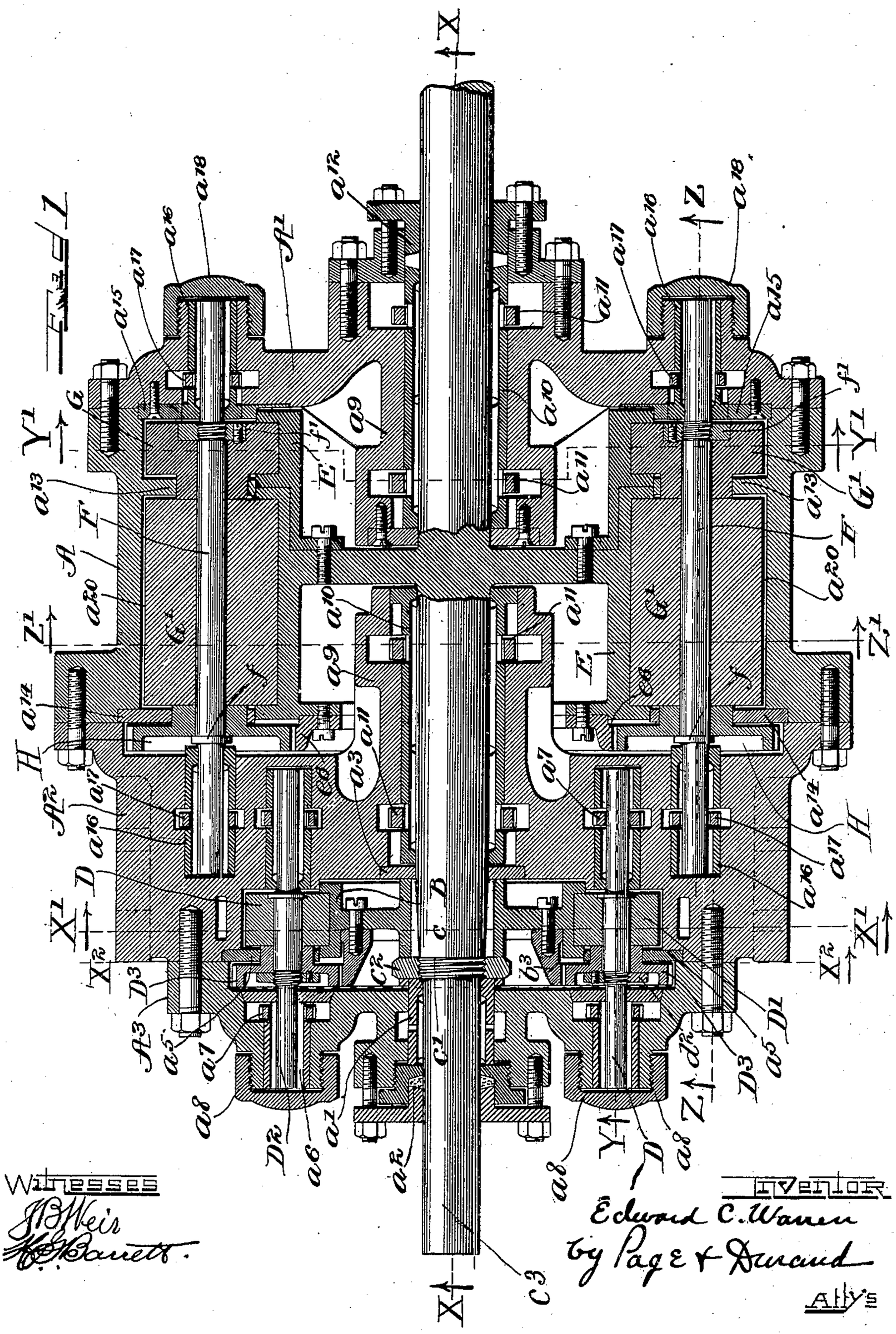
No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 1.



Witnesses
H. C. Weir
K. C. Barrett.

Inventor
Edward C. Warren
by Page & Durand
Atty's

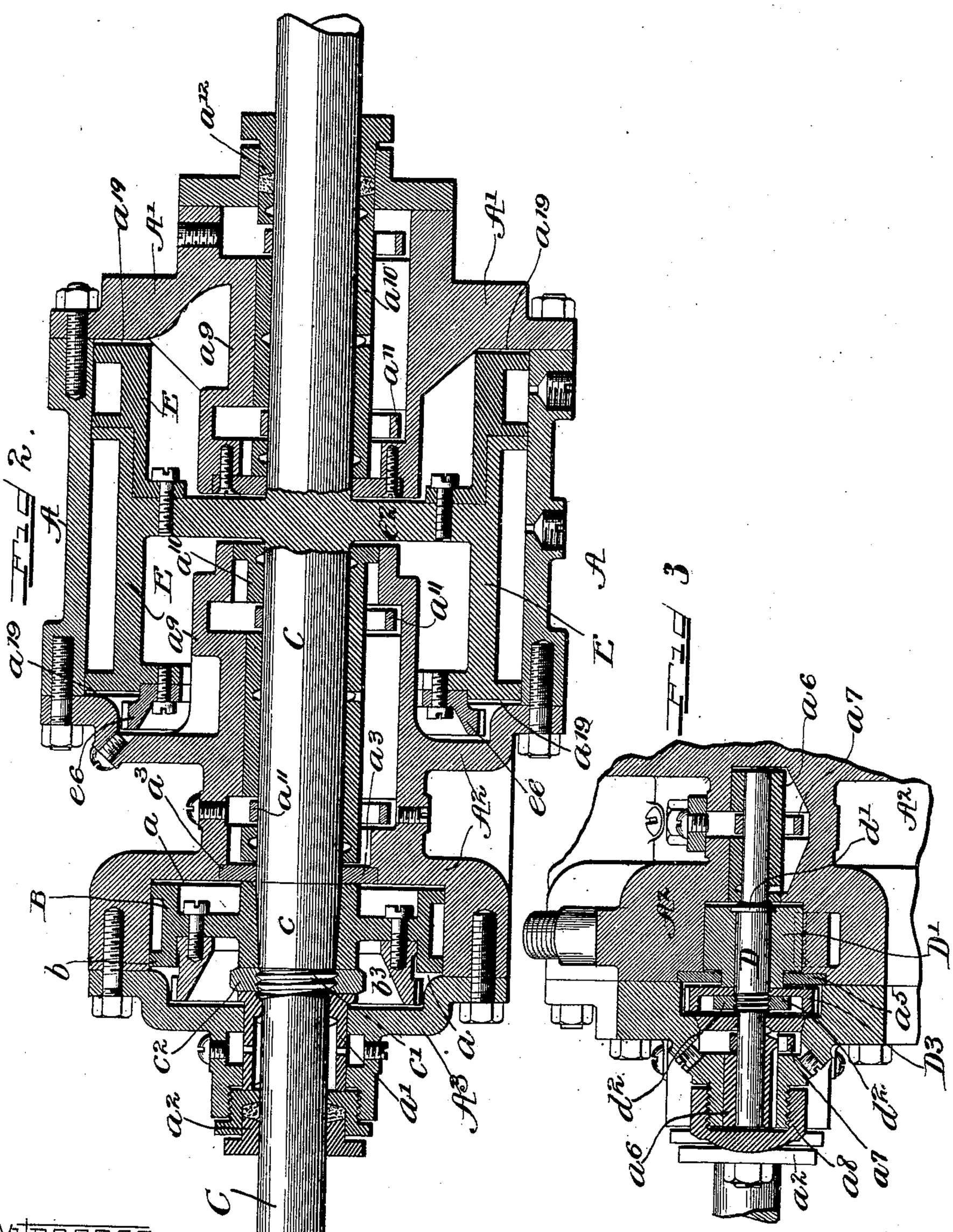
No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 2.




Witnesses
J. B. Weil.
H. B. Barnett.

Inventor
Edward C. Warren
by Page & Durand Attys

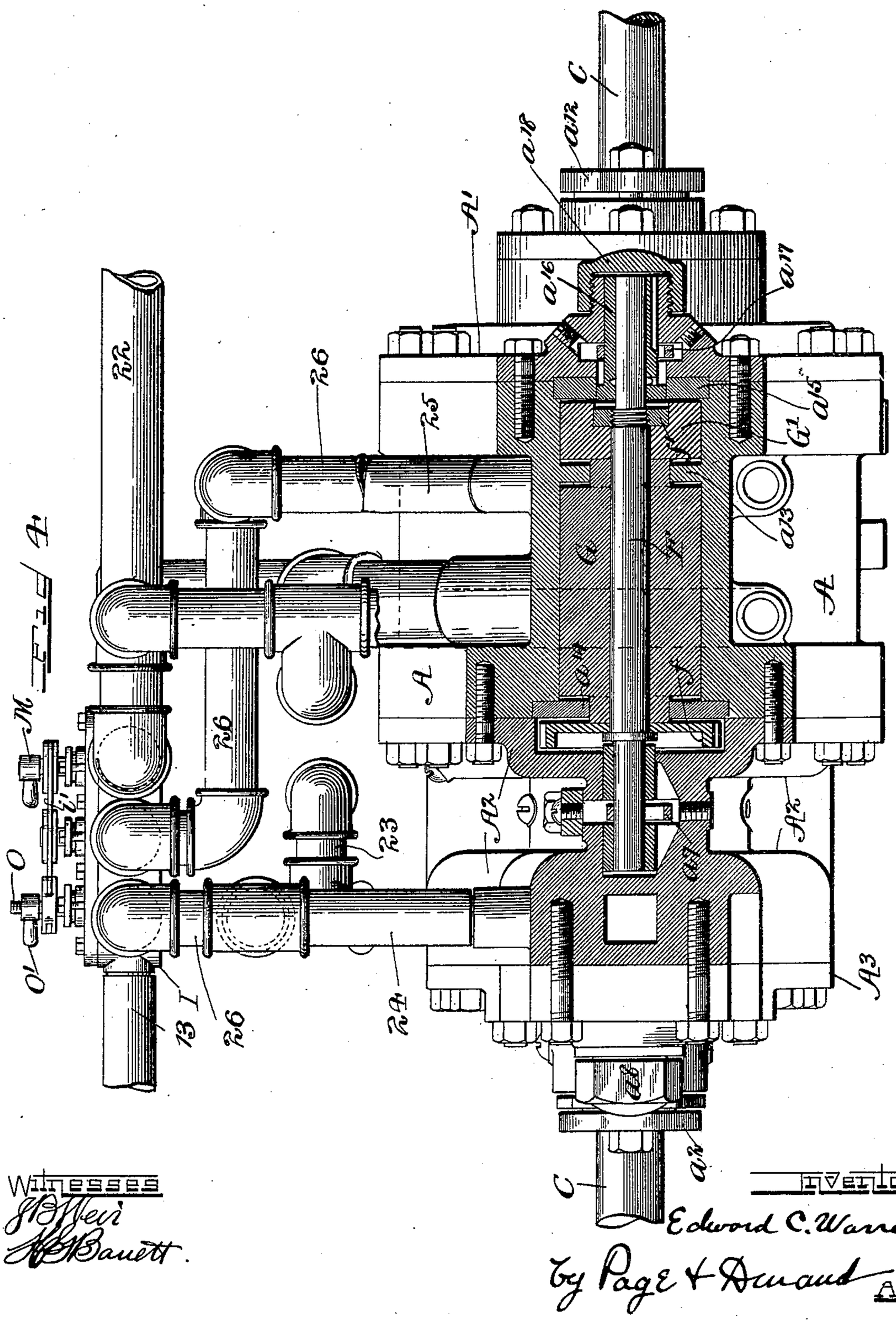
No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 3.




Witnesses
S. B. Weir
H. B. Barrett.

Inventor
Edward C. Warren
by Page & Durand Atty's

No. 680,509. Patented Aug. 13, 1901.

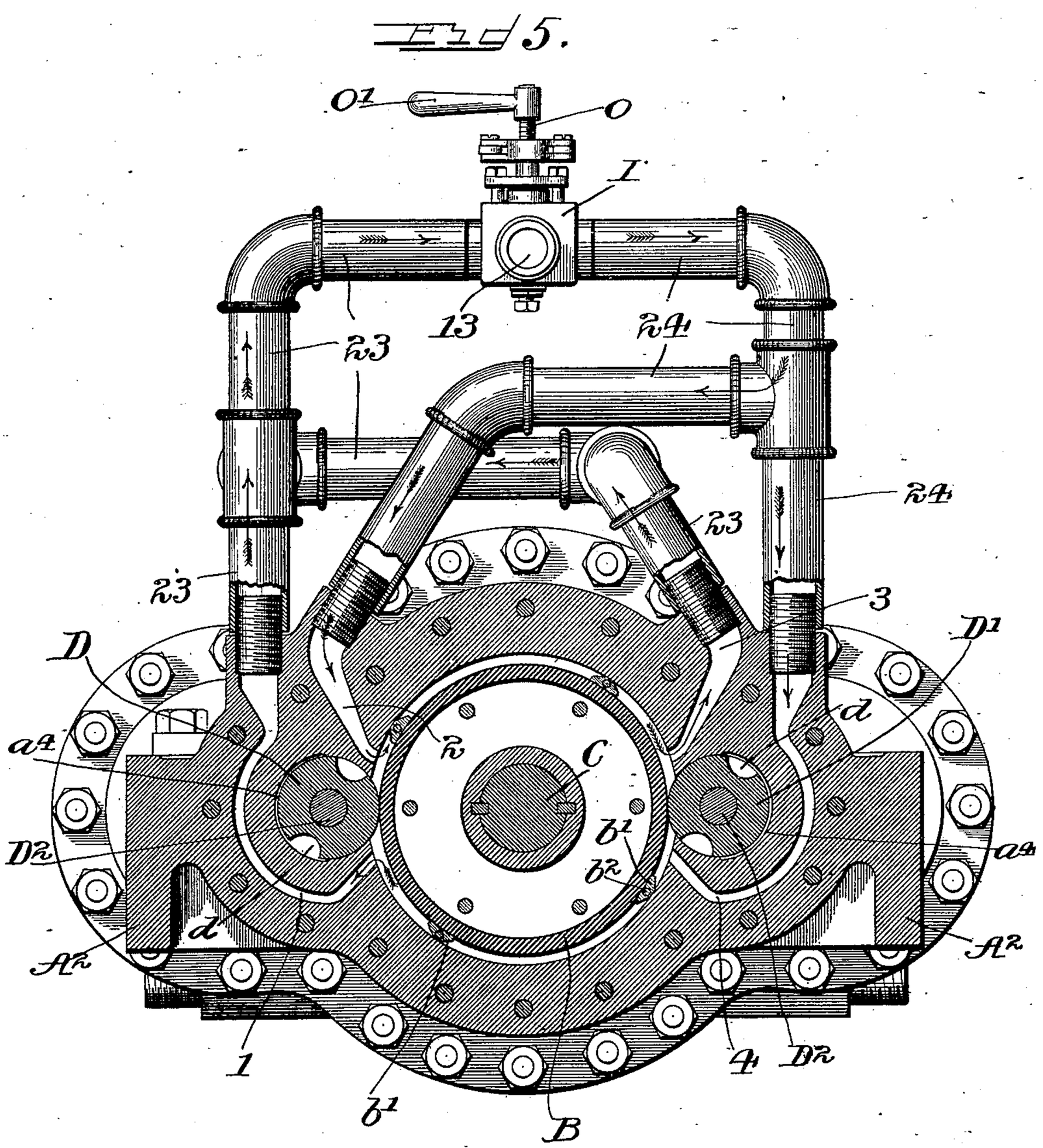
# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 4.

Fig 5.




Witnesses
J. B. Weir
H. B. Barnett

Inventor
Edward C. Warren
by Page & Dyrand Atty's

No. 680,509. Patented Aug. 13, 1901.

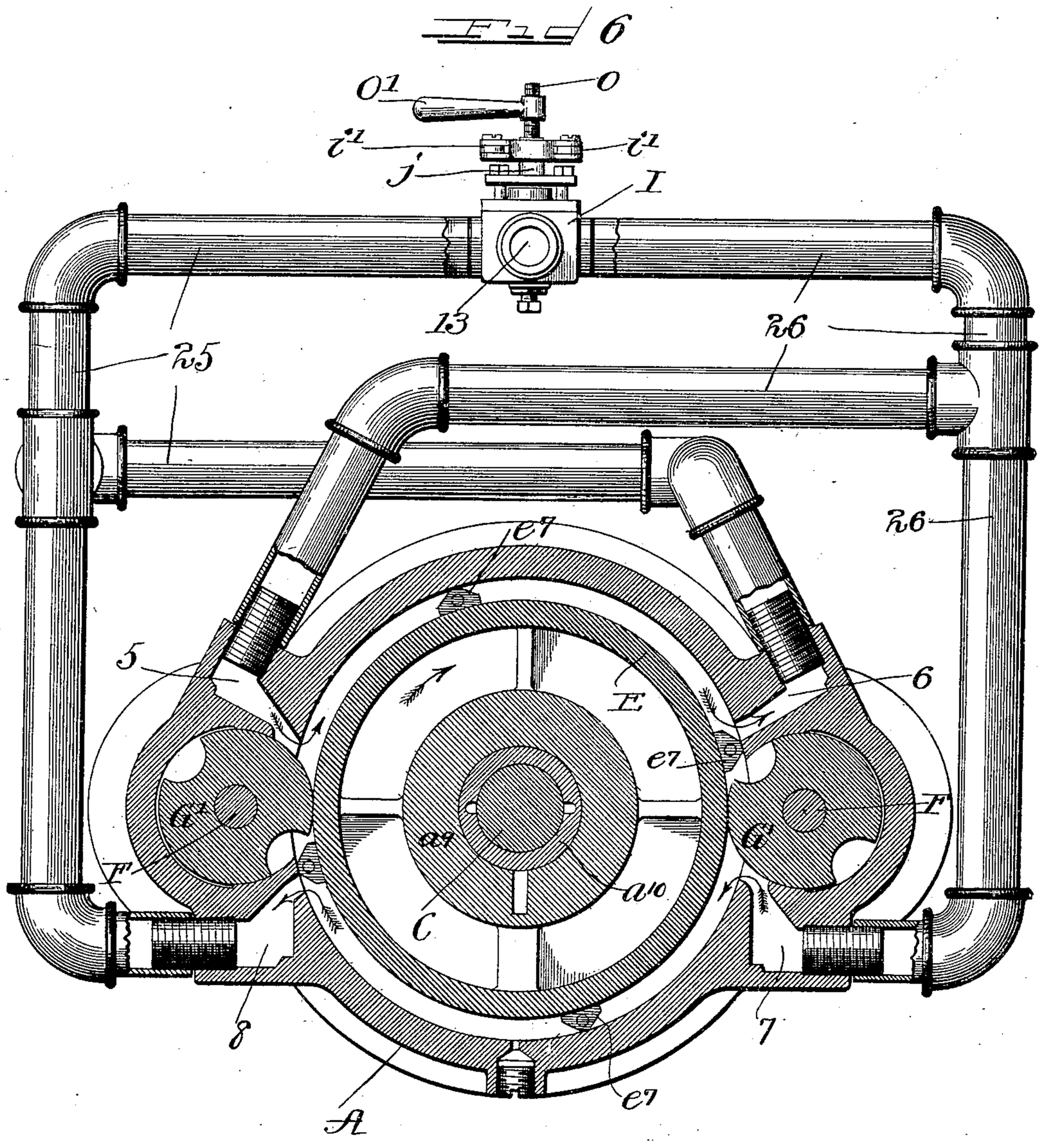
# E. C. WARREN.

## ROTARY ENGINE.

Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 5.

Fig 6




Witnesses
J. B. Weir
H. G. Barnett

Inventor
Edward C. Warren
by Page & Durand
Atty's

No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 6.

Fig. 7

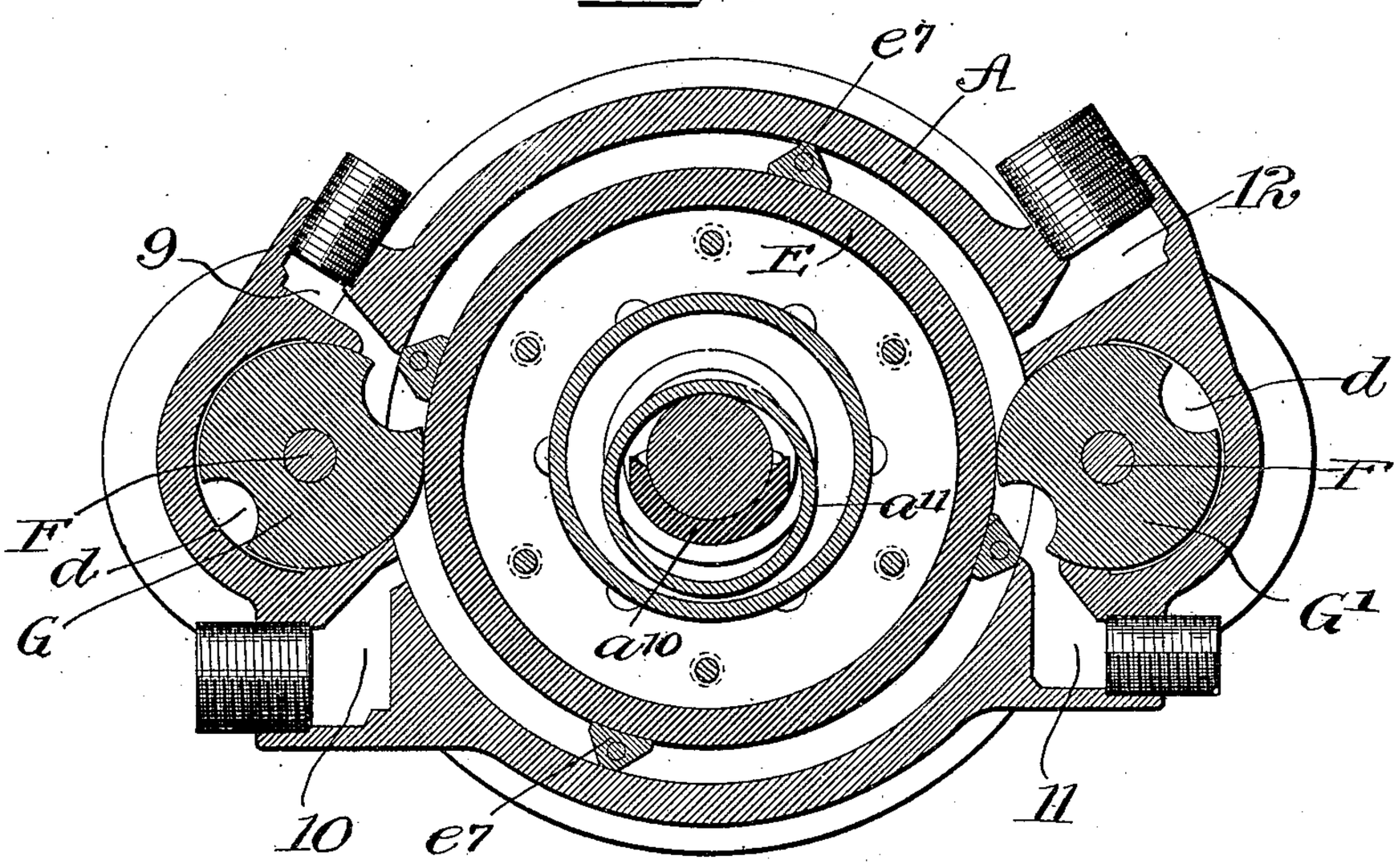
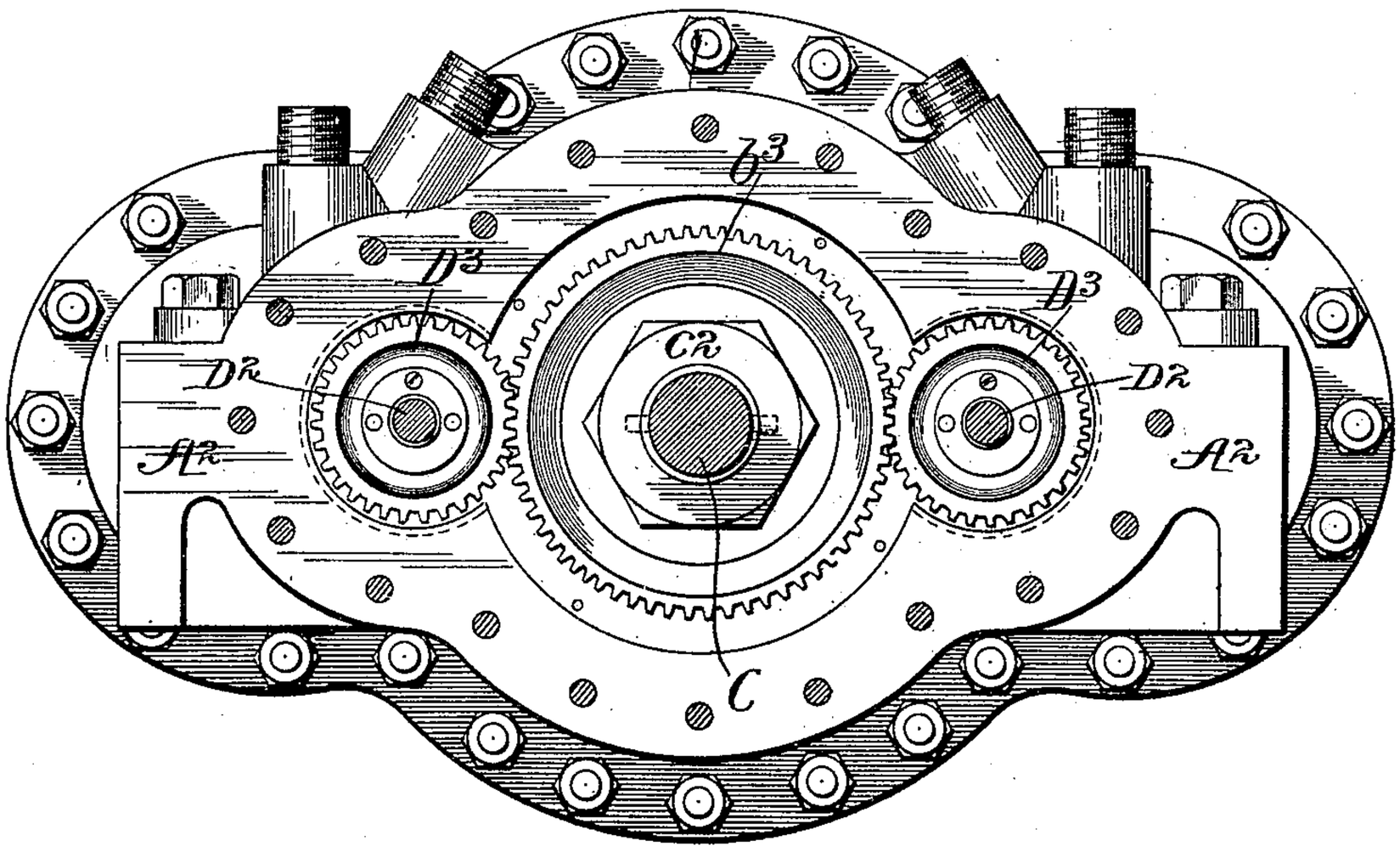



Fig. 8.




Witnesses
J. B. Weir
H. B. Barnett

Inventor
Edward C. Warren
by Page & Durand
Atty's

No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 7.

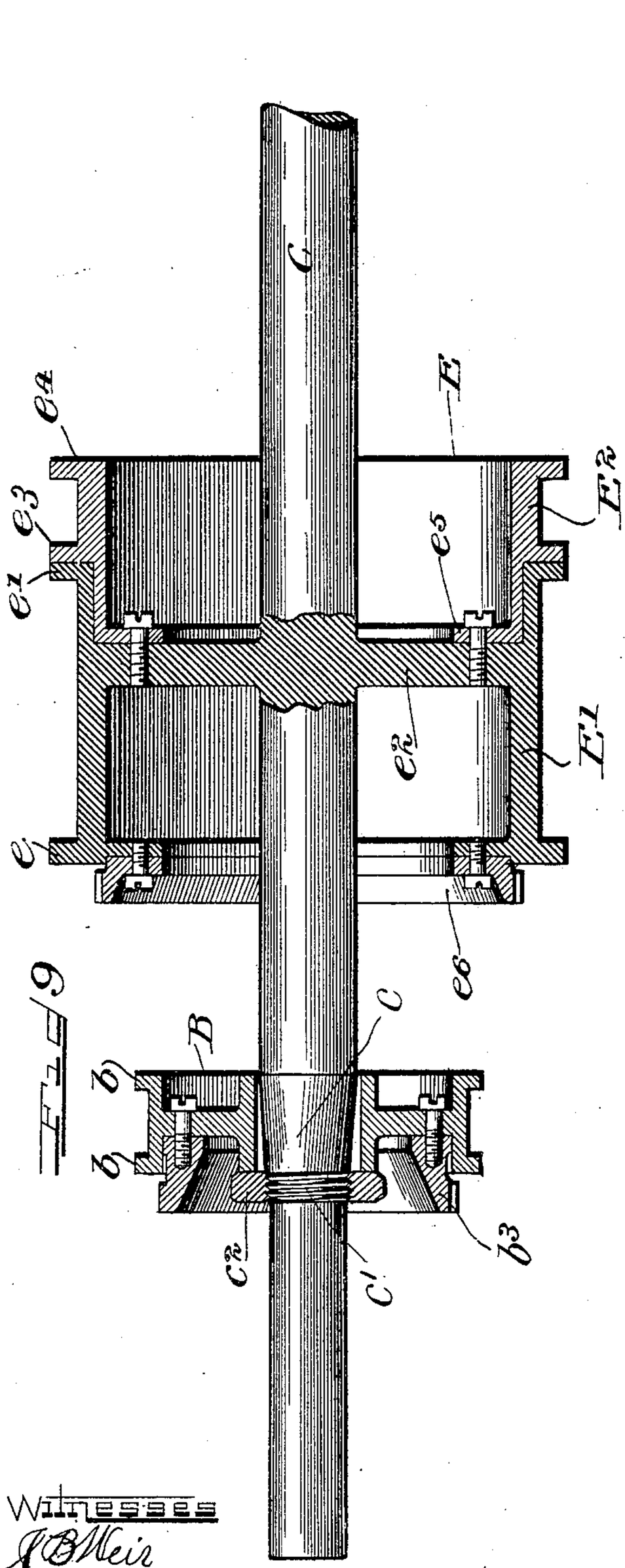



FIG 9.

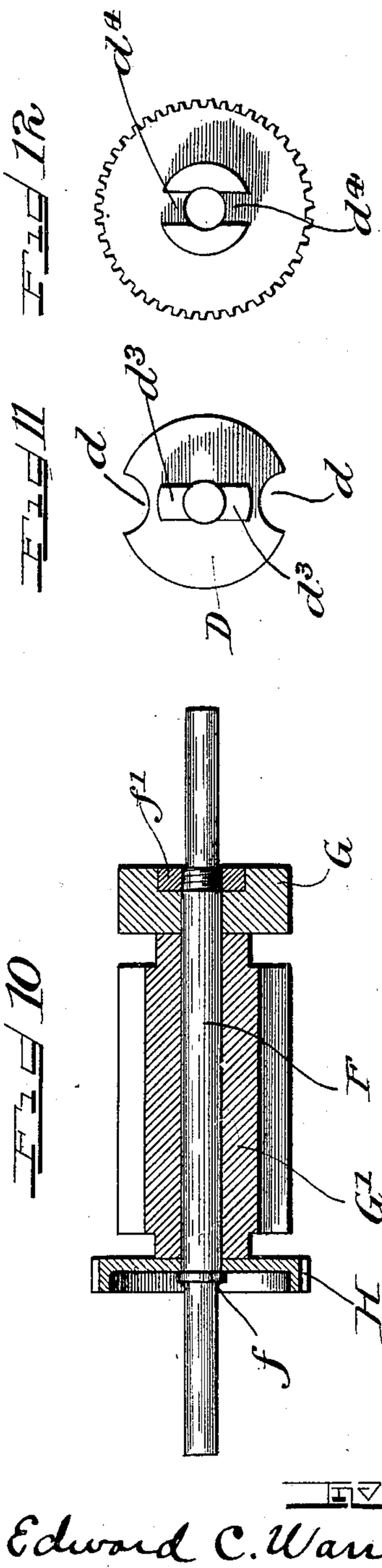



FIG 12. FIG 11.




FIG 10.

Witnesses
J. B. Weir
H. G. Barrett

Inventor
Edward C. Warren
by Page & Durand Atty's

No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 8.

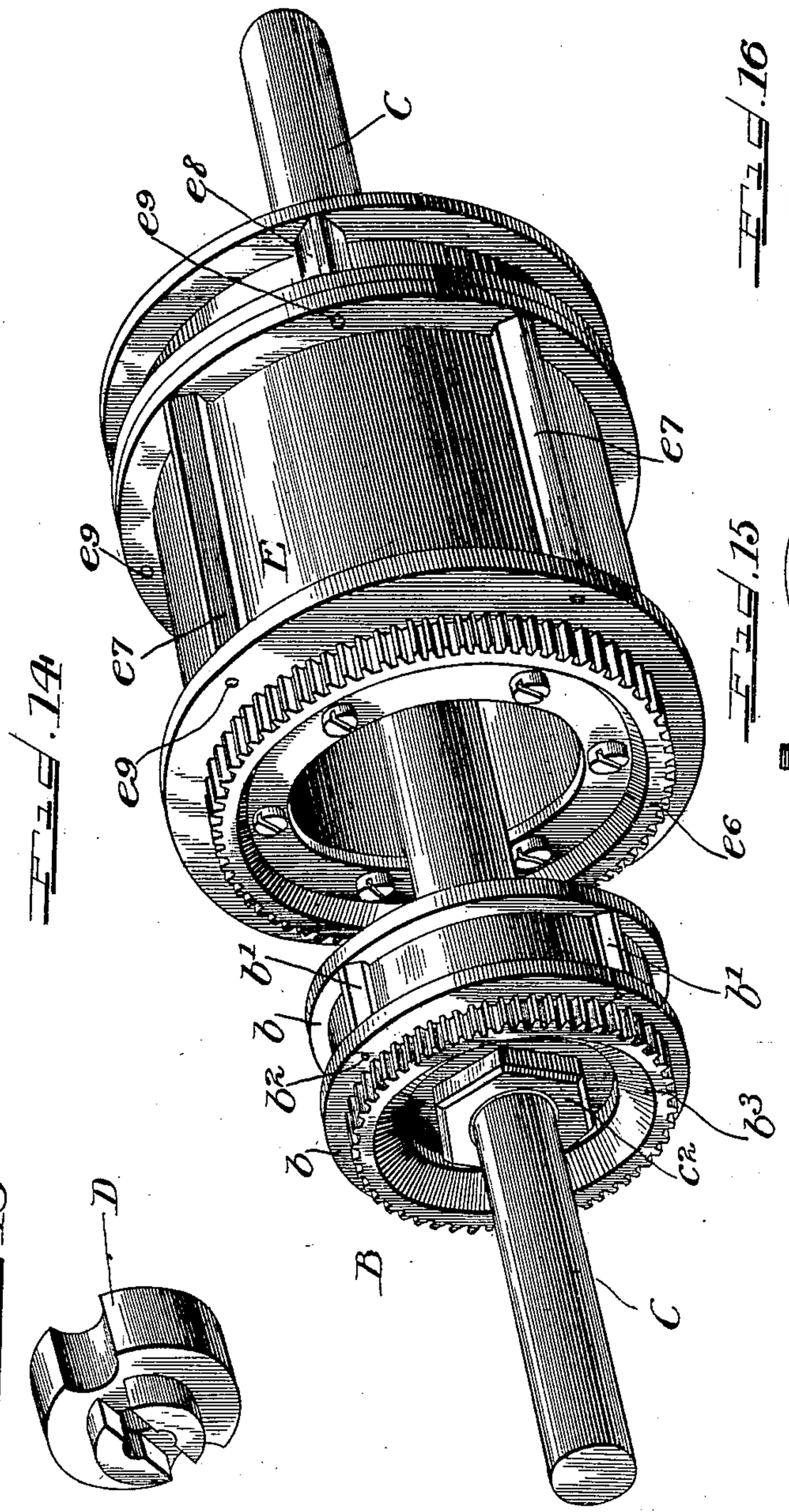



FIG. 14.




FIG. 13.

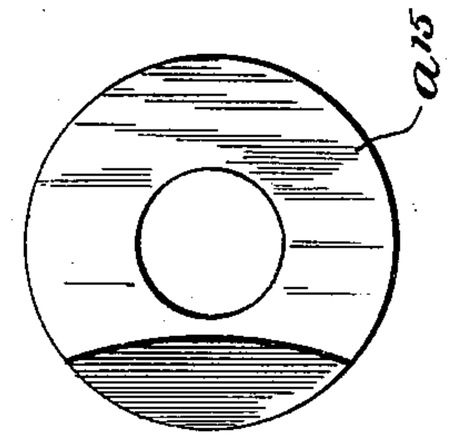



FIG. 16.

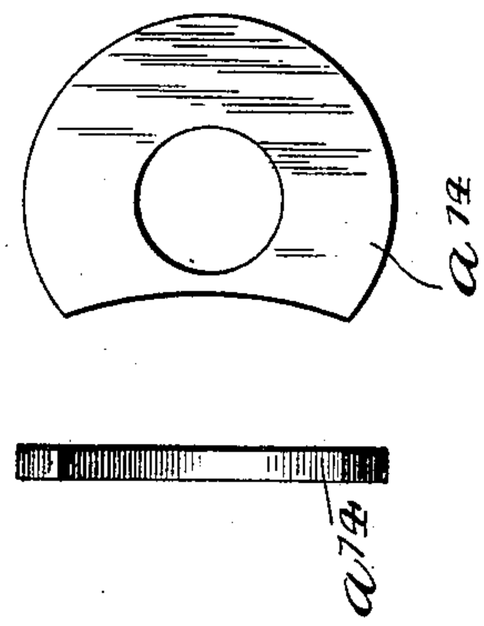



FIG. 15.

Witnesses
J. B. Weir
H. G. Bennett

Inventor
Edward C. Warren
by Page & Durand
Attys

No. 680,509. Patented Aug. 13, 1901.

# E. C. WARREN.

## ROTARY ENGINE.

(Application filed Jan. 22, 1900. Renewed Feb. 5, 1901.)

(No Model.) 9 Sheets—Sheet 9.

Fig. 17.

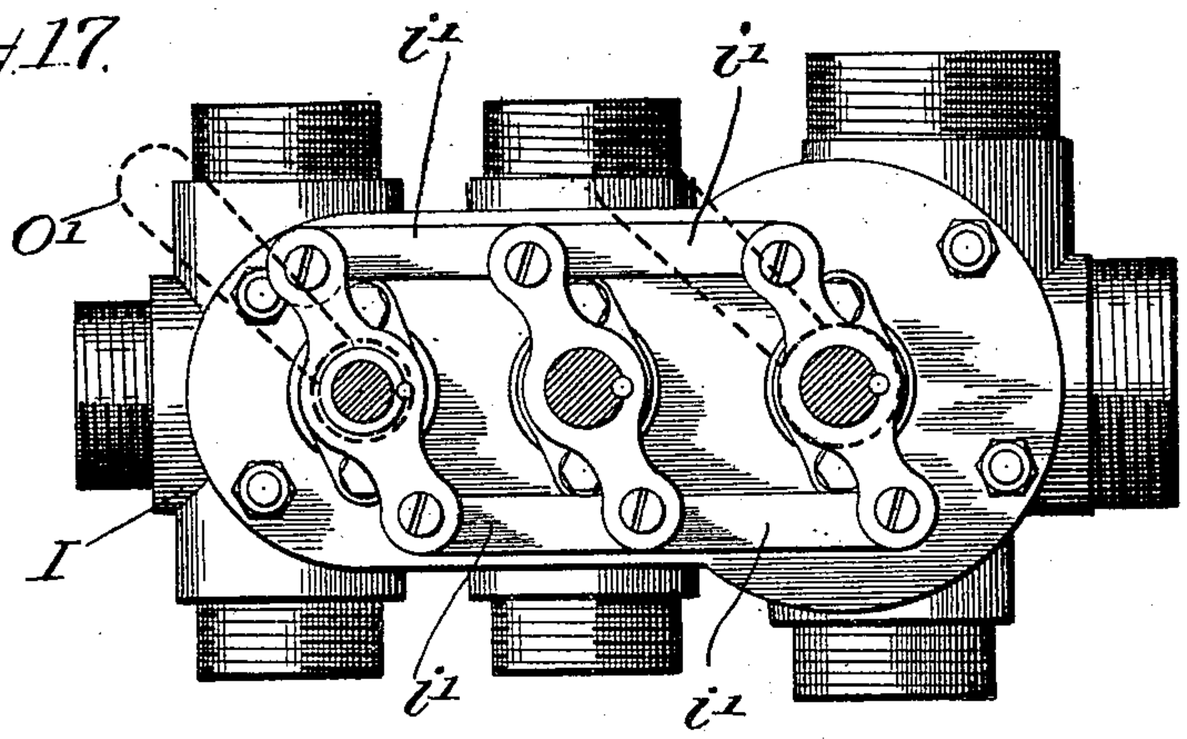



Fig. 18.

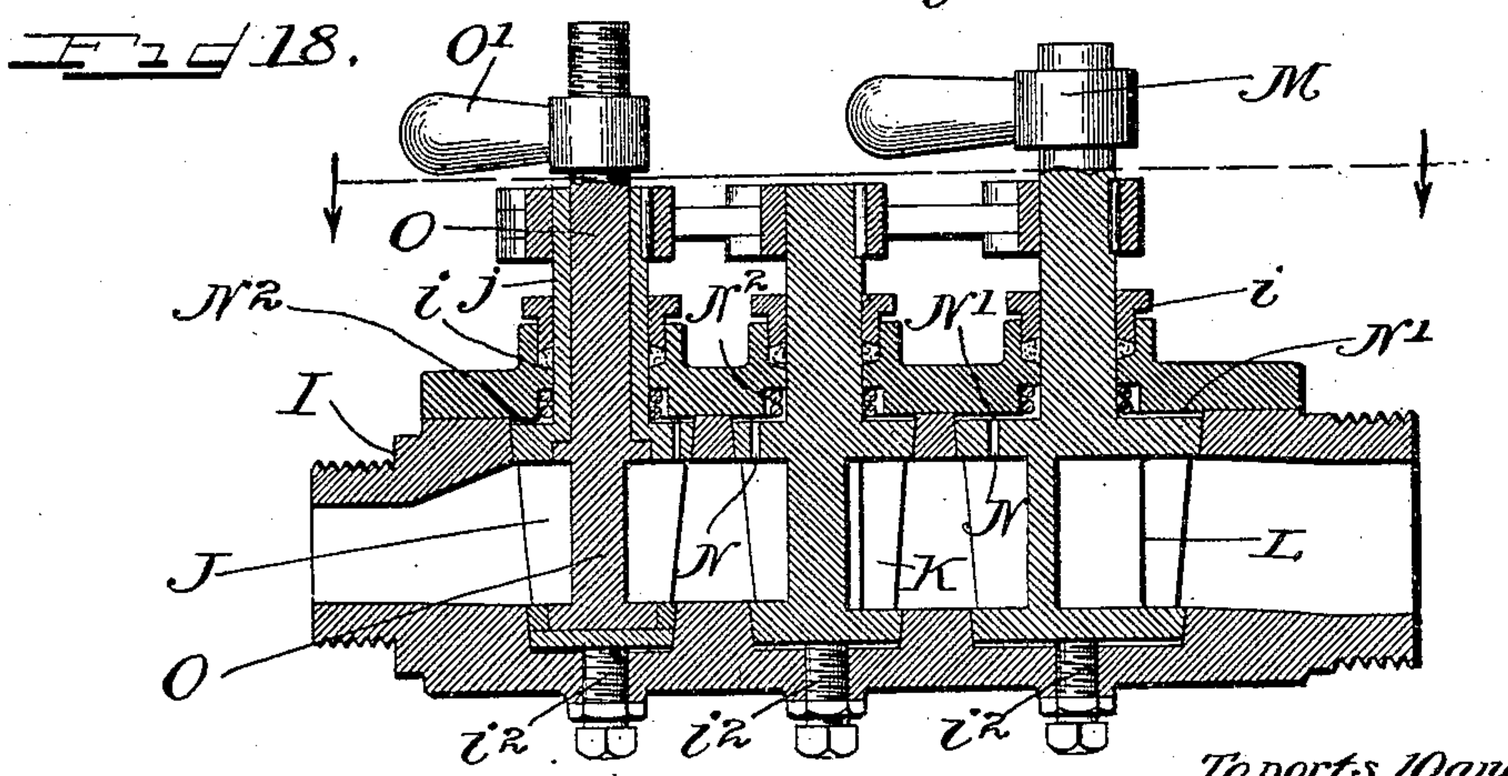
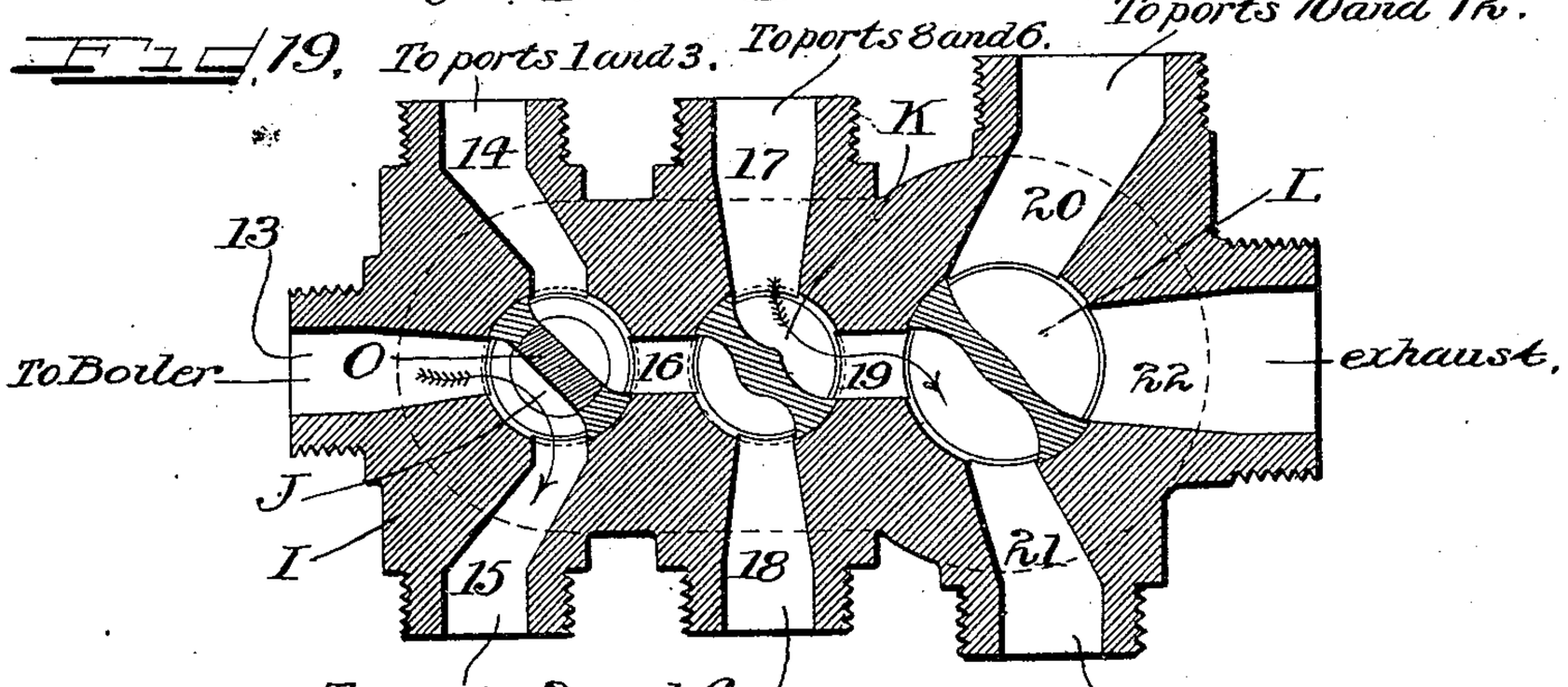



Fig. 19.




Witnesses
J. B. Weir
W. S. Smith

Inventor
Edward C. Warren
by Page & Durand
Attys

# UNITED STATES PATENT OFFICE.

EDWARD C. WARREN, OF CHICAGO, ILLINOIS.

## ROTARY ENGINE.

SPECIFICATION forming part of Letters Patent No. 680,509, dated August 13, 1901.

Application filed January 22, 1900. Renewed February 5, 1901. Serial No. 46,153. (No model.)

*To all whom it may concern:*

Be it known that I, EDWARD C. WARREN, residing at Chicago, in the county of Cook, State of Illinois, have invented a certain new and useful Improvement in Rotary Engines, of which the following is a specification.

My invention relates to rotary fluid-motors in general, but more particularly to those of the annular chamber rotary-abutment type.

Objects of my invention are to provide a compact and an efficient rotary engine, to provide a construction tending to facilitate the assembling of the various parts, to secure a maximum strength and rigidity with a minimum of metal, to dispense with packing and to reduce friction, to provide a construction in which all parts subject to wear are readily removable for the purpose of repair, to provide a smooth and easy-running engine capable of high speed, to provide a construction in which the parts will not tend to work loose, to provide a rotary engine which can be readily reversed to provide an improved form of reversing-valve, to provide an improved form of valve mechanism whereby the engine can be reversed and whereby the high-pressure piston can be rendered neutral and live steam admitted directly to the intermediate-pressure chamber, to provide an improved construction and arrangement of gearing for connecting the piston with the rotary abutments, to provide an improved and highly efficient construction of compound rotary engine, and to provide certain details and features of improvement tending to render a motor of this character serviceable and thoroughly reliable.

To the attainment of the foregoing and other useful ends I provide an engine-casing having space between its inner surface and the ends of the pistons and provide a thrust-bearing which prevents end movement on the part of the shaft. Each piston is preferably provided with flanges, which form the end walls of the annular pressure-chambers. The peripheries of the flanges fit the casing, and the rotary abutments are constructed to fit snugly between the flanges. In this way comparatively tight pressure-chambers are provided, reducing leakage to a minimum, and at the same time the pistons are free to revolve smoothly and with very little friction. The combined intermediate and low pressure piston is preferably made in two sections, and one section is provided with a web, which is formed integral with the shaft. As a matter of further improvement the rotary abutments for this intermediate and low pressure piston are made in sections, which are provided with interlocking ends. The said piston is provided with a toothed ring which engages pinions on the abutment-shafts, and these pinions are preferably formed with hub portions which interlock with the ends of the abutments. The high-pressure piston, which is preferably keyed to the piston-shaft, is also provided with a toothed ring which engages pinions on a second pair of abutment-shafts, and these pinions, like the first, also have portions which interlock with the ends of the abutments. With this construction and arrangement the various parts can be easily assembled, and, furthermore, all parts subject to wear are readily removable for the purpose of repair or substitution. By forging or otherwise forming the low-pressure portion of the piston integral with the shaft strength and rigidity are secured and danger of the piston working loose from the shaft is avoided. The cylinder or casing is preferably constructed in such manner that all parts are inclosed, thereby not only rendering the engine dust-proof, but also muffling the rattle of the gearing. The engine is readily reversible, and for such purpose I provide an improved form of reversing mechanism consisting of three rotary plug-valves which are connected for simultaneous adjustment and which are adapted to control the ports and passages leading to the three pressure-chambers. Also, as a matter of further and special improvement, I provide one of these rotary plug-valves with a supplemental by-pass valve, whereby the high-pressure piston can be rendered neutral and the live steam admitted directly to the intermediate-pressure chamber.

Other advantages and features of improvement will hereinafter more fully appear.

In the accompanying drawings, Figure 1 is a horizontal and central section through a rotary engine embodying the features of improvement and principles of my invention. Fig. 2 is a vertical section on line *x x* in Fig. 1. Fig. 3 is a vertical section on line Y Y in Fig. 1. Fig. 4 is a vertical section on line Z Z

in Fig. 1. Fig. 5 is a transverse vertical section on line $x'$ $x'$ in Fig. 1. Fig. 6 is a transverse vertical section on line Y′ Y′ in Fig. 1. Fig. 7 is a transverse vertical section on line Z′ Z′ in Fig. 1. Fig. 8 is a tranverse vertical section on line $x^2$ $x^2$ in Fig. 1, or, in other words, a view showing the supplemental cylinder-head removed. Fig. 9 is a detail view of the piston-shaft and two pistons, showing the latter in central longitudinal section. Fig. 10 is a detail view of one of the abutments for the intermediate and low pressure piston, showing the abutment and pinion in longitudinal section and mounted upon the abutment-shaft. Fig. 11 is an end view of one of the abutments, showing the interlocking lugs. Fig. 12 is a view of one of the pinions, showing the recessed hub which is engaged by the lugs on the abutment. Fig. 13 is a perspective of the shorter section of one of the rotary abutments which coöperate with the intermediate and low pressure piston. Fig. 14 is a perspective of the two pistons and piston-shaft. Figs. 15 and 16 are detail views of the recessed rings which are arranged at the ends of the abutments and which form the end walls of the abutment-chambers. Fig. 17 is a plan of the improved reversing mechanism. Fig. 18 is a vertical section on line $Y^2$ $Y^2$ in Fig. 17. Fig. 19 is a horizontal section on line $Z^2$ $Z^2$ in Fig. 17.

As thus illustrated, the cylinder or engine casing is composed of an intermediate or body portion A, a couple of oppositely-arranged heads A′ and $A^2$, and a supplemental head or casting $A^3$. The head $A^2$ preferably has its outer side recessed to receive the high-pressure piston B. The supplemental head $A^3$ is bolted to the head $A^2$ and is adapted to inclose the said piston. A piston-shaft C, having a tapered portion $c$ and a threaded portion $c'$, is arranged to extend longitudinally through the cylinder or casing, and the piston B is clamped upon the tapered portion $c$ by a nut $c^2$, screwed upon the threaded portion $c'$. The said piston is annular in form and provided with annular peripheral flanges $b$, which serve as end walls for the annular high-pressure chamber. Piston-heads $b'$, preferably four in number, are arranged between the said flanges and are removably secured to the piston by pins $b^2$, which extend through the heads and flanges. An annular toothed ring $b^3$ is secured to the outer end of said piston, preferably by screws or bolts, and the engine-casing is constructed so as to provide spaces $a$ at each end of the piston—that is to say, in such manner that the only portions of the piston which contact with the casing are the peripheries of the flanges $b$. In this way the annular high-pressure chamber is rendered comparatively steam-tight, and at the same time the piston is permitted to rotate with a minimum of friction. The reduced end portion $c^3$ of the shaft extends through a bushing $a'$ and a stuffing-box $a^2$, the inner portion of which latter is screwed into the casing and arranged to bear against the end of the said bushing. The opposite end of the bushing bears against the nut $c^2$, and the hub of the piston bears against a removable plate or ring $a^3$. With this arrangement and by rotating the threaded portion of the stuffing-box the hub of the piston can be maintained in contact with the said wearing-plate. The thrust-bearing thus provided serves to prevent end movement on the part of the shaft, and thereby prevents the ends of the piston from contacting with the casing.

The cylinder-head $A^2$ is recessed at either side of the piston to receive a couple of rotary abutments D and D′. These abutments are mounted upon longitudinally-extending shafts $D^2$ and are provided with peripheral notches or recesses $d$, which receive the piston-heads during the rotation of the piston. The pinions $D^3$, which are also mounted upon the said abutment-shafts, are arranged to engage the toothed ring $b^3$. Each abutment-shaft is provided with a shoulder $d'$, and the pinion and abutments are clamped against these shoulders by nuts $d^2$, the abutments being provided with lugs $d^3$, which engage recesses $d^4$ in the hubs of the pinions. (See Figs. 11 and 12.) The pressure on the abutments is counterbalanced by providing pressure-spaces $a^4$ at the opposite sides of the abutments, and the outer walls of the abutment-chambers are preferably formed by notched or horseshoe-shaped rings $a^5$. (See Fig. 15.) The peripheral notches of these rings, which are arranged between the pinions D and the abutments, conform to or fit the periphery of the outer flange on the piston. The end portions of the abutment-shafts are preferably supported in oil-ring bearings consisting of bushings $a^6$ and oil-rings $a^7$, and the outer ends of the shafts are covered by caps $a^8$. The engine-casing is provided with passages 1, 2, 3, and 4, which open into the annular high-pressure chamber at points immediately above and below the abutments and which serve alternately as supply and exhaust ports, according to the direction in which the engine is running. By thus admitting motive fluid at opposite points the pressure upon the piston is balanced, and the shaft is therefore subject to no lateral thrust. An admission of motive fluid through passages 2 and 4 will obviously cause the piston to rotate in the direction indicated by the arrow, (see Fig. 5,) the exhaust escaping through ports 1 and 3, and a reversal of this order of admission and exhaust will of course cause the piston to rotate in the opposite direction. It will be readily understood that the piston and abutments necessarily rotate at speeds which cause the piston-heads to enter or engage the recesses in the abutments.

The body or intermediate portion A of the cylinder is chambered to receive the combined intermediate and low pressure piston E, and the cylinder-heads A′ and $A^2$ are bolted to

this body portion, as shown in Figs. 1 and 2. Said piston is preferably composed of two telescoping sections E′ and E², and it will be observed that this piston, which is cylindric or drum-like in form, is of larger diameter than the high-pressure piston. The section E′ is provided with flanges *e* and *e′* and also with an internal web $e^2$, which is formed integral with the shaft C. Section E² is provided with flanges $e^3$ and $e^4$ and also with a web $e^5$. The said web $e^5$ is bolted or otherwise secured to the web $e^2$. When thus fastened together the two sections provide a cylindric piston having end flanges *e* and $e^4$, and the two flanges *e′* and $e^3$ combine to form an intermediate flange, which divides the interior of the casing into two annular compartments. One of said compartments—that is to say, the space between the flanges $e^3$ and $e^4$—is preferably smaller than the other and serves as an intermediate-pressure chamber. The space between the flanges *e* and *e′* serves as a low-pressure chamber. Steam is exhausted into the intermediate-pressure chamber from the high-pressure chamber and from the intermediate into the low. This piston is provided with a toothed ring $e^6$, which is preferably bolted to the end of section E′ and which is similar to ring $b^3$. Piston-heads $e^7$ are arranged between the flanges *e* and *e′*, and similar heads $e^8$ are arranged between the flanges $e^3$ $e^4$. These piston-heads, like those of the high-pressure piston, are secured in place by pins $e^9$, and it will be observed at this juncture that the piston-heads $e^8$ alternate with those of the high-pressure piston and that the piston-heads $e^7$ alternate with the heads $e^8$.

The cylinder-heads A′ and A² are provided with inwardly-extending bosses $a^9$, which serve as bearings for the shaft C. These bosses are preferably provided with bushings $a^{10}$ and oil-rings $a^{11}$. The cylinder-head A′ is also provided with a stuffing-box $a^{12}$, similar to the one at the opposite end of the shaft. With this arrangement and construction it will be seen that the piston-shaft is mounted for rotation in bearings which are long and which support the shaft for nearly its entire length. It will also be observed that each oil-ring is arranged in a recess adapted to contain oil, and in this way constant lubrication of the bearings is insured. It will be further observed that each bushing is provided with suitable oil-ducts.

Arranged at opposite sides of the combined intermediate and low pressure piston and in the same plane as the abutments D D′ are a couple of similar abutments, which coöperate with said piston and which are mounted upon a couple of rotary abutment-shafts F. In this case, however, each abutment is made in two sections, the short section G extending and fitting between the flanges $e^3$ and $e^4$ and the long section G′ being arranged between the flanges *e* and *e′*. These abutment-sections are provided with interlocking end portions similar to the interlocking arrangement shown in Figs. 11 and 12. Pinions H are also mounted upon the said abutment-shafts F and arranged to engage the toothed ring on the piston. These pinions have recessed hubs which interlock with lugs on the ends of the abutments, the same as in Figs. 11 and 12, and each abutment-shaft is provided with a shoulder *f*, against which the pinion and abutment-sections are clamped by the nut *f′*. Each abutment-section is provided with a couple of notches or recesses similar to those of the abutment D. (See Fig. 1.) These notches or recesses are adapted to receive the piston-heads $e^7$ and $e^8$, and as the former alternate with the latter the recesses in abutment-section G alternate, therefore, with those of section G′. It will be understood that this portion of the engine operates in a manner similar to the high-pressure portion—that is to say, the pinions H and the toothed ring $e^6$ are so proportioned that the piston and abutments rotate at such relative speeds that the piston-heads meet or enter the abutment-recesses. The abutment-sections are separated by webs $a^{13}$, formed integral with the casing. Rings $a^{14}$, similar to the one shown in Fig. 15, are arranged between the pinions and abutments, and rings $a^{15}$ (see Fig. 16) are arranged between the abutments and the cylinder-head A′. These rings are arranged to bear upon the flanges *e* and $e^4$, while the intermediate flange of this piston makes contact with the webs $a^{13}$. The abutment-shafts F are, like the shafts D², supported in oil-ring bearings consisting of bushings $a^{16}$ and oil-rings $a^{17}$. The outer ends of said shafts are covered by caps $a^{18}$. This combined intermediate and low pressure piston is, like the high-pressure piston, provided at its ends with spaces $a^{19}$, which permit the piston to rotate freely and with only its periphery in contact with the casing. The pressure on the abutments is counterbalanced by providing pressure-spaces $a^{20}$, which, like the recesses or spaces back of the abutments D and D′, are filled with motive fluid carried by the recesses in the abutments. The engine-casing is provided with passages 5, 6, 7, and 8, which open into the intermediate-pressure chamber at points immediately above and below the rotary abutments, and which serve as supply or exhaust ports, according to the direction which the engine is running. Ports or passages 9, 10, 11, and 12 are provided for the low-pressure chamber, and these, like the preceding passages, serve as supply and exhaust ports.

My improved reversing mechanism by which the order of admission and exhaust through the ports and passages can be reversed at will, so as to reverse the motion of the pistons, comprises a valve-casing I and three rotary plug-valves J, K, and L. (See Figs. 17, 18, and 19.) The said valves are each provided with two oppositely-arranged recesses, as best shown in Fig. 19. The stems of the valves are extended upward through

stuffing-boxes *i*, and each stem is provided with a double arm, the ends of the arms being connected by rods *i'*, as illustrated in Fig. 17. A hand-lever M or the like is secured to the stem of the valve L, and it is obvious that a movement of the said lever will effect a simultaneous adjustment or rotation of the three rotary valves. It will be observed that the valves are preferably tapered or plug-shaped in form and that they rotate upon the ends of the screws $l^2$. Each valve is preferably provided with a duct N, which permits steam to pass to the space N' above the valves, and the downward pressure thus exerted upon the valves keeps them seated. In addition to this, however, springs $N^2$ are arranged between the upper surfaces of the valves and the valve-casing, as shown in Fig. 18. The casing I is provided with an end passage 13, which leads to the valve J, and leading laterally from this valve are the two passages 14 and 15. A short passage 16 serves to connect valve J with valve K, and the passages 17 and 18 extend laterally from the said valve K. The passage 19 connects valve K with valve L. A couple of passages 20 and 21 lead laterally from valve L. The end passage 22 extends through the end of the casing from said valve L. The passage 13 is a supply-opening and is connected by suitable piping with a boiler or other source of fluid-pressure. Passage 14 is connected with ports 1 and 3 by pipes 23, as indicated in the drawings, while passage 15 is connected with ports 2 and 4 by similar pipes 24. The passage 17 is connected with ports 8 and 6 by pipes 25 and passage 18 with ports 5 and 7 by pipes 26. Passage 20 is pipe-connected with ports 10 and 12 and passage 21 with ports 9 and 11, the piping for these two passages not being shown. The passage 22 can be connected with the exhaust-pipe in any suitable manner. With this arrangement and with the valves adjusted to the position shown in Figs. 17, 18, and 19 the order of admission and exhaust will be as follows: Steam or other motive fluid entering the passage 13 will pass through the valve J into passage 15 and from the latter into the high-pressure chamber by way of ports 2 and 4. The exhaust from said high-pressure chamber will then pass out by way of ports 1 and 3. From these ports the exhaust will escape into passage 14 of the valve. From said passage 14 the exhaust will then pass through the valve J and into passage 16, through valve K into passage 18, and thence into the intermediate-pressure chamber by way of ports 5 and 7. Exhaust from the intermediate-pressure chamber will then pass out by way of ports 8 and 6, through passage 17, valve K, passage 19, and valve L into passage 21, and from the latter passage into the low-pressure chamber by way of ports 9 and 11. The exhaust from said low-pressure chamber will then pass out by way of ports 10 and 12 and, passing through passage 20 and valve L, escape through the final exhaust-passage 22. The passage of the steam through the high, intermediate, and low pressure chambers in this manner will cause the piston to revolve in the direction indicated by the arrow. It is obvious, however, that by placing the valves in an opposite position to that shown in Fig. 19 the order of admission and exhaust will be directly opposite to that just described and that the pistons will then revolve in an opposite direction.

As a matter of further and special improvement and for the purpose of enabling the operator to render the high-pressure piston neutral and admit live steam directly to the intermediate-pressure chamber I provide a supplemental or by-pass valve O. This supplemental or by-pass valve is located in the center of valve J, and its stem *o* extends upward through the hollow stem *j* of the valve J. The end of said stem *o* is provided with a hand-lever *o'*, by which the valve can be rotated. In this way I provide the plug-valve J with an independently-adjustable rotary valve, which when adjusted to an opposite position to that shown in Fig. 19 will permit live steam to pass through the center of valve J and into passage 16, from which latter the steam will of course then be free to pass directly into the intermediate-pressure chamber.

What I claim as my invention is—

1. In a rotary engine, the combination of a suitably-ported cylinder, one or more abutments, a rotary shaft and a hollow cylindric piston which is made in two sections, one of which is provided internally with a web which is forged integral with the said shaft, and the other of said sections being formed with an end web which is bolted to the said web on the other section.

2. In a rotary engine, the combination of a ported cylinder, suitable abutments, a rotary shaft, and a hollow cylindric piston composed of a couple of telescoping sections and provided internally with a web which is formed integral with the said shaft.

3. In a rotary engine, the combination of a ported casing, one or more abutments, a rotary shaft, and a hollow cylindric piston composed of a couple of telescoping sections, each section being provided internally with a web, and one of said webs being formed integral with the said shaft.

4. The combination of a cylinder, suitable rotary abutments, a rotary shaft, a piston composed of two telescoping sections and provided internally with a web which is formed integral with the said shaft, pinions on the abutment-shafts, and an annular ring which is secured to one end of the said piston and which is provided with teeth adapted to engage the said pinions.

5. The combination of a cylinder and one or more abutments, a rotary shaft, a high-pressure piston keyed to said shaft and a second piston which is provided peripherally

with flanges which divide the interior of the cylinder into intermediate and low pressure chambers, the said second piston being made in two sections, one of which is provided internally with a web formed integral with the said shaft.

6. A rotary engine comprising a cylindric or drum-like piston which is provided peripherally with annular flanges, rotary abutments arranged to extend between said flanges, pinions on the abutment-shafts, an annular ring which is secured to one end of said piston and provided with teeth adapted to engage said pinions, and a cylinder or casing which incloses the piston and abutments and also the said gearing.

7. In a rotary engine, and in combination with oppositely-arranged rotary abutments, a hollow cylindric piston which is provided peripherally with annular flanges and which is composed of a couple of sections, one of which is provided internally with a web formed integral with the shaft, a cylinder having heads provided with bosses which extend into the piston and form bearings for the shaft, pinions on the abutment-shafts, and an annular ring secured to one end of said piston and provided with teeth which engage the said pinions, the said ring and pinions being inclosed by the said cylinder.

8. In a rotary engine, the combination of oppositely-arranged rotary abutments, a rotary shaft, a cylindric piston provided internally with a web formed integral with the shaft, pinions on the abutment-shafts, an annular ring secured to one end of said piston and provided with teeth which engage said pinions, and a cylinder or casing having inwardly-extending bosses which form bearings for the shaft and which are provided with bushings and oil-rings, substantially as described.

9. A compound rotary engine comprising a high-pressure chamber and inclosed piston, a second piston having flanges which divide the interior of the cylinder or casing into intermediate and low pressure chambers, suitable abutments coöperating with said pistons, the said cylinder or casing having space between its inner surface and the ends of the pistons, a rotary shaft upon which said pistons are mounted, and a thrust-bearing which prevents end movement on the part of said shaft.

10. The combination of oppositely-arranged rotary abutments, a rotary shaft, a piston keyed upon said shaft, a second piston having an internal web which is formed integral with said shaft, a casing having space between its inner surface and the ends of said pistons, and a thrust-bearing for the hub of said keyed piston, substantially as and for the purpose set forth.

11. The combination of a rotary shaft, a high-pressure piston mounted thereon, a second piston which is also mounted upon said shaft and which is flanged to divide the interior of the casing into intermediate and low pressure chambers, suitable abutments coöperating with said pistons, and means for supplying motive fluid.

12. The combination of a cylinder, one or more abutments, a rotary shaft, a high-pressure piston keyed to said shaft, and a combined intermediate and low pressure piston having a web formed integral with said shaft, substantially as set forth.

13. The combination of a combined intermediate and low pressure piston composed of a couple of telescoping sections which are bolted together and one of which is formed integral with the rotary shaft, a high-pressure piston keyed to said shaft, oppositely-arranged rotary abutments, and a cylinder or casing provided with suitable ports and passages.

14. The combination of a shaft having a tapered portion, a piston locked upon said tapered portion by a nut screwed upon said shaft, a thrust-bearing for the hub of said piston, a second piston having a web formed integral with said shaft, suitable abutments coöperating with said pistons, and a suitable cylinder or casing having ports and passages for admitting and exhausting the motive fluid.

15. A rotary engine comprising a flanged piston, rotary abutments coöperating with said piston, each abutment being composed of a plurality of sections having interlocking end portions, and a cylinder or casing having suitable ports or passages.

16. A rotary engine comprising a piston which is flanged and which is composed of two sections, rotary abutments arranged to coöperate with said piston, a casing adapted to inclose said piston and abutments, each abutment being made in two sections which have interlocking end portions, and the said casing being provided internally with webs which extend between the said sections, substantially as described.

17. A rotary engine comprising a flanged piston made in sections, a shaft upon which said piston is mounted, rotary abutments cooperating with said piston, each abutment being composed of sections which are mounted upon a shaft and which are provided with interlocking end portions, a gear carried by the piston-shaft and arranged to engage pinions on the abutment-shafts, the said pinions having hub portions which interlock with the end portions of said abutments, and a casing adapted to inclose the piston and abutments and also the said gearing, and having webs which extend between the said abutment-sections, substantially as described.

18. A rotary engine comprising a piston provided with end flanges and also with an intermediate flange, a casing or cylinder having webs which are located opposite the said intermediate flange, rotary abutments coöperating with said piston, each abutment being made in sections which are separated by said webs and which have interlocking end por-

tions, pinions having hubs which interlock with the ends of the abutments and which are gear-connected with the piston-shaft, the said piston being made in sections, and removable rings being arranged opposite the end flanges of the piston, substantially as and for the purpose set forth.

19. The combination of a rotary piston made in sections, and a rotary abutment composed of sections having interlocking end portions, substantially as described.

20. In a rotary engine, and in combination with a suitable piston and cylinder, a rotary abutment-shaft having a shoulder, a pinion mounted upon said shaft, an abutment composed of interlocking sections which are arranged upon said shaft, the said pinion also interlocking with the said abutment, and a nut for tightening the pinion and abutment against the said shoulder on the shaft.

21. The combination of a combined intermediate and low pressure piston, a cylinder inclosing said piston and having heads, a high-pressure piston arranged in a recess formed in one of said cylinder-heads, a supplemental head for inclosing said high-pressure piston, both pistons being mounted upon a single shaft and suitable abutments being provided and arranged to coöperate with said pistons.

22. The combination, in a compound rotary engine, of a shaft, a piston mounted thereon, a cylinder inclosing said piston and provided with heads, a second piston mounted upon said shaft and arranged in a recess formed in one of said cylinder-heads, a supplemental head for inclosing said second piston, and oppositely-arranged rotary abutments.

23. The combination, in a compound rotary engine, of a combined intermediate and low pressure piston having a web which is formed integral with the shaft, a cylinder inclosing said piston and provided with heads, a high-pressure piston keyed to said shaft and arranged within a recess formed in one of said cylinder-heads, a supplemental head for inclosing said high-pressure piston, and suitable abutments arranged to coöperate with said pistons.

24. A compound multiple-expansion rotary engine comprising a plurality of pistons which are mounted upon a single shaft, suitable abutments coöperating with said pistons, a casing or cylinder having space between its inner surface and the ends of the said pistons, and a thrust-bearing for the hub of one piston, substantially as and for the purpose described.

25. In a rotary engine, the combination of a piston made in two sections and provided with a web which is formed integral with the piston-shaft, a second piston which is keyed to said shaft, rotary abutments which are gear-connected with said piston-shaft, a casing adapted to inclose the piston and abutments and also the said gearing and having space between its inner surface and the ends of the pistons and also between its inner surface and the abutments, and a thrust-bearing which prevents end movement on the part of said shaft, substantially as described.

26. In a rotary engine, and in combination with a cylinder and suitable abutments, a piston having annular flanges formed upon its periphery, piston-heads arranged between the flanges, pins extended through the flanges and piston-heads, an annular toothed ring which is bolted to one end of the piston, and spur-gearing for connecting said toothed ring with the said abutments, substantially as and for the purpose set forth.

27. In a compound rotary engine, the combination of an annular high-pressure piston having annular peripheral flanges, a toothed ring secured to one end of said piston, rotary abutments arranged to coöperate with said piston, pinions having hub portions which interlock with the said abutments, the said pinions being arranged to engage said toothed ring on the piston, a shoulder on the abutment-shaft, a nut for clamping the pinion and abutment against said shoulder, and a casing or cylinder having space between its inner surface and the ends of the piston and also between its inner surface and the rotary abutments, substantially as and for the purpose described.

28. In a reversible compound multiple-expansion fluid-motor, the combination of a piston-shaft, a high-pressure piston mounted upon said shaft, a combined intermediate and low pressure piston which is also mounted upon said shaft and which is provided with flanges which divide the interior of the casing into annular compartments, oppositely-arranged rotary abutments which coöperate with said piston and which are gear-connected with said piston-shaft, the said casing being provided with suitable ports or passages and a reversing-valve being provided for reversing the order of admission and exhaust, substantially as described.

29. In a reversible compound multiple-expansion rotary engine, a throttling and reversing device consisting of a valve-casing, a plurality of rotary valves adapted to control the passages in said casing and having pressure-spaces at their larger ends to keep them seated, means for connecting the valves for simultaneous adjustment, and means for connecting the passages in the valve-casing with the ports and passages in the engine-casing.

30. In a compound reversible rotary engine, and in combination with an engine-casing and suitable pistons, a throttling and reversing device consisting of a valve-casing, a plurality of rotary plug-valves for controlling the passages in the valve-casing, each valve having two oppositely-arranged recesses, pressure-spaces for keeping the valves seated, means for connecting the valves for si-

multaneous adjustment, and means for connecting the passages in the valve-casing with the ports and passages in the engine-casing.

31. In a compound reversible rotary engine, and in combination with an engine-casing and suitable pistons, a valve-casing, a plurality of rotary valves adapted to control the passages in said valve-casing, one of said valves being provided with an independently-adjustable valve by which the high-pressure piston can be rendered neutral and live steam permitted to enter the intermediate-pressure chamber, means for connecting the said rotary valves for simultaneous adjustment, and means for connecting the passages in the valve-casing with the ports and passages in the engine-casing.

32. In a compound reversible rotary engine, and in combination with an engine-casing and suitable pistons, a valve-casing, a plurality of rotary plug-valves connected for simultaneous adjustment and adapted for controlling the passages in said valve-casing, one of said valves being provided with a supplemental rotary valve by which the high-pressure piston can be rendered neutral and live steam admitted directly to the intermediate-pressure chamber, and means for connecting the passages in the valve-casing with the ports and passages in the engine-casing.

33. In a compound reversible rotary engine, and in combination with an engine-casing and suitable pistons, a valve-casing having an opening or passage at each end and a plurality of passages at each side, rotary plug-valves for controlling said passages in the valve-casing, each valve being provided with a couple of recesses, means for connecting said valves for simultaneous adjustment, a supplemental rotary valve arranged within one of said rotary plug-valves and adjustable independently for the purpose of rendering the high-pressure piston neutral and admitting live steam directly to the intermediate-pressure chamber, means for connecting one of said openings in the valve-casing with a source of fluid-pressure, means for connecting the other end opening of the valve-casing with an exhaust-passage, and means for connecting the lateral or side passages of said valve-casing with the ports and passages in the engine-casing.

EDWARD C. WARREN.

Witnesses:
P. J. HACKETT,
L. D. ARMSTRONG.