No. 758,943. PATENTED MAY 3, 1904.

R. P. THOMPSON & E. KÖEB.

BALANCED VALVELESS TWO-CYCLE GAS ENGINE.

APPLICATION FILED FEB. 21, 1903.

NO MODEL. 3 SHEETS—SHEET 1.

Fig. 1.

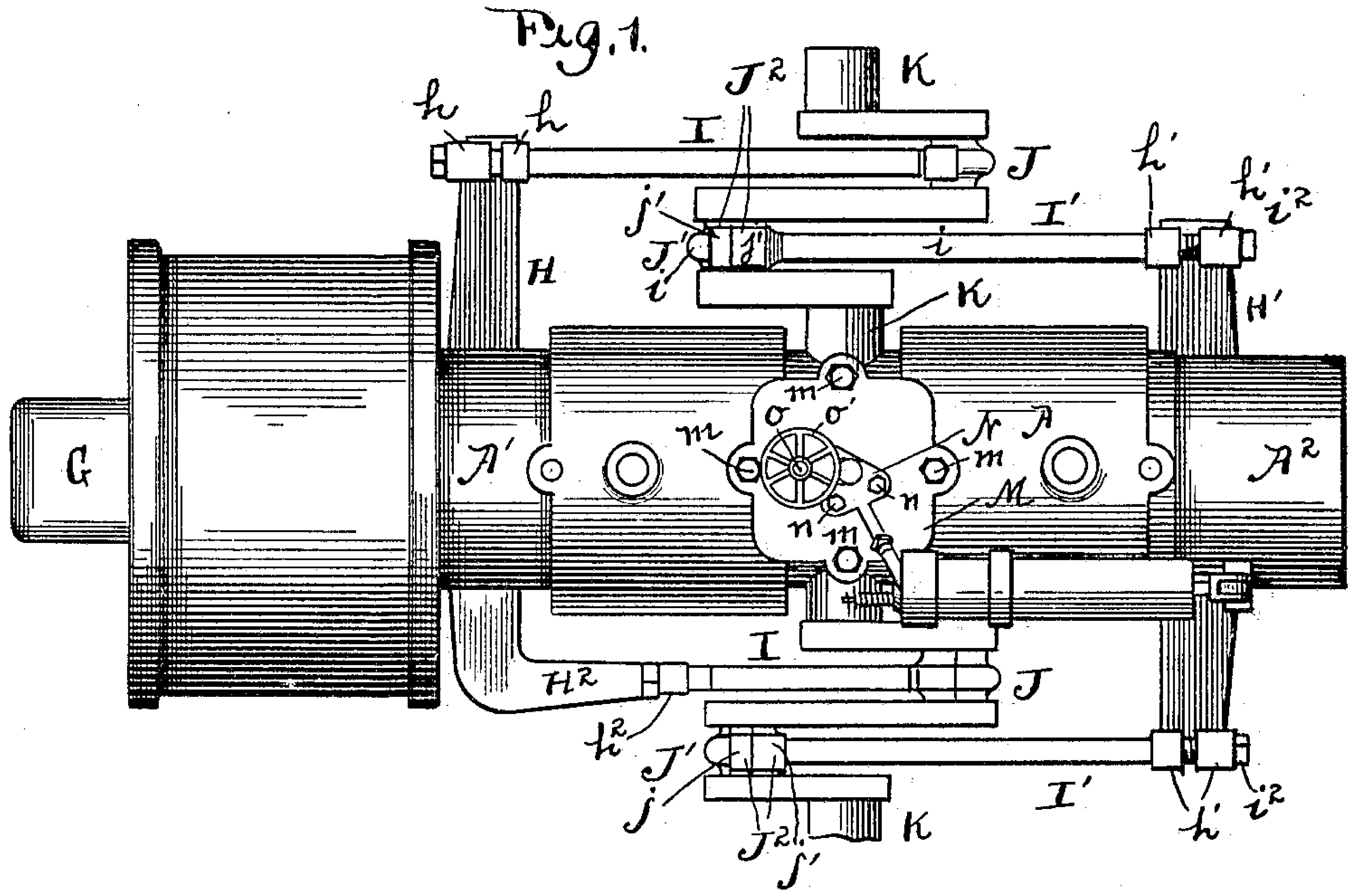
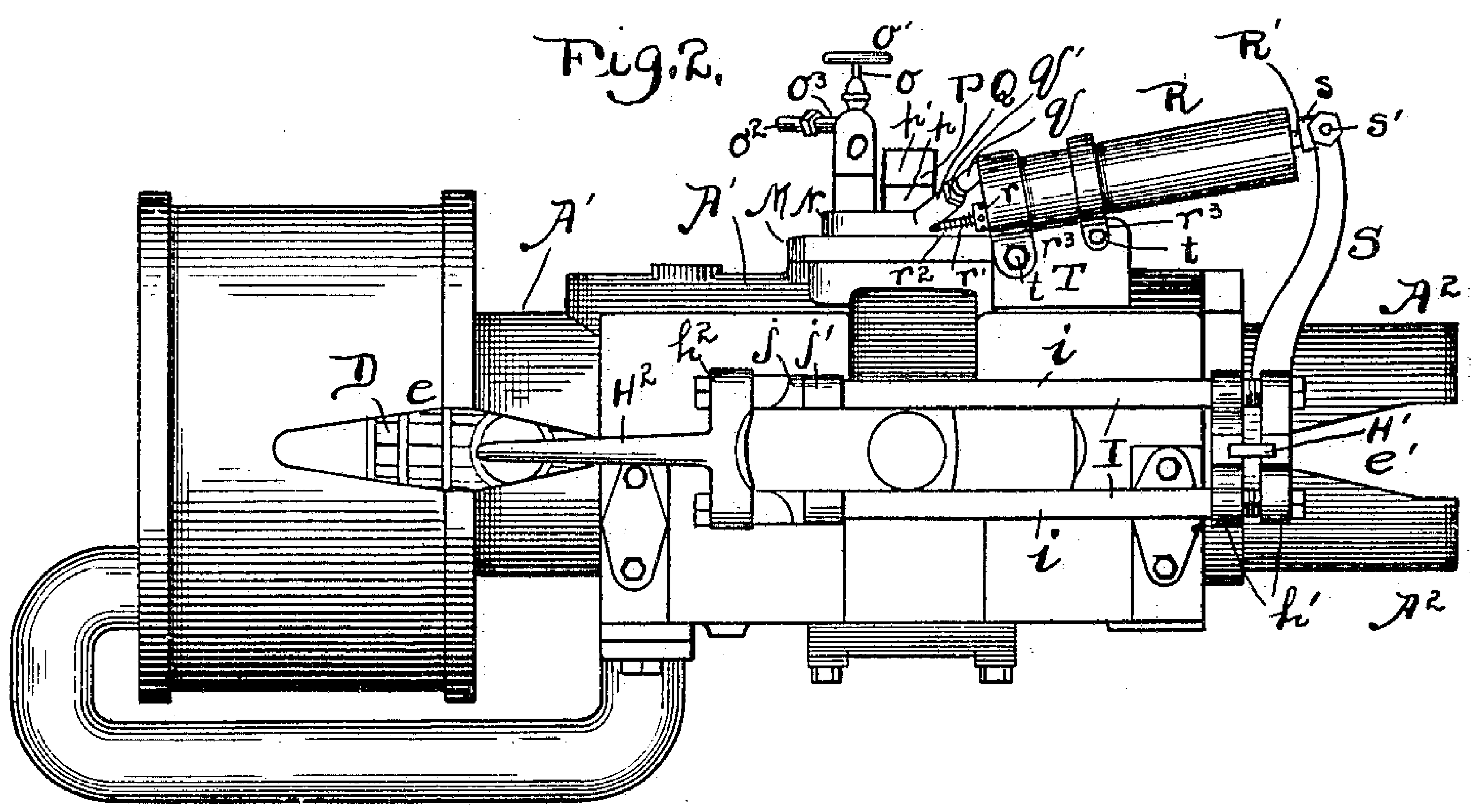


Fig. 2.



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NO MODEL. 3 SHEETS—SHEET 2.

Fig. 3.

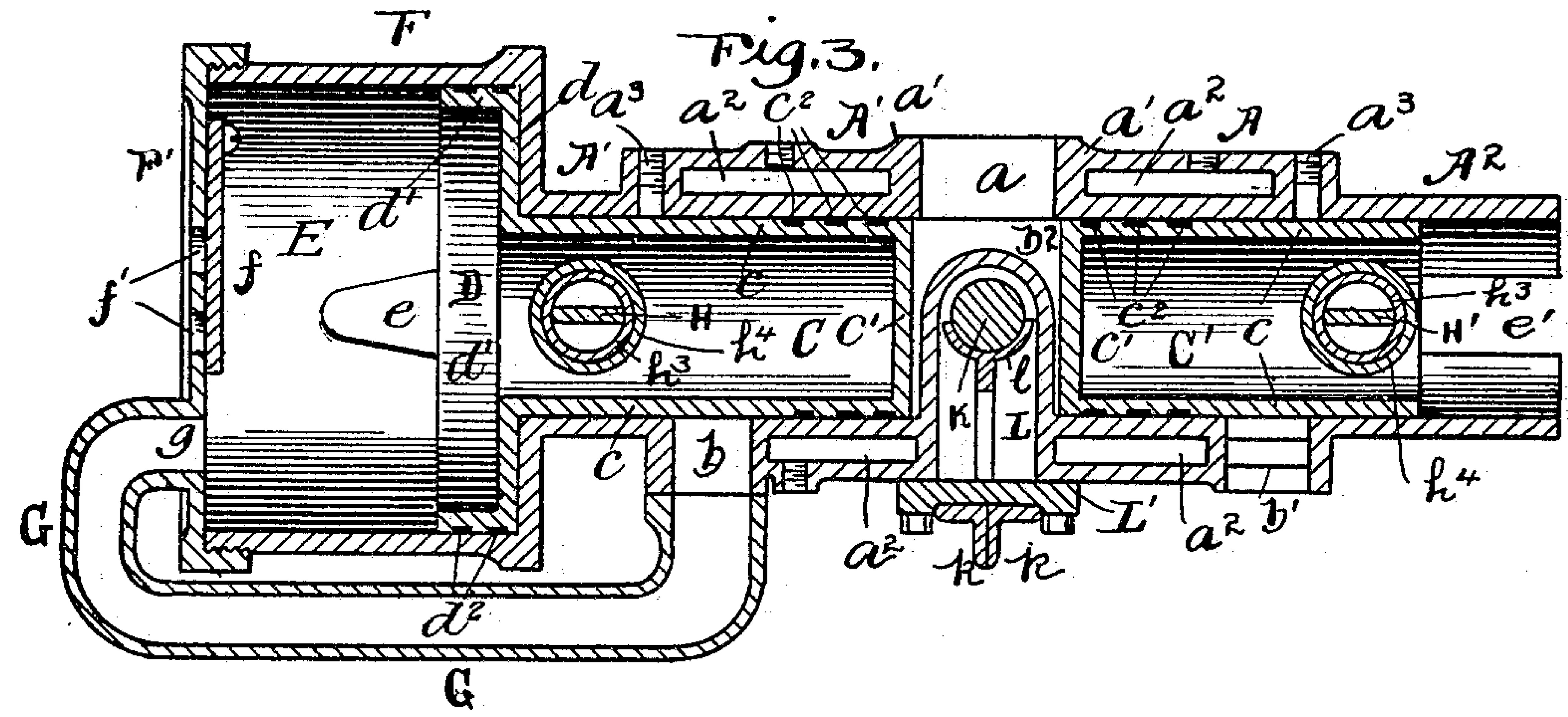


Fig. 4.

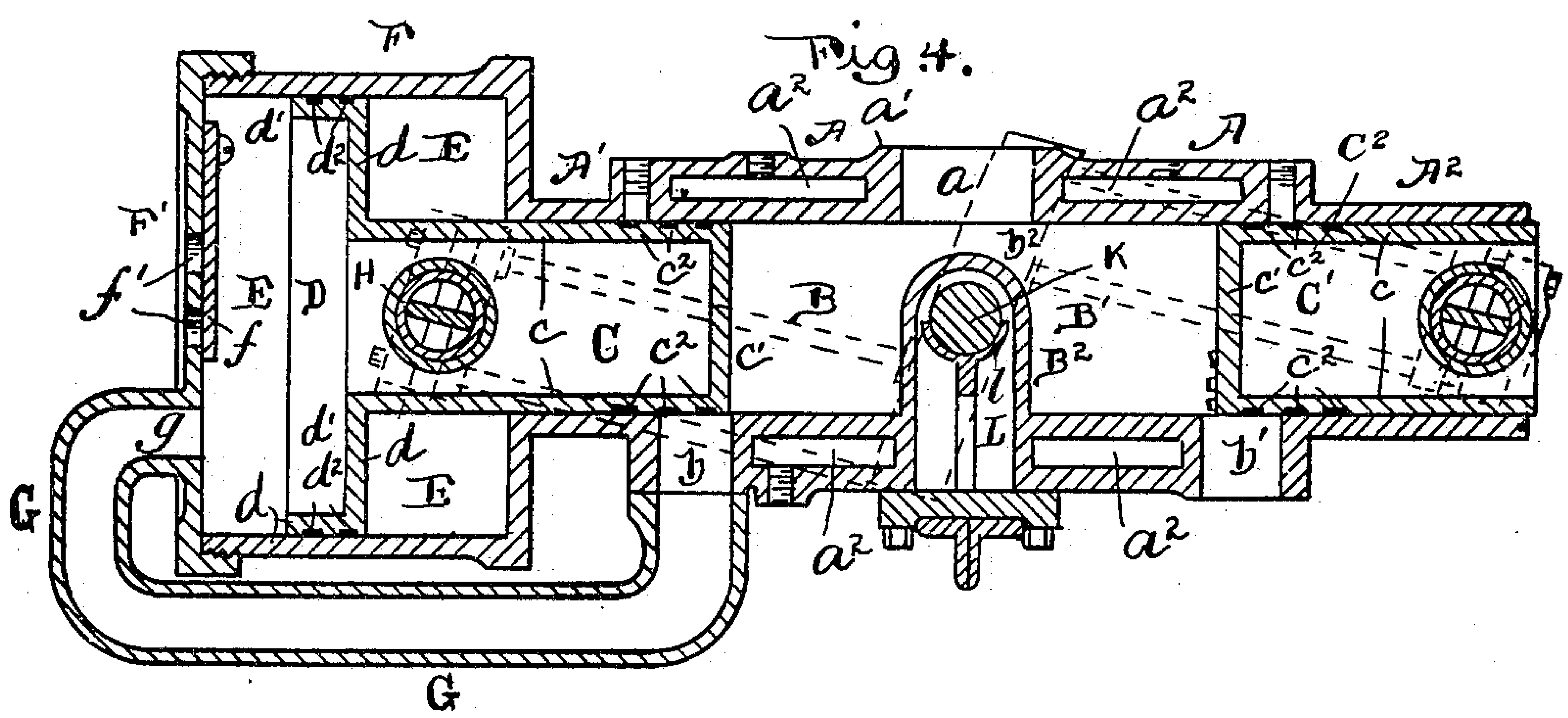
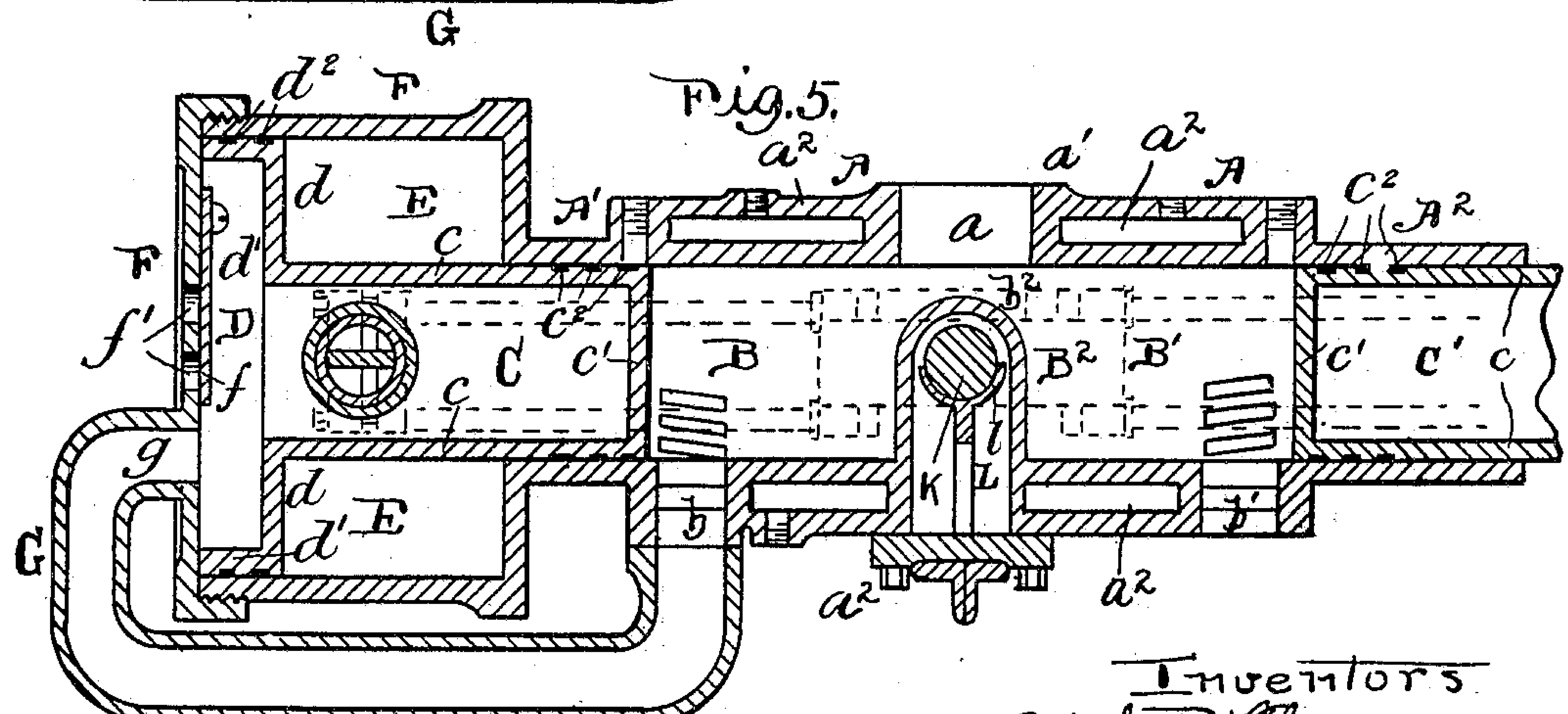


Fig. 5.



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NO MODEL. 3 SHEETS—SHEET 3.

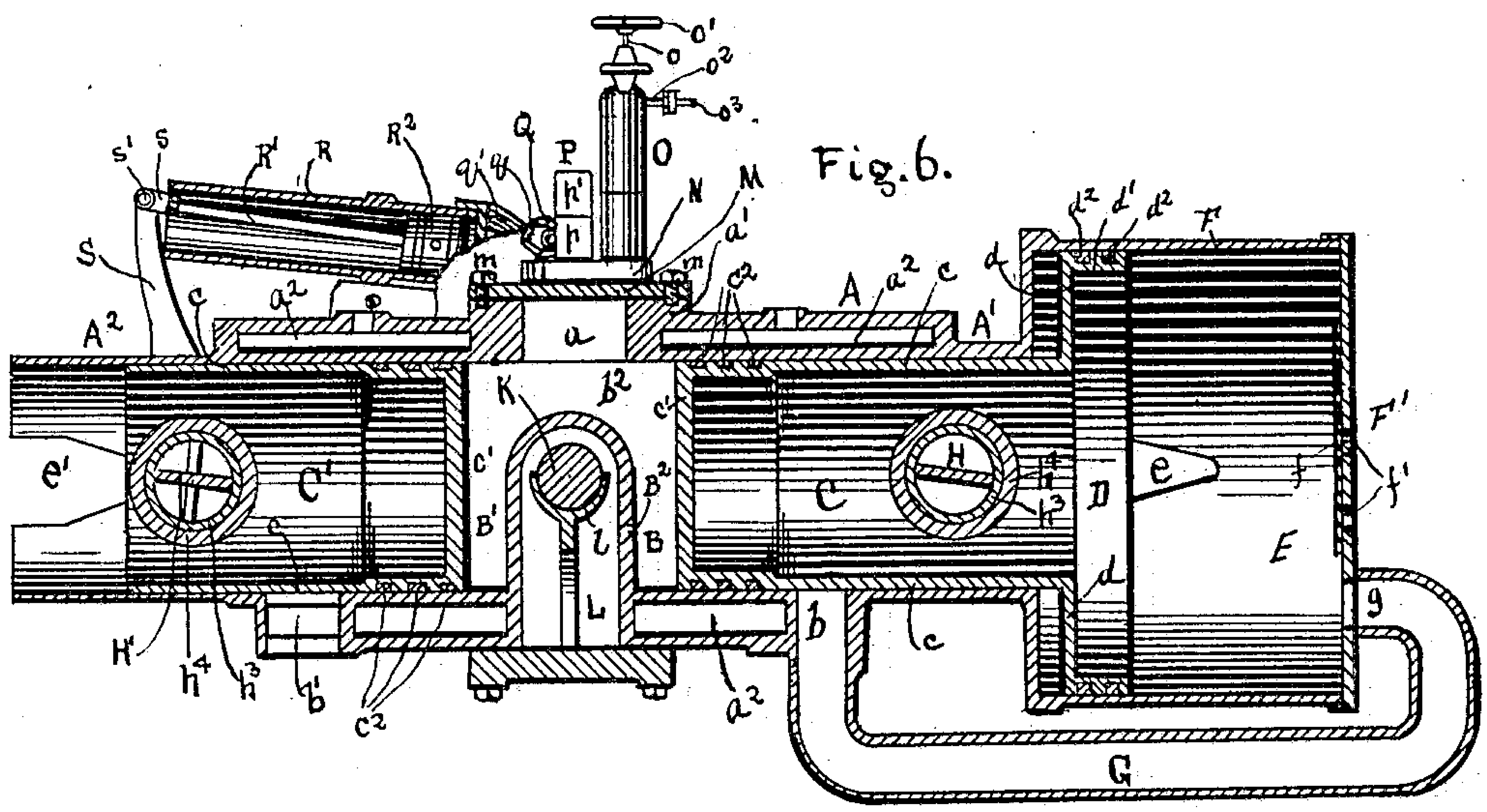

Fig. 6.

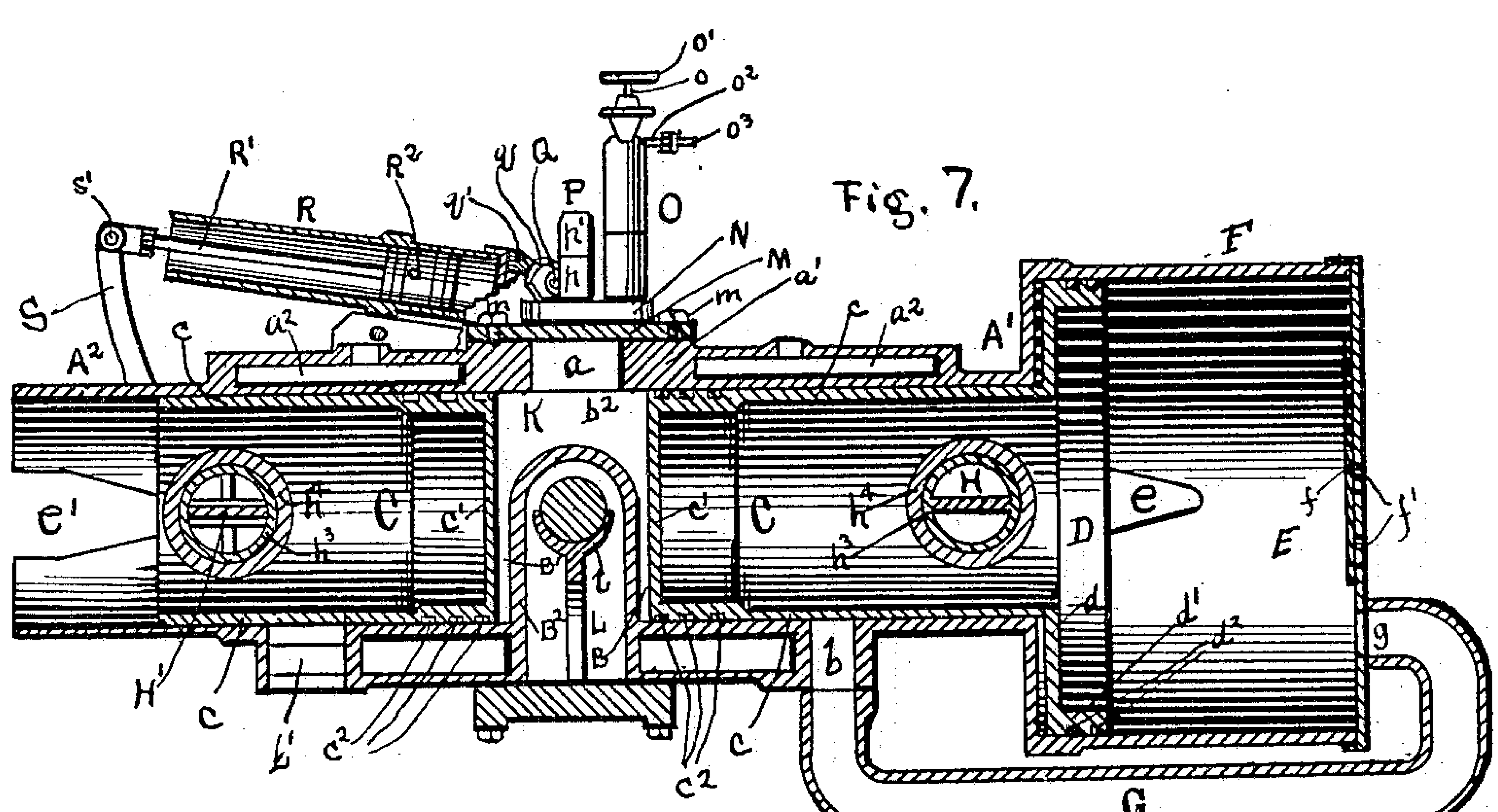

Fig. 7.

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UNITED STATES PATENT OFFICE.

RALPH P. THOMPSON AND EMIL KÖEB, OF SPRINGFIELD, OHIO.

BALANCED VALVELESS TWO-CYCLE GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 758,943, dated May 3, 1904.

Application filed February 21, 1903. Serial No. 144,434. (No model.)

To all whom it may concern:

Be it known that we, RALPH P. THOMPSON and EMIL KÖEB, both citizens of the United States, both residing at Springfield, in the county of Clark and State of Ohio, have invented certain new and useful Improvements in Balanced Valveless Two-Cycle Gas-Engines, of which the following is a specification.

This invention relates to balanced valveless two-cycle gas-engines more especially intended for use for driving automobiles, but which can be used for other like purposes where a simple, strong, efficient, and light-running engine is a requisite.

The main objects of the invention are to secure as perfect freedom as possible from the vibrations in use by so arranging the reciprocating parts as that one part balances the other, to insure compactness without destroying the capacity of the engine for work, to simplify the construction and improve the operation of the engine as a whole, and to furnish a positive and reliable supply of air for clearance of the explosion-chamber and have a sufficiency of air for the next charge.

Other objects are the employment of two pistons connected to cranks of a crank-shaft in such manner as to bring the pistons toward each other on the compression-stroke and have the pistons on the outward or working stroke travel in the opposite direction and recede from each other; to obtain the highest efficiency possible in a gas-engine of a high piston speed without the requirement of rapid-moving pistons by having the speed at which the pistons recede from each other in the working stroke to be twice the speed of either piston alone; to utilize to the best advantage the momentary effect of the explosion by both pistons yielding to the force of the explosion; to furnish an arch space in the explosion and compression chamber for the reception of the crank or driving shaft and the walls of which bridge together the working cylinders and also form a part of the explosion-chamber, the arrangement being one by which the shaft is located in the same plane as the axis of the cylinders and at the closest point practicable to the pistons, which enables connecting-rods of equal length and weight to be employed between the pistons and the crank-shaft; to form the working cylinders and explosion-chamber in one piece and furnish sufficient strength for the cylinder as a whole to withstand the strain when the engine is supported at the outer ends of the cylinder; to dispense with valves for the induction and eduction passages leading into and out from the compression and explosion chamber by having one of the working pistons control the induction-port, while the other working piston controls the eduction-port; to properly locate the position of the ports in relation to the travel of their pistons as to attain the proper time for the exhaust of an exploded charge and for the intake of the air for the next charge, making the timing of the exhaust and the intake positive under all conditions; to insure a positive supply of fresh air for each succeeding explosion and have the fresh air replace and expel the products of combustion of a previous explosion, making the operation of the engine that of the two-cycle type of engine wherein each outstroke of the piston constitutes a working stroke; to cause a compression-stroke for the air-pump which supplies air to the explosion and compression chamber to take place upon the opposite cycle to the compression-stroke in the working cylinders, so that at the finish of the working stroke of the compression-cylinders compression of air has taken place in the air-escape and the air so compressed is discharged into the explosion and compression chamber as the working pistons are making their return or compression stroke.

The invention consists in the features of construction and combination of parts hereinafter described and claimed.

In the drawings illustrating the invention, Figure 1 is a top or plan view of the preferred type of construction; Fig. 2, a side elevation of the construction shown in Fig. 1; Fig. 3, a vertical central longitudinal section through the cylinder and pistons, showing the power-pistons at the limit of their initial or compression stroke and in position for the explosion of a charge and showing the air-pump piston at the limit of its receded stroke; Fig.

4, a similar view to Fig. 3, showing the power-pistons carried outward and nearly to the limit of the power-stroke and showing the pump-piston advanced to a point where it will act and compress air between the piston and the head of the pump-cylinder for the compressed air, with the opening of the induction-port to enter the explosion and compression chamber of the piston-cylinder, the eduction-port being slightly opened to exhaust the products of the exploded charge and the induction-port for the fresh compressed air just ready to open; Fig. 5, a similar view to Fig. 3, showing the power-pistons at the limit of their outward or power stroke and showing the air-pump piston advanced to the limit of its compression-stroke, with the induction and eduction ports for the compression and explosion chamber both open, leaving a clear passage through the explosion and compression chamber for the air which has been forced thereinto by the compression-stroke of the pump-piston to clear the explosion and compression chamber and the cylinder of the pistons of the previously-exploded charge; Fig. 6, a vertical central longitudinal section showing the power-pistons partially on their return or inward stroke and the position of the piston of the fuel-injector in its relation to the power-pistons; and Fig. 7, a similar view to Fig. 6, showing the power-pistons at the terminus of their return or inward stroke and the position of the piston of the fuel-injector at this time.

The main cylinder A has at one end a neck A′ and at the other end an extension A^2, with a chamber extending the full length of the main cylinder and the neck and extension thereof, which chamber constitutes the explosion and compression chamber and the chambers for the travel of the power-pistons, which pistons are located and operate on opposite sides of the center of the main cylinder. The upper side of the cylinder at the longitudinal center has an opening *a*, surrounded by a wall *a*′, through which opening the explosive charge is admitted into the explosion and compression chamber, and in the body of and circumferentially around the cylinder on each side of the opening *a* is a passage a^2, which passages are for the reception of a cooling medium, and, as shown, at each end of the main cylinder on the upper side is a duct or passage a^3 for supplying lubricant to the power-piston. The interior of the main cylinder forms as a whole a single explosion and compression chamber at the center thereof, with end chambers B and B′ for the travel of the power-pistons, and the piston-chambers B and B′ are separated for a portion of the diameter of the cylinder by an arched wall or bridge B^2, located in line with the charging opening or passage *a* of the cylinder. An induction-port *b* is located on one side of the arched wall or bridge and opens into the piston-chamber B, and an eduction-port *b*′ is located on the opposite side of the arched wall or bridge and opens into the piston-chamber B′, the port or opening *b* supplying fresh air to the explosion and compression chamber and the port or opening *b*′ exhausting the burned gases and vapors after each explosion. The arched wall or bridge B^2 does not extend to the top of the interior of the cylinder, but stops short thereof, leaving an opening b^2, so that when the power-pistons are at the limit of their return or compression stroke, as shown in Fig. 3, a compression and explosion chamber is formed between the two power-pistons and common to both of said pistons. A working or power piston C is located and operates in the chamber B, and a working or power piston C′ is located and operates in the chamber B′, each piston having a reciprocating travel in its chamber to the limit of the strokes. Each working or power piston, as shown, has a body formed of a cylindrical wall or shell *c*, closed end wall or head *c*′, and circumferential packing-rings c^2 on the exterior at the inner end. The piston C has a longer body than the piston C′ and at its outer or advanced end carries a piston D, which may be formed with the piston C or be made separate therefrom, as may be desired, and the piston D has a body formed of an end wall *d*, extending from the periphery of the piston C, a cylindrical rim or shell *d*′, and circumferential packing-rings d^2 around the exterior of the rim or shell. The piston D is located and operates in a chamber E within a cylinder or casing F, which may be formed with the neck or end extension A′ or may be separate therefrom and suitably attached thereto. The open end of the cylinder or shell F, as shown, is closed by a cap or cover F′, having therein perforations *f*′ closed by a flap-valve *f*, attached to the inner face of the cap or cover, with its free end overlapping the perforations or holes and closing the same when the valve is down, shutting off the admission of air into the chamber E of the pump and when the valve is raised allowing air to flow into the chamber E in front of the piston. The wall of the cylinder or casing F on opposite sides and extending rearwardly from a point adjacent to the longitudinal center of the casing or cylinder has openings *e*, through which openings air can escape during a portion of the travel forward and back of the piston D in the chamber E, relieving the piston of pressure on each side thereof until the advance end of the piston in the outstroke reaches and passes the outer ends of the side openings *e* for the further advance or outstroke of the piston to compress the air caught between the piston and the end wall or cap of the casing or cylinder, giving the piston a compression-stroke for the air during a part of its outstroke.

The shell or casing F, with its chamber E and the piston D, constitutes an air-pump for compressing air within the chamber E after the piston D has passed the outer end of the side openings *e*, and in the cap or head F is a port or passage *g*, which communicates with a pipe or conduit G, leading to the induction-port *b* of the compression and explosion chamber, so that the air-pump will force air from the chamber E through the port or opening *g*, pipe or conduit G, and port or opening *b* when the port or opening *b* is uncovered by its piston C, leaving a clear passage from the chamber E of the air-pump into the explosion and compression chamber.

The chamber E of the pump and the piston D are of an increased diameter over the chamber B and power-piston C, which gives the air-pump an increased capacity over the capacity of the compression and explosion chamber, and if the piston of the pump were operative its full stroke a greater supply of air than what is required or necessary for use in clearing the explosion-chamber and furnishing fresh air for the next charge would be obtained, and for this reason the actual compression of the air by the piston D does not commence until the piston has passed the outer ends of the side openings *e*, which ends are located in such relation to the wall of the end cap or head as to furnish a chamber of the required capacity for the supply of air needed, the terminal point for the outer ends of the side openings or passages *e* being a predetermined point forward, which will furnish a sufficient length of stroke for the piston to give the required supply of air necessary for clearance and charging purposes in the compression and explosion chamber. The coacting relation between the piston for the pump and the power-pistons is such that when the power-pistons are in the position shown in Fig. 3 ready for the explosion of a charge to drive the power-pistons outward or with their power-stroke the pump-piston is at the limit of its return or inward stroke. The explosion of the charge forces the power-pistons outwardly for their power-stroke, and with the outward or advance stroke of the piston C the pump-piston is carried inwardly or in the direction for the compression-stroke, without, however, compressing air until the piston reaches and passes the outer ends of the side openings or passages *e*, at which time air cannot escape from the chamber E through the side openings or passages. At the time the pump-piston D reaches the outer end or terminus of the side escape openings or passages for air from the pump-chamber the piston C′ has reached a point, as shown in Fig. 4, where the eduction-port *b*′ is open for the escape of the gases, vapors, and products of explosion, and with the further outward or power stroke of the working or power pistons the induction-port is opened by the outward traverse of the piston C, and the eduction-port is still further opened by the outward traverse of the piston C′, and with the opening of the induction and eduction ports the continued outward or compression stroke of the pump-piston forces air from the pump-chamber through the port or passage *g*, pipe or conduit G, and induction port or passage *b* into the chamber between the two working or power pistons, and the air is forced through this chamber and out at the eduction-port, effectually and rapidly clearing the chamber of the gases, vapors, and products of the explosion. The reverse or inward stroke of the working or power pistons closes first the induction-port and then the eduction-port, and the air remaining in the chamber between the two working or power pistons is gradually compressed therein for the next explosive charge. Each outward or power stroke of the working or power pistons operates, as above described, to force air into the compression and explosion chamber for clearance and charging purposes by the force of the air-pump, and each inward or return stroke of the working or power pistons compresses the air, as described, and these movements, operations, and results will continue until the engine is stopped or ceases to run.

The piston C is carried by a cross-head H, and the piston C′ is carried by a cross-head H′, each cross-head extending both sides of the piston which it carries. The cross-head H passes through the side opening *e* in the pump-cylinder and the neck A′, and the cross-head H′ passes through an opening *e*′ on each side of the extension A^2, which openings *e* and *e*′ are of the requisite length for the stroke of the piston. Each cross-head has a rocking or oscillating movement to permit of the movements of the crank-rods and cranks, and for this purpose each cross-head is secured in a tube or sleeve h^3, which turns in a tubular support or bearing h^4, attached to each working or power piston near its outer end, as shown in Figs. 3, 4, and 5, and in order to permit of the rocking movement, by which each cross-head is turned angling, each opening *e* and *e*′ is made widest at the point where the greatest angle or rise of the flat cross-head occurs. One end of the cross-head H extends straight out, as do both ends of the cross-head H′, and the other end of the cross-head H is turned at right angle to the main body and forms an arm or extension H^2, standing parallel with the side of the engine-cylinder. Each straight extended end of the cross-head H and the cross-head H′ has secured thereto eye-blocks *h* and *h*′, and the arm H^2 of the cross-head H has an eye-block h^2 at its end. The straight-out extended end of the cross-head H and the opposite ends of the cross-heads H and H′ each has connected therewith a crank-rod, and a crank-rod is also connected with the arm H^2 of the cross-head H and with the opposite end of the cross-head H′, setting the crank-rods staggered—that is, a crank-rod I for the cross-head H is outside of the cross-rod I' of the cross-head H' and on the opposite side of the engine the crank-rod I' for the cross-head H' is outside of the crank-rod I for the cross-head H, enabling all of the cross-rods to be given the same length and transmitting the strain equally to the crank-shaft on each side of the engine-cylinder. Each crank-rod, as shown, is formed of a rod bent on itself, so as to have side arms *i* and a curved end *i'*, and the free end of each arm of the crank-rods is screw-threaded and passes through the eye-blocks at the ends of the cross-heads and receives nuts i^2, by means of which the rods are drawn solid against their respective cranks. The crank-rods I each run to a crank J on a crank-shaft K, and the crank-rods I' each run to a crank J' on the crank-shaft K, and each crank-rod is connected to the cross-pin of its crank by a box or bearing J^2, formed of two half-boxes *j* and *j'*, encircling the crank-pin, with the half-box *j*, having a semicircular head, receiving the curved end *i'* of the cross-head, as shown in Figs. 1 and 2.

The crank-shaft K passes through a space formed in the cylinder of the engine at the center longitudinally thereof and below the curved top of the arched wall or bridge B^2, as shown in Figs. 3, 4, and 5, and the location of the crank or power shaft K is one which brings it in line with the longitudinal center or axis of the engine-cylinder and also locates the shaft at the nearest point possible to the pistons, by which arrangement connecting-rods of equal length and weight can be employed, and the arrangement also is one which is very compact, bringing the working parts—that is, the power-pistons, the cross-heads, the crank-rods, and the crank or power shaft—within the smallest space practicable for efficient and reliable operation. The crank or power shaft at each side or end of the arched wall or bridge is supported in a half box or bearing *l* on an upright or standard L, projecting up from a cross-plate L', extending beneath the engine-cylinder and bolted to the cylinder and further supported by angle-irons *k* in the construction shown.

The flat face of the wall *a'* has mounted thereon a plate M, secured in place by bolts *m* or otherwise, and on the plate M is mounted a plate or head N, secured in place by bolts *n* or otherwise. A shell or casing O extends up from the plate N and has therein a gasolene-passage, the inflow of gasolene into and through which is controlled by a needle-valve or point on a stem *o*, actuated by a hand-wheel *o'* or otherwise, and the gasolene enters the shell or casing from a suitable source of supply through a pipe o^2, connected with a nipple o^3, leading into the shell or casing and in communication with the passage therein, which passage is not shown. The head or block N has extending up therefrom a shell or casing P, in which and in the head or block N and plate M is a mixing-chamber for air and gasolene, which chamber is not shown, but is located directly above the passage *a*, and communication between the mixing-chamber and the passage is controlled by a valve. (Not shown.) A pipe Q communicates with the mixing-chamber for air and gasolene and is connected by a coupling *q'* with a nipple or pipe *q*, leading to the chamber of an injector R, which is formed of a cylinder having therein a piston R^2 on a piston rod or stem R', and the receiving end of the cylinder of the air-injector has a plug, with openings *r* leading to the external air and in communication with a passage in the plug controlled by a valve on a stem *r'*, around which is a spring r^2, by means of which the valve is held closed, through which ports or openings *r* when the controlling-valve is opened air is admitted into the cylinder of the air-injector in front of the piston thereof for the forward stroke of the piston of the air-injector to force the indrawn air through the connecting-pipe Q into the receiving and mixing chamber of the head or plate N to there mix with the gasolene admitted to such chamber through the shell or casing O for the mixture to be projected into the compression and explosion chamber of the engine-cylinder. An arm S has its outer end entered between a fork or coupling *s* on the end of the piston rod or stem R', and is pivotally held in place by a pin or bolt *s'* to allow of the necessary rock of the piston rod or stem R' for the movements of the piston or plunger which it carries. The lower end of the arm S is attached to one end or arm of the cross-head H' in any suitable manner, so as to be rigid therewith and have a reciprocating movement given thereto coincident with the reciprocating movement of the cross-head, and at the same time the rocking or oscillating movement of the cross-head derived from the movements of the crank-rods and cranks gives an oscillating movement for the upper end of the arm S, by which a reciprocating movement is transmitted to the piston rod or stem R', which actuates the piston or plunger R^2 of the air-injector. The arm S is rigidly attached at its lower end to the cross-head and forms, in effect, a continuation or part of the connecting-rod between the power or working piston and the shaft, making this rod, in effect, an extension of the connecting-rod extending out from the pivotal point of the rocking cross-head in right-angle relation to the connecting-rod proper of the power or working piston, so that the arm S is given a throw or movement that is simultaneous with the throw or movement of the connecting-rod. At the pivotal point of the rocking cross-head the movement of the arm is a reciprocating one; but as the rocking cross-head travels out at each point farther out the movement of the arm is more and more affected by the angularity of the connecting-rod at the different positions of the stroke, causing the extreme outer end of the arm to describe an arc of a circle. It will be seen that the movement of this arm is a complex movement, comprising a reciprocating travel and a travel on the arc of a circle for its upper end, and this complex movement of the arm S is taken advantage of to effect the stroke of the fuel-charge-injector piston, enabling the piston of the injector to finish its stroke ahead of the full compression-stroke of the working piston at a sufficient period of time in advance for the injector to act and inject the fuel into the power or working cylinder and saturate the air therein under compression, charging the air with the fuel and producing a mixture within the working cylinder in the explosion and compression chamber between the two pistons before the finish of the compression-stroke of the power-piston. The relative positions of the power-pistons and the piston of the fuel-injector at the time the fuel-injector has its piston advanced to inject the fuel charge into the chamber between the two power-pistons is shown in Fig. 6, and the position of the piston of the fuel-injector in its relation to the power-pistons after the charge of fuel has been injected and the piston of the fuel-injector has been withdrawn from its advanced position to indraw a fresh supply of air is shown in Fig. 7. It will be seen that the power-pistons and the piston of the fuel-injector have a coacting relation by which the fuel-injector will operate to project a charge of fuel into the combustion-chamber between the power-pistons as such pistons approach the limit of their return or inward throw, and that with the completion of the return or inward throw of the power-pistons the fuel-injector has its piston on the return stroke for indrawing a new supply of air for the charge. The cylinder of the air-injector, as shown, has therearound bands which terminate in ears r^3, between which ears is entered the upper edge of a plate T, attached to the engine-cylinder, and through the ears and the plate bolts t pass, attaching the air-injector to the engine-cylinder.

The engine is to have a sparking device and other appliances common to gasolene or hydrocarbon engines, which devices and appliances can be of any usual and well-known form of construction and are therefore not shown and described.

The strokes of the working or power pistons and of the pump-piston are so regulated and timed as to force the air for clearance for a new charge into the compression and explosion chamber as the working or power pistons travel outward or on the power-stroke and for compressing the air for the new charge as the power-pistons travel inward or return to their initial position, the compressing of the air taking place after the induction and eduction ports are closed by their respective power-pistons. The operation of the power-pistons and the pump-pistons is in correlation with the operation of the gasolene and air feed and the air-injector for forcing the mixture of air and gasolene into the explosion and compression chamber as the compressing of the air in such chamber is completed by the return of the power-pistons to initial position. It will thus be seen that the movements of the working or power pistons, the air-pump for clearance and for supplying fresh air to the compression and explosion chamber, the gasolene and air feed and the air-injector all have a unity of operation and are all dependent upon the revolution of the crank-shaft, so that with the revolutions of the shaft the several parts will work in unison and at the proper time to perform their respective operations. It will further be seen that the construction and arrangement of the power-pistons, the pump-piston, and the air-injector and the connections between these parts is one in which the reciprocating parts each balance the other, thus doing away as far as practicable with the effects of vibrations in the operation of the engine, which result is attained, mainly, through the employment of two pistons connected to cranks, which cranks are set in proper relation on the crank-shaft to bring the pistons toward each other on the compression-stroke and to recede from each other on the outward or working stroke, and in addition to a perfect balancing the equivalent of a high piston speed is obtained by reason of the fact that the speed at which the pistons recede from each other is twice the speed of either piston alone and high piston speed is a requisite to the highest efficiency for gas-engines. The two pistons when at rest are equidistant from the center or the compression and explosion chamber, which enables the momentary effect of the explosion of the charge to be fully utilized and to a better advantage, because both pistons yield simultaneously to the force of the explosion and both pistons transmit their power simultaneously to the power or crank shaft. The arched wall or bridge separates the piston-chambers or cylinders one from the other and at the same time leaves an open space above the arched wall or bridge for the reception of the charge to be exploded, and it also furnishes a guide by which the force of the explosion will be transmitted to the full face of each piston. The arched wall or bridge furnishes a space at the longitudinal center of the engine-cylinder in which to locate the power or crank shaft and have the shaft located in direct line with and in the same plane as the axis of the cylinder and as close as practicable to the power or working piston for the use of connecting the crank-rods of equal length and weight. The arched wall or bridge ties together the two working cylinders and also forms a part of the explosion-chamber and enables the working cylinders and the compression and explosion chamber to be cast in one piece with sufficient strength to withstand strain when the engine is supported at the outer ends of the cylinder. The controlling of the induction and eduction ports by the power or working piston dispenses with the use of special valves and appliances for operating the valves, making, in effect, a valveless engine so far as concerns the controlling of the induction into and eduction from the power or working cylinders. The location of the induction and eduction ports in relation to the arched wall or bridge and the traverse of the power or working pistons is one which allows of eduction or exhaust from the chambers of the power or working pistons to take place momentarily before the induction-port is open for the intake of the fresh air, thus insuring the discharge of the gases, vapors, and products of an exploded charge by the admission of the air under pressure from the force-pump and also insuring a positive timing of the exhaust and intake under all conditions when the power or working pistons are in operation. The air-pump working coincident with the strokes of the power-pistons furnishes a supply of fresh air for a succeeding explosion and also to expel the gases, vapors, and products of a preceding explosion, and the operation of supplying fresh air and expelling the gases, vapors, and products of a previous explosion reaches its limit at each full stroke of the power or working pistons, making the operation of the engine that of what is known as the "two-cycle" type of gas-engine, wherein each outstroke of the piston constitutes a working stroke, which result is accomplished by reason of the air-pump having its piston to perform the compression-stroke for the air on the opposite cycle to the compression-stroke in the working or power cylinder, so that at the finish of the working stroke of the power-pistons compression has taken place in the air-chamber, and the air so compressed passes through the induction and eduction ports, which are opened and closed by the strokes of the power-piston. This construction and arrangement of air-pump and power-pistons overcomes the difficulty of supplying a fresh charge of air in a two-cycle type of gas-engine, which difficulty has been the means of delaying the development of an efficient gas-engine of the two-cycle type. The correlation between the pump and the power-cylinders and the pistons of each must be one by which a part of the space of time which is utilized to inject the fresh charge of air into the working cylinders must necessarily be taken from the last part of the working stroke of the power-piston, and it is therefore of the greatest importance to the efficiency of the engine that this shortening of the working stroke be reduced to the least possible minimum, thereby allowing of the longer duration from the pressure of the explosion of a charge against the working pistons, and with the engine of the present invention two distinct advantages appear—namely, the rapid separation of the pistons, whereby the force of the explosion is allowed to expand down to a great degree before the exhaust takes place, and the compression and positive injection of the fresh charge of air in the shortest space of time practicable by which as small an amount as possible of the working stroke is destroyed.

It will be seen that with the construction of the engine of our invention four distinct and desirable advantages appear—namely, freedom from vibration, compactness in building, simplicity in construction and operation, and a positive air-supply for clearance and a fresh charge.

What we regard as new, and desire to secure by Letters Patent, is—

1. In a balanced valveless two-cycle gas-engine, the combination of an engine-cylinder having a compression and explosion chamber, an arch or wall projecting into the explosion-chamber, a pair of power-pistons operating in the engine-cylinder on opposite sides of the arch or wall, an eduction-port on one side of the arch or wall, an induction-port on the opposite side of the arch or wall, said ports controlled by the traverse of their respective power-pistons in the engine-cylinder and an air-pump and piston therefor, one end of said air-pump forming an air-chamber in advance of said piston, said air-chamber having communication with the induction-port of the engine-cylinder, substantially as described.

2. In a balanced valveless two-cycle gas-engine, the combination of an engine-cylinder having a compression and explosion chamber, an arch or wall projecting into the explosion-chamber, a pair of power-pistons operating in the engine-cylinder on opposite sides of the arch or wall, an eduction-port on one side of the arch or wall, an induction-port on the opposite side of the arch or wall, said ports controlled by the traverse of their respective power-pistons in the engine-cylinder, a crank-shaft passing through a space formed by the arch or wall and lying in the same plane as the axis of the engine-cylinder, connecting-rods between the power-pistons and the crank-shaft, and an air-pump and piston therefor, one end of said air-pump forming an air-chamber in advance of said piston, said air-chamber having communication with the induction-port of the engine, substantially as described.

3. In a balanced valveless two-cycle gas-engine, the combination of an engine-cylinder having a compression and explosion chamber, an arch or wall projecting into the explosion-chamber, a pair of power-pistons operating in the engine-cylinder on opposite sides of the arch or wall, an eduction-port on one side of the arch or wall, an induction-port on the op-

posite side of the arch or wall, said ports controlled by the traverse of their respective power-pistons in the engine-cylinder, a crank-shaft passing through a space formed by the arch or wall and lying in the same plane as the axis of the engine-cylinder, connecting-rods between the power-pistons and the crank-shaft, an air-pump and piston therefor, one end of said air-pump forming an air-chamber in advance of said pistons, said air-chamber having communication with the induction-port of the engine, and an air-injector and piston therefor, mounted on the engine-cylinder and having in conjunction with the power-pistons and the piston of the air-pump a balanced action, substantially as described.

4. In a balanced valveless two-cycle gas-engine, the combination of an engine-cylinder having therein a compression and explosion chamber, piston-chambers one on each side of the compression and explosion chamber, an arch or wall central of the engine-cylinder and separating the piston-chambers, a pair of power-pistons one operating in each piston-chamber of the engine-cylinder on opposite sides of the arch or wall, an eduction-port on one side of the arch or wall, an induction-port on the opposite side of the arch or wall, said ports controlled by the traverse of their respective power-pistons in their chambers of the engine-cylinder, a crank-shaft passing through the engine-cylinder below the arch or wall and in the same plane as the axis of the cylinder, connecting-rods between the pistons and the crank-shaft, and an air-pump and piston therefor, located in axial alinement with the engine-cylinder, said air-pump having an air-chamber in advance of its piston and said air-chamber having communication with the induction-port of the engine, substantially as described.

5. In a balanced valveless two-cycle gas-engine, the combination of an engine-cylinder having therein a compression and explosion chamber, piston-chambers one on each side of the compression and explosion chamber, an arch or wall central of the engine-cylinder and separating the piston-chambers, a pair of power-pistons one operating in each piston-chamber of the engine-cylinder on opposite sides of the arch or wall, an eduction-port on one side of the arch or wall, an induction-port on the opposite side of the arch or wall, said ports controlled by the traverse of their respective power-pistons in their chambers of the engine-cylinder, a crank-shaft passing through the engine-cylinder below the arch or wall and in the same plane as the axis of the cylinder, connecting-rods between the pistons and the crank-shaft, an air-pump and piston therefor, located in axial alinement with the engine-cylinder, said air-pump having an air-chamber in advance of its piston and said air-chamber having communication with the induction-port of the engine, and an air-injector and piston therefor, mounted on the engine-cylinder and having in conjunction with the power-pistons and the piston of the air-pump a balanced action, substantially as described.

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