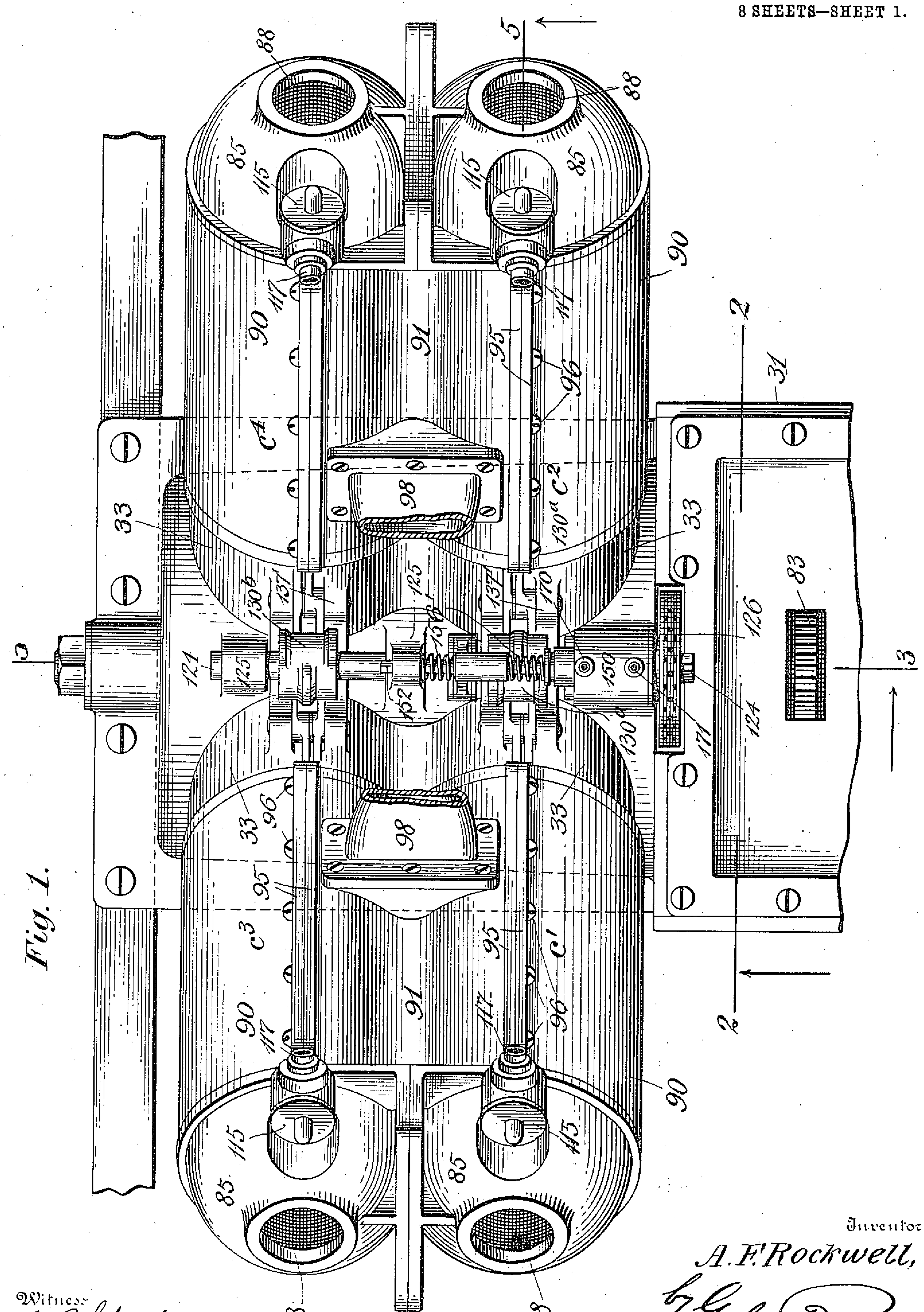
A. F. ROCKWELL.

MOTOR.

APPLICATION FILED MAR. 12, 1906.

962,254. Patented June 21, 1910.

8 SHEETS—SHEET 1.



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3 SHEETS—SHEET 2.

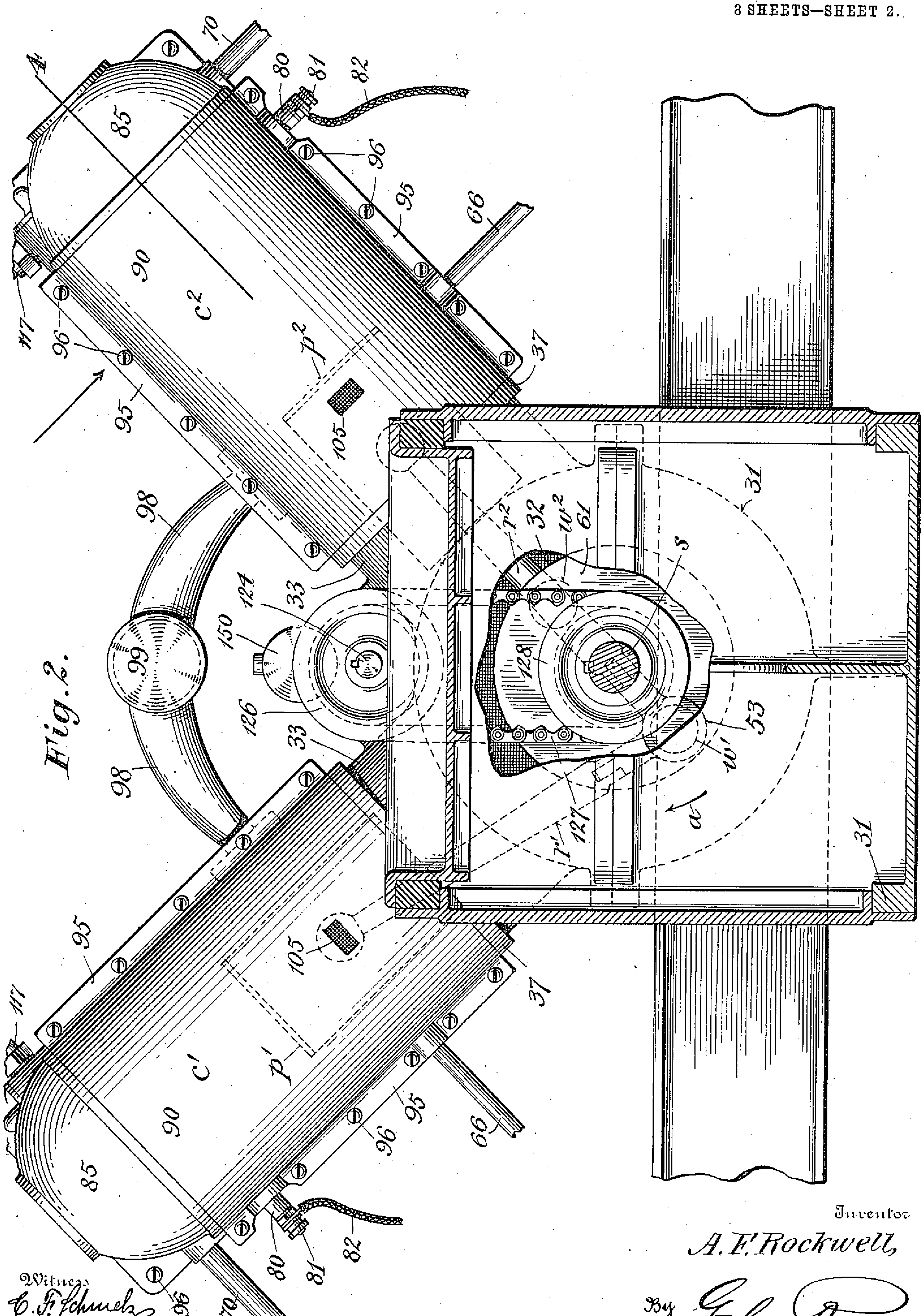

Fig. 2.

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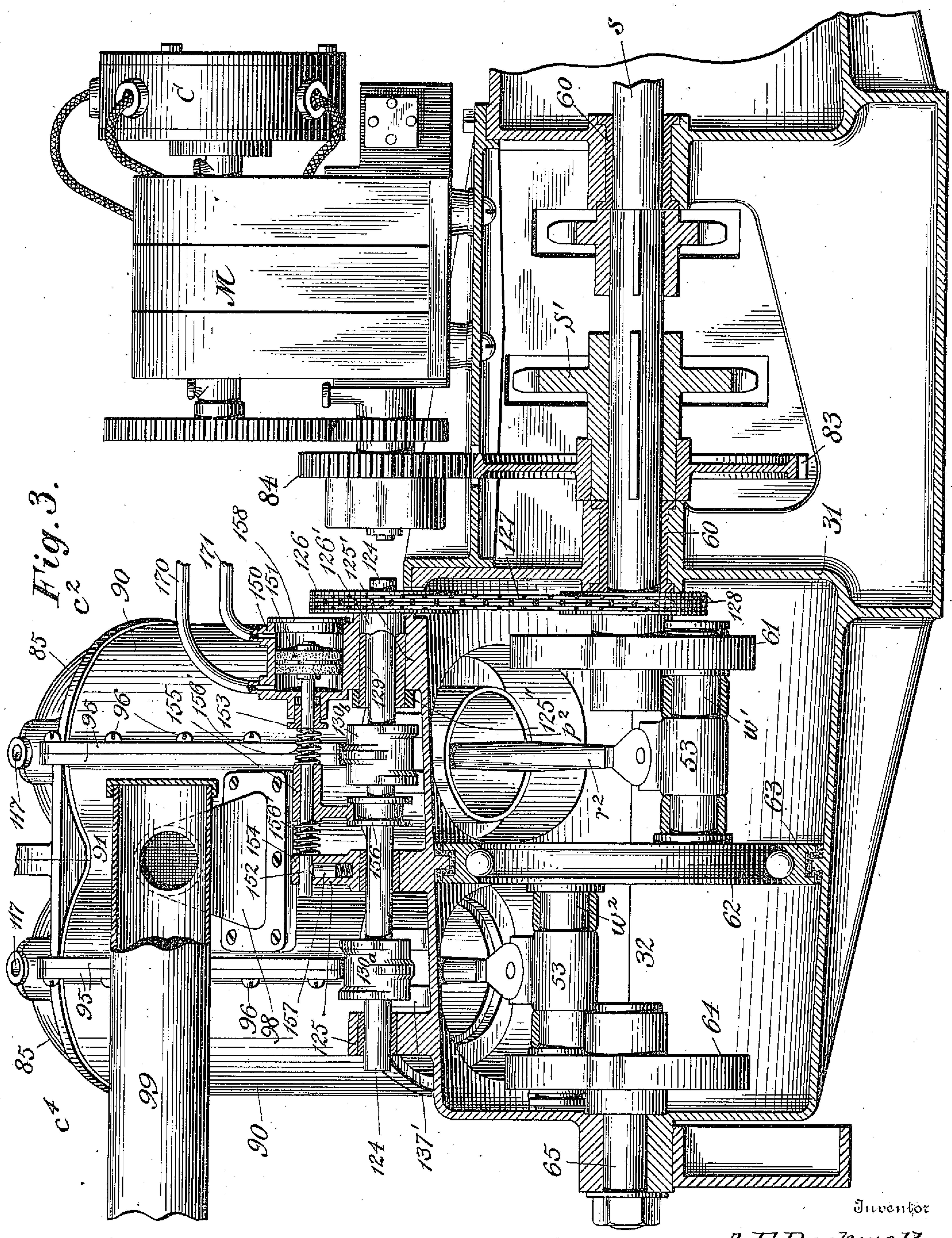

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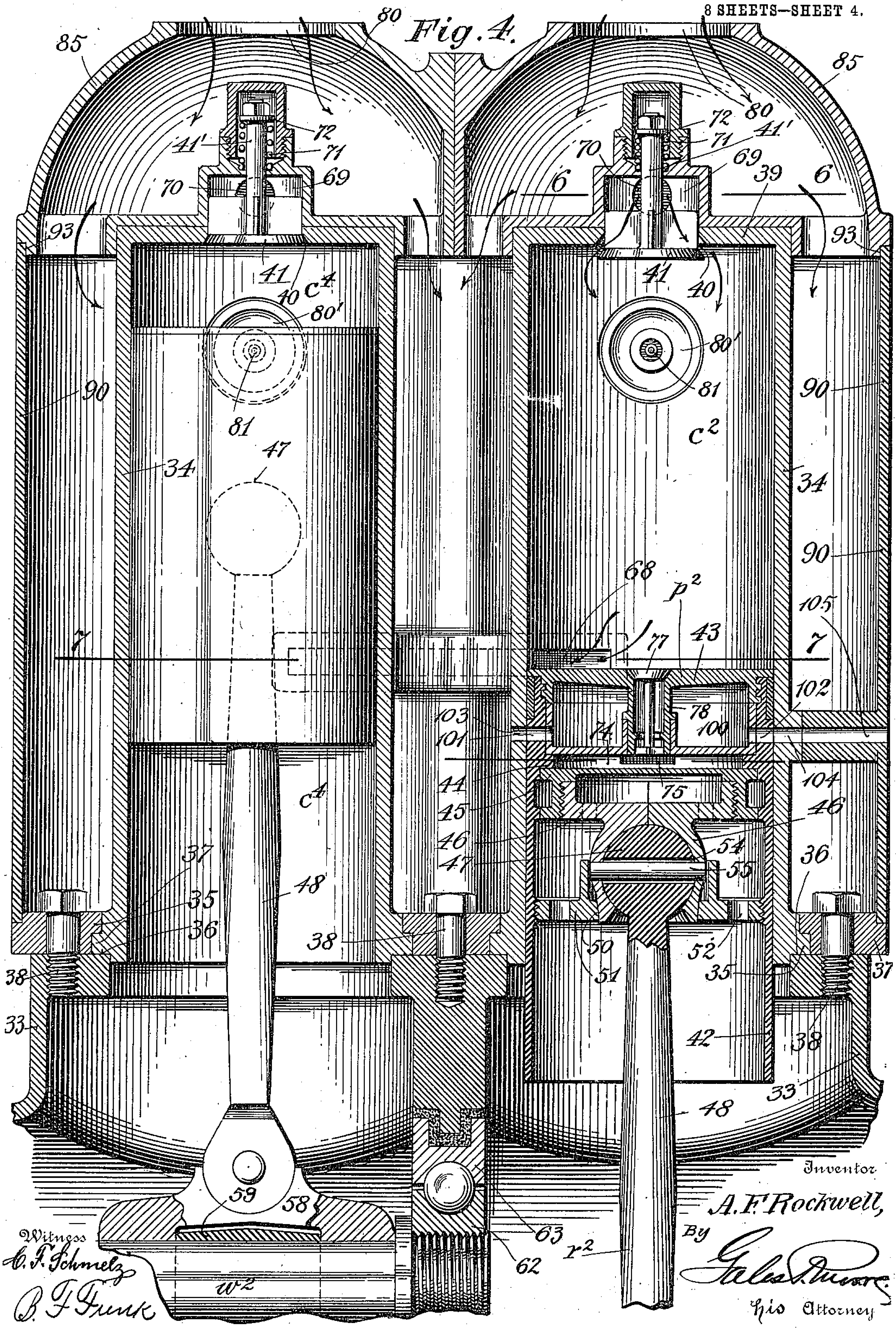
8 SHEETS—SHEET 4.

Fig. 4.



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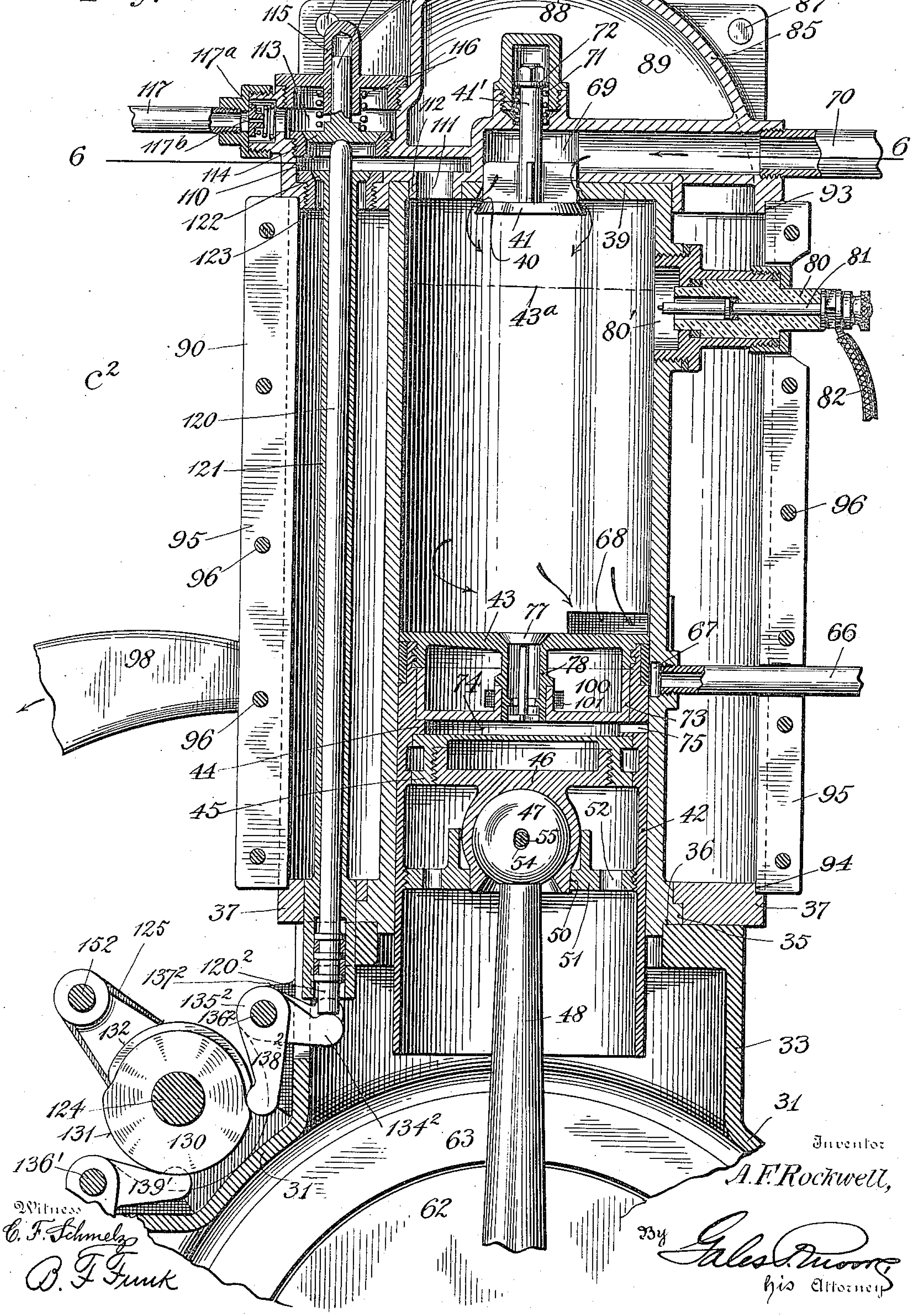
8 SHEETS—SHEET 5.

Fig. 5.



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8 SHEETS—SHEET 6.

Fig. 6.

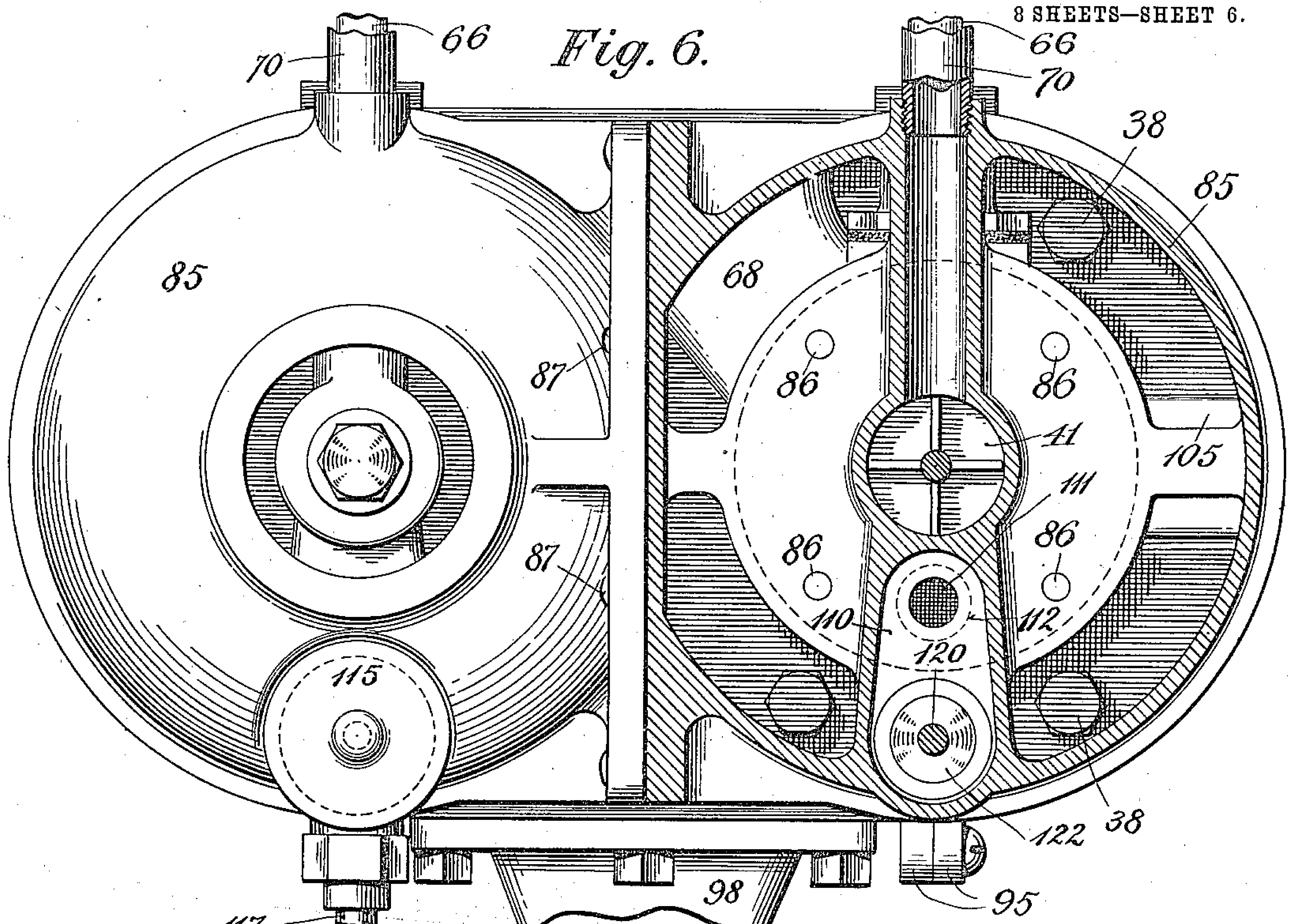
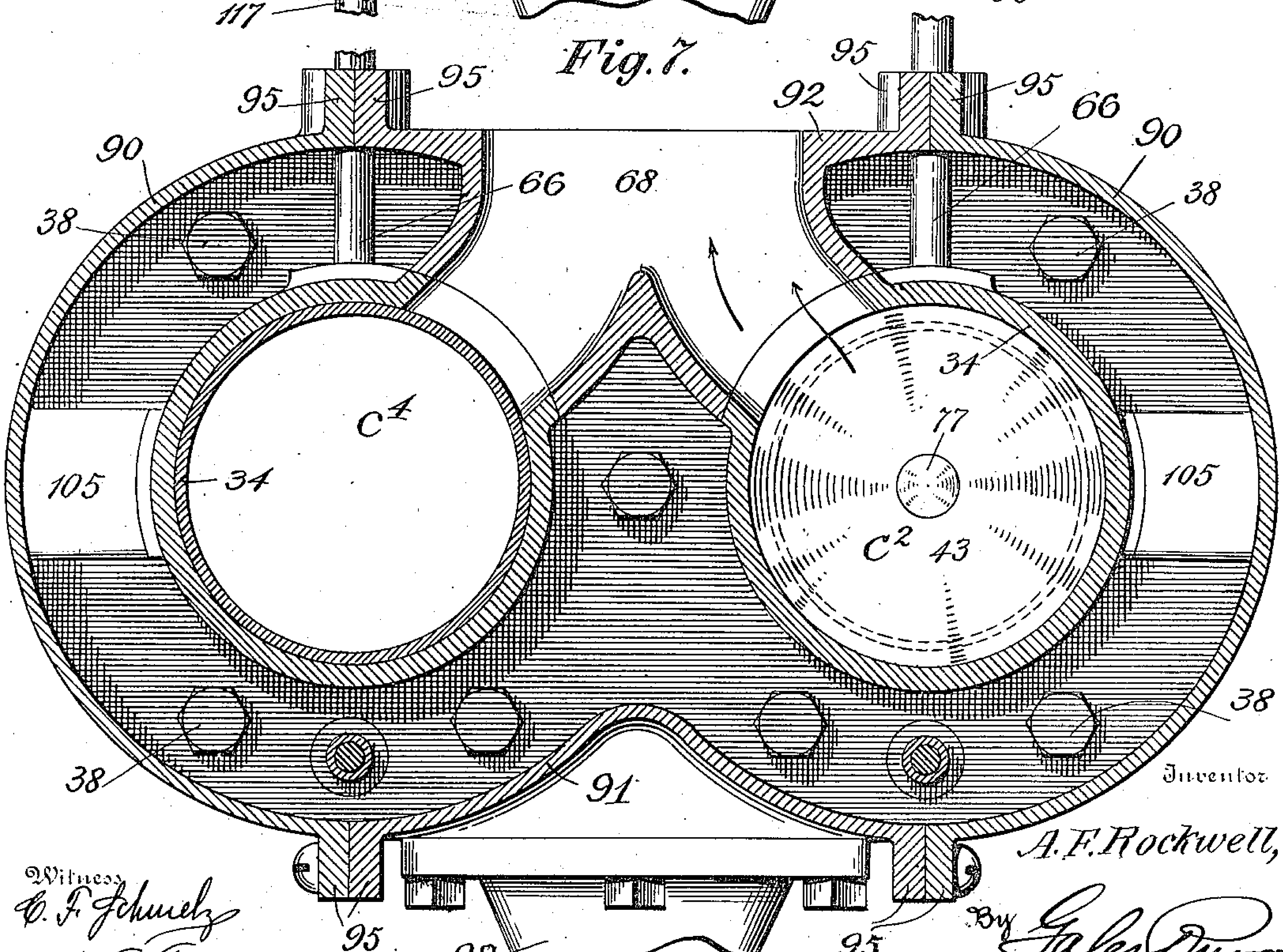


Fig. 7.



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8 SHEETS—SHEET 7.

Fig. 8.

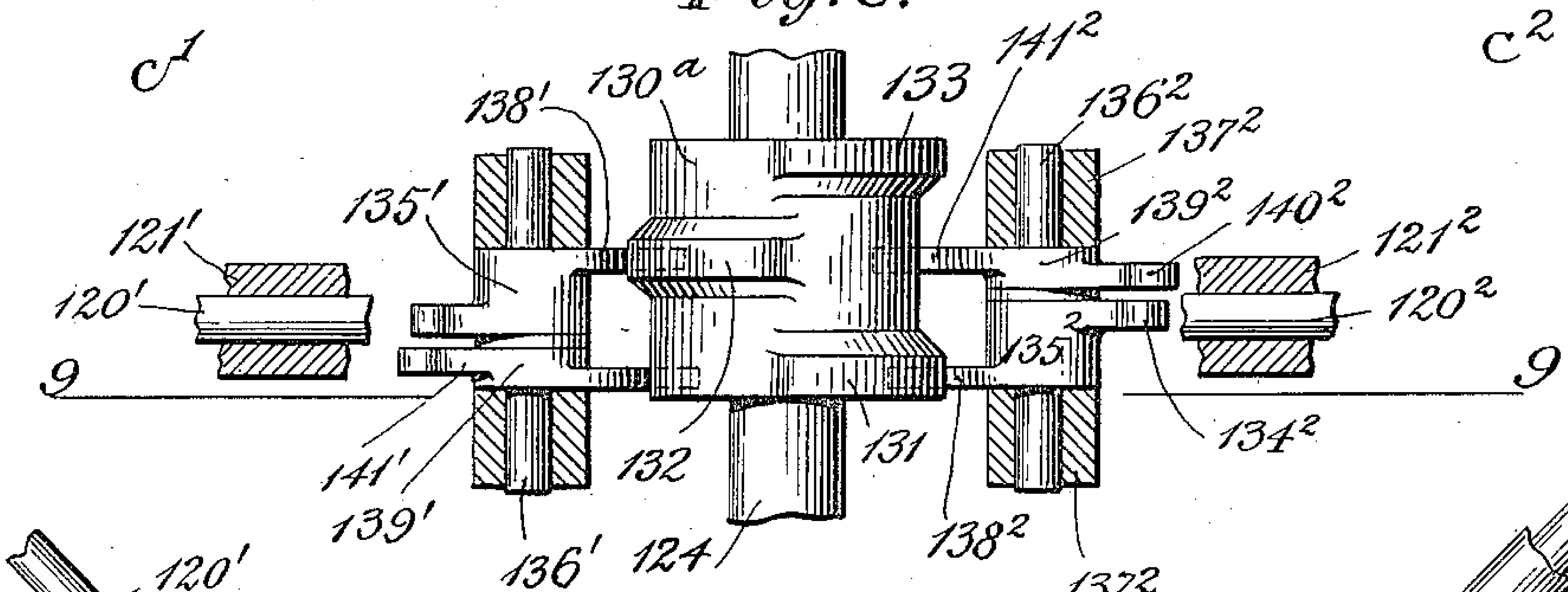


Fig. 9.

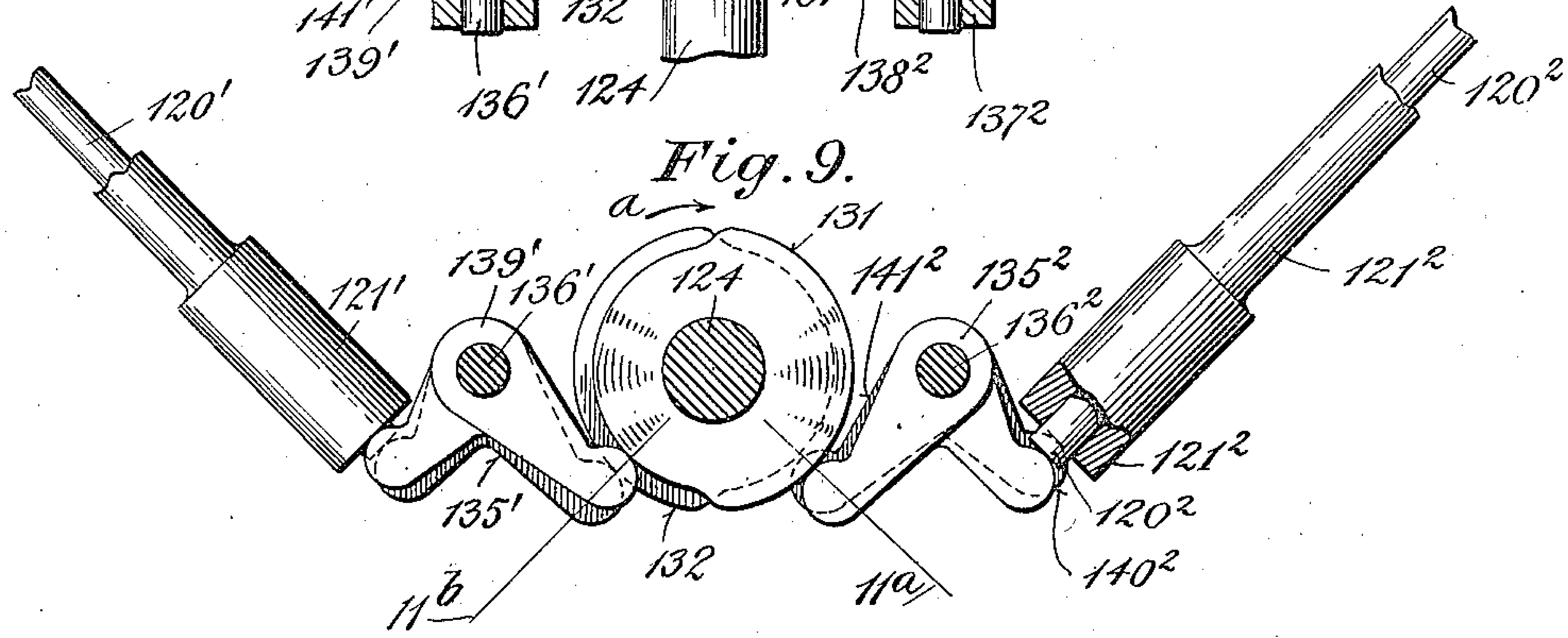


Fig. 10.

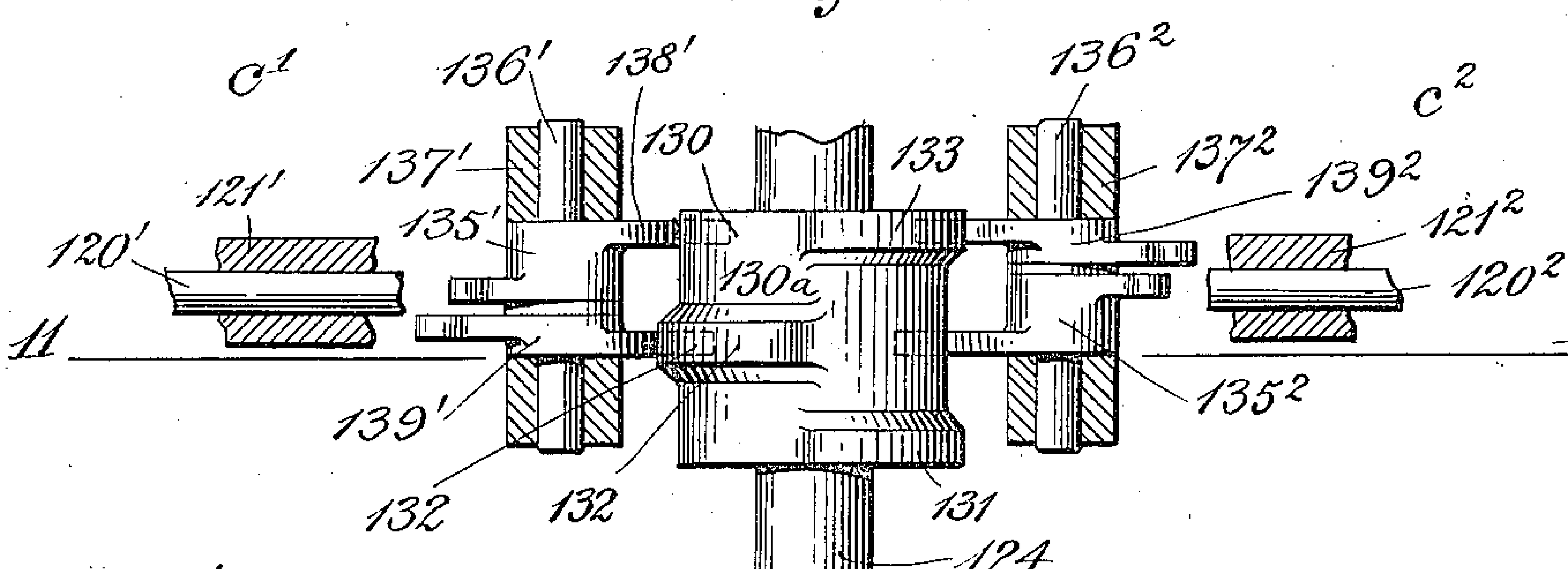
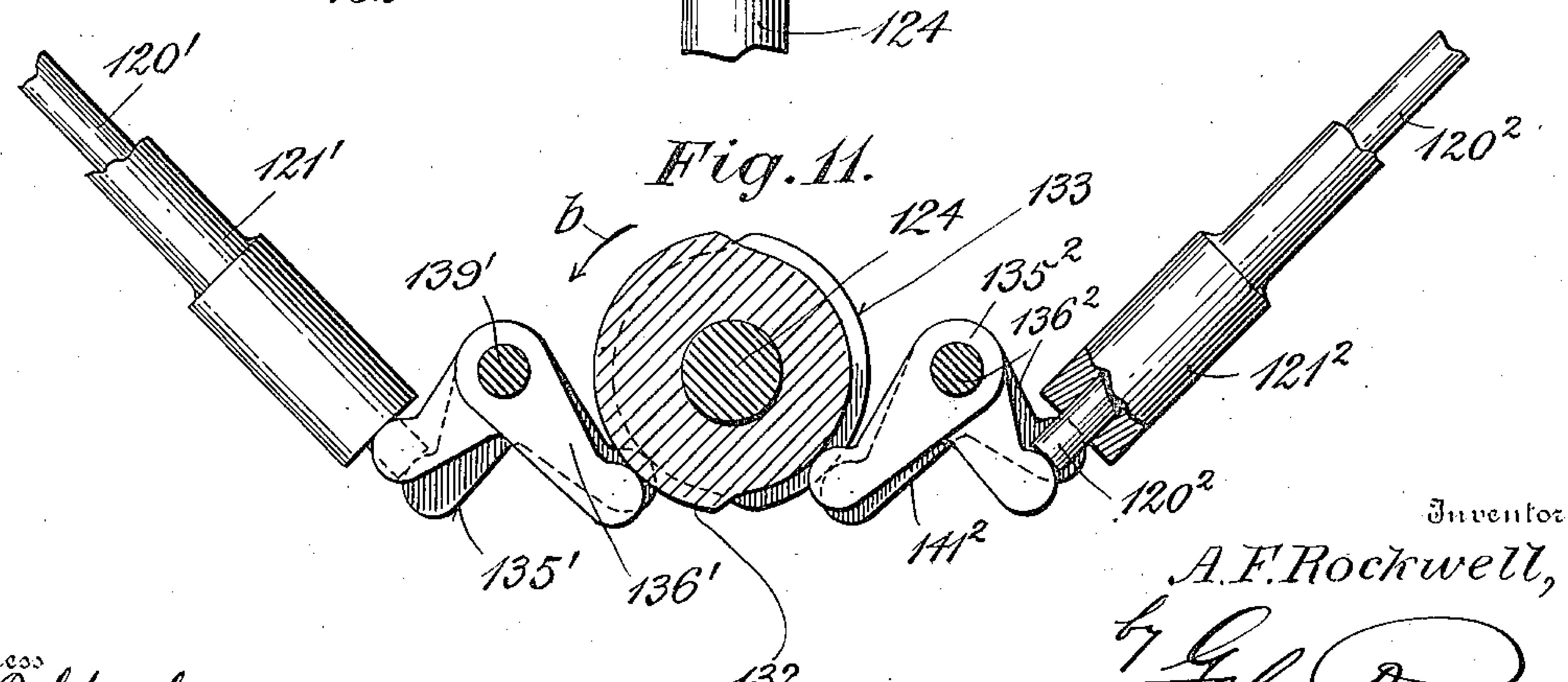


Fig. 11.



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8 SHEETS—SHEET 8.

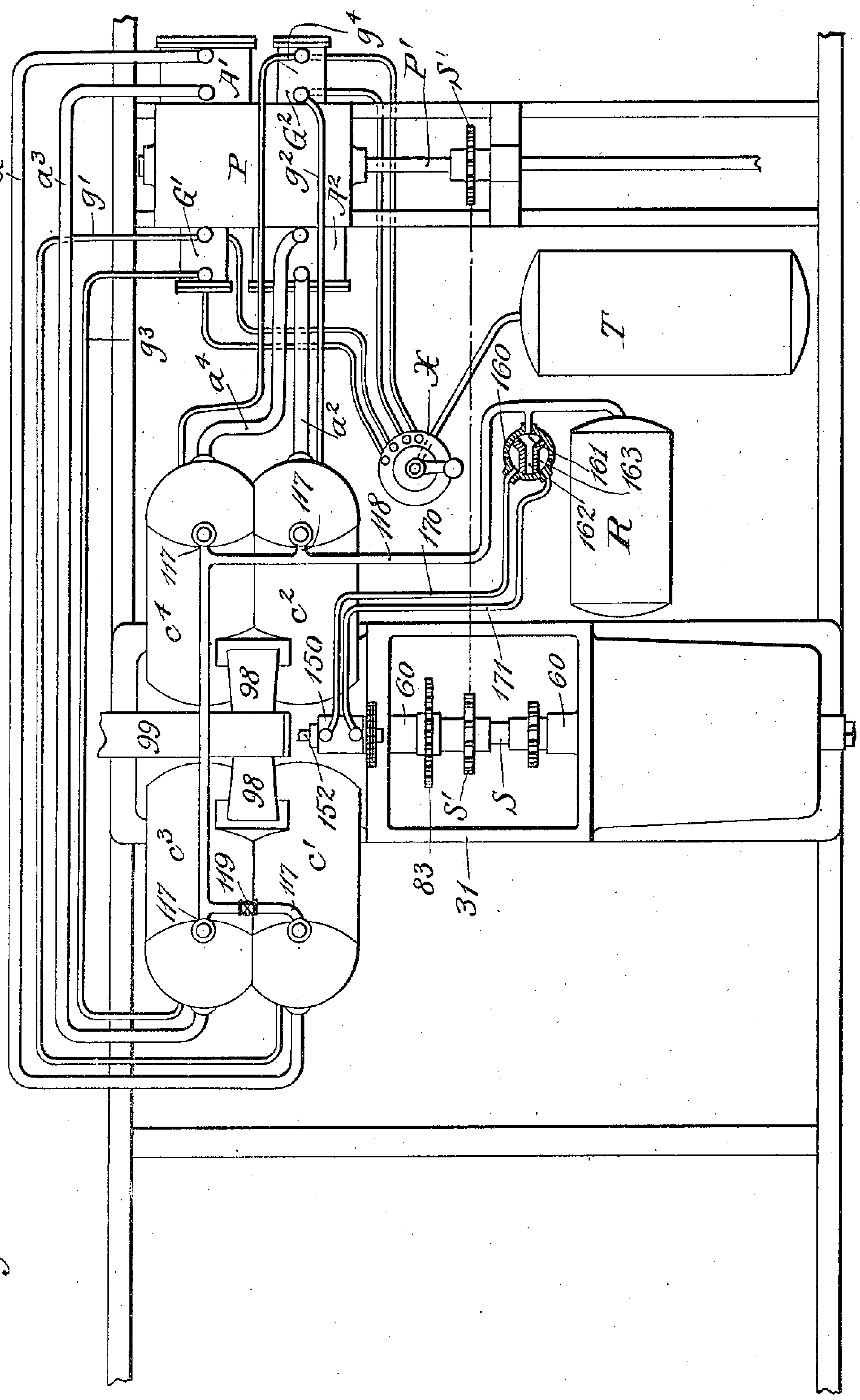

Fig. 12.

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MOTOR.

962,254. Specification of Letters Patent. Patented June 21, 1910.

Application filed March 12, 1906. Serial No. 305,664.

To all whom it may concern:

Be it known that I, ALBERT F. ROCKWELL, a citizen of the United States, residing at Bristol, county of Hartford, State of Connecticut, have invented a certain new and useful Motor, of which the following is a full, clear, and exact description, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, forming part of this specification.

This invention relates to the general class of motors, but more especially to that class in which a cylinder (or cylinders) may be charged with a proper fuel, usually a mixture of hydro-carbon gas and air, said fuel being subsequently compressed by the movement of a piston and then fired to cause an explosion which constitutes the motive force of the motor.

The primary object of the invention is to provide an explosive engine cylinder with a suitable mechanism whereby the initial fluid supply may be discontinued and a secondary fluid supply, under pressure, be admitted to the cylinder, and vice versa, either being capable of driving the motive or power transmitting elements thereof. In other words, the invention has for one of its objects the association of suitable mechanisms with the engine cylinder whereby the initial fluid, to wit, the fuel adapted to be ignited, may be cut off, and a second fluid which may be non-combustible may be introduced into the cylinder so as to drive the motor, the latter fluid being under compression.

It is also the purpose of this invention to provide means whereby part of the pressure in the cylinder or cylinders, resulting from the combustion of the fuel may be stored in a suitable receptacle to be subsequently used as the secondary fluid to operate the motor when the primary fluid or fuel is cut off.

My invention has, furthermore, for its object the provision of fluid-admitting and exhausting devices the movement of which, when in active operation, are at all times synchronized with the travel of the piston so that whenever the engine is to be operated by the secondary fluid, said devices will be in position to perform their respective functions at the proper time relative to the position of the piston.

My invention has furthermore, for its object the provision of a mechanism whereby the secondary fluid-admitting and exhausting devices may be actuated to run the engine by the secondary fluid in either direction, in other words, forward or backward, substantially by a shifting movement of a controlling mechanism coöperating with the engine cylinder.

My invention has also for its object the provision of a fluid supply or reservoir adapted to be charged during the operation of the motor by gas-mixture, this charging operation being accomplished by the consecutive explosions each of which contributes a small portion of vapor to the supply already contained in the reservoir, until the pressure in the latter at least equals that of the explosive force within the cylinder, when the full power of the explosion will remain in the cylinder and actuate the piston under maximum pressure.

Further objects of my invention will be found in the organization of the mechanism as a whole, and also in the particular construction of some of the component elements, as will be hereinafter more fully described and particularly pointed out in the claims, reference being had to the accompanying drawings, in which similar characters denote similar parts, and in which—

Figure 1 is a top view of a convertible air or gas engine incorporating my invention. Fig. 2 is an end view thereof, the base casing being shown in section taken on line 2, 2 of Fig. 1. Fig. 3 represents a vertical transverse section on line 3, 3 of Fig. 1. Fig. 4 shows a central section of one pair of adjacent cylinders, on line 4, of Fig. 2. Fig. 5 is a similar section of one of said cylinders taken in a plane at right angles with the section shown in Fig. 4, and as indicated by line 5, of Fig. 1. Fig. 6 represents a top view of one pair of adjacent cylinders, the cap of one being shown in horizontal section on line 6, 6 of Figs. 4 and 5. Fig. 7 is a horizontal section on line 7, 7 of Fig. 4. Fig. 8 is a top view of one of the valve-actuating mechanisms in position when the engine is running forward under air-pressure. Fig. 9 represents a section on line 9, 9 of Fig. 8. Figs. 10 and 11 are views similar to Figs. 8 and 9, and illustrate the valve mechanism in position to run the engine by air, backward and Fig. 12 is a diagrammatical top view of the power plant as a whole, illustrating a coöperative organization of the several active elements.

In order fully to comprehend the nature of the present invention I deem it expedient to describe first the preferred construction of the engine, as it is adapted to be operated by a proper mixture of hydro-carbon gas, which is compressed to the required degree by the piston in the cylinder, and subsequently ignited or fired in a manner generally employed in what is commonly known as "explosive" engines.

Whereas, primarily, the number of cylinders which compose the engine, is, generically speaking, immaterial, I prefer to employ a plurality thereof, so organized that an impulse may be imparted to the crank shaft of the engine at every quarter of its rotation, and for this reason the motor is shown in the drawings as comprising four cylinders, the pistons of which are operative on only two crank-pins; or, in other words; each crank-pin is actuated by two pistons having movements on lines substantially at right angles relative to each other, so that when one piston is at the end of its stroke, or at "dead centers," the other piston pertaining to the same crank-pin is practically at half-stroke. This organization is clearly shown in Figs. 1 and 2 of the drawings, in which c^1, c^2 denote in a general way one pair of cylinders, the pistons p^1, p^2 of which are connected by connecting rods r^1, r^2 with the same crank-pin w^1 of the engine shaft s. The second crank-pin w^2, of the crank shaft s, is shown as disposed opposite the crank-pin w^1, or substantially 180 degrees remote therefrom, and is connected with the pistons in the cylinders c^3, c^4, so that when the engine is running in a direction indicated by arrow a (see Fig. 2) cylinder c^1 is under half compression, cylinder c^2 is exhausting, cylinder c^3 has been fired and its piston is substantially at one-half of its working stroke, and cylinder c^4 is ready to be fired.

From the foregoing it will be seen that during the rotation of the crank shaft, the latter receives successive impulses in the cylinders as follows; c^4, c^1, c^2, c^3, c^4, c^1, c^2, and so on during the operation of the engine in the direction of arrow a, this result being naturally due to the fact that the axes of the adjacent cylinders c^2 and c^4, are disposed at right angles to the axes of the adjacent pair of cylinders c^1 and c^3, which enables me to condense the engine into a comparatively small space, and to avoid having a separate crank-pin for each piston.

Inasmuch as the construction and function of the several cylinders above named is similar throughout, the following description of one is deemed sufficient to arrive at a clear understanding of the mechanism as a whole.

Referring to the drawings, 31 denotes a bed casing comprising a crank chamber 32, the upper part of which is provided with a plurality of tubular projections 33 to which the respective cylinders are secured. While the casing may be made of any metal, I prefer to make the cylinders 34 of steel, not only to increase their strength, but also to reduce their weight, and, on account of their comparatively thin walls, increase their adaptability for cooling. The lower end of each cylinder 34 is positioned on the casing 31 by an annular flange 35 and a shoulder 36, and is firmly held in place by a clamping member 37 adapted to engage two adjacent cylinders (as for example c^2 and c^4, see Fig. 4) and secured to the projections 33 by means of screws 38. The upper closed end 39 of the cylinder 34 is provided with a central aperture 40 usually closed by a valve 41 and through which fresh air may be forced into the cylinder when the piston is near the lower end of its stroke.

The engine shown in the drawings is of what is generally known as the "two-cycle" type, namely, the compressed charge is exploded when the piston is near the upper end of each stroke; the used or spent gas is exhausted at the lower end of the piston-stroke, and a new charge is introduced into the cylinder to be compressed during the return movement of the piston when the crank shaft completes its individual rotation.

The piston herein shown comprises a tubular shell 42 closed at its upper end by a head-plate 43 and provided with an annular shoulder 44 which serves as an abutment for an annulus 45, in screw-threaded engagement with and for holding together a two-part thrust member 46. This member has a spherical recess for receiving the ball-end 47 of a connecting rod 48, which may be the rod r^2 or any piston rod used with one of the pistons whereby the reciprocating movement of the piston is communicated to the crank-pin w^1 of the main engine shaft s. The lower portion of the thrust member 46 is slightly tapered, as shown at 50, to be engaged by a check nut 51 in screw-threaded engagement with the piston shell 42 and having perforations 52, which permit the use of a spanner wrench and which, furthermore, serve as vents for the shell. It will be noted that when the check nut 51 is tightened, the annulus 45 will be forced against the shoulder 44 and thus establish a tight joint between these parts.

The lower end of the pitman rods 48 is shown as being articulated on a head strap 53 in engagement with the crank-pins w^1 and w^2, the organization being such as to afford a certain amount of freedom in allowing the pitman to actuate the crank-pin without liability of cramping or binding. In virtue of this articulation, the pitman rod 48 is held against axial rotation, and this fact is taken advantage of to prevent the piston 42 from rotating axially within the cylinder, a circumstance which in the present construction is desirable on account of certain coöperative ports and passages to be hereinafter described.

Referring to Figs. 4 and 5, it will be seen that the ball-end 47 of the connecting rod 48 is provided with a vertically-elongated transverse aperture or slot 54, adapted to receive a pin 55 which is secured in the two-part thrust member 46 and arranged in axial parallelism with the crank-pin w^1. While the elongation of the aperture 54, therefore, permits of a slight oscillation of the ball-end 47 in a plane parallel with the crank-pin, the member 46 is locked against rotation relative to the pin 55, on account of the absence of freedom between the pin and the sides of the slot 54 (see Fig. 5).

The crank-pin w^1 is connected with the pistons p^1 and p^2 disposed in the same plane and at right angles to the axis of the crank-pin; and, while the connector strap 53 is shown as provided with a single end, the companion strap for the rod r^1 is bifurcated and straddles the strap 53 in a manner similar to that shown in Fig. 4, in which the piston rod r^4 is illustrated as being articulated on the bifurcated strap 58 in engagement with the crank-pin w^2 which also carries the single-end connecting rod strap 59 of the piston in the cylinder c^4.

In Fig. 3 the engine shaft s is shown journaled in bearings 60 and having a crank disk 61 which carries one end of the crank-pin w^1, the other end of which is secured in a disk 62 supported for rotation in a ball race 63 and serving as a center bearing disposed between the crank-pins w^1, w^2, the latter being also secured to a crank disk 64 loosely mounted on a stud 65 which is rigidly held in the casing.

The elements thus far described do not particularize any special engine, at least as far as its motive power is concerned, and, in order to arrive at a clear understanding of the operation of the motor either by the primary or secondary fluid pressure, I deem it expedient, first to explain the several devices which are called into action when the engine is to be run by the primary fluid, as gas.

Practice has fully demonstrated that the efficiency and economy of what is generally known as "an explosive engine", using gas for its piston impulse, depends largely upon the gas mixture used. Without entering minutely into the details of what constitutes a proper mixture, let it suffice to state here that the component elements of the mixture are in the present instance supplied to each cylinder at opposite ends thereof.

In Fig. 5 the gas supply pipe 66 is shown terminating in a port or pocket 67, opening into the cylinder and normally closed by the piston shell 42. The piston is here shown in its lowermost position, and the used gas in the cylinder is not only permitted to escape through the exhaust port 68, but is practically forced out by fresh air which enters under pressure through the aperture 40 and past the valve 41 above described. The fresh air is conducted to the valve chamber 69 through a pipe 70, the valve being normally closed by a spring 71 engaging a collar 72 secured to the valve stem 41^1 in any convenient manner. The valve 41 is preferably of the cone type and centrally disposed in the top plate 39 of the cylinder, so that the air will enter the latter in a spreading or diffusing manner. The air supply will continue during the initial return movement of the piston and immediately thereafter will cease, which will result: first in closing the exhaust port, and immediately thereafter permit a supply of fuel, as gas, to enter the cylinder.

By referring to Figs. 4 and 5, it will be seen that the upper portion of the piston comprises a cup-shaped member 73, the bottom of which rests upon the annular shoulder 44 above mentioned, and which may be forced into close contact therewith by the head plate 43 in screw-threaded engagement with the piston shell 42. In this manner a chamber 74 is formed in the piston, and a port 75 leads from said chamber to the outer surface of the piston. The path of the port 75, during the upward piston travel, intersects the fuel pocket 67, so that after the exhaust port 68 has been closed, the gas pocket will be in communication with the chamber 74, and the fuel may then be forced into the cylinder past a preferably gravitative valve 77, which is mounted for a limited rise and fall movement in a tubular hub 78 constituting a part of the piston head 43 and having an air tight joint with the cup member 73. The valve 77 is also of the cone type, so that the fuel may be spread as it is forced into the cylinder, thus encountering the fresh air which has entered from above and consequently thoroughly commingling therewith. The continued upward travel of the piston will result in cutting-off the gas supply (as soon as the port 75 has passed the pocket 67) and, inasmuch as previous to this time the required amount of air will have been delivered in the cylinder, the now complete mixture will be compressed ready to be fired or exploded.

In the present instance I have provided a spark plug 80, the metallic core 81 of which may be connected by a conductor 82 with any suitable spark producing device, preferably a magneto M (see Fig. 3) which is operated by gears 83, 84 from the engine shaft s, and a commutator C sections of which are electrically-connected with the spark plugs of all four cylinders, respectively, in the usual manner. The explosion or firing of the compressed charge in the cylinder is effected with the aid of the piston, the circumferential surface of which is naturally at all times free from soot and always presents a perfectly clean metallic surface for the electric spark issuing from the core 81, as determined by the commutator or spark timing device of the magneto M. The metal parts of the spark plug are preferably at a greater distance apart than the distance prevailing between the sparking pin and the piston when the piston is in position for firing so as to prevent short circuiting and to avoid the possibility of the spark jumping from the core, except in the cylinder in which is a piston opposite it, to present its surface for that purpose. The firing space 80^1 of the plug is of such size that the piston in its highest position indicated by dotted lines 43^a will still leave an open connection between said space 80^1 and the interior of the cylinder, so that the charge may be properly ignited.

In order to insure the proper operation of the gas engine, I have provided means for cooling the working parts so as to maintain them at the required temperature, and in the present instance I have shown a system whereby the cylinder as well as the pistons are cooled by air in what may be termed a positive manner. The cylinders are provided at their tops with capping members 85 secured thereto by rivets 86, (see Fig. 6) and each adjacent pair of which are preferably united by means of screws 87, substantially to form a unitary device (see Figs. 5 and 6). Each cap 85 is provided at its top with an aperture 88, through which atmospheric air may pass into the hollow dome 89 of the cap and thence into a cylinder jacket which preferably comprises a pair of end sections 90, a cooling section 91 (so called on account of its connection with an air-blast producing device) and an exhaust section 92 which permits the engine exhaust to escape into the open air, or, if desired, into a muffler or similar device. The several jacket sections are positioned on the cylinders by means of a circumferential recess 93 engaging the upper edges of the sections, and also by means of a similar groove 94 formed in the cylinder clamping member 37 above mentioned and engaging the lower edge of the jacket sections, which may be provided with suitable flanges 95 adapted to receive screws 96 for holding the several sections together. By this construction a clear space will be obtained all around each individual cylinder, which if preferred may be provided with pins, ribs or similar devices (not shown) for radiating the heat from the cylinder into the jacket space.

The cooling section 91 of the jacket is connected with a conduit 98, two of such conduits (see Fig. 1) being employed in taking care of the four cylinders and the jackets therefor, and being in communication with a pipe 99 leading to an exhaust fan or similar device (not shown).

From the foregoing description it will be seen that an exhausting air current is established in the jackets, cool air entering through the several apertures 88 in the cylinder caps 85, thence passing in contact with the entire outer surface of the fire exposed and consequently heated portions of the cylinders, and thence to the exhauster which discharges the now heated air into the atmosphere.

Inasmuch as the tops of the several pistons are, as a matter of course, exposed to the heat of the explosion, I deem it advantageous to provide means whereby the temperature of the pistons may be kept at a reasonably low degree, these means consisting substantially of a cool air-passage disposed directly beneath the piston head, as clearly shown in Figs. 4 and 5, in which it will be seen that the cup member 73 (in combination with the head plate 43) constitutes a chamber 100 having oppositely-disposed openings or ports 101, 102, which, when the piston is near its lowermost position, will register with apertures 103, 104, respectively in the cylinder wall 34. Of these the aperture 103 opens directly into the interior of the jacket, while the aperture 104 is in constant communication and alinement with a conduit 105 formed in the end section 90 and open to the atmosphere. Now it follows that when the piston is in the position shown in Figs. 4 and 5, and the air conduits and ports just described are in register with each other, the suction or partial vacuum established in the jacket will result in causing an influx of atmospheric air through the chamber 100, therefore replacing the heated air contained therein by cool fresh air, and consequently reducing the temperature of the upper piston shell and the head, which latter may be provided with heat-radiating pins if so desired.

As stated in the beginning of this specification, the present invention has for one of its objects the provision of means whereby the motor may be operated either by a fuel or secondary fluid under pressure, the latter feature necessitating some sort of fluid supply which may be in the nature of a tank or reservoir such as is designated by R (see Fig. 12). Now I prefer to charge the reservoir by taking advantage of the high pressure resultant from the explosions in the cylinders, it being understood, however, that any number of cylinders may be connected with the reservoir for this purpose, in which case the remainder will serve as power-imparting devices, and exhaust into the atmosphere either direct or through a muffler (not shown). The particular manner in which the reservoir is charged by the explosions in the cylinders is best shown in Fig. 5, in which the cap 85 is illustrated as providing a chamber 110 connected with the interior of the cylinder by a duct 111 provided in a lug 112 projecting into the cylinder head-plate 39 and serving as a device for positioning both, the cap and cylinder, relatively to each other, and to lock the latter against accidental rotative displacement.

Disposed above the chamber 110, is a valve chamber 113 normally closed against the chamber 110 by a valve 114, the stem 114[1] of which is guided in a cap 115 and which may be normally closed by a spring 116. The chamber 113 is connected with the reservoir R by means of a pipe 117, so that when the reservoir R is charged with a fluid under pressure, the valve 114 will be held closed thereby, and the explosions in the cylinder cannot become effective in adding to the pressure in the reservoir unless their force is more than equal to the combined forces of reservoir pressure and spring 116. It will, therefore, become evident that when an explosion takes place in the cylinder, and the resisting force on the valve is less than the pressure resulting from the explosion, the valve will be forced open and thus allow a portion of the exploded gas to enter the chamber 113 and consequently increase the pressure in the reservoir. On the other hand when the latter is fully charged, the valve 114 will remain closed, and the explosion in the cylinder will have its full operative effect upon the piston, so that in this manner the pressure in the reservoir will be automatically kept at its maximum, provided the motor is running as an explosive engine.

In the event that the reservoir is empty or under low pressure at the time of starting the engine, the tendency of the pressure, resulting from the exploded gases, to pass into the pipe 117, might retard the proper working of the piston, or pistons unless some means were provided for preventing too much pressure from entering said pipe 117 at each explosion. In Fig. 5 I have shown a simple means of retarding the introduction of the exploded gases which means is illustrated as a spring pressed inwardly opening check valve 117[a] said valve normally resting on a seat at the entrance to the pipe 117 and having a passage 117[b] of smaller diameter than the diameter of said pipe 117 so that a relatively small amount of the pressure will pass into the pipe during each explosion. As will be seen by reference to Fig. 5 the valve 117[a] is capable of opening inwardly so that when it is desired to operate the engine by the pressure from the reservoir R, (an operation to be fully explained hereinafter) the passage of the fluid from the reservoir R to the chamber 113 will be unobstructed.

In the diagram, Fig. 12, I have illustrated the organization of the several cylinders and their connections with the reservoir R through the main pipe 118, and it will here be seen that the cylinder C′ may be disconnected from the reservoir by means of a stop valve 119, under which condition the piston in said cylinder will be acted upon by the entire force of the explosion, and the reservoir will be charged by the explosions in the remaining cylinders c^2, c^3 and c^4, only.

It should, of course, be understood that each cylinder may be provided with a stop valve, if desired, so that any one cylinder of the series, or any number of them may be connected with or disconnected from the reservoir, the contents of which are to be utilized not only for supplying the pressure required for operating the motor pistons, but also for moving several movement-controlling devices into operative and inoperative positions.

In operating the motor by the secondary fluid pressure only, the mixture-supplying devices as well as the igniting apparatus may be thrown out of action, as will be hereinafter described, and it now becomes necessary to actuate the means for controlling the admission of pressure fluid and the exhaust of the used fluid. These means comprise the valve 114 previously referred to, and now operative as a fluid admission valve actuated in a positive manner by a rod 120 which is guided for vertical movement in a sleeve 121. This sleeve is mounted for vertical movement in the cylinder clamp 37, and has at its upper end a valve-disk 122 for closing a passage 123, leading from the chamber 110 into the interior of the jacket and constituting the exhaust port for the motor when it is operated by the secondary fluid. Means is shown for synchronizing the opening and closing movements of the valves 114 and 122 with the movement of the piston, so that the inlet valve will be open during the downward or working stroke of the latter, while the exhaust valve will be opened when the piston is at the end of its working stroke, and then remain open during its entire return stroke. These valve movements are effected by a valve actuating mechanism clearly shown in Figs. 1, 3, and 8 to 11, and comprising a shaft 124 journaled in bearings 125 provided therefor on the cylinder casing 32. At one end, this shaft is mounted for longitudinal movement in the hub 126[1] of a sprocket 126 connected by a chain 127 with a similar sprocket 128 secured upon the engine shaft *s*, said hub having a spline connection 129 with the shaft 124 and held against longitudinal movement in the bearing 125[1] by a collar 125[11].

Secured upon the shaft 124 are came 130, each of which is provided with a series of cam faces 131, 132, 133, adapted to operate the air inlet and exhaust valves by actuating a series of levers in engagement with the valve stems, respectively.

Referring at first to the air valves of cylinder c^2 (see Figs. 5 and 10) it will be noted that the lower end 120^2 of the inlet stem 120 rests upon one arm 134^2 of an angle lever 135^2 which is pivoted at 136^2 in a pair of ears 137^2 formed on the casing 31, and the other arm 138^2 of which is adapted to be actuated by one of the cam faces of the cam 130, according to the longitudinal position of the shaft 124. Disposed adjacent to the angle lever 135^2 and also pivoted on the stud 136^2, is another angle lever 139^2, the arm 140^2 of which is in engagement with the lower end 121^2 of the exhaust valve sleeve 121, while the other arm 141^2 is adapted to be engaged by one of the cam faces on the cam 130.

The angle levers 135^2 and 139^2 are preferably in constant contact with the valve-stem ends 120^2 and 121^2, respectively. The shaft 124 is mounted for longitudinal shifting movement, either to bring the several cam faces into a neutral or inactive position relative to the arms 138^2 and 141^2 (this position being in evidence in the general figures of the drawings) or to bring the cam faces 131, 132 into position for operating said arms, see Fig. 8, which shows the organization when the motor is operated by the secondary fluid, forward; or to bring the cam faces 132, 133 into operative position relative to said arms, as is illustrated in Fig. 10 which illustrates the condition which exists when the engine is operated by the secondary fluid, backward.

Attention is called to the fact that the cam faces 131, 133 are both similarly disposed relative to the cam face 132, and that when the cam face 132 becomes active, both of the other faces 131, 133 must necessarily become inactive on the same side of the shaft 124, and vice versa. In other words; In Figs. 8 and 9 the cam face 132 is in such position as to leave the exhaust lever free, and the exhaust valve is therefore closed; while the cam face 131 holds the inlet valve open. In Figs. 10 and 11 the cam shaft 124 is shown shifted longitudinally and without any change in its rotative position, relative to that shown in Fig. 10 and the position of the valves is, therefore, reversed.

In view of the organization of the pair of co-acting cylinders c^1, c^2, the pistons of which are connected with the same crank-pin, w^1, and the axes of which are disposed substantially at right angles relative to each other, I am enabled to operate the inlet and exhaust valves of the cylinder c^1 by the same cam faces which actuate the valves of the cylinder c^2 in the manner above described, this feature being possible by the fact that the angular relationship or distance between the cam-operated points of the two sets of valve-actuating angle levers is the same as that between the cylinder axes, as is indicated by lines 11^a, 11^b in Fig. 9, it being understood, of course, that the inlet lever 135^1 is similar to the lever 135^2, and also that the exhaust levers 139^1 and 139^2 are alike.

By referring to Fig. 8 it will be seen that the arm 138^2 of the inlet lever 135^2 is in alinement with the cam arm 141^1 of the exhaust lever 139^1 for cylinder c^1, and that, furthermore, the arm 141^2 of the exhaust lever 139^2 for cylinder c^2 is in alinement with the cam arm 138^1 of the inlet lever 135^1 for cylinder c^1. Hence it follows that the inlet valve of cylinder c^2, and the exhaust valve of cylinder c^1 are operable by the same cam face (131 in Fig. 8, and 132 in Fig. 10) during the rotation of the cam shaft 124. Likewise, the exhaust valve of cylinder c^2, and the inlet of cylinder c^1 are operable by the same cam face (132 in Fig. 8, and 133 in Fig. 10) during the rotation of the shaft 124. Now, inasmuch as the cam faces of the cam 130 are effective only in opening the valves, it will be readily understood that, according to the condition shown in Figs. 8 and 9, the inlet valve stem 120^2 (for cylinder c^2) is in raised position and the exhaust sleeve 121^2 is lowered, so that the piston of cylinder c^2 is under pressure. Furthermore, the inlet stem 120^1 is raised and the exhaust sleeve 121^1 is in its lowest position, the piston in cylinder c^1 being consequently also under pressure. By referring to Fig. 1 it will be seen that the acting faces of the cam 130^b for operating the valves of cylinders c^3 and c^4 are set in a diametrically-opposite position, to correspond to the position of the crank-pin w^2 which is, as previously stated, disposed diametrically-opposite to the crank-pin w^1. Therefore, it is evident that the positions of the valves pertaining to the cylinders c^3 and c^4 are reversed from those of the valves for the cylinders c^1 and c^2, respectively, so that for cylinder c^3 the inlet valve is closed, and the exhaust valve is open, and, for cylinder c^4 also, the inlet is closed, and the exhaust valve is open, and that consequently both cylinders c^3 and c^4 are exhausting. If it is now taken into consideration that each of the cams is so set relative to the crank-pin belonging to its coöperative pair of cylinders that the change of position in the valves is effected when the pistons are near the end of their respective strokes, the position of the cam 130^b in Fig. 1 indicates that the shafts s and 124 are rotating in the direction of arrow a (Figs. 2 and 9).

When the cam shaft 124, with the cams 130^a and 130^b, is shifted to bring the faces 132, 133 into coöperation with the valve levers, as shown in Figs. 10 and 11, the valves will be reversed, thus bringing the pistons of the cylinders c^3 and c^4 under pressure, and the cylinders c^1 and c^2 to exhaust, therefore reversing the direction of movement of both shafts *s* and 124, as indicated by arrow *b* in Fig. 11.

When the cams are in their non-operative or neutral positions, the cam face 132 is disposed between the actuating arms of the inlet and exhaust levers, (see Fig. 1) and in order to facilitate the shifting movment of the cam shaft, the several cam faces are provided at their sides with inclined surfaces for gradually acting upon the arms of the valve levers, when the shaft 124 is rotating, these surfaces permitting the latter to be shifted from its neutral position in one direction to control the valves for running the engine forward, and in the other direction for causing a backward rotation of the engine shaft.

Means are provided for shifting the shaft 124 longitudinally for the purposes mentioned, and while hand-operated devices may be advantageously used, I prefer to employ a fluid-actuated device which receives its actuating fluid pressure from the reservoir R.

The bearing 125^1 for the sprocket hub 126^1 has an upward extension 150 bored out to form a cylinder adapted to receive a piston 151 which is secured upon a rod 152, passing through a stuffing box 153 and guided in an ear 154 projecting from one of the bearings 125 previously referred to. The piston rod 152 carries a fork 155 in engagement with a spool 156 which is secured upon the cam shaft 124, and springs 156^1 may be interposed between the fork hub and the bearing 125 and stuffing box 153 respectively, to return the piston 151 to a practically central position in the cylinder 150, at which time the valve cams are in their neutral positions. In order to frictionally hold the piston rod in its neutral position, I preferably employ a spring-pressed pin 157 having a pointed end for engaging a properly formed recess in the rod (see Fig. 3).

The outer end of the cylinder 150 is closed by a cap 158, and the piston 151 is adapted to be moved in opposite directions by air pressure entering the cylinder through either one or the other of a pair of tubes 170, 171, respectively, the influx of air being controlled by a valve mechanism which will admit fluid under pressure from the reservoir into one or the other of the tubes, and on the other hand will relieve both sides of the piston from pressure when the engine is to be operated as a gas motor, or by the primary fluid, only.

A simple form of controller for the piston 151 is illustrated in Fig. 12 as being in communication with the tubes 170, and 171 as well as the reservoir R. The controller may comprise a three way valve casing 160 having an inlet port 161 at all times in communication with the reservoir R and the port 162 in the plug 163. The outlet ports of the plug are adapted to be brought into register with the pipe inlets respectively by turning the valve plug to right or left, so as to admit pressure to either the tube 170 or 171 according to which direction it is intended to run the motor, that is to say, forward or backward. When the plug is in the neutral position as shown in Fig. 12, the piston 151 will be maintained in the position shown in Fig. 3, by the springs 156^1, 156^1, this being the position of the piston during the time the motor is operating under the primary fluid, and during this time the members 120, 121 and their coöperating elements will remain inactive. As soon, however, as the piston is shifted to either the right or left so as to cause the cams to become operative, the members 120 and 121 will be caused to operate so as to permit the stored pressure in the reservoir to become the motive fluid for actuating the pistons.

It is to be understood that while the motor may be operated from the reservoir R so long as there is sufficient pressure in the said reservoir, I prefer to run it by the secondary fluid as a starting medium in lieu of the usual method of "cranking", a method which is generally unsatisfactory.

The sprocket S^1 on the shaft S is adapted to drive a sprocket S^{11} on the shaft P^1 of the pump P comprising four double action cylinders A^1 A^2 and G^1 G^2, the first named of which A^1 will supply the proper amount of fresh air to the engine cylinder c^1 through the pipe a^1, (which corresponds to the pipe 70, Fig. 5) and also to the engine cylinder c^3 through a pipe a^3. The gas required for the mixture is forced into the cylinders c^1, c^3 by a piston operative in the gas cylinder G^1 of the pump through pipes g^1, g^3, respectively. In a similar manner the engine cylinder c^2 is supplied with air from the pump cylinder A^2 through a pipe a^2, and with gas through a pipe g^2 connected with the pump cylinder G^2, the other end of which has a pipe g^4 leading to the engine cylinder c^4, the air being carried thereto through a pipe a^4 connected with the opposite end of the pump cylinder A^2.

Now it will be seen that a source of gas supply is provided as for example, the tank T interposed between which and the pump cylinders is a controller X having a plug therein, whereby gas may be admitted to one or more cylinders or entirely cut off from said cylinders if desired. In this manner any number of the cylinders may be supplied with gas according to the power required of the motor.

In the drawings accompanying this specification, I have illustrated a motor comprising four cylinders which by virtue of their organization, will impart four impulses to the engine shaft for each rotation thereof. While this motor, together with its various accessories, is deemed sufficient to explain the invention, I prefer to employ a motor comprising more cylinders, organized in coöperative pairs so as to obtain a greater number of impulses and consequently enhance the power and smooth running qualities of the engine.

From the foregoing description it will be apparent that when the motor is to be run by a secondary fluid the direction of movement of the fluid impulse receiving member or members may be controlled by shifting the cams either to the right or to the left, so that the motor may be caused to run either forward or backward. After the direction of movement of the impulse receiving part has been determined and effected, the primary fluid may be introduced and the mechanisms necessary for the proper operation of the motor by the primary fluid having been caused to operate, the direction of movement of the impulse receiving member or members controlled by the mechanism operating with the secondary fluid will continue. Therefore it is apparent that the motor may be run either forward or backward by the secondary fluid or either forward or backward by the primary fluid, which in the present instance is gas. By utilizing the construction of motor previously herein before described, the direction of the movement of the impulse member or members of the motor may be positively controlled so that in starting the motor, if it is desired to move backwardly, it will be necessary only to shift the cams into the proper position so as to move the piston or pistons in the direction to cause the shaft to move backwardly and then introduce the gas so that the backward motion will continue. The secondary fluid having been cut off, the backward movement of the shaft will be caused to continue. If it is desired to rotate the shaft in a forward direction, the cams may be shifted so as to cause the secondary fluid to pass into the cylinder or cylinders at such time as to cause the piston to move the shaft in a forward direction, after which the gas may be introduced into the cylinder or cylinders to continue the movement. At any time while the motor is running under the primary fluid, the secondary fluid may be cut off and the cams shifted to cause the impulse receiving member or members (as for example pistons) to move in the proper direction and as soon as they are started in the proper direction, the gas introduction continues.

I do not herein claim the cooling means here shown and described, as this forms the subject-matter of my co-pending application Serial No. 295,638. Nor do I herein claim the sparking mechanism here disclosed, as this is included in the subject-matter of my co-pending application Serial No. 305,665.

What I claim is:

1. The combination with an engine cylinder, a gas mixture supply mechanism therefor and means for controlling the operation of said mechanism, of an air pressure reservoir, air admitting and exhausting devices for said cylinder one of said exhausting devices being a check valve, and means for controlling the operation of said devices whereby the check valve may become the admitting device.

2. The combination with a gas engine cylinder, a mechanism for supplying gas mixture thereto, a secondary fluid supply reservoir in communication with the explosion chamber of said cylinder, a check valve for normally closing the passage between the reservoir and the cylinder, of means for discontinuing the operation of the gas supply mechanism, and means for actuating said valve to admit the secondary fluid pressure from the reservoir to the cylinder.

3. The combination with an engine cylinder, of an air admission valve for supplying the cylinder, a gas port in communication with said cylinder, a piston for compressing a mixed charge of air and gas, a reservoir, a communication port between said reservoir and said cylinder, a normally seated check valve for preventing communication between the reservoir and the cylinder, said check valve being adapted to be unseated by each explosion to permit part of the exploded charge to pass into the reservoir, and means for intermittently opening said normally seated check valve to permit pressure from the reservoir to pass into the cylinder.

4. The combination with a motor cylinder and a piston therein, of means for permitting a fuel charge to be introduced into said cylinder, a reservoir, a port in communication with said reservoir and said cylinder, a ported valve in said port and opening in one direction only, the port in said valve permitting a part of the exploded gas to pass into said reservoir, a valve for normally preventing the return of said exploded gas into said reservoir, and means for unseating said last named valve.

5. The combination with a cylinder and a piston therein, of a source of fluid supply having a port connected to said cylinder, a valve for normally closing communication

between said port and said cylinder, a normally closed exhaust valve having an elongated cylindrical stem, a longitudinal valve unseating member within the stem and adapted to unseat the admission valve, and means for alternately moving the valve unseating member and the cylindrical stem.

6. In a motor, the combination with a cylinder, means for feeding a charge thereto, and a storage receptacle in communication with said cylinder, of a valve in said communication between said cylinder and said receptacle, said valve having an aperture therethrough; substantially as described.

7. In a motor, the combination with a cylinder, means for feeding a charge thereto, and a storage receptacle in communication with said cylinder, of an automatically-seating outwardly-opening valve in said communication, an automatically-seating inwardly-opening valve in said communication and provided with an aperture therethrough, and means for opening said outwardly-opening valve; substantially as described.

8. The combination with a cylinder of an explosion motor, of a reservoir adjacent to said motor, a conduit leading from said motor and communicating with said reservoir, a ported valve in said conduit, an imperforate valve in said conduit, and an exhaust valve adapted to be opened when said imperforate valve is closed and closed when said imperforate valve is opened.

9. The combination with a cylinder of an explosion motor, of a reservoir adjacent to said motor, a conduit leading from said motor and communicating with said reservoir, a ported valve in said conduit, an imperforate valve in said conduit, an exhaust valve adapted to be opened when said imperforate valve is closed and closed when said imperforate valve is opened, and means for operating said valves, comprising shifting cams adapted to be moved into and out of actuating positions.

10. In an explosion motor, the combination with a cylinder having a valved fuel inlet port and an open exhaust port, an air inlet port for the admission of compressed air, an air exhaust port, said two latter mentioned ports being provided with valves, and means movable into and out of operative position for alternately opening the two last mentioned ports.

11. In an explosion motor, the combination with a cylinder having a valved fuel inlet port and an open exhaust port, an air inlet port for the admission of compressed air, an air exhaust port, said two latter mentioned ports being provided with valves, and means comprising a rotating member for opening and closing the two last mentioned ports.

12. The combination with an explosion motor cylinder, of valved ports for said cylinder, a source of air supply in communication with said ports, a shiftable means for opening and closing said ports, and a single device in communication with said source of air supply for actuating said shiftable means.

13. In a motor, the combination with a cylinder having a port, and a valve controlling said port, of a shiftable valve-operating member, means for shifting said member, and oppositely acting springs exerting their influence upon said valve-operating member and yieldingly holding the same out of valve-operating position; substantially as described.

14. In a motor, the combination with an engine cylinder having inlet and exhaust ports, a shiftable shaft provided with means for opening and closing said ports, means for shifting said shaft, comprising a piston and cylinder, one of these being movable with relation to the other, and springs for normally holding the movable member in a determined position with relation to the immovable member.

15. A motor, comprising a plurality of cylinders, means for introducing a fuel into and exhausting it from the respective cylinders, means for introducing and exhausting a compressible secondary fluid into and from said cylinders, and means for cutting off the secondary fluid from a determined number of cylinders and at the same time permitting the fuel to be introduced into all the cylinders.

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

ALBERT F. ROCKWELL.

Witnesses:

B. F. Funk,

H. W. Tuttle.