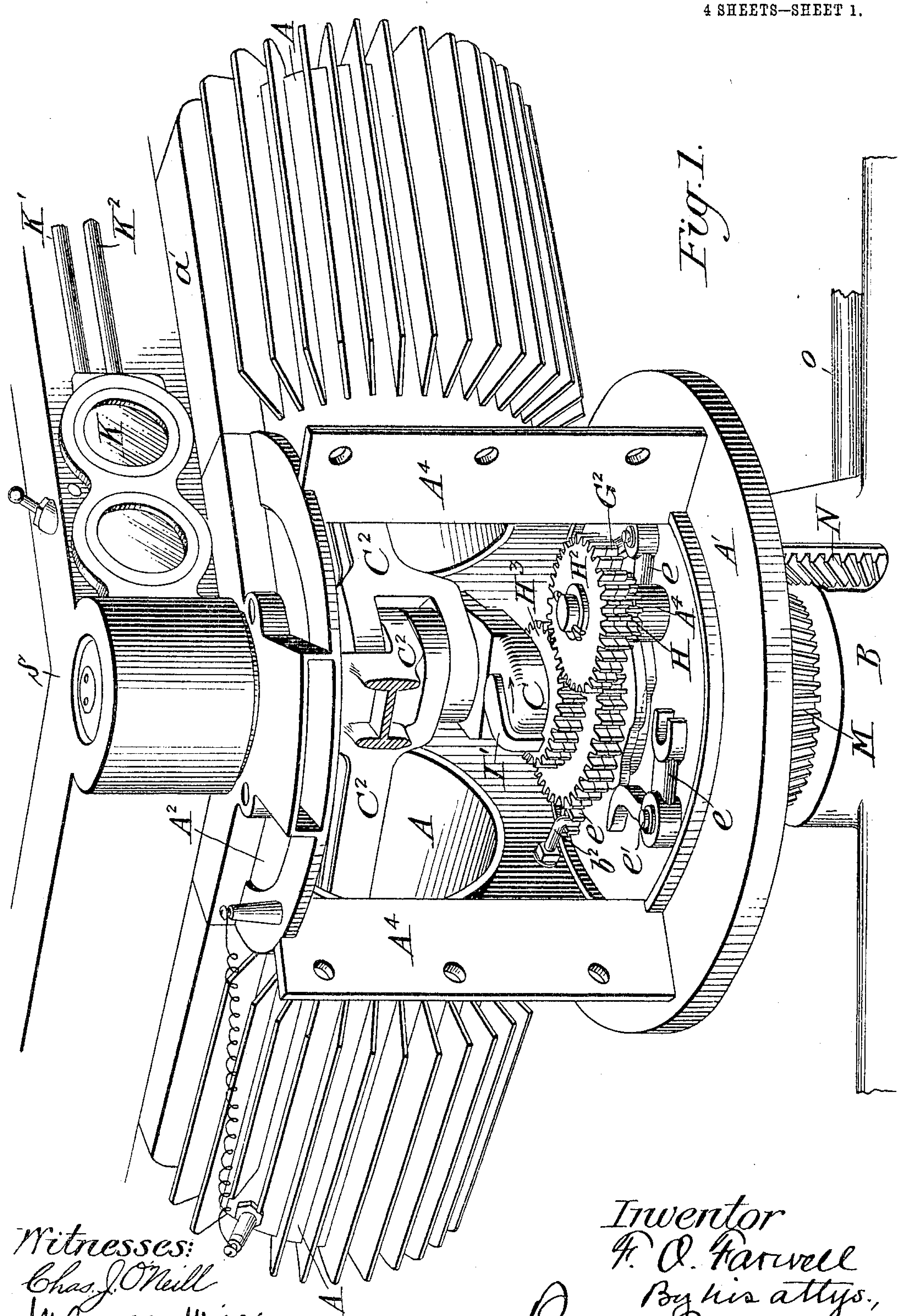
No. 806,125. PATENTED DEC. 5, 1905.

F. O. FARWELL.

ROTARY EXPLOSIVE ENGINE.

APPLICATION FILED APR. 16, 1904.

4 SHEETS—SHEET 1.



Witnesses:
Chas. J. O'Neill
W. Beall Williams

Inventor
F. O. Farwell
By his attys.,
Pennie & Goldsborough

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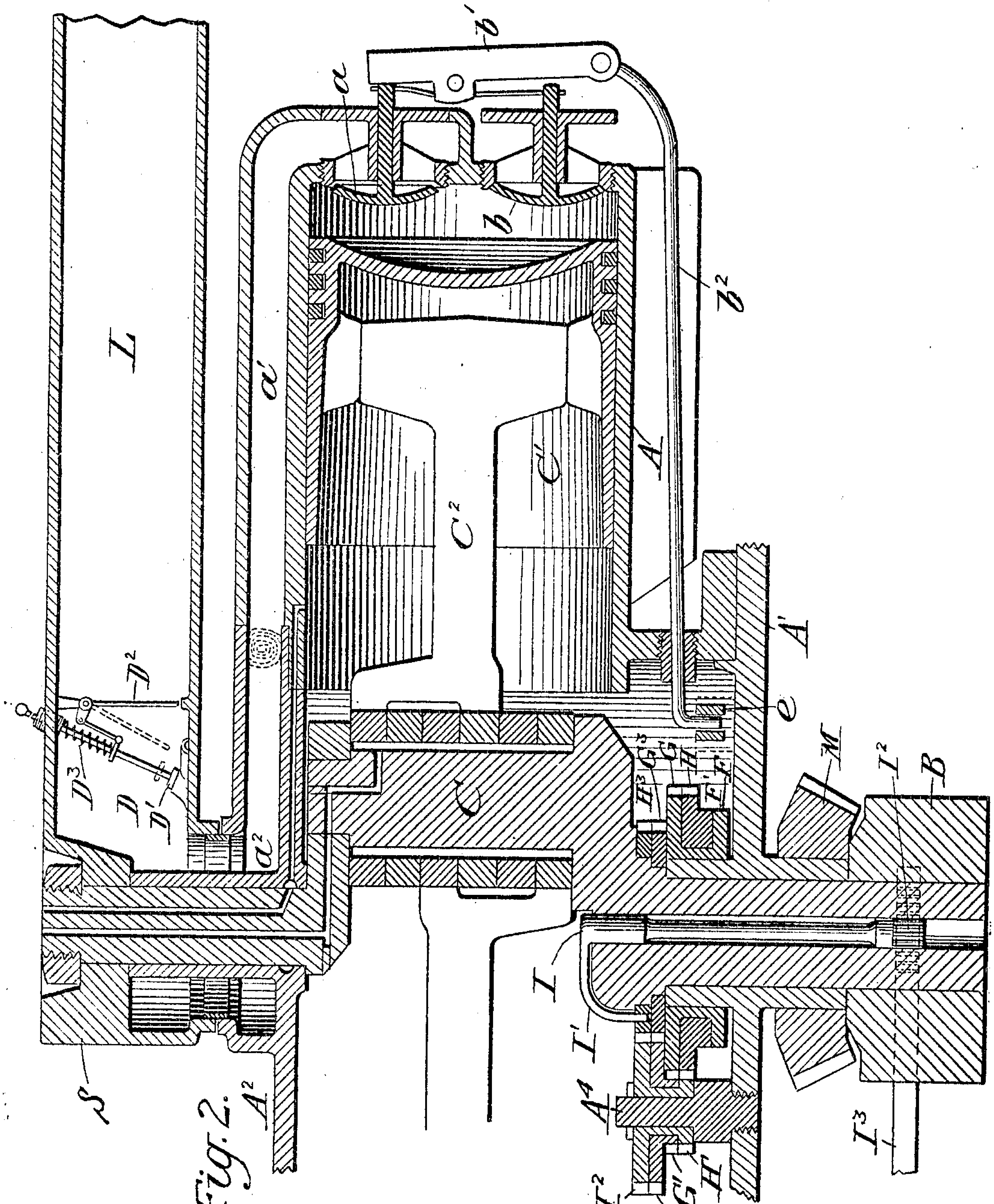

Fig. 2.

Witnesses:
Chas. J. O'Neill
W. Beall Williams

Inventor:
F. O. Farwell
By his attys.
Pennie & Goldsborough

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Fig. 5.

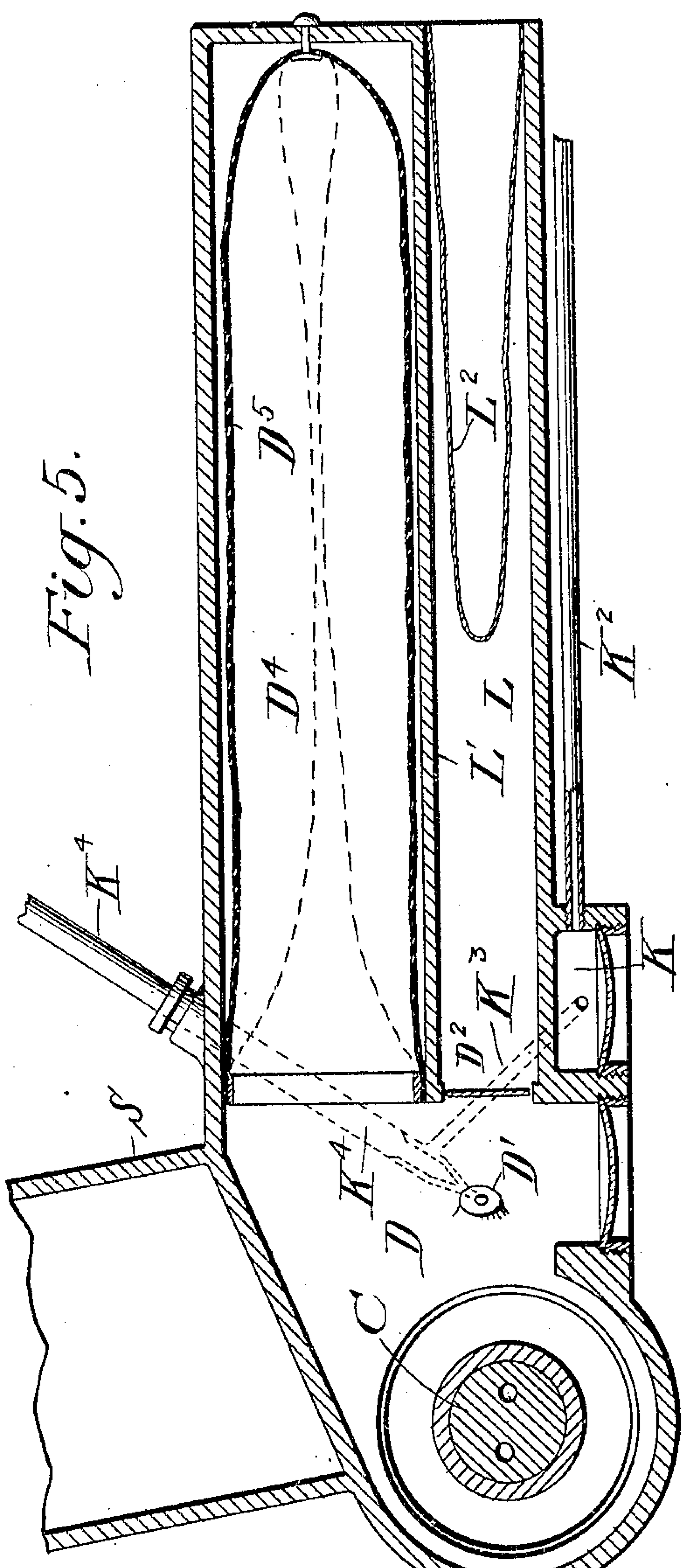


Fig. 3.

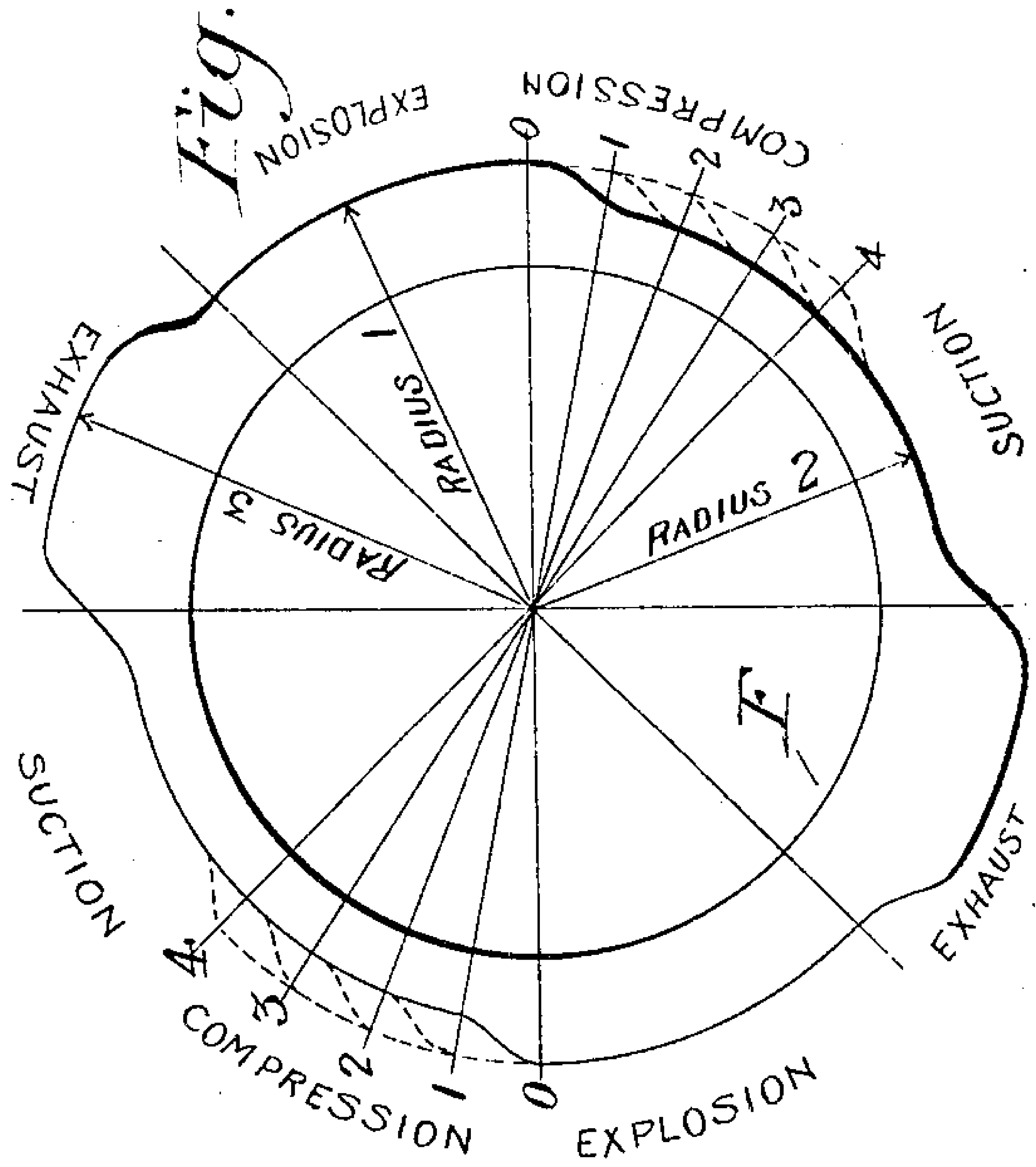
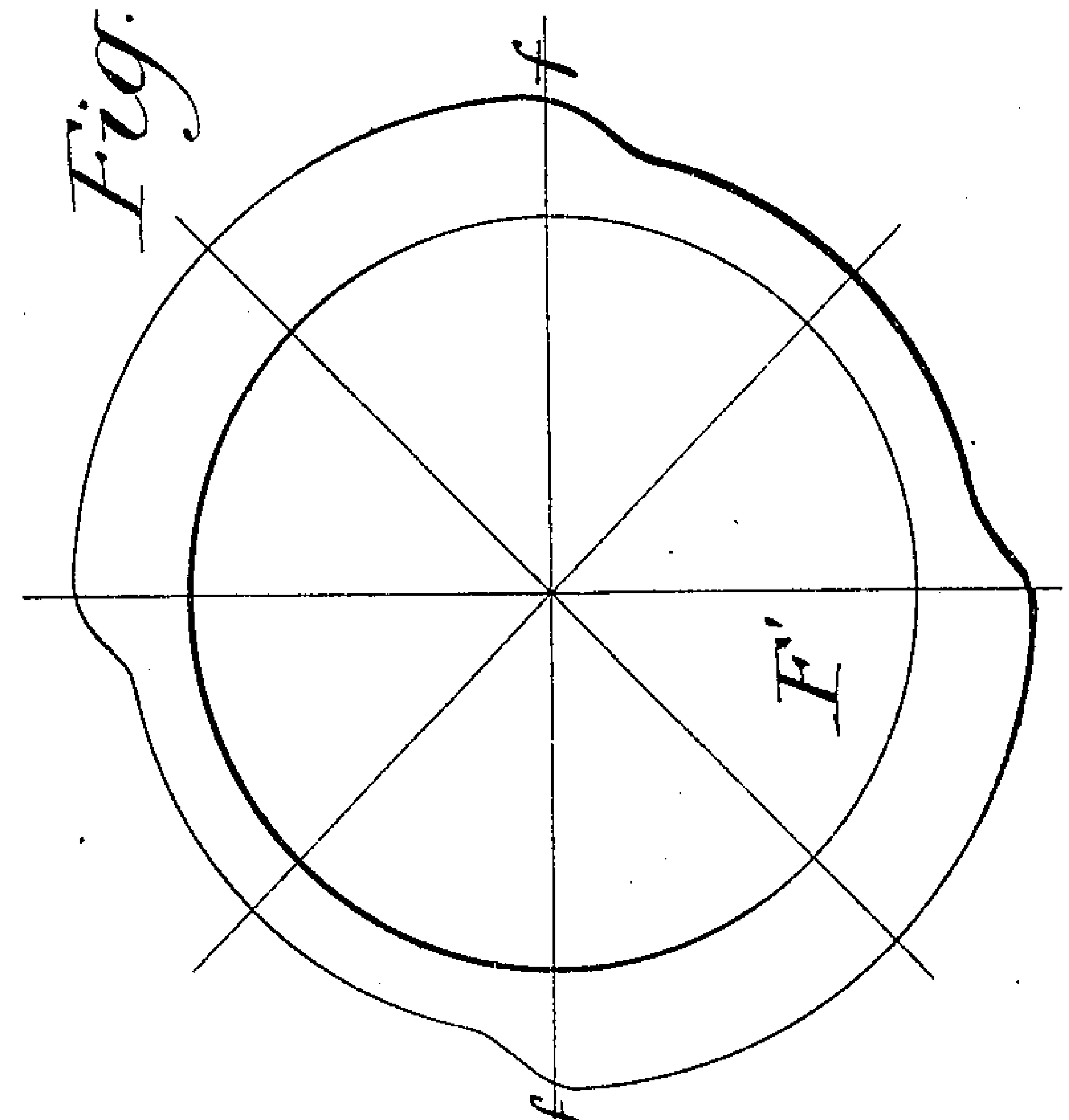


Fig. 4.



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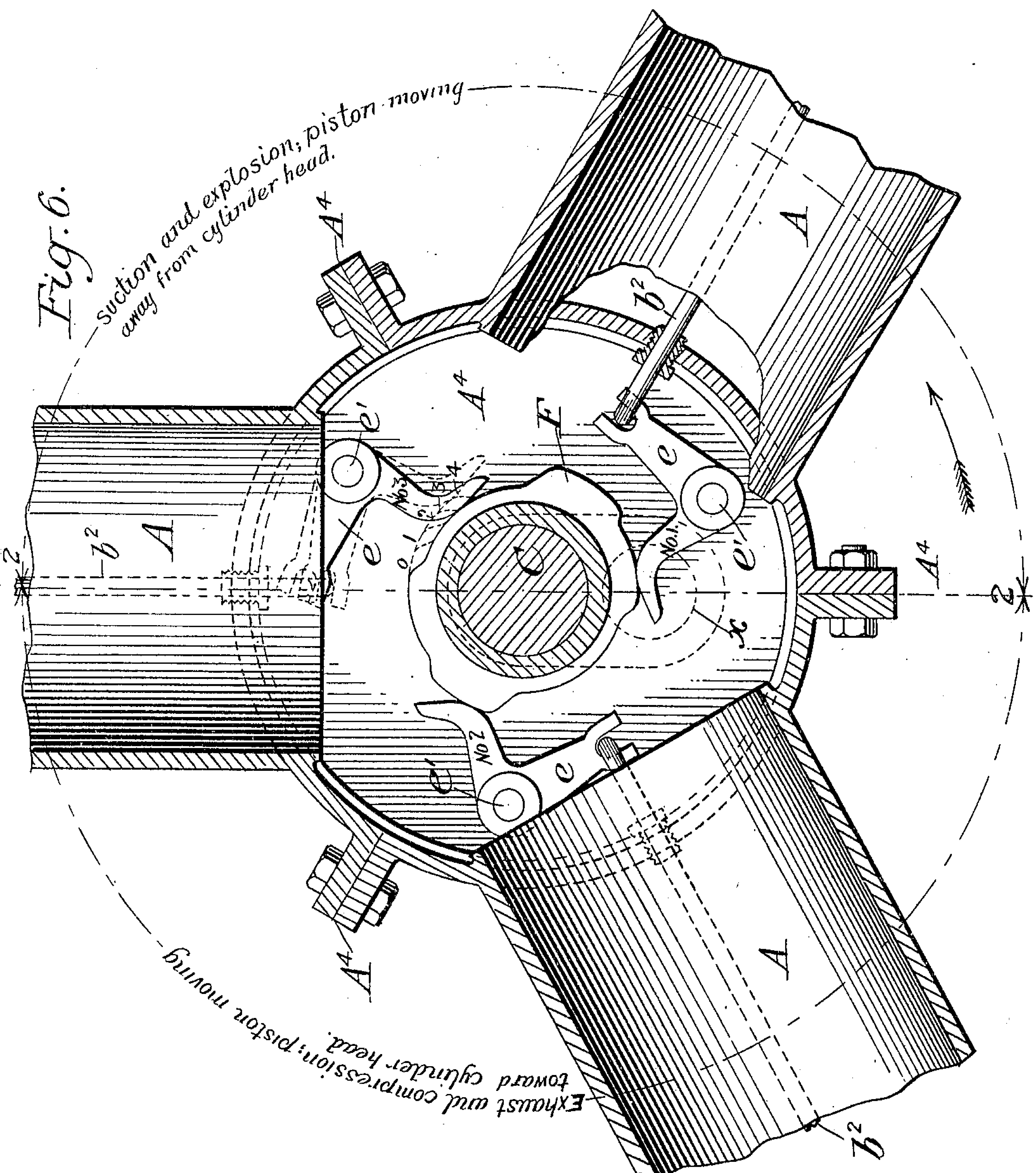

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Pennie & Goldsborough

UNITED STATES PATENT OFFICE.

FAY OSCAR FARWELL, OF DUBUQUE, IOWA, ASSIGNOR OF ONE-HALF TO THE ADAMS COMPANY, OF DUBUQUE, IOWA, A CORPORATION OF IOWA.

ROTARY EXPLOSIVE-ENGINE.

No. 806,125. **Specification of Letters Patent.** **Patented Dec. 5, 1905.**

Application filed April 16, 1904. Serial No. 203,391.

To all whom it may concern:

Be it known that I, FAY OSCAR FARWELL, a citizen of the United States, residing at Dubuque, county of Dubuque, State of Iowa, have invented certain new and useful Improvements in Rotary Explosive-Engines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates to explosive-gas engines, and has for its primary object to provide an engine of the character indicated capable of developing great economy when run below its maximum power and speed.

Further objects of the invention are to provide an engine having a wide range of power and speed and having a practically noiseless exhaust when running below its maximum power, due to the expansion of the explosive mixture to a low point before exhaust occurs.

An additional object is to produce an explosive-engine that may be readily started at all times, even after having been exposed for long periods to extreme cold.

Experience has shown that a satisfactory motor for vehicle propulsion must be capable of developing a wide range of speed and power, must run economically when operated at a small percentage of its maximum power, and must be capable of being readily started in cold weather or after having been exposed to extreme cold without the external application of heat. It has been found that it requires more than ten times as much power to drive a vehicle up a fifteen-per-cent. grade than it does to drive the same vehicle at the same speed on a level road. Consequently if the vehicle be provided with a motor of sufficient power to drive it at "legal speed" on a level road the motor will necessarily have to be geared to about one-tenth of that speed in climbing a fifteen-per-cent. grade, or, in the alternative, if the motor is of sufficient power to drive a vehicle up a fifteen-per-cent. grade at the legal speed it will have to be run at about one-tenth of its maximum power on level roads. In motor-vehicle practice it is very desirable that the engine have sufficient power to enable the vehicle to ascend grades at fair speed, but high-power motors as heretofore constructed are very wasteful of fuel when run at relatively low speed and power, as would be the case most of the time in ordinary riding or touring. The methods heretofore employed to reduce and regulate the power of gasolene vehicle-motors are to throttle the charge of gas and air and to delay the point of ignition. In throttling the charge a vacuum is formed in the cylinder on the suction-stroke, which in high-power engines running light may be as much as ten to twelve pounds to the square inch. This is equivalent to a back pressure on the engine of like amount, which causes a great loss in power, and consequently a loss in fuel. Furthermore, in throttling a gasolene-engine the velocity of the air passing through the carbureter is much reduced, and it is found to be practically impossible to maintain the same mixture of air and gas at various degrees of throttling. Therefore the explosive charge does not develop its full efficiency, or portions of unconsumed gas are blown from the exhaust without effecting any useful purpose. Regulation by delaying the point of ignition reduces the power developed by the engine, because the charge is ignited so late that it has not time to complete combustion before the exhaust-valve is opened to let the charge out. It will therefore be seen that this method is also wasteful of power and fuel, in that it blows the gases through the exhaust-valve while they are still burning, thereby heating it and the muffler to a point which they cannot long endure.

An essential feature of my invention consists in allowing the piston on its suction-stroke to draw in a full charge unrestrained by throttle or stiff springs and then on the compression-stroke blowing back through the still unclosed inlet-valve a portion of the charge commensurate with the reduction in power desired. After the inlet-valve has closed that portion of the charge still remaining in the cylinder is compressed and ignited under conditions to produce complete combustion before exhaust. That portion of the charge which is blown back before the inlet-valve closes is preferably drawn in by another cylinder or into a mixing-chamber provided with a suitably-expansible receptacle, which receives and retains the surplus charge until another suction-stroke of the piston occurs. The portion of the charge that is retained in the cylinder may thus be varied from the full charge when the inlet-valve closes immediately at the beginning of the compression-stroke (under which conditions the engine will develop its maximum power) to a very small percentage of the full charge when the inlet-valve is not closed until the completion of the compression-stroke, when the engine will develop its minimum power.

To this end the invention comprises an explosive-engine having a mixing-chamber and a cylinder or series of cylinders provided with an inlet valve or valves controlling the passages between the mixing-chamber and the respective cylinders and mechanism for controlling the operation of said inlet-valves, said mechanism comprising a main cam for operating the valves and an adjustable cam coöperating therewith to vary the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons, together with means for maintaining a constant mixture of air and gasolene and means for taking care of that part of the charge which is blown back when a small amount of power is used.

In the accompanying drawings I have shown the invention applied to a three-cylinder rotary engine. It is to be understood, however, that the invention is not limited to this particular type, as the salient features of construction and operation may be embodied in an engine having any number of cylinders and placed in any desired relation.

In the drawings, Figure 1 shows an engine involving my invention represented in perspective, one cylinder being removed to illustrate the interior mechanism of the engine. Fig. 2 is a vertical cross-section on lines 2 2 of Fig. 6. Fig. 3 is an enlarged detail view of the main-valve-operating cam. Fig. 4 is a similar view of the adjustable cam for regulating the operation of the inlet-valve. Fig. 5 is a horizontal section through the upper stationary support or bracket containing the main gasolene and air inlet valves and the mixing-chamber or carbureter. Fig. 6 is a horizontal section through the engine, showing the inside of the crank-casing and illustrating the several positions of the valve-operating levers with respect to the actuating-cam.

Referring to the drawings, A indicates the cylinders, of which there are three in number, bolted together through their mating flanges A^4 to constitute an annular casing, from which the several cylinders project radially. Said casing is mounted upon a flanged bearing-plate A′, which in turn is supported in a suitable base or bracket B, and the top of the casing is closed by a circular cover-plate A^2. Mounted within the engine-casing, one end being supported in the bracket B and the other in the bracket or support S above the engine, is a stationary crank-shaft C. Working in the several cylinders A are pistons C′, connected to the crank-shaft C by suitable pitmen C^2, so that in practical operation the engine-casing with the three cylinders extending therefrom and the pistons coöperating therewith revolve around the vertical stationary crank-shaft. Each of said cylinders is provided with an inlet-valve *a* and an exhaust-valve *b*, preferably located in the end thereof. The hollow bracket S constitutes a common mixing-chamber D for carbureting and supplying explosive mixtures to the various cylinders. Each cylinder is connected with the mixing-chamber D by a passage *a′*, which extends along the top of the cylinder and unites with an annular chamber a^2 in the flanged plate A^2, which chamber a^2 is in direct communication with the mixing-chamber D. In the construction illustrated and shown more particularly in Fig. 2 of the drawings the inlet and exhaust valves of each cylinder are operated by a common lever *b′*, which opens said valves alternately. Said lever *b′* is operatively connected to a link or pitman b^2, which extends below the cylinder with its end projecting within the crank-casing and operatively engages a corresponding cam-lever or rock-lever *e*, pivoted to the bearing-plate A′ upon a vertical stud *e′*.

Surrounding the crank-shaft C is a compound cam for controlling the valves, comprising the main-valve-operating cam F, and the inlet-valve-closing cam (or variable compression-cam) F′, and the several gears for operating the same, which will be hereinafter more particularly described. These cams revolve in the same direction as the engine, but in order to enable them to properly act upon the levers *e* to control the valves of the respective cylinders said cams are driven at a differential speed with respect to that of the engine. The engine is preferably operated upon what is known as the "four-cycle principle"—namely, suction or admission of charge, compression of charge, explosion or power stroke, and exhaust. This gives one power-stroke for each cylinder every two revolutions of the engine. Under these conditions it is necessary that the speed of the cams F and F′ in relation to the speed of the engine be such that in four revolutions of the engine the cams will make three complete revolutions, and therefore the cam-lever *e* will move relatively to the cam one-eighth of the circumference of the latter for each half-revolution or each cycle of the engine. The cams are therefore divided into eight sections, as shown more particularly in Fig. 3. This construction enables a single cam to be employed to operate all three of the cam-levers *e*, and as said levers *e* are journaled on plate A′ one hundred and twenty degrees apart around the circumference of a circle concentric with the engine-casing they each have a bearing upon that part of the cam F which imparts to them the proper movement at the proper time. Referring to the main cam F, Figs. 3 and 6, it will be noticed that it has three radii, 1, 2, and 3, upon which the concentric cam-surfaces are struck, so that the position of the inlet and exhaust valves of each cylinder is exactly determined by the relation of the corresponding lever *e* with respect to the cam-surfaces. Taking one cylinder, for example, when lever *e* is in contact with the cam-surfaces defined by radius 1 both the inlet and exhaust valves are allowed to close; when the lever *e* is in contact with radius 2, the inlet-valve is open, as shown in Fig. 2, but the exhaust-valve remains closed; and when the lever *e* is in contact with the cam-surfaces defined by radius 3 the exhaust-valve is open and the inlet-valve is closed. The cam F′ is provided with cam-surfaces or faces struck upon two radii corresponding to radius 1 and radius 2 of cam F, so that when said cam F′ overlies cam F under normal conditions the peripheral contour of the latter is not changed, as the edge of the cam F′ lies wholly within the periphery of cam F. Said cam F′, however, has an independent movement of rotation in relation to cam F of about one-eighth of its circumference, so that the former may be revolved on the latter to cause portions of its cam edges defined by radius 1 to overlie and project beyond the edges of cam F, which are limited or defined by radius 2, as clearly illustrated in Figs. 1 and 6. The effect of this is to vary the point in the compression-stroke of any cylinder where the lever *e* will pass from radius 2 to radius 1, thus allowing the inlet-valve to close. The means for actuating both cams and for adjusting cam F′ relative to cam F may be more particularly described as follows: Surrounding the crank-shaft C and preferably keyed thereto is a gear G^3, which meshes with a planetary gear G^2, mounted upon a stud A^4, secured to the plate A′. Connected to planetary gear G^2, and preferably formed integral therewith, is a reducing-gear G′, which meshes with a gear G, formed as an upward-flanged extension of the cam F. It will be seen, therefore, that the planetary gears G′ G^2 in circling around the stationary or anchor-gear G^3 will impart motion to gear G and cam F in the same direction that the engine revolves, but at a slower speed, as already described. The ratio between the rotary motion of the cam F and the engine is as three to four, and under these conditions of operation the cam will act upon the lever *e*, and through it and the link b^2 the lever b' will operate the inlet and exhaust valves at predetermined positions—that is to say, the exhaust-valve will always begin to open on the dead-center on the completion of the explosion or power stroke and will be closed at the other dead-center when the inlet-valve will begin to open; but it will be noticed that the cam-surface defined by radius 2 is carried beyond the point where compression begins to the other dead-center where compression ceases, so that if the main-valve operating cam F alone were employed and no other means provided for closing the inlet-valve the entire charge drawn in on the suction-stroke would be blown back through the still open inlet-valve, except what would be left in the cylinder-clearance, and as this would not be under compression and the explosion would be slow it is apparent that but little power would be developed. The closing of the inlet-valves *a* at proper points in the compression-strokes of the corresponding cylinders is determined, however, by the cam F′, as above indicated.

The cam F′ and the gear H are secured together and loosely surround the sleeve that connects the main cam F with the gear G. The gear H engages the planetary gear H′, which is connected by a sleeve to the planetary gear H^2, which engages gear H^3, loosely surrounding the crank-shaft.

Passing through the crank-shaft C is a stud or shaft I, which has at its upper end a curved finger I′, engaging the gear H^3, and at its lower end a pinion I^2, which is engaged by a rack I^3, which latter extends through the base of the engine and is connected to a governor or other means for controlling the speed of the engine. The shaft I, with its finger I′, is capable of imparting to the gear H^3 a movement of about one-half of a revolution, thereby imparting to cam F′ about one-eighth of a complete revolution. If gear H^3 were turned to its extreme position in the direction indicated by the arrow in Fig. 1, the cam F′ would assume a position on the cam F which would not change the shape of the latter, as the points *f f* on said cam F′ would coincide with the points marked O O on cam F, as shown in Fig. 3. In this adjustment of the cams the inlet-valve will not be closed until the completion of the compression-stroke and, as before stated, the entire charge of gas will be blown back through the inlet-valve, except the small portion remaining in the clearance-space, and as this will not be under compression and will burn slowly the engine will develop its minimum power. If, however, the gear H^3 were moved by finger I and shaft I′ to its extreme position in the direction opposite that of the arrow in Fig. 1, the cam F′ would assume a position on the cam F bringing the point *f* to coincide with the point 4. (Indicated in Fig. 3.) In this position of the cams the inlet-valve would be closed at the completion of the suction-stroke and the entire charge would be retained in the cylinder and be subsequently compressed and ignited, so that the engine would develop its maximum power.

Thus far we have referred to the operation of a single cylinder. By referring, however, to Fig. 6 it will be readily seen how the three cylinders are operated by the single cam. In the figure aforesaid the three levers *e* are designated 1, 2, and 3, respectively, for the sake of convenient reference. Assuming the crank-pin to be in the position indicated at *x* and that the various links b^2 are in the center of each cylinder and that the engine revolves in the direction indicated by the arrow, the cylinder whose valves are operated by lever 1 would be in the explosive or power stroke and the lever would engage that portion of the cam designated as radius 1 and both the inlet and exhaust valves of the cylinder would be closed. The cylinder controlled by lever 2 would be about two-thirds through the exhaust-stroke, and the lever *e* engaging the radius 3 the exhaust-valve would be open. The cylinder controlled by lever 3 would just have commenced the compression-stroke, and if the compression-cam F′ were in the position indicated by the dotted line the lever *e* would be in the position shown by the dotted lines on radius 1 and both valves would be closed and a full charge compressed; but if the compression-cam F′ were moved around to the left to any of the points marked 3, 2, 1, or 0 the inlet-valves would not be closed until corresponding amounts of the respective charges had been blown back, and there would be a corresponding reduction in power. Thus if the cam F′ were adjusted so that its point *f* occupied the position indicated by the numeral 3 in Figs. 3 and 6 three-fourths of the maximum power would be developed by the engine. If it were at point 2, one-half of the power would be developed, &c. It will therefore be seen that the amount of power developed by the engine depends entirely upon the position of the compression-cam F′ with respect to cam F, and the position of the compression-cam is regulated while the engine is in motion by movement of the rack I^3, which may be controlled by a centrifugal governor or by means of a hand or foot lever controlled by the operator.

It is highly desirable that a uniform mixture be supplied to the various cylinders in the form of explosive charges under all conditions of operation. As hereinbefore described, it will be noted that each cylinder draws in a full charge of the explosive mixture at each suction-stroke and that a varying proportion of the charge is blown back and is drawn in by another cylinder, and therefore the quantity of gas that the carbureter is called upon to supply may vary from a full charge for each cylinder to a very small part of the full charge, and the amount of gas blown back varies correspondingly. To provide for these varying conditions, the carbureter or mixing-chamber is constructed substantially as follows: Surrounding the upper end of the crank-shaft and secured thereto is a casting S, constituting the bracket hereinbefore referred to, which has two arms, preferably extending at right angles to each other, and in addition to forming the carbureter this casting forms the support for the upper end of the crank-shaft. One branch of the casting may be used as a tank for lubricating-oil. This, however, forms no part of the invention. The other branch is divided by a longitudinal partition L′ into two chambers or passages. The smaller of these passages is the air-inlet, which is open to the air at its outer end, but is closed at its inner end by a swinging valve D^2, pivoted to the under side of the top wall of said casting, so that said valve may swing inwardly, as shown in dotted lines in Fig. 2, and will thus admit air, but will not swing outwardly, and thus prevents the escape of gas. In this air-passage there is preferably placed a conical muslin bag L^2, which forms a strainer and prevents dust from entering the engine with the air. In the other passage D^4 there is mounted a flexible bag D^5, preferably of soft leather, which is secured at its inner end to the walls of the passage and is free to expand and collapse, as shown by full and dotted lines in Fig. 5. The liquid fuel, such as gasolene, is fed through a pipe K′, Fig. 1, into a small reservoir K, located on the side of the casting S and preferably covered with a glass plate, so that its contents may be seen, and said reservoir is provided with a second pipe K^2, which serves to conduct any surplus gasolene back to the tank, thus keeping a constant level of gasolene in said reservoir. Leading from the reservoir K to the gasolene-valve D′ is a passage K^3, preferably formed in the body of the casting and terminating in an open port communicating with chamber D. The passage K^3 is regulated by a needle-valve K^4, (shown in Fig. 5,) which is operated by a suitable handle projecting from the exterior of the casting. The gasolene-valve D′ is forced to its seat over the port in passage K by means of a spring D^3 around the stem of said valve, which spring also serves, through a suitable link connection, to normally close the air-valve D^2. It will thus be seen that the gasolene-valve D^4 is opened by the action of the inrushing air, which lifts valve D^2 and at the same time raises valve D′ off its seat, thus permitting exactly the requisite quantity of air and a correctly-proportioned amount of gasolene to meet in the mixing-chamber D, from which point the explosive mixture thus formed is delivered to the various cylinders in succession.

The operation of the engine embodying the features as above described is substantially as follows: Assuming that the engine is to be started after it has been idle for some considerable time and that it is very cold or frosty, which conditions render the ordinary gasolene-engine very difficult to start, the operator moves the compression-cam F′ to the point of "no compression" by means of rack I^3 and the several gears hereinbefore described. In this position of the operating parts the engine will turn easily, as there is no compression. Gasolene is supplied to the reservoir K by a pump or other means, and a proper quantity is allowed to flow into the chamber D by lifting valve D′ by hand. This gasolene would flow into chamber a^2. If the weather were moderately warm and the engine revolved by hand, the air in being drawn in on the suction-stroke would probably gasify the liquid on its first passage over it and an explosive mixture would be formed, although the air entering would have very little velocity; but under the conditions of cold above referred to the liquid does not gasify readily and the charge entering the cylinder for the first time will not be rich enough to explode; but as the inlet-valve is held open on the compression-stroke the entire charge will be blown back, expanding the bag D^4 until it is subsequently drawn in by another cylinder, and this process of the air surging back and forth from one cylinder to another and passing over the liquid gasolene will gasify sufficient of the latter to make an explosive mixture in a very few revolutions of the engine in the very coldest weather, after which of course the engine can be adjusted to any desired degree of compression and its normal operation taken up.

It is to be particularly noted that the engine as above described has the following salient and characteristic advantages: First, the engine is very readily turned over in the starting operation, because of the total absence of compression; secondly, if the charge is not rich enough to explode it is passed from cylinder to cylinder through the mixing-chamber until it acquires the requisite richness to explode instead of being blown out of the exhaust-valve and wasted, as is common in most engines of this general type; thirdly, after the engine has started on the low compression the power and speed thereof may be increased and controlled entirely by varying the compression or the amount of gas retained in the cylinder after the closing of the inlet-valve, thus working a relatively great economy in the fuel consumed for the lower ranges of power and speed.

It will be understood, of course, that when the engine is working under full compression, giving its maximum power, no gas is blown back through the inlet-valve, and the flexible bag D^4 will remain collapsed and the full charge will be drawn through the air-valve D^2 and the gasolene-valve D′, as the valves will remain open during the entire suction-stroke; but when the engine is working on low compression a considerable quantity of gas is blown back, which is prevented from escaping by the air-valve D^2, and partly inflates the bag D^4, and when the cylinder which is compressing has made one-third or more of the compression-stroke the next cylinder ahead will have passed dead-center and will be entering upon the suction-stroke and will therefore draw in the gas which is being blown back by the compressing-cylinder through passage a' from said compressing-cylinder, central chamber a^2, and passage a' of the suction-cylinder directly without passing into the chamber D. As there would not be enough of the explosive mixture under these circumstances to supply the suction-cylinder, the remaining quantity required for that purpose would be drawn through the valve D^2 and the gasolene-valve D′, these valves remaining open only during a portion of the suction-stroke. The spring D^3 is made sufficiently strong to resist the suction action until the gas-bag D^4 has been exhausted or collapsed, and then the inrushing air through the valve D^2 is of constant velocity whether the engine is working under high or low compression, and the quantity of gasolene taken up in proportion to the air will remain constant, thus making a uniform mixture; but obviously the length of time that these valves will remain open will vary with the quantity of gas required.

The engine is preferably constructed with unusually small clearance or compression space in the end of the cylinders. What is considered good practice in operating gas-engines is about eighty pounds compression running to about two hundred and forty pounds in combustion and leaving a general terminal pressure of about forty pounds when exhausted. This forty pounds of course is wasted and also causes the objectionable noise of the exhaust from the ordinary gas-engine. The construction above described gives a maximum compression of ninety pounds, a combustion-pressure of three hundred pounds, and a terminal pressure of about fifty pounds, so that in case of full load when the engine is working under full compression it is slightly more wasteful than the ordinary type of engine under similar conditions; but under normal conditions, which maintain for perhaps ninety-five per cent. of the time, the compression would not run above fifty pounds, which would rise to one hundred and fifty pounds under combustion and because of the longer expansion-stroke would be expanded to nearly atmospheric pressure when exhausted, under which conditions the engine would develop great efficiency and would be practically noiseless.

What I claim is—

1. An explosive-engine, comprising a mixing-chamber and an explosion-chamber, an inlet-valve controlling the passage between said chambers, an exhaust-valve for the explosion-chamber, and a cam-ring common to both of said valves and having projections of different heights controlling the opening and closing of the respective valves, said cam-ring having adjustable means for varying the period of time the inlet-valve is held open during the compression-stroke of the engine.

2. An explosive-engine, comprising a mixing-chamber and an explosion-chamber, an inlet-valve controlling the passage between said chambers, an exhaust-valve for the explosion-

chamber, and a cam-ring common to both of said valves and having projections of different heights controlling the opening and closing of the respective valves, said cam-ring having an adjustable section for varying the period of time the inlet-valve is held open during the compression-stroke of the engine.

3. An explosive-engine, comprising a mixing-chamber and an explosion-chamber, an inlet-valve controlling the passage between said chambers, an exhaust-valve for the explosion-chamber, and mechanism common to both of said valves controlling the opening and closing of each, said mechanism comprising a cam-ring having projections of different heights for controlling the operation of the respective valves, and an adjustable ring having a projection coöperating with and modifying the operation of the inlet-valve controlling projection on the cam-ring to vary the period of time the inlet-valve is held open during the compression-stroke of the engine.

4. An explosive-engine, comprising a series of rotary cylinders, pistons working therein, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, and a cam for controlling the operation of all of said inlet-valves, said cam having adjustable means for varying the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons.

5. An explosive-gas engine, comprising a series of rotary cylinders, pistons working therein, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, and a cam for controlling the operation of said inlet-valves, said cam having an adjustable section to vary the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons.

6. An explosive-engine, comprising a series of rotary cylinders, pistons working therein, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, exhaust-valves for the individual cylinders, a cam for controlling the operation of all of said valves, said cam having an adjustable section for varying the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons.

7. An explosive-gas engine, comprising a series of rotary cylinders, pistons working therein, a crank-shaft to which said pistons are connected, inlet-valves for the respective cylinders, a cam controlling the operation of all of said valves and having a differential rotation with respect to the rotatory motion of the cylinders, and an adjustable cam coöperating with said first-mentioned cam to vary the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons.

8. An explosive-gas engine, comprising a series of rotary cylinders, pistons working therein, a crank-shaft to which said pistons are connected, a mixing-chamber common to said cylinders, inlet-valves for the respective cylinders, a cam controlling the operation of all of said valves and having a differential rotation with respect to the rotatory motion of the cylinders, and an adjustable cam coöperating with said first-mentioned cam to vary the period of time the respective inlet-valves are held open during the compression-stroke of the corresponding pistons.

9. An explosive-engine, comprising a stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, a cam for controlling the operation of said inlet-valves, a second cam coöperating with and adjustable with respect to said first-mentioned cam to vary the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons, and means for imparting a differential rotation to said cams with respect to the rotation of the engine.

10. An explosive-gas engine, comprising a stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, valve-rods for operating said inlet-valves, rock-levers for actuating said rods, a rotary cam coöperating with said rock-levers to control the inlet-valves, a second cam coöperating with and adjustable with respect to said first-mentioned cam to vary the period of time the respective inlet-valves are held open during the compression-strokes of the corresponding pistons, and means for imparting a differential rotation to said cams with respect to the rotation of the engine.

11. An explosive-gas engine, comprising a stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, exhaust-valves for the several cylinders, a rotary cam controlling the operation of the inlet and exhaust valves, a second cam coöperating with and adjustable with respect to said first-mentioned cam to vary the time of closing of the respective inlet-valves during the compression-strokes of the corresponding pistons, and means for imparting a differential rotation to said cams with respect to the rotation of the engine.

12. An explosive-gas engine, comprising a

stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, exhaust-valves for the several cylinders, a rotary cam controlling the operation of the inlet and exhaust valves, a second cam coöperating with and adjustable with respect to said first-mentioned cam to vary the time of closing of the respective inlet-valves during the compression-strokes of the corresponding pistons, means for imparting a differential rotation to said cams with respect to the rotation of the engine, and connections between said cams and the inlet and exhaust valves of the respective cylinders, each connection comprising a rock-lever coöperating with both valves, a rock-lever engaging said cams, and a rod or link between said rock-levers.

13. An explosive-gas engine, comprising a stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, a cam surrounding said crank-shaft for controlling the operation of said inlet-valves, a second cam coöperating with and adjustable with respect to the first-mentioned cam to vary the time of closing of the respective inlet-valves during the compression-strokes of the corresponding pistons, and planetary gearing connecting said cams and said crank-shaft to impart a differential rotation to said cams with respect to the rotation of the engine.

14. An explosive-gas engine, comprising a stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, a cam surrounding said crank-shaft for controlling the operation of said inlet-valves, a second cam coöperating with and adjustable with respect to the first-mentioned cam to vary the time of closing of the respective inlet-valves during the compression-strokes of the corresponding pistons, planetary gearing connecting said cams and said crank-shaft to impart a differential rotation to said cams with respect to the rotation of the engine, and means for shifting the relation of the second cam with respect to the first cam.

15. An explosive-gas engine, comprising a stationary crank-shaft, a series of cylinders and coöperating pistons rotating about said shaft, a mixing-chamber common to said cylinders, inlet-valves controlling the passages between the mixing-chamber and the respective cylinders, a main cam surrounding said crank-shaft for controlling the operation of said inlet-valves, a second cam coöperating with and adjustable with respect to said main cam to vary the time of closing the respective inlet-valves during the compression-strokes of the corresponding pistons, gears on the respective cams, resistance-gears on the stationary crank-shaft, planetary gears connecting the respective gears on the cams and the resistance-gears, to impart a differential rotation to said cams with respect to the rotation of the engine, a rotatory shaft in said crank-shaft connected to the resistance-gear actuating the adjustable cam, and means for rotating said shaft to vary the position of said adjustable cam with respect to the main cam.

16. An explosive-gas engine, comprising multiple rotary cylinders, a mixing-chamber common to said cylinders, valves controlling the passages to said cylinders, and a common regulable means for holding said valves open during predetermined portions of the compression-strokes of the corresponding pistons, whereby portions of the respective explosive charges are blown back and passed to successive cylinders.

17. An explosive-gas engine, comprising multiple rotary cylinders, a mixing-chamber common to said cylinders, inlet-valves controlling the passages to said cylinders, and an adjustable cam for holding all of said valves open during predetermined portions of the compression-strokes of the corresponding pistons, whereby portions of the respective explosive charges are blown back and passed to successive cylinders.

In testimony whereof I affix my signature in presence of two witnesses.

FAY OSCAR FARWELL.

Witnesses:
C. L. Butler,
F. A. Oatey.