No. 733,777. PATENTED JULY 14, 1903.

F. J. WATERS.

ROTARY STEAM ENGINE.

APPLICATION FILED OCT. 10, 1902.

NO MODEL. 4 SHEETS—SHEET 1.

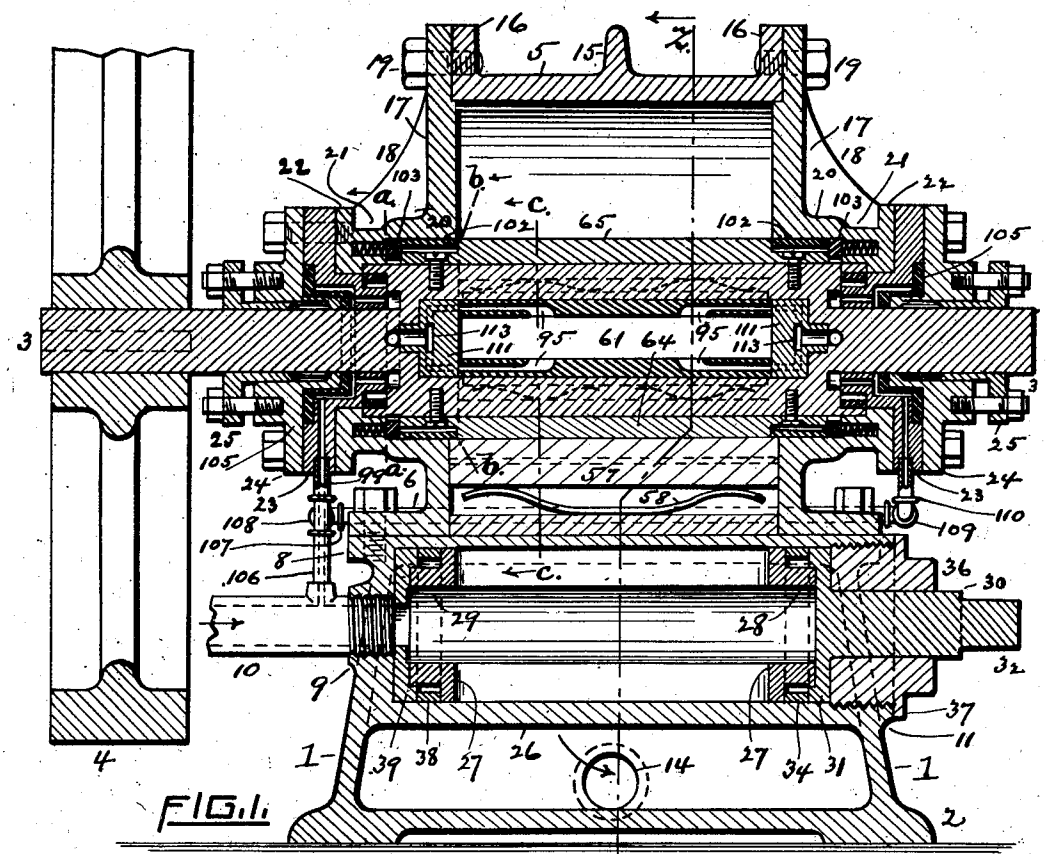


FIG. 1.

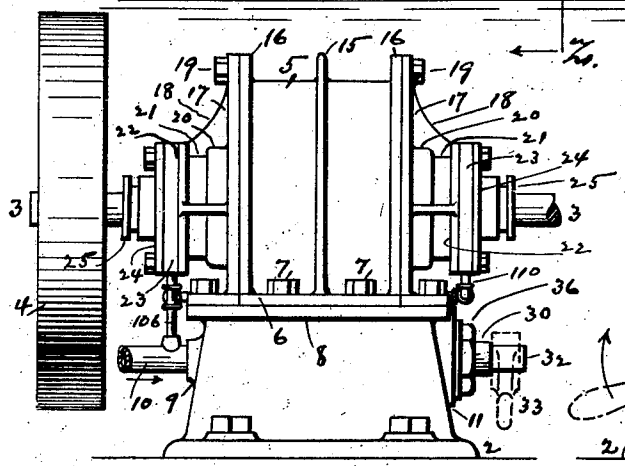


FIG. 2.

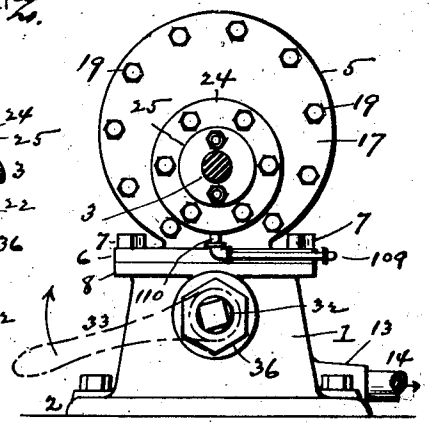


FIG. 3.

WITNESSES.

Charles T. Hannigan.

Joseph R. Bullock Jr.

INVENTOR.

Frank J. Waters

By Warren R. Pence

Attorney

THE NORRIS PETERS CO., PHOTO-LITH., WASHINGTON, D. C.

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NO MODEL. 4 SHEETS—SHEET 2.

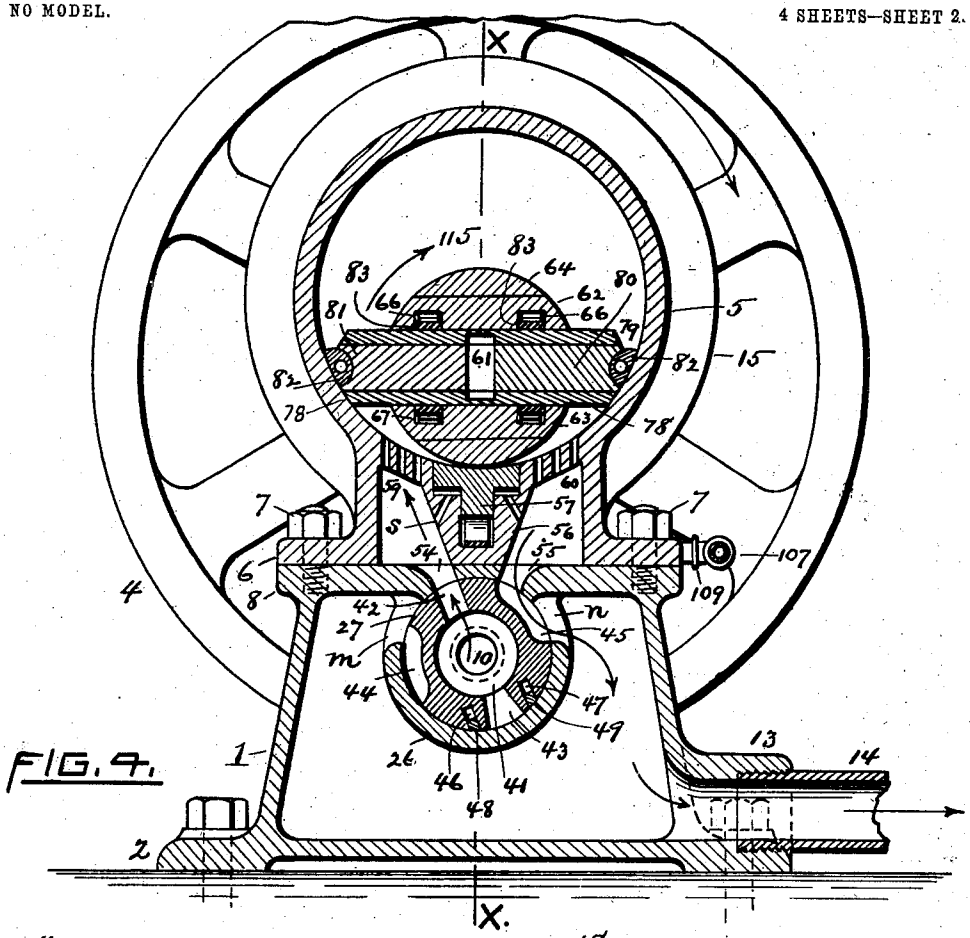


FIG. 9.

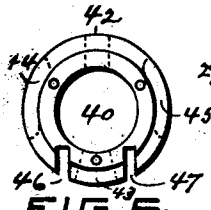


FIG. 6.

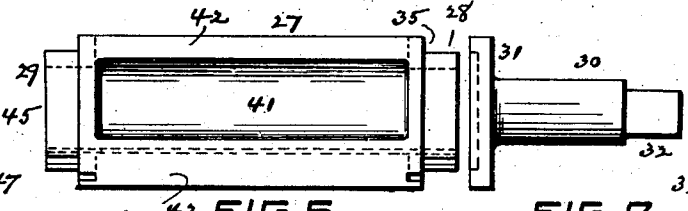


FIG. 5.

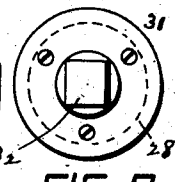


FIG. 7.

FIG. 8.

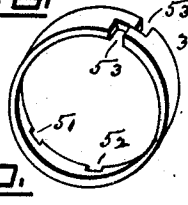


FIG. 10.

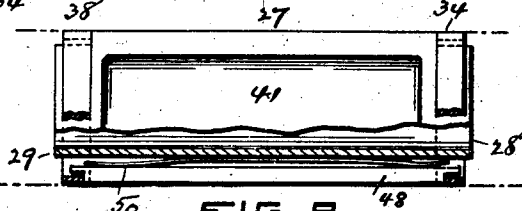


FIG. 9.

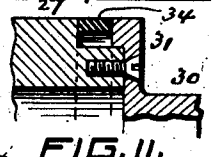


FIG. 11.

WITNESSES.

Charles T. Hannigan.

Joseph R. Bullock Jr.

INVENTOR.

Frank J. Waters

By Warren R. Peirce

Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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FIG. 14.

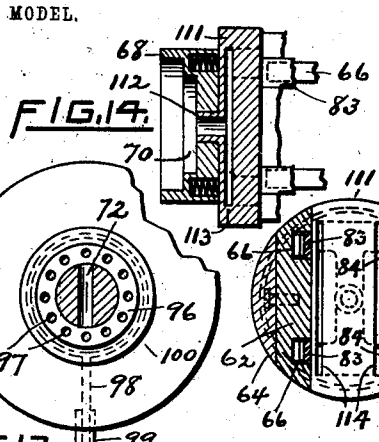


FIG. 15.

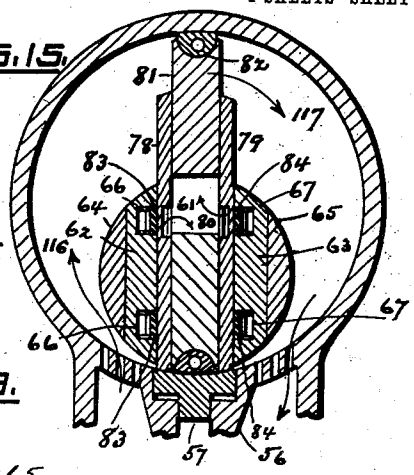


FIG. 12.

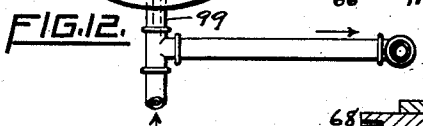


FIG. 13.

FIG. 16.

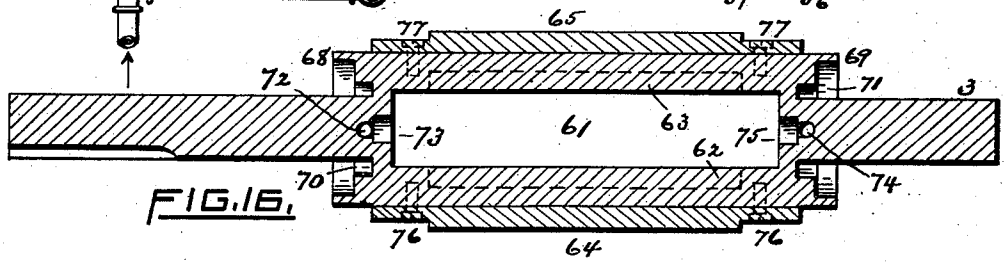


FIG. 17.

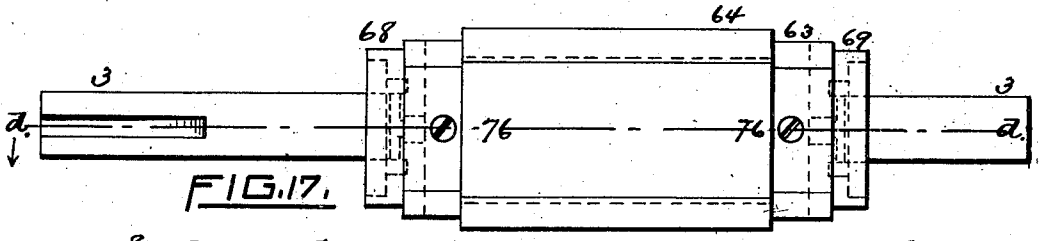
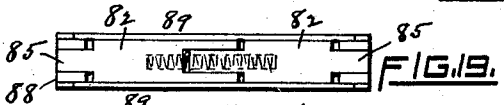


FIG. 19.



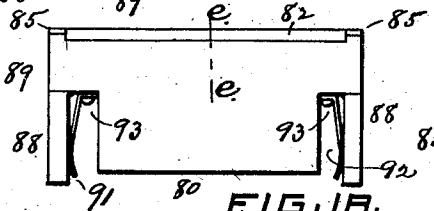


FIG. 18.

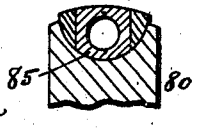


FIG. 20.

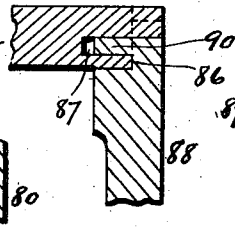


FIG. 21.

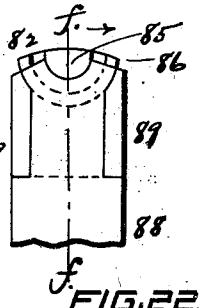


FIG. 22.

WITNESSES.

Charles T. Hannigan.

Joseph R. Bullock, Jr.

INVENTOR.

Frank J. Waters

by Warren R. Pine

Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 733,777. PATENTED JULY 14, 1903.

F. J. WATERS.

ROTARY STEAM ENGINE.

APPLICATION FILED OCT. 10, 1902.

NO MODEL. 4 SHEETS—SHEET 4.

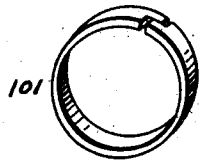


FIG. 23.

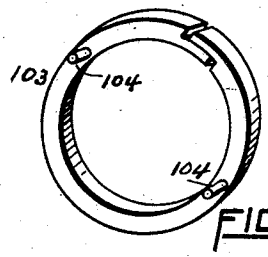


FIG. 24.

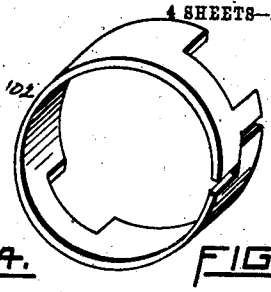


FIG. 25.

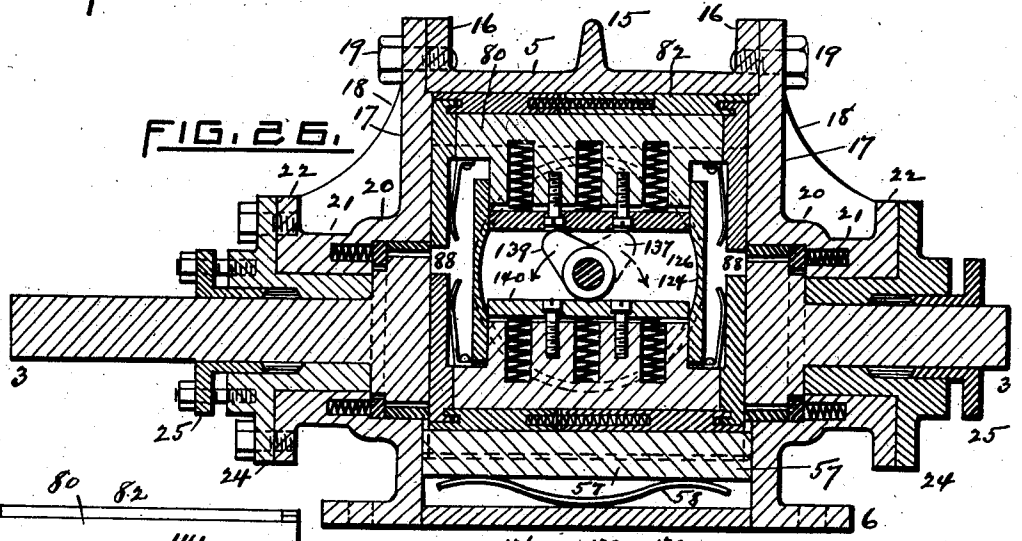


FIG. 26.

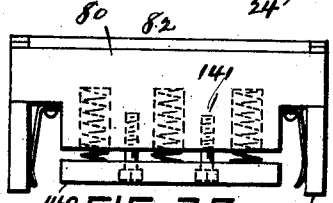


FIG. 27.

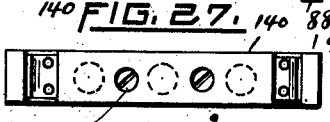


FIG. 28.

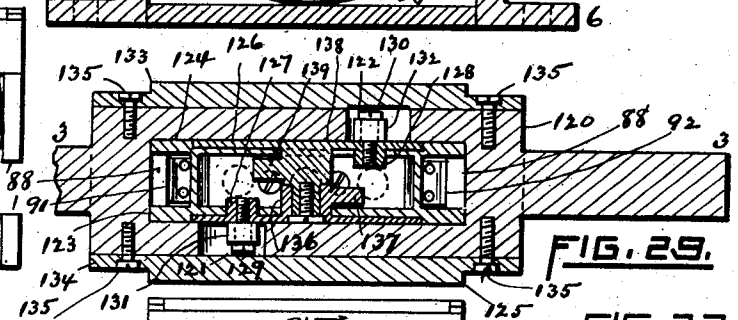


FIG. 29.

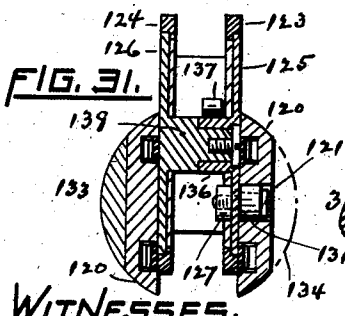


FIG. 31.

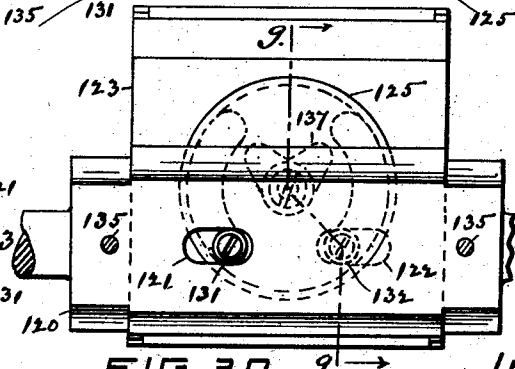


FIG. 30.

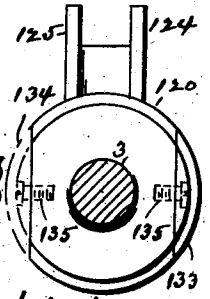


FIG. 32.

WITNESSES.

Charles T. Hannigan.

Joseph R. Bullock, Jr.

INVENTOR.

Frank J. Waters

By Warren R. Pence

Attorney.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 733,777. Patented July 14, 1903.

UNITED STATES PATENT OFFICE.

FRANK J. WATERS, OF PROVIDENCE, RHODE ISLAND, ASSIGNOR OF TWO-THIRDS TO WILLIS A. DREW, FRANK E. FARNHAM, ARTHUR C. FARNHAM, AND ALFRED HARRISON, OF PROVIDENCE, RHODE ISLAND, JAMES GEE, OF CRANSTON, RHODE ISLAND, AND HENRY J. PAGE, OF WARWICK, RHODE ISLAND.

ROTARY STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 733,777, dated July 14, 1903.

Application filed October 10, 1902. Serial No. 126,786. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. WATERS, a citizen of the United States, residing at Providence, in the county of Providence and State of Rhode Island, have invented certain new and useful Improvements in Rotary Steam-Engines, of which the following is a specification, reference being had therein to the accompanying drawings.

Like characters indicate like parts.

Figure 1 is a view of my improved rotary steam-engine as seen on line *x x* of Fig. 4. Fig. 2 is a side elevation of the same. Fig. 3 is an end elevation thereof. Fig. 4 is a sectional view of said engine as seen on line *z z* of Fig. 1. Fig. 5 is a side elevation of the balanced reversing-valve. Fig. 6 is an end elevation of the same. Fig. 7 is a side elevation of the trunnion which supports said valve. Fig. 8 is an end elevation of the same. Fig. 9 is a view of said valve partly in side elevation and partly in central longitudinal section. Fig. 10 is a perspective view of one of the spring ring-packings of said valve. Fig. 11 is a detail view showing in section a part of said valve, the spring ring-packing in position thereon, and the means for securing the trunnion upon the valve. Fig. 12 is a view, partly in elevation and partly in section, on line *a a* of Fig. 1. Fig. 13 is a view, partly in elevation and partly in section, on line *b b* of Fig. 1. Fig. 14 is a central longitudinal section of one of the steam-valves, showing the ports which conduct the steam to the expansion-chamber of the pistons. Fig. 15 is a cross-sectional view as seen on line *c c* of Fig. 1. Fig. 16 is a central longitudinal section, on line *d d* of Fig. 17, of the main shaft of my improved engine and the hub diametrically slotted for the reception of the piston-case therein. Fig. 17 is a side elevation of the same. Fig. 18 is a side elevation of one of the piston-blades. Fig. 19 is a top plan view of the same. Fig. 20 is an enlarged detail view as seen on line *e e* of Figs. 18 and 19. Fig. 21 is an enlarged detail view of the rocking packing-bar of the piston-blade, together with the means of supporting the same in position as seen on line *f f* of Fig. 22. Fig. 22 is an enlarged end view of the same. Figs. 23, 24, and 25 are perspective views of three of the spring ring-packings. Figs. 26 to 32, inclusive, are views of a modified form of my invention in which the expansion of the piston is caused by mechanism instead of by steam-pressure. Of these, Fig. 26 is a central longitudinal section of the engine provided with such mechanical expansive means. Fig. 27 is a side elevation of said modified form of the piston-blade. Fig. 28 is a top plan of the same. Fig. 29 is a central longitudinal section of the main shaft and the piston and piston-case thereon provided with said mechanical devices. Fig. 30 is a side elevation of the same. Fig. 31 is a cross-sectional view as seen on line *g g* of Fig. 30. Fig. 32 is an end elevation of the parts shown in Fig. 30.

My invention relates to rotary steam-engines, and more particularly to the use of an expansive piston mounted in a piston case or frame therein and suitable valves for the same; and it consists of the novel construction and combination of the several parts, as hereinafter described, and specifically set forth in the claims.

In the drawings the exterior parts of my improved engine are best shown in Figs. 2 and 3. The base 1 of the engine is an inclosed chamber having a flange 2, by which it is bolted to the floor or other proper support.

3 is the main shaft, on which the fly-wheel 4 is splined, as usual.

The cylinder 5 has a base 6, by which it is fastened by bolts 7 to the upper plate or table 8 of the base 1.

The base 6 has a boss 9, provided with a screw-threaded circular opening in which the pipe 10 is fitted, which takes steam from the boiler to the engine. On the opposite side the base is made with a boss 11, having a large screw-threaded circular aperture in which is fitted a sleeve or tube 12. The base 6 also has a tube or boss 13, provided with a screw-

threaded circular aperture in which is fitted the exhaust-pipe 14 to carry away the exhaust-steam from the engine.

The cylinder 5 has a central circumferential rib 15 to strengthen and stiffen said cylinder. The cylinder 5 has at each end a circular flange 16, and each end of the cylinder is closed by a head 17, provided with strengthening side ribs 18 and bolted at 19 to the flange 16 of said cylinder. Each cylinder-head 17 has integral therewith the concentric sleeves or tubes 20 and 21 and the circular flange 22.

23 is a tube or port-sleeve whose purpose I will presently describe, and 24 is a stuffing-box surrounding the main shaft 3 of the engine and provided with the usual packing, which is compressed by a gland 25 in the well-known manner.

In the base or chamber 1 and integral therewith is a valve-seat 26, substantially tubular in form and shown in Figs. 1 and 4. This tubular valve-seat has the two opposite ports *m* and *n*. In this tubular valve-seat is mounted a valve 27, capable of limited oscillation therein, which valve is shown separately in Figs. 5 and 9. The ends 28 29 of the valve 27 are reduced concentrically in diameter, and on the valve end 28 is fitted and fastened in any suitable manner, preferably by screws, as shown in Fig. 11, a trunnion 30, whose inner end is diametrically enlarged, as seen at 31, and chambered, as indicated in dotted lines in Fig. 7, so as to receive the end 28 of the valve 27. The outer end 32 of the trunnion 30 is squared in cross-section, as shown in Fig. 8, for the reception of a wrench or lever 33, (see Fig. 3,) by means of which said trunnion 30 can be turned, and with it the valve 27, for the purpose hereinafter explained. A split-spring ring-packing 34, Fig. 10, surrounds the end 28 of the valve 27 and lies between the annular shoulder 35 of said valve (see Figs. 5 and 9) and the circular flange or head 31 of the trunnion 30. A sleeve 36 has a smooth central bore through which the trunnion 30 passes and also an exterior screw-thread, as shown in Fig. 1, by which it is engaged with the tubular valve-seat 26, the circular flange 37 of said sleeve lying over the open end of the boss 11 of the base 1, as illustrated in Fig. 1.

On the end 29 of the valve 27 is placed a split-spring ring-packing 38, and the same is held in position thereon from lateral movement by the washer 39, having a central circular aperture and provided with an annular flange which receives and surrounds the extremity of said end portion 29 of the valve 27, as shown in Fig. 1.

The valve 27 is in general shape cylindrical, having a concentric aperture 40 through its end 29, as shown in Fig. 6, and a concentric chamber 41 extends in the valve 27 longitudinally. The chamber 41 is circular in cross-section, as best seen in Fig. 4. The valve 27 has an upper port 42, extending both longitudinally, as shown in Fig. 5, and radially, as shown in Fig. 4, whose longitudinal sides are parallel, and also a diametrically opposite lower port 43, extending both longitudinally, as shown in Fig. 5, and radially, as shown in Fig. 4. These ports 42 and 43 open into the central chamber 41 of the valve 27. On the sides of the valve 27 are two grooves or depressions 44 and 45, which, with the tubular valve-seat 26, constitute ports or steam-passages, as will be hereinafter explained.

The valve 27 has at its bottom two parallel grooves 46 and 47, Figs. 4, 6, and 9, in which respectively are packing-bars 48 49 of about the same width as the grooves, so as to move freely therein, but having a thickness from top to bottom less than the depth of said grooves. The outer edge of each packing-bar is flush with the peripheral surface of the valve and curved to correspond therewith, as illustrated in Fig. 4. In the space between the inner edge of the packing-bar and the bottom of the slot is a bow-spring 50, as seen in Fig. 9. The ends of the packing-bar have ears (shown in Fig. 9) which hold the bar in place by projecting within the spring-rings 34 38, said rings being provided with slots 51 52, as seen in Fig. 10, for the reception of the ends of said packing-bar. The spring-ring packing 34 (or 38) is split, as shown at 53, Fig. 10, to afford the requisite elasticity of action.

The table or upper plate 8 of the base or chamber 1 has two ports or passages 54 and 55 of such size and shape and so located that the port 42 of the valve 27 may be moved to register with either one of them, as shown in Fig. 4.

At the bottom of the cylinder 5 is a steam-chest, (see Fig. 4,) and extending longitudinally therein is a block or piece 56, which in cross-section has the shape of a truncated wedge, the lower or smaller edge of which rests upon the central longitudinal portion of the table 8. Said block 56 has on its upper part a longitudinal slot or groove T-shaped in cross-section. The piece or block 57 is a partition dividing the steam-chest beneath the cylinder into two compartments. A packing-strip 57, substantially T-shaped in cross-section, is loosely inserted in the T-shaped slot or groove. The upper surface of the packing-strip 57 is longitudinally concaved to be continuous in curvature with the inner surface of the cylinder 5, and a bow-spring 58 in the bottom of said slot bears up against the lower edge of the packing-strip 57, as seen in Figs. 1 and 4.

The bottom of the cylinder 5 has small parallel vertical ports or openings 59 60 through it.

The main shaft 3 extends through the cylinder 5 longitudinally, but eccentrically, and the portion thereof within the cylinder constitutes a hub. This hub is made up of several parts and is separately illustrated in Figs. 13, 16, and 17 and in combination with other parts in Figs. 1, 4, and 15. One por-

tion of this hub is integral with the main shaft 3, as seen in Fig. 16, and is substantially rectangular on two of its opposite faces, but concentrically curved or convexed on its other two opposite faces. It is provided with a central transversely-directed slot 61, rectangular in shape, as seen in Figs. 1, 15, 16, and 29, and also has closed ends. In combination with this integral portion of the hub are the two fixed guide-plates 62 63, also integral with the main shaft 3, and two detachable strips 64 65, substantially segmental in cross-section. The fixed guide-plates 62 63 have longitudinal slots 66 67. (Shown in dotted lines in Figs. 1 and 16 and transversely in solid lines in Figs. 4, 13, and 15.) The guide-plates 62 and 63 have curved edges, as seen in Figs. 4, 13, and 15, continuous in curvature with the convex surfaces of the strips 64 and 65, so that together they form a true circle, as seen in central transverse section, and they have at their ends the annular flanges 68 69 and the concentric annular chambers 70 71. (Best shown in Fig. 16.) A port 72 opens at one end into the chamber 70 and at the other end into the passage 73, and a port 74 opens at one end into the chamber 71 and at the other into the passage 75, as seen in Fig. 16. The strips 64 and 65 are reduced in thickness and curvature at their ends and are secured by screws 76 77 to the fixed guide-plates 62 63. The parts 62 to 77, inclusive, above described move with the main shaft 3 in the rotation thereof. The reciprocating part or piston proper is described as follows: There are two rectangular sliding guide-plates 78 and 79 parallel with each other and connected at their opposite ends by strips, as best seen in Figs. 31 and 32. Between the guide-plates 78 79 are the two pistons or blades 80 and 81, each provided with a packing-strip 82. (Best shown in Figs. 4 and 15.) These parts 78, 79, 80, and 81 have sliding movements in a direction at right angles with the axial line of the main shaft, the plates 78 and 79 sliding between the plates 66 67 and the piston-blades 80 and 81 sliding between the plates 78 and 79. Packing-strips 83 and 84 are located in said slots 66 and 67 and bear against the sliding plates 78 and 79 by the pressure of bow-springs placed behind them in the slots 66 67. These parts 62 to 77, inclusive, and 78 to 83, inclusive, constitute the piston of the engine, the characteristic feature of which is, as shown in the drawings, that its axial line is considerably lower than the axial line of the cylinder 5, in which it moves and operates, and that the plates 78 79 and the piston-blades 80 and 81 move from the radial distance shown in Fig. 15 as occupied by the piston-blade 80 to the radial distance shown in said Fig. 15 as occupied by the piston-blade 81. The packing-bars 82 have a rolling motion. They are shown in detail in Figs. 18 to 22, inclusive, and in position on the piston in Figs. 4 and 15. Each packing-bar 82 is made up of two pieces, as seen in Fig. 19, one tongued and the other mortised and both longitudinally bored for the reception of a spiral spring, (shown in dotted lines in Fig. 19,) by which said two parts are expanded or spread apart as far as is allowed by their supporting means. The outer edge of each packing-bar 82 is convexed transversely in a curve corresponding to the curvature of the inner surface of the cylinder 5, Figs. 4 and 15. Each packing-bar 82 has a semicircular trunnion 85 and a semi-annular tongue 86 with a semi-annular groove 87 between said tongue and trunnion. At each end said packing-bar 82 rests by its trunnion 85 in a semicircular socket formed in the outer end of a supporting-bar 88, which is also provided with a semi-annular groove for the reception of the tongue 86 of the packing-bar 82, as shown in Fig. 21. Said supports are loosely mounted by tenons between two cross-pieces 89, Figs. 19 and 22, and are secured in position by a semi-annular tongue 90, engaging with the groove 87. The cross-pieces 89 support the piston-blade 80. Springs 91 92, secured by screws 93, are fastened to the piston-blade 80 and press against the inner edge of each of the supporting-bars 88 to normally spread apart the lower ends of said supporting-bars, and so to cause the upper ends of said supporting-bars to press inwardly against the packing-bars 82, a space being provided, as shown in Fig. 18, between the outer edges of the piston-blade 80 and the adjacent inner edge of each supporting-bar 88. The supporting-bars 88 are inserted in the slot 61 with their outer edges in sliding contact with the inner faces of the port-blocks 111 111. In the central longitudinal line of each of the sliding plates 78 and 79 are two ports 95 (shown in Fig. 1) and extending from the inner surface of said plates within the same to the opposite edges thereof.

Between the flange 22 of the cylinder-head 17 of the cylinder 5 and the stuffing-box 24 is the tubular sleeve 23, having two concentric bores (shown in vertical diametrical section in Fig. 1 and in elevation in Fig. 12,) as seen on line *a a* of Fig. 1. The inner (smaller) end of the sleeve 23 is shown as 96 in Fig. 12 and has a series of small ports 97. As shown at 98 in Figs. 1 and 12 a straight passage-way extends radially from the bottom of said sleeve 23, the outer end of which passage is enlarged to receive the upper end of a steam-pipe 99. The intermediate portion 100 of the sleeve 23, Fig. 12, comes to the inner edge of the annular flange 68 of the fixed piston member, as seen in Fig. 1, said flange 68 being also shown in Figs. 14, 16, and 17. In the annular space of said flange 68 and the sleeve 23 is placed the split-spring ring-packing 101. (Shown separately in Fig. 23.) The inner edge of the sleeve 23 closes the outer opening of the chamber 70 71, as shown in Fig. 1. A split-spring ring-packing 102 (shown separately in Fig. 25) surrounds the fixed portion of the piston and passes over the reduced ends of the strips 64 and 65 and has two

diametrically opposite slots, as shown in Fig. 1. A split-spring ring-packing 103 (shown separately in Fig. 24) lies in the annular space between the outer edge of the ring-packing 102 and the inner edge of the integral sleeve 20 of the cylinder-head 17, as seen in Fig. 1. The ring-packing 103 has dowels 104 projecting from the outer edge thereof, (see Fig. 24,) and these are loosely engaged in holes in the inner edge of said integral sleeve 20 of the cylinder-head. Other sockets are also made in said inner edge and in them are placed spiral springs which press against the outer edge of the ring-packing 103, as seen in Fig. 1.

A sleeve 105 has an outwardly-extending flange on one end and an inwardly-extending flange on the other end, and, as shown in Fig. 1, the outwardly-extending flange lies in an annular recess in the outer side of the sleeve or tube 23 and the inwardly-extending flange extends to and receives the main shaft 3. This sleeve 105 has a diameter less than the inner diameter of the sleeve 23, and so leaves between said sleeves an annular steam-passage, as seen in Fig. 1.

A steam-pipe 106 opens from the steam-pipe 10, and a pipe 107 is coupled at 108 to the pipe 106 and extends horizontally to the opposite side of the engine, where it is coupled at 109 to a pipe 110, which enters the port through the sleeve 23 on the side of the engine opposite the fly-wheel 4.

In Fig. 14 is shown a port-block 111, having the central tube or short pipe 112 adapted to lie in the bore 73 of the fixed portion of the piston. The block 111 has a vertical port 113, into which the tube 112 opens, as seen in Fig. 14, and from the port 113 at the top and bottom, as indicated in dotted lines in Fig. 13, are horizontal ports which themselves open into two vertical ports 114. These ports 114, as seen in Fig. 1, open into the ports 95 in the fixed portion of the piston. Each port-block 111 lies in the diametrically opposite slots of the packing-ring 102, Fig. 25.

Through the wedge-shaped block 56 are two ports *s s*, extending diagonally from each outer side to the central longitudinal groove therein.

Having thus specified and described the several parts of my improved rotary engine, I will now explain its operation.

Steam from the boiler under pressure passes into and through the pipe 10. A portion of the steam passes from the pipe 10 into the vertical pipe 106 and thence through the pipes 107, 109, and 110, and a portion of the steam passes through the pipe 10 into the central bore or chamber 41 of the oscillating valve 27. By operating the lever 33 the valve 27 is oscillated in its bearings or seat 26, so that its upper port 42 registers with either the port 54 or 55 of the table or plate 8 of the base or chamber 1 of the engine. In further describing the engine I will do so, considering the parts to be in the positions indicated in Fig. 4, where the valve-port 42 registers with the port 54. The steam entering in the central chamber 41 of said valve 27 in part flows into the chamber or closed port 43, the purpose of said closed port being to balance the valve, which oscillates on a fixed axial line. The packing-bars 48 and 49, pressed outwardly by the bow-springs 50 50, are kept in sliding friction with the inner surface of the circular valve-seat 26, and so prevent steam-leakage from the balancing valve-port 43. The remainder of the steam received in the chamber 41 of the valve 27 passes out through the port 42, through the port 54 into the chamber (shown in Fig. 4) formed by the perpendicular sides and ends of the cylinder-base and the wedge-shaped block 56, and thence passes up through the series of small ports 59 into the cylinder 5. Here the steam (when the piston is in the position shown in Fig. 4) impinges upon the then lower exposed surface of the sliding plate 78 and (as there is no steam-pressure resistance, because there is no steam then passing up through the ports 60) causes the piston and the main shaft, with which a portion of said piston is integral, to rotate, thus revolving the shaft 3 and wheel 4. At the same time the steam which passes from the pipe 10 up through the pipe 106 into the steam-passages shown in Fig. 1 and also the steam which passes from the pipe 106 through the pipes 107, 109, and 110, as shown in Fig. 1, cause the expansion of the piston in the following manner: The steam passing up from the pipe 106 enters the radial port in the sleeve or tube 23 and thence passes into the annular steam-passage between the sleeves 23 and 105, thence through the ports 97, Figs. 1 and 12, into the annular steam passage or chamber 70, Figs. 1 and 14, thence through the port 72, thence through the tube 112, the port 113, the top and bottom ports, Fig. 13, and ports 114 of the port-block 111, and thence through the ports 95 into the expansion-chamber 61 of the piston. The steam from the pipe 106, which passes thence through the pipes 107, 109, and 110, takes a similar course on the opposite side of the engine and also enters said piston expansion-chamber 61. The steam on entering the chamber 61 presses equally against the inner ends of the piston-blades 80 and 81, as indicated by the small arrows in Fig. 15, and so crowds said piston-blades outwardly in opposite directions as far as is allowed by the contact of the packing-bars 82 82 with the inner surface of the cylinder 5. Recurring now to Fig. 4, as the steam passing up through the ports 59 moves the piston-plate 78 in the direction of the arrow 115 the steam in the expansion-chamber 61 forces outwardly the piston 81 continually more and more as the shaft 3 and the piston-hub rotates until the piston 81 reaches the full limit of its movement, when it comes into the position illustrated in Fig. 15. By this time the piston 80, coming around from the position seen in Fig. 4 to that seen in Fig. 15, has been moved inwardly within the chamber 61 by reason of

the packing-strip 82 thereof following the curvature of the inner surface of the cylinder 5. As soon as the piston-case and piston, rotating in the direction indicated by the arrow 115 in Fig. 4 and by the arrows 116 and 117 in Fig. 15, has come to such position that the packing-bar 82 of the piston 80 has passed down beyond the ports 60 the steam then in that part of the cylinder 5 where the arrow 117 is shown in Fig. 15 is enabled to escape through the ports 60, as indicated by the arrow 118 in Fig. 15, and by the continued rotation of the piston-case and the movement of the piston 81 therein is driven out through the port 55 of the table or plate 8, thence through the side port 45 of the valve 26, thence through the port *n* of the tubular valve-seat 27 into the chamber of the base 1, as indicated by the arrow 118 in Fig. 4, from which it passes, as indicated by the arrow 119, through the tube 13 and out of the exhaust-pipe 14. The pressure of the bow-spring 58, Figs. 1 and 4, in the wedge-shaped block 56 against the T-shaped packing-strip 57 causes a steam-tight contact of said packing-strip 57 with the parts of the piston or piston-frame which may at any instant of time be adjacent thereto. The packing-bars 83 and 84 are pressed by the bow-springs in the slots 66 67 of the piston guide-plates 78 79, and this pressure prevents any escape of steam from the expansion-chamber 61 of the piston. The ring-packing 101, Fig. 23, which, as before described, lies between the flange 68 of the hub and the inner edge of the sleeve 23, as shown in Fig. 1, prevents any escape of steam at that place from the annular steam passage or chamber 70, Figs. 14, 16, and 17. The packing-rings 102, Fig. 25, and 103, Fig. 24, prevent any escape of steam from the cylinder 5. The packing-rings 34 and 38 prevent the escape of steam from the chamber 41 of the valve 27. The ports *s s* allow the passage of steam to the under surface of the packing-strip 57 in the groove of the block 56, and thus balance the steam-pressure on the upper surface of said packing-strip 57. The oscillation of the packing-bars 82 of the pistons 80 and 81 and the fact that their edge has the same degree of curvature as the inner surface of the cylinder 5 enables them to maintain a steam-tight contact with the inner surface of the cylinder 5 in whatever position they may be in said cylinder, as will be apparent by examining Figs. 4 and 15. By moving the lever 33 the valve 26 is oscillated to a position such as to allow the port 42 of said valve to register with the port 55, whereupon the direction of the rotation of the main shaft 3 and the piston is reversed.

It is evident that in this engine there is no "dead-center" and that the steam-pressure is always applied at a right angle and that there is no variation in the angle of steam-pressure on the piston. For these reasons this improved rotary engine is especially useful and adapted to the propulsion of automobile vehicles and steam-launches, while for millwork or similar uses it is equally useful and may be compounded merely by duplication and applying the power of several engines directly to one main shaft.

In Figs. 26 to 32, inclusive, is shown a modified form of the invention by which mechanical means instead of steam-pressure are used to cause the piston expansion. In such construction the parts 23, 101, 106, 107, 108, 109, 110, and 111 are dispensed with, which have for their function the conveyance of steam to the expansion-chamber 61 of the piston and the prevention of escaping steam therefrom. In this modified construction the hub or piston-frame 120, as shown in Figs. 30 and 31, has on opposite sides slots 121 122. The piston guides or plates 123 124 each have a circular depression in which are loosely mounted disks 125 126. The disks 125 126 have bosses 127 128, in which are secured screw-threaded bolts 129 130. Friction-rollers 131 132 are rotatably mounted on the bolts 129 130, which rollers project into the slots 121 122, respectively. On the rear of each piston-guide is cut one curved slot ninety degrees in extent, as indicated in dotted lines in Fig. 30, the curved slot of one of the piston guides or plates being diametrically opposite to the curved slot of the other. The segmental strips or pieces 133 134 are fastened by screws 135 to the piston-frame 120 and complete its true circular form, as shown in Figs. 31, 32. The segmental strips 133 134 cover the exterior edges of the slots 121 and 122, as shown in Fig. 29. Integral with the disk 125 on the rear or inner side thereof are the concentric sleeve or tube 136 and the toe 137. Integral with the disk 126 on the rear or inner side thereof are the hub 138 (whose end is concentrically reduced to enter loosely the sleeve 136 of the other disk and is also centrally bored and screw-threaded, as seen in Fig. 29) and the toe 139. The piston-blades are provided with sockets on their inner edges, and in each socket is a spiral spring, as seen in Figs. 26, 27, and 28. Each piston-blade is also provided with a spring-bar 140, having each two circular and shouldered holes. Headed screws 141 pass loosely through these holes and are screwed into the piston-blade. The outer ends of the spiral springs bear against the bar 140. The disks 125 126 are connected by the screw 141, which enters the screw-threaded bore of the hub 138 of the disk 126 and which has a head lying flush with the outer surface of the disk 125. In this way the disk 125 turns by its sleeve 136 on the hub 138 and the disk 126 turns on the screw 141. The operation of this mechanically-actuated piston-blade is as follows: By the continuous rotation of the shaft 3 and its connected hub or piston-frame the friction-rollers 131 132 of the disks 125 126, passing through the curved slots in the piston-plates 123 124, are caused to oscillate a quarter-revolution in each rota-

tion of the shaft 3. Thus the rotary motion of the shaft imparts a reciprocating oscillatory motion to the disks 125 126, thereby causing the toes 137 139, attached to said disks, respectively, to move in opposite directions, as indicated by the arrows in Fig. 26, to the extent of ninety degrees and back again. These toes 137 and 139 when in motion in a direction opposite to that indicated by the arrows in Fig. 26 simultaneously press outwardly the spring-bar 140 of that piston-blade which is then moving upwardly until said piston-blade has reached the limit of its upward movement, as is shown by the position of the piston-blade 80 in Fig. 26. Then the toes 137 139 begin their oscillation in the direction indicated by the arrow in Fig. 26 and continue movement in that direction through arcs ninety degrees in extent, so that the opposite piston-blade is pushed outwardly to the full distance. Thus by the concentric oscillations of the toes 137 139 the piston-blades 80 and 81 are given alternately an outward sliding movement between the piston guides or plates 123 124, and the outer edge of the packing-bars 82 82 upon the piston-blades 80 and 81, respectively, are pushed into contact with the inner surface of the cylinder 5. These outward movements of said piston-blades constitute the expansion of the piston, which in the construction illustrated in Figs. 1, 4, 12, 13, 14, and 15 is accomplished by the pressure of steam introduced into the chamber 61 of the piston, as hereinbefore specified. The inward movements of the piston-blades in this modified form of my invention are caused by the cam-like action of the inner curvature of the cylinder 5 against the packing-bars 82 82 as the latter move along in sliding contact therewith, the radial distance between the axis of the piston-frame and the inner surface of the cylinder being regularly reduced in length from the radial distance of the packing-bar 82 of the piston-blade 81 (shown in Fig. 15) to the radial distance of the packing-bar 82 of the piston-blade 80. (Shown in Fig. 15.) During the time of such inward movement of the piston-blades alternately the toes 137 139 do not resist such motion, because they are then oscillating in the same direction as the incoming piston-blade. The purpose of the spring-bars 140 and the springs which actuate them and of the studs 141 is to provide sufficiently elastic action to the piston-blades to allow for any cramping or obstacle encountered.

I reserve as the subject-matter of another application for Letters Patent to be filed by me the hereinbefore-described improvements in reversing-valves.

I claim as a novel and useful invention and desire to secure by Letters Patent—

1. In a rotary engine, the combination of a cylinder, a rotatable main shaft in said cylinder having a diametrically-slotted hub, a piston-case slidably mounted in the slot of the hub, two piston-blades slidably mounted in said piston-case with their inner edges apart but exposed to steam-pressure in said piston-case, and a steam-pipe adapted to rotate said piston-blades with said hub and to communicate with the space in the piston-case between the inner edges of the piston-blades, substantially as specified.

2. In a rotary engine, the combination of a tubular cylinder, a rotatable main shaft mounted longitudinally but eccentrically in said cylinder and provided with a diametrically-slotted hub, a piston-case slidably mounted in the slot of the hub, two piston-blades slidably mounted in said piston-case with their inner edges apart but exposed to steam-pressure in said piston-case, and with their outer edges in contact with the inner surface of said cylinder, substantially as described.

3. The improved rotary piston herein described, consisting of a hub having a central rectangular slot through it, two slidable guide-plates connected at their ends and mounted in said slot, and two independently-slidable piston-blades mounted between said guide-plates, substantially as specified.

4. The improved rotary steam-piston herein described, consisting of a hub having a central rectangular slot through it and also having closed ends, two slidable guide-plates connected at their ends and mounted in said slot and provided with steam-passages discharging at or about the center of said guide-plates, and two independently-slidable piston-blades mounted between said guide-plates with their inner ends in proximity with the discharging ends of said steam-passages, substantially as specified.

5. In a rotary engine, the combination of a main shaft and a piston secured to said shaft in the axial line thereof and comprising the following parts, a hub having a central rectangular slot through it and also having closed ends, two slidable guide-plates connected at their ends and mounted in said slot and provided with steam-passages discharging at or about the center of said guide-plates, and two independently-slidable piston-blades mounted between said guide-plates with their inner ends in proximity with the discharging ends of said steam-passages, substantially as specified.

6. In a rotary engine, a piston comprising the following parts, a hub having a central rectangular slot through it and also having closed ends and provided with longitudinal slots, two slidable guide-plates connected at their ends and mounted in said slot and provided with steam-passages discharging at or about the center of said guide-plates, and two independently-slidable piston-blades mounted between said guide-plates with their inner ends in proximity with the discharging ends of said steam-passages, in combination with packing-bars in said piston-case slots adapted to bear against said sliding guide-plates respectively, and springs in said slots arranged to press said packing-bars against said

guide-plates, substantially as shown and described.

7. In a rotary engine, the combination of a tubular cylinder, a main shaft mounted in said cylinder longitudinally but eccentrically and provided with a diametrically-slotted hub, a piston mounted in the slot of the hub and adapted to have a sliding movement therein transversely thereof, a packing-bar whose outer edge has a curvature fitting the curvature of the inner surface of the cylinder and gibbous in cross-section, loosely mounted in and contacting with the outer edge of said piston in a concave seat thereof and adapted to roll peripherally in said seat, and means adapted to press said packing-bar into contact with said cylinder, substantially as described.

8. The combination in a piston, of two parallel piston plates or guides, a piston-blade mounted and movable between said plates or guides, a packing-bar mounted on the edge of the piston-blade and made in two parts loosely tongued together at their inner ends, and a spline-spring contained in longitudinal bores of said two pieces; which bores are in line with each other, together with a cylinder with whose inner surface said packing-bar is adapted to contact, substantially as shown.

9. The combination of a hub having a rectangular slot through it, two piston guide-plates parallel with each other and mounted in said hub, a piston-blade mounted movably between said piston guide-plates, two side supporting-bars loosely mounted on the opposite sides of the piston-blade, each provided with a spring normally spreading it outwardly at its inner end, and a packing-bar loosely mounted at its ends on the outer ends of said supporting-bars and made up of two parts tongued and butted at their inner ends and provided with a spring to normally spread said two parts, substantially as described.

10. The improved piston-plate herein described, consisting of a rectangular block, two side bars connected with said block and adapted to support the same and each provided near its outer end with an annular groove somewhat less that one hundred and eighty degrees in extent, and a packing-bar having its outer edge transversely curved and provided with an annular tongue, an annular groove and a trunnion at each end, which annular tongue annular groove and trunnion are somewhat less than one hundred and eighty degrees in extent, all assembled and coöperating substantially as shown and for the purpose specified.

11. The combination of a hub having a rectangular slot or chamber, piston-plates mounted in said slot or chamber, two slidable piston-blades mounted between said piston-plates so that their inner ends are separated to afford an intermediate steam-space, steam-passages in said piston-plates, and a port-block at each end of the piston case or frame having a tube arranged to conduct steam under pressure, and steam passages or ducts in said port-block opening into the steam-passages of the piston-plates, substantially as specified.

12. In a rotary steam-engine, the combination of a tubular cylinder having cylinder-heads each provided with a circular aperture, a rotatable piston-case having circular reduced ends, a split-spring ring-packing on each of said ends and fitting in said apertures, respectively, and a solid ring-packing on the outer edge of each split-spring ring-packing provided with springs adapted to press said solid ring into contact on its inner edge with the outer edge of its adjacent split-spring ring-packing, substantially as shown.

13. In a rotary steam-engine, the combination of a tubular cylinder having two cylinder-heads, each provided with a sleeve extension and circular aperture, a rotatable hub having circular reduced ends, a split-spring ring-packing on each of said ends and fitting in said sleeves and apertures of the cylinder-heads, and a split-spring ring-packing for each of the first-named ring-packings laterally secured in position and laterally spring-pressed into contact with its adjacent ring-packing first aforesaid, substantially as specified.

14. In a rotary steam-engine, the combination of a tubular cylinder having two cylinder-heads each of which is provided with a sleeve extension and a circular bore, a hub having a central slot and at each end an annular flange and two concentric annular chambers one larger in diameter than the other and also a central bore two piston guide-plates in said slot each provided with steam-passages, two piston-blades mounted movably between said piston-plates with their inner ends apart, a port-block at each end of the hub having a central tube fitting in the adjacent bore of the hub and provided with steam passages or ducts opening into the steam-passages of the piston-plates, a main shaft mounted in the sleeves and bores of the cylinder-heads connected and rotatable with said hub and having two diametrical steam-passages through it which open from the smaller concentric chamber of the hub into said tube of the port-block, a port-sleeve adjacent to each port-block and surrounding the main shaft and provided with a radial steam-passage and annular steam-passages and a series of steam-passages connecting said annular steam-passages with the smaller concentric annular chamber of the hub, and steam-pipes arranged to conduct steam from a boiler to the radial steam-passages of the port-sleeves, substantially as described.

15. In a rotary steam-engine, the combination of a tubular cylinder having two cylinder-heads each of which is provided with a sleeve extension and a circular bore, a hub having a central slot and at each end an annular flange and two concentric annular chambers one larger in diameter than the other

and also a central bore, two piston guide-plates in said slot, each provided with steam-passages, two piston-blades mounted movably between said piston-plates with their inner ends apart, a port-block at each end of the hub having a central tube fitting in the adjacent bore of the hub and provided with steam passages or ducts opening into the steam-passages of the piston-plates, a main shaft mounted in the sleeves and bores of the cylinder-heads connected and rotatable with said hub and having two diametrical steam-passages through it which open from the smaller concentric chamber of the hub into said tube of the port-block, a port-sleeve adjacent to each port-block and surrounding the main shaft and provided with a radial steam-passage and annular steam-passages and a series of steam-passages connecting said annular steam-passages with the smaller concentric annular chamber of the hub, a split-spring ring-packing placed between the annular flange of the hub and the smaller end of the port-sleeve, and steam-pipes arranged to conduct steam from a boiler to the radial steam-passages of the port-sleeves, substantially as specified.

16. In a rotating steam-engine, the combination of a tubular cylinder having an inlet-port and an outlet-port, a steam-chest beneath said cylinder and communicating therewith by said ports, a block or partition in said steam-chest dividing it into inlet and outlet compartments and provided with a longitudinal groove or slot T-shaped in cross-section and also with two ports or steam-passages extending from said groove or slot through said partition into said inlet and outlet compartments, respectively, a bow-spring in the bottom of said groove or slot, a packing-bar T-shaped in cross-section resting in said groove or slot upon said spring and having its upper surface longitudinally concaved to correspond to the curvature of the inner surface of the cylinder, and a piston rotatably mounted in the cylinder and in contact with the concaved surface of said packing-bar, substantially as specified.

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

FRANK J. WATERS.

Witnesses:

JOSEPH R. BULLOCK, Jr.,

WARREN R. PERCE.