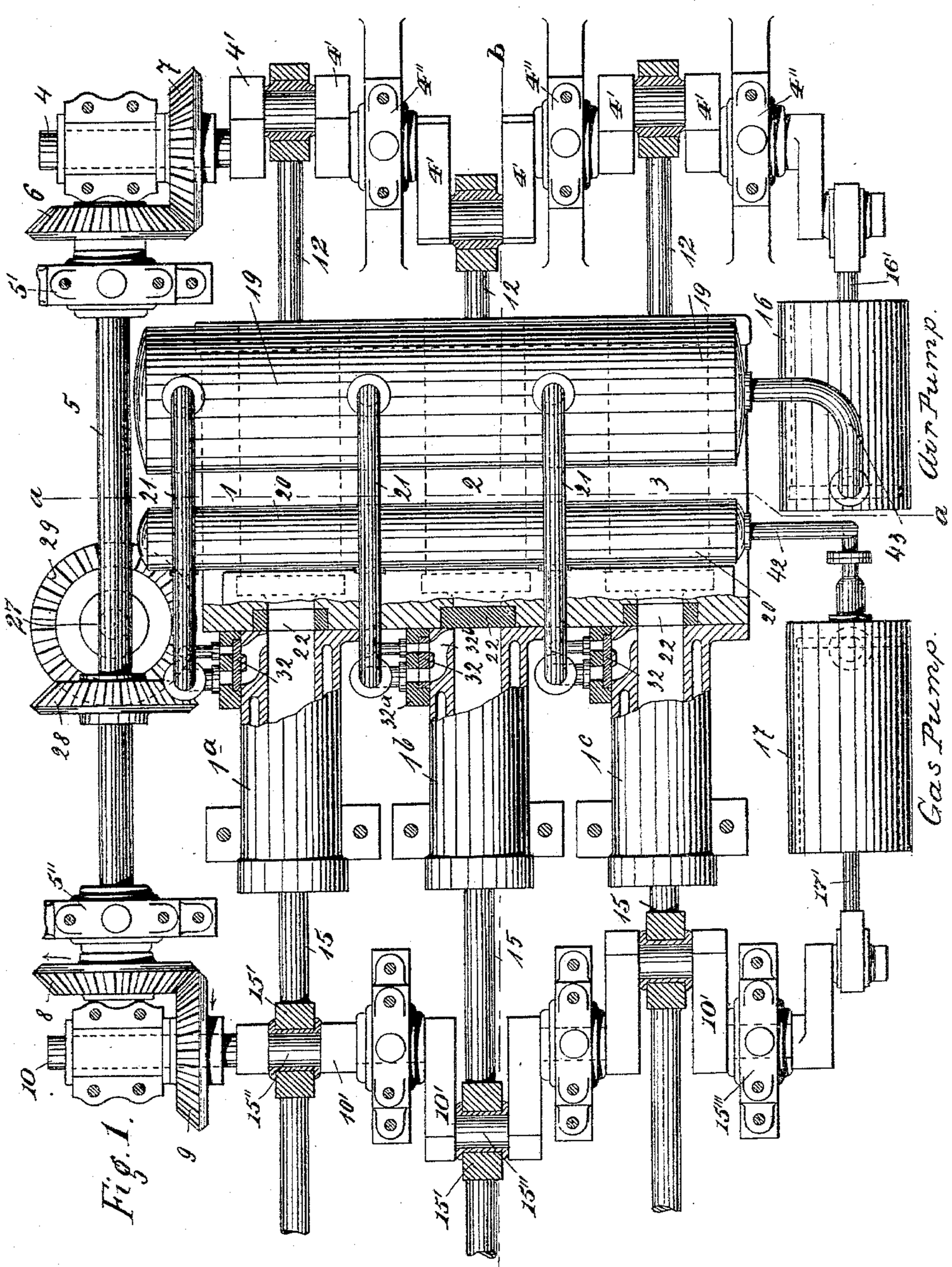
(No Model.) 3 Sheets—Sheet 1.

G. G. SMITH.

DIFFERENTIAL GAS MOTOR.

No. 597,749. Patented Jan. 25, 1898.



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(No Model.) 3 Sheets—Sheet 2.

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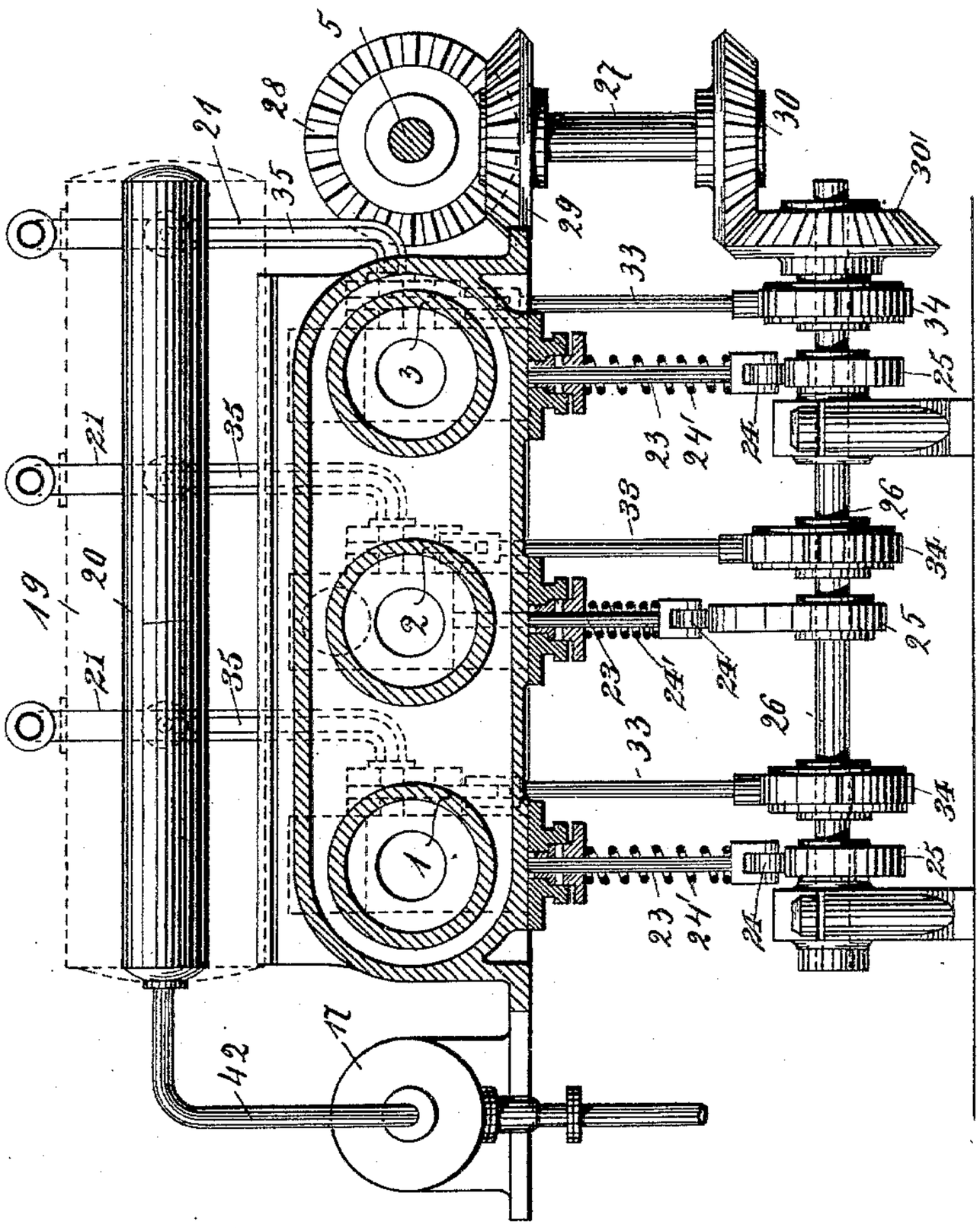
Fig. 2.



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(No Model.) 3 Sheets—Sheet 3.

G. G. SMITH.

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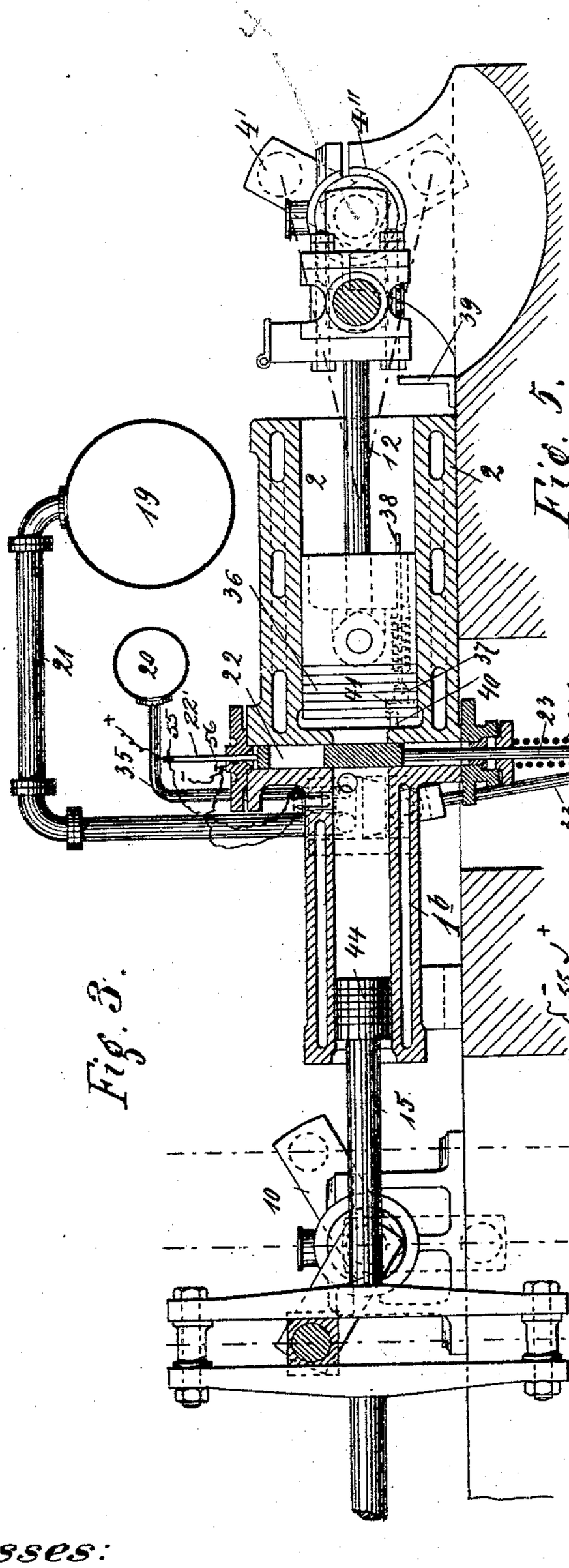

Fig. 3.

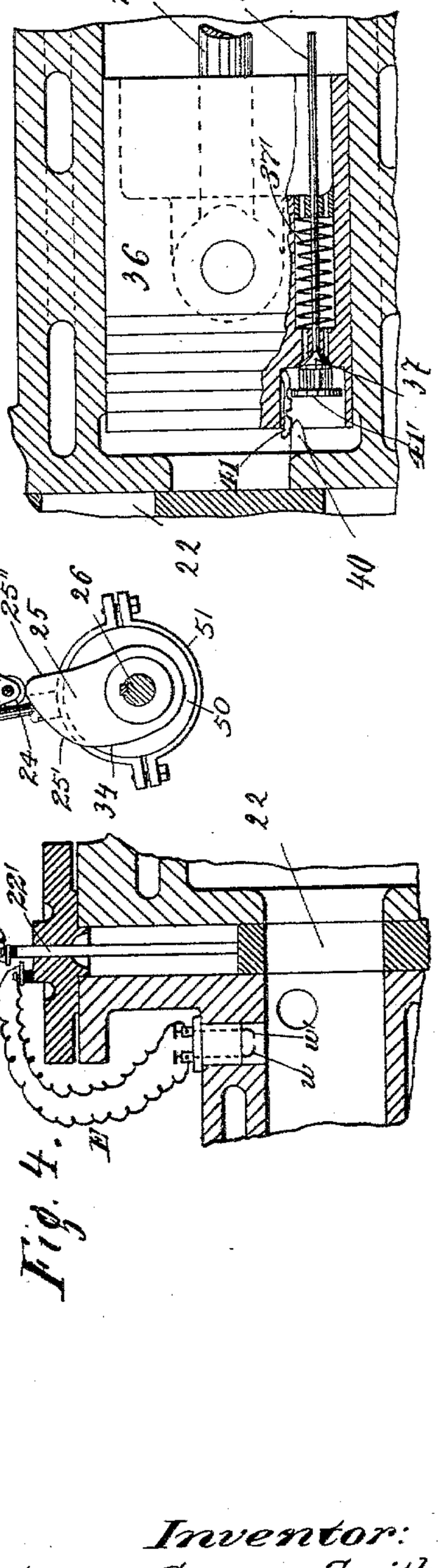

Fig. 5.

Fig. 4.

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UNITED STATES PATENT OFFICE.

GEORGE GREGORY SMITH, OF ST. ALBANS, VERMONT.

DIFFERENTIAL GAS-MOTOR.

SPECIFICATION forming part of Letters Patent No. 597,749, dated January 25, 1898.

Application filed May 10, 1897. Serial No. 635,802. (No model.)

To all whom it may concern:

Be it known that I, GEORGE GREGORY SMITH, a citizen of the United States, residing at St. Albans, in the State of Vermont, have invented certain new and useful Improvements in Differential Gas-Motors, of which the following is a specification.

This invention relates to gas-engines, one object of the invention being to furnish an improved gas-engine embodying means whereby an effective stroke or impulse will be imparted to the piston at every complete rotation of the crank-shaft and also embodying means whereby the products of combustion will be entirely expelled from the explosion-chamber and working cylinder during the back stroke of the working piston and before a fresh charge of the explosive mixture is supplied to thereby obviate the loss of explosive efficiency accruing from the intermixture of the products of combustion with the fresh charge, as in cycle-system engines of ordinary and well-known constructions, in which approximately thirty-three per cent. of the products of combustion remains in the cylinder, and consequently mixes with the fresh gas, thus materially deteriorating the efficiency of the explosive charge.

A further object of the invention is to provide in a gas-engine having a working cylinder and an explosion-chamber means controlled by the crank-shaft for establishing and cutting off communication between the working cylinder and the explosion-chamber at predetermined points in the movements of the piston or immediately before and immediately after, respectively, the ignition of the explosive charge to thereby separate the cylinder and explosion-chamber during the exhaust of the products of combustion and prevent the intermixture of a fresh charge with said products.

A further object of the invention is to provide a gas-engine comprising a working cylinder having a piston; a crank-shaft in connection with said piston; an explosion-chamber leading to the working cylinder and also having a piston; a crank-shaft in connection with this piston; means connecting the two crank-shafts so that said shafts will have comparative velocities of a predetermined ratio, the piston-actuating crank being so set as to impart a movement to the working piston slightly in advance of the other piston; means for supplying a combustible mixture or explosive charge to the explosion-chamber; a slide-valve located between the working cylinder and explosion-chamber; means controlled by the movements of a crank-shaft for actuating the slide-valve to establish communication between the working cylinder and explosion-chamber just preceding an explosion and for cutting off communication between said cylinder and explosion-chamber after an explosion, and means for igniting the explosive charge in the explosion-chamber.

In the drawings accompanying and forming part of this specification, Figure 1 is a plan view, partially in horizontal section, of a multicylinder engine embodying my present invention, the bed-plate of the engine not being shown. Fig. 2 is a vertical cross-sectional view of the gas-engine, taken in dotted line *a a*, Fig. 1, as seen from the right in said figure. Fig. 3 is a vertical longitudinal section of the gas-engine, taken in a line corresponding to the dotted line *b b*, Fig. 1, as seen from below in said figure. Fig. 4 is a longitudinal section, similar to Fig. 3, on a relatively large scale of a portion of the engine, showing one form of device for igniting the explosive charge; and Fig. 5 is a longitudinal section on a relatively large scale of a portion of one of the working cylinders and its piston and showing the exhaust-valve and the actuating device therefor.

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

For convenience my present invention is shown embodied in a so-called "multicylinder" gas-engine; but it is desired to state that while for some reasons it is preferable to employ an engine having a series of cylinders it will of course be understood that my invention is applicable to a one-cylinder engine. Therefore I do not desire to limit this invention to an engine having any particular number of working cylinders.

In the preferred form thereof illustrated in the accompanying drawings the engine comprises in part three working cylinders, (designated by 1, 2, and 3, respectively,) three explosion cylinders or chambers (designated by 1^a, 1^b, and 1^c, respectively) communicat-

ing at their inner or rear ends with the interiors of the working cylinders 1, 2, and 3, respectively, and which explosion-chambers are of considerably less internal diameters than the internal diameters of the working cylinders with which they communicate. Each working cylinder is furnished with a piston 36, which is connected by means of a piston-rod 12 to a crank 4′ of a main crank-shaft 4, journaled in suitable bearings 4″, as shown most clearly in Figs. 2 and 3 of the drawings.

In three-cylinder engines the three cranks of the main crank-shaft (which cranks are for convenience designated by similar characters) are set at angles of one hundred and twenty degrees apart—that is to say, with the axes of their crank-pins equidistantly disposed about and intersecting a common arc.

Each explosion-chamber is furnished with a piston 44, the piston-rod 15 of which is preferably connected by a slide-block 15′ to the crank-pin 15″ of a crank 10′ on a crank-shaft 10, which crank-shaft is journaled in suitable bearings 15‴, as shown in Fig. 1, with its axis in parallelism with the axis of the main shaft 4. The three cranks of the crank-shaft 10 are set at angles of one hundred and twenty degrees apart and are so disposed with relation to the cranks of the main crank-shaft 4 that the working piston 36 will preferably have a lead over the adjacent piston 44 substantially equal to a thirty-degree throw of a crank—that is to say, when the working piston 36 has arrived at the end of its instroke the piston 44 will still have a portion of its outstroke to complete, so that when the next charge is exploded in the explosion-chamber it will drive the two pistons 36 and 44 in the effective direction and thereby attain an effective working power which is slightly in excess of the actual calculated differential power of the engine, it being of course understood that the two crank-shafts 4 and 10 are operatively connected together for unitary movement at coinciding velocities.

As shown in Fig. 1 of the drawings, the actuating-connector between the two crank-shafts 4 and 10 comprises an intermediate shaft 5, journaled at opposite ends thereof in suitable bearings 5′ and 5″, respectively, and having at one end thereof a bevel-gear 6, which meshes with a bevel-gear 7, fixed to the crank-shaft 4, and also having at the opposite end thereof a bevel-gear 8, which meshes with a bevel-gear 9, fixed to the crank-shaft 10.

As a convenient means for supplying air and gas in proper relative proportions to the explosion-chamber under the requisite pressure and mixing the same so that on the ignition of the charge an explosion of high efficiency will result I have provided a supply apparatus which in the preferred form thereof shown in the drawings comprises an air-pump (designated by 16) having its piston-rod 16′ connected to a crank on the main shaft 4, a gas-pump 17, having its piston-rod 17′ connected to a crank on the shaft 10, an air-reservoir 19, adapted for storing air at requisite pressure and having an induction-pipe 43 leading to the interior of the air-pump cylinder 16, a gas-reservoir 20, adapted for storing gas at the requisite pressure and having an induction-pipe 42 leading to the interior of the gas-pump cylinder 17, a valve-chest 32^a in connection with each explosion-cylinder and having a mixing-passage 32^b leading therefrom to the interior of the explosion-cylinder, an air-conduit 21, leading from the air-reservoir 19 to the interior of the valve-chest 32^a, a gas-conduit 35, leading from the gas-reservoir 20 to the interior of said valve-chest, a valve 32, seated in the valve-chest and adapted for periodically establishing and cutting off communication between the mixing-passage 32^b and the air and gas conduits 21 and 35, respectively, and means operable at predetermined points in the movements of the working piston for actuating the valve 32.

To avoid the danger due to the storage of a considerable quantity of the mixed explosive at the requisite pressure, the air and gas are stored under pressure in different reservoirs and are separately conducted in proper relative proportions to the mixing-passage communicating with the explosion-chamber, where they are mixed to form the explosive charge, the apparatus shown in the drawings and described in the preceding paragraph constituting a convenient means for effecting this end; but it will be understood that any suitable supply apparatus may be employed in lieu of that shown and described.

For the purpose of positively preventing the intermingling of the products of combustion with the fresh charge of gas and to facilitate the complete exhaust of said products of combustion I have provided means for periodically closing and opening the passage-way between each working cylinder and its adjacent explosion-chamber. This means, in the preferred form thereof shown most clearly in Figs. 1 and 3 of the drawings, comprises a vertically-disposed slide-valve or partition 22, seated for reciprocatory movement in a slideway intersecting the longitudinal axis of the explosion-chamber, and as a means for actuating this slide-valve I have provided in connection therewith an actuating-rod 23, preferably having a roll 24 at the lower end thereof, which bears upon the working face 25′ of a cam 25, which cam is fixed to a shaft 26, and which shaft is actuated, preferably, from the horizontal intermediate shaft 5 by suitable gearing, preferably comprising a bevel-gear 28, fixed to the shaft 5 and meshing with a bevel-gear 29, fixed to a vertically-disposed shaft 27, having at the lower end thereof a bevel-gear 30, which in turn meshes with a bevel-gear 30′, fixed to the shaft 26.

As a means for retaining the roll of the valve-actuating rod 23 in engagement with

the working face of the cam 25 a spiral spring 24′ is provided, which spring bears at its upper end against the under side of the cap of a stuffing-box, through which the rod extends, and bears at its lower end against the roller-carrying bracket. The working face of the cam 25 has an abrupt let-off portion 25″, adapted for effecting a quick opening movement of the valve 22 at a predetermined point in the rotation of the shaft 26, as will be understood by reference to Fig. 3 of the drawings. The cam 25 will be so constructed and so timed in its movements relatively to the movements of the working piston 36 that an opening movement will be suddenly imparted to the slide-valve 22 immediately upon the arrival of said piston at the end of its back stroke and immediately preceding the explosion of the charge in the explosion-chamber, and a closing movement of said valve will be effected immediately after the explosion of the charge takes place and on the beginning of the advancing movement of the piston, to thereby cut off communication between the explosion-chamber and working cylinder while the products of combustion are being exhausted and to establish communication between said cylinder and explosion-chamber immediately after the products of combustion have been exhausted and after the working piston has arrived at the end of its back stroke.

The valve 32, which controls the admission of air and gas to the mixing-passage 32^b, in communication with the explosion-chamber, comprises, in the form shown most clearly in Figs. 2 and 3 of the drawings, an eccentric 50, fixed to the shaft 26 and having an eccentric-strap 51, connected, by means of an actuating-rod 33, to the lower end of the slide-valve 32; and said actuating device is so timed in its movements as to establish communication between the valve-chest 32^a and the explosion-chamber immediately after the slide-valve 22 has closed the passage-way between the explosion-chamber and working cylinder and is actuated to cut off communication between said valve-chest and explosion-chamber immediately after an opening movement has been imparted to the slide-valve 22 and just preceding the ignition of the explosive charge.

As a simple and convenient means for igniting the explosive charge in the explosion-chamber at the completion of each back stroke of the working piston and at each opening movement of the slide-valve 22 I have shown (see Figs. 3 and 4 of the drawings) an electrical igniting device, which comprises a normally open electrical circuit (designated in a general way by E) having two spark-producing terminals *w* and *w′*, located within the explosion-chamber, and a circuit-maker located within said circuit and preferably consisting of a contact member 55, carried on an insulated block at the upper end of an upwardly-extending stem 22′ on the slide-valve 22, and a coöperative contact member 56, fixed to an insulated block secured to the cylinder-casting and located in the path of movement of the contact member 55. The construction and organization of the igniting device may be modified without departure from this invention.

As a means for facilitating the exhaust on the back stroke of the working piston the piston-head has an exhaust passage-way formed therethrough which is closed by a piston-valve 37 when the working piston 36 is at the end of its back stroke and during the forward stroke thereof. This valve is normally retained in a closed position by a spiral spring 37′.

As a means for actuating the valve to open the same near the completion of the forward stroke of the piston said valve is furnished with an actuating-stem 38, one end of which projects beyond the forward end of the piston, and a stop-plate 39 is fixed to the bed of the engine and located in the path of movement of the valve-stem, so that when the piston has arrived at a predetermined point in the advancing movement thereof the valve-stem will strike the stop-plate 39, which will arrest the movement of the valve during the continuation of the forward stroke of the piston and open the exhaust-passage through the piston-head, and as a means for holding the valve in its open position during the backward stroke of the piston I have provided a spring-catch 41, located in position for engaging a flange 41′ on the end of the valve when the valve is in its open position. This catch is sprung out of engagement with the valve to allow said valve to close when the piston has arrived approximately at the end of its backward stroke by means of a catch-actuating cam 40, fixed to the end of the cylinder in the path of movement of the catch 41, as will be readily understood by reference to Fig. 5 of the drawings.

The operation of the engine is as follows: When the working piston 36 is in the position shown in Fig. 1, the piston 44 of the explosion-chamber will have traveled a distance equal to thirty degrees of its crank-stroke to travel in a forward direction, the mixing-valve will have been just opened, and the explosion-chamber will have been filled with explosive mixture. Immediately after this the mixing-valve 32 will be closed and the slide-valve 22 will be opened to open communication between the working cylinder and the explosion-chamber. At this time the explosive charge is ignited and the piston 36 will be driven forward, the piston 44 being also driven forward the last thirty degrees of its stroke, which will assist in carrying the piston 36 past its dead-center position, after which said piston 44 will be drawn back by the working piston 36 through the connections hereinbefore described. When the working piston 36 has reached its extreme forward position, the piston-valve 37 will be opened by the stop-plate 39 and will be held open during the

back stroke of said piston by means of the catch hereinbefore described, which catch will be released when the piston 36 arrives near the end of its backward stroke. The products of the explosion in the working cylinder will be blown out through the exhaust-opening in the cylinder-head on the back stroke of the piston, and the slide-valve 22 will preferably be closed gradually by the cam 25 during the back stroke of the piston 26, so that the products of the explosion contained in the explosion-chamber will also escape through the exhaust-passage in the working piston.

It should be observed that the slide-valve 22 must be fully closed before the piston 44 has arrived at its extreme backward position or about the time said piston is in the position shown in Fig. 3, so as to allow time for the opening of the gas and air valves to feed the requisite charge to the explosion-chamber. As soon as this has taken place the slide-valve 22 is retracted by means of its retracting-spring 23 to establish communication between the working cylinder and the explosion-chamber, after which the next explosion takes place and the operations are repeated.

My present invention is applicable to one-cylinder engines if a fly-wheel is employed, but is more particularly applicable to multi-cylinder engines, in which case the fly-wheel may be dispensed with, and the engine will also be reversible—as, for instance, if three cylinders are employed the engine may be reversed by reversing the order of explosions in the cylinders—that is, if the first explosion takes place in cylinder 1^a when the engine is running forward it would be simply necessary to have such explosion take place in cylinder 1^c to effect a reversal in the operation of the engine.

It will be obvious that the means for actuating the slide-valve 22 and mixing-valve 32 may be variously modified without departure from the invention.

Having described my invention, I claim—

1. A gas-engine embodying two communicating cylinders set end to end and each having a piston; means connecting said pistons in such manner that they will move simultaneously in the same direction, one slightly in advance of the other; a slide-valve located between the two cylinders; and means for actuating the slide-valve to establish and cut off, alternately, communication, between said cylinders.

2. The combination, with a working cylinder and its piston, of an explosion-chamber communicating with the cylinder; a piston in said explosion-chamber, having its axis in alinement with the working-cylinder piston; actuating connections between said pistons; a slide-valve supported between the communicating ends of the working cylinder and explosion-chamber and shiftable in a plane transverse to the axis of movement of the pistons; and means controlled by the pistons, at predetermined points in the strokes thereof, for actuating the slide-valve to cut off communication between the working cylinder and explosion-chamber on the beginning of the forward stroke of the pistons.

3. The combination, with a working cylinder and its piston, of an explosion-chamber having a piston in coöperative connection with the working-cylinder piston; means for periodically supplying explosive charges to the explosion-chamber; means for exploding said charges on the arrival of the working piston at the end of its back stroke; a slide-valve located between the piston-cylinder and explosion-chambers; and means in connection with, and operable at predetermined points in the stroke of, the working piston, for actuating the slide-valve to cut off communication between the cylinder and chamber immediately after an explosion occurs, and for establishing communication between said cylinder and chamber immediately after the working piston has arrived at the end of its back stroke and after the products of combustion have been exhausted.

4. A gas-engine comprising two axially-alined communicating cylinders, one of which constitutes a working cylinder and the other of which constitutes an explosion-cylinder; two pistons working in the two cylinders; means connecting the two pistons and insuring a movement of one piston slightly in advance of the other; means for periodically supplying explosive charges to the explosion-cylinder; means for igniting the explosive charge; and a slide located between the two piston-cylinders and controlled by the movements of the piston for cutting off communication between the two cylinders immediately succeeding an explosion.

5. In a gas-motor, the combination of a working cylinder having a piston, and an explosion-chamber having a piston and arranged end to end with the working cylinder; a slide to divide said cylinder and chamber; means for shifting the slide before each explosion, to establish communication between the cylinder and chamber; means for feeding the explosive mixture under pressure to the explosion-chamber, shortly before each forward stroke of the working piston; means for exhausting the gases of combustion, entirely, both from the working cylinder and from the explosion-chamber; driving-shafts in connection with the working-cylinder piston and explosion-chamber piston, respectively; means for gearing the two said shafts; and means for igniting the explosive mixture.

6. The combination of a working cylinder and an explosion-chamber, each having a piston; two coöperatively-connected driving-shafts in connection with the piston of the working cylinder and with the piston of the explosion-chamber, respectively; a valve in connection with the explosion-chamber; means for operating the same to admit the explosive mixture to the chamber; a slide between the

cylinder and chamber, and means for opening the same suddenly before each explosion; means for exhausting the gases of combustion from both cylinder and chamber; and means for igniting the explosive mixture in the chamber at each stroke of the working piston.

7. The combination of a working cylinder and an explosion-chamber arranged end to end therewith; a piston to each cylinder; crank-shafts in connection with said pistons; gearing connecting the crank-shafts; a valve in connection with the explosion-chamber, and means for feeding explosive mixture under pressure thereto; means for operating said valve, to admit the mixture to the chamber at each stroke of the working piston; a slide to divide the cylinder and chamber, and means for opening the same suddenly before each explosion and for closing it gradually after each explosion; means, in connection with the working piston, to allow the escape of the gases of combustion both from the cylinder and also from the chamber while the partition-slide is gradually closing; and means for igniting the explosive mixture in the chamber as soon as the slide falls.

8. The combination of a cylinder and an explosion-chamber arranged end to end and each having a piston; a partition-slide between the same; means operative, at predetermined points in the movements of the working piston, for operating said slide to establish and cut off, alternately, communication between the cylinder and chamber; two crank-shafts in operative connection with the two pistons, respectively; an actuating-connector between the two shafts, the cranks of the two shafts being so disposed, relatively, that when the working piston has completed its backward stroke the chamber-piston shall not quite have completed its forward stroke; a valve to admit explosive mixture under pressure to the explosion-chamber; means for igniting the mixture when the partition-slide is open; and means for exhausting the gases of combustion both from the chamber and cylinder.

9. The combination of three working cylinders having arranged end to end therewith each an explosion-chamber; pistons in the working cylinders; explosion-chamber pistons each arranged in advance of its respective working piston; a driving-shaft operatively connected to the working pistons; a driving-shaft operatively connected to the chamber-pistons; valves in connection with the chambers, and means for operating the same to admit explosive mixture under pressure to the chambers; partition-slides between each cylinder and its explosion-chamber; means for operating said slides to open communication between the working cylinders and explosion-chambers, successively, before each explosion; means for exhausting the gases of combustion from the cylinders and chambers; and means for igniting the mixture in the chambers at each stroke of each piston.

10. The combination of three cylinders having pistons as specified, and a driving-shaft operated thereby; a rearwardly-extending explosion-chamber to each working cylinder; a partition-slide between the same and the cylinder; means for operating the said slide; a valve to admit explosive mixture under pressure to the chambers; a reservoir to contain gas under pressure; a reservoir to contain air under pressure; an air-pump in connection with the latter, and means for driving the same from one of the machine-shafts; a gas-pump to keep the gas-reservoir charged, and means for driving the same; pipe connections from each reservoir to the valve of the combustion-chamber; means for igniting the mixture in the chambers at each stroke of each piston; and means for exhausting the gases of combustion from the chamber and cylinder, substantially as described and for the purpose specified.

In witness whereof I have hereunto set my hand in presence of two witnesses.

GEORGE GREGORY SMITH.

Witnesses:
HENRY HASPER,
W. HAUPT.