(No Model.)

6 Sheets—Sheet 1.

H. C. BAKER.

GAS ENGINE.

No. 563,249.

Patented July 7, 1896.

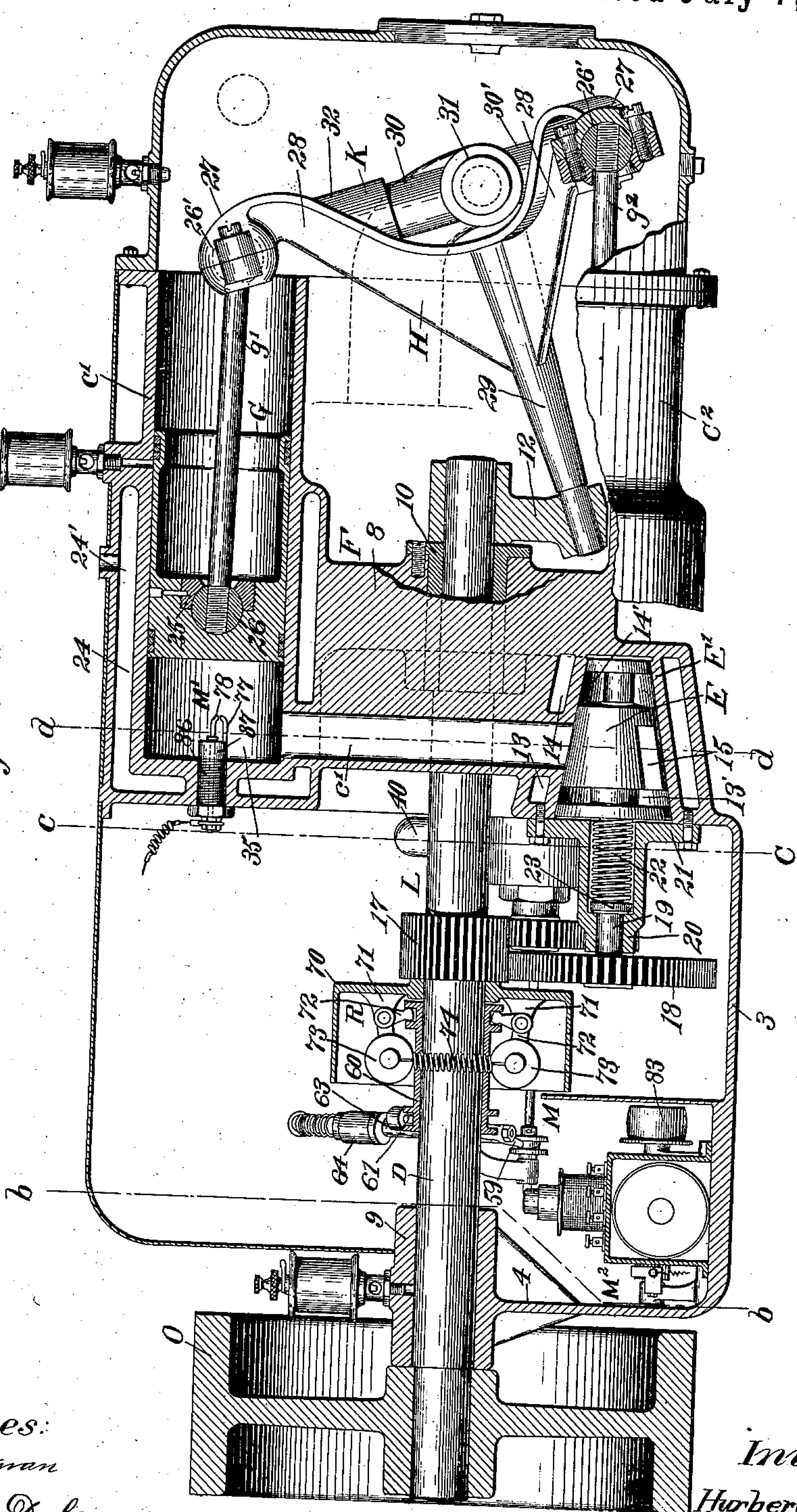

Fig. 1.

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(No Model.)

6 Sheets—Sheet 2.

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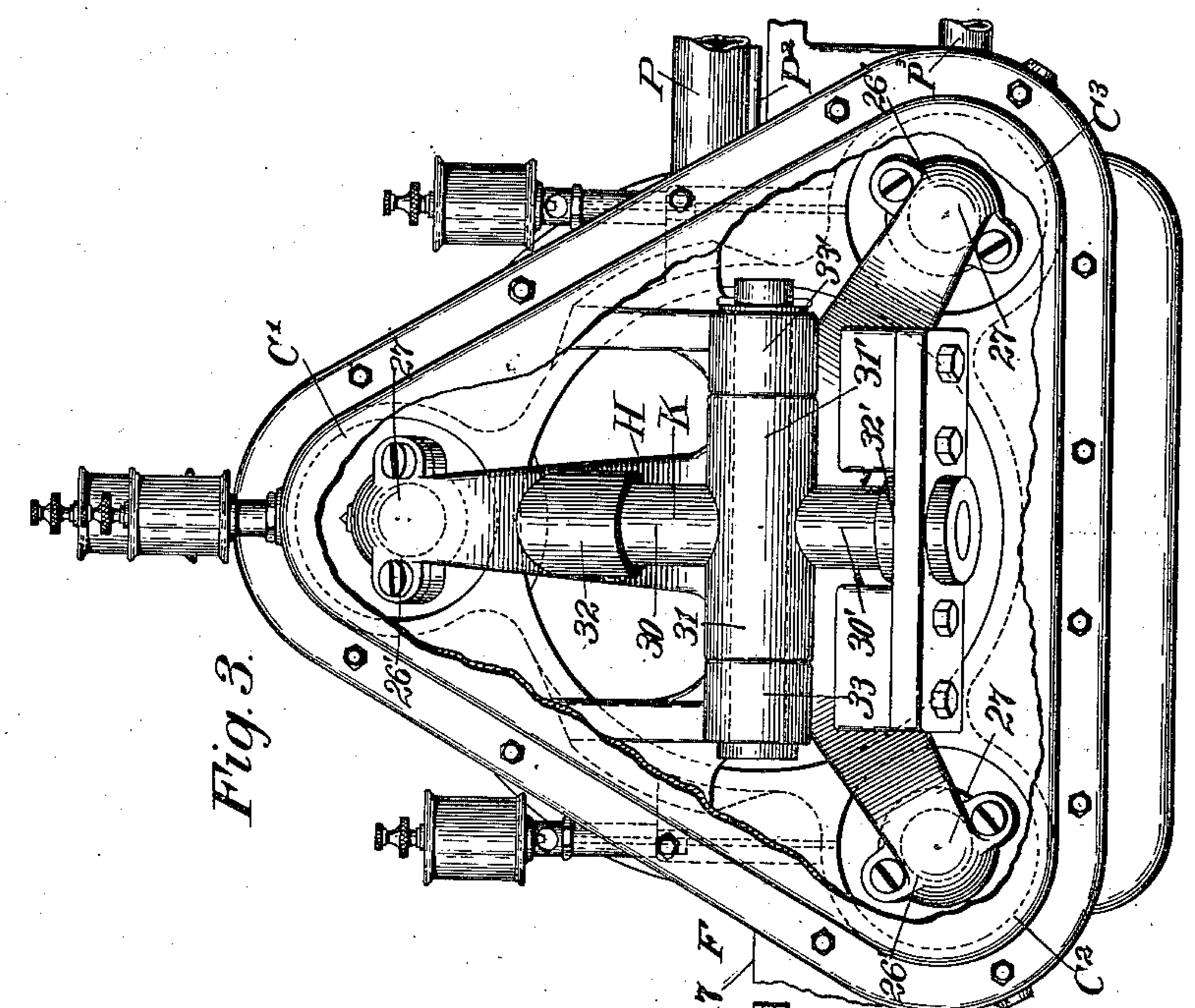

Fig. 3.

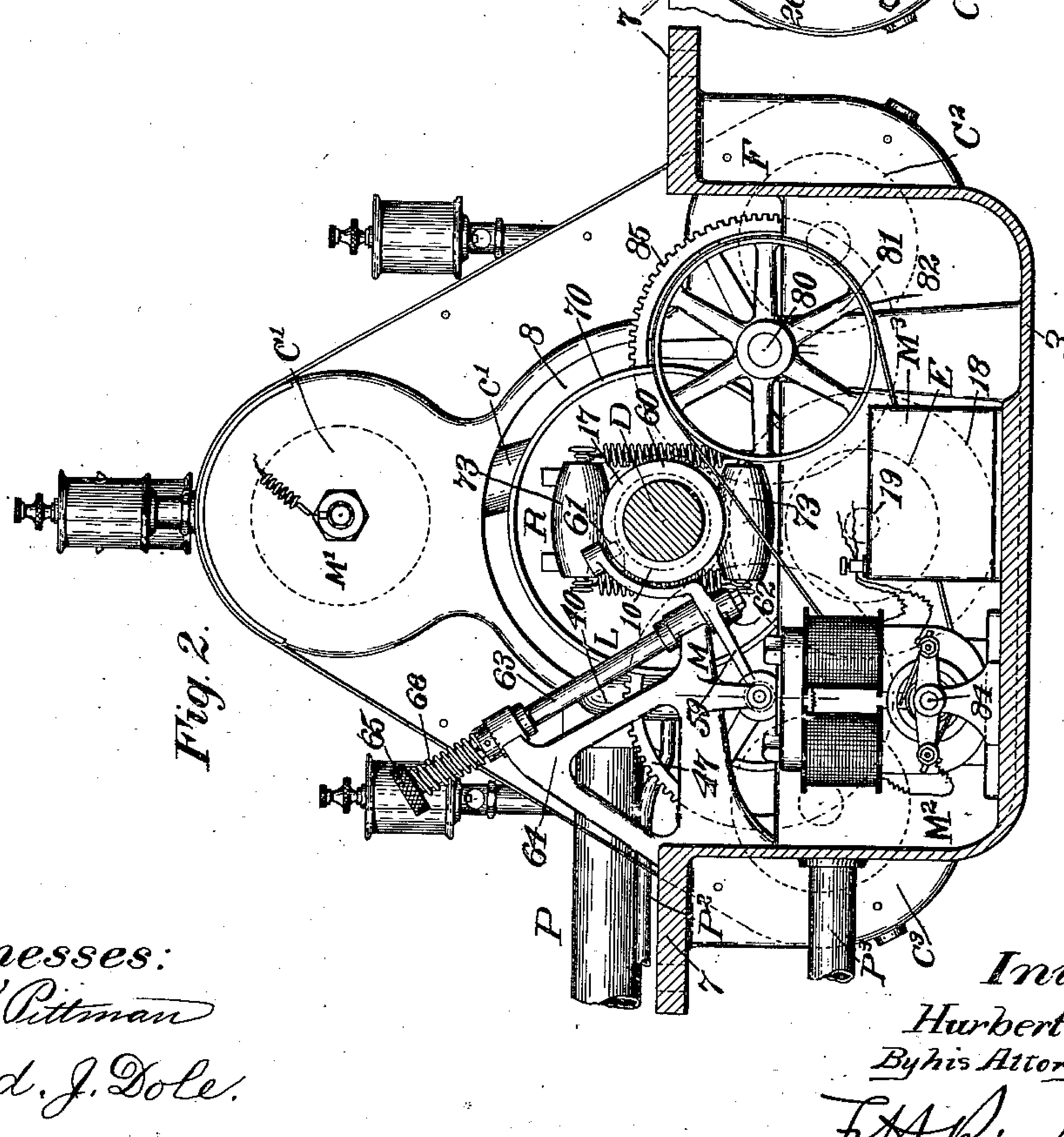

Fig. 2.

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6 Sheets—Sheet 3.

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GAS ENGINE.

No. 563,249.

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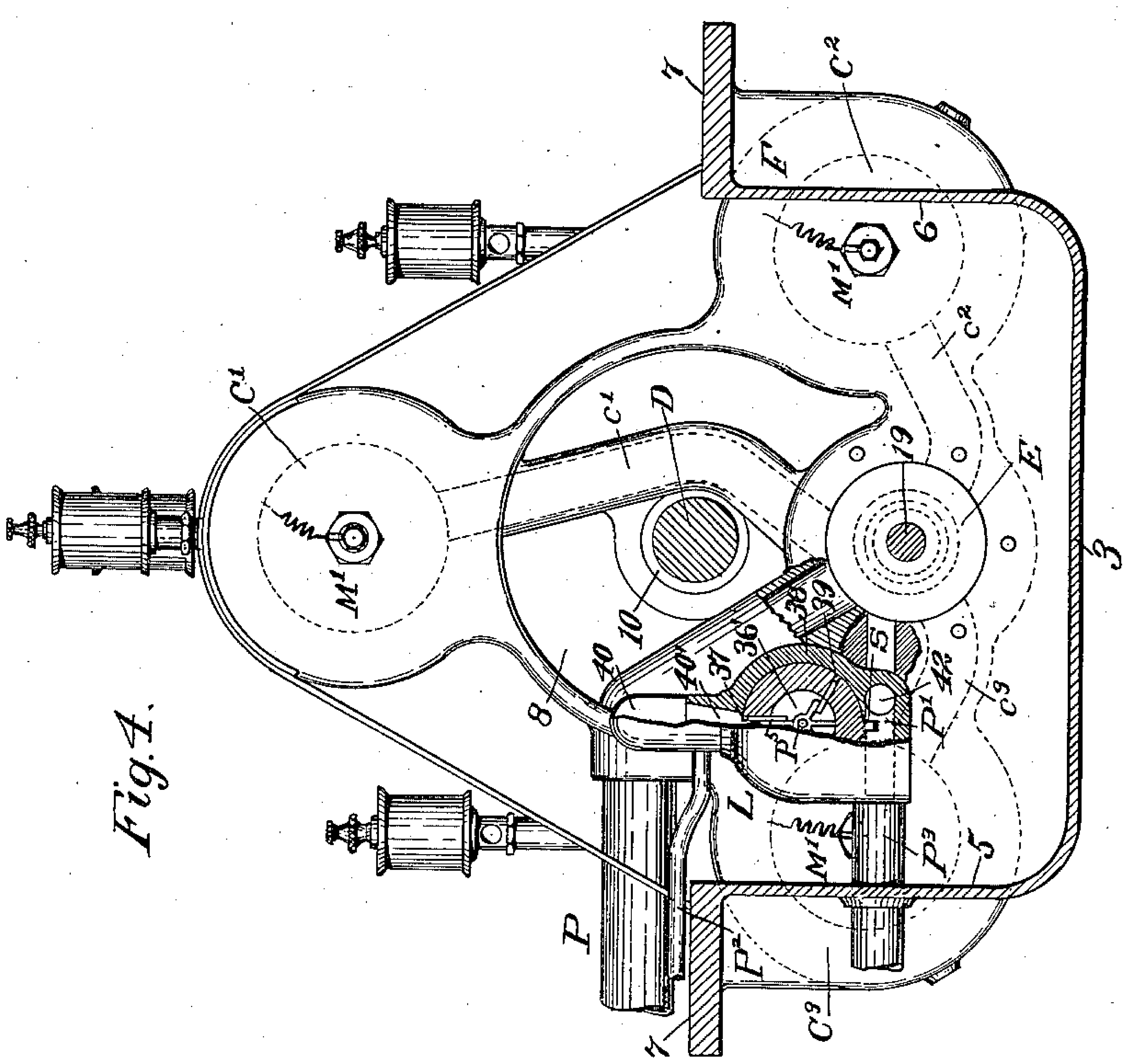
Fig. 4.



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6 Sheets—Sheet 4.

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GAS ENGINE.

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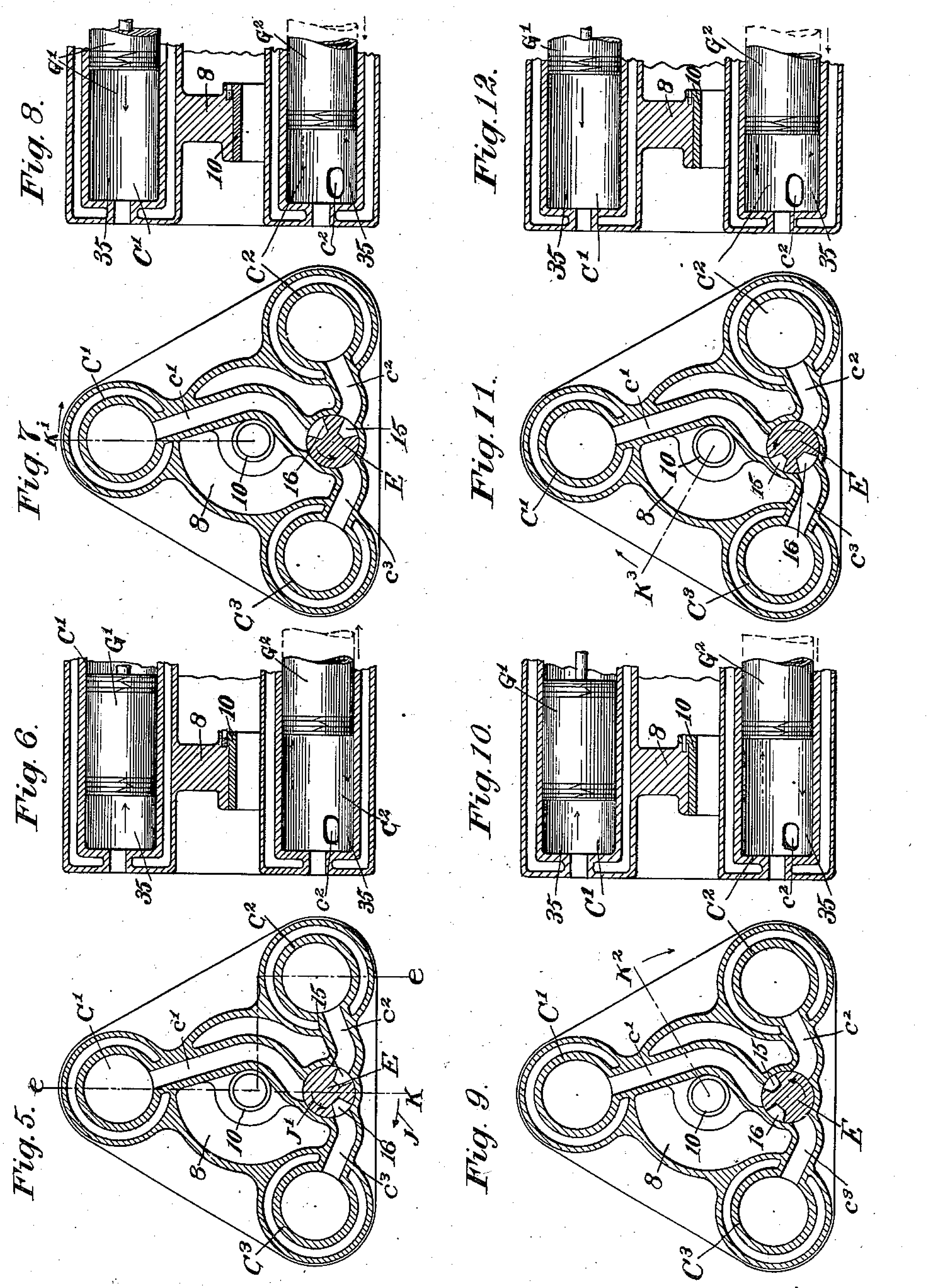

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6 Sheets—Sheet 5.

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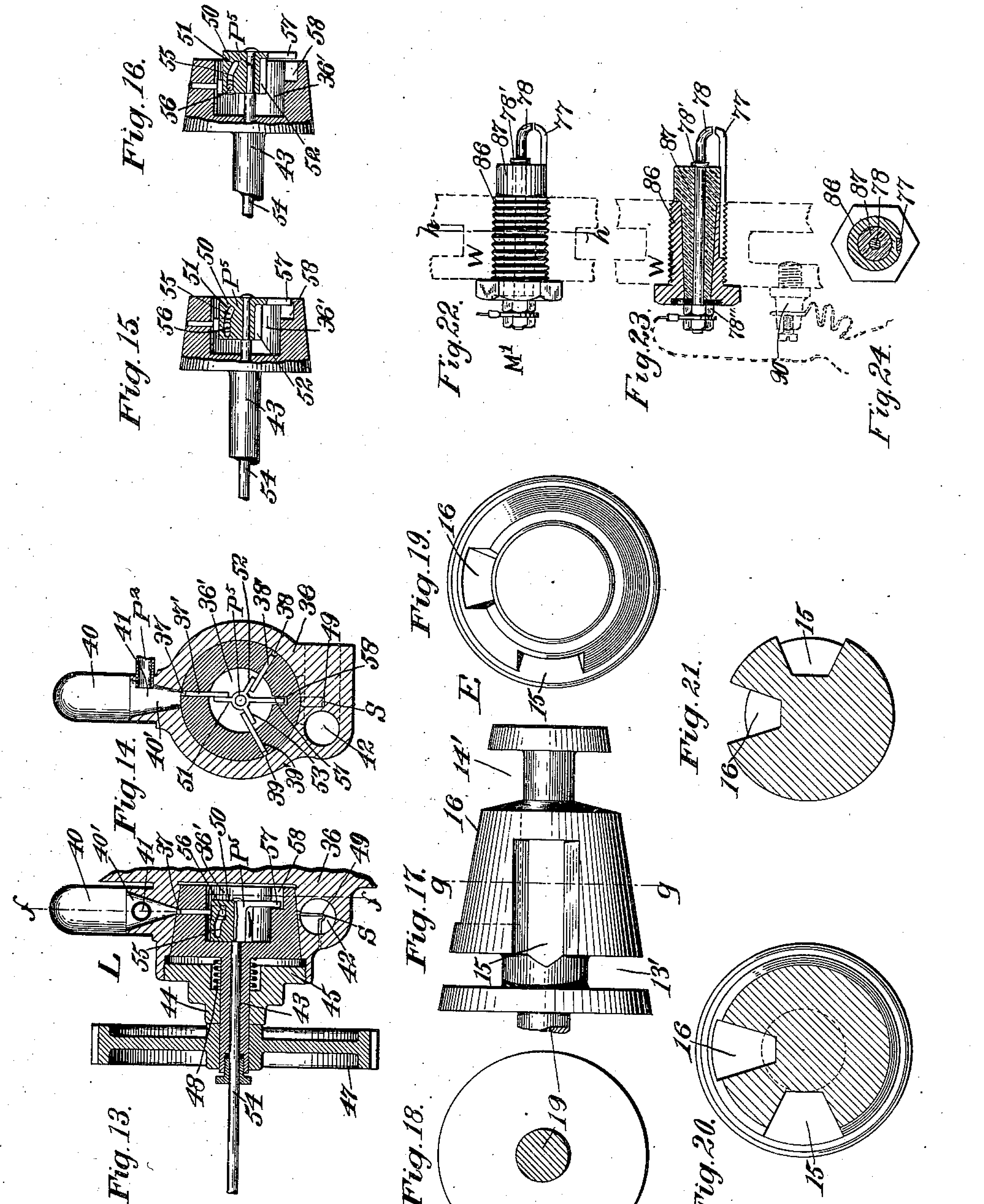
GAS ENGINE.

No. 563,249. Patented July 7, 1896.



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6 Sheets—Sheet 6.

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GAS ENGINE.

No. 563,249. Patented July 7, 1896.

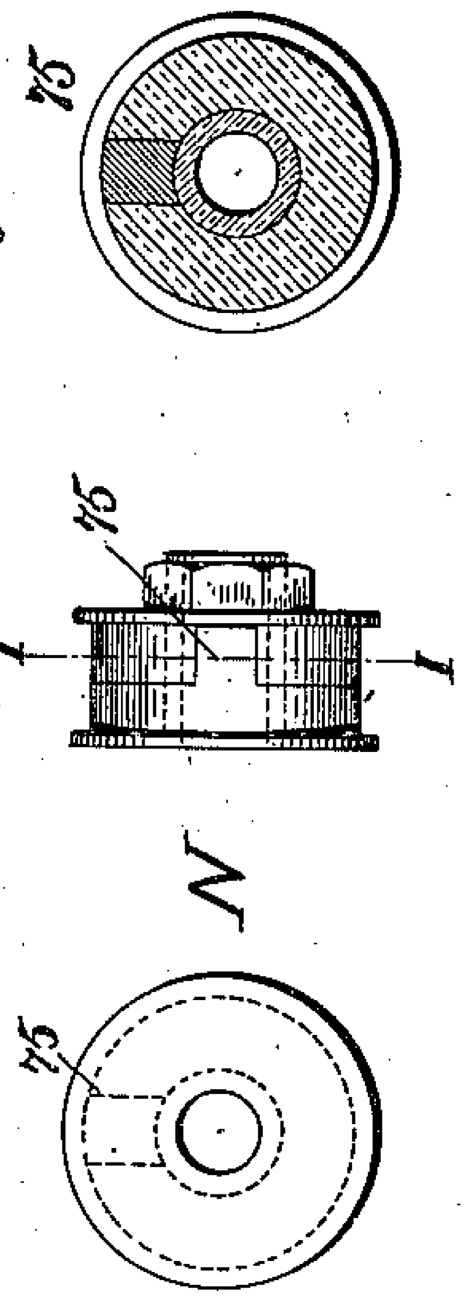

Fig. 32. Fig. 31. Fig. 30.

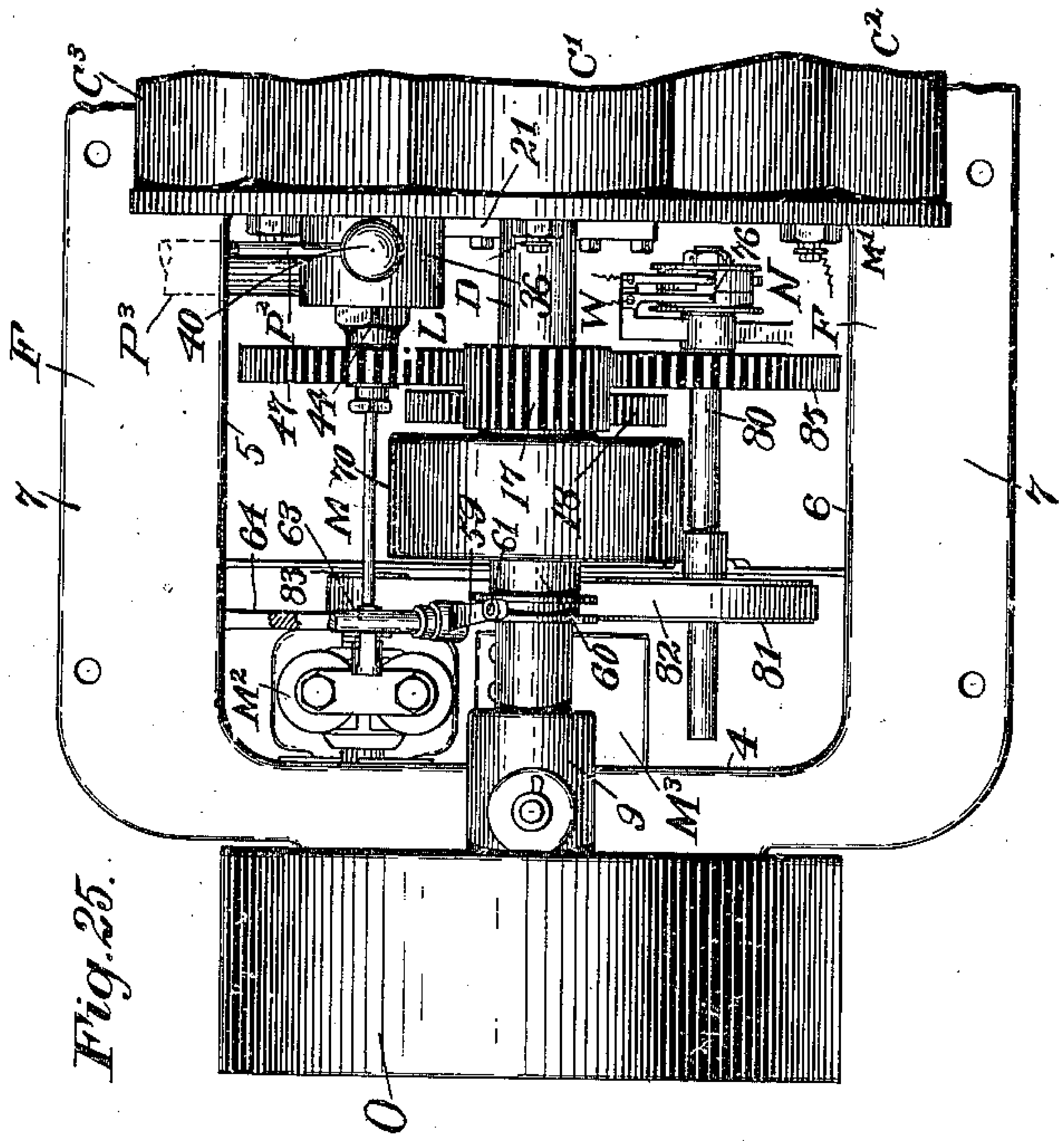

Fig. 25.

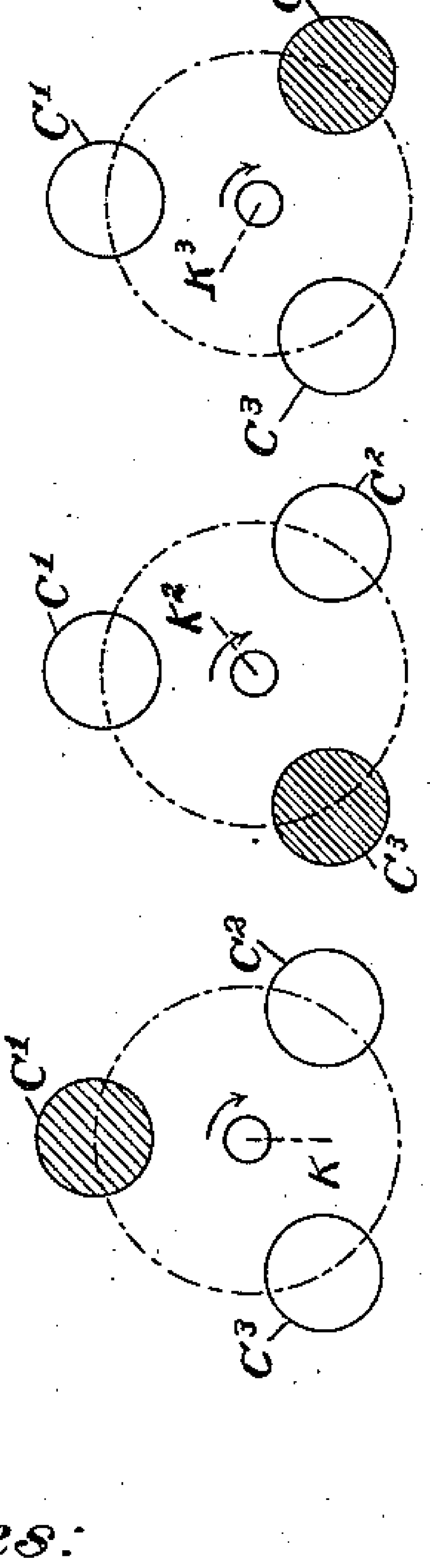

Fig. 28. Fig. 27. Fig. 26.

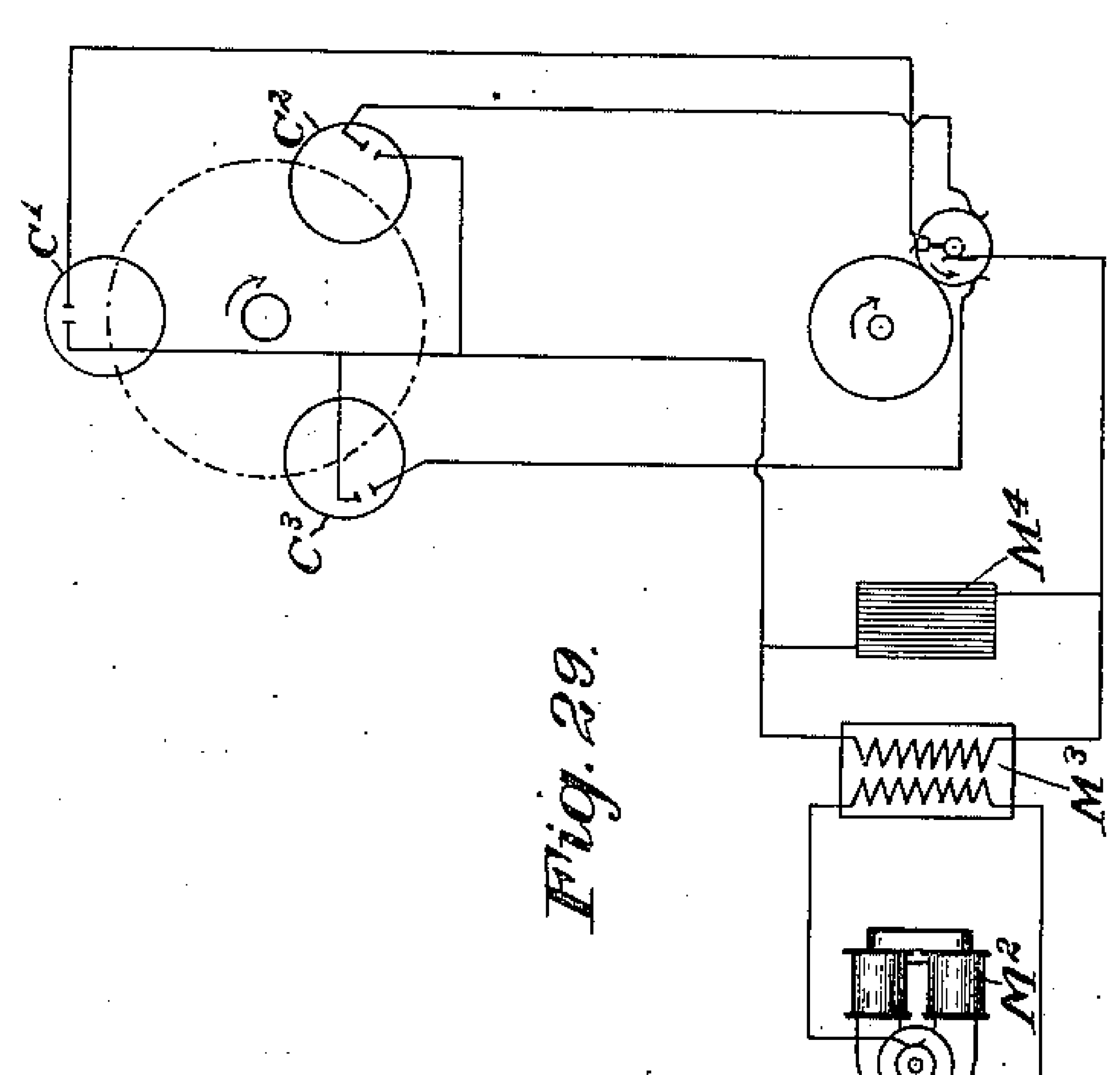

Fig. 29.

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UNITED STATES PATENT OFFICE.

HURBERT C. BAKER, OF HARTFORD, CONNECTICUT.

GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 563,249, dated July 7, 1896.

Application filed August 17, 1895. Serial No. 559,593. (No model.)

To all whom it may concern:

Be it known that I, HURBERT C. BAKER, a citizen of the United States, residing at Hartford, in the county of Hartford and State of Connecticut, have invented certain new and useful Improvements in Gas-Engines, of which the following is a specification.

This invention relates to gas-engines of that class in which the power for driving the piston is derived from the explosion within the piston-cylinder of a suitable combustible mixture—such, for instance, as a mixture of air and the vapor of naphtha or other volatile liquid hydrocarbon.

One object of my present invention is to produce an improved, compact, durable, and efficient engine of the class specified, and one which will run at a high rate of speed and develop the maximum amount of power for a given quantity of gas consumed, and one which will also operate with a relatively uniform rotative effect, with little noise, and with a minimum amount of friction of the working parts.

Another object of my invention is to provide, in connection with the gas-engine, improved means for the automatic production of the gas or combustible mixture in quantities proportioned to the work performed by the engine, and whereby the supply of gas—which in this engine is carried to and is exploded in the piston cylinder or cylinders—is automatically decreased and increased in proportion to the increase and decrease, respectively, in the speed of the engine when said engine is running below its speed limit, and is automatically shut off when the engine reaches its speed limit.

Another object of my invention is to furnish an improved gas-engine having a series of cylinders equidistantly disposed about a crank-shaft, with their axes parallel to each other and to said crank-shaft, and having pistons operatively connected with the crank-shaft by means of a universally-oscillating connector or compound lever, and having improved means for producing the explosive mixture and introducing the same into the exploding ends of the successive cylinders alternately, and also having improved igniting means controlled by the crank-shaft for alternately igniting the explosive mixtures in the successive cylinders.

Another object of my invention is to so construct and organize the several coöperative mechanisms of the gas-engine that each piston will have a double reciprocation between each explosion, and will have an action in alternating relation with the other pistons, and whereby the explosive mixture will be first drawn into the exploding-chamber by one forward stroke of the piston, will then be compressed by a backward stroke of the piston, after which the igniting mechanism will operate to explode the compressed combustible mixture, which will drive the piston forward, after which the products of combustion are exhausted upon the next backward stroke of said piston.

Another object of my invention is to furnish improved valve mechanism directly actuated by the crank-shaft for properly controlling and timing the induction of the explosive mixture to the combustion-chambers of the several cylinders, and for controlling and timing the exhaust of the products of combustion, so that the piston will, in point of time, have effective operations alternately.

In the preferred embodiment of my invention herein shown and described the gas-engine comprises, in part, a suitable bed or framework; a crank-shaft journaled for rotation in suitable bearing in said bed; one or more cylinders substantially in axial parallelism with the crank-shaft; one or more pistons operatively connected with the crank-shaft by means of a reciprocatory connector; an induction and eduction port communicating with each cylinder; gas producing and controlling mechanism embodying a rotative feed-valve actuated by the crank-shaft, and a governor controlled by the speed of the crank-shaft and having means for effecting a variation in the feeding capacity of the valve in proportion to the speed of the crank-shaft; a rotative engine-valve driven from the crank-shaft, and adapted for controlling the induction of the gaseous mixture to each cylinder, and also for controlling the exhaust; and igniting apparatus controlled by the crank-shaft for igniting the gaseous mixture in each cylinder to effect an explosion of the same at the required time and cause the piston to move forward, all substantially as hereinafter described, and more particularly set forth in the claims.

In the drawings accompanying and forming part of this specification, Figure 1 is a sectional side elevation of the gas-engine, said section being taken on the longitudinal line drawn through the center of the engine. Fig. 2 is a sectional end view of the engine, taken in dotted line *b b*, Fig. 1, looking toward the right hand in said figure. Fig. 3 is an end view of the engine as seen from the right hand in Fig. 2, a portion of the hood or end casing being broken away. Fig. 4 is a cross-sectional view of the gas-engine, taken in dotted line *c c*, Fig. 1, and looking toward the right hand in said figure, parts thereof being broken away to more clearly show the relations of the inlet and outlet passages of the cylinders and the induction and exhaust ports of the engine-valve. Fig. 5 is a cross-sectional view, on a relatively small scale, of a portion of the engine, taken in dotted line *d d*, Fig. 1, and shows the position of the engine-valve on the explosion of the mixture in the upper cylinder, in which position the induction-port of the valve is in communication with, and explosive mixture is being drawn into, the lower left-hand cylinder, and the exhaust-port of said valve is in communication with, and the products of combustion are being exhausted from, the lower right-hand cylinder. Fig. 5 is the first one of a series of groups of figures illustrating successive positions of the engine-valve and the relative positions of two pistons during two complete rotations of the crank-shaft or one complete cycle of movements of the engine-valve. Fig. 6 is a vertical longitudinal section of a portion of the engine, taken in dotted line *e e*, Fig. 5, looking toward the left hand in said figure, and shows the upper and lower right-hand pistons in the relative positions they occupy when the engine-valve is in the position shown in Fig. 5. Fig. 7 is a sectional view similar to Fig. 5, showing the engine-valve advanced sufficiently to bring its exhaust-port into communication with the upper cylinder and with its induction-port in communication with the lower right-hand cylinder. In this position of the valve the upper cylinder is being exhausted, the lower right-hand cylinder is drawing in gaseous mixtures, and the mixture which was drawn into the lower left-hand cylinder on the preceding operation of the valve is being compressed. Fig. 8 is a sectional view similar to Fig. 6, showing the relative positions of the same piston when the valve is in the position shown in Fig. 7. Fig 9 is a cross-sectional view similar to Figs. 5 and 7, showing the engine-valve advanced sufficiently to bring its induction-port partly in communication with the upper cylinder. In this position of the valve the upper cylinder is drawing in explosive mixture, the lower right-hand cylinder is compressing the mixture drawn into it on the last preceding operation of the valve, and the gaseous mixture which was compressed in the lower left-hand cylinder on the last preceding operation of the valve and cylinder-piston is being exploded. Fig. 10 is a vertical section similar to Figs. 6 and 8, and shows the relative positions of the two pistons shown in Figs. 6 and 8 when the valve is in the position shown in Fig. 9. Fig. 11 is a cross-sectional view similar to Figs. 6, 7, and 9, showing the next succeeding or third position of the engine-valve, and shows the exhaust-port of the valve in communication with the lower left-hand cylinder and the ports of the other cylinders closed. In this position of the valve the piston of the upper cylinder is on its return or backward stroke and is compressing the gaseous mixture contained in the exploding end of said cylinder, while the gaseous mixture compressed in the lower right-hand cylinder by the last preceding operation of the piston of said cylinder is being exploded and the products of combustion in the lower left-hand cylinder are being exhausted. Fig. 12 is a vertical section similar to Figs. 6, 8, and 10, and shows the relative positions of the two pistons shown in said figures when the valve is in the position shown in Fig. 11. Fig. 13 is a vertical longitudinal section of a portion of the engine, on a relatively large scale, showing the construction and organization of the feed-valve, or what will be sometimes herein termed the "naphtha-valve," said figure being intended to illustrate the arrangement and operation of the feed-regulator. Fig. 14 is a cross-sectional view, taken in dotted line *f f*, Fig. 13, looking toward the left hand in said figure and showing a portion of the parts in the same position shown in said Fig. 13. Fig. 15 is a sectional side elevation of the valve and feed-regulator detached from the valve-chest, and shows the feed-regulator in an intermediate or middle position or in the position it occupies when the engine is running at a moderately high rate of speed, and the feeding capacity of the valve is reduced as compared with its capacity when the feed-regulator is in the position shown in Fig. 13. Fig. 16 is a sectional side elevation similar to Fig. 15, of the valve, showing the feed-regulator in the position it occupies when the engine has reached its speed limit and the regulator is in the position to cut off the supply of liquid. Fig. 17 is a side elevation, on a relatively large scale, of the engine-valve detached. Fig 18 is an end view of said engine-valve as seen from the left hand in Fig. 17. Fig. 19 is an end view of said engine-valve as seen from the right hand in Fig. 17. Fig. 20 is a cross-sectional view of the engine-valve, taken in dotted line *g g*, Fig. 17, looking toward the left hand in said figure. Fig. 21 is a cross-sectional view of said valve, taken in dotted line *g g*, Fig. 17, and looking toward the right hand in said figure. Fig. 22 is a side view, on a relatively large scale, of the igniter or spark-producing device of the ignition apparatus. Fig. 23 is a longitudinal section of said igniter. Fig. 24 is a cross-sectional view of said igniter, taken in line *h h*, Fig. 22, looking toward the right hand in said figure. Fig. 25 is a plan view of a portion of the gas-engine as seen from above in Figs. 1, 2, and 3, said figure being intended to illustrate the relative positions of the gas producing and igniting apparatuses. Figs. 26, 27, and 28 are similar graphic diagrams, illustrating, in the order of their numeration, three successive explosions of the mixtures in the three engine-cylinders, and illustrating the alternating order of explosions relatively to the three successive cylinders, the group of figures illustrating one cycle of explosions alternately in successive cylinders during one and one-third of a revolution of the crank-shaft of the engine. Fig. 29 is a diagrammatic view illustrating one form of electric ignition apparatus in circuit with the three cylinders of the gas-engine. Fig. 30 is an end view of one form of revoluble commutator or three-way switch as seen from the left hand in Fig. 31. Fig. 31 is a side view of said three-way switch; and Fig. 32 is a cross-sectional view of said three-way switch, taken in dotted line I I, Fig. 31, and looking toward the left hand in said figure.

Similar characters designate like parts in all the figures of the drawings.

As a preliminary to the general description, construction, and mode of operation of the several mechanisms of my improved gas-engine, it is desired to state that, while I prefer to use a mixture of naphtha and air for generating a highly-combustible gas for operating the engine, any suitable liquid hydrocarbon mixed with air may be employed for this purpose. For instance, a combustible gas may be generated for this purpose by forcing air through such liquid hydrocarbons as petroleum, rock-oil, kerosol, rhigol, gasolene, canodol, benzin, ligroine, petrolin, petroleum-ether, spirits of petroleum, &c., the volatile products of which, when mixed with air, form explosive mixtures adapted for the purposes of the present invention, and inasmuch as all hydrocarbons which can be employed for this purpose will, when mixed with air, generate an explosive gas, this product—which constitutes the explosive charge for the cylinder or cylinders of the engine—will, for convenience, be hereinafter referred to as "gas."

In the preferred embodiment thereof herein shown and described, the gas-engine has three cylinders, which are designated by C′, C², and C³, respectively, which are equidistantly disposed about and are in parallelism with the main or crank shaft, (designated by D.) It will be understood, however, that one or any suitable number of cylinders, arranged in any suitable manner, may be employed within the scope and limits of my invention, although in most cases it is preferable to employ three cylinders arranged as shown in the drawings. Therefore I do not desire to limit my invention to any particular number of cylinders or to the particular arrangement thereof.

In the present instance, the cylinders C′, C², and C³ of the engine are shown integral with a base or framework. This framework or base—which is designated in a general way by F, and which may be of any suitable construction for carrying the fixed and operative parts of the engine—will preferably comprise the bed-plate 3, the rear end wall 4, the two side walls 5 and 6, which rear and end walls are shown flanged at their upper ends, as at 7, and the main body portion 8, in which body portion 8 the cylinders C′, C², and C³ are formed, and in which the ports of the cylinders are located, as will be understood by reference to Figs. 1 to 5, inclusive, of the drawings.

It will be understood, that while it is desirable to cast the cylinder and framework in one piece, the framework might be made in several pieces bolted together, and the cylinders might be made separately and secured to the framework in any suitable manner.

The main shaft D of the engine, which will be herein termed "the crank-shaft," is shown supported at its rear end in a suitable bearing 9, formed in the rear wall 4 of the framework, and is shown supported at its forward end in a bushing 10, secured in a bore in the main body portion of the framework. This shaft is preferably located in horizontal parallelism with the axes of, and midway between the three cylinders C′, C², and C³, and is provided at its forward end with a crank 12, as will be understood by reference to Fig. 1 of the drawings.

As a simple and convenient means for supplying gas in regulated quantities, alternately, to the three cylinders C′, C², and C³ at regular intervals, I have shown the engine provided with one engine-valve, (designated in a general way by E,) which will preferably be located in a valve-chest E′ intermediate between two cylinders, and communicates with said three cylinders through port-passages c', c^2, and c^3, respectively; but it will be obvious that a separate valve might be employed in direct communication with each cylinder. In the preferred form thereof herein shown this engine-valve E, which is in the nature of a rotary plug-valve, and which is seated for rotation in the conical valve-chest E′, is peripherally grooved slightly remote from its opposite ends thereof, to form, when said valve is seated in the valve-chest, a gas-supply chamber 13 of considerable area near the rearward end of said valve, and an exhaust-chamber 14 of considerable area at the forward end of said valve, as will be readily understood by reference to Fig. 1 of the drawings. By grooving the valve slightly remote from its opposite ends, as described, cylindrical journals 13′

and 14′ are formed at the extreme end of the valve-body, which have bearings at the extreme ends of the valve-chest. The gas-supply or inlet pipe P^2 leads into the supply-chamber 13 or supply end of the valve-chest E′ from one side thereof, as shown most clearly in Fig. 4, and exhaust-pipe P leads out from the exhaust-chamber 14 or exhaust end of the valve-chest at one side thereof, as shown in said Fig. 4, and as will be hereinafter more fully described.

At the requisite points in the periphery of the engine-valve E are located the inlet and exhaust ports 15 and 16, respectively, the inlet port of which is open at one end to the supply-chamber 13, and the exhaust-port of which is open at one end thereof to the exhaust-chamber 14, as will be understood by comparison of Figs. 1 and 4. These ports 15 and 16 are in the nature of recesses of the requisite area formed longitudinally in the periphery of the valve. This valve E is actuated directly from the crank-shaft D through the medium of a driving-pinion 17, fixed to said crank-shaft, which meshes with a driven pinion 18, fixed to the rearward end of the valve-stem 19, which valve-stem is seated in an elongated bearing 20 of a cap-plate 21, fixed to the open end of the valve-chest.

As a means for keeping the plug-valve E to its seat, the interior of the valve-stem bearing 20 is enlarged at its inner end to receive a seating-spring 22, which is in the nature of a spiral spring carried upon the valve-stem intermediate to the reduced outer end of the bearing 20 and journal 13′ of the valve E, said spring having a bearing at its outer end against a washer 23, loosely mounted upon the valve-stem 19, as will be understood by reference to Fig. 1 of the drawings. This valve is geared to the crank-shaft and timed to make one complete rotation to every two complete rotations of said shaft, and rotates in an opposite direction to the crank-shaft, so as to supply gas alternately to the three cylinders at each two complete reciprocations of the pistons of said cylinders.

To prevent overheating of the cylinders and valve-chest, a water-space 24 is formed around said cylinders and valve-chest, after the usual manner of engine construction, a constant circulation of water being maintained in the water-space around the cylinders and valve-chest through the inlet and outlet opening 24′ in any suitable manner.

The pistons G′, G^2, and G^3 of the cylinders C′, C^2, and C^3, respectively—which pistons may be of any suitable general construction—are each shown tubular and open at the forward ends thereof; and each piston has an adjustable ball-socket 25 in the forward face of the piston-head thereof adapted to receive a ball upon a piston-rod. The piston-rods (designated in a general way by g', g^2, and g^3, respectively) are each shown provided with a ball 26 and 26′, one at each end thereof, the balls 26 of which are seated for universal movements in the ball-sockets 25 of the piston-head, and the balls 26′ of which are seated for universal movements in ball-sockets 27, formed in the outer end of the radially-disposed arms 28 of the universally oscillatory crank-shaft actuator or rock-beam, comprising two members, (designated in a general way by H and K, respectively,) the actuating member H of which has a stem 29, concentric to the centers of the ball-sockets 27, and is connected at its rearward end to the crank 12 of the crank-shaft D, as will be readily understood by reference to Fig. 1 of the drawings.

As a novel and convenient means for supporting the oscillatory actuator or rocking beam in operative relation with the longitudinal axes of the three cylinders and at the same time facilitate a free universal movement or rocking beam of said actuator while preventing the same from turning, I have provided, in connection with the main actuating member H, a universally-movable carrying member, (designated in a general way by K,) which, in the preferred form thereof herein shown, comprises four radially and rectangularly disposed arms 30 and 30′ and 31 and 31′, the ones 30 and 30′ being normally vertically disposed and having their outer ends pivotally seated in bearings 32 and 32′ upon the crank-shaft actuator H, and the arms 31 and 31′ being horizontally disposed and having their outer ends pivotally supported in fixed bearings 33 and 33′ upon the framework of the engine, as will be readily understood by a comparison of Figs. 1 and 3 of the drawings.

By the construction and organization of connecting and actuating mechanism between the piston and crank-shaft I am enabled to maintain a fixed operative relation between the parts of said connection and effect a uniform movement of said parts with comparatively little lost motion.

As a convenient and improved means for supplying liquid hydrocarbon to the engine, and also as a means for increasing and decreasing the quantity of the supply in proportion to the speed of the engine, and for cutting off the supply when the engine has reached its speed limit, I have provided, in connection with the induction-chamber of the engine-valve, a rotative supply-valve, which will be herein termed the "feed-valve" or the "naphtha-valve," (designated in a general way by L,) which feed-valve is actuated directly upon the crank-shaft, as hereinafter described, and in connection with said feed-valve I have provided a regulating or feed-valve-regulator apparatus, (designated in a general way by M,) which is controlled in its operation by the movement of the crank-shaft D.

Before describing the construction and mode of operation of the feed-valve and regulating apparatus it is desired to state that the working strokes of the pistons are relatively short as compared with the length of their cylinders and have their extreme backward stroke terminated at points remote from the inner end of the cylinders, so as to leave a space of considerable area at the inner end of said cylinders, as shown at 35, which spaces constitute the explosion-chambers for the explosive charge.

Briefly stated, the liquid hydrocarbon is supplied to the feed-valve from a suitable supply-pipe P^2, is carried around and deposited in the inlet-pipe P′ of the engine-valve E, where it is mixed with air introduced by a suitable pipe P^3 in communication with the pipe P′, whence the gas generated by the mixture of the gas and air is introduced through the engine-valve into the port-passages c', c^2, and c^3 alternately, and thence to the exploding-chambers 35 of the piston-cylinders C′, C^2, and C^3, where said gas is compressed, ignited, and exploded, in a manner hereinafter more fully set forth.

The naphtha or liquid supply apparatus, in the preferred form thereof herein shown and described, is located at one side of and slightly above the engine-valve E, and comprises, in part, a rotative feed-valve L, seated in a valve-case 36, which in this instance constitutes a part of the framework of the engine; gearing operatively connecting the valve L and crank-shaft D, and adapted for rotating said valve and maintaining a predetermined ratio of movement between the valve and crank-shaft; means for supplying liquid to the valve, and means for supplying air to the valve-case to effect a mixture between the liquid and air to generate the gas for operating the engine. This feed-valve, which is preferably of the "plug-valve" variety, has an axial recess, as at 36′, at its inner end, and also has a series of liquid receptacles or pockets—herein shown as three in number, and designated by 37, 38, and 39, respectively—which pockets open to the periphery of the valve and are shown extending radially toward the center of said valve.

The valve-case 36 is shown having a relatively small reservoir 40 at the upper end thereof, which has a funnel-shaped outlet 40′, with which the pockets of the valve L successively register during the rotation of the valve, and also has an inlet-opening 41 through said reservoir, through which opening the liquid is introduced into the reservoir from the liquid-supply pipe P^2. The valve-case 36 also has at the lower side thereof an outlet-opening 42, with which the pockets of the valve L successively register, and into which outlet said pockets deposit their contents during the rotation of the valve. This outlet 42 practically constitutes the mixing-chamber for the air and liquid, and communicates with the air-supply pipe P^3, and also communicates with the engine-valve chest E′ through the gas-conduit P^2, as will be readily understood by a comparison of Figs. 1, 4, 13, and 14 of the drawings.

The feed-valve L, in the form thereof herein shown, has an axially-bored stem 43, which extends through a bearing 44 on a cap 45, secured to the open end of the feed-valve case 36, and has fixed to the outer end thereof a spur-wheel 47, which meshes with the pinion 17 on the crank-shaft D. A spring 48 is interposed between the valve L and the cap 45 for keeping the valve to its seat.

As a convenient means for spreading the liquid as it is delivered from the pockets of the feed-valve L and for holding the liquid near the axis of the volume of air as it passes through the mixing-chamber in the feed-valve case, I have provided a liquid-spreader, (designated in a general way by S,) which, in the preferred form thereof herein shown, is in the nature of an angle-plate, and is secured in the mixing-chamber of said case with the free end thereof extending upward, and terminating in the outlet-opening of said valve-case in close proximity to the periphery of the valve and with its angle substantially in alinement with the axis of the air-supply. The angle of the spreader is preferably looped or U-shaped, as shown at 49, to form a temporary retainer for the liquid, and so as to prevent said liquid dropping to the bottom of the mixing-chamber before being acted upon by the inflowing air.

As a convenient means for automatically regulating the supply of liquid, the feed-valve is preferably provided with a regulator or cut-off, (designated in a general way by P^5,) which constitutes one member of the feed-regulating apparatus, and is adapted for increasing and decreasing the capacities of the liquid-receiving pockets 37, 38, and 39 of the valve. This regulator, in the form thereof herein shown, comprises a series of slides or cut-off plugs 37′, 38′, and 39′, having a sliding fit in the pockets 37, 38, and 39, respectively—which pockets extend through, and communicate with, the exterior and interior of the valve, as shown most clearly in Figs. 13 and 14, and a sliding actuating member 50 for the cut-off slide, which actuating member consists, in the form thereof herein shown, of a series of radially-disposed arms 51, 52, and 53, secured to an actuating-rod 54, extending through the axial bore of the valve-stem 43, and each of said arms 51, 52, and 53 having a transverse cam-groove 55, in which is seated a pin 56 at the lower end of each cut-off slide, respectively, said cut-off-slide actuator being guided in its movements and held against rotation preferably by means of an arm 57, seated in a longitudinal guideway 58, formed in the interior of the feed-valve L.

As a means for automatically operating the cut-off slides of the regulator P^5, the actuating-rod of the sliding actuating member 50 of said regulator is operatively connected by means of a lever 59 with a reciprocatory member 60, mounted upon the crank-shaft D, which member constitutes a part of and is operated by a governor (designated in a general way by R) carried upon and rotating with the crank-shaft, which governor may be of any suitable or usual construction for automatically reciprocating the actuating-rod of the regulator. The reciprocatory member of the governor is in the nature of a sleeve fitted to said shaft, and has a peripheral groove in which a pin 61 upon the free end of the lever 59 is seated. This lever 59 is pivotally carried near the middle portion thereof upon a crank or eccentric 62 at the lower end of an actuating-rod 63, journaled in bearings on a bracket 64, which constitutes a part of the framework of the engine and has a pivotal connection with the regulator-actuating rod 64. The lever-shifting rod 63 is provided at the upper end thereof with a hand-wheel 65, by means of which the same may be turned to shift the lever and to reciprocate the cut-off-slide actuator.

As a means for holding the lever-shifting rod 63 against accidental movement about its axis, I have provided a spring-actuated detent 66, which normally engages in a notch in a fixture on the bracket 64, as will be readily understood by a comparison of Figs. 1 and 2 of the drawings. The mechanism here described constitutes a means for starting and stopping the engine by hand. By operating said handle the parts are actuated to reduce to zero the feeding capacity of the feed-valve, and by thus shutting off the supply of explosive the engine is allowed to come to rest, and this action at once results, whatever may be the position of the governor when the handle is operated.

The governor R, which may be of any construction suitable for actuating the regulator P^5, comprises, in the form thereof herein shown, the cylindrical case 70, fixed to the crank-shaft and having two outwardly-extending brackets 71, one at each side of said crank-shaft; a bell-crank 72, pivotally carried on each bracket and having its inner end in engagement with the reciprocatory member 60; a ball 73, secured to each bell-crank at the outer end thereof; and connecting-springs 74 between the two balls. It will be obvious that any form of governor adapted for actuating the regulator-feed may be employed, in lieu of the governor herein shown and described, without departure from my invention.

As a convenient means for igniting the gas in the exploding-chambers of the cylinders C′, C^2, and C^3, alternately, and at the required intervals, I have provided an ignition apparatus, (designated in a general way by W,) which, in the preferred form thereof herein shown, comprises a series of igniters, (designated in a general way by M′,) extending, one into the exploding-chamber of each cylinder, as shown most clearly in Figs. 1 and 4; and a spark-generating electrical apparatus having the terminals of its electrical circuit in connection with the igniter, and embodying a circuit maker and breaker (herein shown as a three-way switch, designated by N) which is controlled in its movements by the rotation of the crank-shaft D of the engine.

In the preferred form thereof herein shown the electrical apparatus for producing the spark for exploding the gas in the several cylinders of the engine, alternately, comprises an alternating electrical circuit having a pair of electrical conductors in engagement with the spark-producing terminals 77 and 78 of each igniter M′, a dynamo M^2 for generating the electrical current; a transformer M^3 in said circuit; a condenser M^4 in said circuit; a circuit maker and breaker N, herein shown as a rotative three-way switch having a contact-point 75 in position and adapted for successively engaging the alternately-arranged contact-points 76 of the branch conductor of the electrical circuit which leads to the successive igniters, and said contact-maker being adapted for alternately closing the short circuits between the several igniters and the switch at the requisite intervals; and means for actuating the dynamo and circuit maker and breaker from the crank-shaft D of the engine.

As one convenient means for actuating the dynamo and circuit-breaker, the circuit-maker N is carried upon a counter-shaft 80, supported in suitable brackets upon the framework of the engine, which shaft carries a driving-pulley 81, connected by a belt 82 to a driven wheel 83 upon the dynamo-shaft 84; and said counter-shaft is rotated by means of a spur-wheel 85, carried thereon, which meshes with a pinion 17 upon the crank-shaft D, as will be understood by reference to Figs. 1, 2, and 25 of the drawings.

It will be understood that where it is preferable to employ the ignition apparatus, herein shown and described, for producing the explosions of the gas in the several cylinders, any suitable apparatus might be employed for this purpose, within the scope and limits of my invention; and that while certain features of said apparatus constitute subject-matter of certain claims herein, I do not desire to limit myself to the employment of any of the specific elements of said electrical apparatus in connection with the other specific features of my present invention, as such elements may be variously modified.

The igniter M′, which is herein shown in the nature of a plug, and which is fitted in the combustion end of the cylinder, as illustrated in Fig. 1, consists, in the preferred form thereof (shown most clearly in Figs. 22, 23, and 24) of an outer and inner member 86 and 87, respectively, the one 86 of which will preferably be made of metal or other suitable conducting material, will be externally screw-threaded to fit a screw-threaded hole formed in the engine-cylinder, and will also have a conical axial bore therethrough; and the inner member 87 of which will preferably be constructed of porcelain or non-conducting material, will be fitted to the axial bore of the outer member, and will have a longitudinal recess through the center thereof.

Extending through the inner member 87 of the igniter is one of the spark-producing terminals 78, which is secured therein; and secured to the outer member 86 is the opposite spark-producing terminal 77. The spark-producing terminal 78 is shown in the nature of a rod having a flange 78′ near the inner end thereof, and having its outer end screw-threaded to receive a nut 78″, which has a bearing against a piece of insulating material at the forward end of the igniter, and is adapted to draw the rod forward to bring the flange 78′ tightly against the inner end of the central member 87, as will be herein understood by reference to Figs. 22 and 23 of the drawings. The inner spark-producing ends of the two terminals will preferably be bent inward toward each other to bring the points thereof into the requisite proximity to provide a spark-gap 89 of the desired length. The spark-producing terminal 77 may, if desired, constitute an integral part of the outer member 86; but it is herein shown as an elongated plate let into the periphery of said outer member, where it will be secured by soldering or brazing. As represented by full and dotted lines in Figs. 22 and 23, one of the conductors of the electrical circuit is fixed directly to the inner terminal 78, whereas a connection between the other conductor of the electrical circuit is formed between the outer terminal 77 and said conductor by the cylinder-casing, the conductor being secured to a plug 90, which is screwed into said casing. It will be obvious, however, that the two conductors might be connected directly with two terminals, if desired.

The engine-valve E and the feed-valve L are so organized and timed in their movements as to make one complete rotation every two complete rotations of the crank-shaft; and the liquid-receiving pockets of the feed-valve are so disposed as to successively deposit their contents upon the spreader in the mixing-chamber simultaneously with the opening of the induction-port of the engine-valve to the successive induction-passages of the cylinder.

During the operation of the engine, the liquid hydrocarbon is admitted through the supply-pipe P^2 into the reservoir 40, whence it passes to the feed-valve L, and is carried around and deposited, drop by drop, and at regular intervals onto the liquid-spreader S in the mixing-chamber 42, where it is spread and mixed with the air introduced through the air-supply pipe P^3, whence it is conducted to the engine-valve chest E′, and is admitted to the successive cylinders alternately and at regular intervals during the rotation of the engine-valve E, where it is exploded through the medium of the ignition apparatus W to drive a piston and rotate the crank-shaft D, which crank-shaft controls the operation of the feed-valve L and engine-valve E, one explosion taking place at every two-thirds of a revolution of the crank-shaft, as will be more fully understood by reference to Figs. 26, 27, and 28 of the drawings, which figures represent, respectively, by dotted radial lines k, k^2, and k^3, three successive positions of the crank 12 during three successive explosions of the gas, the cross-sectioned circles C′, C^3, and C^2 in said Figs. 26, 27, and 28, respectively, representing the alternating order of the explosions in the successive cylinders C′, C^2, and C^3.

For a more particular understanding of the cycle of operations, reference is made to Figs. 5 to 12, inclusive, which represent four successive "quarter" positions of the engine-valve E and two of the pistons of the engine. The rotation of the crank 12 is divided into four quarter "stages" or "cycles," the dotted lines k, k', k^2, and k^3 designating the four successive positions of the crank when the engine-valve E is in the four successive positions illustrated in Figs. 5, 7, 9, and 11, respectively, the respective directions of movement of the crank 12 and the valve E designated by the arrows J and J′, respectively.

Referring to Figs. 5 and 6, which I may, for convenience, assume to be the "first" positions of the crank, engine-valve, and pistons, the crank is in a vertical position corresponding to the position shown in Fig. 26, the engine-valve is closed to the port-passage c', which leads to the cylinder C′, has its exhaust-port open to the port-passage c^2, which leads to the cylinder C^2, and has its induction-port open to the port-passage c^3, which leads to the cylinder C^3, as shown in Fig. 5. In this position of the valve E, the piston of the cylinder C′ is slightly remote from its extreme backward position ready to be forced forward by the explosion of the combustible material in the rear end of said cylinder, and the piston of cylinder C^2 is at the extreme forward position ready to exhaust the products of combustion upon its backward movement. When the valve E is in the position shown in Fig. 5, the explosion in the cylinder C′ will take place, which will drive the piston in said cylinder C′ to its extreme forward position, (illustrated in Fig. 8,) which forces the piston C^2 backward and exhausts the products of combustion contained in C^2, and during this operation the piston of cylinder C^3 has also been moved forward, which will cause gas to be drawn into said cylinder C^3.

Referring to Figs. 7 and 8, which illustrate the "second" successive positions of the crank 12 and valve E, the valve E in this position is closed to the port-passage of the cylinder C^3, has its exhaust-port open to the cylinder C′ and its induction-port open to cylinder C^2. In this position of the valve, the products of combustion created by the explosion of the gases in the preceding operation are exhausted from the cylinder C' by the return or backward movement of the piston in said cylinder, the cylinder C^2 is drawing in gas by the action of the piston in said cylinder, and the gas drawn into the cylinder C^2 by the preceding operation is being compressed by the retractive movement of the piston in said cylinder C^3.

Referring to Figs. 9 and 10, which illustrate the "third" positions of the crank 12 and the engine-valve E, said engine-valve has its induction-port open to the cylinder C' and closed to the cylinders C^2 and C^3. In this position of the valve, the gas is being drawn into the cylinder C' by the advancing of the piston in said cylinder, the gas drawn into the cylinder C^2 by the preceding operation is being compressed by the retractive movement of the piston in said cylinder, and the gas in the cylinder C^3 is being exploded.

Referring to Figs. 11 and 12, which illustrate the "fourth" positions of the crank 12 and engine-valve E, the valve E has its exhaust-port open to the cylinder C^3 and is closed to cylinders C' and C^2. In this position of the valve, the gas is being compressed in cylinder C', the gas is being fired in cylinder C^2, and the products of combustion are being exhausted from cylinder C^3, the pistons of cylinders C' and C^2 being in the positions illustrated in Fig. 12 during this operation.

By comparison of Figs. 5 to 12, inclusive, and Figs. 26, 27, and 28, and by reference to the preceding description of the operation of the engine, it will be seen that in one cycle of operations—and correspondingly in the successive cycles of operations—the gas is first drawn in, then compressed, and then exploded in each cylinder; but these operations take place alternately with respect to similar operations in the other cylinders; that is to say, when the gas is being exploded in cylinder C', the products of combustion are being exhausted from cylinder C^2, and gas is being drawn into cylinder C^3; next, cylinder C' is being exhausted, the gas in cylinder C^2 is being exploded, and the gas in cylinder C^3 is being compressed; next, gas is being drawn into cylinder C', is being compressed in cylinder C^2, and is being exploded in cylinder C^3, and next, gas is being compressed in cylinder C', is being fired in cylinder C^2, and the products of combustion are being exhausted from cylinder C^3. From this description of the alternating order of operation of the successive pistons in the cylinders it will be apparent that the work is uniformly distributed, that the engine is well balanced and will run with uniformity and with little vibration.

The working parts of the engine will be lubricated in any usual or suitable manner.

The crank-shaft D is, for convenience, provided with a fly-wheel O.

By the construction and organization of valves and valve-actuating mechanism herein described, it will be seen that the engine-valve and feed-valve are rotated synchronously in the same direction and at coinciding velocities, and that the crank-shaft simultaneously rotates in a direction opposite to the direction of rotation of said valve and at a different rate of speed, the shaft and valves being so connected and timed in their movements that the ratio of comparative movements between the shaft and valve, respectively, shall be as two is to one.

In some cases—that is, when certain kinds of liquid fuel are employed to generate an explosive gas by being mixed with air, as herein described—it may be desirable to employ means other than that herein shown for heating the air to evaporate the liquid; but usually sufficient heat is created by exhausting the products of combustion through the engine-valve, as hereinbefore described, to effect the required evaporation of the mixture before the same enters the induction-port of the cylinder; and this method of evaporating the liquid in engines of this class is well known in the art. The foregoing statement is considered adequate for a full understanding of this particular feature of the engine.

Having thus described my invention, I claim—

1. The combination with an engine-cylinder, and with a crank-shaft supported for rotation in substantial parallelism with the cylinder, and with means for rotating said crank-shaft; of a liquid-feed valve and an engine-valve in coöperative connection, and adapted for intermittent communication with the cylinder; and means controlled by the crank-shaft for simultaneously actuating said valves, substantially as described, and for the purpose set forth.

2. In an engine of the class specified, the combination with an engine-cylinder and a crank-shaft, supported in longitudinal parallelism with each other, and with means for rotating said crank-shaft; of a rotative liquid-feed valve; a rotative engine-valve intermediate to, and adapted for intermittently establishing communication between, the feed-valve and cylinder; and rotary driving mechanism connecting the crank-shaft and valves, and adapted for simultaneously rotating said valves, substantially as described, and for the purpose set forth.

3. In an engine of the class specified, the combination with the engine-cylinder and crank-shaft, supported in substantial longitudinal parallelism with each other, and with means for rotating said crank-shaft; of a rotative liquid-feed valve having one or more liquid-receiving pockets; a rotative engine-valve having a port in communication with the feed-valve, and adapted for intermittently establishing communication between the feed-valve and cylinder; and rotating driving mechanism connecting, and adapted for effecting, a simultaneous rotation of the

crank-shaft, feed-valve, and engine-valve, substantially as described, and for the purpose set forth.

4. In an engine of the class specified, the combination with an engine-cylinder having a port-passage leading thereto; of a rotative engine-valve having a port adapted for intermittently communicating with the port-passage of the cylinder; a rotative feed-valve having peripherally-disposed liquid-receiving pockets; a conduit between, and intermittently communicating with, the port of the engine-valve and a pocket of the feed-valve; a liquid supply in communication with the pockets of the feed-valve; an air-supply communicating with the conduit between the feed-valve and engine-valve; a crank-shaft for rotating the feed-valve and engine-valve in synchronism; a cut-off device carried by the feed-valve and adapted for varying the capacities of the liquid-receiving pockets; a governor in operative connection with the crank-shaft and cut-off device, and adapted for automatically controlling the movements of said cut-off device, substantially as described, and for the purpose set forth.

5. In an engine of the class specified, the combination with an oil-conduit and an air-conduit; of a feed-valve case located between, and in communication with, said oil-conduit and air-conduit; a continuously-rotative valve supported in said case, and having a series of slide-regulated feed-pockets; slides fitting said feed-pockets; and means for rotating said feed-valve, and for automatically actuating the slides to increase or decrease the capacities of the feed-pockets.

6. In an engine of the class specified, the combination with the cylinder or cylinders thereof; of an apparatus for generating an explosive mixture, which apparatus consists of a liquid-supply conduit and an air-supply conduit; a normally continuously-rotative feed-valve having a plurality of radially-disposed feed-pockets open to the periphery of the feed-valve, and adapted for intermittently communicating with the oil-supply conduit and air-supply conduit, alternately; means for continuously rotating said valve; and means for increasing or decreasing the capacities of the feed-pockets, substantially as described, and for the purpose set forth.

7. In an engine of the class specified, a rotative feed-valve having a plurality of relatively-independent feed-pockets; an automatically-operable cut-off device carried by said feed-valve, and comprehending a plurality of cut-off slides fitting the feed-pockets; and means for automatically actuating the cut-off device.

8. In an engine of the class specified, the combination with a crank-shaft, and with a series of cylinders disposed about said crank-shaft with their axes in substantial longitudinal parallelism with said crank-shaft; of pistons located in said cylinder; a universally-movable actuator, supported for movement about a fixed axis located in the plane of the crank-shaft and operatively connecting said piston and crank-shaft; a rotative feed-valve in geared connection with the crank-shaft, and adapted for intermittently communicating with the cylinders in alternating order; an oil supply and liquid supply in communication with the feed-valve; and a governor in operative connection with the feed-valve and crank-shaft and adapted for controlling the feed, substantially as described, and for the purpose set forth.

9. An engine of the class specified, comprehending a suitable framework; a crank-shaft journaled for rotation in said framework; a series of piston-cylinders disposed about said crank-shaft with their longitudinal axes in substantial parallelism with said shaft, and each cylinder having an explosion-chamber at one end thereof; an ignition device projected into each explosion-chamber; reciprocatory pistons supported in said cylinders; a universally-movable crank-shaft actuator operatively connecting the pistons and crank-shaft; a rotative liquid-feed valve in geared connection with the crank-shaft, and having a series of feed-pockets corresponding in number to the number of engine-cylinders; an oil-conduit in communication with said valve; an air-conduit also in communication with said valve, and in intermittent communication with the engine-cylinders; cut-off slides in operative connection with the feed-pockets of the feed-valve; means controlled by the crank-shaft for automatically actuating the cut-off slides to regulate the feed; and an electrical spark-generating apparatus controlled by the crank-shaft and having electrical terminals in connection with the ignition devices, and adapted for intermittently producing a spark within the explosion-chambers of the several cylinders, substantially as described.

10. In an engine of the class specified, the combination with the engine-cylinder having a suitable induction-port, and with the cylinder-piston; of a crank-shaft supported with its axis in substantial parallelism with the longitudinal axis of the cylinder; an actuator between the piston and crank-shaft; a rotative engine-valve having a port adapted for intermittently communicating with the engine-cylinder, and having its axis of movement in parallelism with the shaft; and a train of gears operatively connecting the engine-valve and crank-shaft, and adapted for rotating said valve in synchronism with the crank-shaft and in direction opposite to the direction of rotation of said crank-shaft, substantially as described.

11. In an engine of the class specified, the combination with the engine-cylinder having a suitable induction-port; of a rotative valve having a port adapted for intermittently communicating with the port of the cylinder; a crank-shaft; means for rotating the crank-shaft in one direction; and driv-

ing means operatively connecting the crank-shaft and rotative valve, and adapted for rotating said valve in a reverse direction from, and at a different rate of speed than, the crank-shaft, substantially as described.

12. In an engine, the combination with the cylinder having an induction-port, and with the cylinder-piston; of a crank-shaft operatively connected with said piston; a rotative liquid-feed valve; a rotative engine-valve having a port adapted for intermittently communicating with the port of the cylinder, and also for intermittently communicating with the feed-valve; and gearing operatively connecting the engine-valve, the crank-shaft, and the feed-valve together, and synchronously rotating the engine-valve and feed-valve in the same direction at corresponding velocities, and at a different velocity from the velocity of the crank-shaft.

13. In an engine, the combination with the engine-cylinder having an induction-port, and with the piston; of a crank-shaft in substantial axial parallelism with the cylinder; a connector between, and operatively connecting, the piston and crank-shaft; a rotative engine-valve having its axis in substantial parallelism with the crank-shaft, and having a port adapted for intermittently communicating with the port of the cylinder; and actuating mechanism operatively connecting the crank-shaft and engine-valve, and rotating the engine-valve in an opposite direction relatively to, and in synchronism with, the crank-shaft, and for effecting a two-to-one ratio of movement between, said crank-shaft and engine-valve, substantially as described.

14. In an engine, the combination with the cylinder and its piston; of a crank-shaft and a rotative engine-valve having their axes in substantial parallelism, and in substantial parallelism with the axis of the cylinder, and actuating mechanism connecting the piston crank-shaft and engine-valve, and adapted for effecting a synchronous rotation of the crank-shaft and engine-valve in opposite directions, and at comparative speeds of relatively different velocities, substantially as described, and for the purpose set forth.

15. In an engine, the combination with the cylinder and its piston; of a crank-shaft and a rotative engine-valve having their axes in substantial parallelism, and substantially parallel to the axis of the cylinder; and actuating mechanism operatively connecting the piston, crank-shaft, and engine-valve, and embodying means for rotating the crank-shaft and engine-valve in opposite directions, respectively, and at comparative velocities, the ratio of which is two to one, substantially as described.

16. In an engine of the class specified, the combination with the framework; of a horizontally-disposed crank-shaft; a series of cylinders having their axes in substantial parallelism with, and disposed about, the axis of the crank-shaft; pistons working in said cylinders; and a universally-movable crank-shaft actuator supported for movement about a fixed axis located in the plane of the crank-shaft, and operatively connecting the crank-shaft and pistons, and comprehending an actuating member having a stem connected with a crank on the crank-shaft, and also having a series of radially-disposed arms which are operatively connected with the pistons; and a carrying member for the actuating member having a pair of horizontally-disposed arms and a pair of vertically-disposed arms, one pair of which are pivotally supported in fixed bearings on the framework, and the other pair of which are pivotally supported in bearings on the actuating member, substantially as described.

17. In an engine of the class specified, the combination with the engine-cylinder having an explosion-chamber at one end thereof, and having an induction-port opening into said explosion-chamber, and with the piston, crank-shaft, and connections; of a feed-valve actuated by the crank-shaft; an engine-valve actuated by the crank-shaft, and having ports adapted for intermittently establishing communication between the feed-valve and the explosion-chamber of the cylinder; an igniter having ignition-points located in the explosion-chamber; ignition apparatus in connection with said igniter; and means in connection with, and controlled by, the crank-shaft for actuating the ignition apparatus, and for intermittently creating a spark between the ignition-points of the igniter to ignite and explode the gas in the explosion-chamber, substantially as described, and for the purpose set forth.

18. In an engine in the class specified, the combination with the engine-cylinder having an induction-port, and with the engine-valve adapted for communicating with the port of the engine-cylinder; of a rotative feed-valve located at one side of the engine-valve, and having a slide-regulated liquid-receiving pocket located in a plane intersecting the axial plane of the feed-valve; an automatically-operable cut-off slide fitted for sliding movement in said liquid-receiving pocket; means for continuously rotating the feed-valve; a slide-actuator controlled by the movements of the feed-valve-rotating means; an oil supply in communication with the feed-valve; an air supply in communication with the feed-valve, and adapted for intermittently communicating with the engine-cylinder through the engine-valve; and means for continuously rotating the engine-valve, substantially as described, and for the purpose set forth.

19. In an engine of the class specified, the combination with the engine-cylinders, pistons, engine-valve, and crank-shaft, and with the universally-movable actuator operatively connecting the pistons and crank-shaft; of a continuously-rotative feed-valve in geared connection with the crank-shaft, and having

a series of radially-disposed elongated feed-pockets; cut-off slides fitted for sliding movement in said feed-pockets; means controlled by the crank-shaft for automatically operating the cut-off slides to increase or decrease the capacities of the feed-pockets; a mixing-chamber communicating with the feed-valve and engine-valve; means for supplying air through said mixing-chamber; an oil supply in communication with the feed-valve; and means controlled by the crank-shaft for continuously rotating the engine-valve, substantially as described.

20. In an engine of the class specified, the combination with the cylinder having induction-ports, and with the engine-valve and its actuator; of a liquid-supply conduit; an air-supply conduit; a mixing-chamber in communicative relation with the liquid-supply conduit and air-supply conduit, and with the engine-valve chest and a feed-valve chest; a rotative liquid-feed valve located between the liquid-supply conduit and air-supply conduit, and having a series of slide-regulated feed-pockets adapted for transferring liquid from the liquid-supply conduit to the air-supply conduit in regulated quantities; an automatically-operable cut-off device embodying cut-off slides fitting the feed-pockets of the feed-valve; and rotative means controlled by the engine-valve actuator for rotating the feed-valve in synchronism with the engine-valve, and for automatically actuating the cut-off device, substantially as described, and for the purpose set forth.

21. In an engine of the class specified, the combination with the cylinder and with the engine-valve, and with a liquid-supply conduit; and with an air-supply conduit; of a mixing-chamber between, and connecting, the air-supply conduit and engine-valve chest; a rotative feed-valve located between the air-supply conduit and the discharge end of the liquid-supply conduit, and having one or more peripheral feed-pockets adapted for transferring liquid during the rotation of the valve, from the liquid-supply conduit to the air-supply conduit; a cut-off device carried by the valve and adapted for varying the capacity of the liquid-receiving pocket or pockets; a shaft for rotating the engine-valve and the feed-valve; a governor in operative connection with the shaft, and adapted for controlling the movements of the cut-off device; and an actuating-connector operatively connecting the cut-off device and governor, substantially as described.

22. In an engine of the class specified, the combination with the engine-cylinder having an induction-port, and with the engine-valve and its chest; of an air-conduit in communication with said engine-valve chest; a feed-valve chest having an outlet-opening at the lower side thereof in communication with the air-conduit, and also having an inlet-opening at the upper side thereof; a rotative feed-valve seated in said chest, and having feed-pockets adapted for successively communicating with the inlet and outlet openings of the feed-valve chest; a liquid-conduit in communication with the inlet-opening of said feed-valve chest; and means for simultaneously actuating the feed-valve and engine-valve, substantially as described, and for the purpose set forth.

23. In an engine of the class specified, the combination with the engine-cylinder, and with a liquid-supply conduit and an air-supply conduit; of a rotative feed-valve having one or more peripheral feed-pockets adapted, during the rotation of the valve, for intermittently communicating with, and for transferring liquid from, the liquid-supply conduit to the air-supply conduit; an automatically-operative cut-off device carried by the valve, and adapted for varying the capacity of each feed-pocket; a shaft for rotating the feed-valve; and a governor in operative connection with the shaft and cut-off device, and adapted for controlling the movements of said cut-off device.

24. In an engine of the class specified, the combination with the engine-cylinder; of an air-conduit and a liquid-conduit; a rotative feed-valve between the air-conduit and the discharge end of the liquid-conduit, and having a series of liquid-receiving pockets; cut-off slides shiftably in connection with said pockets, and adapted for varying the capacities of said pockets; and actuating mechanism in connection with, and adapted for operating said cut-off slides, substantially as described.

25. In an engine of the class specified, the combination of a framework, a crank-shaft, and a series of cylinders, each having an explosion-chamber at one end thereof and disposed in substantial parallelism about said crank-shaft; pistons located in said cylinder; a universally-movable crank-shaft actuator operatively connecting the pistons and crank-shaft; means for intermittently supplying a combustible mixture in regulated quantities to the explosion-chambers of the several cylinders in alternating order; igniters having ignition-terminals located in the several explosion-chambers of the cylinders; and electrical spark-producing apparatus in operative connection with the crank-shaft, and comprehending an electrical circuit having electrical conductors in connection with the terminals of the igniters, and also having in said circuit a transformer, a condenser, and a contact maker and breaker adapted for intermittently making and breaking the circuits to effect ignitions of the explosive mixtures in the several cylinders in alternating order, substantially as described.

26. In an engine of the class specified, the combination with the framework; of a horizontally-disposed crank-shaft journaled in said framework; a series of three cylinders having their axes disposed in parallelism about the axis of the crank-shaft; pistons

working in said cylinders; a universally oscillatory actuator operatively connecting said pistons and crank-shaft; a rotative engine-valve having ports adapted for intermittently communicating with the three cylinders alternately; a rotative feed-valve in communication with the engine-valve; a regulator in connection with said feed-valve, and in operative connection with the crank-shaft; gearing operatively connecting the two valves to the crank-shaft and adapted for effecting a simultaneous rotation of said valves at a different velocity from, and in a different direction to, the crank-shaft; and an electrical ignition apparatus embodying an electrical circuit having terminals projected into the three cylinders; a three-way switch in said circuit, and actuating mechanism operatively connecting the ignition apparatus and the crank-shaft, substantially as described, and for the purpose set forth.

HURBERT C. BAKER.

Witnesses:
FRANCIS H. RICHARDS,
F. N. CHASE.