No. 681,162. Patented Aug. 20, 1901.

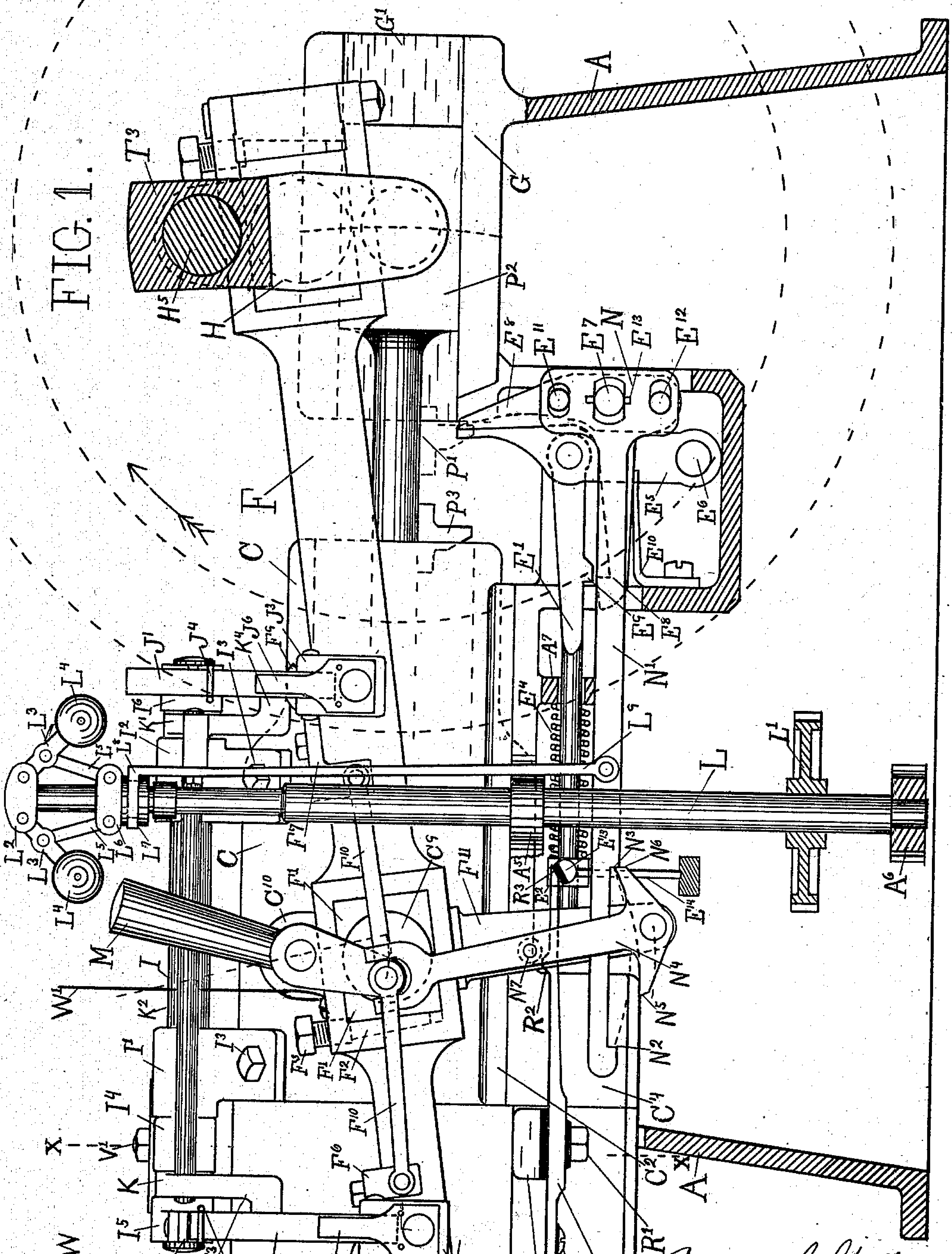
A. C. WOLFE.

GAS OR OTHER EXPLOSIVE ENGINE.

(Application filed Dec. 17, 1900.)

(No Model.)

5 Sheets—Sheet 1.



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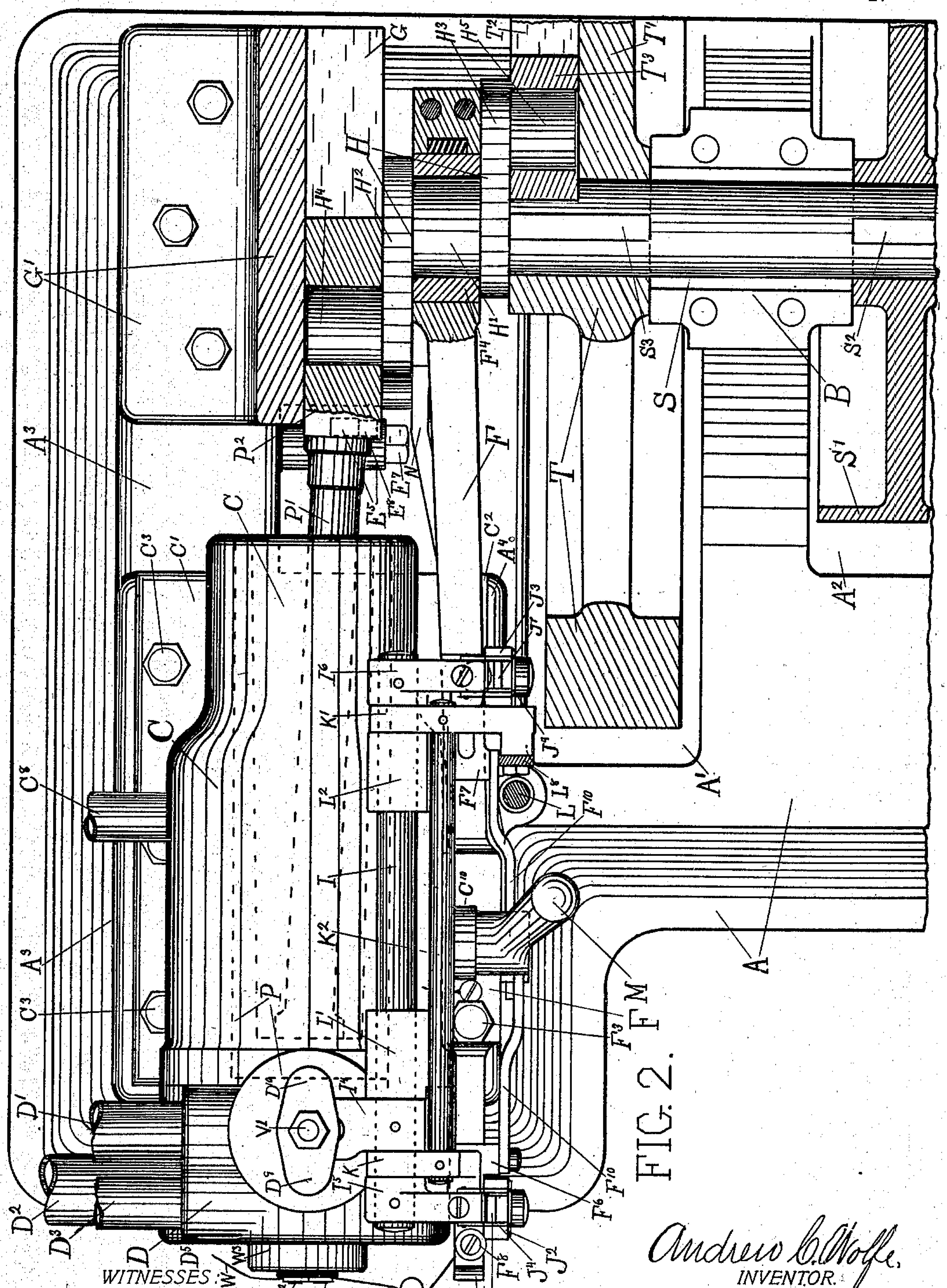

FIG. 2.

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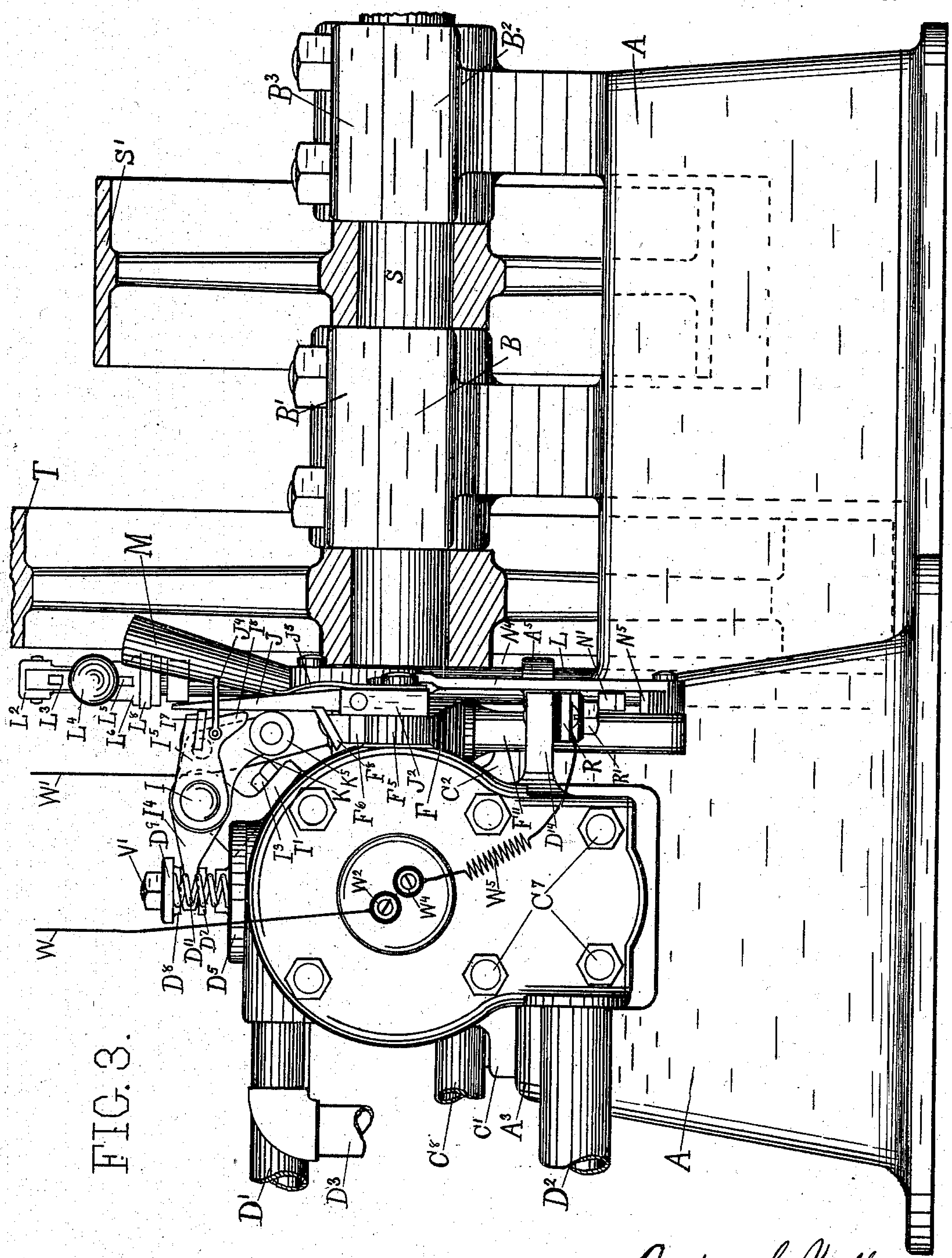

FIG. 3.

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(No Model.)

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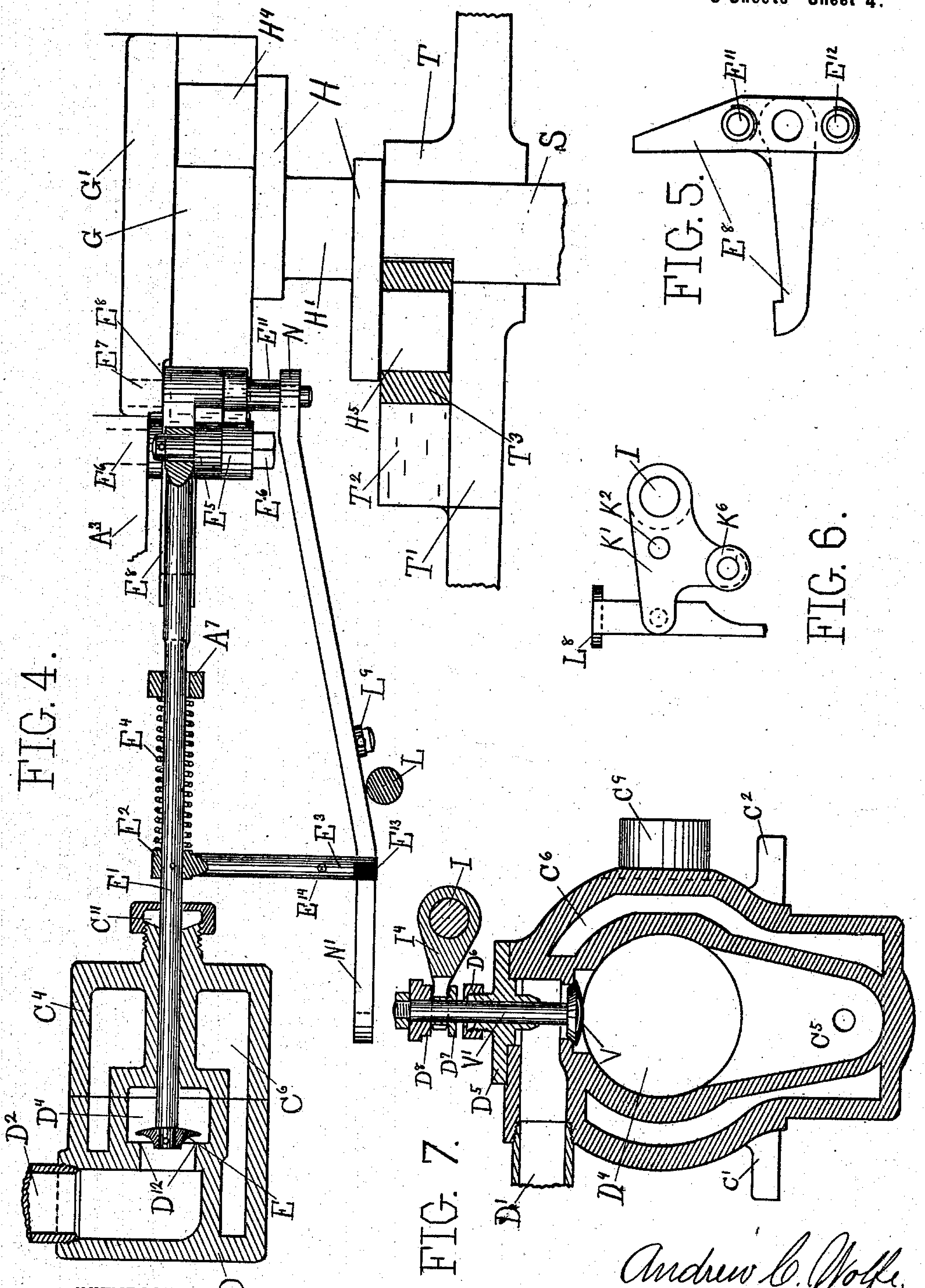

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GAS OR OTHER EXPLOSIVE ENGINE.

(Application filed Dec. 17, 1900.)

(No Model.)

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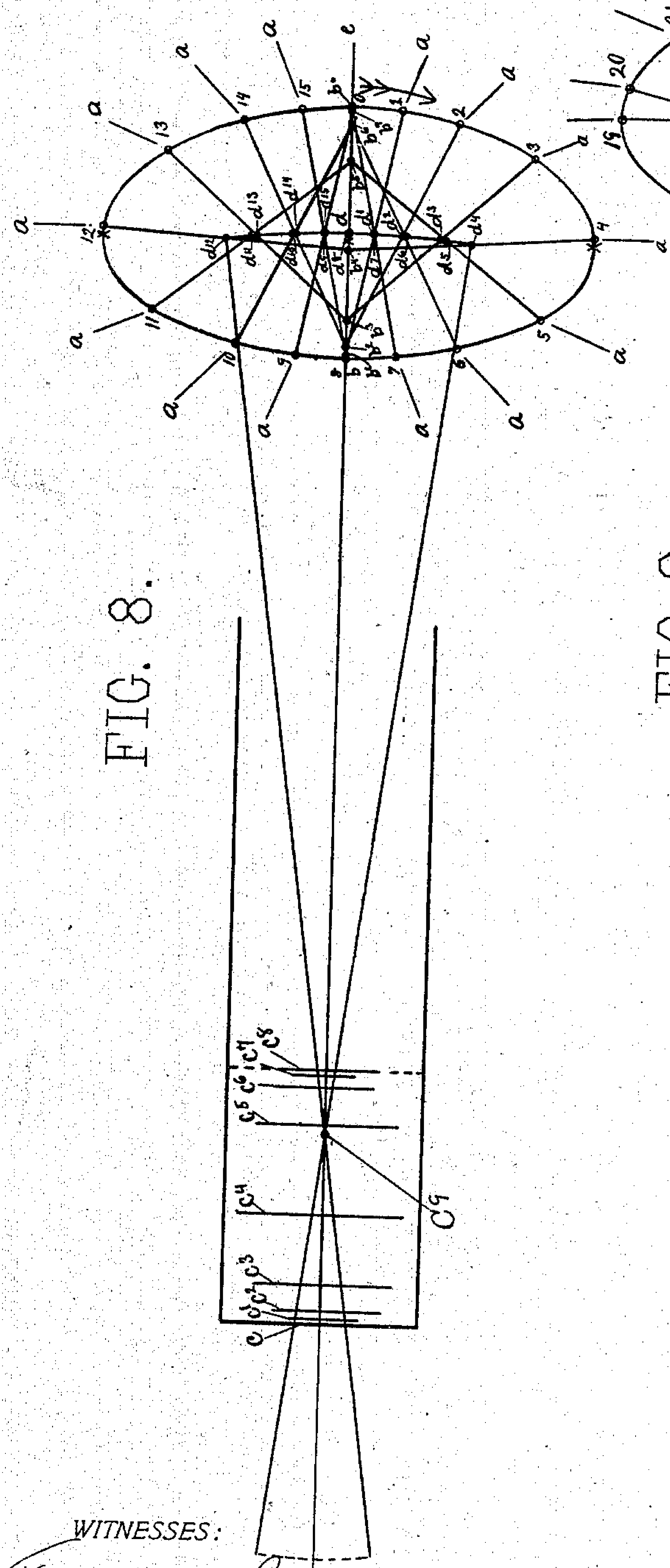

FIG. 8.

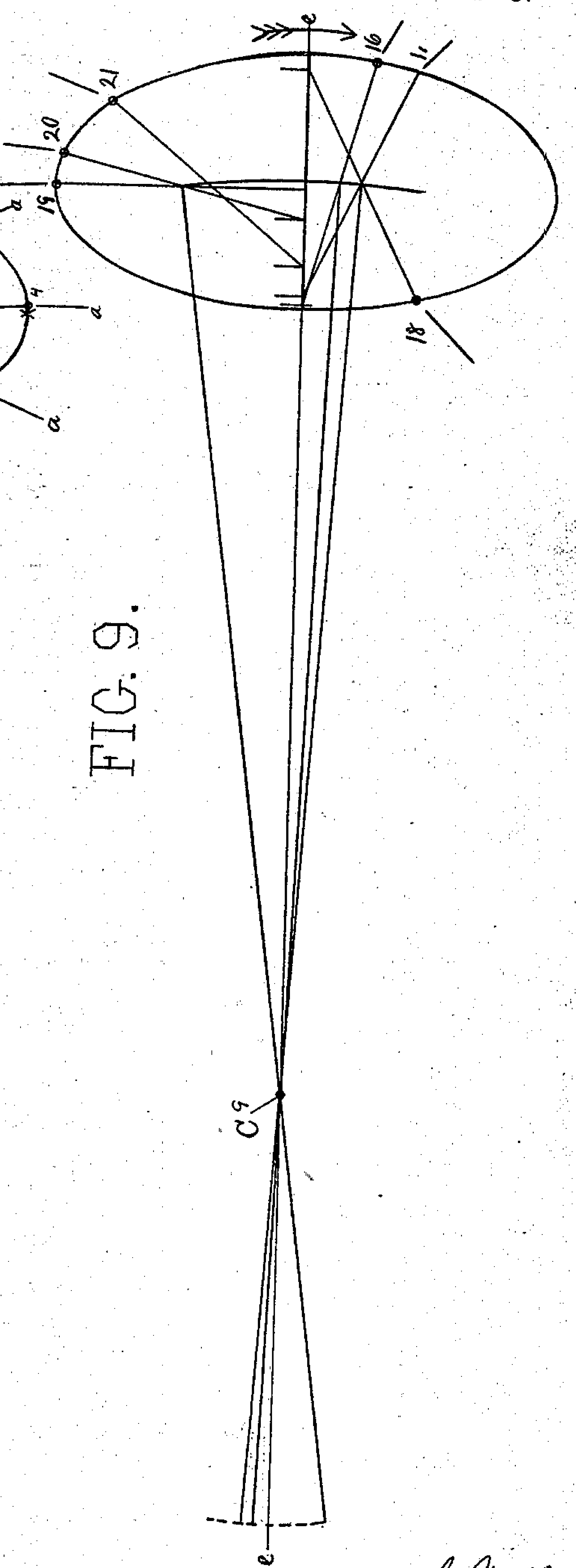

FIG. 9.

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UNITED STATES PATENT OFFICE.

ANDREW C. WOLFE, OF DENVER, COLORADO, ASSIGNOR OF TWO-THIRDS TO FRANK DILLINGHAM AND CHARLES K. WOLFE, OF SAME PLACE.

GAS OR OTHER EXPLOSIVE ENGINE.

SPECIFICATION forming part of Letters Patent No. 681,162, dated August 20, 1901.

Application filed December 17, 1900. Serial No. 40,181. (No model.)

To all whom it may concern:

Be it known that I, ANDREW C. WOLFE, a citizen of the United States, residing at Denver, in the county of Arapahoe and State of Colorado, (whose post-office address is No. 1450 Sixteenth avenue,) have invented a new and useful Gas or other Explosive Engine, of which the following is a specification.

This invention relates to improvements in gas-engines or other explosion-engines of the general class utilizing the power developed by successive explosions of gaseous or other fuel combined with air; and the principal objects of these improvements are, first, to provide a gas-engine in which the piston retreats before the explosion at a much more rapid rate than in the usual form of gas-engine; second, to provide a gas-engine in which the point of application of power to the engine-shaft and fly-wheel shall be at a greater relative distance from the axis of rotation than in the present forms of gas-engines; third, to provide a gas-engine in which the explosion and expansion of the gas shall occupy a comparatively short space of time to avoid excessive heating of the cylinder; fourth, to provide a gas-engine in which there shall be relatively more dwell of the piston at and near the extremes of its movement for the purpose of providing more time for the escape of the products of combustion before the return stroke of the piston; fifth, to provide a gas-engine having a relatively slower movement of the piston at the beginning of the outward stroke, permitting the rotative and connecting parts to pass farther into their advantageous position before firing the explosion; sixth, to provide a gas-engine in which the power derived from the explosion is chiefly applied to the rotating parts during a comparatively small portion of the revolution; seventh, to provide a gas-engine having double means for operating the admission-valve, the same having movement in the operative direction at opposite times in the revolution; eighth, to provide a gas-engine having the exhaust-valve opened directly by the extreme outer movement of the piston; ninth, to provide a gas-engine having the exhaust-valve latched open and closed at a predetermined point in the return stroke of the piston by governor-controlled means; tenth, to provide a gas-engine having a single reverse-lever so connected as to instantly place the forward or backward admission-valve connections into operative position and at the same time to change the connections to the exhaust-valve release into position for running in the opposite direction and also to change the firing mechanism suitable to operation in the reversed direction; eleventh, to provide a gas-engine in which the valve-gear placed in operative position by the reverse-lever is the one operated by the governor, and, twelfth, to provide a rigid piston-rod moving in a straight line to avoid wear of piston and cylinder.

The above objects are accomplished by means of the mechanism illustrated in the accompanying drawings, in which—

Figure 1 is a longitudinal elevation with the balance-wheel, shaft, and a part of the bed removed or broken away. Fig. 2 is a plan view with the governor-shaft and connection and the parts about the shaft and double crank shown in section on a plane at the shaft-center. Fig. 3 is a front end elevation, but with the balance-wheel and pulley shown in section. Fig. 4 is a plan view of the exhaust-valve and valve connections and section through the lower extension of the cylinder and cylinder-head; also, an outline of the double crank, piston-guide, and hub of fly-wheel. Fig. 5 is a side elevation of the latch or retaining-pawl for the exhaust-valve. Fig. 6 is a rear view of one of the arms of the governor-controlling device and connection. Fig. 7 is a transverse vertical section through the admission-valve and cylinder-head upon line X X of Fig. 1 as seen from the left therein and with the fulcrum-rod and other parts removed. Fig. 8 is a diagrammatic view showing the relative positions of the double crank, fly-wheel, and piston at a number of different portions of the revolution; and Fig. 9 is a diagrammatic view representing the positions of the double crank and fly-wheel at the positions of valve operation. In Fig. 2 the outer parts of the bed and pulley are broken away.

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

The cylinder (designated in a general way by C) and the cylinder-head D are similar to the usual gas-engine cylinder and head in general principle, being open at one end and provided with the usual jacket or space for the circulation of the cooling-water, the details of which it is deemed unnecessary to show in this case, as the novelty centers chiefly in the connections from the piston to the engine-shaft, the valve-moving devices, and parts connected therewith.

The cylinder C is shown flattened somewhat upon the right side, as in Figs. 3 and 7, to make room for the fulcrum-rod pivoted upon the side of the cylinder, which is one of the features of this engine.

The bed of the engine is represented in a general way by A and is of the common box form, with a deep cavity or recess A′ for the balance-wheel and a similar but shallower cavity A^2 for the belt-pulley. Between these cavities the bed rises to form the main bearing B, which has the usual cap B′, and outside of the pulley-recess the bed rises to form a similar outer bearing B^2, having cap B^3, and in these bearings the main engine-shaft S is journaled in the usual manner. The belt-pulley S′ is secured to the shaft S between the bearings B and B^2 in the usual manner, as by the key S^2. The end of the shaft S projects inward from the bearing B and has securely fixed to it the fly-wheel T, as by the key S^3. In Fig. 1 the rim of this fly-wheel has its position represented by the dotted lines.

Formed integral with the hub portion of the fly-wheel T and extending between the adjacent arms of the same is an extension T′, having in it a radial raceway T^2, open upon the side coincident with the end face of the shaft and hub, and in this raceway, as a guide, is slidably mounted a block T^3, having through its central part a hole, which is parallel with the shaft S. The shaft has one side cut away, thus extending the raceway closer to the axis of rotation, and in the said raceway the block T^3 freely slides a radial distance equal to about one-half the stroke of the engine, the center of the hole through the block approaching to within a distance equal to one-half the engine-stroke of the axis of shaft S. The radial raceway T^2 is a substitute for the usual crank of an engine, but is a variable one, and the power is delivered to the fly-wheel T and shaft S by means of the sliding block T^3 and connections, which will be hereinafter described.

The bed A has two parallel raised parts A^3 and A^4, upon which are secured the flanges C′ and C^2 of the cylinder C in the customary manner, as by the bolts C^3. The raised part A^3 extends beyond the cylinder toward the rear and terminates in the guide G, and secured to the same is the Z-shaped plate G′, which forms the top and lateral guide for the outer end of the piston-rod.

The front end of the cylinder C has a downward extension C^4, which forms a bearing at C^5 for the exhaust-valve stem, around which the water-jacket C^6 of the cylinder passes. Secured to the front end of the cylinder C in any desired manner, as by the bolts C^7, is the cylinder-head D, into which are screwed the inlet-pipe D′ for the admission of the gas, the exhaust-pipe D^2, and the exit-pipe for the cooling-water D^3. The head has also mounted in it the inlet-valve V and the exhaust-valve E, which will be described later in detail.

The inlet-pipe for the cooling-water is shown at C^8 and is preferably tapped into the cylinder C. Projecting from the flattened side of the cylinder, and preferably made integral therewith, is a pivot or trunnion C^9, which supports and forms the journal for the fulcrum-rod or fulcrum-lever F, and the trunnion C^9 may therefore be called a "fulcrum."

The fulcrum-rod F is provided with an adjustable bearing of a form usual in connecting-rods, with the brasses F′, wedge F^2, which is shown by dotted lines in Fig. 1, and adjusting-screw F^3, and the fulcrum-rod is free to oscillate above and below a horizontal position. The rear end of the fulcrum-rod F is provided with a similar adjustable bearing F^4 at such a distance from fulcrum C^9 as to be in line with the axis of shaft S when the fulcrum-rod is in its horizontal position. The extent of oscillation of fulcrum-rod F is a distance equal to about one-half the stroke of the engine each way from its horizontal position.

The front end F^5 of fulcrum-rod F extends some distance past fulcrum C^9, constituting a lever for valve operation, having reversed movements from that part of the rod upon the opposite side of the point of oscillation upon C^9.

The piston P is represented by the dotted lines in Fig. 2 and is of the usual trunk form common to gas-engines. It is, however, provided with a rigid piston-rod P′ (also shown partly by dotted lines in Fig. 1) and is secured in the piston in a manner common to steam-pistons. (Not shown.) The outer or rear end of piston-rod P′ terminates in a rectangular slide P^2, which reciprocates freely in the guide G G′, which guide is parallel with the bore of cylinder C, but is slightly out of line with the center of the cylinder to accommodate the connections to the fly-wheel T, and hence the piston-rod has a slight permanent angle, but a straight-line movement. The piston-slide P^2 has a transverse horizontal hole through it similar to the hole through block T^3.

The means of connecting and transmitting power from piston-rod P′ to the block T^3 and fly-wheel T is a double crank, (designated in a general way by H.) It will be well to here specify just what is meant by a "double crank," and it will be designated as one having a central journal with a crank at each side of same, the adjoining cranks being diametrically opposite. The opposite cranks being in this case similar—that is, having similar throw—the centers of their bearing portions and of the central journal are in a straight line, and the double crank, as here shown, is therefore essentially a lever of the first class.

The central journal H' of the double crank H has formed, preferably, integral with it the adjacent crank-plates H^2 and H^3, and these have formed integral with them the cranks or crank-pins H^4 and H^5. The crank H^4 is journaled in the hole in slide P^2 of piston-rod P', the center journal H' is journaled in the bearing F^4 of fulcrum-rod F, and the crank H^5 is journaled in the hole in block T^3. The operation of this double-crank connection from piston-rod to fly-wheel is as follows: Starting with the piston in its innermost position and with the double crank in the position shown in Fig. 2, or horizontal, the gas for the explosion is compressed and occupies the clearance-space at the end of the piston and is fired or exploded soon after the rotation of the fly-wheel places the engine past what is known as the "dead-center," and the force of explosion of the gas against the piston impels it outward, impelling the crank H^4 toward the rear. At the time of and immediately following the instant of explosion the fulcrum-rod F, with its bearing F^4, carrying journal H' of crank H, has advanced to a position somewhat below the central or horizontal position when set to run in the direction indicated by the arrow in Fig. 1, and in consequence the double crank H stands at a considerable downward angle from the crank H^4, which is sustained in a position on a level with the piston-center by the guide G G' and slide P^2. In consequence of this angular position the crank H^4 may move rearward, provided the journal H' and bearing F^4 of connecting-rod F may be allowed to descend. The descent of journal H' can only take place by the crank H^5 moving downward and forward, which can only occur by the rotation of the fly-wheel and swinging of raceway T^2 about the axis of shaft S. The fly-wheel is therefore rotated by the impelling force given to it by the block T^3 from crank H^5, which is occasioned by the force of the explosion applied to crank H^4, acting upon journal H' as a fulcrum. The continuation of the outward movement of the piston after the fulcrum-rod bearing F^4 has attained its lowest position causes the continuation of the rotary movement of the fly-wheel, which raises the double crank H and fulcrum-rod F up to a horizontal position opposite to that from whence it started, as shown in outline in Fig. 4, with the crank H^4 in its outermost or rear position and the crank H^5 in its front horizontal position, and a continuation of the fly-wheel movement from the force of its momentum raises the journal H' and fulcrum-rod F above the horizontal center and until its highest position is reached, as represented in Fig. 1, and, continuing, restores the double crank H, fulcrum-rod F, and piston P to their starting positions as the fly-wheel completes its revolution, the piston having been returned to its innermost position by the crank H^4 as the fulcrum-rod F was raised to its uppermost position and then lowered to the horizontal position again.

Fig. 3 shows the fulcrum-rod F in the horizontal position.

The inner and outer extreme positions of the piston and the corresponding positions of the fly-wheel in this improved engine are similar to the corresponding positions in an ordinary engine; but the relative intermediate positions of the piston and fly-wheel are very different from those of an ordinary engine. Also the point of application of the power to the fly-wheel and the duration of the impulse differ materially from engines of the common type, and these relative movements and positions of fly-wheel, piston, and double crank are illustrated in the diagrammatic view Fig. 8.

Sixteen equiangular positions of the fly-wheel T and raceway T^2 are shown in Fig. 8, the same differing from each other by a uniform angle of twenty-two and one-half degrees, and these positions are represented by the radiating lines *a a a*, the axis of revolution being represented at *d*.

The position of crank H^5 corresponding to the innermost position of the piston is at O on the horizontal or center line *e e*, and the successive positions of crank H^5 upon the several radii *a a a* are represented at 1 2 3, &c., to 15. It will be seen that the path of movement of the crank H^5 is an ellipse, substantially as shown by the line drawn through the said sixteen positions, and the width of this ellipse is equal to the stroke of the piston, which is also equal to the total throw of the crank H^4, while the length of the ellipse is equal to twice the stroke of the piston or to the sum of the throw of the opposite cranks H^4 and H^5. The form of the ellipse is slightly distorted by the curved path of movement of the journal H' as it is guided by the fulcrum-rod F, and as a result the inner side of the ellipse is less curved than the outer side.

The positions of the crank H^4 corresponding with positions 0 to 8 of crank H^5 are represented at b, b', b^2, b^3, b^4, b^5, b^6, b^7, and b^8, respectively, upon the center line *e e*, while the corresponding positions of the inner end of the piston are represented at c, c', c^2, c^3, c^4, c^5, c^6, c^7, and c^8. The different angular positions of the double crank H are represented by the lines terminating, respectively, at the positions 0 1 2 3 to 15 of the crank H^5, while the corresponding positions of journal H' are shown at d d' d^2 d^3 to d^{15}, located upon the curved line representing the arc of movement of the fulcrum-rod bearing F^4. The extreme positions of the fulcrum-rod are represented by lines passing through the fulcrum C^9 and terminating at d^4 and d^{12}.

By analysis of the diagram we ascertain that for position 1 of crank H^5 the piston has advanced but nine-tenths of one per cent. of its total stroke, and for position 2 its advance is but five and one-fourth per cent. of its stroke, for position 3 its advance is fifteen and one-half per cent., for position 4 its advance is forty-four per cent., for position 5 its advance is seventy-nine per cent., for position 6 its advance is ninety-four per cent., for position 7 its advance is ninety-eight and three-fourths per cent. of the stroke, and for position 8 its advance is one hundred per cent. of the stroke.

From the diagram and the foregoing statements it will be observed that for a uniform movement of the fly-wheel the relative movement of the piston is highly accelerated during the middle portion of the stroke, its rate at the middle of the stroke being double the usual rate in an engine, and there is of course a proportionate retardation in the relative movement of the piston at and near the end portions of the stroke, where it moves exceedingly slow. It will likewise be apparent that while the rate of piston travel relative to fly-wheel rotation is vastly accelerated during the middle portion of the stroke the point of application of the power to the fly-wheel is also very much farther out from the axis of rotation during the middle portion of the stroke and, in fact, during substantially the whole of the effective part of the stroke after firing and previous to exhaust, and hence the application of the power is much more effective than in the ordinary engine, as the farther from the axis the power is applied the greater the proportion of the power that is devoted to the acceleration of the fly-wheel and the less the proportion that is wasted in friction and direct thrust against the bearings of the engine-shaft and all other bearings receiving the impulse given by the piston. Notwithstanding the fact that the relative piston travel is thus accelerated and that the point of application of the power to the fly-wheel is thus a greater distance from the axis of rotation the angular position of the double crank with reference to direction of piston movement is also slightly more effective than in the ordinary engine, the angle of double crank H being about twelve degrees for position 1, twenty-six and one-third degrees for position 2, forty-eight and one-half degrees for position 3, and eighty-six and one-fourth degrees for position 4. The similar positions in an ordinary engine for the same points in piston advance with connecting-rod two and one-half times the stroke and averaged between the two ends or neglecting the connecting-rod angle would be eleven degrees, twenty-four degrees, forty-two and one-fourth degrees, and seventy-seven and three-fourths degrees, respectively.

The above three principal differences in rate of advance of piston, increased distance from axis of application of power, and greater crank angle all contribute to a much more rapid advance of the piston between the point at which the charge is fired and the point at which the exhaust is opened, and hence it may appropriately be stated here that this high acceleration of the speed of the piston through the middle portion of the stroke permits the advance of the piston as it retreats before the force of the explosion much more in harmony with the nature of an explosion than in an engine having the usual form of connections, and this feature brings about important advantages, among which may be cited the shorter duration of the high temperature occasioned by the explosion, and consequently a material reduction of the heating effect of the explosion upon the cylinder, and hence the material increase in the proportion of heat value utilized in effective work and the consequent reduction in heat value lost in radiation and carried off by the cooling water surrounding the cylinder and cylinder-head, also the greater length of time during which the piston is at or very near to the outer terminal position contributes very highly to the exit of the products of combustion before the material advance of the piston on the return stroke, and hence leaves the subsequent charge of explosive mixture less diluted with non-inflammable gases and more effective. Likewise the longer dwell of the piston at or near the inner terminal position allows of the advance of the fly-wheel and double crank H farther past the central position before the charge is fired, by which means the parts are all better positioned to advantageously utilize the force of the explosion and to allow of the more rapid advance of the piston as and immediately following the explosion taking place and to do this without serious loss in compression pressure.

It has been ascertained that the time of firing the charge or igniting the gas may readily be delayed until the raceway T^2 has attained an angle of twenty-two and one-half degrees past the center, which is equivalent to position 1 in Fig. 8, and it is even desirable and best at some speeds to delay firing until the raceway T^2 has attained an angular advance of thirty degrees, which position is shown in Fig. 9 at 16, and for this position the piston has advanced but one and three-fourths per cent. of its stroke, and the angle of the double crank H is about sixteen and one-fourth degrees. Position 17 represents the position of crank H^5 when the angular advance of the raceway T^2 is forty-five degrees. The piston has then advanced but five and one-fourth per cent. of its stroke, the explosion is scarcely past its highest pressure, and the high angle of the raceway and double crank H contribute to an efficient application of the force of the explosion, while the position of the crank H^5 in the raceway T^2 has already attained a radial distance of one and one-fourth times the usual crank length, and it continues to increase until at double the usual radial distance from the axis of rotation at one-half stroke and only recedes to a position equal to one and one-fourth times the ordinary radial distance at the time of opening the exhaust, which may be at position 18, when the piston has completed ninety-four per cent. of its stroke, or even at a later position at substantially the full completion of the stroke.

With the valve connections shown, which will be more fully described later, the exhaust begins to open at about position 18 and becomes fully opened at the full termination of the stroke, equivalent to position 8 in Fig. 8, and it remains open until the fly-wheel has rotated to within about three degrees of the three-quarter-revolution point, as at position 19, and when position 20 is reached, corresponding to a fly-wheel advance of about two hundred and seventy-five degrees in the revolution, the admission-valve opens, and at position 21, about fifteen degrees later, the admission-valve closes and the remainder of the stroke is devoted to compression of the succeeding charge. It may be remarked here that the gas or other fuel mixed with air is admitted under quite a high initial pressure in this two-cycle engine. It is found that the clearance-space may be considerably reduced in this form of engine because of the peculiar operation of the connections above described, and hence this remainder of the stroke is more than usually effective in compression, and occurring so late as it does in the stroke and the advance of the piston comparatively slow in proportion to fly-wheel advance at the last of the stroke the retarding effect upon the fly-wheel is materially reduced over the usual form of gas-engine.

The inlet-valve V is located in the upper part of the cylinder-head D, as shown in Fig. 7, and opens inward in the usual manner into the clearance-space D^4. The valve-stem V' is sleeved in the disk-cap D^5, which is secured to head D, and passes out through the stuffing-box D^6 and has securely fixed upon it the collars D^7 and D^8, the latter having extensions D^9 and D^{10}, under which are placed two lifting-springs D^{11}, which close the valve when it is not forced open by the valve-operating connections. (See Figs. 2 and 3.) Over the top portion of the cylinder C is located a rock-shaft I, mounted in bearings I' and I^2, which are secured to the cylinder C in the usual manner, as by the bolts I^3, and to this rock-shaft is securely fixed the lever or arm I^4, which is forked at its outer extremity, the prongs projecting between the collars D^7 and D^8, and by this means the valve V is opened and allowed to close by the rocking of the shaft I.

Securely fixed upon the end portions of the shaft I are the levers I^5 and I^6, which project oppositely from lever I^4, and each is preferably provided with an inserted hardened plate I^7 for receiving the impact of the valve-opening fingers or pawls J and J', which are pivotally secured to blocks J^2 and J^3, which are in turn pivoted to the outside of the fulcrum-rod F at points upon opposite sides of the fulcrum C^9, upon which the fulcrum-rod oscillates. The pivots of the blocks and of the fingers are at right angles to each other, and hence the fingers J and J' are capable of moving longitudinally and transversely with reference to the fulcrum-rod F, the movement in one direction being to allow of the oscillation of the fulcrum-rod without materially disturbing the vertical position of the fingers and the movement in the other direction providing for the movement of the tops of the fingers toward and away from the engaging plates I^7 as the fingers engage with and disengage from the said plates and are controlled by the governing and reversing mechanism to be presently described. The fingers are maintained in a substantially vertical position by means of the wire loops J^4, which are secured to the levers I^5 and I^6.

Freely mounted for oscillation upon the rock-shaft I, near the levers I^5 and I^6, are two governor-plates K and K', which are both securely fixed upon the extremities of a connecting shaft or rod K^2, and the plate K' extends to the right to a position adjacent to a governor-shaft L, which is revolubly mounted in suitable bearings of the bed A, as A^5 and A^6. The governor-shaft is revolved in proportion to the speed of the engine in any of the usual ways, as by means of the gear L', driven by a mating gear, both preferably having slanting teeth and a slanting shaft with bevel-gear connection to shaft S. (Not shown.)

At the top of governor-shaft L is secured the head L^2, in which are pivoted the ball-levers L^3, upon which are fixed the balls L^4, and pivoted in levers L^3 are connections L^5, the lower ends of which are pivoted in a sliding collar L^6, which is mounted for free vertical movement upon the governor-shaft L and is provided with an annular groove L^7, which is in engagement with the top end of a connection L^8. A short distance below the top (see Fig. 6) the connection L^8 is pivoted to the outer extremity of plate K', which, with plate K and rod K^2, is raised and lowered by the increase and decrease of speed of the engine by the governor.

The plates K and K' have downward and outward projecting portions K^3 and K^4, upon which are journaled the rollers K^5 and K^6, which are in position and adapted to bear against the inner faces of fingers J and J' and to hold the said fingers out of position to engage with the plates I^7 when the governor raises the rollers K^5 and K^6 and to allow the fingers to engage with the plates I^7 when the governor lowers the rollers K^5 and K^6.

The operative engagement of the fingers J and J' with the plates I^7 occurs during the upward movement of the said fingers as the same are raised by the oscillations of the fulcrum-rod F, and the levers I^5 and I^6 are provided with downward extensions I^8, which perform the function of knock-off cams well known in steam-engine construction, and these knock off or release the fingers from the plates I^7 of levers I^5 and I^6 during the continuation of the upward movement of the fingers upon the rock-shaft I, attaining the requisite position to fully open the valve V or at such time as the said valve has been open sufficiently long to admit the required amount of gas for a charge.

Two of the fingers J and J′ are provided for the purpose of being able to reverse the engine, and only one of the said fingers is allowed to be in the operative position at the same time, and to effect this result there are provided upon the fulcrum-rod F two slides F^6 and F^7, mounted in any desired manner, as by a bolt passing through a slot in the slides, the said slides having inclined or beveled rollers F^8 and F^9, rotatable upon suitable pivots, the lateral position of the rollers being such that they will hold the fingers out of operative position when the slides are so positioned upon the fulcrum-rod as to place the rollers adjacent to the fingers. The slides F^6 and F^7 are positioned upon the fulcrum-rod F by means of the connections F^{10}, pivoted to the said slides at one end and to the lower extremity of a reverse-lever M, which is pivoted to a support C^{10}, secured to the cylinder C. The connections F^{10} maintain the slides F^6 and F^7 at such a distance apart that but one of the rollers F^8 and F^9 can be opposite the adjacent finger at the same time. The reverse-lever M when in the position shown in Figs. 1 and 2 places the roller F^8 in its inoperative position and allows the finger J to be in its operative or engaging position with reference to plate I^7, while the roller F^9 is sustained in its operative position and holds the finger J′ out of its engaging position. With the fingers so controlled by the reversing mechanism only the finger which is allowed to be in the operative position by the reversing-lever will be controlled by the governor or will operate the rock-shaft I and valve V. The fingers J and J′ are maintained elastically or yieldingly against the rollers F^8 and F^9, as above stated, by means of the springs J^5 and J^6, which are preferably secured to the blocks J^2 and J^3.

The exhaust-valve E is shown in Fig. 4, which also shows the lower extension C^4 of the cylinder C and the corresponding lower part of the cylinder-head D in sectional plan, and the valve-stem E′ is mounted for free sliding movement in the hole C^5 of extension C^4, passes out through a gland or stuffing-box C^{11}, and is provided with a fixed collar E^2, which has a horizontal projection E^3, the object of which will be stated later.

Bearing against the collar E^2 is a coil-spring E^4, which abuts against a suitable projection, as A^7, of the bed A and tends to close the valve E against the valve-seat D^{12} of head D when allowed to do so by the valve connections and operating devices. At its outer end the valve-stem E′ is pivoted to a vertical lever E^5, which is fulcrumed upon stud E^6, secured in the raised part A^3 of the bed A. Upon an adjoining stud E^7, also secured in A^3, is an L-shaped lever or pawl E^8, (see Fig. 5,) the pawl portion of which lies immediately beneath the valve-stem E′, and the valve-stem has a downward projection E^9 in position and adapted to be engaged by the complementary engaging surface of the pawl E^8 to retain the exhaust-valve E open after it has been opened by the lever E^5.

Fixedly secured to the under side of the piston-rod P′ is a downwardly-projecting lug P^3, which is in position and adapted to engage with the top portion of the lever E^5 as the piston nears the end of its outward stroke, thereby opening the exhaust valve E, as shown in Fig. 4, and the lug P^3 also engages with the top portion of lever E^8 at the very last of the piston-stroke, thus forcing the pawl into position to engage with the face E^9 of valve-stem E′ upon the beginning of the return stroke of the piston. A suitable spring E^{10} tends to throw the pawl into engagement with E^9 and to retain it in such engagement until forcibly disengaged; but this spring is not depended upon to cause the engagement, and the positive means above stated is therefore provided.

Projecting from the side of the lever E^8 are two studs E^{11} and E^{12}, located upon opposite sides of the pivotal mounting of the lever, and placed against the shoulders of these studs is a trip-plate N, which has through it three horizontal slots, by means of which it is mounted upon the studs E^{11} E^{12} and the end of stud E^7, being secured in place by the pin E^{13}. This plate N has a rod extension N′ extending slightly past and beneath the fulcrum C^9 and is provided with two opposing engaging faces N^2 and N^3 upon the under side of the rod.

Secured to the under side of the fulcrum-rod F is a post or arm F^{11}, upon the lower portion of which is pivotally mounted a trip-lever N^4, having its upper end forked and in engagement with the ends of the connections F^{10}, whereby the trip-lever N^4 is tipped slightly to one side or the other of its central position by the movements of the reverse-lever M. The trip-lever N^4 is provided with two opposite impact-faces N^5 and N^6, one of which, as N^6, is in position to strike one of the engaging faces, as N^3, of the rod N′ during the oscillation of the fulcrum-rod when the reverse-lever M is in the position shown.

Upon placing the reverse-lever M in its opposite position, as indicated by the dotted line in Fig. 1, the trip-lever N^4 is tipped to the right and the impact-face N^6 is thrown below the position for engagement with N^3 and the impact-face N^5 is thrown up into position to engage with the face N^2 of rod N′. It will thus be apparent that with the reverse-lever M and trip-lever N^4 in the position shown in Fig. 1 the extreme upper position of fulcrum-rod F will cause the disengagement of pawl E^8, allowing spring E^4 to close valve E by the end of slot in plate N striking the stud E^{12} and that with the reverse-lever and trip-lever N^4 in their reverse positions the extreme lower position of fulcrum-rod F will cause the release and closure of the valve E by the end of slot in plate N engaging with the stud E^{12}. In Fig. 1 the rotation of the fly-wheel is in the direction indicated by the arrow, the piston is part way back on its return stroke, the fulcrum-rod F has reached its highest position, has just disengaged the pawl E^8, and the spring E^4 has just closed the valve E. The extreme outer position of lug P^3 is represented by dotted lines in Fig. 1.

The governor connection L^8 terminates at its lower end in a rod L^9, which is pivoted to the rod N', as shown, by means of which the rod N' is raised out of position for engagement with faces N^5 and N^6, when the governor is in such position as to also prevent the engagement of one of the fingers, as J, and it is therefore evident that the disengagement of pawl E^8 and the consequent closing of exhaust-valve E will only occur during such of the return strokes of the piston in which the governor position indicates that more force is required to keep up the speed, in which case the exhaust-valve E will be closed, and immediately following its closure the admission-valve V will be opened by the upward movement of one of the fingers, as J, tipping the rock-shaft I.

Projecting from the side of cylinder-head D is a lug D^{14}, Figs. 1 and 2, to which is secured insulatedly a spring R by screw R', and a raised portion R^2 is normally held slightly below a cylindrical projection N^7 (shown by dotted line in Fig. 1) upon the inside of trip-lever N^4. The rear end of spring R terminates in an inclined contact-face R^3, which is engaged by an inclined insulated contact-face E^{13} of projection E^3 from the exhaust-valve stem E'. The projection E^3 is sustained in the horizontal position in any desirable manner, as by the rod E^{14}, resting upon a suitable support. Upon the closure of the exhaust-valve E the spring R is by the above means bent upward sufficiently to cause R^2 to make and break an electrical contact with N^7 about the time the fulcrum-rod F passes the horizontal position next following the closure of the exhaust-valve.

The wires W and W' from the usual spark-coil (not shown) are preferably connected, one with some part mechanically connected with N^7, as to the fulcrum-rod F, and the other to one member, as W^2, of the usual igniter or sparker, which is secured in the plate W^3, secured to the central part of the cylinder-head D and projecting with the mating member W^4 of the sparker into the clearance-space adjacent to the end of the piston. The member W^4 is connected by the wire W^5 with the spring R, being secured by means of the screw R^4.

It will be observed that the construction is such that the spring R will not cause ignition unless the exhaust-valve is closed, which only occurs just previous to the admission of a charge of gas for an explosion, and hence the device is constructed for the economical use of current and also in such a manner as to prevent dangerous or harmful ignition taking place, as at times when it is not required to give an impulse to the piston. At the next succeeding time of the fulcrum-rod passing the horizontal position after ignition takes place the exhaust-valve is open, preventing contact of R^2 with N^7. The tipping of the trip-lever N^4 upon reversing the engine causes the contact to be broken slightly after the dead-center is passed or the horizontal position of the fulcrum-rod is reached in whichever direction the engine is set to run.

It will be apparent that the essential feature of the mounting of the double crank with reference to fulcrum-rod F is that the bearing H' be allowed movement across the path of movement of the piston, but not allowed to move substantially in line with the movement of the piston. I therefore do not wish to limit myself to the curved movement given by the fulcrum-rod. Likewise the throw of the cranks H^4 and H^5 may be unequal and yet maintain substantially the advantages above stated, and I therefore do not limit myself to like cranks.

A summary of some of the chief advantages of the present form of engine as above described when adapted to gas-engine service will be: first, a slower starting of the piston upon its outward stroke, giving a greater advance to the rotative and connecting parts before the time of firing the explosion; second, an exceptionally-rapid advance of the piston throughout the middle portion of the stroke, comprising substantially the whole of the effective part of the stroke, allowing the explosion to be more in the nature of an explosion and giving far less heating effect to the cylinder and far less loss in heat value by the water-jacket; third, a material retardation and dwell of the piston at and near the terminal position in its stroke, giving a far more complete expulsion of the products of combustion before the return of the piston; fourth, the application of the power to the rotative parts at a much greater distance from the axis, and the consequent reduction in losses in friction and the greater efficiency in application of the force of the explosion.

I claim—

1. In an engine of the class specified, the combination, with a piston and piston-rod having a straight-line movement, of a double-crank connection revolubly mounted in a fulcrum-rod for bodily oscillatory movement, one end of the said double crank being journaled in the said piston-rod, and the opposite end having engagement with the rotative member of the engine, and moving in an elliptical path.

2. In an engine of the class specified, the combination, with a guide and a reciprocatory

piston-rod, of a double crank, one end of which is journaled in the said piston-rod, and the opposite end of which travels in a radial raceway in the rotative member; and a fulcrum-rod journaled at one end upon the center of the said double crank, and pivoted at the other end upon a stationary part of the engine.

3. In an engine of the class specified, the combination, with a piston-rod reciprocating in a guide, of a rotary member provided with a radial raceway; a fulcrum-rod pivoted upon a stationary part of the engine; and a double crank, the center bearing of which is journaled in the free end of the said fulcrum-rod, and having one of its ends journaled in the outer end of the said piston-rod, and its opposite end journaled in a block slidably mounted in the said raceway.

4. In an engine of the class specified, the combination, with a reciprocatory member comprising a piston and piston-rod, of a rotative member comprising a shaft, balance-wheel and substantially radial raceway; an oscillating member pivoted upon a stationary part of the engine; and a lever connection from said reciprocatory member to said rotative member, and fulcrumed in said oscillating member.

5. In an invention of the class specified, the combination, with reciprocatory, rotative and oscillatory members, of a double crank mounted for bodily movement across the path of movement of the said reciprocatory member; an admission-valve; and valve-operating connections from said oscillatory member to the said admission-valve.

6. In an engine of the class specified, the combination, with reciprocatory and rotative members, of a double crank journaled in an oscillatory member, and connecting said reciprocatory and rotative members; and valve-operating connections from oppositely-moving parts of said oscillatory member, to an admission-valve.

7. In an engine of the class specified, the combination, with reciprocating and rotative members, of a lever connection from said reciprocating to said rotative members; an oscillating lever in which said lever connection is fulcrumed; valve-operating connections from oppositely-moving parts of said oscillating member to an admission-valve; and reversing means for placing either of said valve-operating connections in operative relation to said admission-valve.

8. In an engine of the class specified, the combination, with reciprocatory, rotative and oscillatory members, of a double crank journaled in said oscillatory member, and connecting said reciprocatory and said rotative members; and an exhaust-valve, opened by the extreme outward movement of said reciprocatory member.

9. In an engine of the class specified, the combination, with reciprocatory, rotative and oscillatory members, of a double crank mounted for rotation in said oscillatory member, and engaging at its end portions with said reciprocatory and rotative members; an exhaust-valve opened by said reciprocatory member; and a pawl for retaining said exhaust-valve open.

10. In an engine of the class specified, the combination, with reciprocatory, rotative and oscillatory members, of a double crank revolubly mounted in said oscillatory member, and connecting said reciprocatory member with said rotative member; a spring-actuated exhaust-valve, opened by the extreme outward movement of said reciprocatory member; a pawl for retaining said exhaust-valve open; and a tripping device, operated by said oscillatory member, to throw out the pawl, and allow the said valve to close.

11. In an engine of the class specified, the combination, with reciprocatory and rotative members, of a double crank revolubly mounted in an oscillatory member, and connecting said reciprocatory and rotative members; valve-operating fingers mounted upon oppositely-moving parts of said oscillatory member; a rock-shaft operatively connected with an admission-valve; and yielding means for throwing said fingers into operative position to engage with said rock-shaft.

12. In an engine of the class specified, the combination, with reciprocatory and oscillatory members, of a double-crank connection from said reciprocatory member to a rotative member, the said double crank being journaled in said oscillatory member; and governor-controlled connections from said oscillatory member to an admission-valve.

13. In an engine of the class specified, the combination, with a reciprocating piston and piston-rod, and a rotary shaft and fly-wheel, of a double crank mounted for bodily oscillatory movement in a fulcrum-rod, and connecting the said piston-rod with the said fly-wheel; yieldingly-supported fingers mounted upon said fulcrum-rod; a governor and connections in operative engagement with the said fingers, to change the same to or from their operative position; and connections from the operative position of the said fingers to an admission-valve.

14. In an engine of the class specified, the combination, with a fulcrum-rod guiding a double-crank connection from a reciprocating piston-rod to a rotative member, of a spring-actuated exhaust-valve, opened by the outward movement of the said piston-rod, and retained open by a pawl; operative connections from said fulcrum-rod to detach said pawl; two oppositely-moving connections upon said fulcrum-rod for actuating an admission-valve; and a reversing lever in position and adapted to throw one or the other of said connections out of operative position.

15. In an engine of the class specified, the combination, with an oscillating lever, actuated by the connection from the reciprocatory

to the rotative members, of yielding fingers mounted upon oppositely-moving parts of said oscillating lever; a reverse-lever having connections whereby one of the said fingers is thrown out of operative position; a governor in operative connection with the finger left in operative position; and connecting means from the operative position of said finger to an admission-valve.

16. In an engine of the class specified, the combination, with an oscillating lever, actuated by the connection from the reciprocatory to the rotative members, of a spring-closed exhaust-valve; a lever connected with said exhaust-valve, and engaged by the piston-rod, to open the valve; a pawl to retain said valve open; and a trip-plate in engagement with said pawl, in position and adapted to be actuated by the said oscillating member, to disengage the said pawl.

17. In an engine of the class specified, the combination, with an oscillating lever, actuated by the connection from the reciprocatory to the rotative members, of an exhaust-valve opened by the piston-rod; a pawl to retain said valve open; a trip connection, whereby the movement of the said oscillating lever allows the closure of the said valve; and connection from the governor to the said trip connection, whereby the governor controls the closing of the said exhaust-valve.

18. In an engine of the class specified, the combination, with a spring-actuated exhaust-valve opened by the outward movement of the piston, of a pawl, for retaining the said valve open; governor-controlled tripping means for disengaging the said pawl; and reversible means upon an oscillating member, whereby the said tripping means may be operated at opposite oscillations of the said oscillating member.

19. In an engine of the class specified, the combination, with an exhaust-valve, closed by reversible means upon an oscillating member in conjunction with governor-controlled tripping means, of an admission-valve and valve-operating connections, operating in connection with reversible, governor-controlled means mounted upon oppositely-moving parts of said oscillating member.

20. In an engine of the class specified, the combination, with an admission-valve, of a rock-shaft operatively connected with said valve; levers upon the opposite ends of said rock-shaft having engaging faces in position and adapted to be acted upon by reciprocating fingers having opposite movement; and knock-off cams upon the said levers, for disengaging the said fingers.

In testimony whereof I have hereunto set my hand and affixed my seal, before two subscribing witnesses, at Denver, Colorado, this 11th day of December, A. D. 1900.

ANDREW C. WOLFE. [L. S.]

Witnesses:
OLGA JACOBSON,
W. J. CHAMBERLAIN.