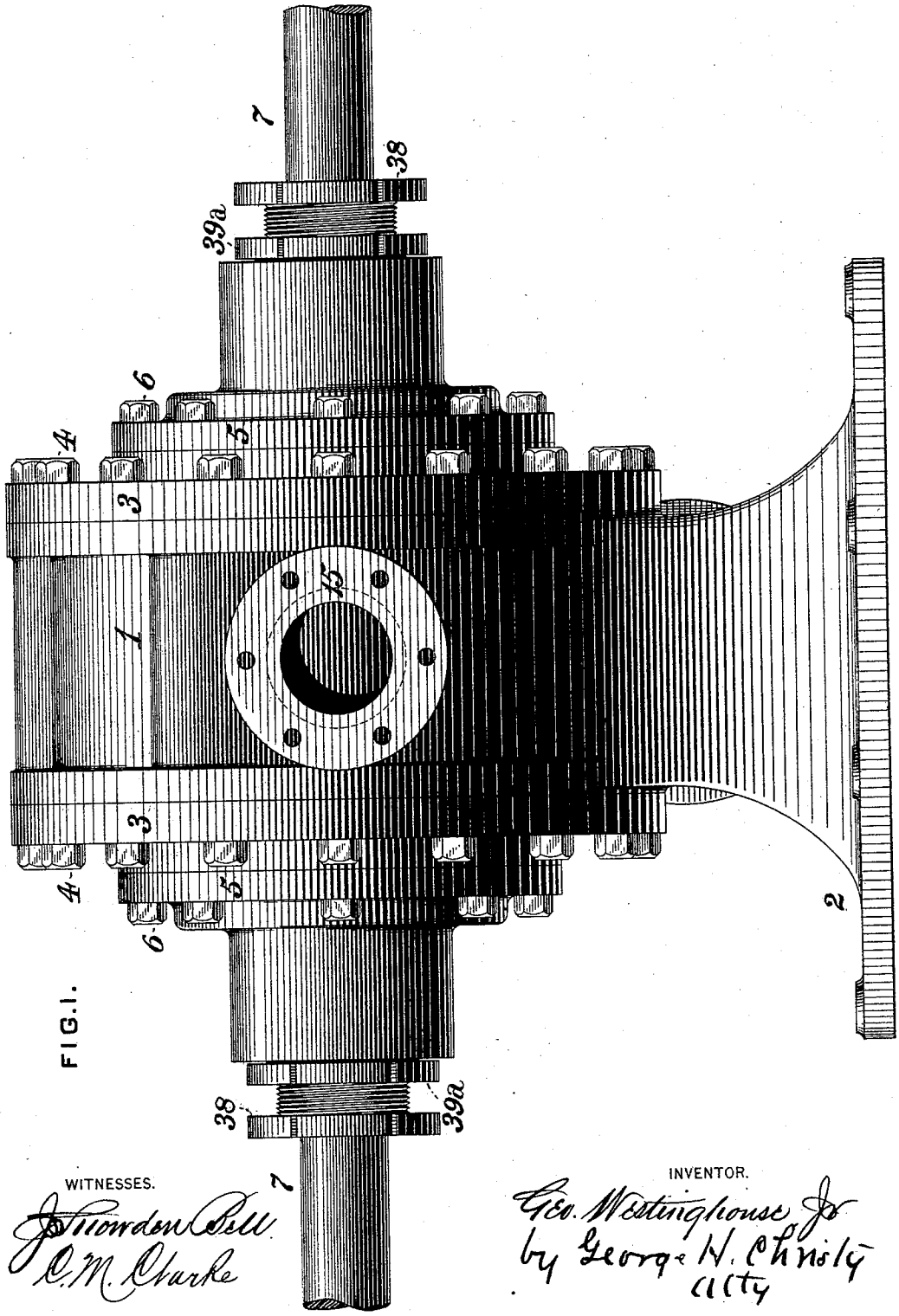
(No Model.) 5 Sheets—Sheet 1.

G. WESTINGHOUSE, Jr.

ROTARY ENGINE.

No. 455,028. Patented June 30, 1891.



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(No Model.) 5 Sheets—Sheet 2.

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ROTARY ENGINE.

No. 455,028. Patented June 30, 1891.

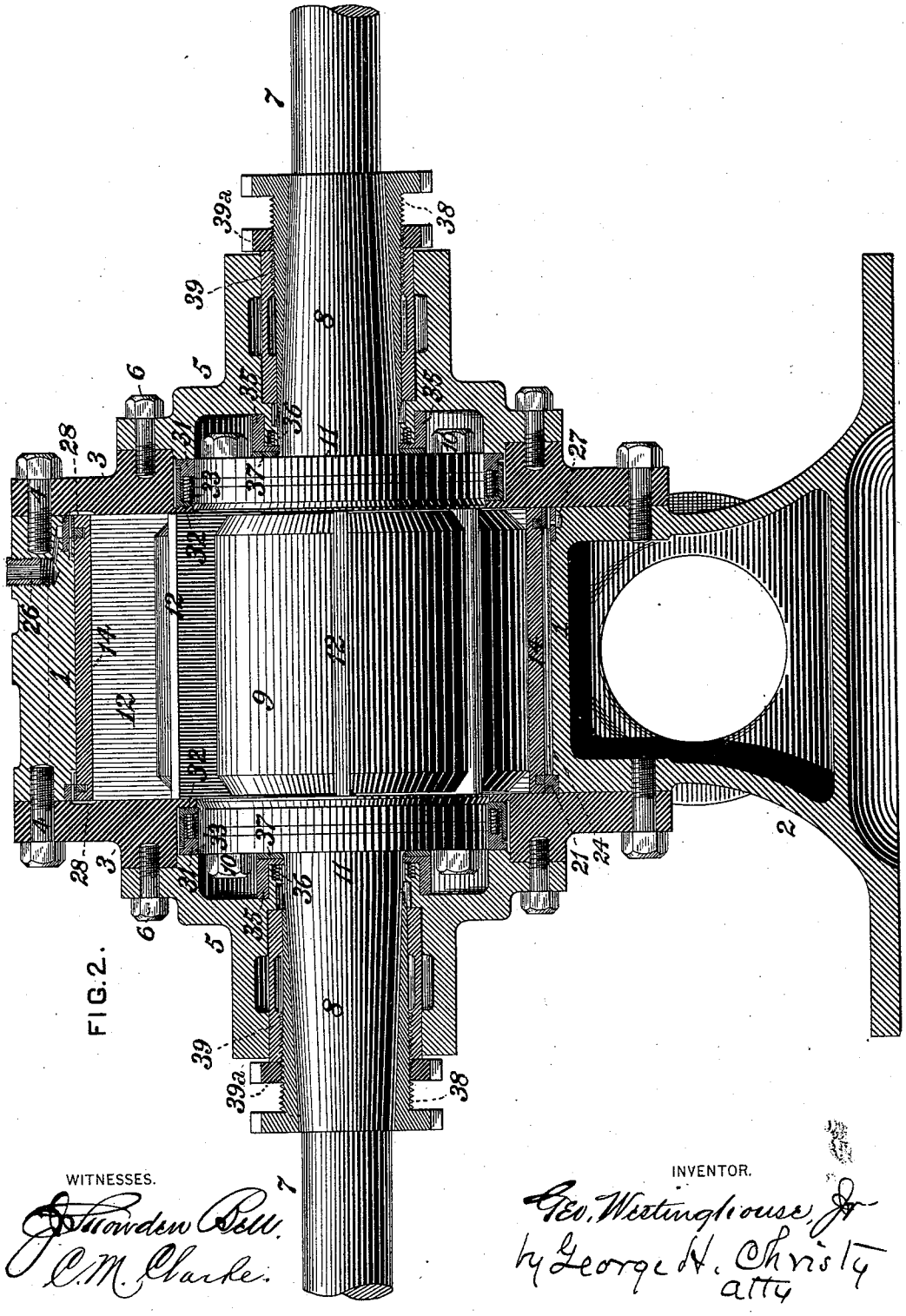

FIG. 2.

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(No Model.) 5 Sheets—Sheet 3.

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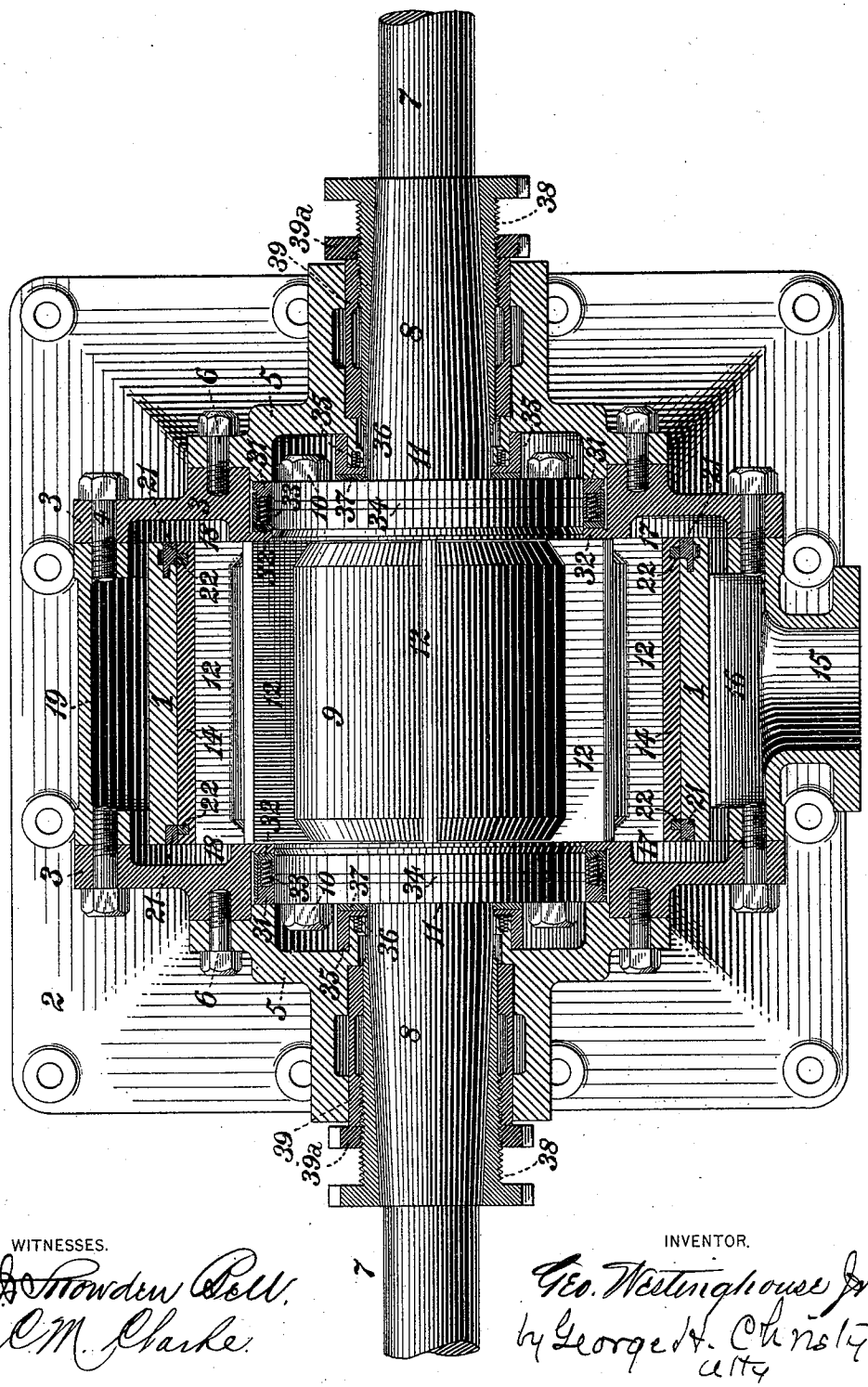
ROTARY ENGINE.

No. 455,028. Patented June 30, 1891.

FIG. 3.



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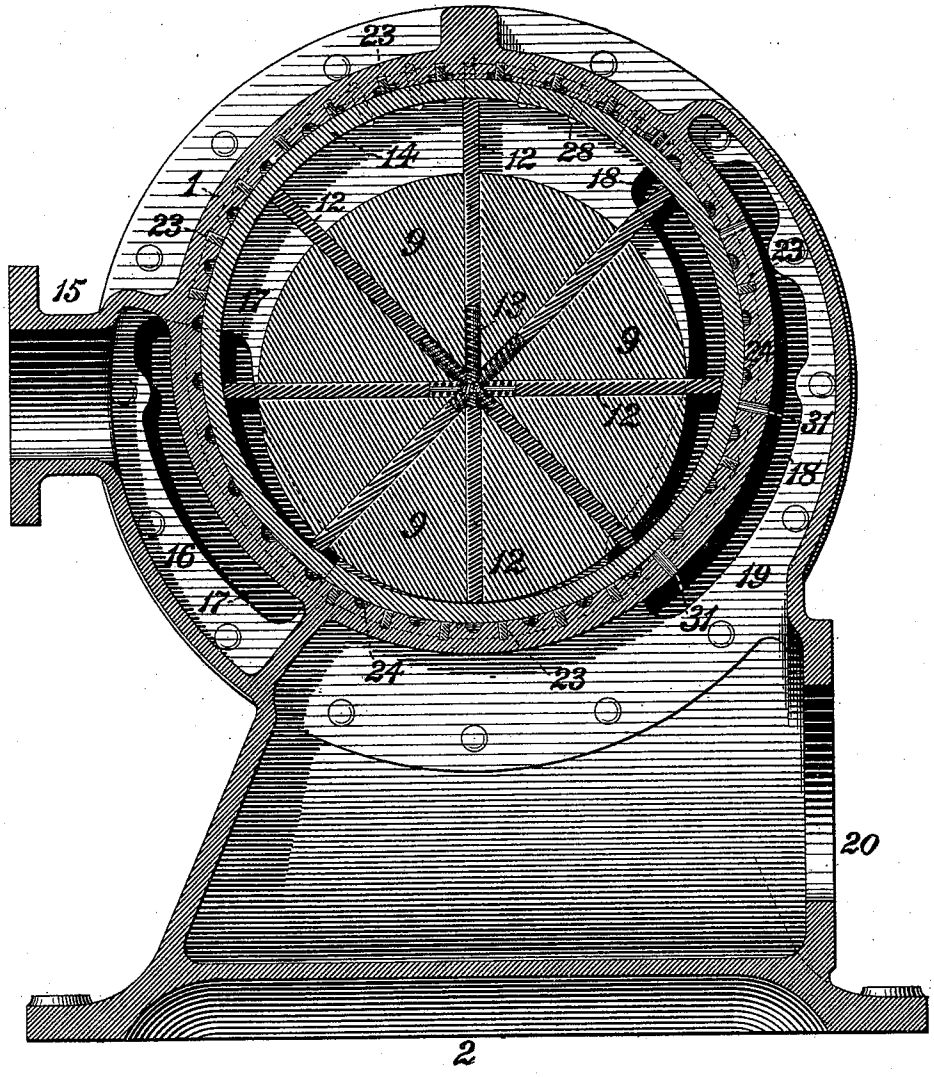
(No Model.) 5 Sheets—Sheet 4.

G. WESTINGHOUSE, Jr

ROTARY ENGINE.

No. 455,028. Patented June 30, 1891.

FIG. 4.



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(No Model.) 5 Sheets—Sheet 5.

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ROTARY ENGINE.

No. 455,028. Patented June 30, 1891.

FIG. 5.

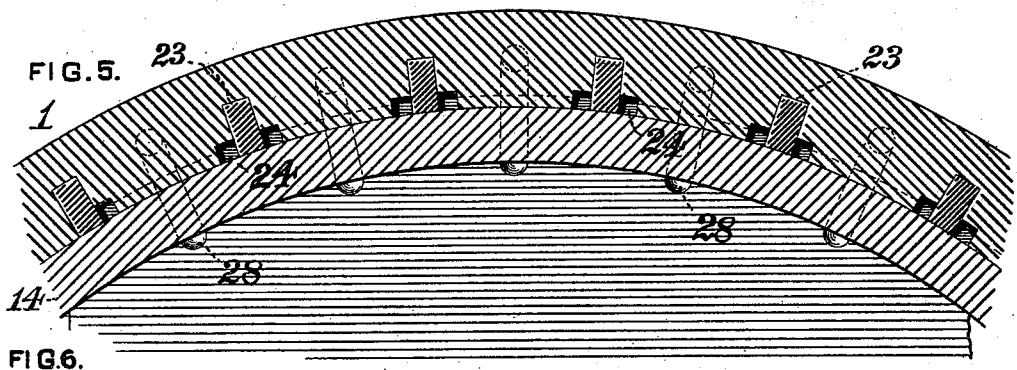


FIG. 6.

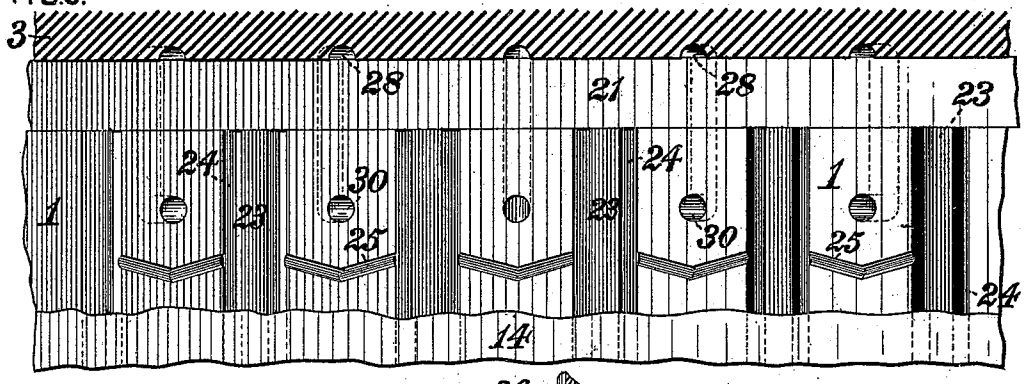
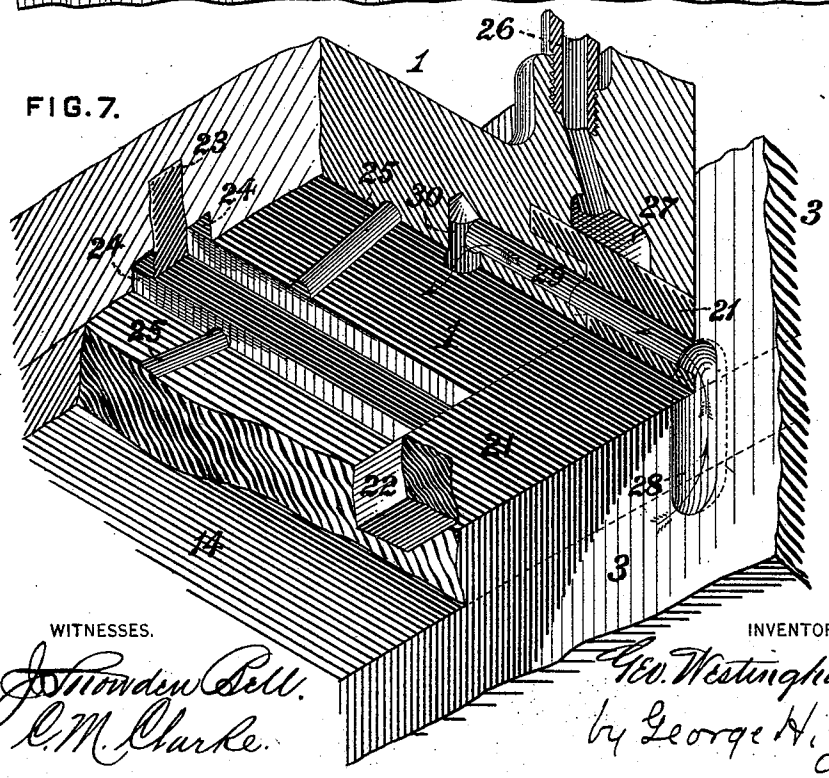


FIG. 7.



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UNITED STATES PATENT OFFICE.

GEORGE WESTINGHOUSE, JR., OF PITTSBURG, PENNSYLVANIA.

ROTARY ENGINE.

SPECIFICATION forming part of Letters Patent No. 455,028, dated June 30, 1891.

Application filed April 3, 1889. Renewed May 13, 1891. Serial No. 392,606. (No model.)

To all whom it may concern:

Be it known that I, GEORGE WESTINGHOUSE, Jr., a citizen of the United States, residing at Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented or discovered a certain new and useful Improvement in Rotary Engines, of which improvement the following is a specification.

The object of my invention is to enable the utilization of motive fluid in engines of the rotary type, to be effected with materially greater economy and advantage than has heretofore been attained by the elimination of the excessive friction ordinarily exerted in operation between the pistons and cylinder and the attainment of the economical results due to a very high piston speed, while maintaining the closeness of contact requisite to prevent leakage and waste of motive fluid, thereby rendering practically and desirably available the distinguishing and advantageous features of simplicity, compactness, and direct and continuous application of power which are presented in the theory and structural principle of engines of this type, but which the present state of the art does not indicate to have been as yet fully or satisfactorily realized in practice. To this end my invention, generally stated, consists in the combination of a cylinder, a series of pistons or abutments rotating with a shaft therein, and a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder.

The improvement claimed is hereinafter fully set forth.

The characteristic defect developed in the operation of rotary engines as heretofore constructed when a sufficient piston speed has been developed to comply in that regard with economical requirements, and that which from its universality has been considered as inherent in the type, has been the great degree of friction of the plates or blades which act as pistons, induced by the high velocity with which they move over the surface of the cylinder. In all engines in which the piston drum or carrier is rotated and the cylinder is stationary the pistons tend to the creation of this excessive friction with a force dependent upon the actuating pressure and the centrifugal force due to their weight, velocity, and operative radii. At that portion of the cylinder where the periphery of the piston-drum is tangential, or approximately so, to the bore of the cylinder the pistons have their minimum outward pressure, while at the opposite portion of the cylinder they have an increased outward pressure dependent upon their weight, velocity, and the pressure exerted upon them. The pistons have, in effect, heretofore exerted the retarding action of brakes, and their friction upon the cylinder, if made sufficiently tight to avoid a corresponding if not greater objection in the leakage past them of unused motive fluid, has absorbed so large a percentage of the actuating-power that at the present day no form of rotary engine is recorded as of general application or recognized in standard practice, and the class is usually considered impracticable, particularly where any substantial consideration is given to the economical use of steam.

My present invention is designed to provide a rotary engine in which the objection above stated will be satisfactorily obviated, and its leading feature consists in the employment of a sleeve or bushing which fits freely in the bore of the cylinder so as to be adapted to revolve therein, and which is practically maintained at an infinitesimal distance from the bore of the cylinder by a packing of steam interposed between the same and the periphery of the bushing. The pistons, therefore, instead of exerting their outward pressure upon the wall of the cylinder, bear upon the inner surface of the bushing, and the centrifugal force of one piston being largely counterbalanced by that of the opposite piston, the resultant action upon the bushing is a tendency to press the latter in the direction of that portion of the bore of the cylinder which is nearly opposite the line on which the piston-drum is tangential to the bushing. When the bushing rotates with substantially the same velocity as the piston-drum, the sliding pistons have the effect of simply an oscillatory motion upon the inner surface of the bushing, and when the bushing rotates without material friction within the cylinder the employment of the bushing effects a reduction of the friction of the sliding pistons to about one-twentieth of that

which would be induced in the rotation of the pistons at a similar velocity over the surface of the bore of a stationary cylinder.

In the accompanying drawings, Figure 1 is a side view, in elevation, of a rotary engine embodying my invention; Fig. 2, a vertical longitudinal central section through the same with the piston-drum and pistons in elevation; Fig. 3, a horizontal longitudinal central section, also with the piston-drum and pistons in elevation: Fig. 4, a vertical transverse central section; Fig. 5, a transverse section, on an enlarged scale, through a portion of the cylinder and the inclosed cylindrical sleeve or bushing; Fig. 6, a view in elevation and on a similar scale of a portion of the bore of the cylinder and of an end packing-ring with a portion of the adjoining cylinder-head in section; and Fig. 7, an isometrical section, on an enlarged scale, through portions of the cylinder, a cylinder-head, end packing-rings, a longitudinal packing-strip, and the sleeve or bushing.

In the practice of my invention I provide a cylinder 1, which is bored out truly throughout its length and is cast integral with or may, if preferred, be made separate from and properly secured to a base or bed plate 2. The cylinder is closed at its end by heads 3, the main annular sections of which are connected by bolts 4 to end flanges on the cylinder. The openings of the main sections 4 are closed by supplemental sections 5, which are secured by bolts 6 to the main sections, and are bored out eccentrically to the cylinder to receive and support the bearings of a shaft 7, which is provided with conical or tapered journals 8, and upon which is fixed a piston-drum or carrier 9, formed of a series of sections secured by bolts 10 to collars 11 on the shaft. The sections of the drum are separated one from the other by radial piston-spaces, within which are fitted a series of blades or pistons 12, which are adapted to slide freely radially to the common axis of the shaft and drum, and which are preferably arranged in pairs, the members of which are in line diametrically. Distance-strips may be interposed between the sections of the drum in order to insure the maintenance of sufficient spaces for the free sliding movement of the pistons, and pins are interposed between the two members of each pair of pistons, which pins may be fitted with helical springs 13, tending to force the pistons outward, and being more particularly useful when the engine is beginning its operation.

In lieu of causing the peripheries of the pistons 12 to bear against the bore of the cylinder in their rotation with the shaft, as in prior constructions, an annular open-ended sleeve or bushing 14 is interposed between the pistons and the cylinder, said bushing, which is equal in length to the bore of the cylinder, being turned truly exteriorly to a diameter which is in a very slight degree less than that of the bore of the cylinder, so as to fit freely therein, and being bored out to an interior diameter equal to the maximum distance between the outer faces of the pistons of each pair. Steam or other motive fluid from a supply-pipe is admitted through a supply nozzle or connection 15 to a chamber 16 on one side of the cylinder, and thence through ports 17 in the ends of the chamber and heads 3 to the space within the bushing, in which it acts successively upon the several pistons 12, and after effecting the rotation of the pistons and the drum and shaft is exhausted through ports 18 in the heads 3 into a chamber 19 on the side of the cylinder opposite that at which motive fluid is supplied, being finally discharged through an exhaust-pipe leading from an opening 20 in the chamber 19. In and by the traverse of each piston past the upper ends of the supply-ports steam is cut off from the next piston in advance, and by reason of the relative eccentricity of the piston-drum and surrounding bushing the volume of steam-space and effective area of piston gradually increase until the pistons pass a line opposite to that at which the drum is tangential to the bushing and cylinder, thereby utilizing the expansion of the steam after being cut off, as in any other form of engine.

Under the above construction, supplemented by the means provided for interposing and maintaining steam as a packing between the adjoining surfaces of the cylinder and the bushing loosely inclosed therein, as presently to be described, very high velocities are readily obtainable, a piston speed of from two to three thousand feet per minute being attained in practice without inconvenience. As a result of such high velocity, a very high frictional force is exerted by the pistons upon the inner surface of the bushing, tending to cause the latter to rotate with the pistons in the direction of their movement, and in order to cause the rotation of the bushing to be effected without any substantial degree of friction upon the cylinder a film of steam is admitted as a fluid packing between the surfaces of the bushing and of the cylinder, upon and within which fluid packing the bushing revolves without practically bearing upon the cylinder or inducing the friction which would be due to continuous contact with an inclosing solid. This end is attained by the employment of packing-strips, grooves, and rings, and supply and discharge passages, the construction and relation of which, in one suitable form, will now be described.

A ring 21 of metal is, for constructive purposes in this instance, inserted in the bore of the cylinder 1 at each of its ends and packing-rings 22 may be fitted into the bushing 14 in position to bear against the rings 21, the rings 22 being provided to reduce end leakage of steam to the minimum and economize the supply required to serve as packing. The bore of the cylinder 1 is divided into a

series of compartments by longitudinal packing-strips 23, which are fitted into the inner surface of the cylinder and may be set out by small springs pressing against their backs, said strips extending from one of the rings 21 to the other. Longitudinal grooves or channels 24, also extending from one ring 21 to the other, are formed on the inner surface of the cylinder, these grooves being either located so as to immediately adjoin the packing-strips, as shown most clearly in Figs. 5, 6, and 7, or being intermediate between and separated by a portion of the surface of the cylinder from the packing-strips. In the former case the two grooves 24 of each compartment are preferably connected by transverse grooves 25 in order to insure the same steam-pressure in both, the grooves 25 being inclined relatively to the grooves 24 in order to prevent cutting or wear in the rotation of the pistons. Steam at a pressure above the maximum pressure, acting on the pistons, is admitted to the series of grooves between each two adjoining packing-strips 23 or between alternate sets or pairs of packing-strips, or between the supply and exhaust ports on the operative side of the cylinder, or that on which the pistons are subject to steam-pressure. The admission of steam to the packing-grooves is effected both from a separate supply-nozzle 26, connected with the main steam-pipe, and from the steam-spaces within the cylinder on its operative side. The passage in the supply-nozzle 26 leads into an annular channel 27, which surrounds one of the end rings 21, the channel 27 communicating by small passages formed in the ring 21 with some or all of the packing-grooves 24. Some or all of the grooves which directly adjoin the packing-strips 23, and which are located on the operative side of the cylinder between the supply and exhaust ports, are supplied with steam by small passages from the channel 27, as are also the other grooves 24 adjacent to the exhaust-ports. The remaining grooves 24 receive steam by means of ports 28, recessed in the cylinder-head sections 3, said ports communicating with ports 29 drilled through the end ring 21, matching the grooves 24. The grooves immediately adjoining the steam-ports obviously require no ports 28, as they receive their steam directly from the steam-ports. The ports 28 serve to maintain on the outer surface of the bushing 14 the same pressure as exists on the corresponding portion of its inner surface, and steam is thus flowing to and from the outside of the bushing to maintain an equilibrium of pressure. The ports 28 communicate by ports 29 with ports 30, opening into the surface of the bore of the cylinder, any excess of pressure in the space between the bushing and cylinder above that which is required to maintain the bushing 14 at an infinitesimally slight distance from the bore of the cylinder being relieved by the ports 30, and by passages 31, hereinafter described, the bushing, in effect, acting as a valve to open a passage whereby excess of steam on the operative side of the cylinder may pass through the ports 30, 29, and 28 into the steam-spaces of the cylinder, and on the exhaust side may pass through the passages 31 into the exhaust-chamber.

On that portion of the cylinder adjoining the circumferential length of the exhaust-ports there are located a series of packing-strips 23—in this instance three in number—with three packing-grooves 24 intermediate between the two members of each pair of strips, the grooves 24 being connected by inclined transverse grooves, as above described. Small openings through the ring 21 admit steam from the annular channel 27 to the grooves 24 and space between the bushing and cylinder, as previously described, and between two of the grooves in each compartment or longitudinal space between packing-strips, a passage 31 is drilled through the wall of the cylinder into the exhaust-chamber 19, said passages, as before stated, permitting the relief of excess of pressure. The lower portion of the cylinder, or that adjacent to the line of contact of the piston drum and bushing, is likewise provided with packing-strips 23 and grooves 24 in free communication with the interior of the cylinder-grooves 28 and grooves 24 supplied with steam directly from the steam-ports are located on that portion of the cylinder adjoining the circumferential length of the steam-ports. The grooves 24, instead of being cut in the cylinder, may be recessed in the strips 23.

The preponderating force of the effect of the centrifugal and other forces of the pistons acting on the cylinder is counterbalanced by the pressure of the steam admitted between the packing-strips. This steam being admitted through a constantly-open supply nozzle and channel is necessarily constantly flowing into the limited spaces between these packing-strips, and by its superior pressure acts to force the bushing out of contact with the cylinder, the excess escaping through the ports 30 drilled in the surface of the cylinder between the strips, and thence by the ports 28 in the heads into the steam-space of the cylinder, in which, in the early part of the operative traverse of the pistons, it assists in increasing the active pressure thereon. The excess also escapes through the passages 31 into the exhaust-chamber in that portion of the cylinder. It has been found in practice that when the bushing is made of sufficient stiffness to resist the somewhat unequal effect of the steam-pressure and of the centrifugal force of the pistons and where the counterbalancing pressures are properly admitted, that the engine works with rotation of the bushing, almost noiselessly and with the minimum of friction, while on the other hand, if the bushing be held stationary, the high rotative speed causes considerable grinding noise and an excessive amount of fric-

tion is induced by the pistons, the latter condition corresponding with that existing in the operation of rotary engines of the ordinary form.

In order to admit of a limited amount of end-play of the shaft and piston-drum without allowing access of steam tending to displace the lubricant from the bearings, the shaft-collars 11, to which the drum-sections are secured, are each inclosed by two packing-rings 31 32, fitting freely over the collars 11, one within the other, the outer ring 32 being of L-shaped section. The rings 31 and 32 are located in the annular spaces between the peripheries of the shaft-collars 11, the main head-sections 3, and the supplemental head-sections 5, and are pressed against the head-sections 5 and 3, respectively, by a series of helical springs 33, which bear at their ends against the rings 31 and 32 in a direction parallel with the shaft. Steam is admitted to the annular space occupied by the rings from the steam-space of the cylinder, so as to make the pressure therein equal to the operative pressure of the engine, and packing-rings 34 may be sprung into circumferential recesses in the collars 11 to insure steam-tight joints. Any steam which may leak past the rings 31 and 32 is prevented from escaping from the annular recesses in the supplemental heads 5 at the outer faces of the collars 11, to the bearings by rings 35, which surround the shaft 8 and the projecting portions of the head-sections 5, which inclose the shaft, and are pressed by springs 36 against washers 37, interposed between the faces of the rings 35 and the collars 11. In lieu of connecting a series of drum-sections to the shaft, as herein set forth, the drum and shaft may be made in one piece, the drum being properly milled out to receive the pistons, in which case the rings above described would be dispensed with.

In order to admit of required adjustment and maintain the shaft 7 in proper linear relation to the bore of the cylinder, the tapered journals 8 of the shaft are fitted in correspondingly-bored bearings 38, which are externally-threaded for a portion of their length adjacent to and extending inwardly from their outer ends. The bearings 38 are in turn fitted into bushings 39, which are forced into projections on the head-sections 5, and are internally threaded at and for some distance from their outer ends. The bearings 38 are screwed tightly into the bushings 39 and locked by jam-nuts 39^a, and the inner ends of the bushings are fitted somewhat loosely in the cylinder-head sections 5. The bushings 39 therefore act in the manner of ball-bearings and admit of the adjustment of the shaft to true position.

My invention has been herein described with reference to the employment of steam or other expansive fluid; but it will be obvious that the engine may, if preferred, be operated by an incompressible fluid, the supply and exhaust ports being in such case materially lengthened in order to avoid unnecessary compression of the motive fluid. It will be further obvious that the device may be used for pumping liquids, the shaft being rotated by motive power applied independently of the pistons. Under such conditions the supply and exhaust ports would likewise be lengthened and the ports between the bushing and the cylinder-heads would be somewhat enlarged and be supplied by fluid under discharge pressure, or in certain cases by fluid under pressure independently exerted.

While I have herein described and shown that which I have ascertained by an extended course of practical research and experience to be a suitable and desirable construction and arrangement of packing-strips and grooves for balancing the pressure between the inner and outer surfaces of the bushing in order that the latter may rotate with the minimum amount of friction, I have also found that the proportions and details indicated may be materially varied, and that in some instances the end rings of the cylinder and of the bushing may be dispensed with while still attaining a material economy relatively to engines in which the anti-frictional bushing is not employed. I do not therefore limit myself to the specific construction and combination of members herein set forth, as any substitution of other devices whereby the admission and maintenance of a fluid packing to and in a space or spaces between a cylinder and an inclosed rotatable bushing are effected, would be within the purview and scope of my invention, and involve no departure from its essential and governing principles.

I claim as my invention, and desire to secure by Letters Patent—

1. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder, a series of pistons or abutments adapted to rotate with a shaft therein, and a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder.

2. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder, a series of pistons or abutments adapted to rotate with a shaft therein, and an externally-fluid-packed sleeve or bushing interposed directly and fitting freely between the peripheries of the pistons and the bore of the cylinder.

3. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder having a series of longitudinal packing-grooves in its bore and a fluid-supply port or channel leading into one or more of the packing-grooves, a series of pistons or abutments adapted to rotate with a shaft within the cylinder, and a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder.

4. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder having a series of longitudinal packing-

grooves in its bore, a fluid-supply port or channel leading into one or more of the packing-grooves, and transverse grooves connecting the packing-grooves one with another, a series of pistons or abutments adapted to rotate with a shaft within the cylinder, and a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder.

5. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder having a series of longitudinal packing-strips in its bore and a series of packing-grooves interposed between the packing-strips, a fluid-supply port or channel leading into one or more of the packing-grooves, a series of pistons or abutments adapted to rotate with a shaft within the cylinder, and a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder.

6. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder having a series of longitudinal packing-strips in its bore and a series of packing-grooves interposed between the packing-strips, a fluid-supply port or channel leading into one or more of the packing-grooves, and an excess-pressure-discharge passage or passages leading outwardly from its bore, a series of pistons or abutments adapted to rotate with a shaft within the cylinder, and a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder.

7. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder having a series of longitudinal packing-strips in its bore and a series of packing-grooves interposed between the packing-strips, a fluid-supply port or channel leading into one or more of the packing-grooves, a series of pistons or abutments adapted to rotate with a shaft within the cylinder, a sleeve or bushing fitting freely between the peripheries of the pistons and the bore of the cylinder, and heads closing the ends of the cylinder and provided with ports establishing communication between the opposite sides of said sleeve or bushing.

8. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder, a shaft journaled in bearings eccentrically to the bore of the cylinder, a piston-drum fixed upon the shaft and carrying a series of pistons fitted to slide in the cylinder radially to the axial line of the shaft, collars fixed upon the shaft at the ends of the piston-drum, heads secured to the ends of the cylinder and recessed to inclose the shaft-collars, packing-rings fitting one within the other around the collars and adapted to bear longitudinally against faces in the heads, and springs bearing against the packing-rings parallel with the shaft.

9. In a rotary engine or pump, the combination, substantially as set forth, of a cylinder, a shaft passing through said cylinder eccentrically thereto and having tapered or conical journals, a piston-drum fixed upon the shaft and carrying a series of pistons fitted to slide in the cylinder radially to the axial line of the shaft, heads secured to the ends of the cylinder, bearings inclosing the shaft-journals and threaded toward their outer ends, and bushings fitted in the cylinder-heads and inclosing the shaft-bearings, said bushings having internal threads at and adjacent to their outer ends engaging the threads of the shaft-bearings and being unthreaded and fitting easily in the cylinder-heads at and adjacent to their inner ends.

In testimony whereof I have hereunto set my hand.

GEO. WESTINGHOUSE, JR.

Witnesses:
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E. NEWELL.