E. W. STEVENS.
INTERNAL COMBUSTION ENGINE.
APPLICATION FILED JULY 16, 1909.

981,811. **Patented Jan. 17, 1911.**

5 SHEETS—SHEET 1.

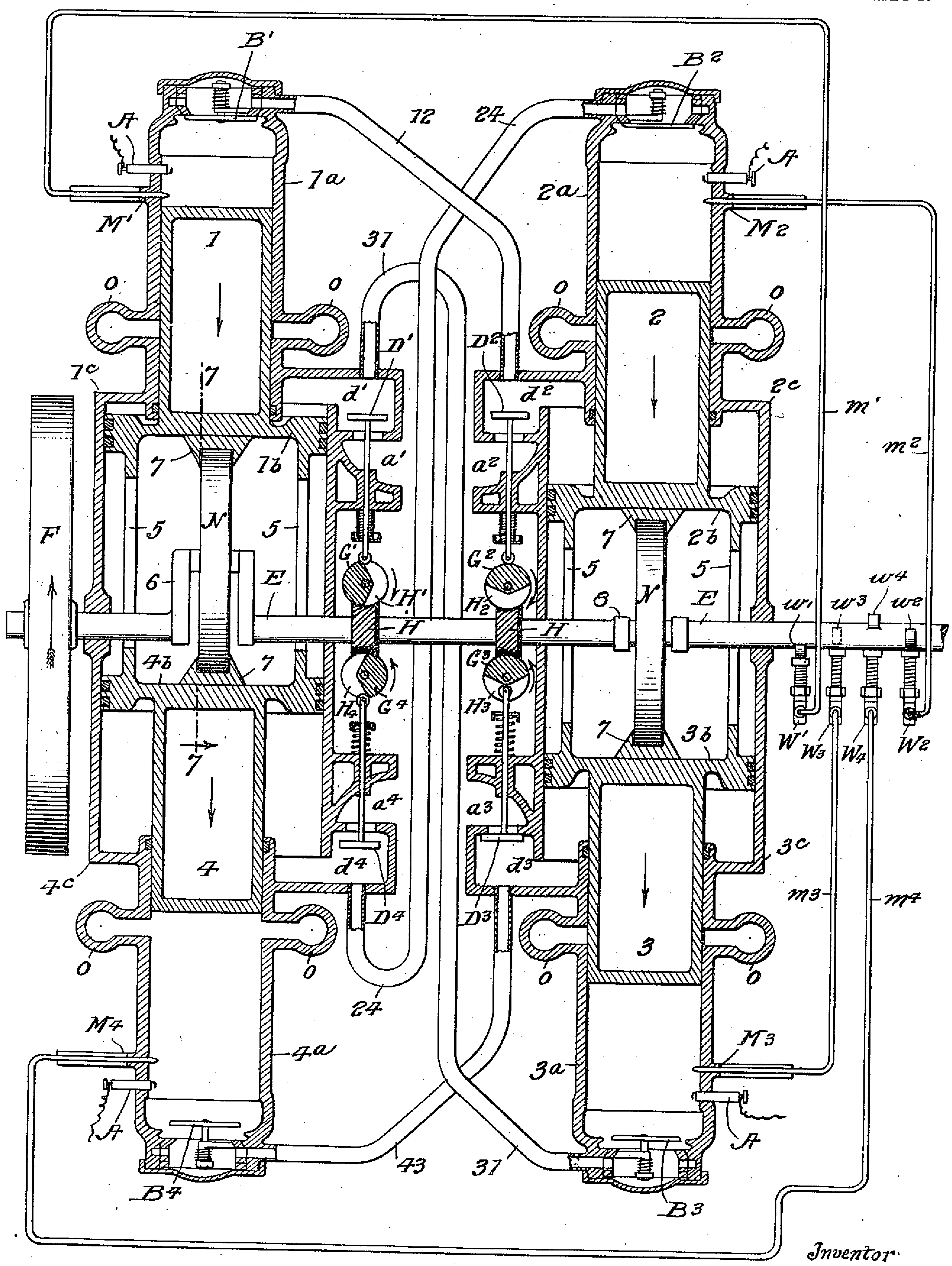


Fig. 1.

Witnesses
L. H. Schmidt.
C. W. Byrn Jr.

Inventor
ELBRIDGE W. STEVENS
By Edw. W. Byrn.
Attorney

E. W. STEVENS.

INTERNAL COMBUSTION ENGINE.

APPLICATION FILED JULY 16, 1909.

981,811. Patented Jan. 17, 1911.

5 SHEETS—SHEET 2.

Fig. 2.

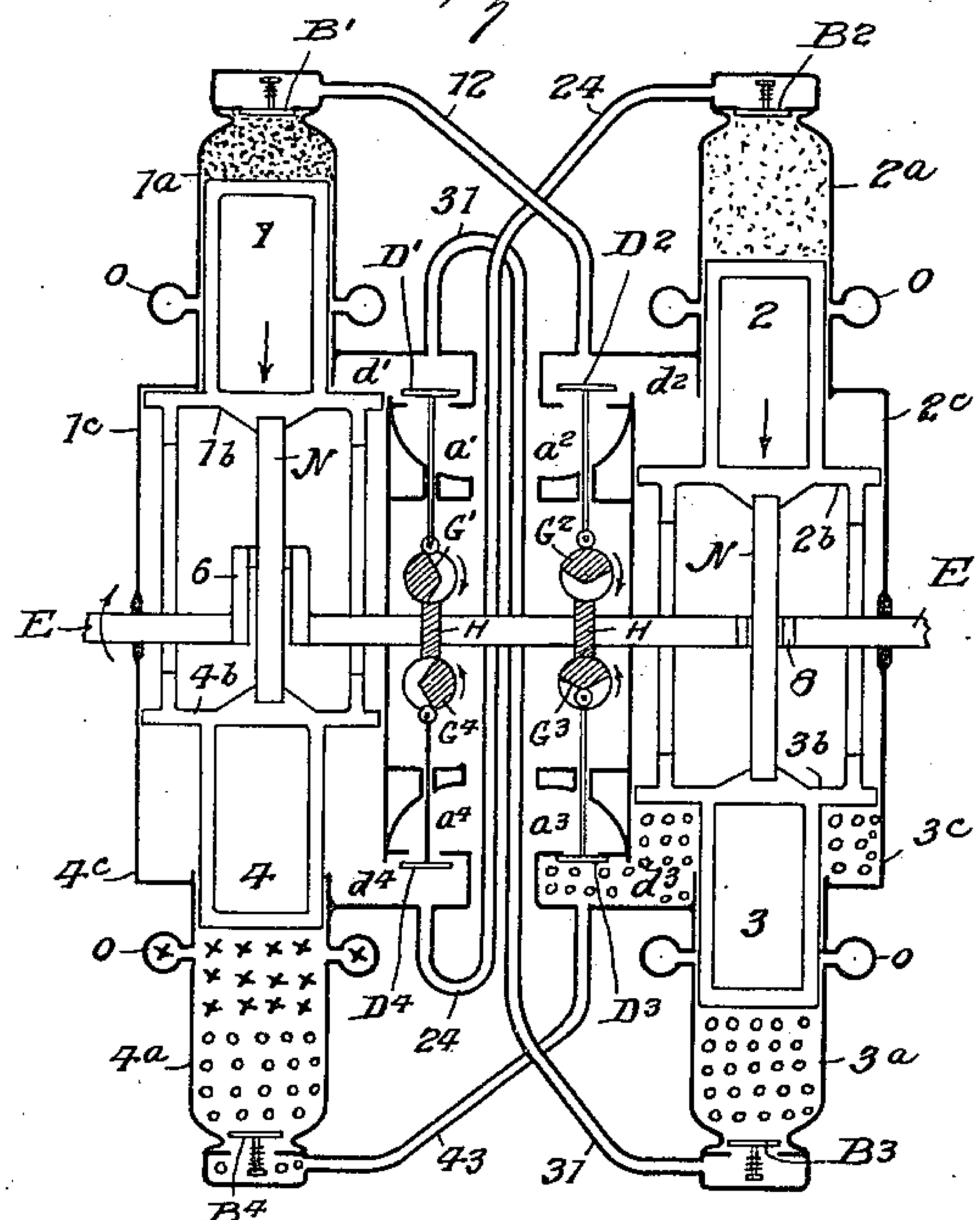
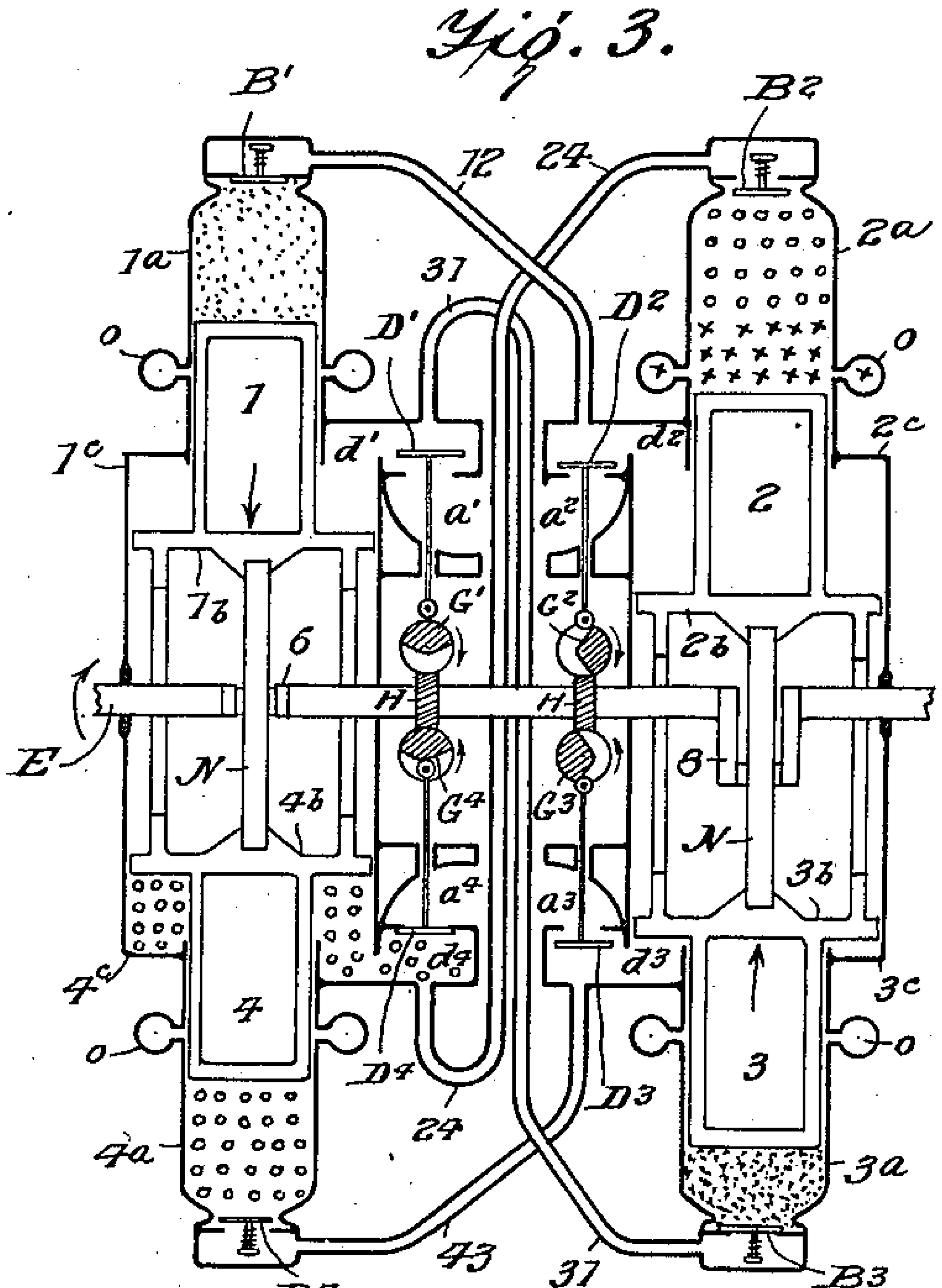


Fig. 3.



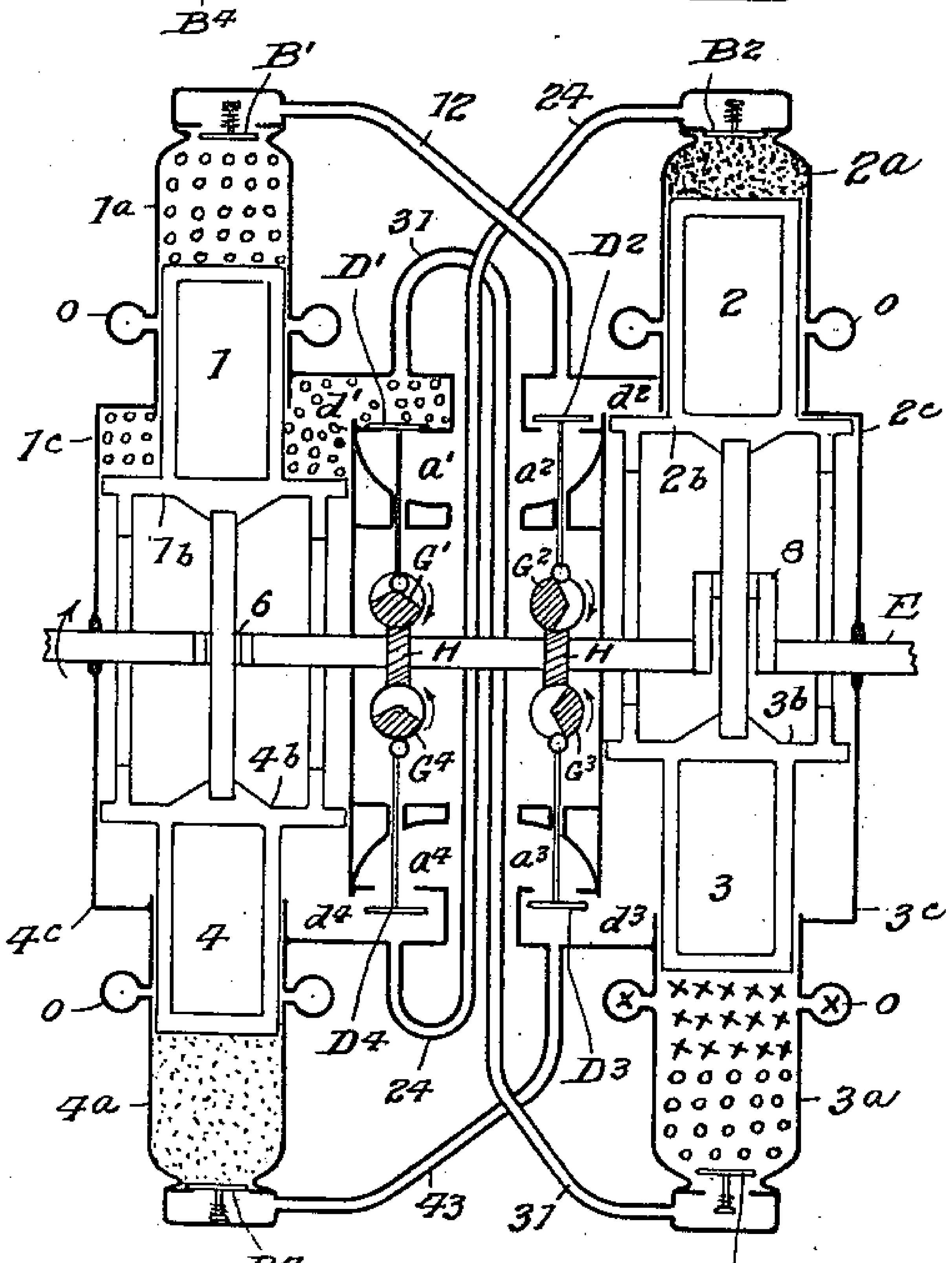


Fig. 5.

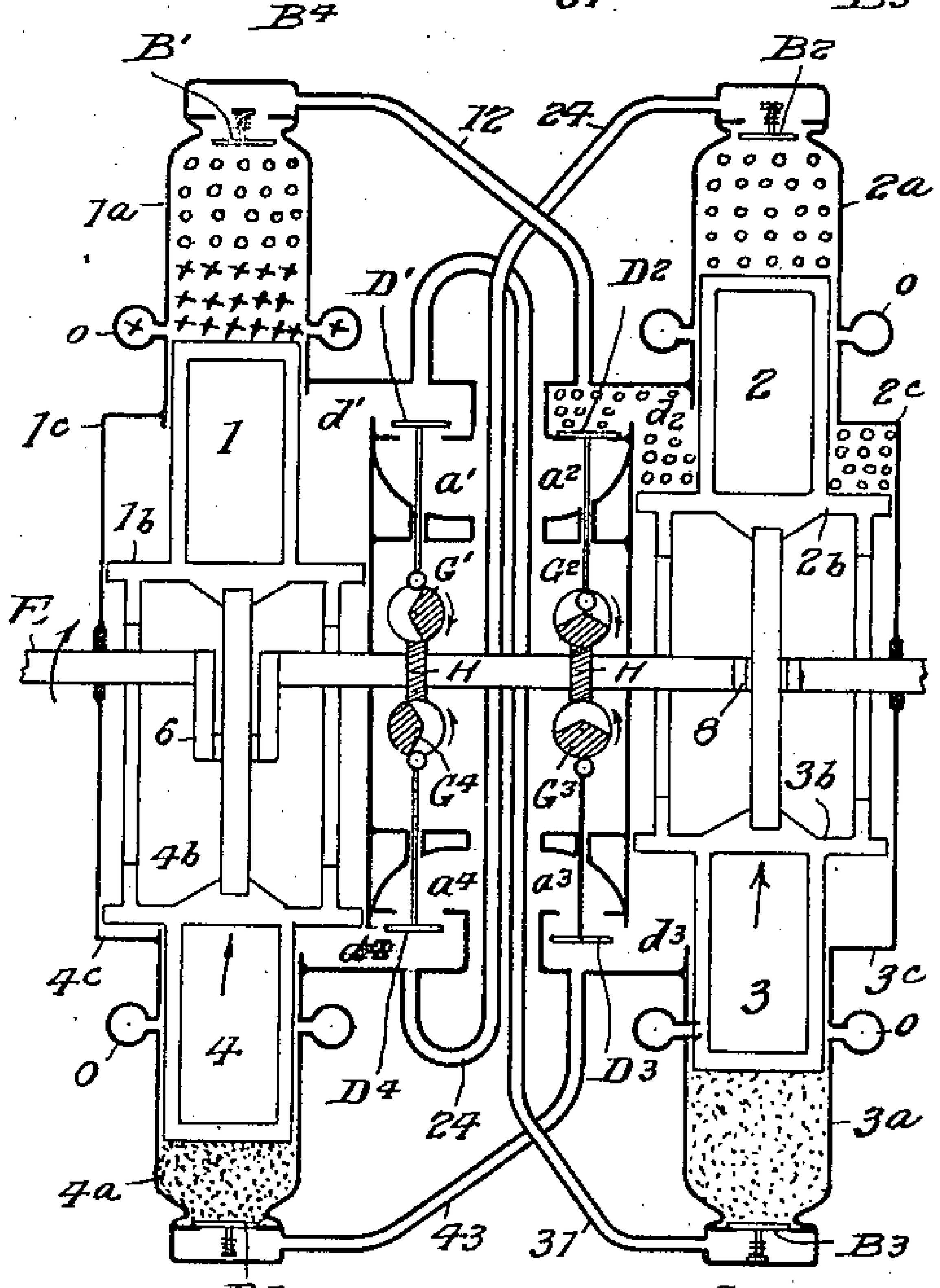


Fig. 4.

Witnesses

L. H. Schmidt.

E. W. Byrn Jr.

FIRED CHARGE

EXHAUST GAS XXXXX XXXXX

AIR

Inventor

ELBRIDGE W. STEVENS.

By

Edw. W. Byrn.

Attorney

E. W. STEVENS.

INTERNAL COMBUSTION ENGINE.

APPLICATION FILED JULY 16, 1909.

981,811.

Patented Jan. 17, 1911.

5 SHEETS—SHEET 3.

Fig. 6.

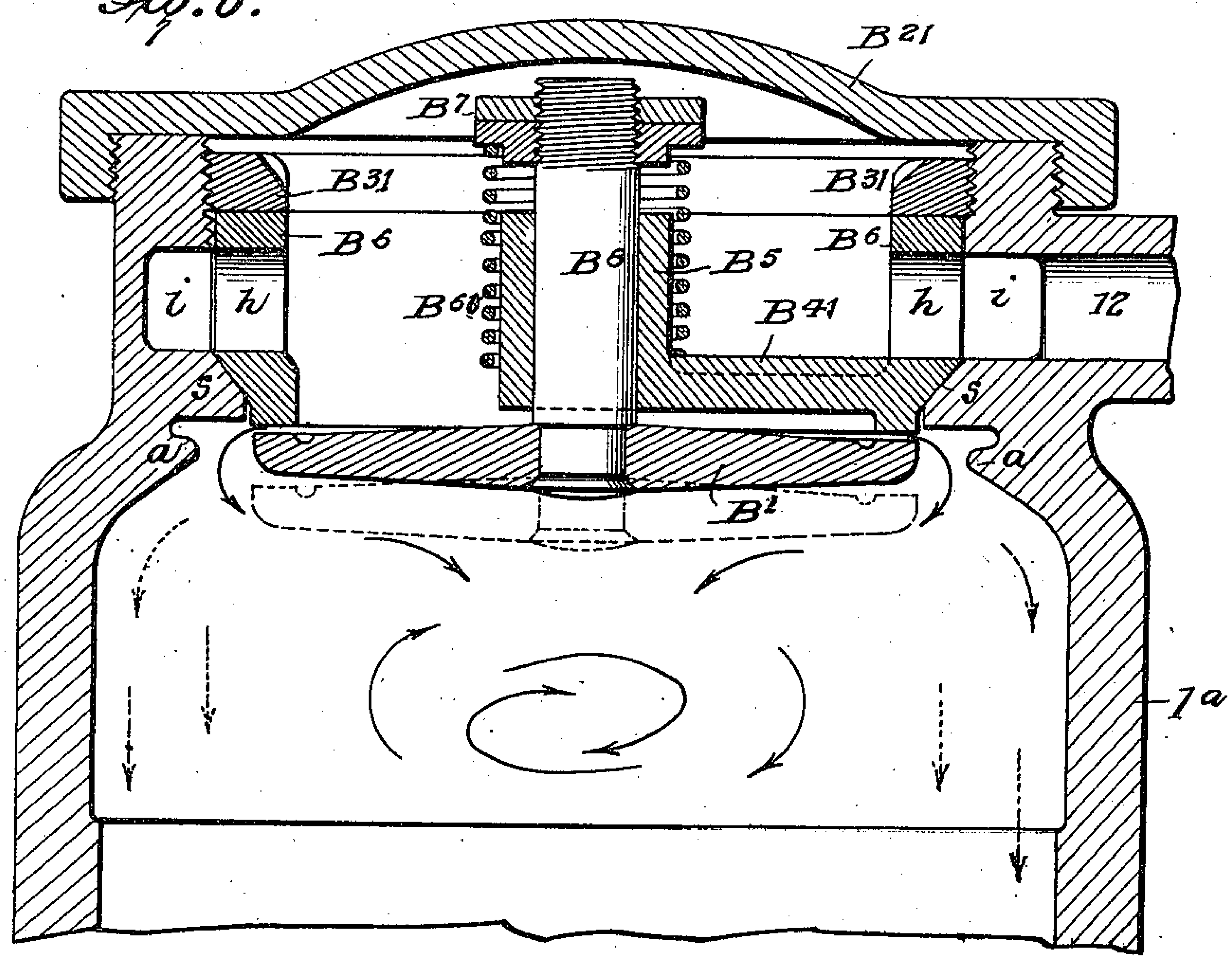
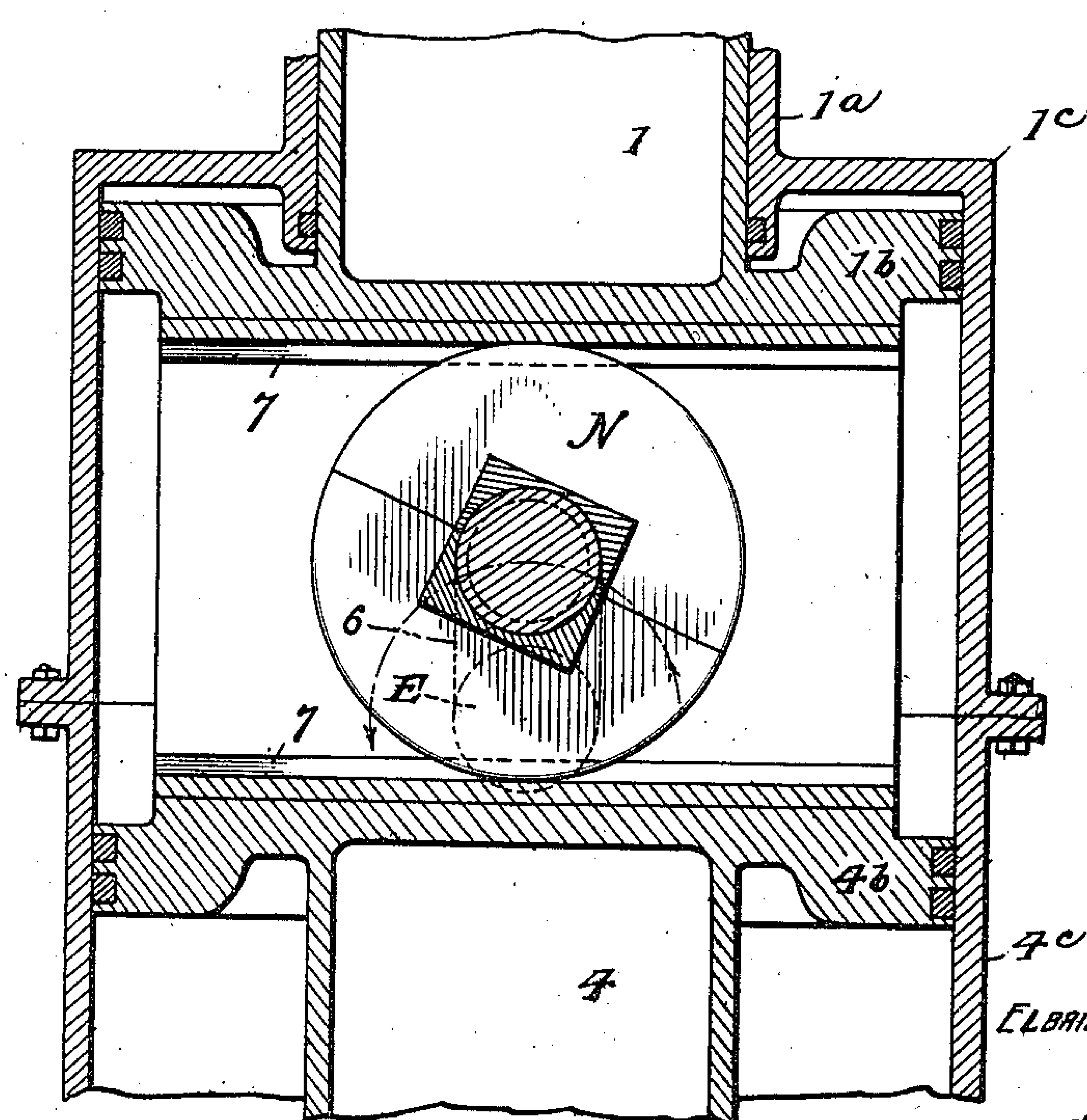


Fig. 7.



Witnesses

L. H. Schmidt.

E. W. Byrn Jr

Inventor

ELBRIDGE W. STEVENS

By

Edw. W. Byrn

Attorney

E. W. STEVENS.

INTERNAL COMBUSTION ENGINE.

APPLICATION FILED JULY 16, 1909.

981,811. Patented Jan. 17, 1911.

5 SHEETS—SHEET 4.

Fig. 8.

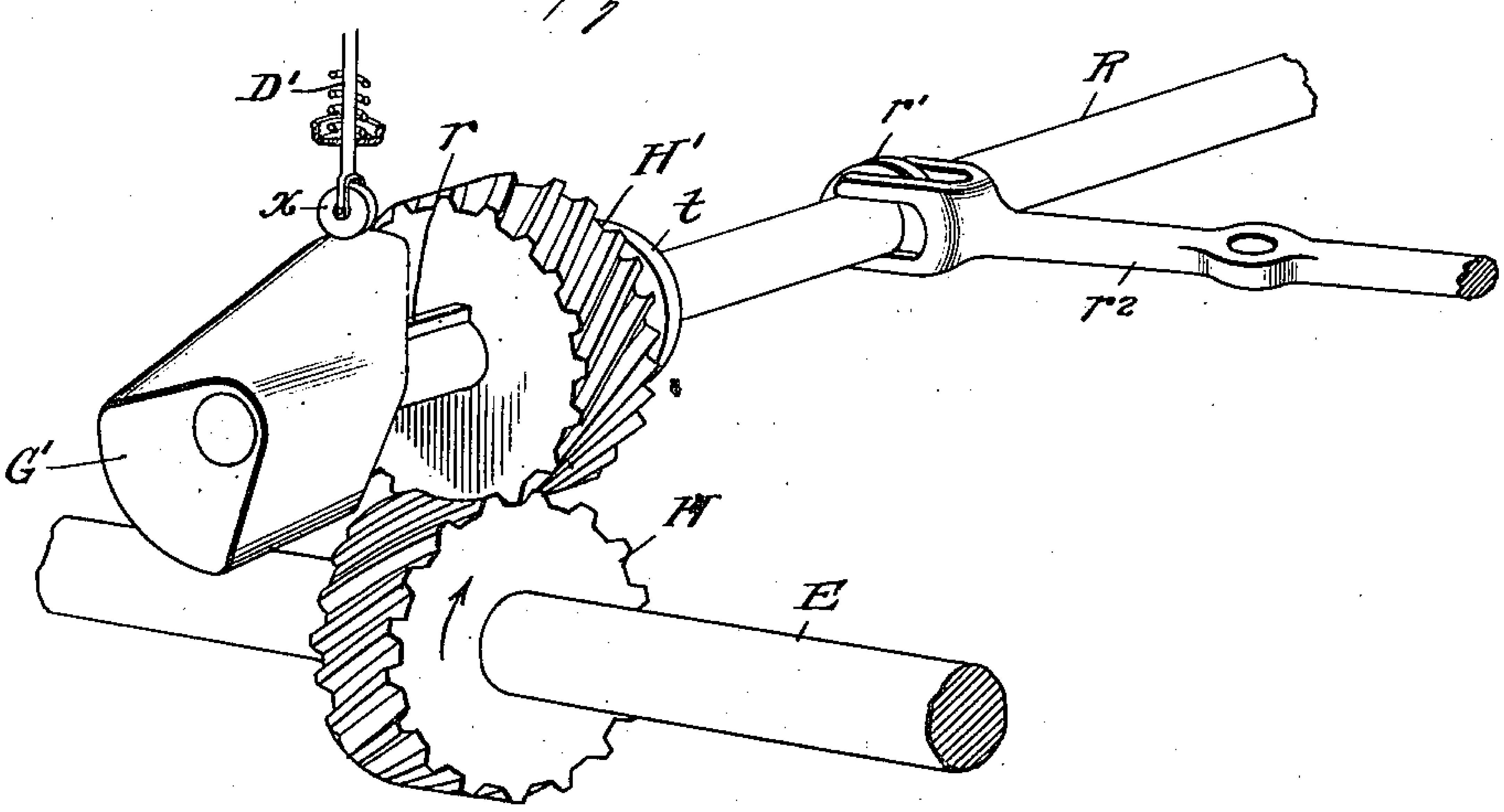


Fig. 9a

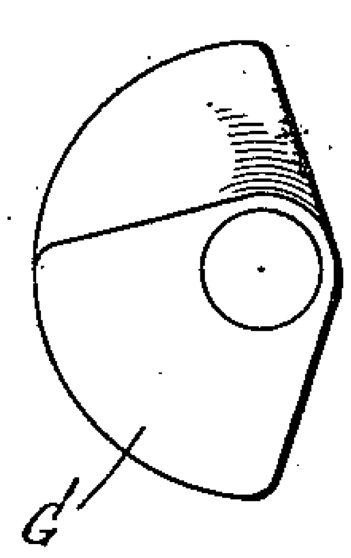


Fig. 9.

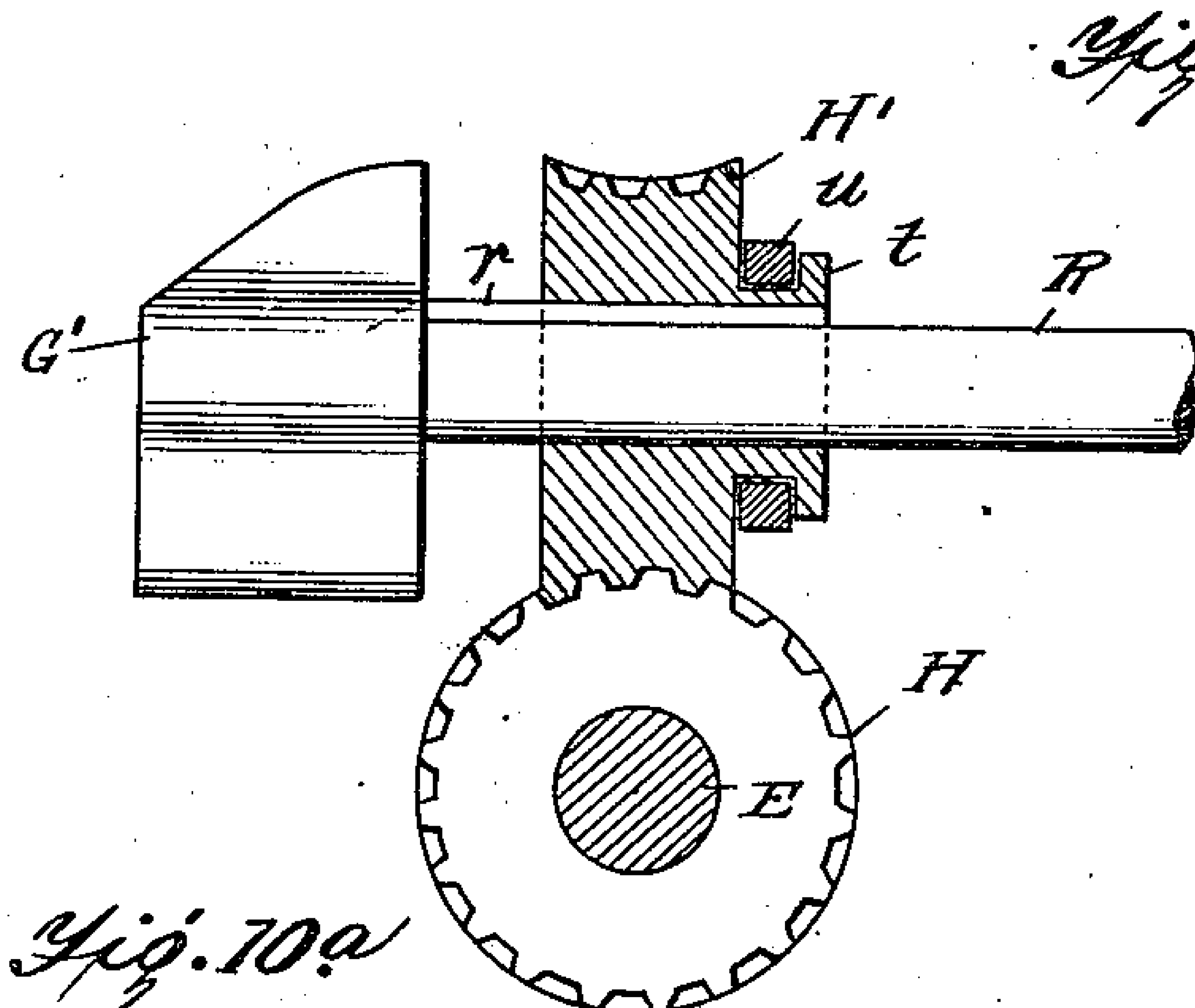
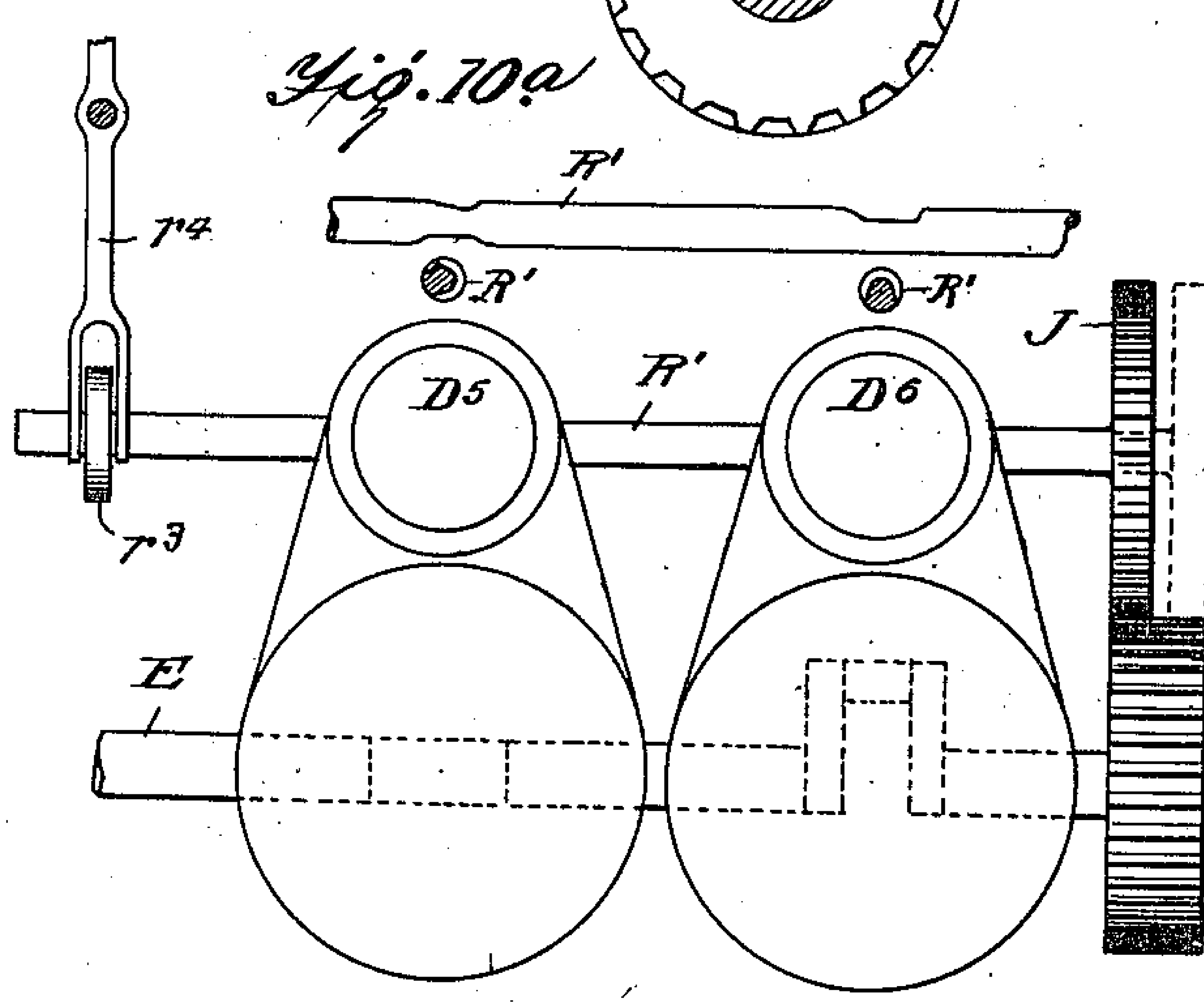


Fig. 10a

Fig. 10.



Witnesses

J. H. Schmidt.

E. W. Byrn Jr.

Inventor

ELBRIDGE W. STEVENS

By Edw. W. Byrn

Attorney

E. W. STEVENS.

INTERNAL COMBUSTION ENGINE.

APPLICATION FILED JULY 16, 1909.

981,811. Patented Jan. 17, 1911.

5 SHEETS—SHEET 5.

Fig. 10c.

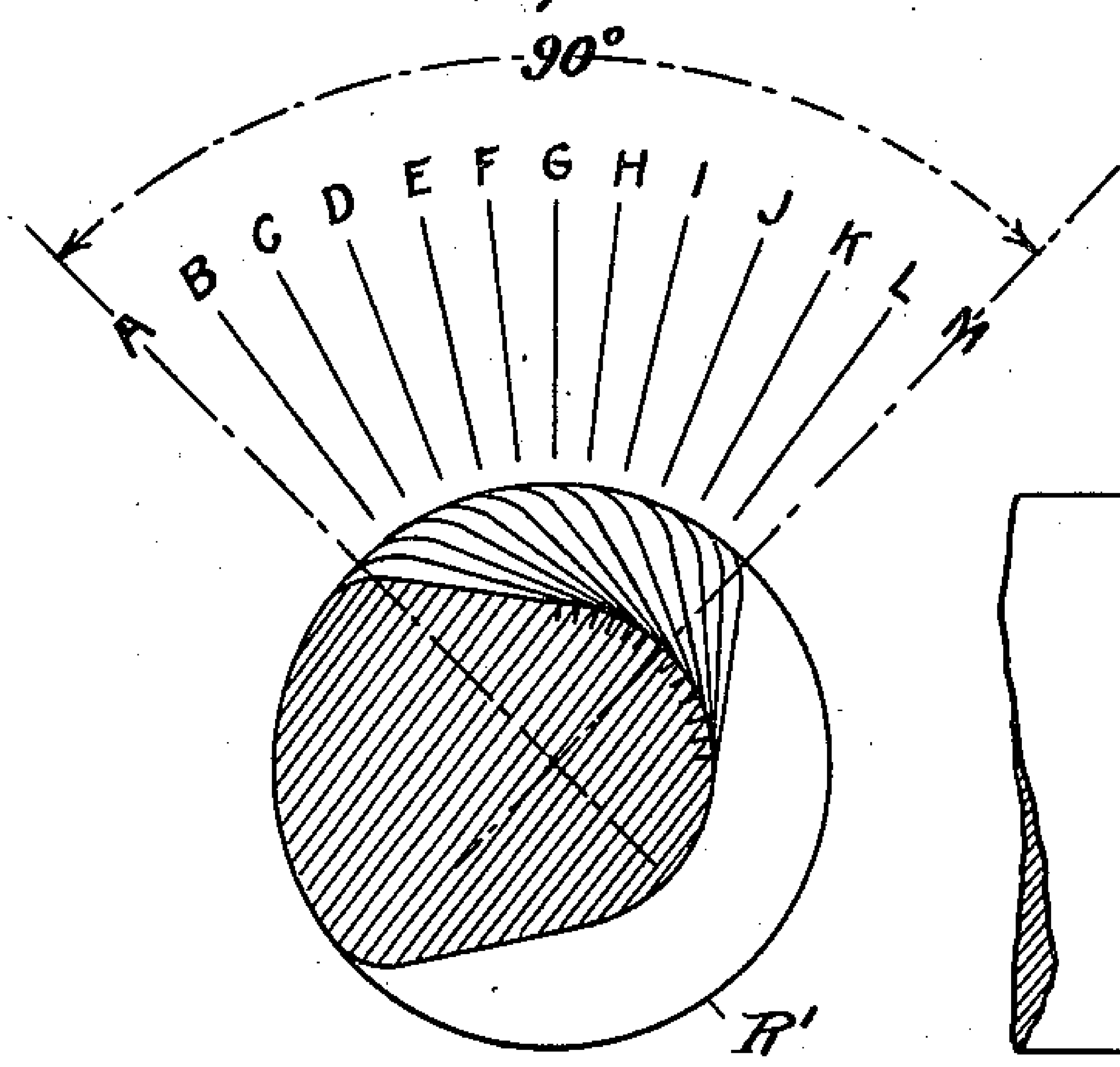


Fig. 10b.

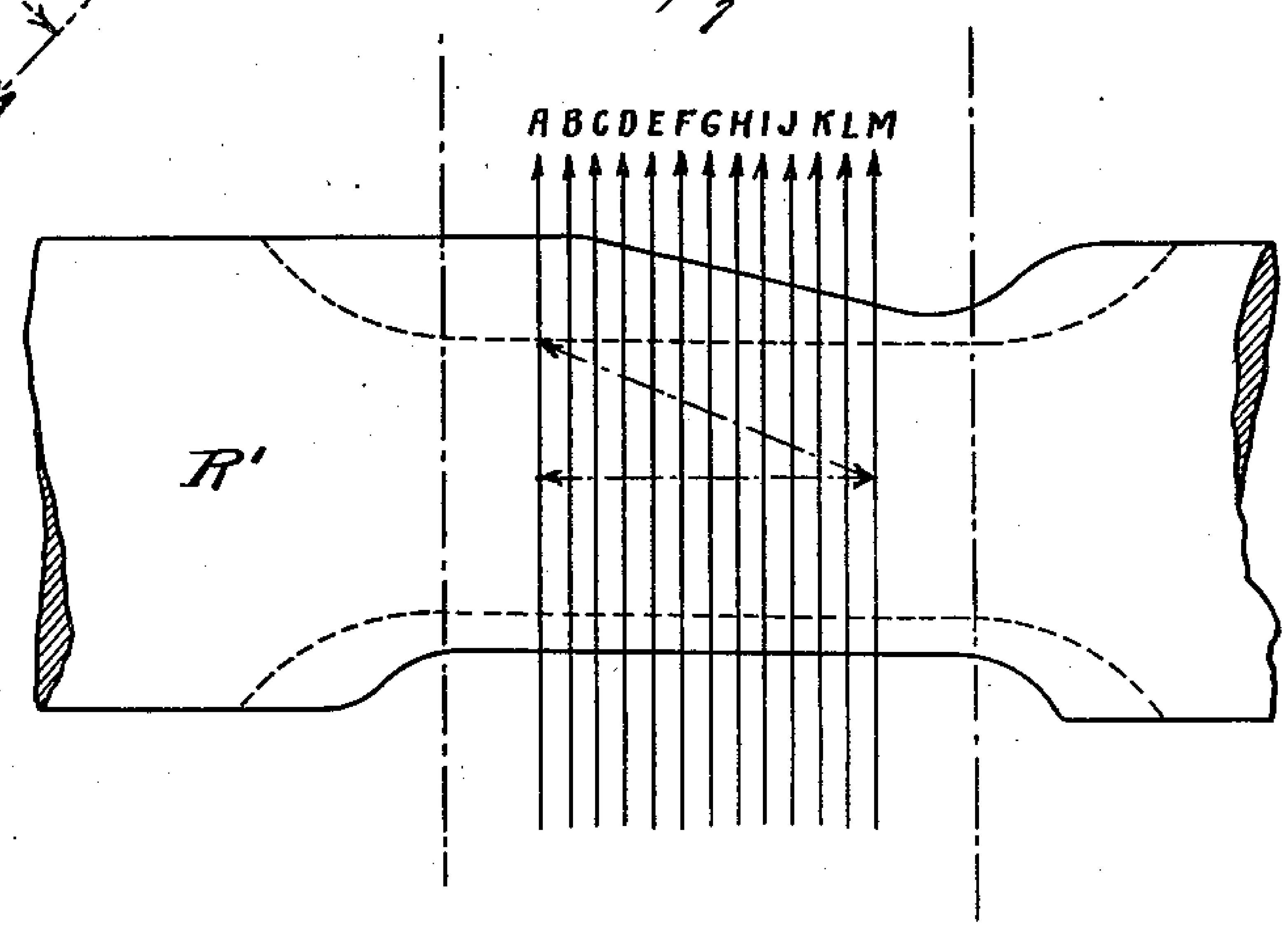
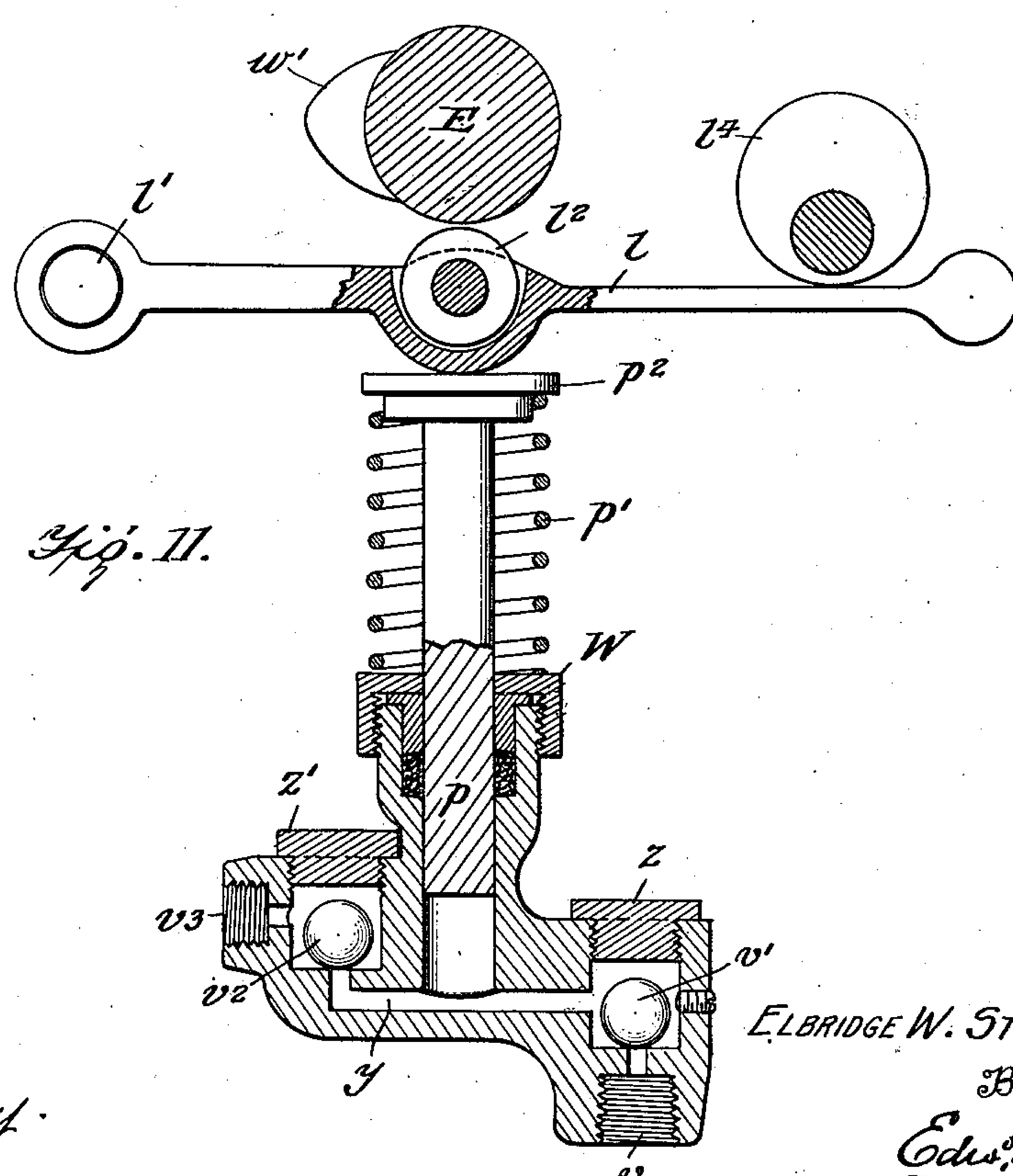


Fig. 11.



Witnesses

L. H. Schmidt.

C. W. Byrn Jr.

Inventor

ELBRIDGE W. STEVENS,

By

Edw. W. Byrn.

Attorney

UNITED STATES PATENT OFFICE.

ELBRIDGE W. STEVENS, OF BALTIMORE, MARYLAND.

INTERNAL-COMBUSTION ENGINE.

981,811. Specification of Letters Patent. **Patented Jan. 17, 1911.**

Application filed July 16, 1909. Serial No. 507,925.

To all whom it may concern:

Be it known that I, ELBRIDGE W. STEVENS, a citizen of the United States, residing at Baltimore city, in the State of Maryland, have invented certain new and useful Improvements in Internal-Combustion Engines, of which the following is a specification.

The object of my invention is to increase the efficiency of two-cycle internal combustion engines, by a perfect scavenging of the burned gases and an increase in the quantity of the explosive charge in a given size of explosion chamber.

My invention relates more especially to that form of engine in which two coaxially alined explosion cylinders have at their inner ends two intermediate and coaxially alined air compression cylinders of larger diameter and of annular form and the pistons are arranged in pairs, each pair consisting of a relatively small explosion piston rigidly connected to and moving with the larger annular air compression piston, the two pairs of such compound pistons being arranged in coaxial alinement, with one pair upon one side of an intermediate crank shaft, and the other pair upon the other side of such crank shaft and, both pairs connected to the crank shaft by means converting reciprocating into rotary motion. Such general construction is already known.

My invention is designed to provide for two cycle engines of this type an improved means for scavenging and a greater efficiency in work.

In all gas engines it is very necessary to scavenge completely the explosion cylinder of the burned gases of the previous explosion, as a very small amount of these last named gases greatly lowers the explosive pressure of the new charge upon ignition. In carrying out my invention, I employ an engine of the known type described having a double piston of two diameters, the smaller piston to act in the regular way of the common two-cycle engine piston, and the larger piston to act as an air pump which discharges air into the smaller and power producing cylinder. In my invention, however, the large annular cylinder is made of a volumetric capacity at least three times the capacity of the smaller cylinder, and the larger air cylinder is so arranged that it discharges one half its capacity of pure air into the smaller explosion cylinder for scavenging the same, which initial transfer of air is equal to one and one half times the capacity of the explosion cylinder, so that a scavenging charge of pure air equal to one and a half times the volume of the explosion cylinder will force out all the burned gases and also half its volume of newly admitted air and will leave the cylinder fully charged with pure air at atmospheric pressure. The other half of the air compression cylinder charge, equal to one and one half times the capacity of the explosion cylinder, is subsequently forced into the air already in the explosion cylinder, making a supercharge of air for explosion, hereinafter more fully explained.

Now it is obvious that if the pure-air-scavenging cylinder drew its capacity from a carbureter (which would mean the filling of this chamber with a mixture composed of hydro-carbon and air) upon its discharging the one and one half times the capacity of the explosion cylinder into said explosion cylinder, that one third of all the fuel used would be wasted by being driven out of the exhaust ports; consequently I scavenge-charge the cylinder with pure air in excess of the volume of the cylinder and inject my fuel directly into the air of the combustion chamber of the engine upon the compression stroke of that cylinder after the closing of the exhaust ports by the piston and before the time of ignition of the charge and I also supercharge the cylinder with double the amount of air for admixture with double the amount of fuel, securing a corresponding increase in efficiency. I also employ two sets of the double pairs of pistons and cylinders acting upon the same crank shaft, but upon two cranks arranged at an angle of 90 degrees to each other, and the two air cylinders of one set are directly and reciprocally connected by pipes and valves to the two explosion cylinders of the other set, so that one set supplies air for the other set.

Figure 1. is a vertical section through the engine, looking at right angles to the shaft. Figs. 2, 3, 4 and 5 are diagrammatic views of the same on a smaller scale, showing the successive positions of the parts in one complete revolution of the shaft. Fig. 6. is an enlarged sectional detail of the air inlet valve for the explosion cylinder. Fig. 7. is a section on the line 7—7 of Fig. 1., looking

in the direction of the arrow. Fig. 8. is a detail in perspective of the spiral gears and air valve actuating cam. Fig. 9. is a sectional side view of the same. Fig. 9^a. is an end projection of the cam. Figs. 10, 10^a, 10^b, 10^c, are views showing a modified arrangement of shafts and gears for operating the air valves, and Fig. 11 is an enlarged sectional detail of the fuel pump.

In the drawing, Fig. 1., the numerals 1, 2, 3, 4, are the four explosion pistons working in the four explosion cylinders 1^a, 2^a, 3^a, 4^a, and 1^b, 2^b, 3^b, 4^b, are the four air compression pistons, working in the air compression cylinders 1^c, 2^c, 3^c, 4^c. These cylinders are arranged in two quadruple sets of four cylinders and pistons each, of which one set has two coaxially alined explosion pistons, 1 and 4, and two coaxially alined air pistons, 1^b, 4^b, arranged in two pairs, each pair consisting of an explosion piston and air compression piston arranged on opposite sides of a crank shaft E from the other pair and both pairs connected together for simultaneous and coextensive movement by the connecting cylindrical cage 5. The crank shaft has a crank 6 Figs. 1 and 7, which carries a roller N that rolls in diametrical tracks 7—7 formed on the inner ends of the air compression pistons, by which the reciprocating movement of the quadruple set of connected pistons is converted into rotary movement of the crank shaft E, bearing the fly wheel F. The pistons 2, 2^b, and 3, 3^b, of the other set are arranged in coaxial alinement within their respective cylinders in similar relation to the crank shaft, except that the crank 8 of this set is at an angle of 90 degrees to the crank 6 of the first named set.

The annular space of each of the air compression cylinders 1^c, 2^c, 3^c, 4^c, is, in volumetric capacity, three times that of the corresponding explosion cylinders 1^a, 2^a, 3^a, 4^a, for which purpose the internal diameter of the air cylinder should be twice that of the explosion cylinder.

12 is a pipe connecting the explosion cylinder 1^a to the air compression cylinder 2^c; 24 is a pipe connecting the explosion cylinder 2^a to the air compression cylinder 4^c; 31 is a pipe connecting the explosion cylinder 3^a to the air compression cylinder 1^c, and 43 is a fourth pipe connecting the explosion cylinder 4^a to the air compression cylinder 3^c. Through these four pipes, in a reciprocal way, the air compression cylinders of one set serve to first scavenge-charge and then super-charge the explosion cylinders of the other set, the scavenging charge being in excess of the volume of the explosion cylinder and the super-charge doubling the imprisoned air for the next explosion. These pipes at one end enter the outer ends of their respective explosion cylinders through inwardly opening spring seating valves B^1, B^2, B^3, B^4. At the other end each of these pipes receives air from air chests d^1, d^2, d^3, d^4, opening into the several air compression cylinders, and into which chests external air is taken in through inlets a^1, a^2, a^3, a^4, through positively controlled and inwardly opening spring-seating valves D^1, D^2, D^3, D^4. These valves have the inner ends of their stems resting upon cams G^1, G^2, G^3, G^4, Figs. 1 and 8 carried by the members H^1, H^2, H^3, H^4, of spiral gears, each consisting of a gear, as H^1, having its axis at right angles to the crank shaft and engaging another gear member H of the crank shaft having its periphery rotating in a plane at right angles to that of the member H^1 of the spiral gear, the member H of the spiral gear being of such diameter and pitch of meshing teeth to H^1, that while the two members of the spiral gear rotate in planes at right angles, they rotate in the same time, a complete revolution of one producing a complete revolution of the other. The cams G^1, G^2, G^3, G^4, are so cut away as to positively hold the valves D^1, D^2, D^3, D^4, open the exact time for taking air into the air cylinders, allowing the valves to close during the scavenging and supercharging operation.

I will now describe how more complete scavenging of the explosion cylinder is effected, reference being had to Fig. 6, which is an enlarged detail of cylinder 1^a of Fig. 1 and its valve. A cover B^{21} is screwed to the top of the explosion cylinder 1^a. A ring-shaped valve seat B^6 is detachably held in the top of the explosion cylinder and has a radial projection B^{41} extending to the center and terminating in an upright sleeve B^5. The valve seat has a beveled edge *s* that rests upon a corresponding beveled shoulder on the inner edge of the cylinder and a screw threaded retaining ring B^{31} is screwed into an interior screw thread in the upper end of the cylinder and holds the valve seat B^6 in place.

B^1 is the air inlet valve of large size, nearly filling the upper end of the cylinder. This has a stem B^8 extending up through the sleeve B^5 and is provided with a cap or nut B^7 against which bears a spiral spring B^{60} which holds the valve B^1 up against its seat.

In the interior of the cylinder, at the top and immediately adjacent to the valve seat, is a circular groove or enlargement of the cylinder forming an inwardly projecting circular lip *a* which is concentric with the valve seat and just a little below the same. 12 is the pipe which takes the compressed air from the air cylinder 2^c of the other set of coöperating parts, see Fig. 1. As the air is forced in through pipe 12, see Fig. 6, it passes into an annular channel *i* in the cylinder and through the holes h in the valve seat B^6 and forces open the valve B^1. At the first downward movement of this valve, the air issues in a circular radiating sheet into the groove formed above the lip a and is immediately deflected inwardly again, by the lip, toward the center, as shown by the full line arrows, where the converging currents produce a vortex or whirlwind action down through the central zone or core, so to speak, of the cylinder, and as the valve B^1 opens wider to the dotted position, it passes the deflector lip a, as shown by the dotted lines, and then the air, without any inward deflection, passes down through the outer zone of the cylinder, as indicated by the dotted arrows, so that the result attained is a complete sweeping out of the whole cross section of the cylinder, first by a central vortex blast, immediately and automatically followed by a change in direction to an enlarged annular zone that makes a perfect cleaning out of the burned gases. The complete result is effected by the novel control of the blast, aided by the fact that the scavenge air charge is in excess of the capacity of the explosion cylinder.

With reference to the method of scavenging and the construction of the explosion cylinder and its air intake valve, just described, I do not claim these in this case, as they have been made the subject matter of a separate application for a patent, filed August 6, 1909, Serial No. 511,532.

I will now describe how the cams G^1, G^2, G^3, G^4, are adjusted to vary the timing of their action on the air inlet valves, reference being had to Figs. 8, 9 and 9^a.

H, H^1 are two members of the spiral gears, seen in Fig. 1. Through the center of gear H^1 passes a shaft R having feather or spline r, so that while the shaft may be moved freely through gear H^1, the shaft and gear rotate together. On the end of the shaft R is rigidly fixed the cam G^1 extending through nearly a half circle. The cam is cut away spirally so that one end of the cam is in advance of the other end. This cam, as it revolves, acts upon a small roller x on the end of the air valve D^1, and lifts it sooner or later by merely moving the shaft R longitudinally by means of a manually operated forked lever r^2 acting on collar r^1 on the shaft. The spiral gear member H^1 has a grooved collar t on one side, see Fig. 9, which is embraced by a fixed and stationary bearing u which is connected to the frame work and which holds the gear member H^1 always in its proper plane, as the shaft R slides through it.

In Fig. 10 a modified form of valve-lifting mechanism is shown, in which the air valves are placed in chests D^5, D^6 off to one side of the cylinders and are both acted upon by cams similar to G^1 in Figs. 8 and 9, only said cams are both on the same shaft R^1, which is a counter shaft parallel to the main shaft E. Longitudinal movement is given to the shaft by collar r^3 and forked lever r^4, and counter shaft R^1 is driven by spur gears I, J, of equal diameter, I being on the main shaft E and having teeth of broad face to accommodate the lateral movement of gear J, as indicated in dotted lines, without breaking connection for rotary movement. In Figs. 10^a, 10^b, 10^c, are shown the form and arrangement of the cams on shaft R^1.

In my engine I have shown no water jacket, nor radiating ribs for the explosion cylinder, it being understood that I may employ either of these well known agencies, for either an air cooled or water cooled effect, it being sufficient for the purposes of my invention to show only the exhaust port o, spark plug A and fuel injection nozzle M^1. &c. The spark plug may be either of the jump-spark type, or the make-and-break, and the liquid fuel nozzles are connected respectively by pipes m^1, m^2, m^3, m^4, to fuel pumps W^1, W^2, W^3, W^4 which are actuated by cams w^1, w^2, w^3, w^4, on the main shaft in the order of firing as hereafter described. The details of these pumps are shown in Fig. 11 in which the body of the pump is formed with three projections, in one of which is formed the screw threaded inlet v for the fuel tank and in the other of which is formed the screw threaded outlet v^3 for the pipe m^1 that leads to an explosion chamber. The upper projection contains the pump cylinder in which plays the plunger p passing through a stuffing box and having a head p^2 against which bears a spiral spring p^1 wound around the plunger stem and normally holding the same up. A check valve chamber is drilled in the projection above the inlet v and is closed by a screw cap z, and a ball v^1 is arranged within to form an inwardly opening check valve. A similar valve chamber, with ball valve v^2 and cap z^1, is arranged on the other side of the pump barrel and a drilled port y connects both valve chambers with the pump cylinder.

Above the plunger head p^2 is a horizontal lever l fulcrumed at l^1 and bearing a friction roller l^2 which is operated upon by the cam w^1 on the main shaft to depress the plunger. To vary the stroke of the pump the lever l is held adjustably at any desired distance from the cam w^1 by means of an adjustable stop formed as an eccentric l^4 on a shaft l^3. By manually turning this shaft and eccentric, the roller l^2 is given a greater or less time of contact with the depressing cam and consequently the plunger is given a greater or less throw and the amount of liquid fuel injected may be exactly regulated. This variation of the fuel charge is correlated to the variation of the air charge as will be more fully explained hereafter.

Operation of engine.—The order of firing is in the following sequence: piston 1— piston 3— piston 4— piston 2.

Referring to Fig. 2, commencing with the large cylinder 1^c; upon the rotation of crank shaft E the spiral gears H, H^1 actuate the cam G^1, which raises the valve D^1, which opens communication with the outside atmosphere and this valve remains open until the downmost point of stroke is reached (shown in cylinder 1^c Fig. 4) at which time this valve D^1 is allowed to close. This valve remains closed until the position of the piston in cylinder 1^c, Fig. 5, is reached when the pressure having fallen in cylinder 3^a, Fig. 5 by the piston uncovering the exhaust ports in the cylinder walls, the air in this large cylinder (cylinder 1^c, Fig. 5) forces open the inlet valve B^3, Fig. 5, and one and one half times the capacity of this cylinder is emptied into it. Obviously, one third the air admitted goes out the exhaust ports *o*. The exhaust gases are shown by the small crosses, the air by the small circles, and the fired and expanding charge by dots. Figs. 2, 3, 4 and 5 represent the positions of parts at the successive quarter turns of the main shaft.

Now for the supercharging of the power cylinder: It is theoretically possible to explode twice the quantity of fuel in a given volume of space, provided twice an amount of oxygen is also added in order to support combustion: Consequently if the valve D^1 Fig. 5 is allowed to remain closed, the large piston of this chamber having a capacity yet of one and one half times the cylinder to which it is connected, (cylinder 3^a Fig. 5) as the action of the engine continues this larger cylinder 1^c continues to send air into the small cylinder 3^a, then, theoretically it is possible to later admit practically twice the quantity of fuel for explosion than if no additional air had been forced in (above atmospheric pressure) with the consequent development (upon explosion of this gas) of twice the power otherwise obtainable. But, by varying the shape of the face of the cam G^1 and adjusting it as herein described, it is possible to either raise the valve D^1 at the position of larger piston of cylinder 1^c Fig. 5, immediately after it has scavenged the cylinder 3^a, or I may defer its time of opening from then on until it reaches the top of its stroke and thereby obtain additional air above atmospheric pressure proportional to the time of opening—the sooner opened the smaller the pressure. It will be understood that when valve D^1, Fig. 5, is raised just after scavenging has been effected, and without supercharging the explosion cylinder, the balance of the imprisoned air in pump cylinder 1^c escapes with a back-lash into the open air through the intake valve D^1 which cannot close by reason of being positively held open, but if not so held open the whole of the contents of pump cylinder 1^c passes into explosion cylinder 3^a, with a consequent supercharging of the same with air. This is an important part of my invention. It will be understood that the other correlated factors of the engine *i. e.* the firing of the charge and the feed of the fuel pumps are provided with corresponding adjustments as to time to provide for the change in the air admission.

In all the Figs. 2, 3, 4, 5, the dots represent the fired charge, the small circles the pure air or compressed pure air, and the cross marks the exhaust gases.

In pointing out more clearly an important and distinguishing feature of my invention, I would state that the air intake valves D^1, D^2, D^3, D^4, instead of opening by suction, are positively and mechanically actuated by their cams G^1, G^2, G^3, G^4. This secures several results. The most important of which is, that I am enabled by the adjustment of the cams to scavenge-charge the explosion cylinder with air at atmospheric pressure, without supercharging it if desired, or I can scavenge-charge it at atmospheric pressure and consecutively supercharge it with a double pressure of air, which with a double quantity of fuel gives a greatly increased efficiency, so that the same engine by a mere matter of adjustment may have its horse power varied within a wide range. Furthermore as the air intake valves are positively and mechanically opened by their cams, the suction pumps do not have on the suction movement to work against the tension of the springs which return these valves to their seats, and consequently the annular air pump pistons are enabled to take in a larger volume of air in the suction movement without rarefying the same in the intake movement. Another important result of the positive operation of the air intake valves of the air pump is, that it relieves the air pump of a great amount of work, for the total amount of lost energy of the pump in a spring-seated suction-opening valve is the tension of that valve spring multiplied by the number of multiples of the area of the valve in the cross sectional area of the pump piston.

I claim:

1. A two-cycle engine, comprising a main shaft with two cranks, four explosion cylinders and pistons and four air compression cylinders and pistons, arranged in two sets, each set consisting of two pairs arranged on opposite sides of the crank shaft and each pair consisting of an explosion cylinder and piston and an annular air compression cylinder of relatively larger capacity than the explosion cylinder and an annular piston, the two pistons being connected, air pipes directly connecting the air compression cyl-

inders of each set to the explosion cylinders of the other set, an inlet air valve to each explosion cylinder, inlet air valves to the air cylinders and means for positively opening said last mentioned air inlet valves and holding them open during a definite period.

2. A two-cycle engine, comprising a main shaft with two cranks, four explosion cylinders and pistons, and four air compression cylinders and pistons, arranged in two sets, each set consisting of two pairs arranged on opposite sides of the crank shaft in coaxial alinement and each pair consisting of an explosion cylinder and piston and an annular air compression cylinder of relatively larger capacity than the explosion cylinder, and an annular piston, the two pistons being connected to each other and also to the coaxial pistons on the other side of the crank shaft, air pipes directly connecting the air compression cylinders of each set to the explosion cylinders of the other set, an inlet air valve to each explosion cylinder, inlet air valves to the air cylinders and means for positively opening said last mentioned air inlet valves and holding them open during a definite period.

3. A two-cycle engine, comprising a main shaft, with two cranks, four explosion cylinders and pistons and four air compression cylinders and pistons arranged in two sets, each set consisting of two pairs arranged on opposite sides of the crank shaft and each pair consisting of an explosion cylinder and piston and an annular air compression cylinder of relatively larger capacity than the explosion cylinder, and an annular piston, the two pistons being connected, and the air cylinder being substantially three times the volumetric capacity of the explosion cylinder, air pipes directly connecting the air compression cylinders of each set to the explosion cylinders of the other set, air valves forming inlets to the pumps and also controlling the volume of the air transference and means for operating and controlling said air inlet valves in a positive manner.

4. A two-cycle engine, comprising a main shaft, with two cranks, four explosion cylinders and pistons, and four air compression cylinders and pistons arranged in two sets, each set consisting of two pairs arranged on opposite sides of the crank shaft in coaxial alinement and each pair consisting of an explosion cylinder and piston and an annular air compression cylinder of relatively larger capacity than the explosion cylinder and an annular piston, the two pistons being connected to each other and also to the coaxial pistons on the other side of the crank shaft, and the air cylinder being substantially three times the volumetric capacity of the explosion cylinder, air pipes directly connecting the air compression cylinders of each set to the explosion cylinders of the other set, air valves forming inlets to the pumps and also controlling the volume of the air transference and means for operating and controlling said air inlet valves in a positive manner.

5. A two-cycle engine, comprising a main shaft with two cranks, four explosion cylinders and pistons and four air compression cylinders and pistons arranged in two sets, each set consisting of two pairs arranged on opposite sides of the crank shaft and each pair consisting of an explosion cylinder and piston and an annular air compression cylinder of relatively larger capacity than the explosion cylinder and an annular piston, the two pistons being connected, air pipes directly connecting the air compression cylinders of each set to the explosion cylinders of the other set, an inlet air valve to each explosion cylinder, inlet air valves to the air cylinders and means for positively opening said last mentioned air inlet valves during a definite period, consisting of cams constructed to positively hold the air valves open during the intake of air by the air cylinders and means to close same when the air is being transferred to the explosion cylinders.

6. A two-cycle engine, comprising a main shaft with two cranks, four explosion cylinders and pistons, and four air compression cylinders and pistons arranged in two sets, each set consisting of two pairs arranged on opposite sides of the crank shaft and each pair consisting of an explosion cylinder and piston and an annular air compression cylinder of relatively larger capacity than the explosion cylinder and an annular piston, the two pistons being connected, air pipes directly connecting the air compression cylinders of each set to the explosion cylinders of the other set, an inlet air valve to each explosion cylinder, inlet air valves to the air cylinders and means for positively opening said last mentioned air inlet valves during definite periods, consisting of cams made adjustable to vary and regulate the volume of transference of air from the air cylinders to the explosion cylinders.

7. A two-cycle engine, comprising two sets of explosion cylinders and pistons and air compression cylinders and pistons, each set having its explosion chambers connected to the air compression chambers of the other set, and each air compression chamber having a positively opened intake valve controlling the intake of air to the air compression chamber and also regulating the transfer of its air to the explosion chamber and means for varying the time of opening of the valve during the compression stroke of the air piston to transfer the whole or a part of the contents of the air compression chamber to the explosion chamber.

8. A two-cycle engine, comprising two sets

of explosion cylinders and pistons and air compression cylinders and pistons, each set having its explosion chambers connected to the air compression chambers of the other set, and each air compression chamber having a positively opened intake valve controlling the volume of the air transferred to the explosion chamber and means for varying the time of the opening of the valve to transfer the whole or a part of the contents of the air compression chamber to the explosion chamber, consisting of a crank shaft and a shaft at right angles thereto, a spiral gear on the crank shaft, a spiral gear on the shaft at right angles to the crank shaft bearing a cam of varying pitch resting against the stem of the positively opened intake valve and operating the same and means for projecting the cam of varying pitch across the valve stem.

9. An internal combustion engine, comprising two sets of air compression cylinders and pistons and explosion cylinders and pistons, the air compression cylinders of each set being connected to the explosion cylinders of the other set, an air intake valve for each explosion cylinder, an air intake valve for each air compression cylinder, positively actuated mechanical means for operating the air intake valves of the air compression cylinders, means for varying the time of opening the same for the purpose of varying the quantity of air transferred to the explosion cylinders and a fuel injection pump for each explosion cylinder with means for varying the amount of fuel injected to correspond to the amount of air introduced into the explosion cylinder.

10. An internal combustion engine having a plurality of concentric explosion cylinders and annular air pumps, with passageways leading from each air pump to an explosion cylinder, a valve chamber formed on each annular air pump with an opening to the outer air, a valve for the latter opening inwardly to the air pump and a positive valve opening gear for holding said valve open during the intake of air to the pump and closing the same during varying periods of the compression stroke, for the transfer of the whole or a part of the contents of the pump to the explosion cylinder.

11. An internal combustion engine, having an explosion cylinder and piston and an air compression chamber, the compression chamber being of greater volumetric capacity than that of the explosion cylinder, a duct leading from the compression chamber to the explosion cylinder, an inwardly opening and positively actuated valve for admitting air to the compression chamber, a valve operating device for opening the valve and holding it open during the entire suction stroke and means for adjusting the device to permit the valve to close at variable times during the compression stroke, to vary the amount of air transferred from the compression chamber to the explosion cylinder, and a fuel pump having an adjustable device to vary the fuel injected in proportional quantity to the air transferred to the explosion cylinder.

12. An internal combustion engine having a plurality of explosion cylinders and pistons each explosion cylinder being provided with an annular concentric air compression cylinder and piston, said air compression cylinder being of larger volumetric capacity than the explosion cylinder, a duct leading from each compression cylinder to its receiving explosion cylinder, a positively actuated valve opening inwardly to the compression cylinder, a valve opening device for holding it open during the entire suction stroke of the piston of the compression cylinder and means for adjusting said device for permitting said valve to close during the whole or part of the compression stroke to transfer the whole or part of the contents of a compression cylinder to an explosion cylinder.

13. An internal combustion engine, comprising an explosion cylinder and piston, an air compression cylinder of greater capacity than the explosion cylinder, a duct leading from the air compression cylinder to the explosion cylinder, a valve controlling the transference of air from the air compression cylinder to the explosion cylinder, a manually operated regulating device for timing the period of action of the valve, and a fuel feed pump with manually operated regulating devices for regulating the quantity of fuel fed to the explosion cylinder.

14. In an internal combustion engine, the combination with an explosion cylinder and piston and an air pump of greater volumetric capacity than the explosion cylinder and connected to said explosion cylinder; of a valve chamber having an opening to the outer air and communicating with the air pump and provided with a duct leading to the explosion cylinder and a valve located in said valve chamber and controlling the opening to the outer air and opening inwardly to the air pump and a positively acting opening gear for the valve including a device for opening the valve during varying periods of the compression stroke.

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

ELBRIDGE W. STEVENS.

Witnesses:
J. W. NORTHRUP,
WM. A. SACKER, Jr.