(No Model.)

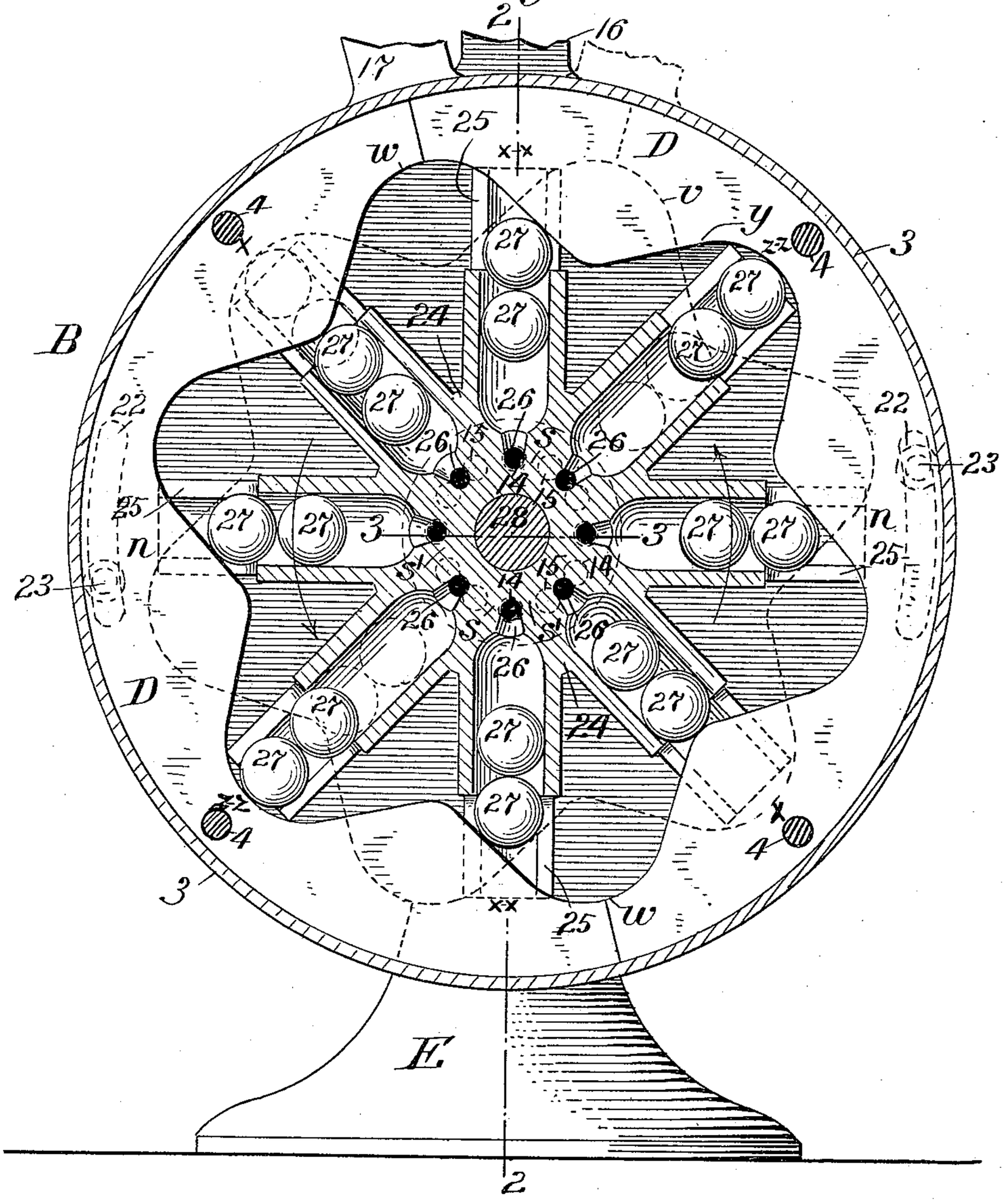
3 Sheets—Sheet 1.

E. B. BENHAM.

STEAM ENGINE.

No. 459,735. Patented Sept. 22, 1891.

Fig. 1.



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STEAM ENGINE.

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Fig. 2.

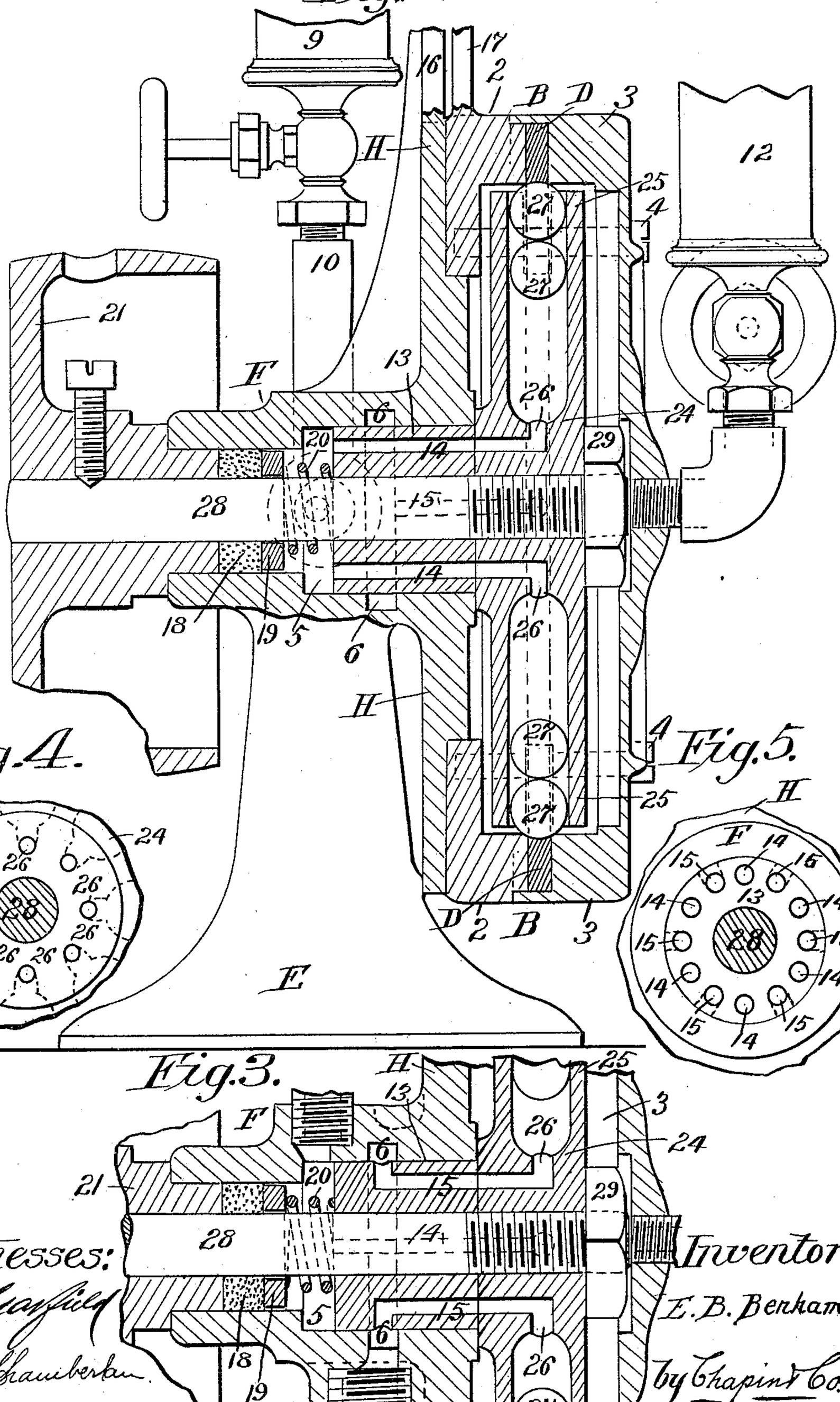

Fig. 4.

Fig. 5.

Fig. 3.

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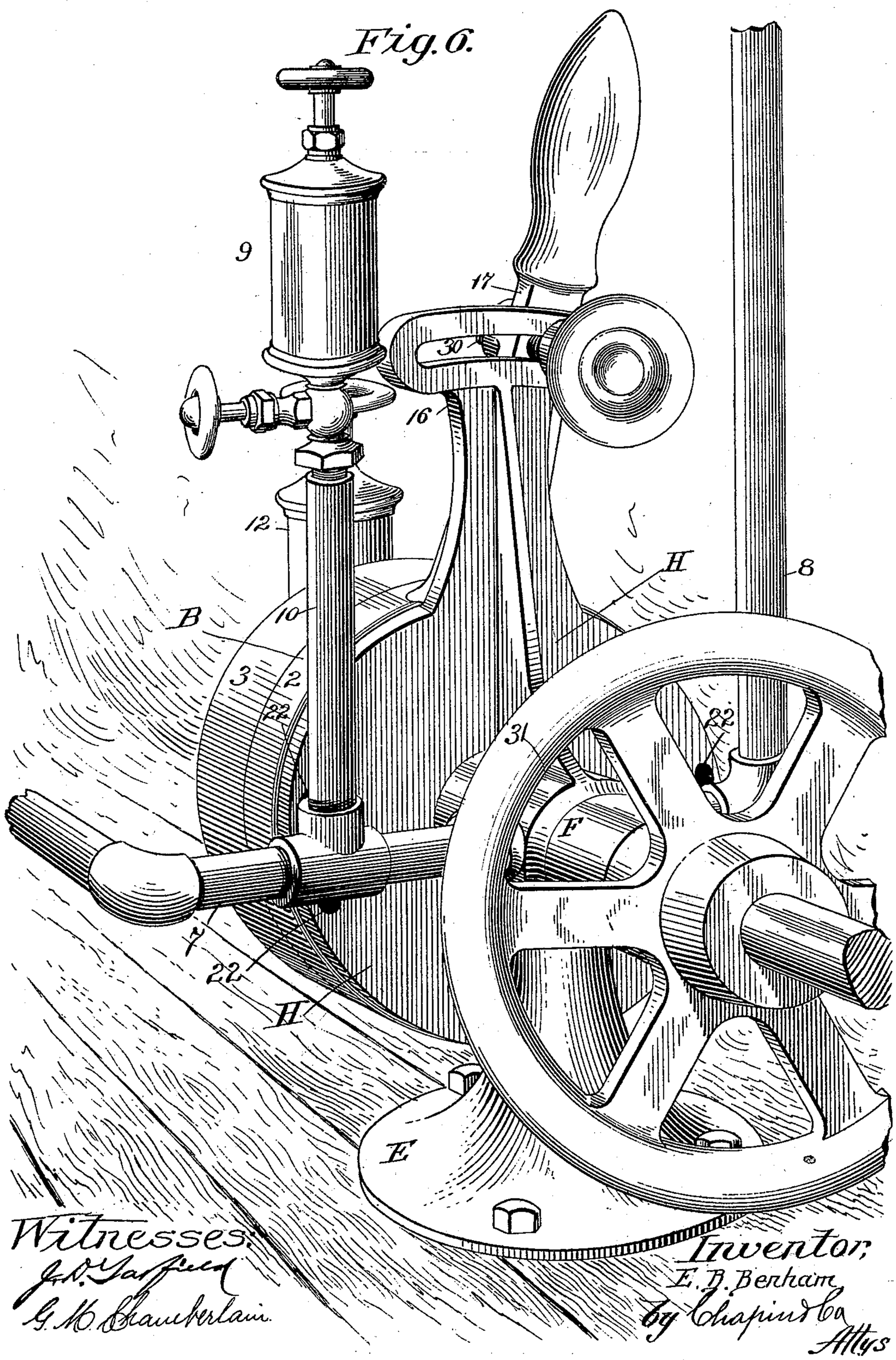
Fig. 6.



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UNITED STATES PATENT OFFICE.

ELIJAH B. BENHAM, OF PROVIDENCE, RHODE ISLAND, ASSIGNOR TO WILLIAM G. NIGHTINGALE, OF SAME PLACE.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 459,735, dated September 22, 1891.

Application filed December 19, 1890. Serial No. 375,256. (No model.)

To all whom it may concern:

Be it known that I, ELIJAH B. BENHAM, a citizen of the United States, residing at Providence, in the county of Providence and State of Rhode Island, have invented new and useful Improvements in Steam-Engines, of which the following is a specification.

This invention relates to steam-engines, the object being to provide an improved construction thereof; and the invention consists in the peculiar construction and arrangement of the parts thereof, all as hereinafter fully described, and more particularly pointed out in the claims.

In the drawings forming part of this specification is illustrated a steam-engine constructed according to my invention, in which—

Figure 1 is a section through the cylinder-head, cylinders, and their inclosing case at right angles to the axial line of the driving-shaft as it appears looking at the front side of the machine. Certain parts, as below fully described, are shown in side view in this figure and others as broken off. Fig. 2 is a vertical section centrally through the cylinder head, case, and driving-pulley, certain parts being shown broken off and others in side view, about on line 2 2, Fig. 1. Fig. 3 is a sectional view of the central portion of the cylinder-head and its case on line 3 3, Fig. 1, illustrating certain steam-conduits communicating with the cylinders. (Not shown in Fig. 2.) Fig. 4 is a plan view of the inner side of that part of the cylinder-head in which the cylinder-ports are formed, the driving-shaft being shown in section. Fig. 5 is a plan view of a portion of the central part of the frame of the machine and an outer end view of the cylinder containing the pressure and the exhaust conduits. Fig. 6 is a rear perspective view of the machine.

The engine herein described has one main frame element, to which the other parts of the machine are attached and which is preferably cast in a single piece, which comprises a broad-based standard E, a hollow hub F, and a circular plate H, said plate having extending upwardly therefrom a reversing-lever standard 16, having in its upper end a slot, through which a screw works for a purpose below described. The said circular plate H, together with a shallow cup-like front piece 3 and a ring 2, constitutes a cylinder-head case B, of which said plate is the back. The said cup-shaped part 3 and ring 2 are secured, one at the side of the other and to said back H in the positions shown in Figs. 2 and 6, by the screw-bolts 4. (See Figs. 1 and 2.) In the inner wall of said hollow hub F are formed two annular chambers 5 and 6, the chamber 5 being denominated a "pressure-chamber," because it receives the fluid (steam or other element) through the feed-pipe 7, which actuates the engine. Said annular chamber 6 is denominated the "exhaust-chamber," because it receives the exhaust-fluid from the cylinders of the engine and the same is discharged therefrom through the exhaust-pipe 8. An oil-cup 9 is placed on the end of a pipe 10, which communicates with said feed-pipe 7, and thereby the requisite lubrication for the interior operating parts of the engine is provided for, the lubricating element passing thereinto with the motor-fluid or steam. An oil-cup 12 is attached by a suitable pipe to the front side of the said case B and supplies lubricating material to the operative parts of the machine within said case, as below described. The oil from said cup 12 is permitted to flow into said case or cylinder-head chamber, and, falling to the lower part thereof, it is then taken up by the pistons while the cylinder-head revolves and distributed over the border of the piston-track, and at the same time the piston-balls become properly lubricated.

A conduit-cylinder 13 (see Figs. 2, 3, and 5) is fixed within the hollow hub F and extends from the inner rear face or side of said cylinder-case B, past said exhaust-chamber 6, to one side of said pressure-chamber 5, as clearly shown in said figures. Said conduit-cylinder has formed therein a series of six conduits 14, which extend from one end and communicate with said pressure-chamber, and a series of six conduits 15, which extend from the same end and communicate, as shown in Fig. 3, with said exhaust-chamber 6, the port ends of said conduits being open on the surface, against which the rotating cylinder-head bears, as below set forth. The outer or port ends of

said conduits 14 and 15, twelve in number, are arranged, as shown in Fig. 5, in alternating positions and in a circle concentric with the axial line of the driving-shaft 28, as illustrated in Fig. 5.

When the engine is built upon a suitable larger scale than is here shown, said conduits 14 and 15 may be formed in the casting of said hub F and the construction of said cylinder 13 as a separate part be avoided. A metallic piston-track D, preferably of steel, is rigidly secured between said cup-shaped part 3 and ring 2 of the case B by said screws 4. (See Figs. 1 and 2, the latter figure showing said track in side elevation and the former figure showing it in section.) Said track D is made, preferably, in two sections, which are divided on the line *o*, Fig. 1, for convenience in assembling with the other parts of the machine. The periphery of said piston-track D is of circular form, secured to and supported by said cylinder-head case B; but its inner border is of sinuous form or having a series of projections and depressions, as shown, whereby is produced thereon a series of inclines, between which and one side of the extremities of the cylinders the pistons are forced, as and for the purpose below described. Said track is located in the machine directly opposite the outer end of the axial line of the cylinders 25, as shown in Fig. 1 and also in Fig. 2, and the operative position of said track circumferentially is one which brings the apexes of the projections on its border opposite the spaces *s* (see Fig. 5) between said pressure and exhaust ports 15 and 14. Thus not until the axial lines of the cylinder shall have passed said apexes can any cylinder take full steam-pressure, whereby the most effective power is caused to be exerted against the pistons when they begin to descend an incline.

Two curved slots 22 (indicated in dotted lines in Fig. 1 and partly shown in Fig. 6) are formed through the frame-plate H, and through said slots are passed two screw-bolts 23, one in each slot, which bolts enter the rear border of the ring 2 and serve to attach the cylinder-head case B to said plate and provide for permitting a certain degree of oscillating movement to said case and the sinuous piston-track D, which movement is limited by the length of said slots 22. The said screw-bolts 23 are clearly indicated in dotted lines in Fig. 1. The parts of the machine illustrated in Fig. 6 prevent the heads of said bolts from being shown in that figure. The said limited oscillating movement which may be given to said case B is effected by a hand-lever 17, (see Fig. 6,) which is fixed to or integral with a part of said case. By seizing the upper part of said lever 17 and swinging it to the right or the left the apexes of said sinuous border of the piston-track D are caused to assume different positions relative to the pressure and exhaust ports 14 and 15, as indicated by the dotted line *v* and the full line *y* in Fig. 1, both of which lines indicate the border of said track, against which the pistons engage. Said apexes of the border of the track D occupy positions opposite said spaces *s* between the pressure and exhaust ports 14 and 15 when the cylinder-head is required to rotate in the direction indicated by the arrow in Fig. 1; but to reverse the motion of the head the track is moved or partially rotated, as shown in Fig. 1, to cause the apexes of said ring projections to be brought opposite another series *s'* of spaces between said ports, so that the pistons may act upon the opposite edge of said projections and cause the rotary motion of the cylinder-head to be reversed. The position of said track (shown by the line *y* in Fig. 1) is that which it occupies to cause the cylinder-head 24 to rotate in the direction indicated by the arrows in said last-named figure, and to hold the case B and said track in that position the hand-lever 17 is swung and secured in the position shown in Fig. 6. To reverse the rotary motion of the cylinder-head, said lever 17 is swung to the opposite direction or to the right, looking at the engine from the front, thereby bringing the sinuous border of said track to the position shown by said dotted line *v* in Fig. 1. A binding-screw 30 passes through a slot, as shown, in the standard 16 and screws into said hand-lever 17, thereby serving to rigidly secure the cylinder-head case B in either of said two positions. A suitable hand-wheel, as shown, is provided for said screw 30 for operating the latter. The border of the ring 2, adjoining the side of plate H, is preferably ground thereon to make a tight joint. The said cylinder-head 24 consists of a central portion, one side of which constitutes a port-face as shown in Fig. 4, from which a series of cylinders 25 radiate, eight cylinders being shown in the drawings as the preferable number. Steam passages or ports 26 are formed in the central portion of said cylinder-head, one end of which communicates with the inner end of each cylinder, and the opposite ends of said ports are open to the rear side or on the port-face of the cylinder-head in circular arrangement around the axis thereof, as clearly shown in Figs. 1 and 4, the lower ends of the cylinders being indicated in dotted lines in this last-named figure. The said cylinder-head is rigidly fixed to one end of the driving-shaft 28, preferably by screwing the end of said shaft into the head and screwing a lock-nut 29 onto the outer end of said shaft; but the latter may be secured to said head in any other suitable manner. Said driving-shaft 28 extends through said conduit-cylinder 13 and the hollow hub F and projects sufficiently beyond the end of the latter to permit of securing rigidly thereon a driving-pulley 21 or a balance-wheel 31, or both, as may be desired. To avoid the multiplication of parts, it is preferable that for convenience in packing the shaft 28 near the outer end of said hub F to prevent leakage the

hub of the balance-wheel or of the pulley, as shown in Fig. 2, should be fitted to enter the outer end of said hub a certain distance and serve as an abutment to retain the packing 18 therein. Said hub of the pulley, being rigidly fixed to the driving-shaft and having a bearing against the end of hub F, as shown, tends to retain the port-face of the cylinder-head 24 in proper operative relation against the adjoining inner end of the conduit-cylinder. In the absence of said hub a collar on shaft 28 may be substituted therefor. A washer 19 is placed on said shaft between said packing and the pressure-chamber 5, and a spiral spring 20, placed between the end of cylinder 13 and said washer, serves to retain said washer in place. The steam-pressure in the chamber 5 acts directly against said washer to force it and said packing against the end of the hub of pulley 21, and hence the cylinder-head is drawn against that part of the engine in which are the said ports 14 and 15 with a force substantially equivalent to that which the steam escaping from the pressure-ports 14 against the cylinder-head exerts. Consequently the pressure is balanced and does not act to separate the port parts of the machine and cause leakage. The open ends of said ports 26, at the rear side of the cylinder-head 24, are arranged in a circle coinciding with the circular arrangement of the open ends of the conduits 14 and 15 in the conduit-cylinder 13, as clearly shown in Figs. 4 and 5, and said port-bearing portion of the cylinder-head, has a rotary motion while bearing against the said inner end of the conduit-cylinder. The outer ends of said cylinders 25 are slotted, as shown in Fig. 1, to permit the edge of the piston-track to project thereinto as the cylinder-head rotates, thereby forming piston-guiding parts on each cylinder extending beyond the steam-chambers thereof.

The pistons of the cylinders 25 consist, preferably, of two hardened steel spheres 27, placed in said cylinders one above the other, as shown. The said spheres 27, which may be properly termed "ball-pistons," are made by the well-known process of rolling spherical objects in a cold state, and thereby are produced spheres of uniform diameter and of uncommon smoothness of surface. Said piston-balls and the bore of the cylinders are perfectly adapted to each other as to dimensions, so that said balls have the usual reciprocating movement in the cylinders without undue friction and with no appreciable leakage of steam between them and the cylinder-walls, and during the operation of the engine and while steam-pressure may be cut off from some of the cylinders said piston-balls maintain the positions shown in Figs. 1 and 2 by centrifugal force, and have a movement in the cylinders toward the center of the cylinder-head by contact with the sinuous border of the track D, but only to the extent of the inwardly-projecting portion of said track. The employment of said ball-pistons is advantageous from several points of view, in that the engagement of the surface thereof with the walls of the cylinder tends to produce a rotation of the spheres rather than a frictional abrasion, and the outer sphere of each cylinder has a rolling contact with the border of said track D, thus obviating the necessity, as in a cylindrical piston, of having a friction-roller in the end of the latter, as shown in Fig. 7. Furthermore, the said piston-balls are advantageous from an economical point of view since they are produced cheaply in large quantities, and in the manufacture of engines of this construction no machinery need be provided for making said balls. As shown in Fig. 2, where the said sinuous track D is shown in section, it is seen that the edge thereof is grooved on a circle corresponding with that of the piston-balls.

The lubrication of the outer piston-balls, the ends of the cylinders in which they roll, and the edge of the track on which they bear and roll is effected from the oil-cup 12, as above described. By employing two piston-balls the outer one is free to act at the end of the cylinder to bear against the sinuous track, while the inner one closes the portion of the end of the cylinder below said outer ball.

From the foregoing description of all of the parts of the herein-described engine it will be noted that no valve is required to govern the pressure and exhaust currents in their movements into and out of the cylinders, but the movement of said currents is controlled entirely by the rotary movement of the cylinder-head having the said ports 26, which during the rotation of said head communicate or register alternately with the pressure and exhaust-conduits 14 and 15 in said conduit-cylinder 13, and said conduits communicate with the pressure and exhaust chambers 5 and 6, respectively. Fig. 1 has indicated thereon in dotted-line circles near shaft 28 the positions of the said pressure and exhaust ports 14 and 15 at the rear of the cylinder-head.

The operation of the within-described improvements is as follows: Referring to Fig. 1 and to two of the cylinders 25 therein, (indicated by *x x* opposite their extremities,) it will be noted that with said cylinders in the positions there shown the outer piston-balls thereof are shown as against the border of the sinuous track D to one side of the highest points or apexes of two of the inclines of said track. The ports 26, which communicate with said two cylinders, are so arranged relative to the pressure-conduits 14 in the conduit-cylinder 13 that when any two of the cylinders of the head 24, which are in the same axial line, having their pistons occupying the positions relative to the inclines of the track D that said cylinders indicated by *x x* occupy, the cylinder-ports 26 thereof are fully open opposite the adjoining ends of the pressure-conduits 14, and thereby the press-

ure acts to drive the piston-balls against the inclines of said track and cause the cylinder-head to rotate in the direction of the arrows in Fig. 1, whereby the ends of the cylinders are forcibly moved in a direction from said inclines. When said last-named two cylinders *x x* shall have been brought opposite the points *w* of said track, the ports of said cylinders *x x* will have passed onto the space on the end of the conduit-cylinder 13 between the pressure and the adjoining exhaust-port, and thereby pressure will be entirely shut off from these last-named cylinders, such shutting off of the pressure operating gradually as the piston-balls descend the inclines of the track to the point *w*. The above-described movement of the ends of the cylinders indicated by *x x* brings the ends of those indicated by *z z* to positions half-way up the next incline. Thus it is seen that in all the cylinders of the head 24 pressure is given to the pistons when they shall have passed the apex of the inclines of the track, and said pressure follows the pistons as they move toward the lowest point *w* of the latter, where the pressure is entirely cut off, the cylinder-ports now beginning to pass over the exhaust-ports and continue to do so while the pistons move upward on the following incline. The exhaust is entirely shut off when the pistons reach the apexes of the track-inclines, and upon passing said apexes they begin to take steam again—that is to say, using the cylinders indicated by *x x* at their extremities as an illustration during the movement of the outer piston-balls 27 of said two cylinders from the positions in which they are shown in Fig. 1 relative to the apexes of the border of the track D by reason of the said peculiar arrangement of the pressure and exhaust conduits terminating in ports at the outer end of the conduit-cylinder 13, in connection with the ports 26 of the cylinder-head, which communicate with said cylinders. Steam-pressure follows the pistons in said cylinders indicated by *x x* until they arrive at the depressed portion *w* of said track intermediately between the apexes thereof, where the pressure is cut off by the movement of the ports 26 from before the pressure-conduits 14. From said depressed point *w* up to the succeeding apexes of the track the pistons receive very little pressure; but upon passing said apexes, as above described, full pressure is exerted upon them, as described. The latter describes the operation of each pair of the cylinders, which are in axial alignment.

It will be observed that certain of the pistons—as, for instance, those of the two cylinders indicated by *n n* at their extremities in Fig. 1—when brought to such nearness to the apexes of the inclines of the track as are the outer piston-balls of said last-named cylinders, at which moment pressure commences to enter back of the pistons, the pistons of other cylinders—as, for instance, those indicated by *x x*—are working against the incline of the track D under the highest pressure. This is so arranged in order that any back-pressure occasioned by the movement of the pistons inwardly while moving up the inclines of the track from the exhaust-point may be overcome to a high degree and the regular and forcible movement of the cylinder-head be not sensibly retarded thereby.

In the operation of the piston-balls, as above described, in connection with the cylinders and the portions of the inclines of the track D against which the outer piston-balls have a bearing force while acting under pressure, said balls, when so bearing against the track, convert each cylinder in which they so act, so to speak, into a crank-arm, the force of the pistons thus being exerted near to the extremities of the cylinders or said arm, whereby the power is applied with the most advantageous effect for the rotation of the driving-shaft 28, to which the cylinder-head is attached.

What I claim as my invention is—

1. In a steam-engine, a frame, substantially as described, a cylinder-head containing several cylinders radiating from a common center and having steam-passages, one for each cylinder, leading from their bases and terminating in ports on the side of said head, a driving-shaft fixed to said head and extending through a hub on said frame, a pressure and an exhaust chamber in said hub, steam-passages leading from said chambers and terminating in ports opposite and communicating with said cylinder-ports, inlet and outlet openings communicating with said chambers, a piston-track having a border of sinuous form supported opposite the ends of said cylinders, which track may be turned in its support to change the positions of the projections on its sinuous border relative to the ports of said steam-passages, and pistons for said cylinders having an engagement against said sinuous track, combined and operating substantially as set forth.

2. In a steam-engine, a frame, substantially as described, having a cylindrical chamber therein to receive a rotating cylinder-head and having a hub extending from one side of said frame, having therein a pressure and an exhaust chamber, and steam-passages leading from said last-named chambers to the inner side of said frame and terminating in pressure and exhaust ports thereon, a cylinder-head having a port-face on one side thereof and having several cylinders radiating from a common center, each of which has a steam-passage extending from its base and terminating in an open port on said port-face, the several cylinder-ports having alternating communication with said pressure and exhaust ports, a driving-shaft fixed to and supporting said head to rotate in said cylinder-chamber and extending through said hub, a piston-track having a border of sinuous form supported in said cylinder-head chamber, and pistons for said cylinders having an engage-

ment against said track-border, combined and operating substantially as set forth.

3. In a steam-engine, a frame, substantially as described, having a cylindrical chamber therein to receive a rotating cylinder-head, a piston-track of sinuous form supported in said chamber, a cylinder-head having a port-face on one side thereof and having several cylinders radiating from a common center, each of which has a steam-passage extending from its base and terminating in an open port on said port-face, and a piston for each of said cylinders, consisting of several spheres which have a united reciprocating movement in said cylinders due to steam-pressure and to the presence of said sinuous track, the outer of said spheres having a rolling engagement with said track and the inner one thereof constituting a rolling abutment for said outer sphere, combined and operating substantially as set forth.

4. In a steam-engine, a frame, substantially as described, having a cylindrical chamber therein to receive a rotating cylinder-head and having a hub extending from one side of said frame outwardly, having therein a pressure and an exhaust chamber, a feed and an exhaust pipe connected to said hub, and a series of steam-passages extending from said last-named chamber and terminating in said cylinder-head chamber in a circle around the axis of said hub, combined with a cylinder-head having on one side a port-face and containing several cylinders radiating from a common center, steam-passages extending from the bases of said cylinders and terminating in ports on said port-face in circular arrangement around the axis of said head, a shaft extending through said hub, to the inner end of which is fixed said cylinder-head, and pistons for said cylinders, substantially as set forth.

5. The combination, with the rotating cylinder-head of a steam-engine having steam-port passages entering the bases of the cylinders thereof, of a sinuous piston-track supported opposite the open ends of said cylinders, and one or more spheres in each of said cylinders constituting pistons therefor, against which steam-pressure acts to force them against the border of said track, substantially as set forth.

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