No. 835,330. PATENTED NOV. 6, 1906.

R. N. STORY.

REVERSIBLE ROTARY ENGINE.

APPLICATION FILED JAN. 31, 1906.

5 SHEETS—SHEET 1.

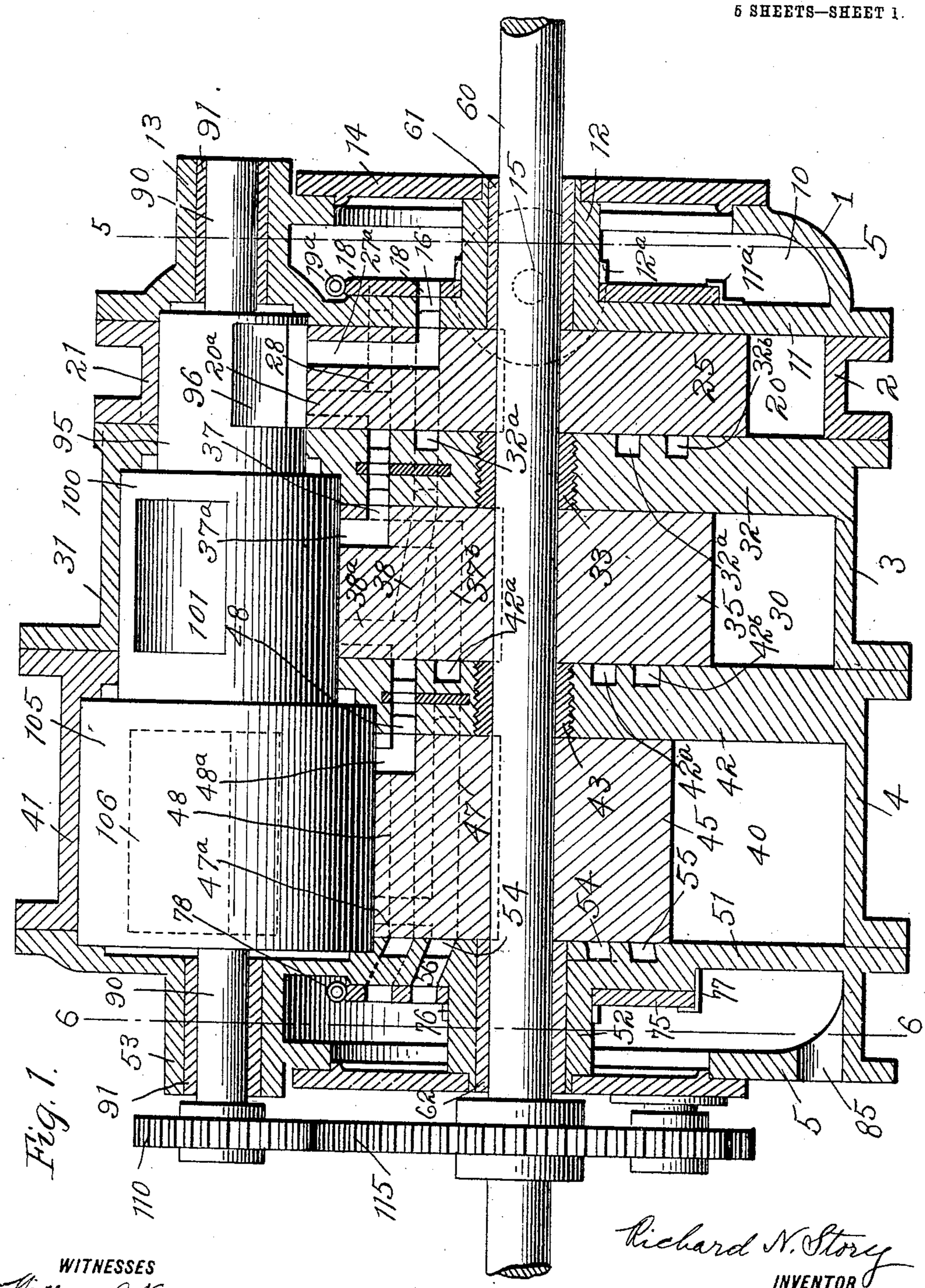

Fig. 1.

WITNESSES

William R. Hammond

R. F. Somers

Richard N. Story

INVENTOR.

BY Knight Bros.

ATTORNEYS

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6 SHEETS—SHEET 2.

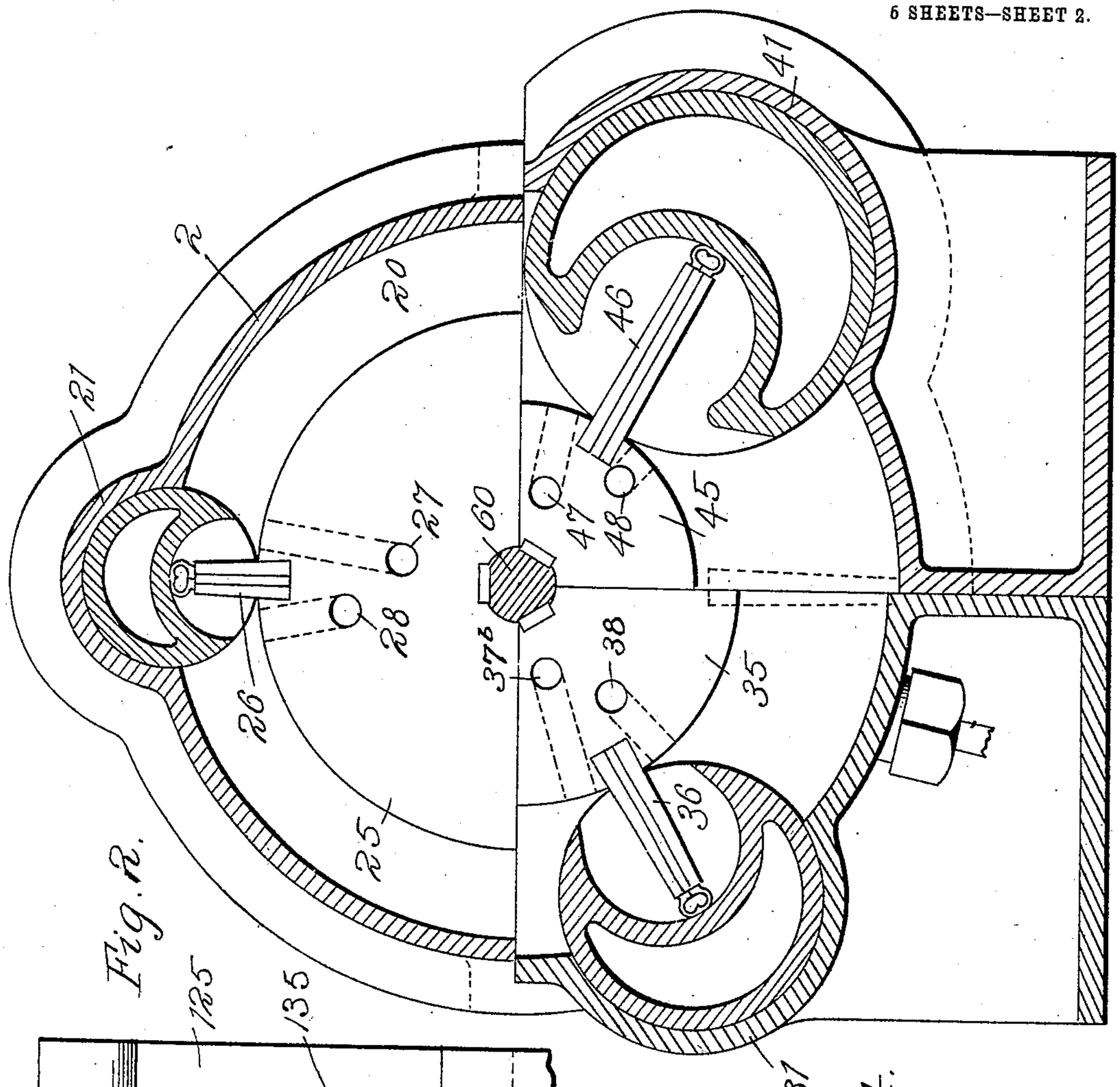

Fig. 2.

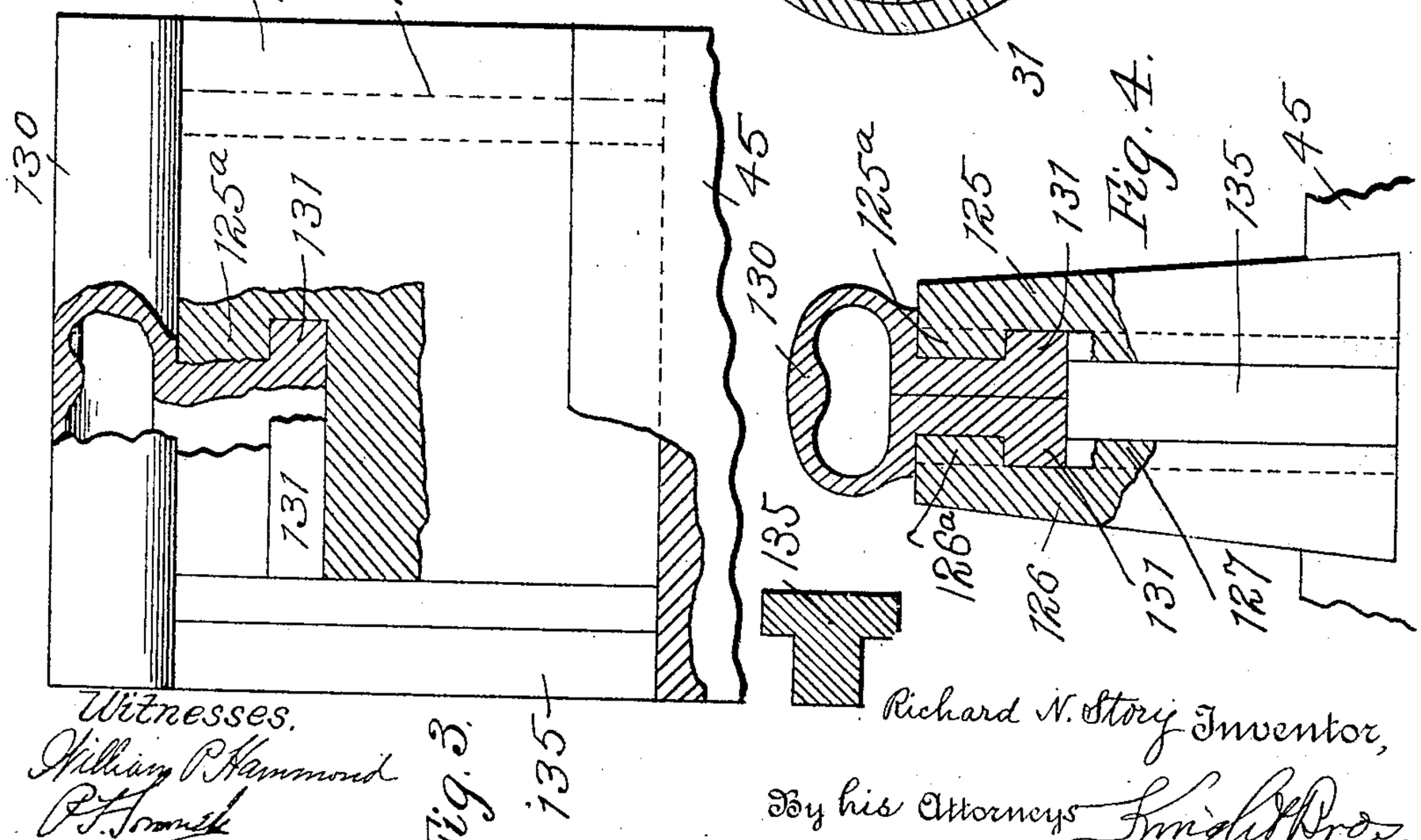

Fig. 3. Fig. 4.

Witnesses.
William P. Hammond
P. Smith

Richard N. Story Inventor,
By his Attorneys Knight Bros.

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5 SHEETS—SHEET 3.

Fig. 5.

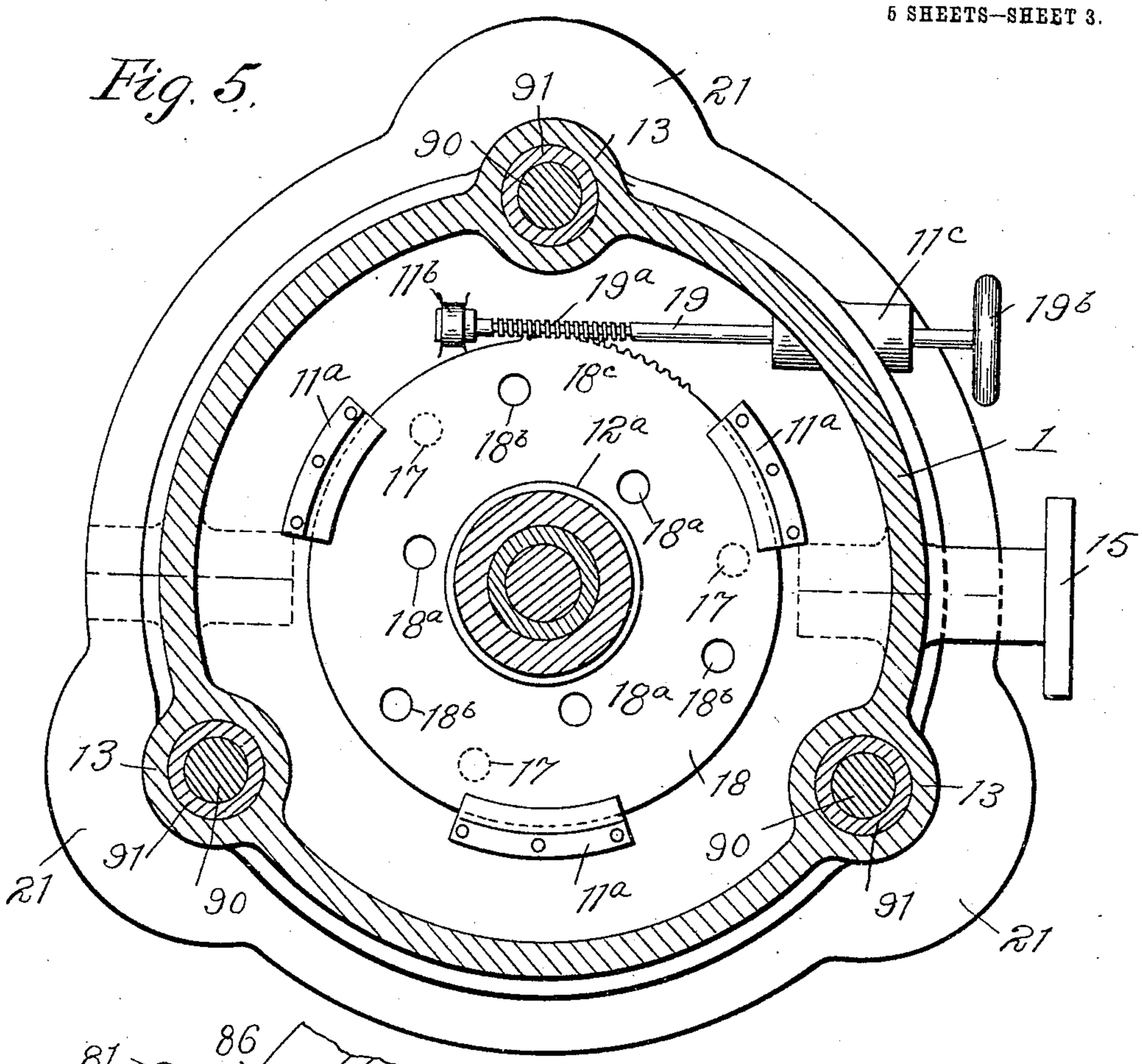
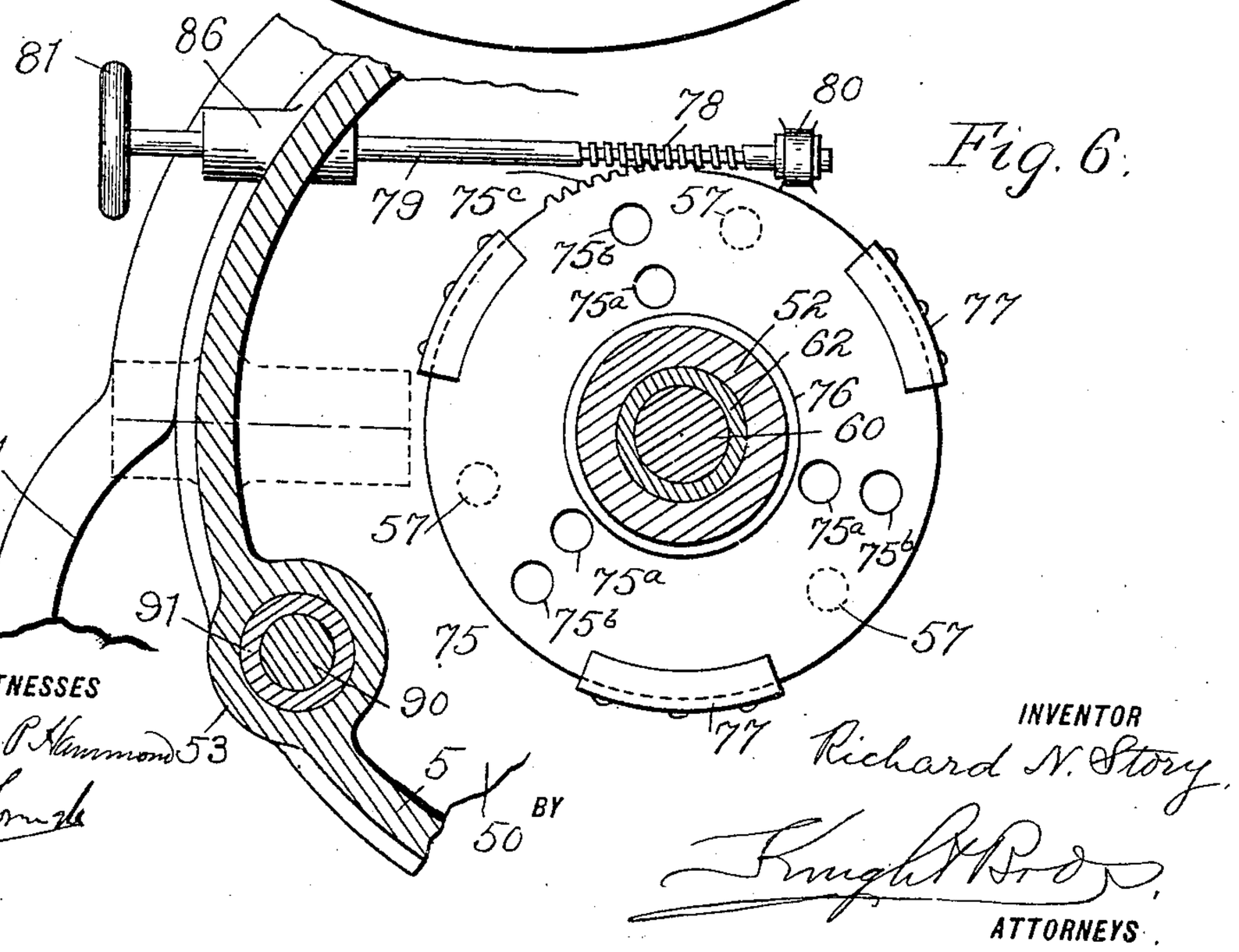


Fig. 6.



WITNESSES

William P. Hammond

R. F. Lowe

INVENTOR

Richard N. Story.

BY

Knight Bros.

ATTORNEYS.

No. 835,330. PATENTED NOV. 6, 1906.

R. N. STORY.

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Fig. 7.

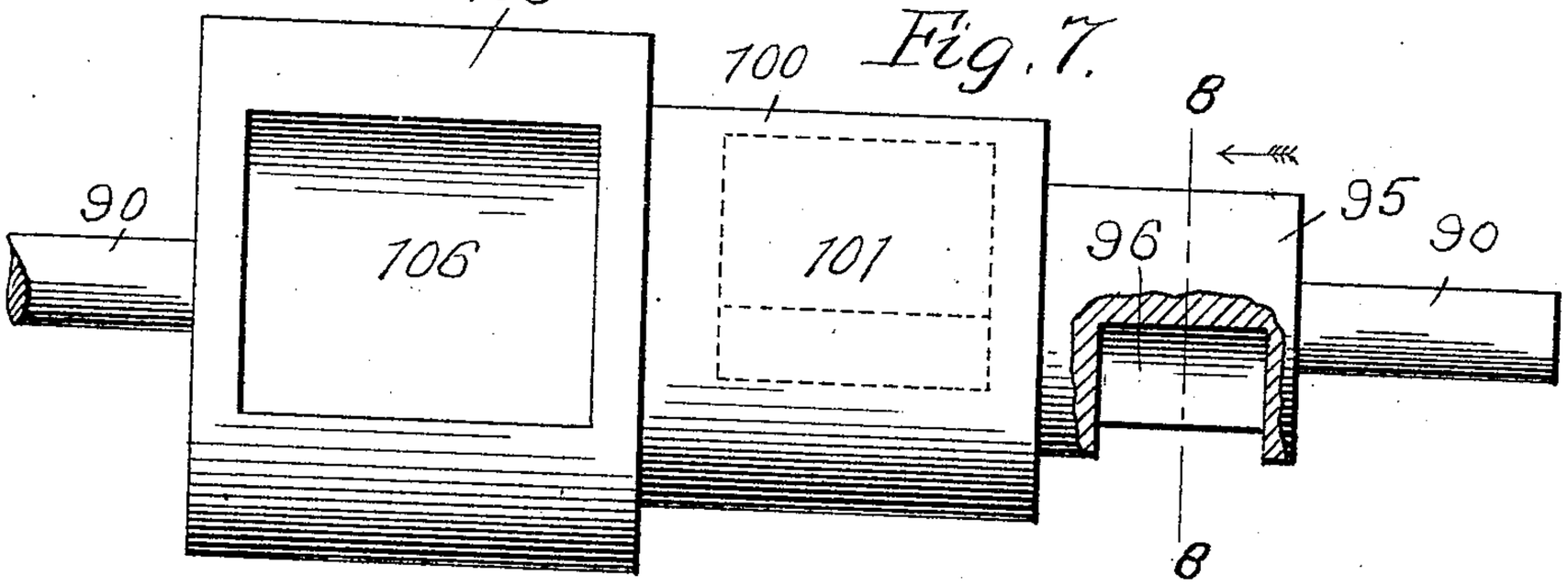


Fig. 8.

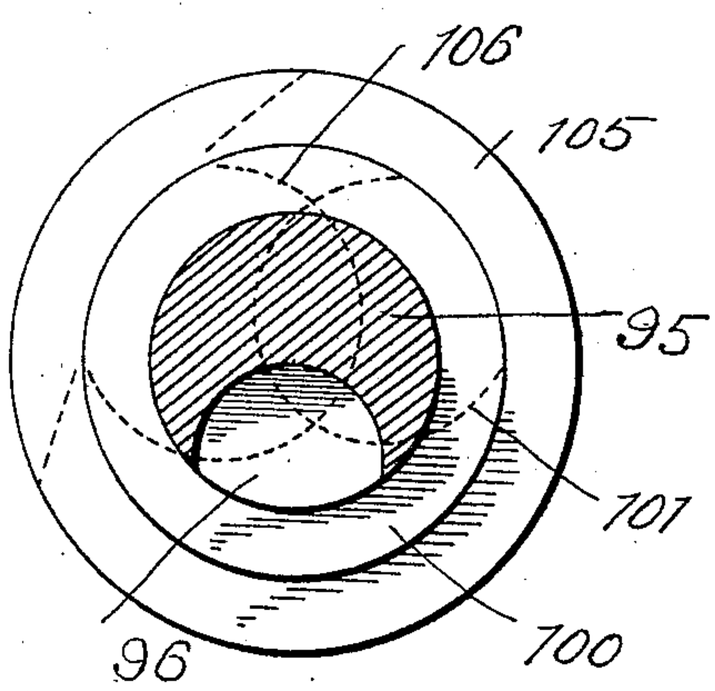


Fig. 9.

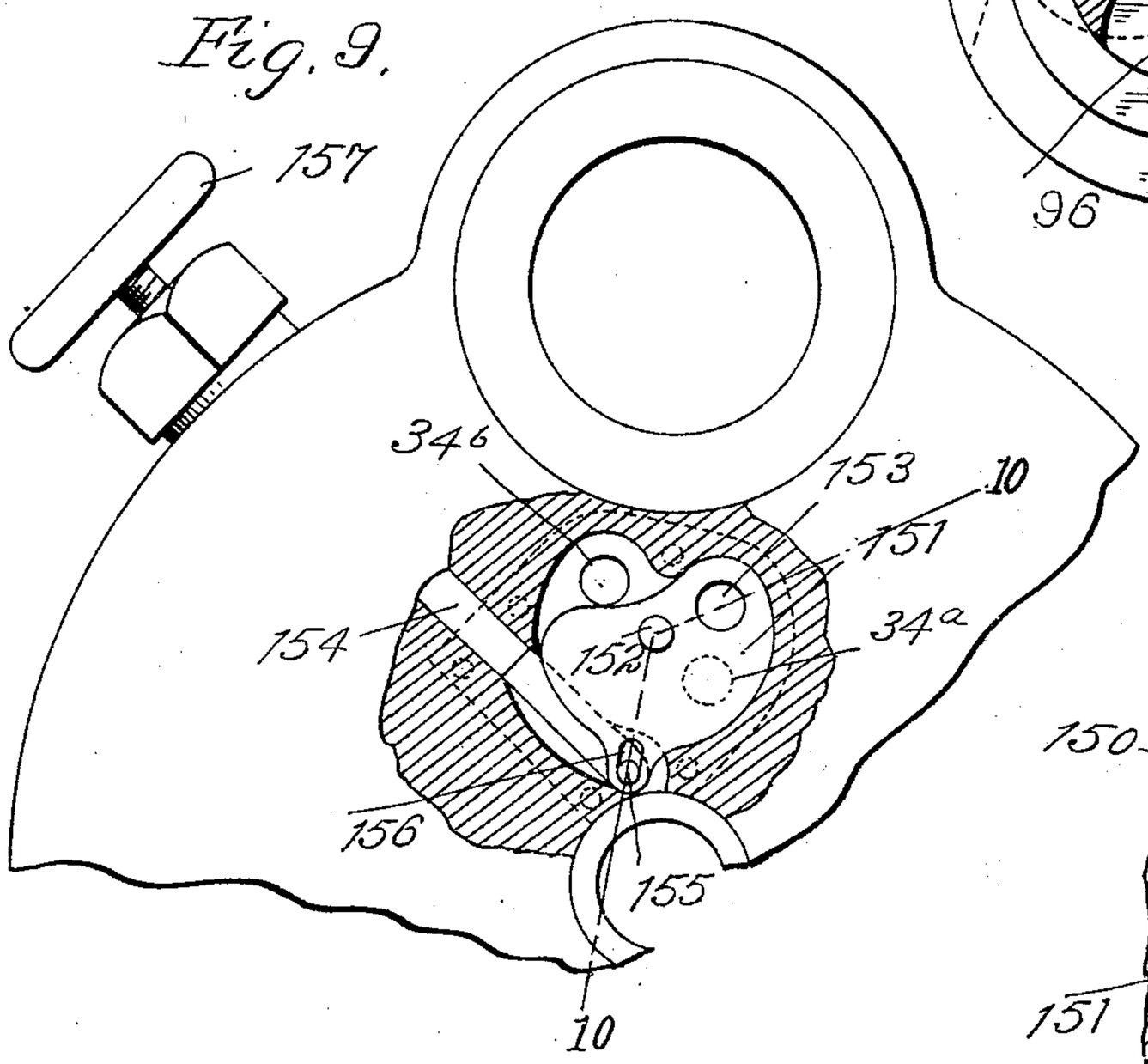
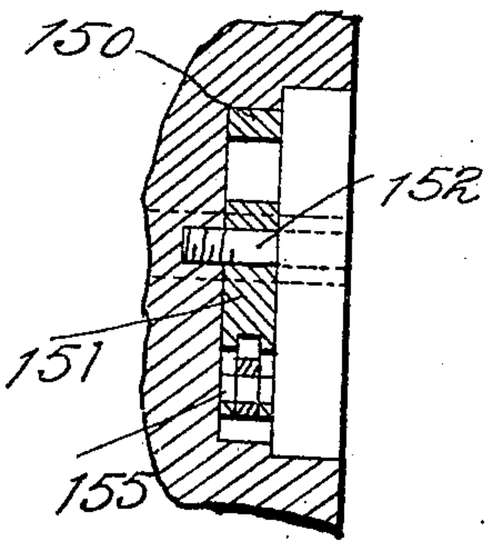


Fig. 10.



Witnesses
William P. Hammond
R. F. Tomich

Richard N. Story Inventor.
By his Attorneys Knight Bros.

No. 835,330. PATENTED NOV. 6, 1906.

R. N. STORY.

REVERSIBLE ROTARY ENGINE.

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6 SHEETS—SHEET 5.

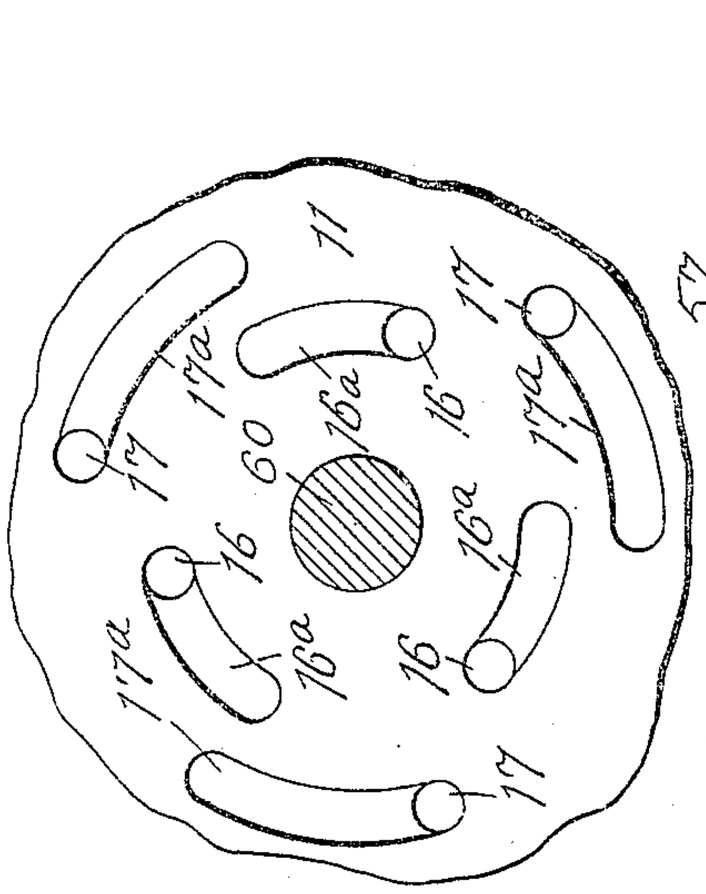

Fig. 11.

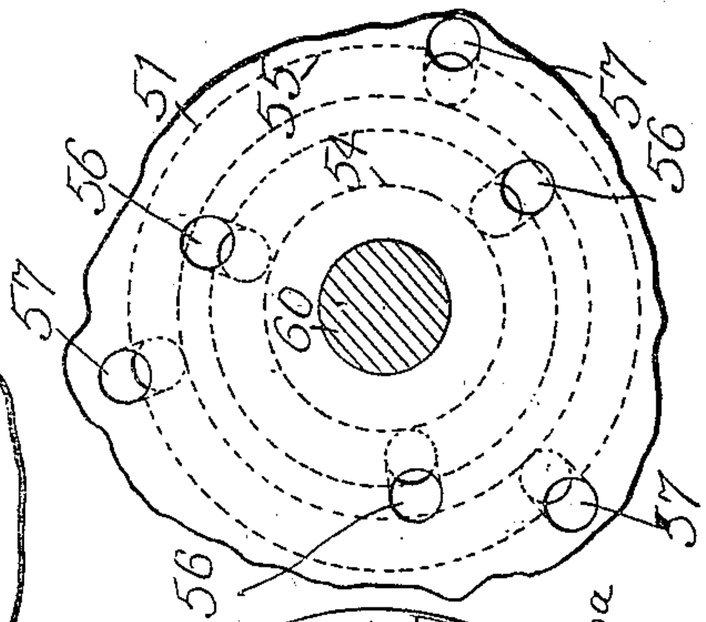

Fig. 17.

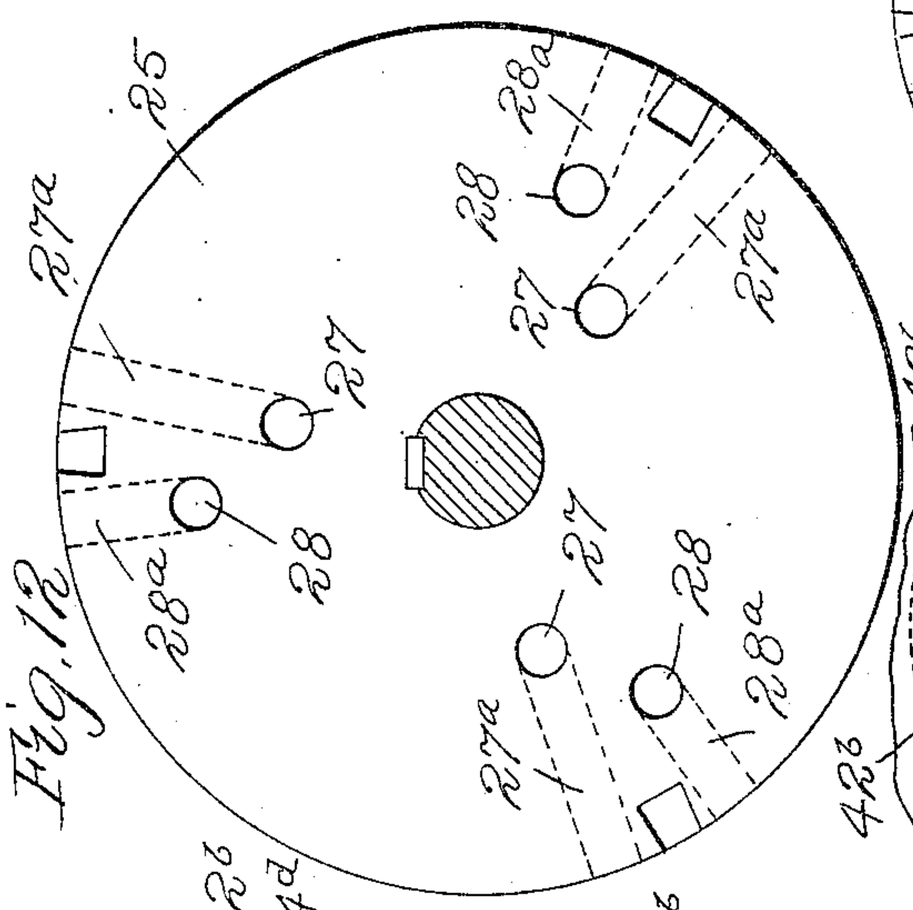

Fig. 12.

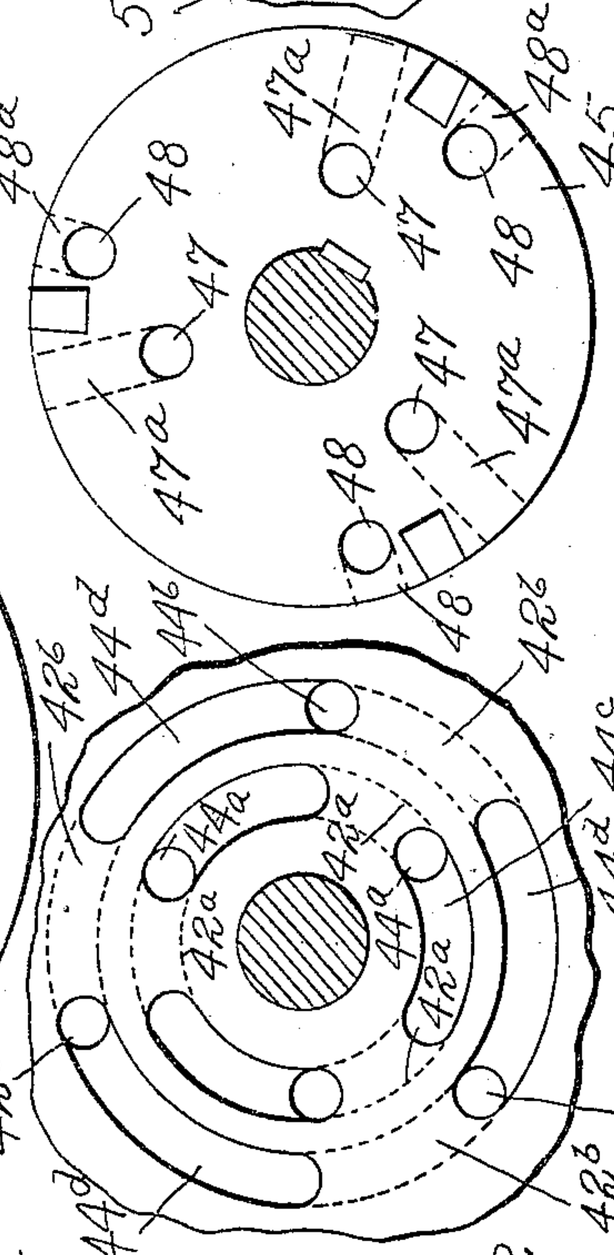

Fig. 16.

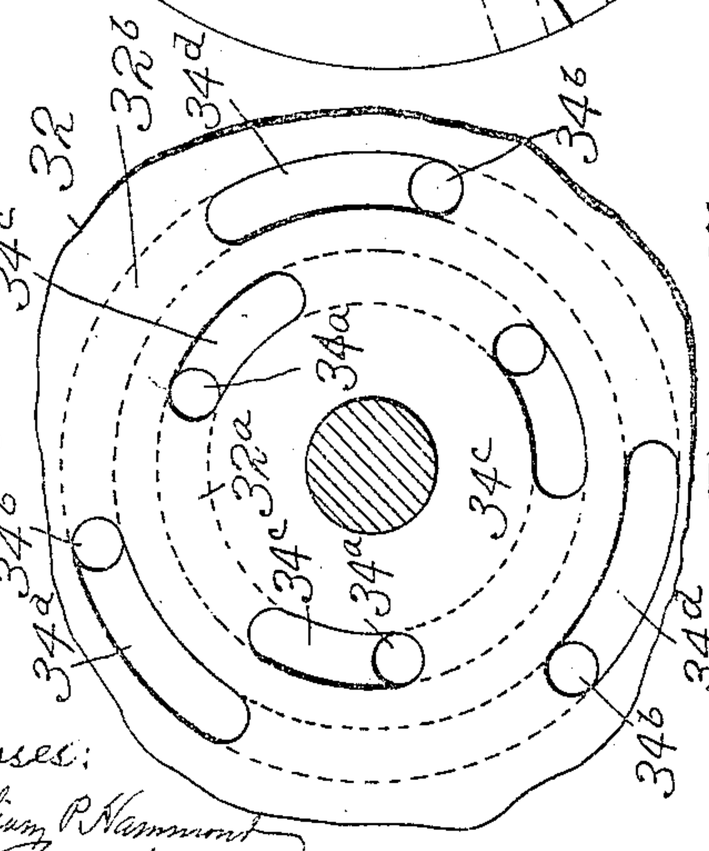

Fig. 13.

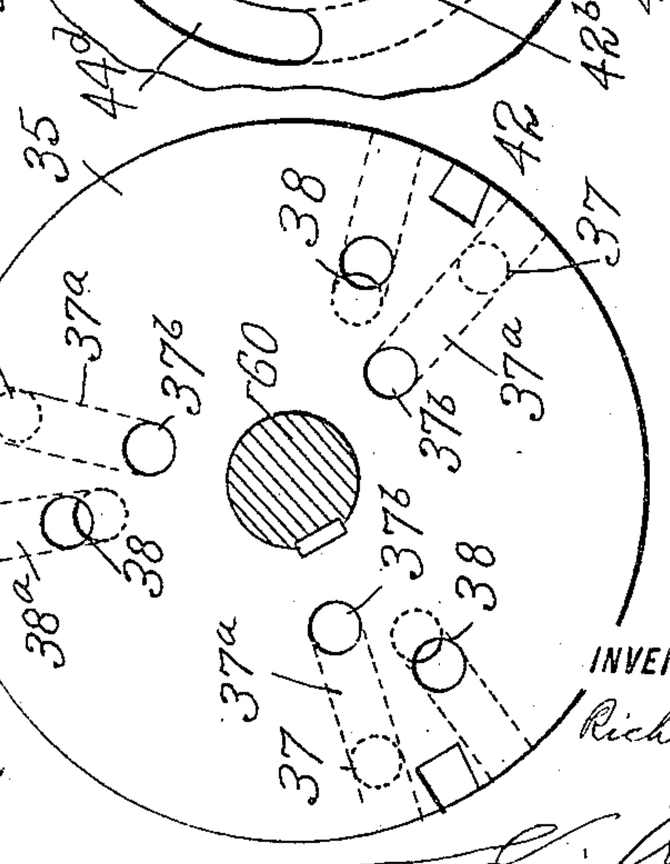

Fig. 14.

Fig. 15.

Witnesses:
William P. Hammond
R. F. Somers

INVENTOR
Richard N. Story
BY
Wright Brown
ATTORNEYS

UNITED STATES PATENT OFFICE.

RICHARD N. STORY, OF PHILADELPHIA, PENNSYLVANIA.

REVERSIBLE ROTARY ENGINE.

No. 835,330. Specification of Letters Patent. Patented Nov. 6, 1906.

Application filed January 31, 1906. Serial No. 298,848.

To all whom it may concern:

Be it known that I, RICHARD N. STORY, a citizen of the United States, and a resident of Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Reversible Rotary Engines, of which the following is a specification.

The object of my invention is to produce a simple and effective reversible rotary fluid-pressure engine which will be equally balanced in all of its parts and which can be constructed as a simple or a multiple expansion engine.

My improved rotary engine is constructed with one or a plurality of circular working chambers or cylinders and an equal number of rotary pistons operating in said circular working chambers, each piston carrying two or more piston-blades arranged at equal distances apart and a plurality of rotary abutments, one for each piston-blade, and means for rotating the abutments from the piston-shaft in proper relation to the piston-blades.

In an engine embodying my improvements and having a plurality of working chambers and pistons the rotary abutments are made in compound form, each compound abutment having as many abutment-heads as the number of working chambers and pistons and the abutment recesses or cavities for the several pistons being arranged at angles to each other and at equal distances apart to correspond with the angular relation of the corresponding piston-blades upon the several pistons.

In constructing my improved rotary engine I prefer to make the casing in sections divided longitudinally or transversely, or both, for the sake of convenience in constructing and assembling the machine. The sections of the casing have preferably formed integral with them parts of the end walls and partitions which separate the several working chambers or cylinders, the central bearings in the end walls and partitions being provided in the form of removable bushings. All of the pistons are mounted upon a common shaft which passes longitudinally through the casing and is journaled in the end walls and partition-walls, the rotary piston-heads being suitably keyed upon the common shaft and carrying the piston-blades, which are detachably secured upon the peripheries of the piston-heads.

A very important feature of my improved reversible rotary engine is the arrangement of the automatic valves and ports. At one end of the casing I arrange a pressure-fluid supply-chamber, from which lead two series of ports at unequal distances from the center. These ports (there being one of each series for each piston-blade of the high-pressure piston) lead from the supply-chamber into the high-pressure working chamber or cylinder, one series being utilized for running in one direction, while the other series is utilized for running in the reverse direction. A rotatable valve-plate rests against the end wall of the casing and is provided with operating means whereby its position can be shifted for cutting off the supply of pressure fluid to both series of ports or for allowing the supply of pressure fluid through either series for running in either direction. The inner face of the high-pressure end wall of the casing is formed with a series of short groove-ports communicating with the ports from the pressure-supply chamber and with the supply-ports cut into the high-pressure piston-head, and the high-pressure face of the first partition-wall is formed with two concentric circular groove-ports communicating with ports leading to the intermediate pressure-cylinder and with the ports of the high-pressure piston, the ports in the high-pressure piston-head (two for each piston-blade) being arranged radially of the piston-head upon opposite sides of the piston-blades and having lateral offsets to place them in communication with the groove-ports of the end wall and first partition-wall. These two series of ports in the casing-walls and piston enable the reversal of the engine. The intermediate and low pressure piston-heads are formed with similar radially-extending ports and auxiliary offset ports which communicate with the ports formed in the partition-walls between the several working chambers or cylinders, suitable valves being arranged in said partition-walls for reversing the action of the engine. The exhaust from the low-pressure working chamber or cylinder is through either one of two series of ports leading into a common exhaust-chamber and controlled by a reversible valve-plate having hand-operated means.

With this improved structure the supply and cut-off of pressure fluid for each working chamber or cylinder is controlled by the rotating pistons, the exhaust from the high pressure being into the intermediate and

from the intermediate to the low pressure cylinder under the automatic control of the rotating piston. The action is substantially the same whether the engine is running ahead or is reversed, the only difference being that when reversed the supply of pressure fluid to the several working chambers or cylinders is through the ports which act as exhausts in the forward motion of the engine, and the exhaust is, on the other hand, through the ports which act as supply-ports in the forward motion of the engine.

The series of compound rotating abutments are driven by direct gearing with the main shaft of the engine, the ratio of the gearing being dependent upon the number of piston-blades upon each rotary piston-head—that is, in an engine having two piston-blades to a piston-head the gearing between the main shaft and rotating abutments will be two to one, while in an engine having three piston-blades to a piston-head the ratio of the gearing will be three to one, and so on.

Whether operating in a forward direction or in a reverse direction, the rotating piston-heads act as automatic valves for opening and cutting off the fluid-supply ports.

The working parts of my improved rotary engine are carefully machined to exactly fit, so as to avoid the necessity of using expensive and unsatisfactory packings, as heretofore has been customary. This exact fit of the working parts of the engine will prevent any objectionable waste of pressure fluid and will at the same time obviate objectionable friction and consequent wear and tear upon the parts.

My invention includes numerous important features of novelty which will be hereinafter clearly described in connection with the accompanying drawings and afterward pointed out more particularly in the annexed claims.

In said drawings Figure 1 is a vertical-longitudinal sectional view of my improved rotary engine, the section-line upon which this view is taken being an imaginary one in that it cuts each of the rotary pistons radially through a supply-port, a condition which could not be present actually, since the piston-blades of the several rotary pistons are set in different radial planes, and a section through a single vertical plane could not show all of these supply-ports. Fig. 2 is a vertical transverse section of the same, showing a composite view of three distinct sections of parts of the engine, so as to illustrate a part of each of the three rotary pistons and the rotary abutments. Figs. 3 and 4 are detail sectional views illustrating the construction of the piston-blades. Fig. 5 is a vertical transverse sectional view taken on the line 5 5 of Fig. 1 through the fluid-pressure-supply chamber, showing the main supply-valve plate. Fig. 6 is a similar view taken on the line 6 6 of Fig. 1 through the common exhaust-chamber, showing the common exhaust-valve plate. Fig. 7 is a side elevation of one of the compound rotary abutments detached from the engine. Fig. 8 is a transverse sectional view of the same, taken on the line 8 8 of Fig. 7. Fig. 9 is an enlarged detail sectional view showing one of the series of controlling-valves which are arranged in the partition-walls between the working chambers or cylinders. Fig. 10 is a detail transverse sectional view of the same, taken on line 10 10 of Fig. 9. Fig. 11 is an inside view of the end wall of the engine-casing at the high-pressure end looking from the low-pressure end. Fig. 12 is an inner face view of the high-pressure piston-head looking from the low-pressure end of the engine. Fig. 13 is an inner face view of the partition-wall between the high and intermediate pressure cylinders looking from the low-pressure end of the engine. Fig. 14 is an inner face view of the intermediate-pressure piston-head looking from the low-pressure end of the engine. Fig. 15 is a face view of the partition-wall between the intermediate and low pressure cylinders looking from the low-pressure end of the engine. Fig. 16 is a face view of the low-pressure piston-head looking from the low-pressure end of the engine. Fig. 17 is a face view of the end wall of the engine at the exhaust end.

As stated above, my present improvements can be embodied in a simple or a multiple-expansion rotary engine. For the purpose of illustration I have shown in the accompanying drawings and will now describe in detail a rotary reversible steam-engine having high-pressure, intermediate-pressure, and low-pressure working cylinders.

The engine-casing in the form of my improved rotary engine illustrated in the accompanying drawings is made up of a plurality of vertical transverse sections 1, 2, 3, 4, and 5. As indicated in dotted lines in Figs. 5 and 6, the sections of the casing may also be divided horizontally. The section 1 forms the live-steam chamber 10 and includes the end wall 11, main shaft-bearing 12, and the three abutment shaft-bearings 13. The section 2 forms the cylindrical wall of the high-pressure working chamber or cylinder 20 and the bearing-offsets 21 for the rotating abutments. The section 3 forms the cylindrical wall of the intermediate working chamber or cylinder 30, the bearing-offsets 31 for the rotating abutments and the partition-wall 32 dividing the high-pressure from the intermediate-pressure cylinders. Section 4 forms the cylindrical wall of the low-pressure working chamber or cylinder 40, the bearing-offsets 41 for the rotating abutments, and the partition-wall 42, separating the intermediate-pressure cylinder from the low-pressure cylinder, and section 5 includes the common exhaust-

chamber 50, the end exhaust-wall 51, the main shaft-bearing 52, and the abutment shaft-bearings 53.

60 is the main shaft of the engine, carrying the three rotating piston-heads and extending longitudinally and centrally through the engine-casing, having suitable bearings at its ends in the bearing-bushings 61 and 62, supported, respectively, in the central bearing-hubs 12 and 52 of the end plates 11 and 51. This shaft 60 is also journaled in the bearing-bushings 33 and 43, mounted in the central openings in the partition-walls 32 and 42, respectively, said bushings 33 and 43 being preferably threaded into the central openings of said partition-walls.

The steam-supply chamber 10 is closed by a circular plate 14, fitting over the bearing 12 61 and rigidly secured in place against section 1 of the casing by tap-bolts or other suitable means. (Not shown.) This live-steam chamber 10 has a suitable steam-inlet 15. (Shown in Fig. 5 and indicated by dotted lines in Fig. 1.)

The end wall 11, as shown in Figs. 1, 5, and 11, is formed with two series of steam-ports 16 and 17, respectively, extending through the wall parallel with the main shaft 60 and communicating at their inner ends with the short face-grooves 16^a and 17^a to supply live steam to the ports of the high-pressure piston for running in both directions, as will presently be explained. These two series of ports 16 and 17 are at unequal distances from the shaft 60, and their face-groove extensions 16^a and 17^a extend upon arcs or circles drawn from the center of said shaft 60.

18 is a circular valve-plate rotatably mounted upon the bearing-hub 12 and confined by a bearing-ring 12^a. This valve-plate 18 is formed with an inner series of three ports 18^a and an outer series of three ports 18^a, which are adapted to open communication, respectively, with the series of ports 16 and 17 above referred to. In Fig. 5 of the drawings the valve-plate 18 is shown in position for supplying live steam through ports 18^a and ports 16. The valve-plate 18 is further confined against the outer face of the end wall 11 of the engine-casing by means of curved cleats or guide-plates 11^a, secured to the end wall 11 and engaging the valve-plate. A segment of gear-teeth 18^c is cut upon the periphery of valve-plate 18 and is in constant mesh with the worm-gear 19^a, formed upon a hand-shaft 19, journaled in bearings 11^b and 11^c and projecting through the wall of casing-section 1 and provided at its outer end with a hand-wheel 19^b, by which the valve-plate 18 can be shifted for cutting off the supply of live steam and for reversing the direction of rotation of the engine.

Keyed to the main shaft 60 within the high-pressure working chamber or cylinder 20 is the high-pressure piston head or disk 25, which is accurately machined to snugly fit between the inner faces of end wall 11 and partition-wall 32. This piston head or disk 25 carries three piston-blades 26, extending radially from its periphery and constructed and rigidly secured in place, as hereinafter fully explained. The piston-blades 26 (in the present instance three in number) are equally spaced upon the periphery of the piston head or disk—that is, are one hundred and twenty degrees apart.

The piston-head 25, which operates in contact with the inner faces of end wall 11 and partition-wall 32, is provided with two series of ports 27 and 28, extending entirely through the piston-head parallel with the main shaft 60, each port 27 communicating with one of the series of radial ports or passages 27^a and each post 28 communicating with one of the series of radial ports or passages 28^a. The two series of ports 27 and 28 are at unequal distances from the center of rotation, and the series of ports or passages 27^a and 28^a open into the high-pressure working chamber 20 upon opposite sides of the piston-blades 26, so as to act interchangeably as supply and exhaust ports. The ports 27 and groove-ports 16^a are equidistant from the center of rotation and are in communication with each other periodically during a certain part of the rotation of the piston. The ports 28 and groove-ports 17^a are also equidistant from the center of rotation and communicate with each other periodically during a certain portion of the revolution of the piston. It will therefore be clear that no matter which direction the engine is rotating in live steam will be supplied during a given portion of the rotation of the piston at one side of each piston-blade.

The partition-wall 32, which separates the high-pressure cylinder 20 from the intermediate-pressure cylinder 30, is formed in its high-pressure face with two concentric groove-ports 32^a and 32^b, cut upon circles drawn at unequal distances from the axis of shaft 60. These circular groove-ports 32^a and 32^b correspond in position with the ports 27 and 28, respectively, of high-pressure piston-head 25, so that during the revolution of the piston 25 ports 27 will be in constant communication with groove-port 32^a and ports 28 will be in constant communication with groove-port 32^b, said communicating ports being employed interchangeably as exhaust-ports for the high-pressure cylinder and supply-ports for the intermediate cylinder, depending upon the position of the valves and the direction of rotation of the engine.

The groove-port 32^a communicates with a series of longitudinal ports 34^a, which extend entirely through the partition-wall 32,

and the groove-port 32^b communicates with a series of longitudinal ports 34^b also extending entirely through the partition-wall 32.

Upon the intermediate-pressure side of the partition-wall 32 said wall has cut into its face two series of short groove-ports 34^c and 34^d, each one of which communicates, respectively, with one of the longitudinal ports 34^a and 34^b. The series of groove-ports 34^c are the same distance from the axis of the shaft 60 as the groove-port 32^a upon the opposite side of said partition-wall, and the series of groove-ports 34^d are at the same distance from the axis of shaft 60 as the groove-port 32^b upon the opposite side of the partition-wall.

In the operation of the engine one of the series of longitudinal ports 34^a or 34^b is open and the other is closed, depending upon the direction of rotation of the engine. To close either of said two series of ports, I provide in the partition-wall 32 three hand-operated valves, each valve being so located that it can shut off one of the ports 34^a or one of the ports 34^b, it of course being understood that when one port is closed the other is open. These valve mechanisms, as well as the three valves in the partition-wall 42 between the intermediate-pressure and low-pressure cylinders, are all of the same construction, and a detailed description of one of them will be hereinafter given.

Keyed to the main shaft 60, within the intermediate working chamber or cylinder 30, is the intermediate-pressure piston head or disk 35, which is accurately machined to snugly fit between the inner faces of the partition-walls 32 and 42. This piston-head or disk 35 carries three piston-blades 36, extending radially from its periphery and constructed and rigidly secured in place in the same manner as the piston-blade 26, which will be hereinafter explained in detail. The piston-blades 36 are equally spaced upon the periphery of the piston head or disk 35.

The piston head or disk 35 is provided with a series of ports 37, entering its face at its high-pressure side and communicating with the series of radial ports 37^a, leading to the intermediate-pressure cylinder. These ports 37 periodically communicate with the short groove-ports 34^d of the partition 32. The radial ports 37^a communicate at their inner ends with longitudinal branch ports 37^b, which lead to the face of the piston-head, which contacts with the partition-wall 42. The piston-head 35 also has a series of ports 38 extending longitudinally through the piston-head at a slight angle to the longitudinal axis and communicating with the radial ports 38^a, leading to the intermediate-pressure cylinder. These ports 38 communicate periodically with the groove-ports 34^c of the partition-wall 32. The radial ports 37^a and 38^a enter the intermediate-pressure chamber upon opposite sides of the piston-blades and act interchangeably as supply and exhaust ports.

The partition-wall 42 separates the intermediate-pressure cylinder from the low-pressure cylinder and has formed in its intermediate-pressure face the concentric groove-ports 42^a and 42^b at unequal distances from the axis of shaft 60 and positioned to communicate constantly with the ports 37^b and 38 of the piston-head 35. These groove-ports 42^a and 42^b communicate, respectively, with the longitudinal ports 44^a and 44^b, passing through the partition-wall 42 and in turn communicating with the series of short groove-ports 44^c and 44^d, cut in the low-pressure face of the partition-wall 42. The ports 44^a and 44^b are controlled by shiftable valve-plates, hereinafter to be described, in the same manner as the longitudinal ports extending through the partition 32, as above referred to.

45 is the low-pressure piston head or disk, keyed to the main shaft 60 within the low-pressure chamber or cylinder 40, said piston-head being accurately machined to snugly fit between the inner faces of the exhaust end wall 51 and the partition-wall 42. This piston head or disk 45 carries three piston-blades 46, extending radially from its periphery and constructed and rigidly secured in place in the same manner as will be hereinafter explained in connection with the piston-blades 26. Piston-blades 46 are spaced equally upon the periphery of the piston head or disk. This low-pressure piston head or disk 45 is provided with two series of ports 47 and 48, extending longitudinally through it. The longitudinal ports 47, communicating with the radial ports 47^a, lead to the low-pressure cylinder, and the longitudinal ports 48, communicating with the radial ports 48^a, also lead to the low-pressure cylinder. The radial ports 47^a and 48^a lead into the working cylinder upon opposite sides of the piston-blades.

The exhaust end wall 51 is formed on its inner face with the exhaust circular groove-ports 54 and 55, which are at the proper radial distances from the axis of shaft 60 to continually communicate with the outlet ends of the longitudinal ports 47 and 48 of the low-pressure piston head or disk 45. These circular exhaust groove-ports 44 and 45 respectively communicate with the two series of exhaust-ports 56 and 57, which extend through the end wall 51 at an angle to the longitudinal axis of the engine and open into the common exhaust-chamber 50.

A circular valve-plate 75 is journaled upon the bearing-hub 52 of end plate 51 and is confined in close contact with the outer face of end plate 51 by means of a collar 76, secured to the bearing-hub 52, and a series of cleats or guide-plates 77, secured to the end plate 51. This valve 75 has cut through it

two series of exhaust-ports or openings 75[a] and 75[b], which are at the proper radial distance from the axis of shaft 60 to communicate, respectively, with the exhaust-ports 56 and 57. The valve-plate 75 is also provided with a segment of rack-teeth 75[c], which are in constant mesh with the worm 78, formed on a shaft 79, journaled in bearings 80 and extending from the exhaust-chamber through the casing-section 5, the outer end of said shaft being provided with a hand-wheel 81. By rotating the plate 75 either series 56 or 57 of the exhaust-ports can be closed.

85 is the exhaust-outlet from the exhaust-chamber 50, which may be placed in communication with a condenser, a muffler, or with the open air.

I have found it desirable in the interest of economy and efficiency to provide my improved reversible rotary engine with the same number of abutments as the number of piston-blades. In the form of machine illustrated in the drawings each piston-head is provided with three piston-blades, so that three rotary abutments are provided for each piston. The drawings illustrate a compound expansion-engine having three rotary pistons, and I have found it desirable to so arrange the piston-blades upon the respective piston-heads that they will have a certain angular relation with each other in order that the abutments for the several pistons can be combined into compound abutments.

As above described, the sectional casing is provided with three equally-spaced offsets to receive the compound abutments, which I will now describe.

90 is one of a series of three abutment-shafts, which shafts are journaled at their opposite ends in the bearings 52 and 53 of the end casing-sections 1 and 5, suitable Babbitt or other bearing metal 91 being mounted in the bearings. Each of these abutment-shafts 90 carries three abutment-heads 95, 100, and 105, which operate in the offset portions 21, 31, and 41 of the casing-sections above referred to. These abutment-heads 95, 100, and 105 are accurately machined to fit snugly within the offset portions of the casing-sections and have close working and live contact with the piston-heads, so as to avoid the necessity of steam-packings. The high-pressure, intermediate-pressure, and low-pressure piston-heads are of graduated diameters in the order named, and the piston-blades are also graduated to correspond—that is, the high-pressure piston-head which is of the greatest diameter is provided with the piston-blades of smallest area, whereas the low-pressure piston-head being of the smallest diameter is provided with the piston-blades of greatest area. It will also be observed that the area of the cylinders is graduated in the same respect, the high-pressure cylinder being narrow and the low-pressure cylinder comparatively broader. To correspond with these proportions of the several cylinders and pistons, the abutment-heads 95, 100, and 105 are graduated as shown.

Each of the abutment-heads is provided with a lunette-shaped recess or opening, as indicated at 96, 101, and 106, into which the blades of the piston-heads project as the blades pass the abutment-heads, it being understood that the surfaces of these lunet-shaped recesses and the outer edges of the piston-blades do not come in contact when the blades pass the abutments, there being no steam-pressure upon the piston-blade as it passes an abutment.

Each abutment-shaft 90 carries at one (or at both ends) a gear-wheel 110, which is in constant mesh with a large gear 115, keyed to the main shaft 60, the proportion of gears 110 and 115 being in the machine illustrated one to three, since each piston-head is provided with three piston-blades and the machine is provided with three compound abutment-heads.

In constructing my improved engine I propose to provide the main shaft 60 with a suitable detachable coupling, connecting it with the shaft to be driven, whereby the machine may be taken apart for the purposes of inspection and repair. This coupling is not shown nor described, since it forms no part of my present invention.

Referring now to the illustration in Figs. 3 and 4, I will describe in detail the construction and means for mounting the piston-blades upon the piston-heads, the blades of all of the heads being of the same construction and mounted in the same manner as above stated. Each piston-blade comprises a main plate having working faces 125 and 126 and the packing end 130 and edge strips 135. The main plate of the blade is of approximate wedge shape in vertical cross-section and is channeled at its outer end and its edges to form the inwardly-presented angular locking-ribs 125[a] and 126[a] and 127. The hollow spring packing end 130 of slightly oval shape in cross-section is formed with the inwardly-presented angularly-flanged locking ends 131, which are interlocked with the angular flanges 125[a] and 126[a] of the main plate. The edge packing-strips 135 are of T-shape cross-section and are seated in the channels in the edges of the main plate, interlocked with ribs 127 and fitting tightly against the spring-head 130 and its ends 131. The piston-head is formed with a series of transverse dovetailed grooves in its periphery at the proper points, and the piston-blades are inserted laterally therein and properly wedged and rigidly secured in position. The parts are all accurately machined and are capable of adjustment radially of the piston-head, the parts being wedged and rigidly se-

cured by insertion of shims in suitable places to secure the piston-blades in the proper position so as to accurately fit within the working cylinders and clear the surfaces of the lunette recesses of the rotary abutments.

Turning next to the structure of the valves mounted within the partitions 32 and 42, three of such valves being arranged in each of said partitions for controlling the openings through the three sets of ports or passages, the preferred structure of said valves will be clearly understood by reference to Figs. 9 and 10 of the drawings. A recess, such as 150, is cut into the face of the partition at the point of location of the valve, and an approximately semicircular valve-plate 151 is mounted in said recess upon a pivot 152, said valve-plate being formed with a single port or opening 153. The threaded valve-rod 154, having pin-and-slot connection 155 156 with the valve-plate 151, passes through a suitable channel or opening in the partition-wall to a point outside of the engine-casing, where it is provided with a hand-wheel 157, by which the valve-plate can be shifted. By reason of the shape of valve-plate 151 it will be observed that when the operating-rod is forced inwardly the port or opening—such, for instance, as 34^b—is thrown open, while the opening 34^a is closed. By reversing the position of the valve-plate it will be observed that the port 34^b will be closed, while the opening 153 of the valve-plate will be brought into register with the port 34^a for opening the latter. These valves 151 are used only for reversing the engine.

The operation of the improved reversible rotary steam-engine in its compound expansion form, as shown in the drawings, may be described as follows: The main supply-valve plate 18 being shifted to the position for opening up the ports 16 through the end wall 11 will supply live steam through ports 27 and 27^a between the piston-blades 26 and abutment-heads 95, the piston-head 25 automatically cutting off the supply of live steam when the ports 27 reach the ends of the groove-ports 16^a, so as to allow the steam to act expansibly for a part of the stroke. This cutting off of the live steam is immediately followed by the resupply of live steam when the ports 27 again come into communication with the succeeding groove-ports 16^a. As the high-pressure piston rotates the high-pressure cylinder exhausts through the ports 28^a and 28 into the circular exhaust-groove ports 32^b of the partition-wall 32, from which the exhaust passes through ports 34^b into groove-ports 34^d. The intermediate-pressure cylinder receives the exhaust from the high-pressure cylinder when the ports 37 come into communication with the groove-ports 34^d, supplying the steam through ports 37^a to the intermediate-pressure cylinder between the piston-blades 36 and rotating abutments 100. The intermediate-pressure cylinder exhausts continuously through ports 38^a and 38 into the circular exhaust groove-port 42^b of the partition-wall 42, from which the steam passes through the ports 44^b into the groove-ports 44^d. The low-pressure cylinder receives the steam from groove-ports 44^d through the ports 48 and 48^a, this low-pressure cylinder exhausting continuously through ports 47^a and 47 into the exhaust groove-port 54 of the end plate 51 and next through exhaust-openings 56 into the common exhaust-chamber 50. In this operation in the forward rotation of the engine it will be clear that each of the three rotary pistons automatically connects and cuts off the supply of steam at the proper points in the revolution. To reverse the engine, the main supply-valve plate 18 is reversed, so as to open up communication between the steam-chest 10 and ports 17, cutting off the ports 16. The valves in partition 32 are then shifted to close communication through ports 34^b and open up communication through ports 34^a. The valves in partition 42 are also shifted to close communication through ports 44^b and open up communication through ports 34^a. Finally, the exhaust-controlling valve 75 is shifted to close communication through ports 56 and open up communications through ports 57. With this reversed condition of the valves the passage of steam through the engine from steam-chest 10 through ports 18^b, 17, 17^a, 28, and 28^a to the high-pressure cylinder and from there exhausting through ports 27^a 27, groove-port 32^a, ports 34^a, groove-ports 34^c, ports 38 and 38^a into the intermediate cylinder, and from thence exhausting through ports 37^a and 37^b to groove-port 42^a, ports 44^a, and groove-ports 44^c, and then through ports 47 and 47^a into the low-pressure cylinder, the steam exhausting from the low-pressure cylinder through ports 48^a 48 and groove-port 55 and ports 57 into the exhaust-chamber 50.

It will be clear that the reversible rotary steam-engine can be constructed within the scope of my invention of the simple or of the compound type. An engine can be made of the simple type with a rotating piston having two or more piston-blades or of the compound type with a plurality of two or more rotating pistons, each piston having two or more piston-blades.

It will be clear that the engine can be operated, as shown in the drawings, in horizontal position, or it can be operated in vertical position, in this latter case it being of course necessary to arrange proper thrust-bearings for the rotating shafts.

While I have illustrated and specifically described my improved reversible rotary engine in its preferred form as a steam-engine, I would have it understood that I do not in-

tend to limit my invention to engines driven by steam-power, but would have it clearly understood that my engine may be designed for any suitable motive fluid without departing from the scope of my invention.

Having thus described my invention, the following is what I claim as new therein and desire to secure by Letters Patent:

1. In a reversible rotary engine, the combination of a casing forming a working chamber and having two supply-ports through one end wall, and two exhaust-ports through the other end wall, valves controlling the supply and exhaust ports, a rotary piston-head operating in the working chamber or cylinder and provided with a radial piston-blade and with two interchangeably-acting supply and exhaust ports through it, said piston-head acting as an automatic valve for cutting off the supply of working fluid to either piston-port.

2. In a rotary engine, the combination of a casing forming a working chamber and having supply and exhaust ports in its end walls, and short groove-ports in the inner face of one wall in communication with the supply-port, a rotary piston-head operating in the working chamber or cylinder and provided with a radial piston-blade and with supply and exhaust ports which lead from the ends of the piston-head to the working chamber, said rotary piston acting as an automatic valve for opening and cutting off the supply of working fluid.

3. In a reversible rotary engine, the combination of a casing forming a working chamber, and having supply and exhaust ports in its end walls, and short groove-port extensions in the inner face of one end wall in communication with the supply-ports, a rotary piston-head operating in the working chamber and provided with a plurality of radial piston-blades and with two series of interchangeable supply and exhaust ports, which lead from the ends of the piston-head to the working chamber, one series of ports entering the working chamber in front of the piston-blades, and the other series of ports entering the working chamber behind the piston-blades, and reversing-valves controlling the supply and exhaust ports.

4. In a reversible rotary engine, the combination of a casing forming a working chamber, and having two supply-ports through one end wall and two exhaust-ports through the other end wall, a rotary piston-head operating in the working chamber or cylinder and provided with a series of radial piston-blades and with two series of interchangeably-acting supply and exhaust ports, one series of ports entering the working chamber in front of the piston-blades and the other series entering the working chamber behind the piston-blades, and reversing-valves controlling the supply and exhaust ports of the casing.

5. In a reversible rotary engine, the combination of a casing having two valved supply-ports, and two valved exhaust-ports, a rotary piston-head operating in said casing and having a radial piston-blade and two ports, one of which piston-ports communicates with one of the supply-ports and one of the exhaust-ports and leads into the working chamber in front of the piston-blade, and the other piston-port communicates with the other supply-port and the other exhaust-port and leads into the working chamber behind the piston-blade, and a suitable coöperating abutment.

6. In a reversible rotary engine, the combination of a casing having two series of supply-ports, and two series of exhaust-ports, with a valve adapted to close either series of the supply-ports, a second valve adapted to close either series of exhaust-ports, a rotary piston-head operating in said casing and having a plurality of radial piston-blades and two series of ports, one series of piston-ports communicating with one series of supply-ports and one series of exhaust-ports and leading into the working chamber in front of the piston-blades, and the other series of piston-ports communicating with the other series of supply-ports and the other series of exhaust-ports and leading into the working chamber behind the piston-blades, and suitable coöperating abutments.

7. In a reversible rotary engine, the combination of a casing having two series of valved supply-ports in one end wall, and two valved exhaust-ports in the opposite end wall, the supply-ports having short groove extensions in the inner face of the cylinder-wall, a rotary piston-head operating in the casing and provided with a plurality of piston-blades, two series of ports passing through the piston-head and communicating respectively with the two series of supply and exhaust ports in the casing-walls, one series of said piston-ports entering the working chamber in front of the piston-blades, and the other series of piston-ports entering the working chamber behind the piston-blades, and suitable coöperating abutments, substantially as set forth.

8. In a reversible rotary engine, the combination of a casing having two series of valved supply-ports in one end wall, and two valved exhaust-ports in the opposite end wall, the supply-ports having short groove extensions in the inner face of the one end wall, and the exhaust-ports being in communication with circular exhaust groove ports in the inner face of the other end wall, a rotary piston-head operating in the casing and provided with a plurality of piston-blades, two series of ports passing through the piston-head and communicating respectively with the two series of supply and with the exhaust ports in the casing-walls, one series of said piston-ports entering the working

chamber in front of the piston-blades, and the other series of piston-ports entering the working chamber behind the piston-blades, and suitable coöperating abutments, said piston-head acting as an automatic cut-off for the supply-ports.

9. In a reversible rotary engine, the combination of a casing having two series of supply-ports in one end wall, and two exhaust-ports in the opposite end wall, the supply-ports having short groove extensions in the inner face of the cylinder-wall, and the exhaust-ports being in communication with circular exhaust groove-ports in the inner face of the wall of the cylinder, valves controlling the supply and exhaust ports, a rotary piston-head operating in the casing and provided with a plurality of piston-blades, and two series of ports passing through the piston-head and communicating respectively with the supply and exhaust ports in the casing-walls, one series of said piston-ports entering the working chamber in front of the piston-blades, and the other series of piston-ports entering the working chamber behind the piston-blades, and suitable coöperating abutments.

10. In a reversible rotary engine, the combination of a casing having a fluid-supply chamber at one end and an exhaust-chamber at the opposite end, two series of fluid-supply ports leading from the supply-chamber into the casing, and two series of exhaust-ports leading from the casing to the exhaust-chamber, a partition-wall dividing the casing into a plurality of working chambers, said partition-wall being provided with two series of ports passing through it, a plurality of rotary piston-heads mounted upon a common shaft within said plurality of working chambers, each piston-head being provided with radial piston-blades and with two series of ports leading into the working chamber in front and rear respectively of the piston-blades and communicating respectively with the series of supply-ports and exhaust-ports, a plurality of abutments operating in the casing and coöperating with the piston-blades, means for operating the abutments, and a plurality of valves controlling the two series of ports through the end walls and partition, whereby the engine may be operated in either direction.

11. In a reversible rotary engine, the combination of a casing forming a working chamber and having working-fluid-supply ports at one end, and exhaust-ports at the other end, a partition-wall dividing the casing into two working chambers, said partition-wall being provided with suitable ports through it, two rotary piston-heads mounted upon a common shaft within said working chambers, each piston-head being provided with a plurality of equally-spaced radial piston-blades and with ports leading into its working chamber and communicating with the ports in one end of the casing and the ports in the partition-wall, each piston-head having the same number of piston-blades, and the blades of the two heads being arranged in different radial planes, abutments operating in the working chambers, and valves controlling the supply and exhaust ports of the casing.

12. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads mounted upon a common shaft and operating in the working chambers, each piston-head being provided with an equal number of equally-spaced radial piston-blades and with supply and exhaust ports through it, the blades of the several piston-heads being arranged in different radial planes, and compound abutments operating in the casing, each compound abutment comprising a plurality of recessed abutment-heads mounted upon a common shaft and arranged with their recesses in different radial planes to coöperate with the arrangement of piston-blades.

13. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads operating in the working chambers and provided each with a plurality of radial piston-blades and with supply and exhaust ports through it, and a plurality of compound abutments operating in the casing and coöperating with piston-blades, each compound abutment comprising a plurality of abutment-heads arranged longitudinally upon a common shaft, and each abutment-head being formed with a recess to admit the passage of the piston-blades.

14. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads of graduated diameters mounted upon a common shaft and operating in the working chambers, each piston-head being provided with a plurality of radial piston-blades and with supply and exhaust ports through it, and a plurality of compound abutments operating in the casing in coöperation with the piston-blades, each compound abutment comprising a plurality of abutment-heads mounted upon a common shaft, and each abutment-head being formed with a recess to admit the passing of the piston-blades.

15. In a rotary engine, the combination of a casing formed with a plurality of working chambers of graduated areas and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads operating in the working chambers and provided each with a plurality of radial piston-

blades and with supply and exhaust ports through it, the blades of the several piston-heads being of graduated size to correspond with the graduated areas of the working chambers, and suitable abutments coöperating with the piston-blades.

16. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads of graduated sizes operating in the working chambers and provided each with a plurality of radial piston-blades and with supply and exhaust ports through it, a plurality of compound abutments operating in the casing and coöperating with the piston-blades, each compound abutment comprising a plurality of abutment-heads mounted upon a common shaft and graduated in size to correspond with the graduated piston-heads, and each abutment-head being formed with a recess to admit the passing of the piston-blades.

17. In a rotary engine, the combination of a casing forming a working chamber and having working-fluid-supply ports at one end and exhaust-ports at the other end, a partition-wall dividing the casing into a plurality of working chambers, said partition-wall being provided with suitable ports through it, rotary piston-heads mounted upon a common shaft within said working chambers, each piston-head being provided with a plurality of radial piston-blades and with ports leading into the working chambers and communicating with the ports in the end walls and partition-walls of the casing, a plurality of compound abutments operating in the casing and coöperating with the piston-blades, each compound abutment comprising a plurality of abutment-heads each of which is formed with a recess to admit the passage of the piston-blades, means for operating the compound abutments, and valves controlling the supply and exhaust ports.

18. In a reversible rotary engine, the combination of a casing having a supply-chamber at one end and an exhaust-chamber at the opposite end, two series of supply-ports leading from the chamber into the casing, and two series of exhaust-ports leading from the casing to the exhaust-chamber, short groove-ports in the inner face of the end wall at the supply end of the casing in communication with the two series of supply-ports, two circular exhaust-port grooves in the exhaust end wall of the casing in communication respectively with the two series of exhaust-ports, partition-walls dividing the casing into a plurality of working chambers, each partition-wall being provided with two circular exhaust groove-ports in one face, two series of ports passing through the partition-wall and communicating respectively with the circular groove-ports, and two series of short groove-ports in the opposite face of the partition-wall and communicating respectively with the two series of through-ports, a plurality of rotary piston-heads mounted upon a common shaft within said plurality of working chambers, each piston-head being provided with radial piston-blades and with two series of ports leading into the working chamber in front and rear respectively of the piston-blades and communicating respectively with the series of supply-port grooves and circular exhaust groove-ports, a plurality of abutments operating in the casing and coöperating with the piston-blades, means for operating the abutments, and a plurality of valves controlling the two series of ports through the end walls and partition-walls, whereby the engine may be operated in either direction.

19. In a reversible rotary engine, the combination of a casing having walls forming a working chamber and two series of ports leading through each of said walls, reversing-valves controlling the said two series of ports in each wall, a plurality of rotary abutments, and a rotary piston-head operating in said working chamber, a plurality of radial blades upon said piston-head, two series of radial ports formed in the piston-blades, one series communicating with the working chamber in front of the piston-blades, and the other series communicating with the working chamber behind the piston-blades, and offset ports leading from each radial piston-port to the ports of the end walls, substantially as set forth.

20. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads operating in the working chambers and provided each with a plurality of radial piston-blades and with supply and exhaust ports through it, and suitable abutments coöperating with the piston-blades.

21. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads operating in the working chambers upon a common axis and provided each with a plurality of radial piston-blades and with supply and exhaust ports through it, suitable abutments coöperating with the piston-blades, and a valve controlling the casing supply-ports.

22. In a rotary engine, the combination of a casing formed with a plurality of working chambers and having supply and exhaust ports in its partition and end walls, a plurality of rotary piston-heads operating in the working chambers upon a common shaft and provided each with a plurality of rigidly-mounted radial piston-blades and with sup-

ply and exhaust ports through it, suitable abutments movably mounted in the casing and coöperating with the piston-blades, and means controlling the casing supply-ports.

23. In a rotary engine, the combination of a casing having end walls and partition-walls forming a plurality of working chambers, said end walls and partition-walls having ports through them, a plurality of rotary piston-heads mounted upon a common shaft and operating in the working chambers, each piston-head being provided with a plurality of radial piston-blades and with two series of supply and exhaust ports passing through it, and suitable abutments mounted in the casing and coöperating with the piston-blades.

24. In a reversible rotary engine, the combination of a casing having end walls and partition-walls forming a plurality of working chambers, said end walls and partition-walls having two series of ports through them, a plurality of rotary piston-heads mounted upon a common shaft and operating in the working chambers, each of said piston-heads being provided with a series of radial piston-blades and with two series of interchangeably-acting supply and exhaust ports extending through it, a plurality of abutments coöperating with said piston-blades, and reversing means controlling the supply and exhaust of working fluid through the ports of the casing.

25. In a rotary engine, the combination of a casing forming a working chamber, an abutment, and a rotary piston-head operating in said chamber and provided with a radial piston-blade, said blade being formed of the interlocked face-plate and spring bearing-head, the bearing-head being of hollow-spring formation capable of yielding engagement with the cylinder-wall.

26. In a rotary engine, the combination of a casing forming a working chamber, a rotary abutment, and a rotary piston-head operating in said chamber and provided with radial piston-blades, each piston-blade being formed of a face-plate dovetailed into the piston-head and having the inwardly-presented locking-flanges, a hollow spring bearing-head formed with inwardly-presented arms having flanges which interlock with the flanges of the face-plate, interlocked T-shaped side bearing-strips, and means for rigidly wedging said parts in operative position upon the piston-blades.

RICHARD N. STORY.

Witnesses:
JOHN EDMONDS,
BEN WEIL.