(No Model.) 6 Sheets—Sheet 1.

E. S. SMITH.

STEAM ENGINE.

No. 457,926. Patented Aug. 18, 1891.

Fig. 1.

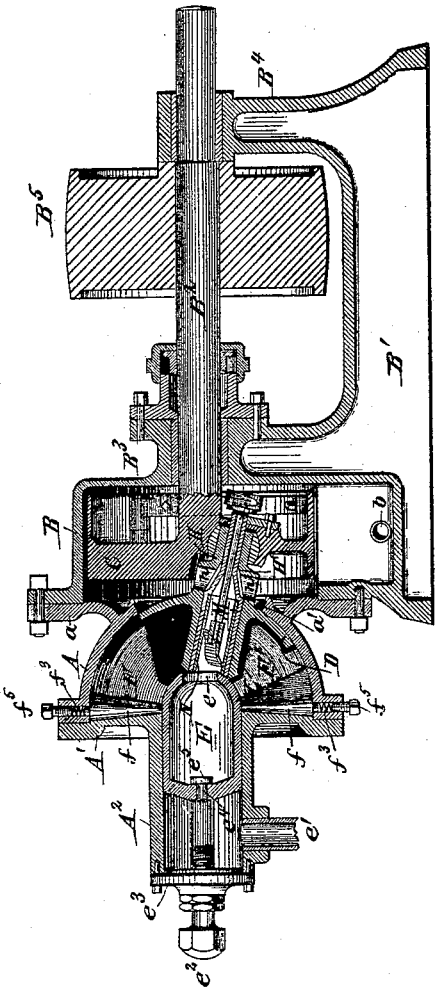


Fig. 4.

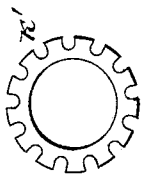


Fig. 3.

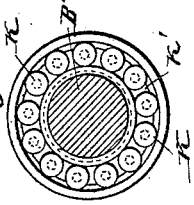
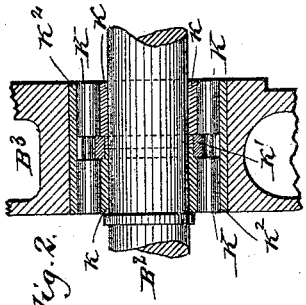


Fig. 2.



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ATTORNEYS.

(No Model.) 6 Sheets—Sheet 2.

E. S. SMITH.

STEAM ENGINE.

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Fig. 5.

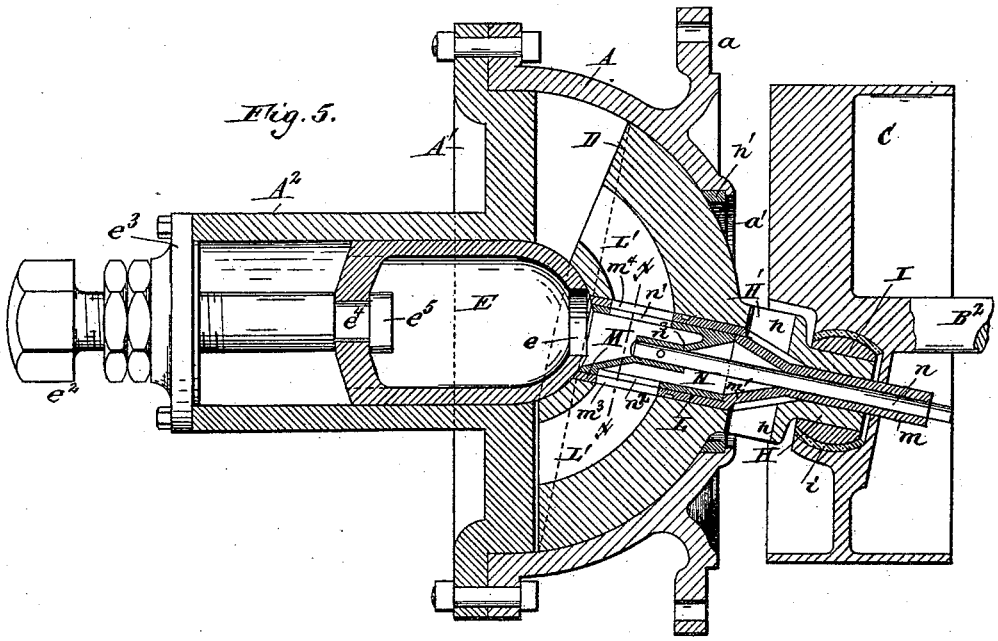
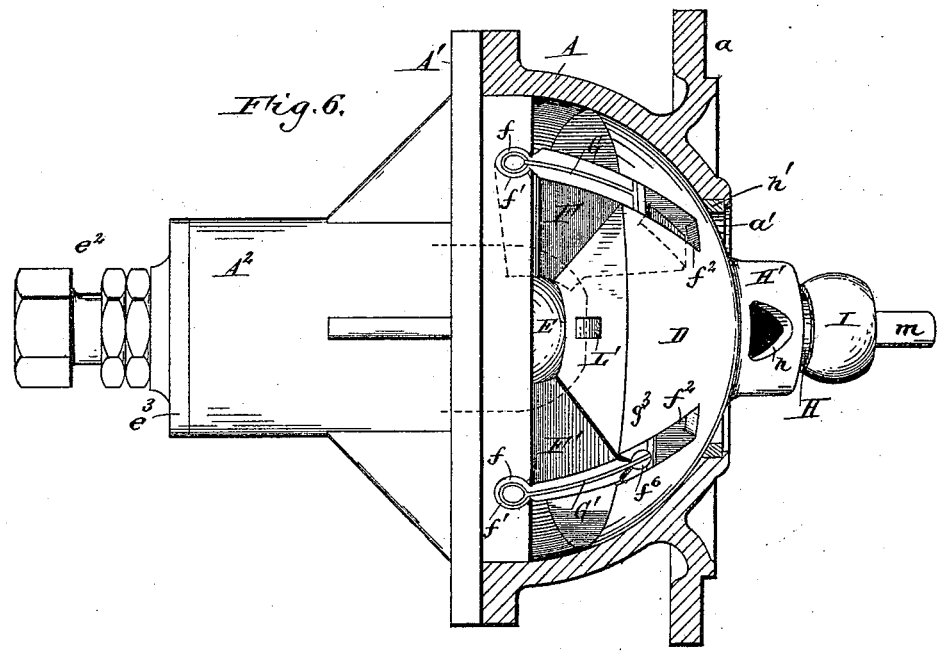


Fig. 6.



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E. S. SMITH.

STEAM ENGINE.

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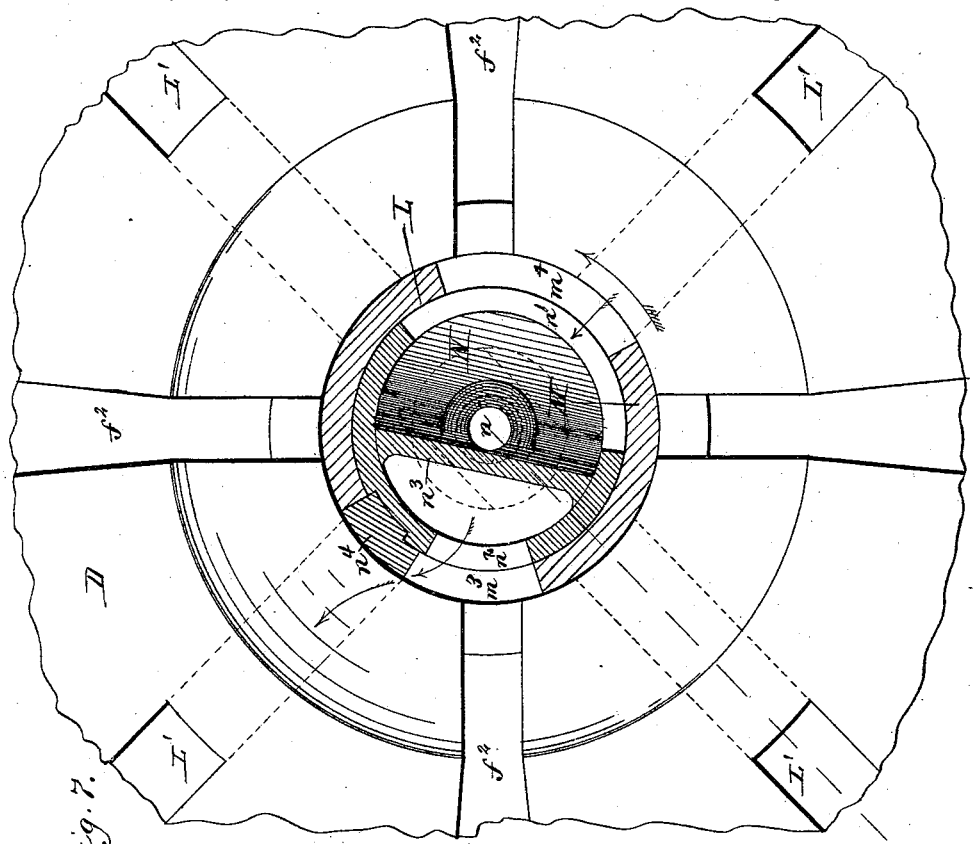

Fig. 7.

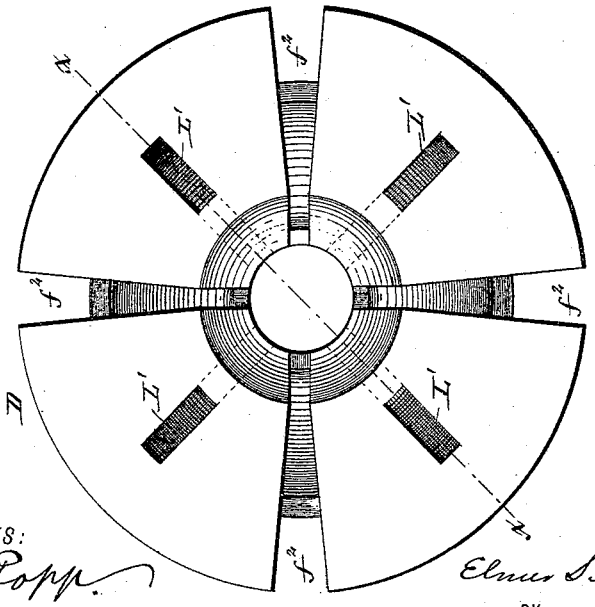

Fig. 8.

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STEAM ENGINE.

No. 457,926. Patented Aug. 18, 1891.

Fig. 20.

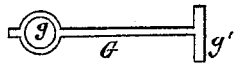


Fig. 19.

Fig. 17.

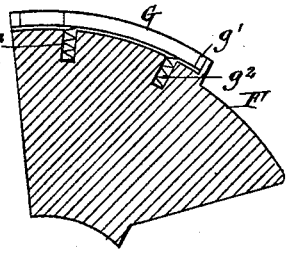


Fig. 10.

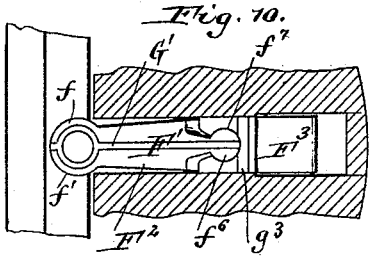


Fig. 18.

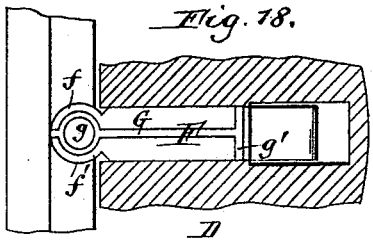


Fig. 9.

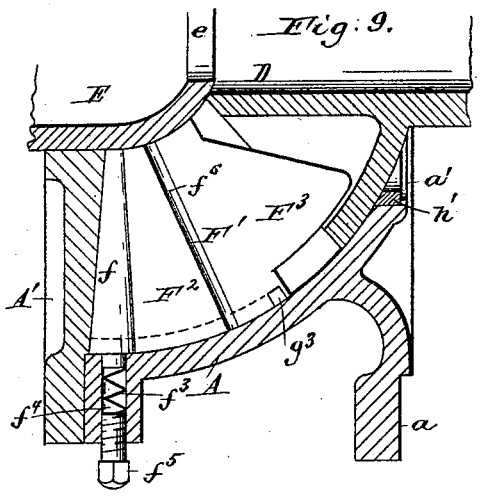


Fig. 12.

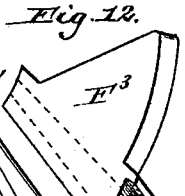


Fig. 11.

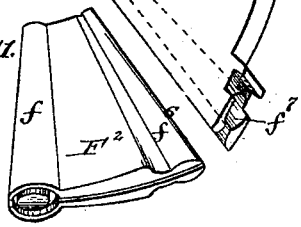


Fig. 14.

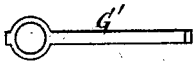


Fig. 15.

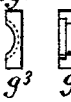


Fig. 16.

Fig. 13.

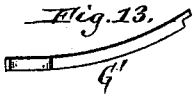
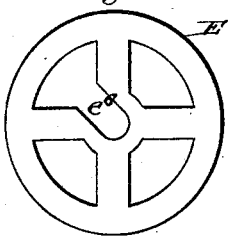


Fig. 21.



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E. S. SMITH.

STEAM ENGINE.

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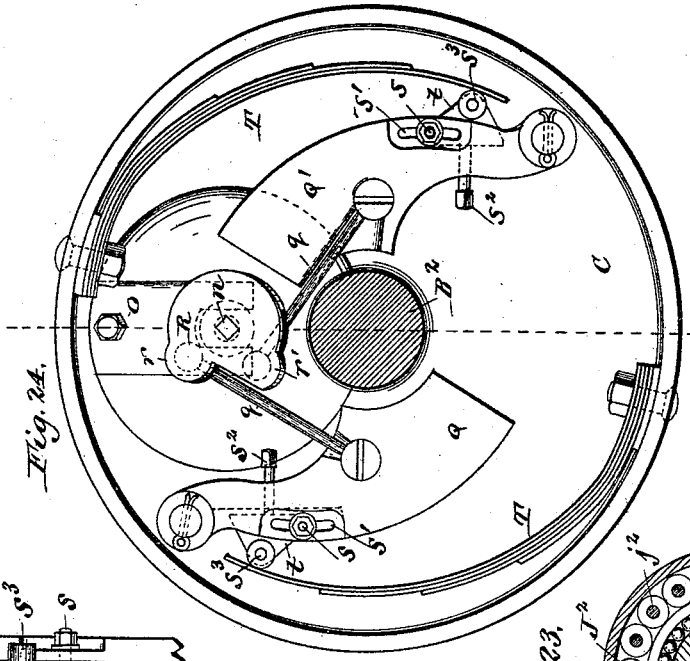

Fig. 24.

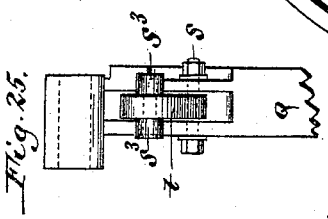

Fig. 25.

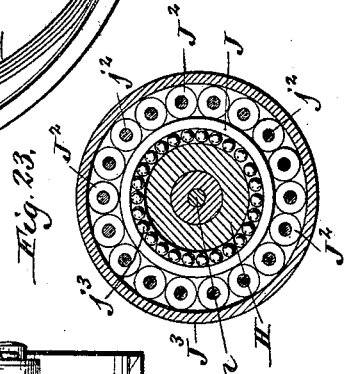

Fig. 23.

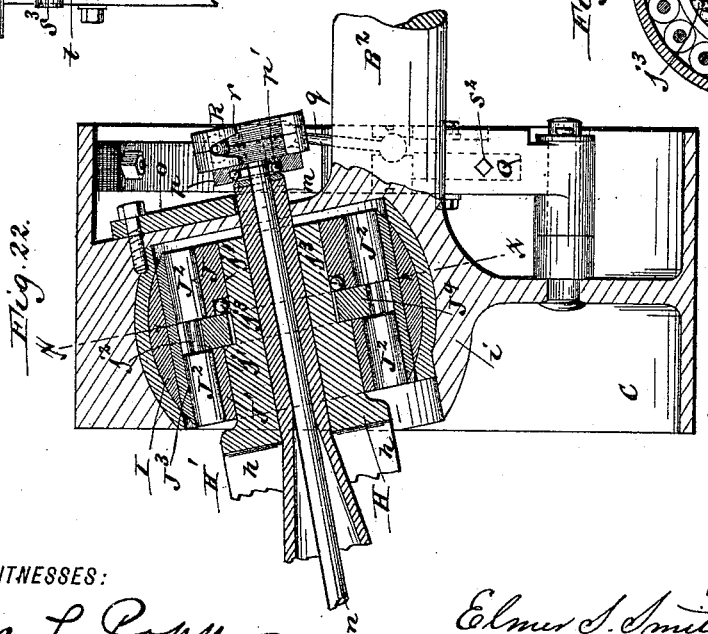

Fig. 22.

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E. S. SMITH.

STEAM ENGINE.

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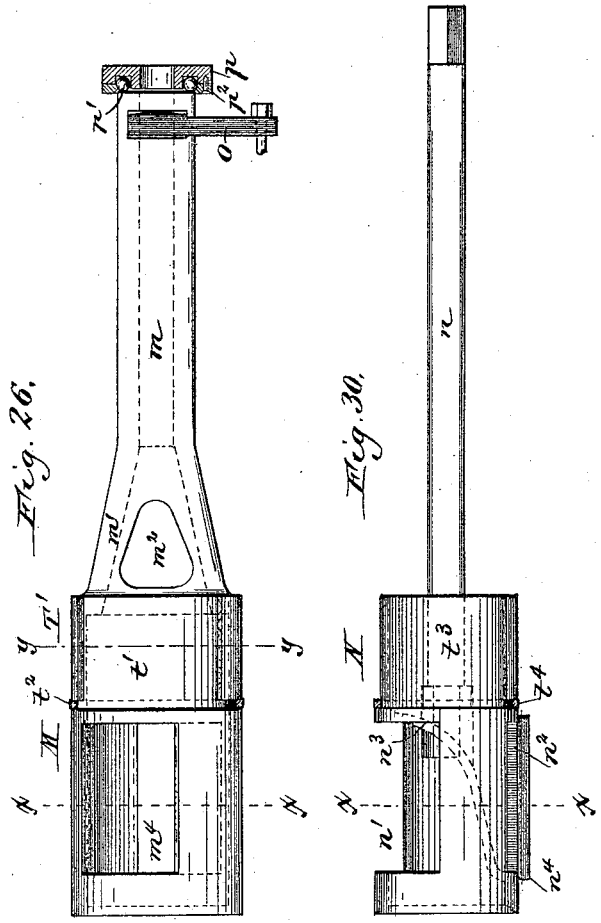

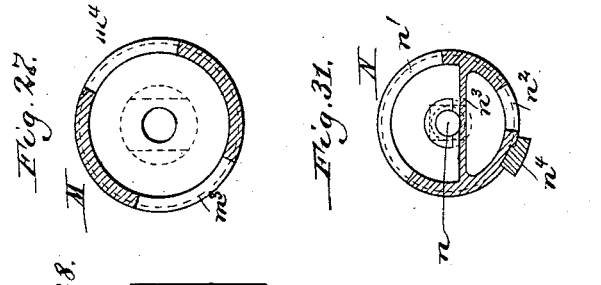

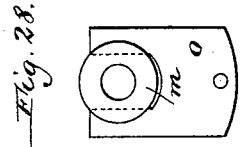

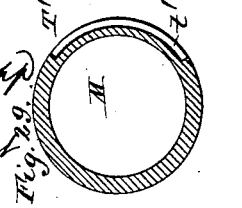

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UNITED STATES PATENT OFFICE.

ELMER S. SMITH, OF NEW YORK, ASSIGNOR TO THE AMERICAN ENGINE COMPANY, OF BUFFALO, NEW YORK.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 457,926, dated August 18, 1891.

Application filed March 2, 1891. Serial No. 383,400. (No model.)

To all whom it may concern:

Be it known that I, ELMER S. SMITH, a citizen of the United States, residing at New York, in the county and State of New York, have invented a new and useful Improvement in Steam-Engines, of which the following is a specification.

This invention relates to an engine which is provided with a disk or piston having a wabbling motion, partly oscillating and partly rotative, and which is arranged in a case or chamber having the form of a spherical segment. An engine of this character is described in Letters Patent No. 366,894, granted to me July 19, 1887.

The object of the present invention is to improve the engine of that patent in various respects, so as to render the engine more efficient, to facilitate the adjustment of the parts, reduce friction, and to render the automatic governor very sensitive.

My improved engine can be actuated by steam, compressed air, water, or any other fluid or liquid under pressure. For the purpose of simplifying this description I will describe it as a steam-engine.

In the accompanying drawings, consisting of six sheets, Figure 1 is a longitudinal sectional elevation of my improved engine. Fig. 2 is a longitudinal section of the main bearing on an enlarged scale. Fig. 3 is a side elevation of the bearing. Fig. 4 is a side elevation of the notched ring which carries the rollers of the main bearing. Fig. 5 is a longitudinal sectional elevation of the case and piston through the ports of the piston and valves, the plane of section being in line $x\,x$, Fig. 8. Fig. 6 is a top plan view of the case and piston partly in section, the view being taken at right angles to the line $x\,x$, Fig. 8. Fig. 7 is a fragmentary face view of the piston on an enlarged scale, showing a cross-section of the valves in line $x\,x$, Fig. 5. Fig. 8 is a face view of the piston. Fig. 9 is a longitudinal sectional elevation of the lower portion of the case and piston. Fig. 10 is a bottom view of the lower jointed division-plate, with the adjoining portions of the piston in section. Fig. 11 is a perspective view of the main portion of the jointed division-plate. Fig. 12 is a perspective view of the wing of the jointed division-plate. Fig. 13 is a side elevation of the packing-strip of the jointed plate. Fig. 14 is a bottom view thereof. Fig. 15 is a bottom view of the detachable head of the packing-ring. Fig. 16 is an edge view thereof. Fig. 17 is a longitudinal section of the rigid division-plate. Fig. 18 is a top view thereof, showing the adjoining part of the case in plan view and the adjoining part of the piston in section. Fig. 19 is an end view of the rigid plate. Fig. 20 is a top plan view of the packing-strip of the rigid division-plate. Fig. 21 is an end view of the hollow follower-pin. Fig. 22 is a longitudinal sectional elevation of the crank-disk and connecting parts. Fig. 23 is a cross-section of the roller-bearing of the wrist-pin in line $x\,x$, Fig. 22. Fig. 24 is a rear elevation of the crank-disk and the governor mechanism attached thereto. Fig. 25 is an edge view of one of the governor-weights. Fig. 26 is a side elevation of the main valve with the roller-bearing of the cut-off valve in section. Fig. 27 is a cross-section in line $x\,x$, Fig. 26. Fig. 28 is an end view of the carrier by which the main valve is rotated. Fig. 29 is a cross-section in line $y\,y$, Fig. 26. Fig. 30 is a side elevation of the cut-off valve. Fig. 31 is a cross-section in line $x\,x$, Fig. 30.

Like letters of reference refer to like parts in the several figures.

A represents the case in which the piston works and which has the form of a spherical segment.

A′ represents the head which is secured to the large end of the case and is provided with a cylindrical extension A^2, which is arranged axially with reference to the case.

a represents an annular flange which surrounds the central opening *a*′, formed in the crown of the spherical case, and by which the latter is secured to the steam-chest B, which receives steam through the supply-pipe *b*. The steam-chest is preferably cast integral with the engine-frame B′, which supports the engine-shaft B^2 by means of a main bearing B^3, adjoining the steam-chest, and an end bearing B^4. The pulley B^5, or other device by which power is transmitted from the engine-shaft, is preferably secured to the latter between the bearings. The engine-shaft is

arranged axially in line with the case A, and carries within the steam-chest a crank-disk C, which may be cast integral with the engine-shaft of steel.

D represents the piston having the form of a spherical segment and fitting with its spherical back in the spherical case, while its face is made convex, so that as the piston is arranged obliquely in the case the piston fills the case only partially and leaves a steam-space between the receding portion of its face and the head A′ of the case.

E represents a follower-pin or knuckle, which is arranged in the cylindrical extension A^2 of the head A′, and projects with its semi-spherical inner end into the case, where it seats itself in a correspondingly-shaped recess or depression in the face of the piston. This pin is made hollow and has at its apex an opening e, through which the exhaust-steam enters the cavity of the pin, from which it escapes through the open outer end of the pin into the extension A^2, which latter is provided with an exhaust-pipe e'. The pin is adjusted longitudinally to take up wear by an adjusting-screw e^2, which passes through a threaded opening in the head e^3 at the outer end of the extension A^2. This adjusting-screw is connected with the follower-pin by a reduced neck e^4 and head e^5, Figs. 1 and 5.

In order to simplify the connection of the adjusting-screw to the follower-pin, the hub at the outer end of the latter is provided with a notch e^6, Fig. 21, which receives the reduced neck, while the head e^5 bears against the inner side of the hub and the shoulder of the screw against the outer side of the hub. This connection permits the follower-pin to swivel on the adjusting-screw and enables the pin to change its position in the casing by a rotative motion, thereby equalizing the wear.

F and F′ represent the division-plates or abutments, which are attached to the head A′ of the case and project across the steam-space into pockets formed in the piston. Two or more of these division-plates are employed, four being shown in the drawings. When four of these plates are employed, two of them, arranged diametrically opposite each other, are preferably rigid plates which have a pivoted or rocking connection only with the head A′ of the case, while the other plates consist each of two parts, which are connected by a flexible joint or radial pivot, whereby the plates are better enabled to follow the wabbling motion of the piston and binding is prevented.

In the drawings, F represents a solid or rigid plate, which is arranged in the upper part of the case, as represented in Fig. 1, and F′ represents the jointed plates, which are arranged in the lower part of the case and at the sides thereof, so that one rigid plate and three jointed plates are represented, which arrangement is, however, less preferable than that in which two rigid plates and two jointed plates are used. The rigid plate holds the piston in position and prevents it from turning so far as to cramp the jointed plates, while the latter by their flexibility adapt themselves to the position which the piston is compelled to assume by the solid plate.

Each of the plates F and F′ is connected with the head A′ by a tapering knuckle f, which enters a similarly-shaped seat f' in the inner face of the head. This knuckle has the form of a steep truncated cone, the apex of which is located in the center of the case. The knuckle is formed on the front end of the plate, and the seat in the head opens rearwardly to allow the plate to project into the steam-space and piston. The sides of the plate are inclined at the same angle as the knuckle, and the sides of the pocket f^2 in the piston are similarly inclined, as represented in Figs. 7 and 8, so that wear can be taken up by adjusting the plates inwardly. Each of the plates is pressed toward the center of the case and against the follower-pin by a spring f^3, which bears against the outer or circumferential end of the knuckle and is seated in a socket f^4 in the case, in which its tension is adjusted by a screw f^5, Fig. 9. The solid plate F fits snugly with its sides against the sides of the pocket of the piston, Fig. 18, except that the rear portion of the socket is slightly enlarged to reduce the area of the contact-surfaces and the resulting friction.

G, Figs. 17 to 20, represents a curved packing-strip, applied to the outer circumferential end of the solid plate and seated in a depression which is formed in the plate and has the form of the strip. The latter is provided near its front end with a ring-shaped enlargement g, which exposes the end of the knuckle and permits the spring f^3 to bear against the knuckle within said ring. The packing-strip is provided at its opposite end with a cross-bar g', which extends from one side of the plate to the other. This strip is pressed outwardly and against the spherical inner surface of the casing by the steam-pressure and prevents leakage past the circumferential edge of the plate. Springs g^2 are preferably arranged in the plate to bear against the under side of the strip and assist in pressing it outwardly.

The jointed plates F′ consist each of a main portion F^2, attached by the tapering knuckle f to the head A′, and a wing F^3, which is seated in the pocket of the piston and connected with the main portion by a conical knuckle f^6, formed on the main portion and entering a conical socket f^7 in the wing. (See Figs. 9 and 10.) This permits the wing of the plate to stand at a greater or less angle to the main portion and enables the plate to adjust itself to the position of the pocket of the piston without binding. The sides of the wing fit snugly against the sides of the pocket; but the sides of the main portion are contracted toward the knuckle f to afford the

main portion some play in the pocket. Each jointed plate is provided with a packing-strip G′, which extends over the circumferential bearing-face of the main portion and is provided with a detached cross-bar g^3, which is seated in the wing and takes part in the oscillatory movements thereof on the knuckle f^6 of the main portion.

H, Figs. 1, 5, 22, and 23, represents the wrist-pin, which is arranged centrally on the spherical back of the piston and which projects into the steam-chest and enters a socket arranged eccentrically in the crank-disk, so as to rotate with the latter.

H′ is a collar arranged between the wrist-pin and the piston and provided with a suitable number of steam-inlet openings h. The circular opening in the crown of the spherical case is large enough to permit of the rotation of the wrist-pin and collar and is provided with a packing-ring h', which is seated in a recess in the opening and bears against the spherical back of the piston, Figs. 5 and 6. The wrist-pin is surrounded by a sleeve I, having an external spherical face, and the socket on the crank-disk is provided with a bearing i, Fig. 5, for the spherical sleeve by placing the latter in the socket and pouring Babbitt or other soft metal around the same. This spherical connection permits the wrist-pin and crank-disk to adjust themselves to any imperfections of workmanship or inaccuracies in the arrangement of the parts.

The friction of the wrist-pin in its socket can be materially reduced by using the roller-bearing represented in Figs. 22 and 23. In this construction the end of the wrist-pin is reduced, as shown at j, and surrounded by a ring or collar J, which is secured to it. A thinner collar J′ is secured to the larger portion j' of the wrist-pin, both collars being of the same external diameter. Rollers J^2 are arranged between the outer faces of the collars and the inner face of a ring J^3, which is pressed into the spherical collar I. These rollers are provided with reduced middle portions j^2 and are held apart by a notched carrying-ring J^4, which is arranged between the collars J and J′ and receives the reduced necks of the rollers in its notches. The centrifugal force generated by the rotation of the wrist-pin tends to throw the rollers toward the crank-disk, and in order to reduce the friction occasioned by this pressure a row of balls j^3 is arranged in an annular recess formed in the side of the rear collar J adjacent to the notched carrying-ring, so that the latter bears against these balls. The form of this notched ring is shown in Fig. 4. This roller-bearing does not only reduce the friction by interposing rollers between the contact-surfaces, but it also reduces the friction by reducing the one-sided pressure against the wrist-pin bearing, which is much larger in a wrist-pin with a plain bearing, such as represented in Fig. 1, because in such a bearing the pin is pressed by the piston against one side of the bearing, leaving a clearance on the other side of the pin, into which the steam enters, which supplements by its pressure the one-sided pressure already applied to the bearing by the piston. In the roller-bearing the pin is practically exposed to the steam-pressure all around its circumference, so that the steam-pressure on the wrist-pin is practically balanced. For the same reason it is desirable in many cases to employ a roller-bearing for the main bearing of the engine-shaft which is adjacent to the steam-chest and exposed to steam-pressure by leakage along the journal. Such a roller-bearing is represented in Figs. 2, 3, and 4, in which K represents the rollers, k k the wear-rings applied to the shaft, k' the notched ring carrying the rollers, and k^2 the wear-ring secured to the bearing and surrounding the rollers.

L represents the cylindrical seat for the main valve, arranged axially in the piston, and L′ are the curved steam-ports of the piston, extending from the sides of said seat to the face of the piston and arranged between the pockets of the division-plates, as represented in Figs, 5, 6, 7, and 8.

M represents the cylindrical main valve, open toward the exhaust end of the engine and provided at its opposite end with a hollow stem m, which connects with the cylinder by a flaring hollow neck m'. The latter is provided with openings m^2, through which the steam enters from the hollow collar H′, the cavity of which surrounds the neck m' and receives the steam through the openings h.

m^3 represents the steam-induction port, and m^4 the exhaust-port formed in the cylinder of the main valve on opposite sides thereof.

In Figs. 5, 7, 30, and 31, N represents the cylindrical cut-off valve, which is arranged within the main valve and provided with a stem n, which extends through the hollow stem of the main valve. The cut-off valve N is provided on one side with an exhaust-port n', which is adjacent to and somewhat longer circumferentially than the exhaust-port m^4 of the main valve, and on the opposite side with a steam-inlet port n^2, which is adjacent to and somewhat shorter circumferentially than the steam-inlet port m^3 of the main valve. The inlet and exhaust ports of the valves are separated by a diagonal diaphragm n^3, which is formed in the cut-off valve and which places the exhaust-ports in communication with the exhaust end of the main valve and the steam-ports in communication with the hollow neck.

n^4 is a rib arranged along the rear or trailing edge of the steam-inlet port n^2 of the cut-off valve and projecting outwardly into the steam-inlet port m^3 of the main valve, with which latter the cylindrical face of this rib is flush. The front edge of this rib performs the function of cutting off the steam. The steam-port is fully open, as represented in Fig. 7, when the rib rests against the rear edge of the steam-port of the main valve, and

is closed to a greater or less extent by shifting the position of the internal or cut-off valve, so as to cause the front edge of the rib n^4 to approach the front edge of the steam-port m^3 of the main valve. This rib is secured to the cut-off valve by screws or other suitable fastenings. The main valve is rotated by a bifurcated carrier O, which is secured to the rear side of the crank-disk, as represented in Fig. 22, and rotates therewith. Both valve-stems project through the crank-disk, and the outer or hollow stem has its sides flattened, as represented in Figs. 26 and 28. The carrier-plate straddles the flattened portion of the hollow valve-stem and compels the latter to rotate with the crank-disk. The inward pressure of the steam on the main valve is received by this carrier-plate, which has the rear sides of its forked branches rounded where they come in contact with the end portions of the stem to permit these parts to adjust themselves to the angle of the main valve. The inward pressure of the steam on the inner or cut-off valve is received by a ball-bearing, (represented in Figs. 22 and 26,) which consists of a grooved collar p, secured to the projecting end of the stem of the cut-off valve, a row of balls p', seated in the groove of said collar and bearing against the end of the hollow stem of the main valve, and a ring p^2, whereby the balls are retained in the groove. This ball-bearing reduces the resistance of the cut-off valve very materially and renders the valve very sensitive.

Q Q', Figs. 22, 24, and 25, represent the governor-weights which are pivoted to the rear side of the crank-disk on diametrically-opposite sides of the engine-shaft and connected with the stem of the cut-off valve by links q and a carrier-plate R. The latter is secured to the projecting end of the valve-stem and is provided with two ears $r\,r'$, each having on its inner side a spherical socket, in which the spherical head of one of the links q is seated. The opposite spherical heads of the links are seated in spherical sockets in the governor-weights. The governor-weights swing in a plane at right angles to the engine-shaft, while the carrier-plate R turns in an oblique plane at right angles to the valve-stem. The spherical connection of the links with the governor-weights and the carrier-plate permits these parts to move freely, although arranged at an angle to each other.

T represents the springs which resist the outward movement of the weights. These springs are secured to the peripheral rim of the crank-disk and bear with their free ends against adjustable bearing-pieces t, secured to the outer sides of the weights. Each of these bearing-pieces is attached to the weight by a pivot-bolt s, which is arranged parallel with the pivot of the weight and which passes through approximately radial slots s' in the weight, so that the bearing-piece can be adjusted toward and from the fulcrum of the weight by shifting the pivot-bolt in these slots. Each bearing-piece is arranged in a recess in the outer side of the weight and can be adjusted on its pivot-bolt toward and from the spring by a set-screw s^3, which is screwed into the weight and bears against the rear side of the bearing-piece. The latter is provided at its apex with rollers s^3, by which it bears against the spring. By adjusting the bearing-piece in the weight the pressure which the spring opposes to the outward movement of the weight can be nicely regulated. The steam which has passed through the induction-port of the main valve into the piston presses against that part of the valve which is adjacent to the induction-port and crowds the valve against the opposite side of its seat. In order to counteract this external pressure on the valve, the cylindrical surface of the portion T' of the valve adjacent to the steam-inlet is depressed or cut away on the opposite side of the valve, as shown at t', Figs. 26 and 29, so as to form a narrow space between the surface of the valve and its seat, into which the steam enters from the steam-chest. This steam applies external pressure to the valve in a contrary direction to that which is applied to the induction side of the valve and whereby the external pressure upon the valve is balanced completely or nearly so. In order to prevent the steam from leaking along the valve to the ports of the piston, the valve is provided with a packing-ring t^2, Figs. 5 and 26, between the depressed portion t' and the ports. The cut-off valve is provided with a similar depressed portion t^3 and a packing-ring t^4 for the same purpose.

I claim as my invention—

1. The combination, with the case having the form of a spherical segment and the similarly-shaped piston filling the case partially, of a follower-pin arranged in the case and bearing centrally against the piston, and an adjusting-screw having a swiveling connection with the follower-pin, substantially as set forth.

2. The combination, with the case having the form of a spherical segment and the similarly-shaped piston filling the case partially, of a hollow central follower-pin provided at its outer end with a notched hub, and an adjusting-screw arranged in the case and having a reduced neck which engages in the notch of the hub, substantially as set forth.

3. The combination, with the case having the form of a spherical segment and the similarly-shaped piston filling the case partially, of a division-plate or abutment consisting of a main portion having a pivotal or rocking connection with the case, and a wing connected with the main portion by a flexible joint and entering a pocket in the piston, substantially as set forth.

4. The combination, with the case having the form of a spherical segment and the similarly-shaped piston filling the case partially, of a rigid division-plate having a pivotal or rocking connection with the case, and jointed

division-plates composed of a main part and a wing connected by a flexible joint, substantially as set forth.

5. The combination, with the spherical case and the spherical piston, of a jointed division-plate consisting of a main part and a wing connected by a tapering knuckle and socket, substantially as set forth.

6. The combination, with the spherical case and the spherical piston, of a jointed division-plate consisting of a main part and a wing connected by a flexible joint, and a packing composed of a curved strip applied to the peripheral edge of the main part, and a cross-bar applied to the wing, substantially as set forth.

7. The combination, with the spherical case and the spherical piston, of a division-plate provided with a conical knuckle seated in a similarly-shaped recess in the case, substantially as set forth.

8. The combination, with the case having the form of a spherical segment, of a division-plate having at one end a pivotal or rocking connection with the case and having its sides converging toward the center thereof, and a spherical piston filling the case partially and provided with a pocket receiving the free end of the division-plate and having converging sides which fit against the converging sides of the division-plate, substantially as set forth.

9. The combination, with the spherical case and the spherical piston, of a division-plate capable of radial movement in the case, and a spring, whereby the plate is pressed inwardly, substantially as set forth.

10. The combination, with the spherical case and the spherical piston, of a division-plate provided with a tapering knuckle which is loosely seated in a similarly-shaped socket in the case, and a spring arranged in the case and bearing against the outer end of the knuckle, substantially as set forth.

11. The combination, with the spherical case and the spherical piston, of a division-plate provided with a tapering knuckle which is loosely seated in a similarly-shaped socket in the case, a packing-strip arranged on the peripheral edge of the plate and provided with an annular enlargement over the knuckle, and a spring arranged in the case and bearing against the knuckle within the annular enlargement of the strip, substantially as set forth.

12. The combination, with the case having the form of a spherical segment and provided with a circular opening in its crown, of a steam-chest attached to the case outside of said opening, a spherical piston provided with a wrist-pin rotating in said opening, a crank-disk arranged in the steam-chest and connected with the wrist-pin, a valve whereby the flow of steam from the steam-chest to the case is controlled, and an annular packing-strip loosely seated in the circular opening of the case and pressed by the steam-pressure in the steam-chest against the back of the piston, substantially as set forth.

13. The combination, with the spherical case having an opening in its crown and a steam-chest attached to the case outside of said opening, of a wrist-pin attached to the piston and projecting through said opening into the steam-chest, a crank-disk arranged in the steam-chest and provided with a socket for the wrist-pin, and rollers interposed between the wrist-pin and its socket, whereby the steam-pressure is equalized around the wrist-pin, substantially as set forth.

14. The combination, with the spherical case having an opening in its crown and a steam-chest attached to the case outside of said opening, of a wrist-pin attached to the piston and projecting through said opening into the steam-chest, a crank-disk arranged in the steam-chest and provided with a spherical socket, a spherical sleeve seated in said socket, and rollers interposed between the sleeve and the wrist-pin, substantially as set forth.

15. The combination, with the spherical case, of a spherical piston provided with a wrist-pin, a crank-disk provided with a socket for the wrist-pin, interposed rollers provided with reduced middle portions, and a notched ring carrying said rollers, substantially as set forth.

16. The combination, with the spherical case, of a spherical piston provided with a wrist-pin, a series of connected rollers arranged between the wrist-pin and its socket, and a ball-bearing, whereby the outward thrust of the rollers is received, substantially as set forth.

17. The combination, with the spherical case, of a spherical piston provided with a wrist-pin, a ring secured around the end of the wrist-pin, rollers interposed between the wrist-pin and its socket, a ring carrying said rollers, and balls interposed between said ring and the ring secured to the wrist-pin, substantially as set forth.

18. The combination, with the spherical case, of a spherical piston provided with a hollow wrist-pin, a valve seated in the piston and provided with a stem extending through the wrist-pin, and a carrier attached to the crank-disk and engaging with the valve-stem, substantially as set forth.

19. The combination, with the spherical case, of a spherical piston provided with a hollow wrist-pin which is connected with the piston by a hollow collar having steam-inlet openings, and a hollow valve arranged within the piston and having a hollow neck and stem arranged within the collar and wrist-pin, the neck of the valve being provided with steam-inlet openings, substantially as set forth.

20. The combination, with the spherical case, the spherical piston provided with a hollow wrist-pin, and the crank-disk, of a main valve seated in the piston and provided with a hollow stem extending through the wrist-pin,

a carrier attached to the crank-disk and rotating the main valve, a cut-off valve arranged in the main valve and provided with a stem extending through the stem of the main valve, and a governor mechanism attached to the crank-disk and connected with the stem of the cut-off valve, substantially as set forth.

21. The combination, with the spherical case and the spherical piston, of a hollow main valve, a cut-off valve arranged in the main valve, and a ball-bearing interposed between the stem of the cut-off valve and that of the main valve, substantially as set forth.

22. The combination, with the cut-off valve and the crank-disk, of governor-weights pivoted to the crank-disk, springs secured to the crank-disk, and adjustable bearing-pieces attached to the weights and bearing against the springs, substantially as set forth.

23. The combination, with the cut-off valve and the crank-disk, of springs attached to the crank-disk, governor-weights pivoted to the crank-disk, and bearing-pieces attached to the weights by pivot-bolts passing through slots, and adjusting-screws bearing against the bearing-pieces, substantially as set forth.

24. The combination, with the spherical case, the spherical piston arranged obliquely in the case, and the crank-disk, of governor-weights pivoted to the crank-disk, a cut-off valve arranged centrally in the piston, a carrier secured to the stem of the cut-off valve, and links having spherical heads which connect the weights with said carrier, substantially as set forth.

25. The combination, with the spherical case and the steam-chest attached thereto, of a main bearing opening into the steam-chest, a shaft and crank-disk arranged in the steam-chest, and rollers interposed between the shaft and the main bearing, whereby the steam-pressure on the shaft is balanced, substantially as set forth.

26. The combination, with the piston having a cylindrical valve-seat, of an open-ended cylindrical valve provided on one side with an induction-port and having its closed cylindrical portion adjacent to the steam-inlet depressed on the opposite side of the valve, whereby steam-pressure is applied against the outer surface of the valve to counteract the steam-pressure exerted against the induction side of the valve, substantially as set forth.

Witness my hand this 24th day of February, 1891.

ELMER S. SMITH.

Witnesses:
EDWARD WILHELM,
JNO. J. BONNER.