(No Model.) 4 Sheets—Sheet 1.

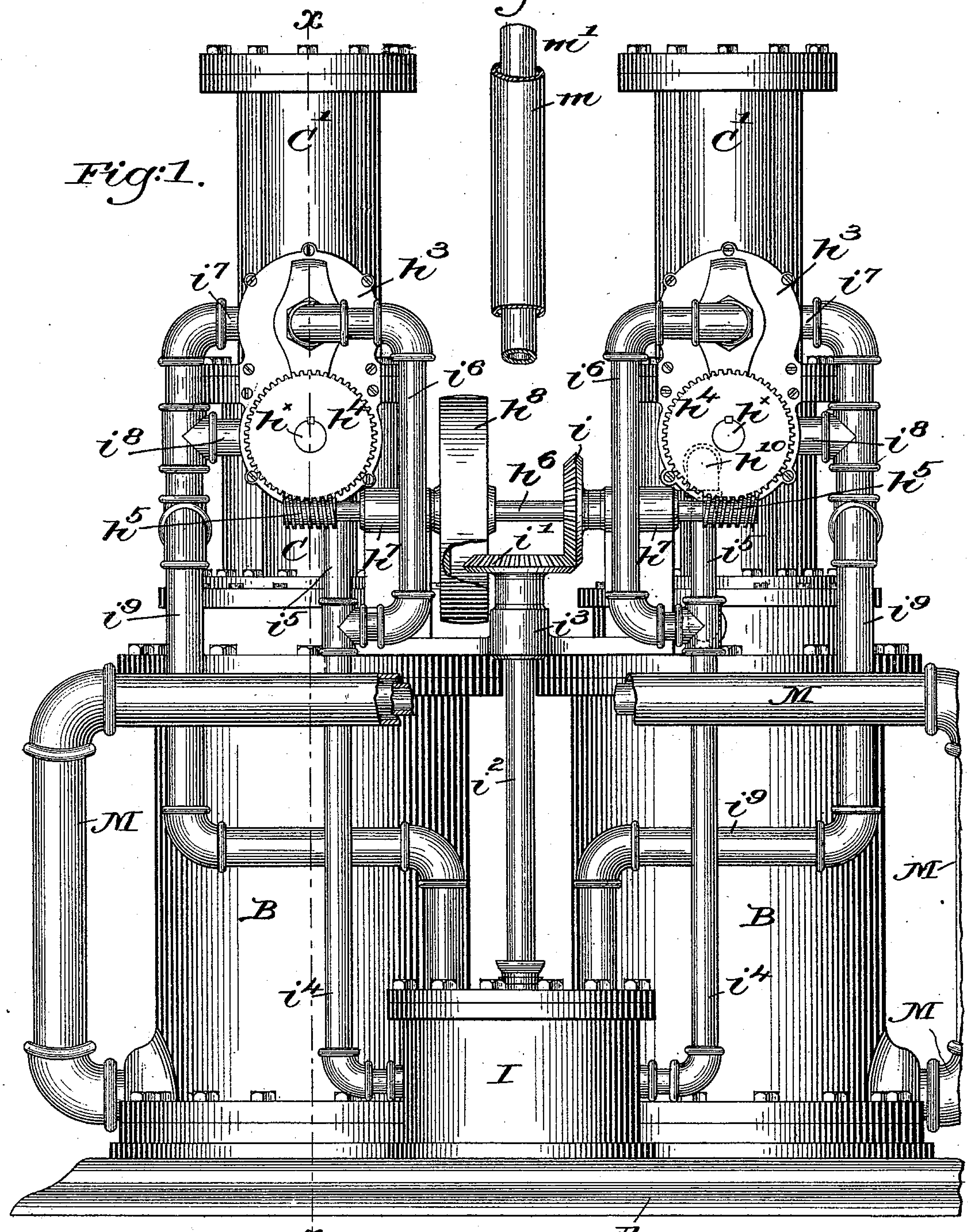
E. D. CHAPLIN.

VACUUM PUMP.

No. 521,432. Patented June 12, 1894.

Fig: 10.

Fig: 1.



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THE NATIONAL LITHOGRAPHING COMPANY, WASHINGTON, D. C.

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E. D. CHAPLIN.

VACUUM PUMP.

No. 521,432. Patented June 12, 1894.

Fig: 2. Fig: 3.

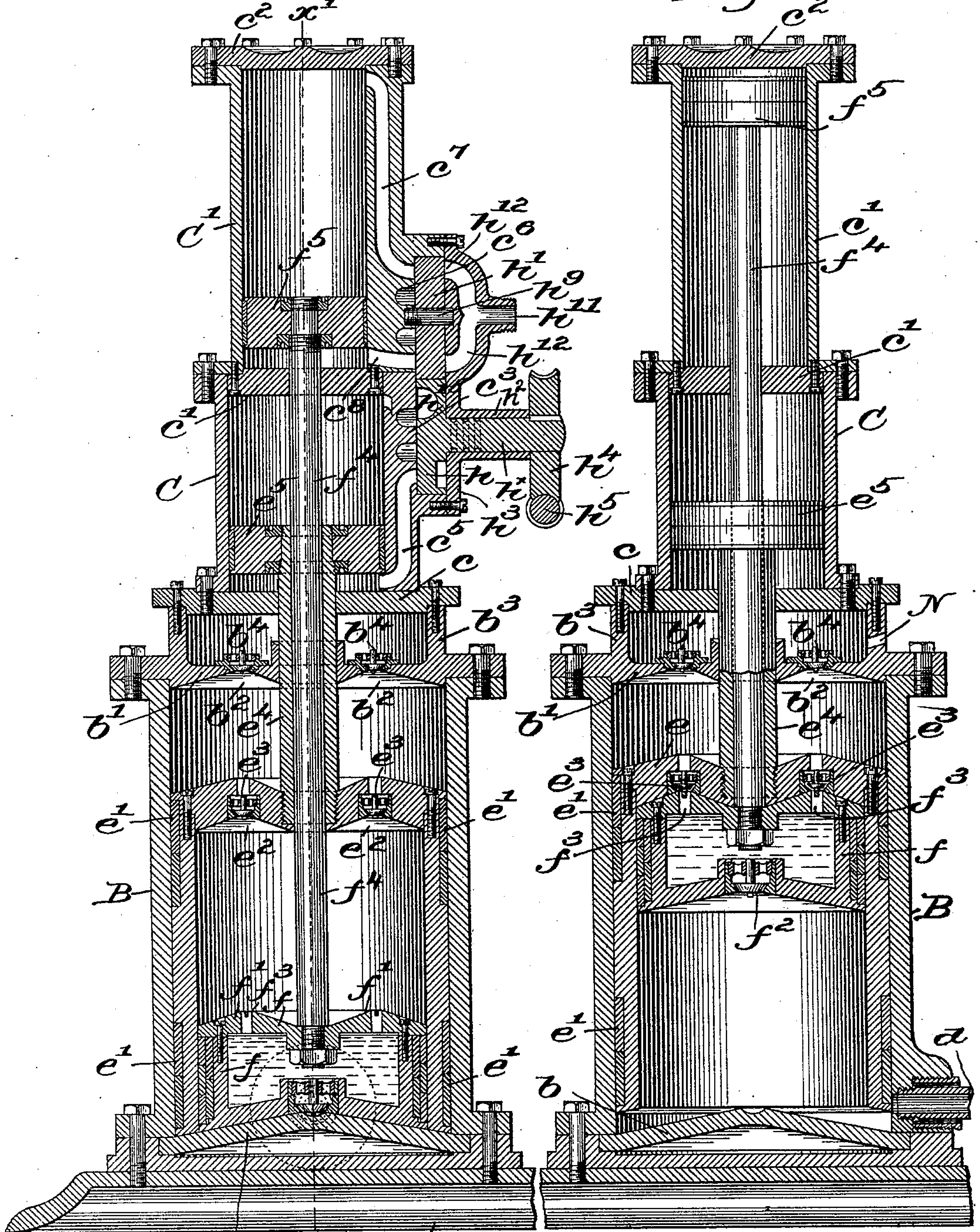

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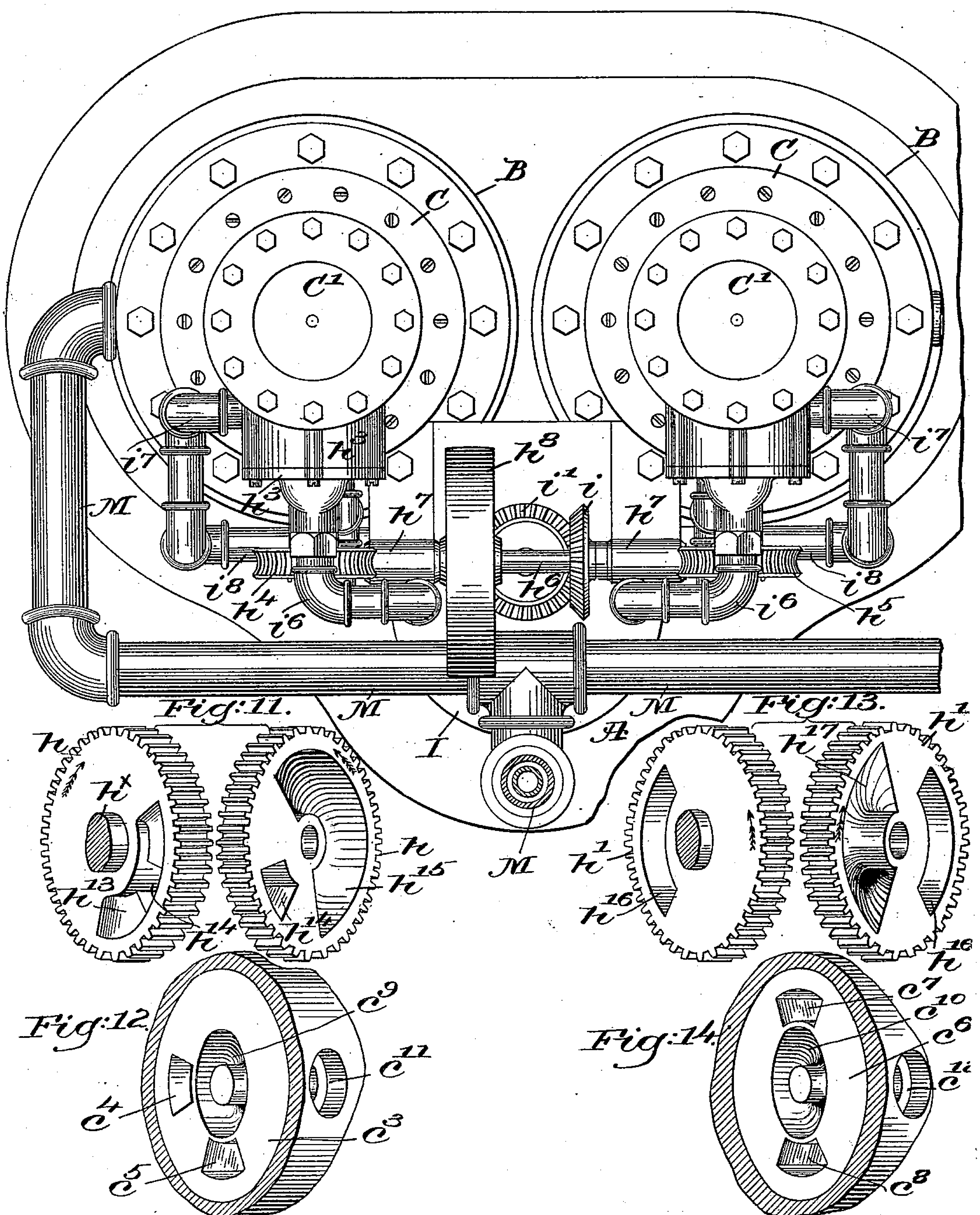
Fig:4.



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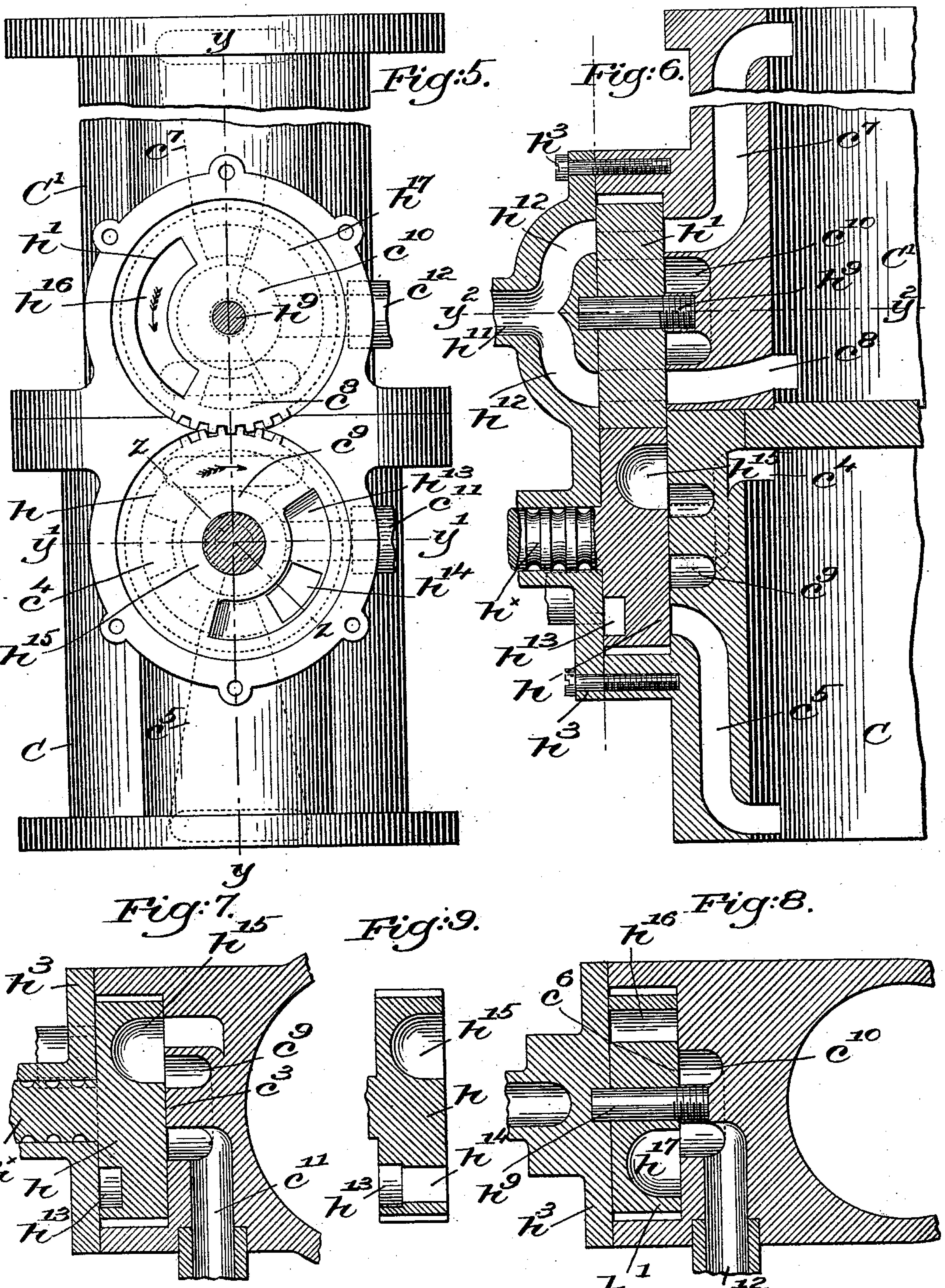

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THE NATIONAL LITHOGRAPHING COMPANY, WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

EDWIN D. CHAPLIN, OF NATICK, MASSACHUSETTS.

VACUUM-PUMP.

SPECIFICATION forming part of Letters Patent No. 521,432, dated June 12, 1894.

Application filed May 29, 1893. Serial No. 475,855. (No model.)

To all whom it may concern:

Be it known that I, EDWIN D. CHAPLIN, of Natick, county of Middlesex, State of Massachusetts, have invented an Improvement in Vacuum-Pumps, of which the following description, in connection with the accompanying drawings, is a specification, like letters on the drawings representing like parts.

This invention relates to vacuum pumps, it having especial reference to pumps employed to exhaust the air from incandescent lamp bulbs. As the air contained in lamp bulbs always carries a certain quantity of moisture, and as it is difficult to obtain a high vacuum in the presence of moisture, it is the common practice to first exhaust the greater part, say ninety-five per cent., of the air together with a like percentage of the moisture, by a vacuum pump of ordinary construction, and then exhaust the balance of the air, or as much of the same as is possible, by a second specially constructed pump, which, by reason of its special construction, together with the absence of any appreciable quantity of moisture enables a high vacuum to be obtained. Pumps for this second or final exhausting, as heretofore constructed have usually been provided with an air inlet controlled by a valve which it is necessary to cover or flood with a liquid, usually oil, in order to form a liquid seal about the valve to prevent possible leakage. In practical operation, however, it has been found that as the air valve is opened, the sealing liquid has a tendency to cling to and follow the valve like the stretching of a piece of rubber and form a thin film of liquid stretching from and surrounding the valve seat to the open valve, which film the rarefied air in the bulbs has not sufficient pressure to break, this film being so strong that in a high vacuum it absolutely prevents the entrance or expansion of air from the bulbs into the pump cylinder. To obviate this difficulty pumps have been constructed having the air inlet in the side of the pump cylinder, so as to be opened and closed by the piston as it reciprocates in said cylinder, the piston fulfilling the functions of a valve. In pumps of this latter construction, that is, having the side air inlet, the tight fitting piston which excludes any considerable quantity of oil, obviates the oil film previously referred to, but it has heretofore been necessary to place such side air inlet near the middle of the cylinder or near the end of the drawing-in stroke of the piston in order that said piston in its return or expelling stroke might first close or cover the inlet, and thereafter expel the air from the cylinder. If such side inlet were located near the bottom of the cylinder, the air which has entered and filled the cylinder during the drawing-in stroke of the piston would simply be returned back again through the open inlet into the bulbs from which it has expanded, before the moving piston could reach and cover the inlet to prevent such return. It has also been found that when the air inlet is placed near the middle of the cylinder, or near the end of its drawing-in stroke as described, the rarefied air has not sufficient time between the uncovering of the inlet as the piston reaches the end of its stroke and the closing of the inlet by the return movement of the piston, to expand into and fill the cylinder, for rarefied air is sluggish in its movements and does not readily expand to fill the cylinder, but needs to be drawn or sucked into the cylinder by a moving piston, which cannot be done when the inlet is not uncovered until the piston has practically reached the end of such drawing-in or sucking stroke.

In my efforts to perfect vacuum pumps I have aimed to construct a pump, first, which should have the air inlet in the side of the pump cylinder to avoid the oil or liquid film surrounding the open valve, referred to; second, to place the said air inlet near or at the bottom of the cylinder or near the beginning of the drawing-in stroke of the piston, in order that said inlet should be uncovered at the very beginning of the stroke to thereby give the longest possible time during the stroke of the piston in which the air might expand into and fill the cylinder, and thereby also avail myself of the full drawing-in or sucking movement of the piston to draw or suck the rarefied air into the cylinder; and lastly to provide a means for closing the said air inlet quickly at the end of the drawing-in stroke of the piston, in order that none of the air drawn or expanded into the cylinder behind the piston shall be returned or forced back again into the bulbs before the piston in its return or expelling stroke should reach and cover the said inlet to prevent such return.

The result of my efforts is the invention forming the subject matter of this present application, and in which the principal or distinctive feature is the employment of two pistons within the pump cylinder, one piston moving within the other, which latter moves to open and close the air inlet and at the same time constitutes a cylinder in which the other piston which draws in and expels the air is reciprocated. These pistons which are preferably provided with valves as necessary may be reciprocated relatively to each other in any suitable or desired manner, but I prefer to employ as a motive power oil or other liquid under pressure, I having found that by the use of hydraulic pressure, I can, as I believe, better control the movements of the piston to facilitate the exhaustion of the air.

The invention also comprehends various constructional features and details which will be fully hereinafter described and pointed out in the claims.

Figure 1 of the drawings represents in side elevation partially broken away one form of pump embodying this invention; Fig. 2, a vertical section of the same taken on the dotted line x—x; Fig. 3, a vertical section taken on the dotted line x'—x', Fig. 2; Fig. 4, a top or plan view of Fig. 1 partially broken away; Fig. 5, an enlarged face view of one pair of power cylinders Fig. 1, with the valve chest caps removed to expose the valves; Fig. 6, a vertical section taken on the dotted line y—y, Fig. 5; Fig. 7, a horizontal section of one of the valves, with its valve seat, the section being taken on the dotted line y'—y', Fig. 5; Fig. 8, a cross section taken on the dotted line y^2—y^2, Fig. 6; Fig. 9, a section of one of the valves taken on the dotted line z—z, Fig. 5; Fig. 10, a detail showing the form of pipes which I prefer to use. Fig. 11 shows the valve h, split and opened like a clam shell to show both sides in perspective. Fig. 12 shows its valve seat; Fig. 13, a view of the valve h', similar to the view Fig. 11, and Fig. 14, its valve seat.

Referring to the drawings which illustrate one form or embodiment of my invention, A represents a suitable base, upon which are erected two vertical pumps, and as both are of the same construction, a detailed description of one only is sufficient, it being understood that like letters represent like parts in both pumps.

B represents the vertical pump cylinder, the lower cylinder head b of which is made conical, as shown in Fig. 2, while the upper cylinder head b' is provided at its inner side or face with an annular cone-shaped recess b^2, said upper cylinder head being provided with a vertically extended annular flange b^3, upon which is sustained and bolted the cylinder head c of the power cylinder C, the latter in turn at its upper end supporting and having secured to it a second vertical power cylinder C′ provided with the proper cylinder heads c' and c^2.

Referring now particularly to Figs. 2 and 3, d represents the air inlet, the same entering the pump cylinder, at its side near and preferably close to the bottom cylinder-head b. Within the cylinder B I have provided, in accordance with this invention, two independent pistons or plungers e and f, the piston e as shown being made cup-shaped and long, and provided at its sides with suitable packing rings e'. The annular cone-shaped top of this outer piston e is fitted to enter the annular recess b^2 in the top cylinder-head b'. The top and sides of the piston e are herein shown as formed of independent parts bolted together, but it is evident the entire piston may be formed in a single piece or member if desired. Within this cup-shaped piston e, which in effect constitutes a second moving cylinder, is placed the inner piston f, shorter in length than the outer piston e and preferably box-like in construction, its under side having preferably a conical recess to correspond with the conical cylinder head b with which it contacts when at the lower end of the stroke, the upper cone-shaped face f' of the said piston f being formed to enter and fit a corresponding recess e^2 at the end or inner face of the head of the piston e. The piston f is provided at its under side with one or more upwardly opening valves f^2, its upper side being perforated by ports or openings f^3, said piston in practice being preferably completely filled with oil or other liquid. The piston e is provided at its head with outwardly opening valves e^3, while the top cylinder head b' is provided with upwardly opening valves b^4. The piston e is shown as fast on the lower end of the tubular piston rod e^4 which passes upwardly through the top cylinder head b' and through the bottom cylinder-head c of the cylinder C, and into the latter where it is provided with a suitable piston e^5. The piston f is fast on the lower end of a piston rod f^4 extended upwardly through the tubular piston-rod e^4 and through the bottom cylinder-head c' of the power cylinder C′ into the latter where it is provided with a piston f^5. The power cylinder C is provided at one side with a suitable valve seat c^3, shown separately in Fig. 12, and as circular, to which lead the ports c^4, c^5, from the upper and lower ends respectively of the power cylinder C, the port c^4 entering the valve seat at one side the center of the latter, while the port c^5 enters the valve seat below the center substantially ninety degrees distant from the port c^4. The power cylinder C′ is also provided with a circular valve seat c^6, see Fig. 14, to which lead the ports c^7, c^8, see dotted lines Fig. 5, from the upper and lower ends respectively of the cylinder, the said ports entering said valve seat at substantially diametrically opposite points located vertically with relation to the valve seat c^6. The valve seats c^3 and c^6 are provided respectively with the exhaust depressions c^9, c^{10}, said depressions communicating respectively with the exhaust ports c^{11}, c^{12}, leading to one side of their respective valve seats, as shown in Figs. 5, 12 and 14.

The valves h and h', which I have herein shown and prefer to employ, are in the form of disks provided at their peripheries with intermeshing teeth whereby rotation of either valve causes a like but opposite rotation of its mating valve.

Referring particularly to Fig. 2, the valve h is mounted upon a central or axial shaft $h^{\times}$ journaled in a suitable boss h^2 formed on a valve face plate h^3 bolted to the cylinder casting, said shaft having at its outer end keyed or otherwise secured to it a worm wheel h^4, which, see Fig. 1, is in mesh with and rotated by a worm h^5 on a horizontally arranged shaft h^6 journaled in suitable bearings h^7, formed in or secured to the frame of the pump, and provided with a belt pulley h^8, by means of which the said worm shaft may be belted to and driven by a suitable driving shaft or wheel, or if desired such worm shaft may be rotated by other means than that herein shown. The valve h' is herein shown as journaled loosely upon a pin or short shaft h^9 mounted in the cylinder casing C' and in the face-plate h^3 secured thereto. The power fluid, preferably a liquid, as oil under pressure, is conducted to the valve h through a pipe entering the face-plate h^3 at the point h^{10}, see dotted lines Fig. 1, while the said power fluid for the valve h' enters the said face-plate at h^{11}, see Figs. 1 and 2. From the power inlet h^{11} for the upper valve h', branches h^{12} lead to diametrically opposite points directly over the entrances to the ports c^7, c^8, of the cylinder C'. The valve h is provided at its outer face side, see Figs. 5, 7 and 11, with an arc-shaped depression h^{13}, in the middle of which is located a port h^{14} which extends through to the inner face side of the valve. The valve h is also provided at its rear side with an arc-like exhaust depression h^{15}. The valve h' is provided with the long arc-shaped port h^{16}, extending through the valve, while the said valve at its rear side is provided with an arc-like exhaust depression h^{17}.

Referring now to Fig. 1, the shaft h^6 has fast upon it the bevel wheel i in mesh with a bevel wheel i' fast on the upper end of the vertical shaft i^2, journaled in suitable bearings i^3 in the frame, said shaft constituting the driving shaft of any suitable or usual rotary or centrifugal pump I, supported upon the base A, said pump having two outlet pipes i^4 leading to the two pumps respectively, each of its delivery pipes i^4 being divided at its end, one branch i^5 leading to the inlet h^{10} for the valve h, while the branch i^6 leads to the inlet h^{11} for the valve h'. The exhaust from the valve h' enters a pipe i^7, Fig. 1, while the exhaust from the valve h enters a pipe i^8, said pipes joining a single pipe i^9 which leads to and constitutes one of the suction pipes for the pump I, said pump I having another like suction pipe leading to the other vacuum pump, as will be clearly understood by reference to Fig. 1.

M represents the air pipe which connects the air inlet of the pump cylinder with the bulbs or other devices which are to be exhausted, said pipe M in the present instance comprising two concentric tubes or pipe m, m', the inner pipe m' constituting the air conduit proper, the space between it and the outer pipe being preferably filled with oil or other sealing fluid to prevent possible leakage.

When the shaft h^6 is rotated, the pump I maintains a constant pressure of fluid in its delivery pipes i^4, and the operation of the pump may then be described as follows, viz:—The valves h and h' are rotated by the shaft h^6 in the direction of the arrows Fig. 5. As soon as the valves have been rotated a short distance from their position Fig. 5, the inlet port h^{14} of the valve h, and the inlet port h^{16} of the valve h' will be moved gradually into position over the ports c^5 and c^8 of and leading to the lower ends respectively of the power cylinders C and C' admitting fluid under pressure from the supply pipe i^4 to the said cylinders below the pistons e^5 and f^5 therein, causing the latter to rise together and thereby move the pump pistons e and f, in the pump cylinder B in unison, the said pistons as herein shown at the very beginning of their movement uncovering the air inlet d. The outer piston e has a shorter stroke than the inner piston f and reaches the end of its stroke in contact with the top cylinder head b' before the piston f has completed more than half its movement, the latter piston f continuing its movement thereafter toward the head of the piston e. The continuous rotation of the valves at this point brings the inlet port h^{14} of the valve h into position over and communicating with the port c^4 leading to the upper end of the lower cylinder C, the exhaust port h^{15} of said valve at the same time reaching a position over and in communication with the port c^5 leading to the lower end of the cylinder, with the result that the direction of movement of the piston e is quickly changed, and the said piston begins its return or downward movement toward the still rising piston f, the two pistons meeting and contacting with each other just before the piston e reaches the end of its downward movement, at which time the valve h' in its rotation has carried its inlet port h^{16} into position over the port c^7 leading to the upper end of the upper cylinder C' and its exhaust port h^{17} over the port c^8 of said cylinder to change the direction of movement of the piston f in the pump cylinder, and cause the latter to descend to the bottom of the pump cylinder preferably in unison and in contact with the piston e through the balance of the stroke of the latter, the piston f thereafter moving downwardly independently of and within the piston e to the end of its stroke. The movements of the pistons are preferably timed as described, but it is evident they may be timed differently or their relative movements changed without departing from the scope of the invention.

The mechanical operation of the pump having now been described, the manner in which the air is exhausted from the bulbs will be described.

Referring to Fig. 2, both pistons are shown at the ends of their down strokes in contact with the bottom cylinder-head b. As previously described, both pistons begin their upward movements or strokes together, and at the very beginning of their strokes uncover the air inlet d, so that the retreating pistons act to draw or suck the air from the lamp bulbs through the pipe M into the cylinder to fill the space left by the retreating pistons. The outer, and what I term the "cut-off" piston e having a shorter stroke reaches the end of its stroke considerably in advance of the main piston f, and immediately begins its return or downward stroke before the piston f has finished its up-stroke, the two pistons meeting, as described, just before the cut-off piston e has reached the end of its return or downward stroke, or just as it has passed and closed the air inlet to cut-off the cylinder from the lamp bulbs. The two pistons now descend together through the balance of and until the cut-off piston e has reached the end of its stroke when the said cut-off piston stops and dwells until the inner or main piston finishes its downward stroke and contacts with the bottom cylinder-head b, such downward movement of the main piston f causing the air previously drawn into the cylinder by its up-stroke, to be forced upwardly through and opening the valve f^2 into the oil or liquid contained within the piston, the air rising through the latter and through the ports f^3 into the auxiliary cylinder formed within the cut-off piston e and between it and the said piston f. At the next up-stroke of these two pistons this body of rarefied air is carried bodily upward between the two pistons until the outer or cut-off piston reaches the end of its stroke, when further rising movement of the piston f within the cut-off piston, together with the return or downward movement of the said cut-off piston, causes the rarefied air contained between the two to be compressed until the two pistons meet, when the piston f, striking the valves e^3, will open the latter and cause the air compressed between the two pistons to be expelled through the said valves into the space between the cut-off piston e and the cylinder head b' in which it is compressed at the next upward stroke of the cut-off piston, and expelled from the cylinder B when the said cut-off piston reaches the end of its stroke and contacts with and opens the valves b^4, the air thus expelled escaping into the atmosphere through the exhaust N, Fig. 3.

The advantages of this pump are as follows, viz:—The air inlet d being placed at or near the bottom of the pump cylinder, is substantially at the very beginning of the stroke uncovered or opened to permit the air from the bulbs to be sucked or drawn into the cylinder by the upward or drawing-in movements of the pistons, said inlet remaining open until the inner main piston f has nearly or quite reached the end of its upward stroke, so that the benefit of its full stroke is obtained in drawing in the air from the bulb. The cut-off piston begins to cut-off or close the air inlet before the main piston reaches the end of its up or drawing-in stroke, so that by the time the said inner or main piston begins its down or expelling stroke, the said cut-off piston may completely close the air inlet, and thereby prevent the return of any air from the cylinders to the bulbs, so that all the air previously drawn into the cylinder must of necessity be expelled through the valve f^2 rather than returned back to the bulbs. I am thus enabled to open and close the air inlet at such times as will secure the most effective exhaustion of air from the lamp bulbs, and this without using the ordinary valves, but by using the cut-off piston e, which, as hereinbefore stated, is not open to the objection of the oil film closing the inlet. The air is not required to expand into and of itself fill the cylinder, but is, from substantially the moment the air inlet is opened, drawn into the pump cylinder by the retreating piston f, so that the greatest possible quantity of air is drawn into the cylinder at each stroke. Neither is the sluggishly moving air required to be drawn quickly into the pump cylinder, but is drawn in gradually throughout the rising or drawing-in stroke of the main piston, giving ample time for moving the air.

By employing hydraulic pressure to move the pistons e and f, I am enabled to better control and govern the movements of said pistons and to give either or both of them such proper amount of dwell at the ends of their respective strokes as will most increase the efficiency of the pump.

By reference to Fig. 2 it will be seen that two degrees of vacuum are formed at each stroke into which the rarefied air drawn from the lamp bulbs is exhausted,—for example, the air drawn from the bulbs into the cylinder beneath the piston f is first expelled or forced into the vacuum chamber within the two pistons, and from such vacuum chamber is again expelled or forced into a second vacuum chamber between the piston e and the top cylinder-head b', the great advantage of this being that the rarefied air from the lamp bulbs and which is drawn into the cylinder by the piston f, is more easily forced or expanded successively into the vacuum chamber between the two pistons, and between the piston e and the cylinder head b', and then into the atmosphere, than could be possible were it attempted to expel such rarefied air from the cylinder B direct into the atmospheric pressure without the intervention of the vacuum chambers.

The pump I, which constitutes a pressure creating device to store pressure with which to actuate the power pistons, is shown connected with the same mechanism which actuates the valves, so that when once properly adjusted the rapidity with which the pressure is created or stored varies directly with the movements of the valves, and the consequent rapidity with which the pressure is utilized. It will also be seen that a series of pumps may be connected together, so that all the valves may be moved constantly with relation to each other, and a single pressure creating device employed for or be provided the several pistons within a single cylinder, as shown.

A single pump cylinder, or with its connected power cylinders, which constitutes what I herein term a "single pump," fulfills the functions, viz:—provides different degrees of vacuum, usually fulfilled by two or more independent pumps connected together, so that a complete exhaust apparatus is in my invention embodied in a single pump, whereas in the present construction a plurality of independent pumps must be connected together to secure different degrees of vacuum.

In practice both pumps are connected as shown in Fig. 1, so that they operate together in expanding air from the lamp bulbs.

I have herein shown and described my invention as embodied in one form of apparatus or machine, but this invention is not limited to the particular construction or form of pump shown, for it is evident the gist of the invention may be embodied in many varying constructions without departing from the spirit and scope of the invention.

I have herein employed the terms upper and lower in connection with the power cylinders and have described the apparatus as vertically arranged, but it will be obvious that my invention would not be departed from by laying the apparatus on its side.

In vacuum pumps which are designed for use in creating the highest possible vacuum it is absolutely necessary that the piston or pistons moving within the pump cylinder be firmly and squarely seated at each end of their respective strokes, in order that all air contained between the moving piston and the wall which constitutes the end of the cylinder within which the piston moves, may be expelled. If there be a particle of clearance at the end of a piston stroke the quantity of air contained in said clearance represents the quantity of air which can never be expelled and therefore never exhausted from the lamp bulb or other article to be exhausted.

By the term "seated" as used in the claim is meant the contact of a piston at the end of its stroke with the end of the cylinder, or with a co-operating piston operating in connection with it and which constitutes the movable end or wall of the cylinder within which the first named piston actually moves, it being immaterial whether the piston contacts with a fixed or movable wall so long as it is firmly seated against such wall to thereby expel all air between said piston and said wall.

I claim—

1. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder, an inlet and outlet therefor; a cut-off piston to open and close said inlet; a main piston; one or more passages therein through which fluid drawn into said cylinder is forced; and means to reciprocate said pistons, substantially as described.

2. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder, an air inlet therefor, a pump piston therein; a power cylinder, its piston connected with and to move said pump piston; valves to control the movements of said power piston and its connected pump piston; and independent automatic valve operating mechanism actuated independently of said pistons whereby the movements of said valves may be varied at will irrespective of said pistons, substantially as described.

3. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder, an air inlet in the side thereof near one end; a tubular cut-off piston within said cylinder to cover and uncover said inlet; a main piston moving within said tubular piston; one or more passages in said main piston through which fluid drawn into said cylinder is forced; valves controlling said passages, and means to reciprocate said pistons to operate, substantially as described.

4. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof; main and cut-off pistons in said cylinder; two power cylinders and pistons therein connected respectively with said main and cut-off pistons, substantially as described.

5. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof; main and cut-off pistons in said cylinder; two power cylinders arranged with axes coincident with the axis of said pump cylinder; and pistons therein connected respectively with said main and cut-off pistons, substantially as described.

6. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof; pump pistons in said cylinder; two power cylinders; pistons

therein connected respectively with and to actuate said pump pistons; and valves for said power cylinders connected to move together, but having differently arranged ports to thereby produce different movements of said pistons, substantially as described.

7. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof at or near one end; main and cut-off pistons therein and means to reciprocate the same, the said cut-off piston being moved to open and again close said port while the main piston is moving in one direction, substantially as described.

8. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof; main and cut-off pistons in said cylinder moving one within the other, and at the ends of their reciprocations in one direction resting upon a common cylinder head, substantially as described.

9. A vacuum pump, containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof; main and cut-off pistons in said cylinder, moving one within the other, said pistons at the ends of their reciprocations in one direction resting upon a common cylinder head and at or near the ends of their reciprocations in the opposite direction contacting one with the other, and valves in said pistons, substantially as described.

10. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; an air inlet in the side thereof; main and cut-off pistons in said cylinders moving one within the other, the inner or main piston at the end of its drawing-in movement contacting with the cut-off piston in its cutting-off movement, the main piston changing its direction of movement to and returning for a time in unison with the further cutting-off movement of the said cut-off piston, substantially as described.

11. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder provided with valves; an air inlet for said cylinder; two pistons moving one within the other in said cylinder; valves in and means to move said pistons whereby a vacuum is formed between the two pistons into which the air drawn into the cylinder is permitted to enter, and a second vacuum formed in the said cylinder between its end and said pistons into which the air from the space between said pistons is exhausted, substantially as described.

12. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; a cut-off piston therein cone shaped at its upper side, and having a cone-shaped recess at its under side; valves in said piston; a main piston movable within said cut-off piston and also made crowning at its upper side and provided with a conical recess at its under side, the conical cylinder head b and head b' having a conical recess, valves in said main piston and in said cylinder head b', power cylinders and pistons therein connected with and to move said main and cut-off pistons, all to operate, substantially as described.

13. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; a pump piston therein; a power cylinder, a piston therein connected with and to operate said pump piston, a pressure creating device and power connections between it and the inlet and exhaust of said power-cylinder, whereby said device takes the exhaust fluid from said power-cylinder and returns it again thereto under pressure to actuate the piston therein; valves controlling said inlet and exhaust, and means to actuate said valves and said pump, substantially as described.

14. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; pump pistons therein; power cylinders and pistons therein connected respectively with and to operate said pump pistons; rotatable toothed intermeshing valves to control movements of said power pistons, and means to rotate said valves, substantially as described.

15. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; pump pistons therein; power cylinders, pistons therein connected with and to operate said pump pistons; valve seats c^3, c^6 provided respectively with exhaust depressions c^9, c^{10}; and inlet ports for the said power cylinders; valves h and h', having inlet ports h^{14}, h^{16}, and exhaust depressions h^{15}, h^{17}, and means to rotate said valves, all to operate, substantially as described.

16. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; pistons therein; power cylinders, pistons therein connected with and to operate said pump pistons; rotatable valves for and to control said power cylinders; and worm-wheel mechanism to rotate said valves, substantially as described.

17. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder, pistons therein; power cylinders, pistons therein connected with and to operate said pump pistons; valves to control said power cylinders and the movements of the pistons therein; a pressure creating device, as the pump I, to create pressure to actuate the power pistons; and common actuating mechanism for said valves and pressure creating device whereby the pressure created varies with and follows the movements of said valves, substantially as described.

18. A vacuum pump containing the following instrumentalities, viz:—a base; a plurality of pump cylinders, pistons in each; power cylinders and pistons therein connected with and to actuate the said pump pistons, valves for the said power pistons; common actuating mechanism for said valves whereby the pistons in the said power cylinders are caused

to move uniformly with relation to each other; a single pressure creating device to supply fluid under pressure for and to operate said power pistons, substantially as described.

19. A vacuum pump containing the following instrumentalities, viz:—a pump cylinder; a main box-like piston *f* adapted to be filled with oil, and a cut-off piston *e*, both in said cylinder; valves f^2 and e^3; and means to reciprocate said pistons relatively to each other, substantially as described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

EDWIN D. CHAPLIN.

Witnesses:

HENRY G. HALLORAN,

FREDERICK L. EMERY.