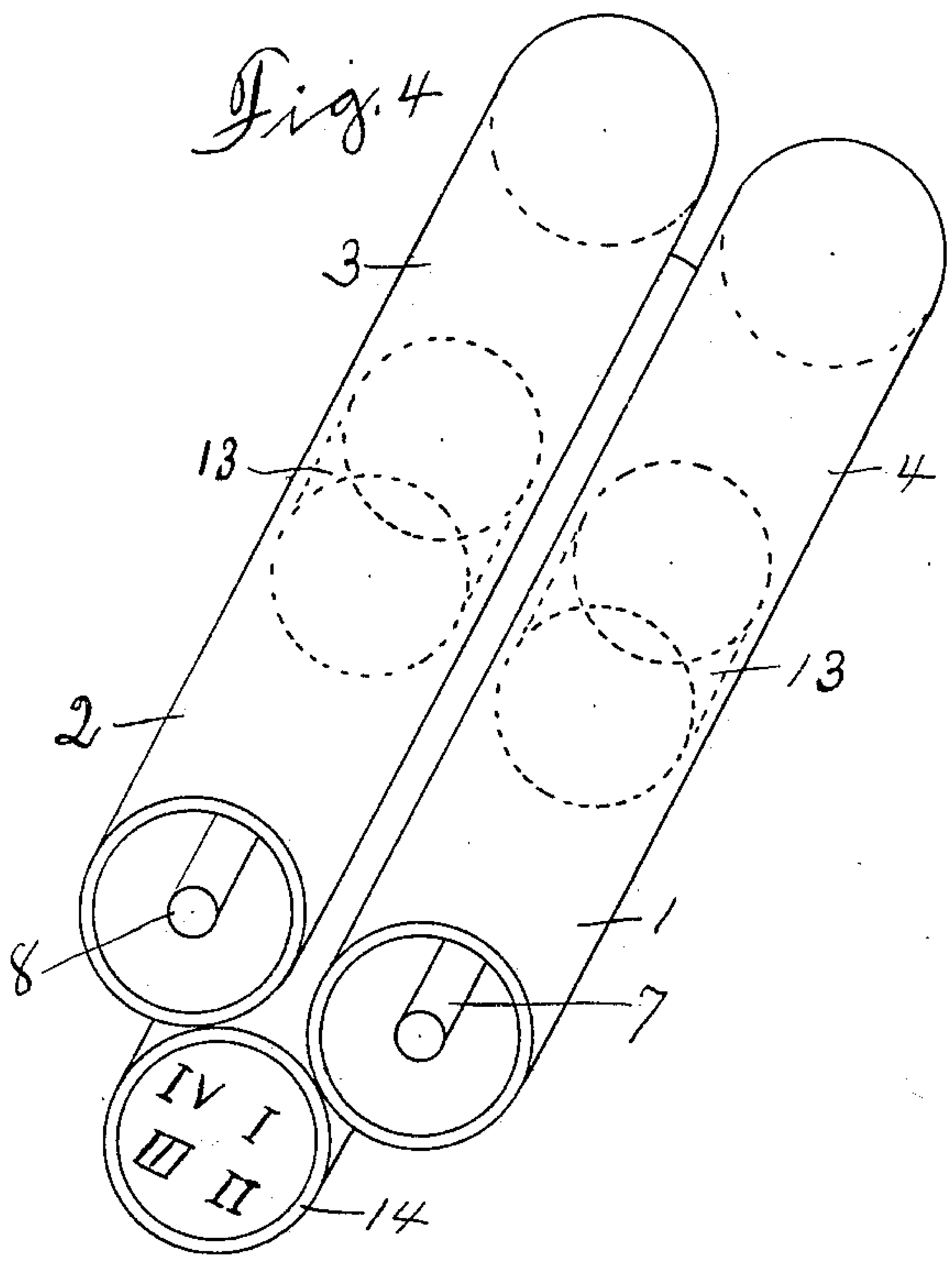
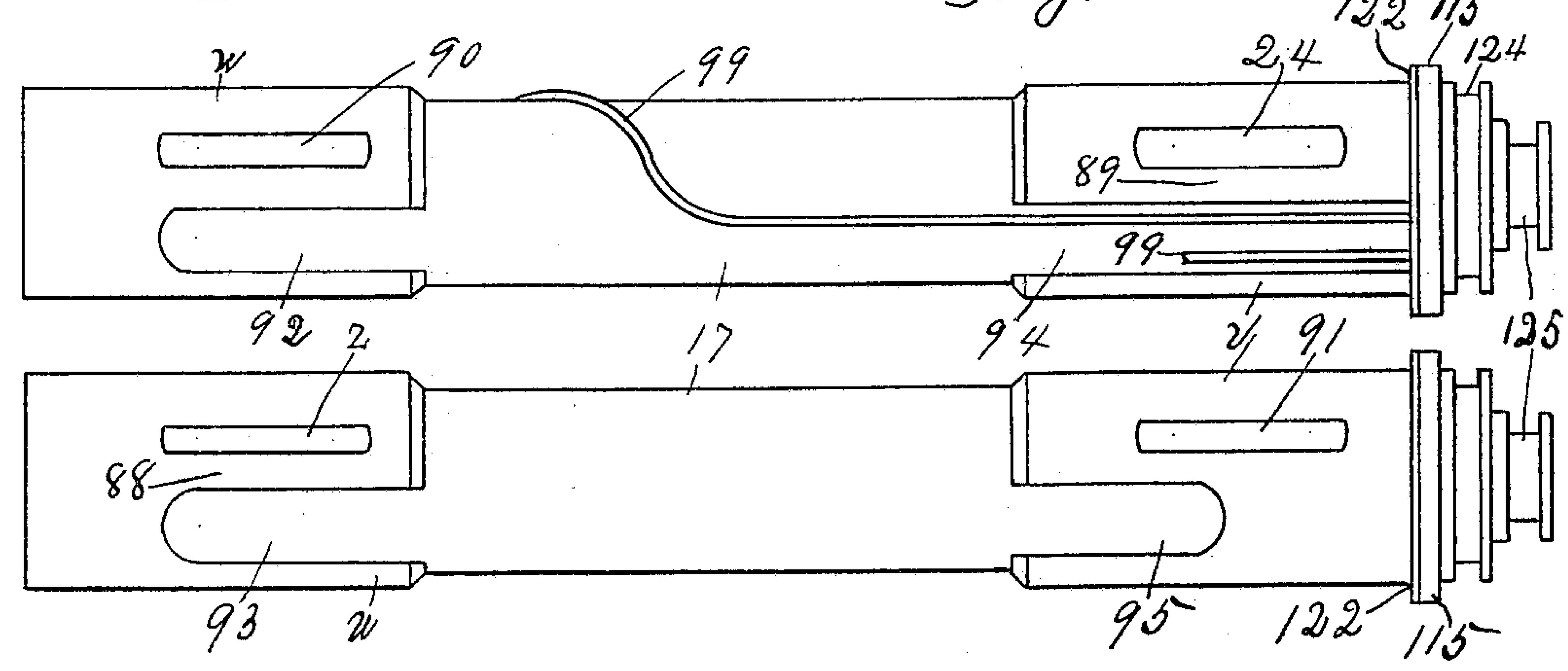


Fig. 19.



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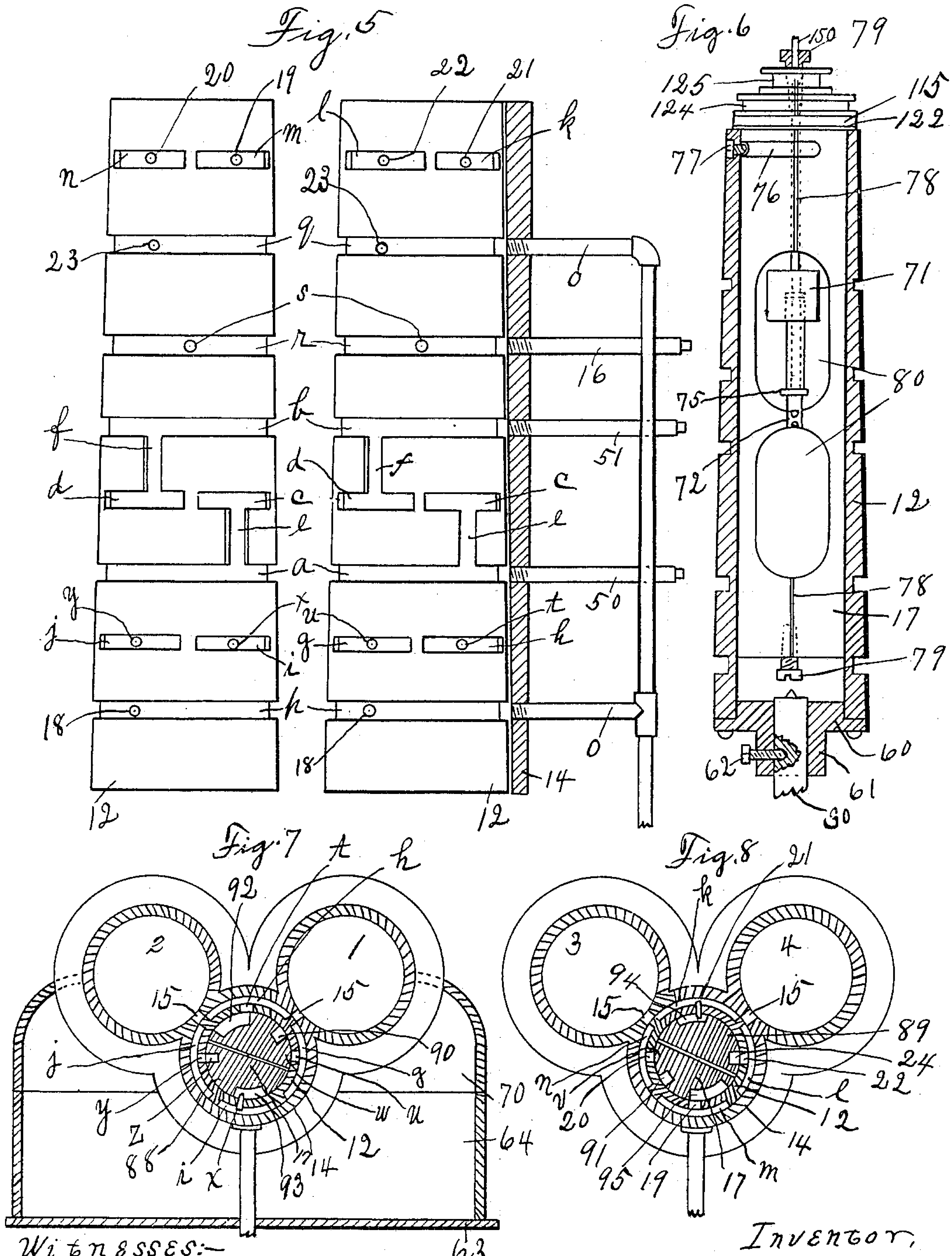
NO MODEL. 6 SHEETS—SHEET 4.



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NO MODEL. 6 SHEETS—SHEET 5.

Fig. 9

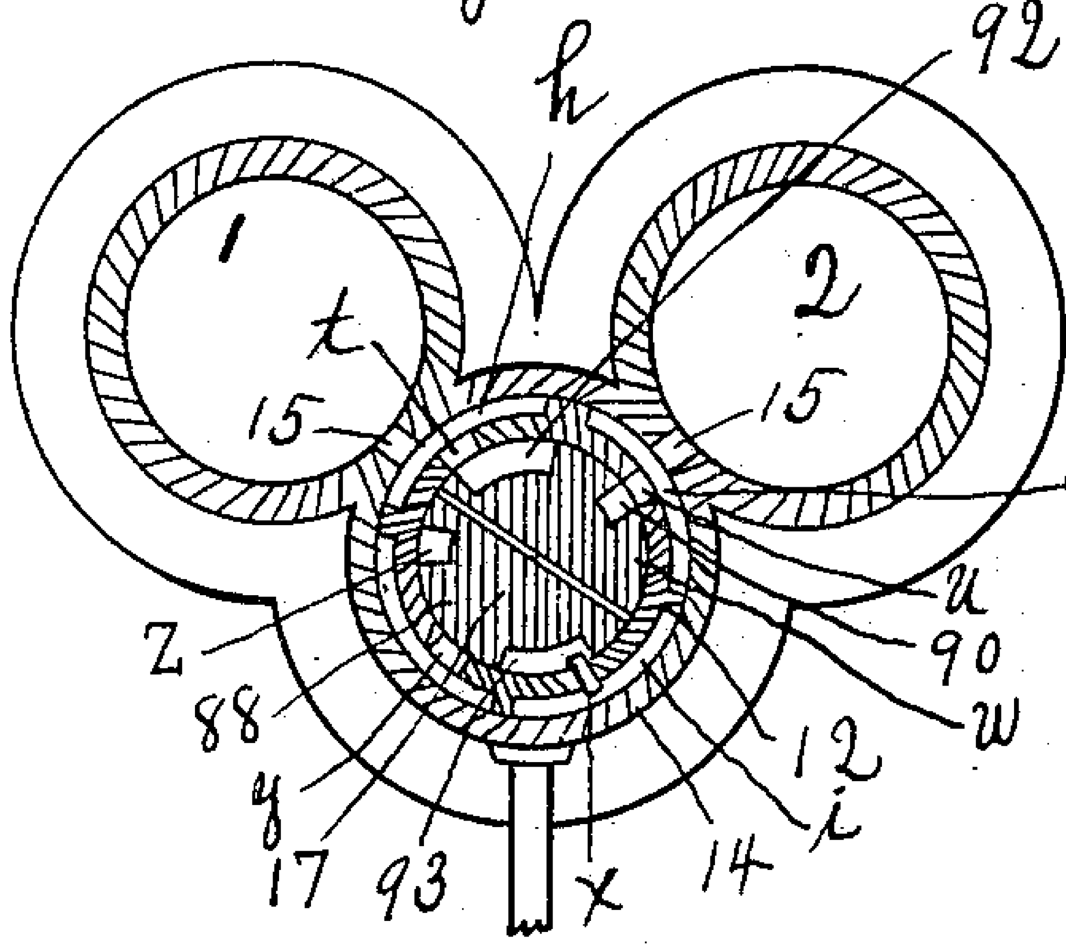


Fig. 10

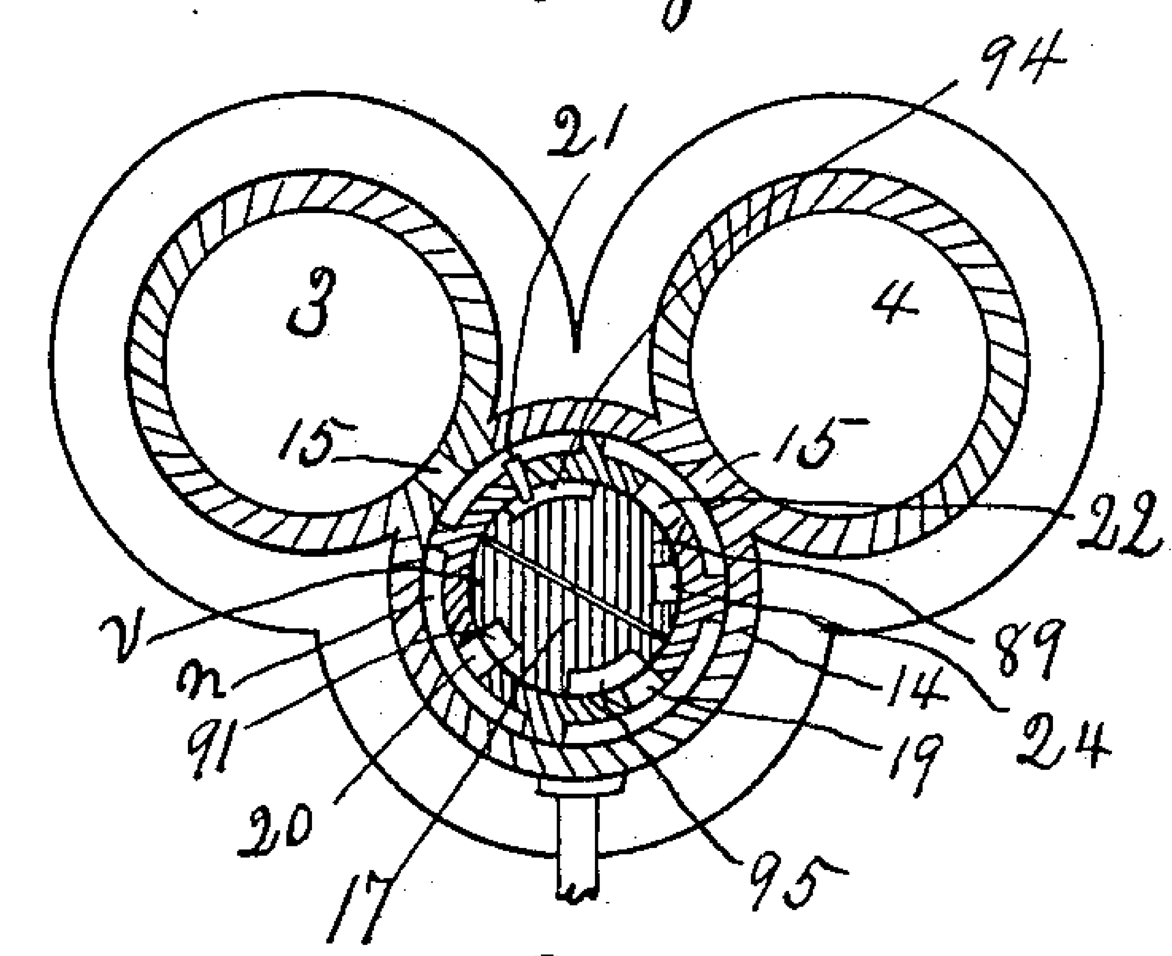


Fig. 11

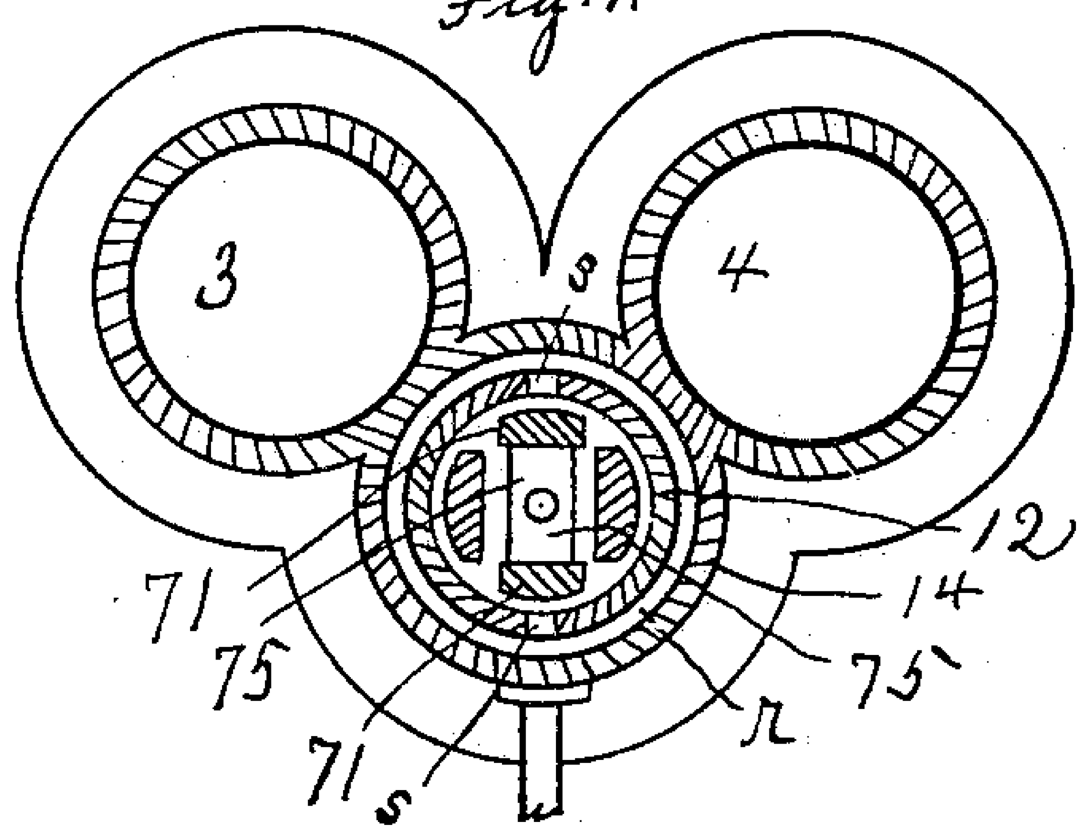


Fig. 12

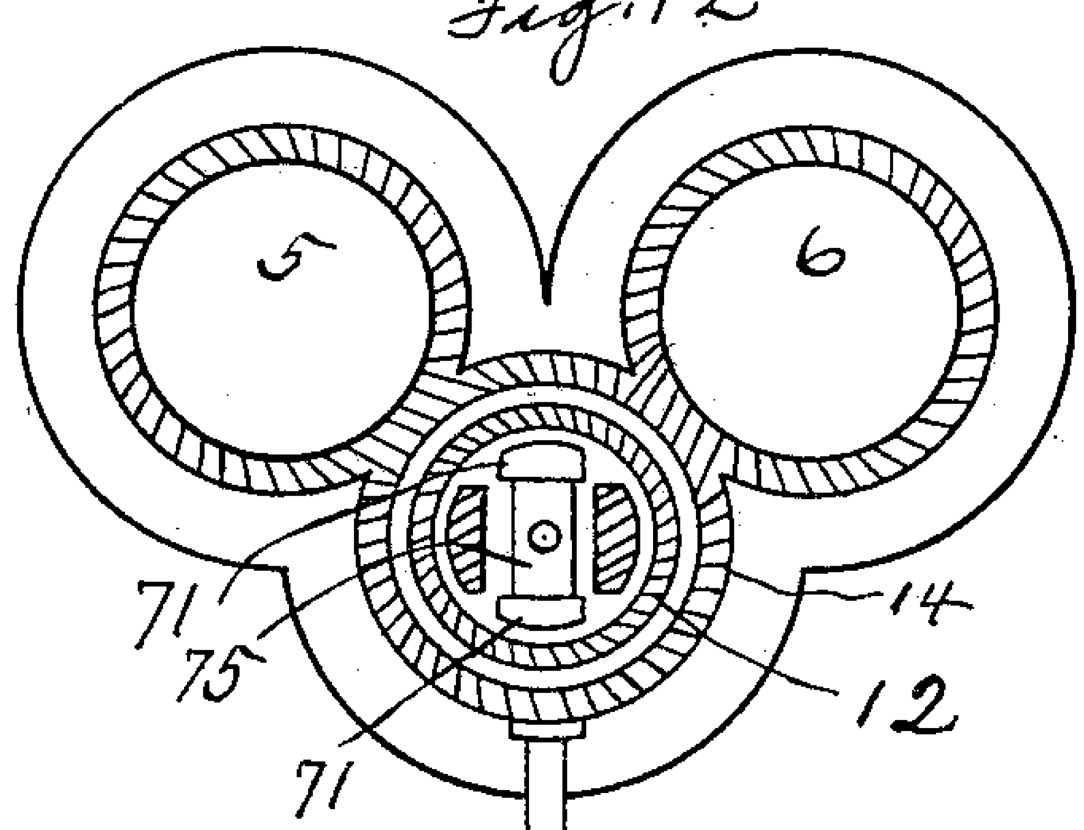


Fig. 13

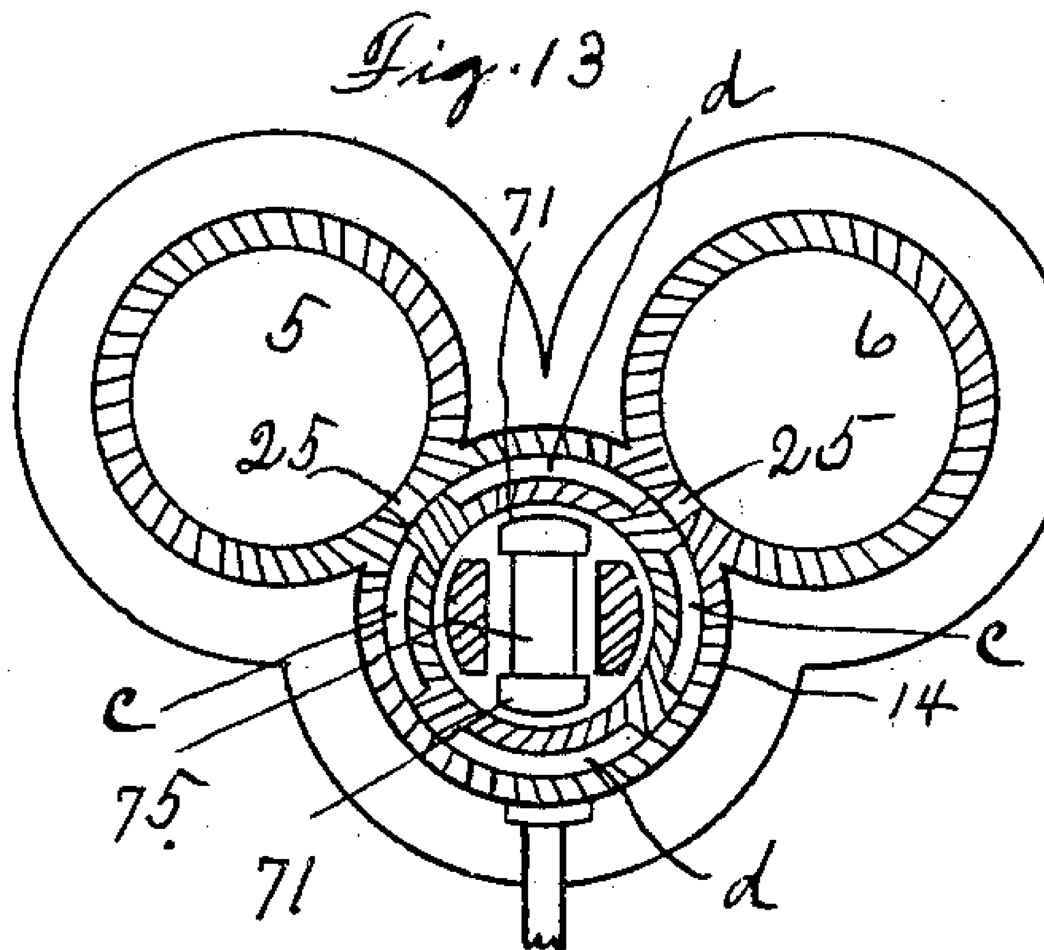


Fig. 14

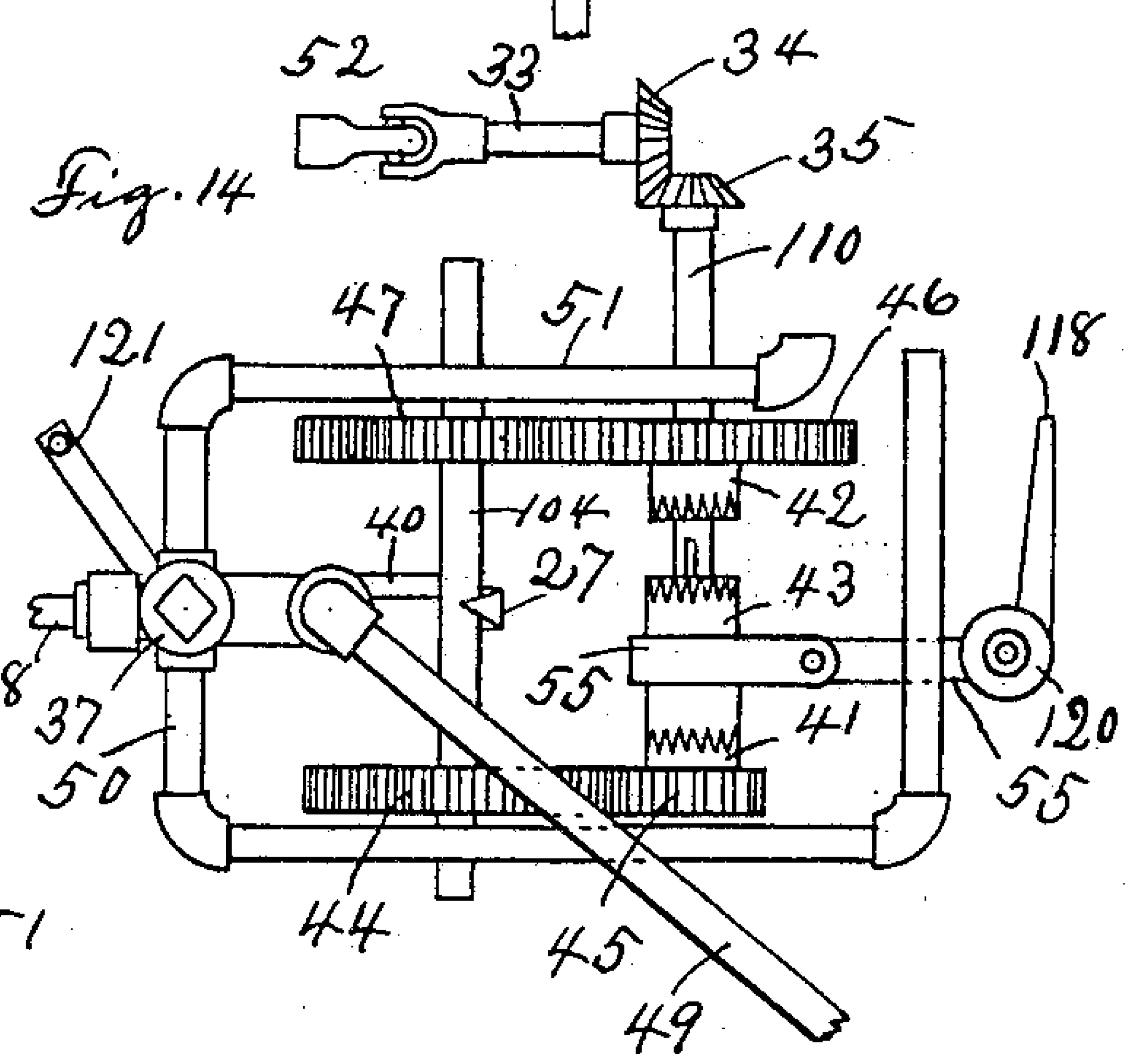
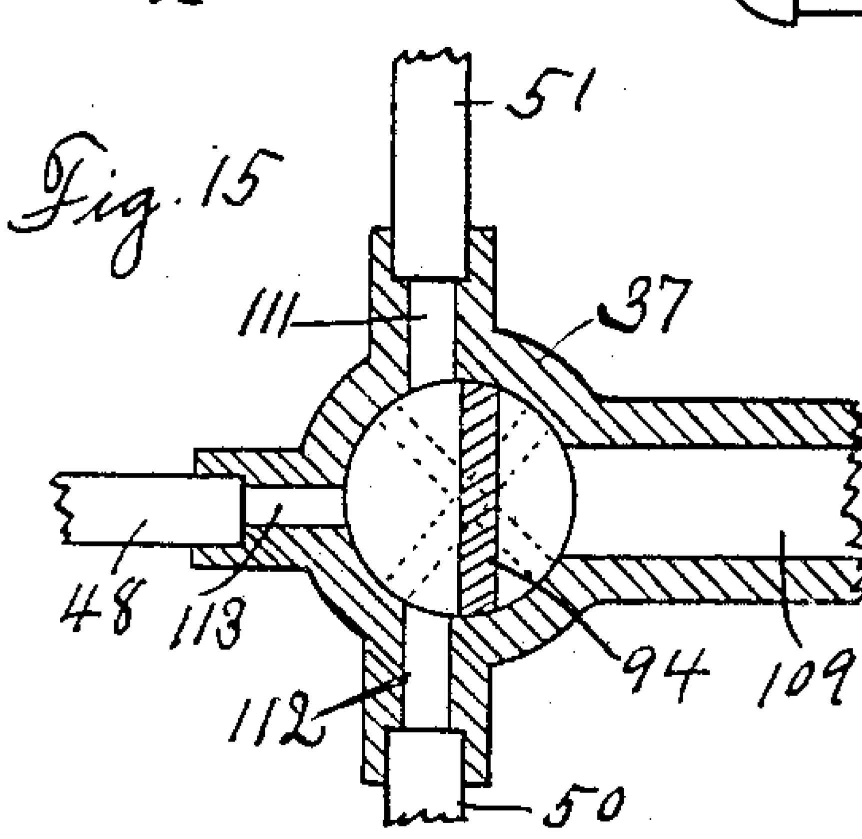


Fig. 15



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MULTIPLE CYLINDER HYDROCARBON ENGINE.

APPLICATION FILED MAY 22, 1901.

NO MODEL. 6 SHEETS—SHEET 6.

Fig. 16

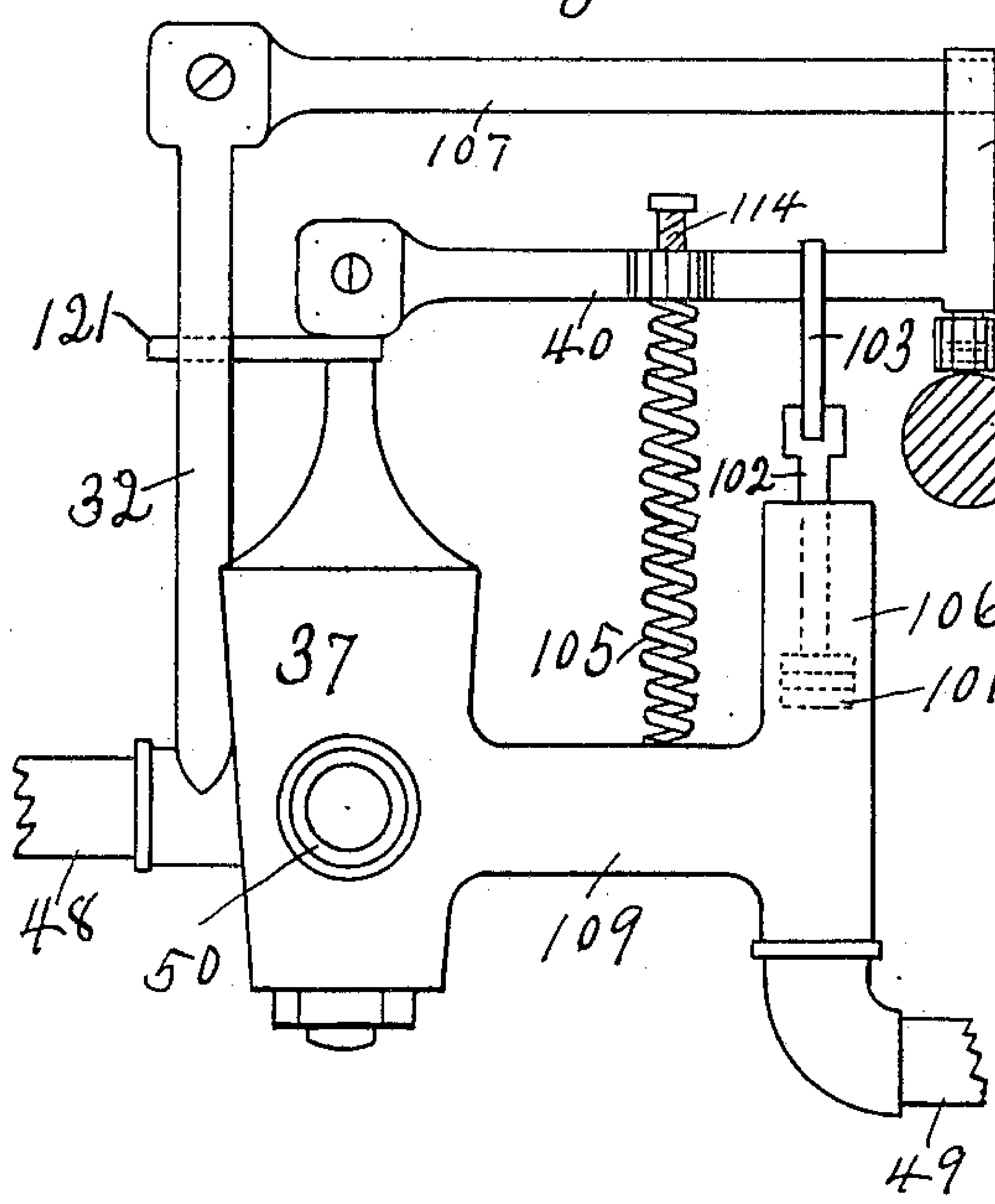


Fig. 20

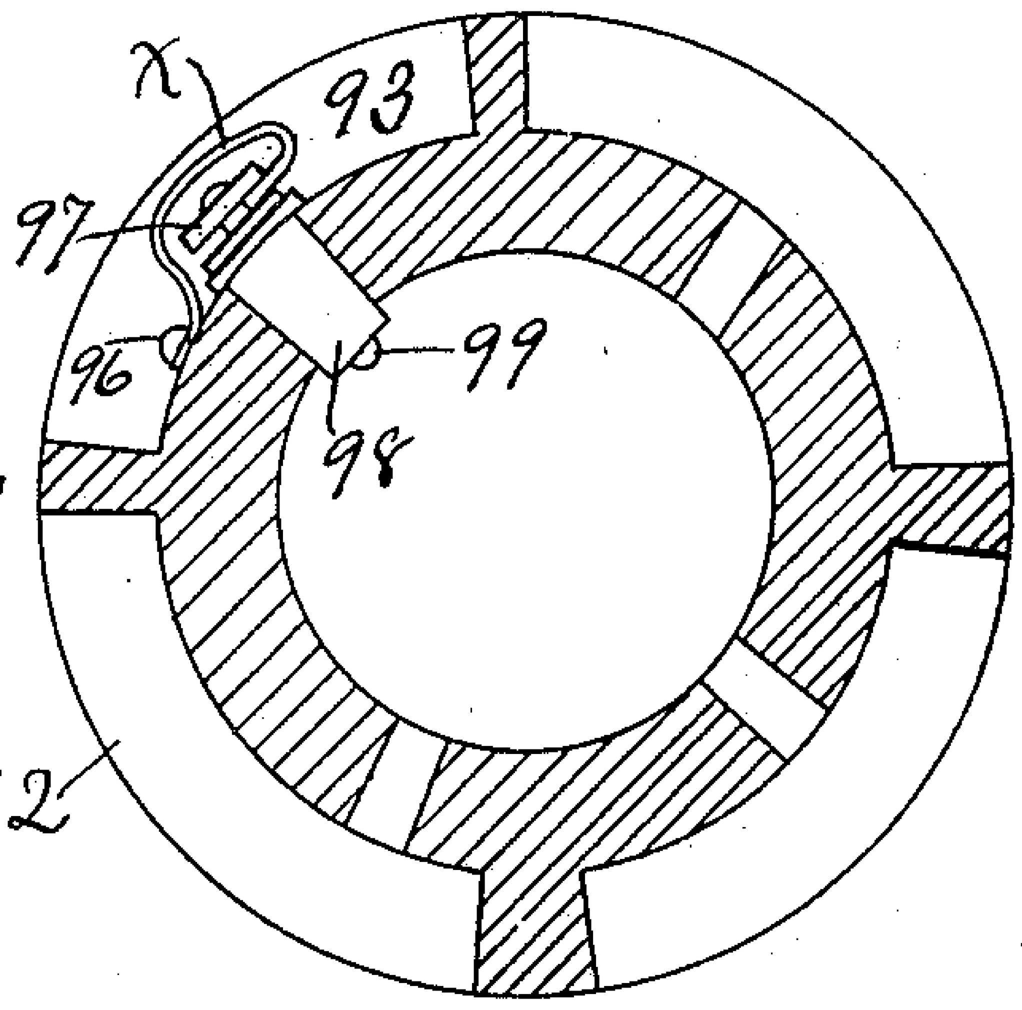


Fig. 21

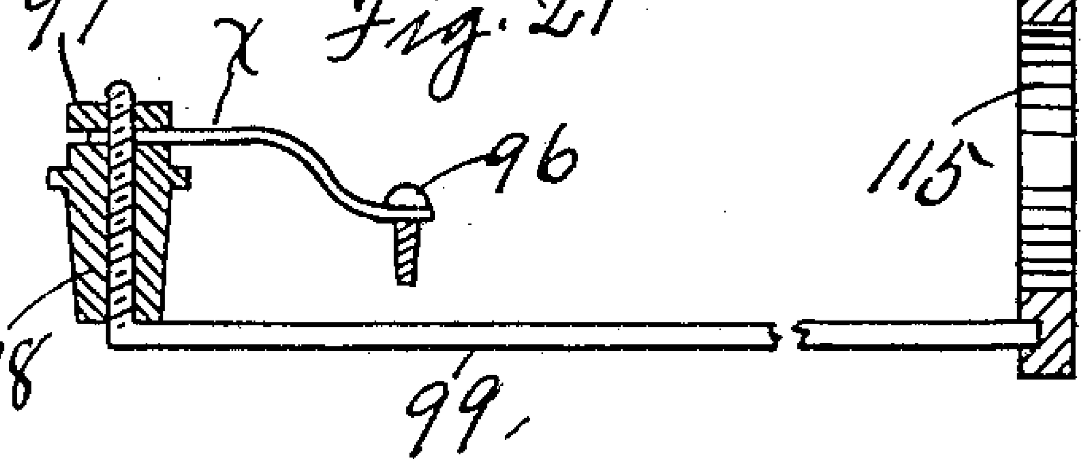


Fig. 17

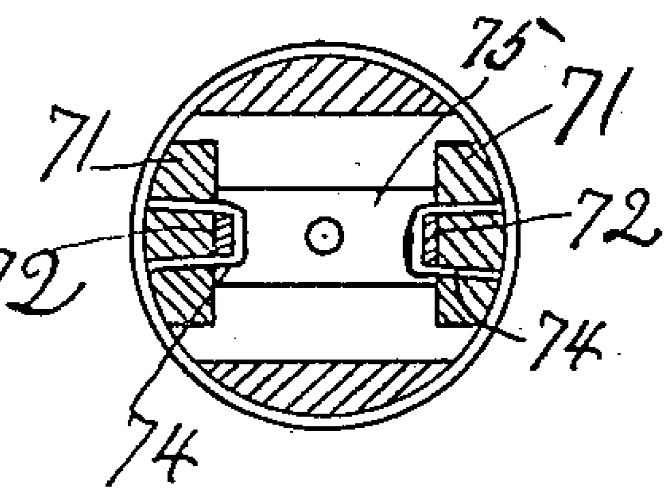
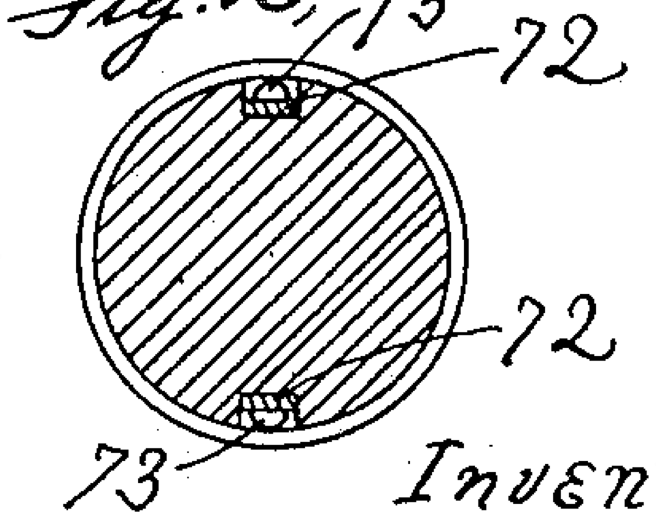


Fig. 18



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No. 758,854. Patented May 3, 1904.

UNITED STATES PATENT OFFICE.

EDWIN L. RUSSELL, OF DALLAS, TEXAS, ASSIGNOR TO RUSSELL MOTOR VEHICLE COMPANY, OF CLEVELAND, OHIO, A CORPORATION OF ARIZONA TERRITORY.

MULTIPLE-CYLINDER HYDROCARBON-ENGINE.

SPECIFICATION forming part of Letters Patent No. 758,854, dated May 3, 1904.

Application filed May 22, 1901. Serial No. 61,441. (No model.)

To all whom it may concern:

Be it known that I, EDWIN L. RUSSELL, a citizen of the United States, residing at Dallas, Texas, have invented a new and Improved Multiple-Cylinder Hydrocarbon-Engine, of which the following is a specification.

This invention relates to engines provided with a plurality of cylinders, the cylinders being fed by a common rotary valve and the pistons of the cylinders being adapted to drive a common crank-shaft which is provided with gearing for driving the rotary valve, and to means for starting and reversing the engine.

The object is to construct an engine which is light and compact and which gives a steady power for driving purposes and which may be started or reversed or stopped with little effort.

Other objects and advantages will be fully explained in the following description, and the invention will be more fully pointed out in the claims.

Reference is had to the accompanying drawings, which form a part of this application and specification.

Figure 1 is a front elevation of the engine, partly in section, a section being made along the line *x x* of Fig. 3. Fig. 2 is a broken rear elevation. Fig. 3 is a longitudinal section practically along the line *y y* of Fig. 1. Fig. 4 is a diagrammatic view in perspective of the cylinders and the rotary valve-seat for convenience in showing the arrangement of the cylinders and explaining the operations that take place in the cylinders. Fig. 5 is a plan view of the rotary valve, the valve being cut in half and both half-sections being turned to view, and the connecting feed and exhaust pipes being indicated. Fig. 6 is a longitudinal section of the rotary valve, showing the oscillating valve and the governor in place. Figs. 7 and 8 are cross-sections of the engine through the explosive-mixture cylinders before the engine has been reversed, the sections being made, respectively, through the grooves *g*, *h*, *i*, and *j*, and *k*, *l*, *m*, and *n* of Fig. 5, showing relative positions of intake and exhaust grooves in the oscillating valve to ports in rotary valve and in the cylinders. Figs. 9 and 10 are similar views showing the relative positions of intake and exhaust grooves in the oscillating valves to ports in the rotary valve and the cylinders after the engine is reversed, the sections being made, respectively, through grooves *g*, *h*, *i*, and *j*, and *k*, *l*, *m*, and *n* of Fig. 5. Fig. 11 is a cross-section through groove *r* of Fig. 5. Fig. 12 is a cross-section through groove *a* of Fig. 5. Fig. 13 is a cross-section through grooves *c* and *d* of Fig. 5. Fig. 14 is a view from the bottom of the hill-climbing gear or back gear and the pump which is operated automatically by the engine for securing a supply of compressed air. Fig. 15 is a horizontal section of the four-way valve. Fig. 16 is a side elevation of the four-way valve and the means for operating the same. Figs. 17 and 18 are cross-sections of the oscillating valve, illustrating the manner of mounting the governor, the views being at right angles to each other. Fig. 19 is a plan view of the oscillating valve, the valve being cut in half and the entire surface being shown. Fig. 20 is an enlarged cross-section of the rotary valve, showing the manner of locating the igniter. Fig. 21 is a detail view of the igniter.

Similar characters of reference indicate the same parts throughout the several views.

The engine is provided with four cylinders, (indicated by 1, 2, 3, and 4 in Fig. 4.) Each cylinder is provided with a piston. The pistons for cylinders 1 and 4 are mounted on a common piston-rod 7 and the pistons for cylinders 2 and 3 are mounted on a common rod 8. The rods 7 and 8 are provided with suitable connecting-rods 9 and 10, respectively, which connect with a common crank-shaft 11. A rotary valve 12 is mounted under the cylinders. This valve feeds all the cylinders 1, 2, 3, and 4 with explosive mixture. Partition-packing 13 is mounted, respectively, between the cylinders 1 and 4 and 2 and 3, the piston-rods 7 and 8 running through these packings.

The two piston-rods are connected to the crank-shaft 11 and the crank-shaft is operated by the piston-rods. A worm-gear 28 is also mounted on the crank-shaft 11 and drives a worm-gear 29, which is mounted on shaft 30. The worm-gear 28 drives the worm-gear 29 and the worm-gear 29 drives the shaft 30. The rotary valve 12 is mounted rigidly on shaft 30. In this manner the pistons, with their connections through the worm-gear and shaft 30, drives the rotary valve 12. The power of the engine is applied or derived from the shaft 30. The valve 12 is provided with a seat 14, and the seat 14 is formed integral with each pair of tandem cylinders. There are four cylinders arranged adjacent to the valve-seat 14, cylinders 1 and 4 being tandem relative to each other, and so are 2 and 3 tandem relative to each other. Each pair of tandem cylinders is separated by the partition-packing 13. The grooves formed in the periphery of the valve 12 and the ports in the valve and in the cylinders are so arranged that the feeding and exhausting of the cylinders will be accomplished successively in each cylinder. Each operation is fully explained below.

In order to give an idea of the general working of the engine, a brief comprehensive description will be given here.

Assume that the rotary valve is divided into four segments I, II, III, and IV, as shown in Fig. 4, and these Roman numerals represent the four operations—intake, compression, expansion, and exhaust. In each cylinder there are four operations during each revolution of the valve 12. In any cylinder operation I is the intaking of explosive mixture. The intake-port is immediately closed by the revolving of the valve, and operation II, compression, commences. (It is assumed that each operation lasts or continues during one-quarter of a revolution of the valve 12.) After compression commences the valve turns one-quarter of a revolution. The height of compression is reached at this point and explosion takes place, (explosion is caused by the ignition of the mixture or gas,) and operation III, expansion, begins. Another turn of a quarter of a revolution of the valve completes the expansion and brings the valve to operation IV, the exhaust. Then a new revolution begins with intake, and so on. The explosion in any cylinder furnishes energy for operating all moving parts in or connected to the other three cylinders. The operations in any cylinder are independent of or separate from the operations in any other cylinder, but the expansion in each cylinder gives energy for the operation of each other cylinder. One revolution of the valve completes four operations in any one cylinder. Consequently during one revolution of the valve sixteen operations take place in the four cylinders.

The simultaneous operations going on in each cylinder may be stated as follows:

In cylinder 1 intake operation I is going on while exhaust operation IV is taking place in cylinder 2; compression, operation II, is going on in cylinder 3, and expansion, operation III, is taking place in cylinder 4.

In cylinder 2 intake operation I is going on while expansion, operation III, is taking place in cylinder 3; exhaust, operation IV, is going on in cylinder 4, and compression, operation II, is going on in cylinder 1.

In cylinder 3 intake operation I is going on while compression, operation II, is taking place in cylinder 4; exhaust, operation IV, is going on in cylinder 1, and expansion, operation III, is going on in cylinder 2.

In cylinder 4 intake operation I is going on while expansion, operation III, is going on in cylinder 1; compression, operation II, is going on in cylinder 2, and exhaust, operation IV, is going on in cylinder 3.

The valve 12 is provided with a casing or seat 14, and this seat is provided with ports 15, which open into the cylinders 1, 2, 3, and 4. Ports 15 are for the admission of the explosive mixture. The rotary valve is tubular and conical. The valve 12 being tubular, only one intake from the carbureter or gas-supply source is necessary. The explosive mixture enters the seat 14 through pipe 16 and passes to the interior of valve 12 by means of the groove *r* and the holes *s* in the groove. From the interior of valve 12 the explosive mixture enters cylinders 1 and 2 through the opening or hole *t* into intake-groove *h*, which passes the ports 15 of cylinders 1 and 2. The explosive mixture is compressed by the closed space about groove *g*, the hole *u* in the groove *g* being closed by the blank space *w* on the oscillating valve 17. At the height of compression the explosive mixture is ignited by the igniter *x* in the expansion-space *i*, and the mixture expands during the time that it takes space *i* on the rotary valve to pass below the port 15 of either cylinder which is kept closed by this space. At the end of expansion-space *i* exhaust-space *j* (which extends practically one-fourth around the rotary valve) allows the spent explosive mixture to pass out through the hole *y* into the groove *z* in the oscillating valve 17, thence on out through the hole 18 to groove *p*, which connects with exhaust-pipe *o*, and on to the atmosphere.

Explosive mixture for cylinders 3 and 4 enters the rotary valve 12 through hole *s* from groove *r*, which runs over the mouth of the intake-pipe 16, which connects with the carbureter. From the interior of the rotary valve the explosive mixture enters or passes into the ports of cylinders 3 and 4 by means of the hole 19 which is in groove *m*. Explosive mixture (when the cylinder is filled) is compressed while space about groove *n* is passing below the port 15 of either cylinder 3 and 4, the port 20, which is in space *n*, being closed by the blank space *v* in the oscillating valve 17. At the height of compression explosive mixture is ignited by the igniter 21, which is located and insulated in the expansion-groove k. This groove k opens to the port of the cylinder with compressed mixture just as the height of compression is reached, which allows the explosive mixture to come in contact with the igniter 21, which is situated in the groove k. The explosive mixture expands while the space about groove k is passing below the port 15 of either cylinder 3 and 4. Then the port of either cylinder is opened by the groove 1, and the spent explosive mixture passes out through the hole 22, which is located in exhaust-groove 1, and thence on to hole 23 in groove q by means of the groove 24 in the oscillating valve 17, which extends below hole 23 and hole 22 of the rotary valve. From groove q the spent explosive mixture is exhausted through exhaust-pipe o. It will be seen that the two cylinders, which are laterally adjacent to each other, have a common intake and a common exhaust. A tabulated statement may make the operation clearer. In the statement below the numbers indicate the cylinders, and for the cylinders in which simultaneous operations are taking place read from left to the right. The names of the operations are in line above cylinder numbers.

Cylinders.	Intake.	Compression.	Expansion.	Exhaust.
Cyl	1	3	4	2
Cyl	2	1	3	4
Cyl	3	4	2	1
Cyl	4	2	1	3

The means for controlling the explosive mixture is fully described above. The means for controlling the compressed air for reversing and starting the engine will be described next.

The grooves a and b connect with the four-way valve 37 by means of the pipes 50 and 51, respectively. Groove a is connected to grooves c by means of grooves e, and groove b is connected to grooves d by means of the grooves f. The grooves c are the air-inlets to the ports 25 of the cylinders 5 and 6. The air is exhausted through the same ports through grooves d and f to groove b and out pipe 51 to four-way valve 37, and thence to the air-reservoir through pipe 49 until the desired pressure is secured. It exhausts into the reservoir until the desired supply is secured and then exhausts through the intake of the four-way valve until the pressure of the reservoir is reduced below the desired pressure and also exhausts to the atmosphere through the intake of the four-way valve while the engine is being run by compressed air for reversing or starting purposes. The engine thus acts as a pump for securing a supply of compressed air, and the compressed air is stored in the reservoir automatically. The cylinders 5 and 6, hereinafter called "compressed-air" cylinders, are formed between the partition-packing 13 in the cylinders and the pistons in cylinders 3 and 4, and are formed alternately with each other when the engine is in operation. When the air is below the required pressure in the air-reservoir, the cam-roller 100 on the cam-lever 40 is lowered (by means hereinafter described) and engages the cam 27, which is mounted on the shaft 104. The cam 27, when the gearing is in motion, will turn the lever 40 far enough to open the valve 37—that is, to turn the plug 94 so that air will flow from the atmosphere to the air-cylinders 5 and 6 through the pipe 48, which is screwed into the valve 37. The air goes to the cylinders 5 and 6 by means of the pipe 50 and is then exhausted back through the valve 37 and through pipe 49 to the air-reservoir. This operation goes on until the desired pressure is reached. When the air in the reservoir reaches the desired pressure, the air in the reservoir raises the lever 40 by means of the connecting-rod 103, which is connected to the piston-rod 102. The piston-rod 102 carries a piston 101, which operates in a cylinder 106. The cylinder 106 may be formed integral with the casting of the valve 37. The compressing of the air in the reservoir goes on until the pressure becomes strong enough to raise the lever 40 high enough to raise the roller 100 above the cam 27. As soon as the roller 100 misses the cam 27 the compression of air ceases until the air is used or exhausted enough to let the piston 101 down, and consequently the roller 100 down, so that it will again engage the cam 27. The pistons 26 and the cylinders of the engine are thus used automatically to pump air into the air-reservoir. The cam 27 is kept constantly in motion by the energy of the engine transmitted through the gearing 28 on the crank-shaft 11, the gearing 29, mounted on shaft 30, and the cog-wheel 31, also mounted on shaft 30. The crank-shaft 11 is driven by the pistons through the piston-rods and their connections to the shaft 11. The worm gear-wheel 28 drives the worm gear-wheel 29 and the shaft 30, which is rotary valve-shaft 30, and the cog-wheel 31. Cog 31 drives cog 46, which is mounted on shaft 110. Cog 46 drives the cog 47, which is mounted on shaft 104. This shows how the shaft 104 is driven by power transmitted from the engine, the gearing referred to being mounted rigidly on the shafts referred to. The gearing shown in Fig. 14 is herein called the "hill-climbing" gear or "back" gear. This gearing is used for concentrating the power or speeding up the power, whereby greater power is gained; but the speed of the carriage or other object being driven by the engine is slower. This gearing will be explained farther on. The cam-lever 40 is normally drawn down by means of the spring 105. The tension of the spring 105 is adjusted by a screw 114. The lever 40 being drawn down, the roller 100 will engage the cam 27 and will continue to engage the cam 27 until the pressure in the reservoir becomes strong enough to raise the piston 101 in the cylinder 106, to force the lever 40 upward against the tension of spring 105. As soon as the pressure become great enough to raise this lever 40 high enough to raise the roller 100 above the cam 27 the compression of air in the reservoir ceases. It is thus seen how the tension of spring 105 will govern or determine the pressure of the air-reservoir. When the desired pressure is obtained in the air-reservoir, additional pressure will overcome the tension of the spring 105 by means of piston 101 and rod 102 and connecting-rod 103, thus causing the roller 100 to rise above and miss the cam 27 as said cam is turning on the shaft 104.

The valve-plug 94 is shown in its normal position—that is, when the engine is not pumping air from cylinders 5 and 6 to the air-reservoir. This may be either when the cam 27 has just passed beyond the roller 100, thus allowing spring 107, which engages cam-lever 40 by means of a slotted stud 108, (which is integral with lever 40,) to bring cam-lever 40 in position to engage cam 27 again (which position is parallel with the pipe 48, screwed into valve 37, and with the valve-pipe 109, which is a part of the casting of valve 37) or when the air in the reservoir has overbalanced the tension on the spring 105 by means of the piston 101, &c., whereby the cam-roller 100 is raised above the cam 27. When the cam-roller 100 is once disengaged from the cam 27, the piston crank-shaft 11 will make eight revolutions before the cam-roller 100 engages the cam 27 again, because the crank-shaft gear-wheel 28 makes two revolutions to one of the rotary-valve gear 29. This speed is transmitted through cog 31 to the hill-climbing gear 46. Thus the speed of the rotary-valve gear 29 is transmitted through gear 46 to gear 47, which is of the ratio of one to four of gear 46, the gear 47 being keyed to the shaft 104, on which cam 27 is mounted.

The valve 37 is provided with four openings. Three—111, 112, and 113—are threaded for receiving threaded pipes 51, 50, and 48, respectively. The pipe 49 is screwed into L-pipe 109, which is integral with the valve-seat casting 37, the pipe 49 being connected with the air-reservoir. The cylinder 106 is integral with the L-pipe 109 and constitutes the air-cylinder in which piston 101 is mounted for controlling the pressure of the air-reservoir. The spring 107 is mounted in the stud 32. This spring is for holding the roller 100 against either side of the cam 27. When the cam 27 engages the roller 100 of the lever 40, the plug 94 is turned crosswise, the four openings of valve 37, as shown by dotted lines in Fig. 15, thus connecting the openings 112 and 113 of the valve 37 with the pipes 50 and 48 for taking air from the atmosphere to cylinders 5 and 6 and connecting the openings 111 and 109 with pipes 51 and 49, whereby the air is forced from cylinders 5 and 6 to the air-reservoir.

The power of the engine is applied through shaft 110, beveled gear-wheel 35, which is rigidly mounted on said shaft, the beveled gear-wheel 34, which is rigidly mounted on the shaft 33, and through the knuckle-joint 52; but the power may be applied in any other suitable manner. Greater speed may be secured for the shaft 110 in the following manner: The cog 46 is mounted loosely on the shaft 110 and is normally made rigid therewith by the clutch 43, the clutch-jaw of clutch 43 meshing with the clutch-jaw 42 being thrown in mesh therewith by means of the lever 118, which is attached to the pivot-post 120, which carries the clutch-yoke 55. The clutch-yoke 55 carries antifriction-rollers 56, which bear against the walls of the groove 57 in the clutch 43. Cogs 47 and 44 are keyed to the shaft 104, and cog 45 is loosely mounted on the shaft 110. Power is transmitted to the cog 46 from the rotary-valve shaft 30. When it is necessary to use greater speed, the clutch 43 is shifted from clutch-jaw 42, which is integral with cog 46 to clutch-jaw 41, which is integral with the cog 45. Power is transmitted to the cog 46 from the rotary-valve shaft 30, but not directly to the shaft 110, as it is normally done, but through the cog 47, shaft 104, cogs 44 and 45 to shaft 110. The speed is gained by reason of the difference in the size of the gearing.

The drawings show the rotary valve 12 provided with a seat or casing 14, which is shown integral with the cylinders 1 and 2 and 3 and 4. The casing is shown beneath the cylinders, which are adjacent to each other; but the arrangement may be different, as the valve and the casing may be placed above the cylinders. The cylinders and the valve-seat 14 are provided with radiating flanges 58 for cooling purposes. The caps 59 may be bolted or otherwise attached to the cylinders 3 and 4. The rotary valve 12 is provided with a cap 60, which is secured thereto by screw-bolts. This cap is provided with a sleeve 61, in which is secured the rotary-valve shaft 30 by means of the screw-bolt 62.

The engine is provided with a frame consisting of the base 63, the side walls 64, and the top of the frame 66. The front end of the engine is provided with an offset or ledge 65, which is for supporting the bearing 67 for the rotary-valve shaft 30. The bearings 68 for the crank-shaft 11 are mounted on top of the frame. The back wall 69 of the frame is made in two parts and provided with hinges 70, by which the upper and lower parts are secured together and by which the engine may be tilted back for convenience in making examination, cleaning, &c. The base 63 may be attached to any suitable support.

The engine is provided with an oscillating valve 17, mounted in the tubular rotary valve 12 for reversing purposes. The oscillating valve carries the governor for controlling the supply of explosive mixture. The governor consists of two blocks 71, having each a curved surface for closing the ports *s* in the rotary valve 12 or partly closing said ports. These blocks are attached to the oscillating valve by means of spring-arms 72, these arms being secured to the oscillating valve by means of screws 73 and to the blocks or weights 71 by means of staples 74. With the weights thus arranged on spring-arms the centrifugal force will cause the blocks or weights 71 to approach more or less near the ports *s* and more or less close these ports, and thus regulate the amount of explosive mixture that is passing from the interior of the rotary valve to the cylinder. The weights are themselves controlled by the yoke 75. This yoke is slidable on the spring-arms 72 and may be set closer to the weights 71 or farther from these weights by means of the rod 150, which passes through the screw 79. If the yoke is placed near the weights, they will not be thrown outwardly toward the ports *s*, but if placed farther away from the weights there will be more of the arms left to spring and allow the weights to be thrown outwardly toward the ports *s*. The means for permitting the valve 17 to oscillate within the valve 12 are shown in Fig. 6. The oscillating valve has a groove 76 therein and the rotary valve carries a set-screw 77, which projects in the groove 76, so that the oscillating valve can oscillate only to the length of the groove 76, which groove extends practically one-quarter around the oscillating valve. The screw 77 prevents longitudinal motion of the oscillating valve within the rotary valve. The oscillating valve 17 consists of a single piece of metal. A kerf 78 is cut in each end of the oscillating valve 17, and the ends of the valve may be expanded by means of screws 79. On each side of the longitudinal central part of the oscillating valve two cut-outs 80 are made, in one of which the weights 71 operate. The oscillating valve 17 is made adjustable in the rotary valve 12 by means of rod 150, and the rotary valve is made adjustable in the seat 14 by means of the nuts 81. The valve 17 is not oscillated relative to the engine-cylinders, but relative to the rotary valve. The oscillating valve is provided principally for reversing purposes. The valve is not really oscillated, but only held stationary for a short time until the rotary valve turns practically one-quarter around. This is done by means of a gripping device. (Shown in Fig. 2.) A casting or frog 82 is bolted to the flange 54 on the end of the valve-seat 14. This frog has a clamp 83, and one end of a band-clamp 84 is secured in this clamp and passed around the end of the oscillating valve 17 and then secured pivotally to a lever 85, which is fulcrumed on the end wall 69 of the frame for the engine, the strap, band, or clamp passing through the clamp 83 on the frog 82. A pull on the lever 85 will cause the band-clamp to grasp the oscillating valve and hold the same stationary. An arm 86 is pivotally mounted on the frame for moving the oscillating valve axially or giving lineal motion to the valve. This arm is convenient for adjusting the oscillating valve. The arm is bifurcated and carries two rollers 87, which prevent friction on the oscillating valve, the rollers resting in a groove in the oscillating valve.

To reverse the engine-valve, the end of the oscillating valve is gripped by the band-clutch 84. This holds the oscillating valve stationary while the energy of the engine drives the rotary valve a fraction of a revolution far enough to convert the exhaust-spaces into compression-spaces, and vice versa. This is accomplished in the first instance by the exhaust-port *y* in the rotary valve sliding over the blank space 88 of the oscillating valve, which changes the exhaust-space in the rotary valve into the compression-space. This statement is relative to the cylinders 1 and 2. During the same time the exhaust and compression spaces for cylinders 3 and 4 on the other end of the rotary valve change by the exhaust port 22 assuming position over the blank space 89 in the oscillating valve. In Fig. 7 the compression-space or the space about groove *g* is converted into the exhaust by the port *u* being opened by the exhaust-groove 90, as shown in Fig. 9. The same thing is accomplished in cylinders 3 and 4 by the other end of the valve, as shown by Figs. 8 and 10. The port 20 in the compression-space on and about groove *n* assumes position over the exhaust-groove 91. The intake-groove 92 of Figs. 7 and 9 in the oscillating valve connects with the explosive mixture in the rotary valve and reaches far enough around the oscillating valve to allow port *t* in intake-groove *h* of rotary valve to remain open after the rotary valve has changed its position. The same is true of groove 95 of Figs. 8 and 10. The expansion-spaces about groove *i* in Fig. 7 and groove *k* in Fig. 8 remain the same while the engine is running in either direction.

The igniters *x* and 21 are located in the portions of the wall of the rotary valve representing expansion-spaces, and the grooves 93 of Figs. 7 and 9 and 94 of Figs. 8 and 10 allow free movement in changing for reversing purposes—that is, allow free movement of the rotary valve relative to the oscillating valve without injuring the igniters, the igniters being located in the grooves *i* and *k* of the rotary valve. The igniters consist of platinum wires, one end of which is fastened to the rotary valve 12 by means of a screw 96 (this connects the wire with the entire frame of the engine) and the other end secured between the nut 97 and the bushing 98, which consists of some insulating material. The nut 97 is screwed on a conductor-rod 99, which connects with an insulated ring 115, mounted on the oscillating valve 17. A spring-pressed brush 116 is provided for connecting the ring 115 with the frame of the engine. This brush is mounted in a casting 117, which is bolted to the end flange 54 of the valve-seat 14. Conductor-rods 99 connect both igniters with the insulated ring 115, the grooves 93 and 94 in the oscillating valve allowing or affording a passage-way for the rods. The central part of the oscillating valve is made smaller than the parts toward the ends thereof. Consequently no groove in the oscillating valve at the central part thereof is necessary for the passage of the conductor-rod from the igniter *x*, which is located in the rotary valve at the opposite end from the insulating-ring 115.

The changes of the mechanism for controlling the explosive mixture which take place when the engine is reversed have been described above. The changes which take place in the mechanism for controlling the compressed air are simple. The engine ceases to explode the gasolene or other explosive mixture as soon as the oscillating valve is checked long enough for the rotary valve to turn the requisite distance about the oscillating valve, because this operation cuts out the igniters. The explosive energy of the engine being dead, the air when suitably directed will cause the engine to run in the opposite direction. Before reversing, the air has been going from atmosphere through pipe 48, through valve 37, through pipe 50 to groove *a*, and thence through grooves *e* and *c* to cylinders 5 and 6, through ports 25, thence back through ports 25, through grooves *d* and *f*, through groove *b* to pipe 51, and thence on through valve 37 and pipe 49 to air-reservoir. As soon as the valves have been shifted, as above described, the four-way valve 37 is opened by means of a lever 121. This opening of the valve 37 causes the lever 40 to set the roller 100 in a position over the center of the shaft 104 of the hill-climbing gear slightly beyond the center of cam 27, which is the same relative distance from the point of the cam before the engine was reversed, but on the opposite side of the cam. This will allow the air from the reservoir to pass back through the pipe 49, valve 37, and pipe 51, (just the opposite of the direction and through the same course it was passing a moment before the engine was reversed.) From pipe 51 the air enters groove *b*, thence to *f* and *d* to cylinders 5 and 6 through ports 25. It is immediately exhausted through the same ports 25, through grooves *c* and *e*, and through groove *a* and on through pipe 50, valve 37, and pipe 48 to the atmosphere. In this operation the openings 113 and 111 of the valve 37 become intake for the cylinders 5 and 6 and opening 112 and pipe 109 become exhaust to the air-reservoir. The compressed air may be used in the same way for starting the engine, the pistons being moved by the force of the compressed air. As soon as the pistons have operated to rotate the rotary valve far enough to expose the igniters to the explosive mixture there is no necessity of any power from the compressed air.

The lever 118 for operating the clutch 43 is fulcrumed on a pivot-post 120, being made rigid with said post, and arm 55 is rigidly mounted on said post and provided with arms which carry the rollers 56. Any suitable arrangement of levers may be provided for operating the clutch 43.

The ring 115 is insulated from the rotary valve 12 by means of insulation 122 and from the oscillating valve 17 by means of insulation 123. A groove 124 may be made near the end of the oscillating valve 17 for the strap-clutch 84, and a groove 125 may be made in this valve for the rollers 87 of the arm 86.

The operation seems to be sufficiently described above. The igniters are to be charged with electricity from any suitable battery, and the pipe 16 is to be connected to a suitable carbureter for supplying the engine with explosive mixture. When there is no supply of compressed air, the engine will have to be started by rotating the valve by hand by some suitable crank or by simply grasping the drive-wheel and moving the same with the hand. When there is a supply of compressed air, the engine may be started by opening the four-way valve, as above described. Peripheral grooves are made in the surface of the rotary valve for controlling the explosive mixture and controlling the compressed air. Peripheral grooves are made in the surface of the oscillating valve for controlling the flow of explosive mixture. The compressed air runs in grooves prepared in the surface of the rotary valve, but does not go to the interior of the rotary valve.

Various other changes may be made without departing from my invention.

Having fully described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. A multiple-cylinder engine comprising a plurality of cylinders each being provided with a piston and a piston-rod, a common crank-shaft operated by said pistons a rotary valve provided with a suitable shaft, operative mechanism by which said valve is rotated by said crank-shaft and a gear-wheel mounted on said valve-shaft for transmitting the power of the engine.

2. An engine comprising a plurality of cylinders, each cylinder being provided with a piston-rod and a piston, a common crank-shaft operatively connected to said piston-rods, a valve-seat integral with said cylinders, a ro-

tary tubular valve mounted in said seat, gearing by which said valve is rotated, and means by which said cylinders are fed with explosive mixture from the interior of said valve.

3. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary valve in operative connection with said cylinders provided with a seat integral with said cylinders and a suitable shaft, a common crank-shaft operated by said pistons, gearing by which said valve is rotated by said shaft, and gearing mounted on said valve-shaft for transmitting the power of the engine.

4. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary tubular valve provided with a seat adjacent to said cylinders and a shaft-operative means by which said valve is rotated by said pistons and gearing mounted on said valve-shaft for transmitting the power of the engine; said cylinders having suitable ports communicating with said valve-casing and said valve being tubular and having suitable intake and exhaust grooves and ports for feeding said cylinders with explosive mixture from the interior of said valve.

5. An engine comprising a plurality of cylinders provided with suitable piston and piston-rods, a rotary tubular valve for feeding said cylinders, a seat for said valve having a port to each of said cylinders and intake and exhaust ports to said valve, said valve having a groove and an intake-port therein for receiving explosive mixture within said valve and suitable intake grooves and ports and exhaust-grooves whereby explosive mixture is fed to said cylinders and spent mixture is exhausted from said cylinders, all of said grooves being in the periphery of said valve, and means whereby said valve is rotated by said pistons.

6. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary valve tubular and conical in shape, a seat for said valve adjacent to said cylinders having ports in communication with said cylinders, and operative means by which said valve is rotated by said pistons, said valve having a groove and a port for receiving explosive mixture therein, common intake and exhaust ports and grooves being provided in said valve whereby the cylinders laterally adjacent to each other are fed with the explosive mixture from the interior of said valve and whereby said valve exhausts said cylinders.

7. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary tubular valve for feeding said cylinders a seat for said valve adjacent to said cylinders said cylinders and said seat being formed integral, operative means for connecting said valve and said piston-rods whereby said valve is rotated by said pistons means mounted in said rotary valve for controlling the supply of explosive mixture to said cylinders and igniters mounted in the periphery of said valve for igniting the explosive mixture in said cylinders.

8. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary tubular valve adjacent to all of said cylinders and provided with a shaft, and operative means for connecting said valve-shaft and said pistons, said valve being provided with intake and exhaust ports communicating with said cylinders, means for converting the intake-ports to exhaust-ports for reversing the engine, and means for automatically maintaining a supply of compressed air to be used for reversing and starting purposes.

9. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary valve provided with suitable gearing by which said valve is rotated by said pistons, said valve being provided with means for feeding and exhausting said cylinders, and an oscillating valve mounted in said rotary valve for reversing the engine.

10. An engine comprising a plurality of cylinders provided with suitable pistons and piston-rods, a rotary tubular valve provided with suitable gearing whereby said valve is rotated by said pistons a valve-seat integral with said cylinders, means for feeding said cylinders with explosive mixture through said valve, means carried in said valve for controlling the supply of explosive mixture and means carried in the periphery of said valve for igniting the explosive mixture in each of said cylinders in succession whereby the energy created by explosion in each cylinder is utilized to drive the said valve for feeding the next cylinder.

11. An engine comprising a plurality of tandem cylinders arranged in pairs, pistons for said cylinders, piston-rods for said pistons, the pistons of the tandem cylinders having their pistons mounted on a common piston-rod, a crank-shaft engaged by said piston-rods, a rotary valve for feeding said cylinders, a valve-seat integral with all of said cylinders, and gearing by which said valve is rotated by said pistons.

12. An engine comprising a plurality of cylinders in pairs, a rotary tubular valve for feeding said cylinders, a seat for said valve integral with said cylinders, the cylinders longitudinally adjacent to each other having a common piston-rod and each having a piston mounted on said rod, a single crank-shaft having suitable bearings, all of the piston-rods being connected to said crank-shaft, gearing by which said shaft drives said rotary valve, and means for supplying said valve with explosive mixture.

13. In an engine composed of a plurality of cylinders provided with suitable pistons, and piston-rods; a valve-seat in operative connection and integral with said cylinders, a rotary

tubular valve mounted in said seat, operative means by which said valve is rotated by said pistons, and means for supplying said valve with explosive mixture, said valve having suitable intake-grooves and exhaust-grooves in the periphery thereof and suitable ports in said grooves in communicative relation to ports in said cylinders.

14. In an engine composed of a plurality of cylinders provided with suitable pistons and piston-rods; a valve-seat integral with and having ports to said cylinders, a rotary valve tubular in structure and mounted in said seat, means for rotating said valve, means for directing explosive mixture to the interior of said valve, said valve having intake and exhaust grooves in the periphery thereof and intake and exhaust ports in said grooves, and exhaust-pipes for discharging the spent explosive mixture.

15. In an engine composed of a plurality of cylinders provided with suitable pistons and piston-rods; a tubular valve-seat adjacent to and integral with said cylinders and having ports to said cylinders, a tubular valve mounted in said seat and constructed with suitable grooves and ports for feeding and exhausting said cylinders, means for feeding and exhausting said valve, operative means by which said valve is rotated by said pistons, and means carried in the periphery of said valve for igniting the explosive mixture.

16. In an engine composed of a plurality of cylinders provided with suitable pistons and piston-rods; a tubular valve-seat adjacent to said cylinders provided with ports to said cylinders, a tubular valve mounted in said seat provided with suitable ports and grooves for feeding and exhausting said cylinders, means carried by said rotary valve for igniting the explosive mixture in said cylinders, and an oscillating valve mounted in said rotary valve for reversing said engine.

17. In an engine provided with a plurality of cylinders provided with suitable pistons and piston-rods, a rotary valve and means for rotating said valve by said pistons; a valve-seat for said valve having ports leading to said cylinders and suitable ports for supplying and exhausting said valve, said valve having ports, leading from the interior thereof to grooves in the periphery thereof for supplying said cylinders with explosive mixture and similar ports and grooves for exhausting the spent mixture from said cylinders and means carried in the periphery of said valve for igniting the explosive mixture.

18. In an engine provided with a plurality of cylinders and a rotary tubular valve for feeding said cylinders with explosive mixture and for exhausting the spent explosive mixture; a pipe for supplying said valve with explosive mixture, and means mounted in said valve for regulating the amount of explosive mixture fed by said valve to said cylinders.

19. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent explosive mixture; means for supplying said valve with explosive mixture, an oscillating valve carried in said rotary valve for reversing purposes, and means carried by said oscillating valve for regulating the supply of explosive mixture fed to said cylinders by said rotary valve.

20. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of the spent mixture; means for supplying said valve with explosive mixture, an oscillating valve carried in said rotary valve for reversing purposes, means carried by said oscillating valve for governing the supply of explosive mixture fed to said cylinders by said rotary valve, and means carried in the periphery of said rotary valve for igniting said explosive mixture in said cylinders.

21. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with the explosive mixture and to exhaust said cylinders of spent mixture; means for supplying said rotary valve with explosive mixture, and means carried in said valve for igniting the explosive mixture in said cylinders consisting of a wire mounted in the periphery thereof for carrying a current of electricity, an insulated rod mounted within said valve and connected to one end of said wire, the other end of said wire being connected to said valve and consequently to the entire engine, and means for making electrical connection with said rod and the engine.

22. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means for supplying said valve with explosive mixture, means carried by said valve for igniting the explosive mixture in said cylinders, means for shifting the position of said valve long enough to cut off explosive mixture from said igniting means whereby the energy of the engine ceases and means operated by said valve for reversing the engine.

23. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means for supplying said valve with explosive mixture, means carried by said valve for igniting the explosive mixture in said cylinders, an oscillating valve mounted in said rotary valve, means for shifting the position of said valves relative to each other whereby the explosive mixture is cut off from said igniting means and in consequence the

energy of the engine is checked, and means for reversing the engine.

24. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means supplying said valve with explosive mixture, an oscillating valve mounted in said valve, and means for regulating the supply of explosive mixture, fed to said cylinders by said rotary valve consisting of weights for closing the intake-ports and spring-arms for attaching said weights to said oscillating valve.

25. In an engine provided with a plurality of cylinders and a rotary tubular valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means for supplying said valve with explosive mixture, an oscillating valve mounted in said rotary valve, and means for regulating the supply of explosive mixture fed to said cylinders by said rotary valve consisting of weights for closing or partly closing the intake-port from said rotary valve to said cylinders, spring-arms attached to said oscillating valve and carrying said weights and a yoke mounted on said arms for regulating the motion of said weights.

26. In an engine provided with a plurality of cylinders and a rotary valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means for igniting the explosive mixture in said cylinders consisting of a wire carried in the periphery of said valve and having one end thereof connected to said valve and consequently to the engine-frame, an insulated rod mounted within said valve and connected to the other end of said wire, an insulated ring to which said rod is connected, and means for making electrical connections with said ring and the frame of the engine.

27. In an engine provided with a plurality of cylinders and a rotary valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means carried in the periphery of said valve for igniting the explosive mixture in said cylinders, means for cutting the explosive mixture off from said igniting means, suitable compressed-air cylinders, and means for admitting compressed air through said valve into the compressed-air cylinders for reversing the engine.

28. In an engine provided with a plurality of tandem cylinders provided with suitable pistons and a rotary valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; intermittent compressed-air cylinders in each rear cylinder in front of its piston and means for admitting compressed air to said compressed-air cylinders for reversing the engine.

29. In an engine provided with a plurality of cylinders and a rotary valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; compressed-air cylinders adjacent to said valve and in front of the pistons of the rear cylinders and means for admitting compressed air through the periphery of said valve to said compressed-air cylinders for reversing purposes.

30. In an engine provided with a plurality of tandem cylinders partition-packing between the front and rear cylinders and a rotary valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; a compressed-air cylinder alternately formed between the partition-packing and the piston in each rear cylinder, means carried in the periphery of said valve for igniting the explosive mixture in said cylinders, means for cutting the explosive mixture off from said igniting means, and means for admitting compressed air through the periphery of said valve into said compression air-cylinders.

31. In an engine provided with a plurality of tandem cylinders partition-packing between the front and rear cylinders and a rotary valve adapted to feed said cylinders with explosive mixture and to exhaust said cylinders of spent mixture; means for forming compressed-air cylinders between the partition-packing and the piston of the rear cylinders; means for accumulating a supply of compressed air automatically by the energy of said engine, and means for admitting compressed air to said compressed-air cylinders through the periphery of said valve for reversing purposes.

32. An engine comprising a plurality of tandem cylinders for receiving explosive mixture, means for forming compressed-air cylinders between the partitions, a rotary tubular valve for feeding and exhausting said cylinders, means for supplying explosive mixture to the interior of said valve, an oscillating valve mounted in said rotary valve, said valves having peripheral grooves therein and said rotary valve having suitable ports for feeding explosive mixture to the explosive-mixture cylinders and similar grooves and ports for exhausting spent mixture, said rotary valve having peripheral grooves for feeding and exhausting compressed air to and from said compressed-air cylinders, means for rotating said rotary valve, a shaft keyed to said valve and suitable mechanism for transmitting the energy of said cylinders to said shaft, means carried by said rotary valve for igniting the explosive mixture in said cylinders and means for reversing said engine consisting of a clutch for shifting the positions of said valves relative to each other and a valve for turning compressed air to said rotary valve.

33. An engine comprising a plurality of cyl-

inders, a tubular rotary valve for feeding explosive mixture to said cylinders and exhausting spent mixture from said cylinders, means for supplying explosive mixture to the interior of said valve, means for rotating said valve, said valve having intake-grooves in the periphery thereof and ports from the interior thereof to said grooves whereby explosive mixture is fed to said cylinders, said cylinders being provided with suitable ports, said rotary valve having suitable ports and grooves for exhausting spent mixture from said cylinders, an oscillating valve mounted in said rotary valve and provided with grooves to complete the passage for explosive mixture through said rotary valve, means carried by said rotary valve for igniting the explosive mixture in said cylinders, and means for shifting the position of said valves relative to each other whereby the intake ports and grooves in said rotary valve are converted to exhaust grooves and ports and vice versa.

34. An engine comprising a plurality of cylinders arranged in a quadrangle, a valve-seat having ports communicating with said cylinders, a rotary tubular valve mounted in said seat and adapted to feed said cylinders with explosive mixture and to exhaust spent mixture from said cylinders, means for driving said valve whereby said valve delivers explosive mixture to said cylinders in succession, means for forming compressed-air cylinders between the packing and the pistons in the rear cylinders for starting and reversing purposes, said valve being adapted to feed compressed air to said compressed-air cylinders and to exhaust air from said cylinders, an oscillating valve mounted in said rotary valve and provided with means for directing and regulating the supply of explosive mixture fed to said cylinders by said rotary valve, said rotary valve carrying means for igniting the explosive mixture in said cylinders, and means for shifting the positions of said valves relative to each other whereby the engine may be reversed, by compressed air.

35. An engine provided with a plurality of cylinders, a rotary valve for feeding said cylinders with explosive mixture, said cylinders being provided with suitable pistons and piston-rods, a crank-shaft, said piston-rods connected to said crank-shaft, a worm gear-wheel mounted on said shaft, a shaft connected to said rotary valve, a worm-gear mounted on said shaft and meshing with said first-named gear, whereby said valve is driven by the energy from said cylinders, said valve being tubular and conical in shape, a seat for said valve, means for adjusting said valve in said seat, gearing for transmitting the power of said engine from said valve-shaft, and means for varying the speed of said gearing.

36. An engine comprising a plurality of tandem cylinders provided with suitable pistons and piston-rods, a rotary valve for feeding said cylinders with explosive mixture, a common crank-shaft, said piston-rods being connected to said shaft, a valve-shaft connected to said valve, suitable gearing by which the energy of said cylinders is transmitted to said valve-shaft for rotating said valve and for applying to the object to be driven, gearing for transmitting the power of the engine, means for varying the speed of said gearing, a pump for compressing air, suitable gearing for automatically operating said pump by the energy of the engine, means for forming compressed-air cylinders between the packing and the pistons in the rear cylinders and means for admitting compressed air to said cylinders for reversing and starting purposes.

In testimony whereof I set my hand, in the presence of two witnesses, this 5th day of April, 1901.

EDWIN L. RUSSELL.

Witnesses:
J. B. WENSLETT,
A. L. JACKSON.