(No Model.) 5 Sheets—Sheet 1.

L. M. SHAW.

PISTON ENGINE.

No. 455,061. Patented June 30, 1891.

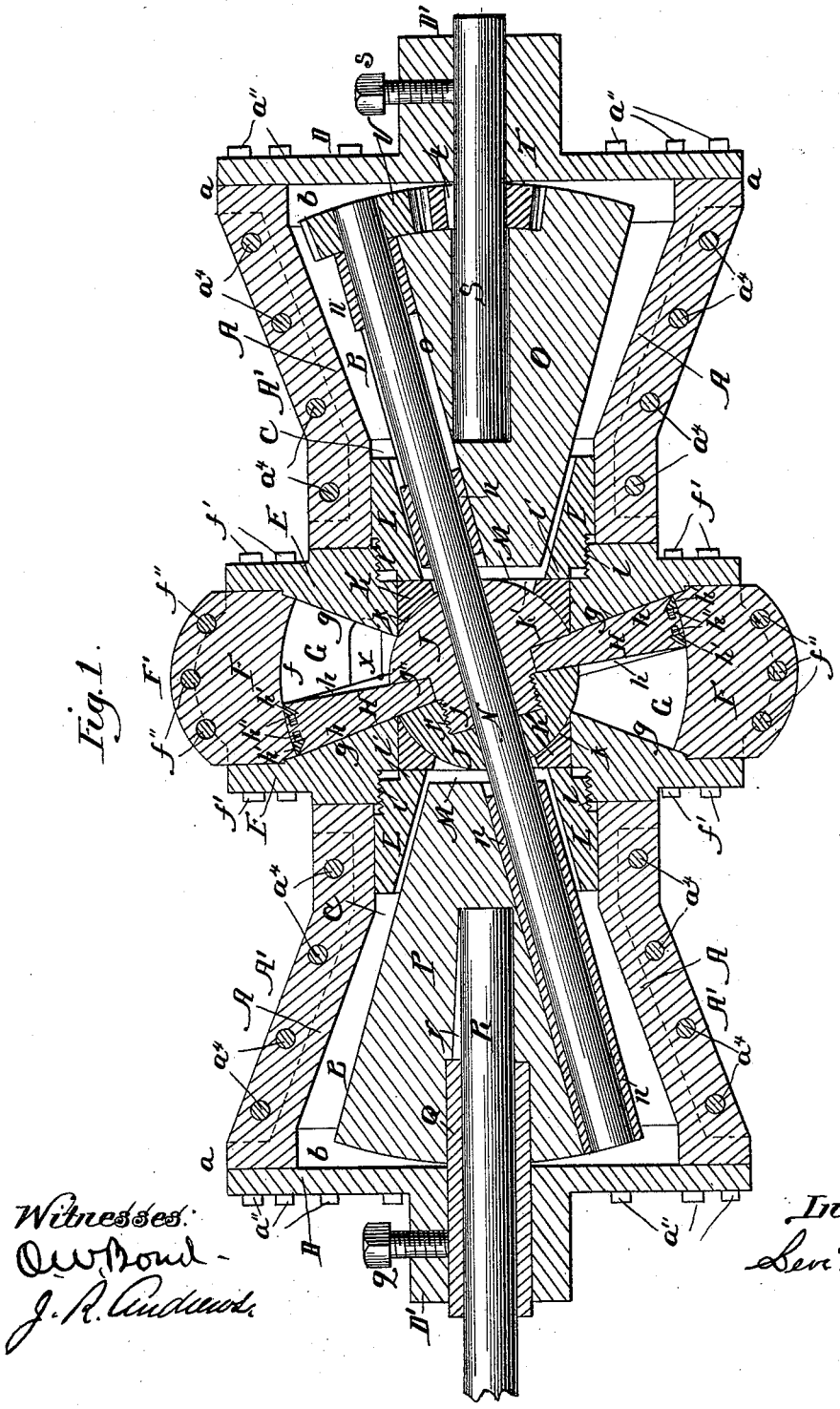

Fig. 1.

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(No Model.) 5 Sheets—Sheet 2.

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PISTON ENGINE.

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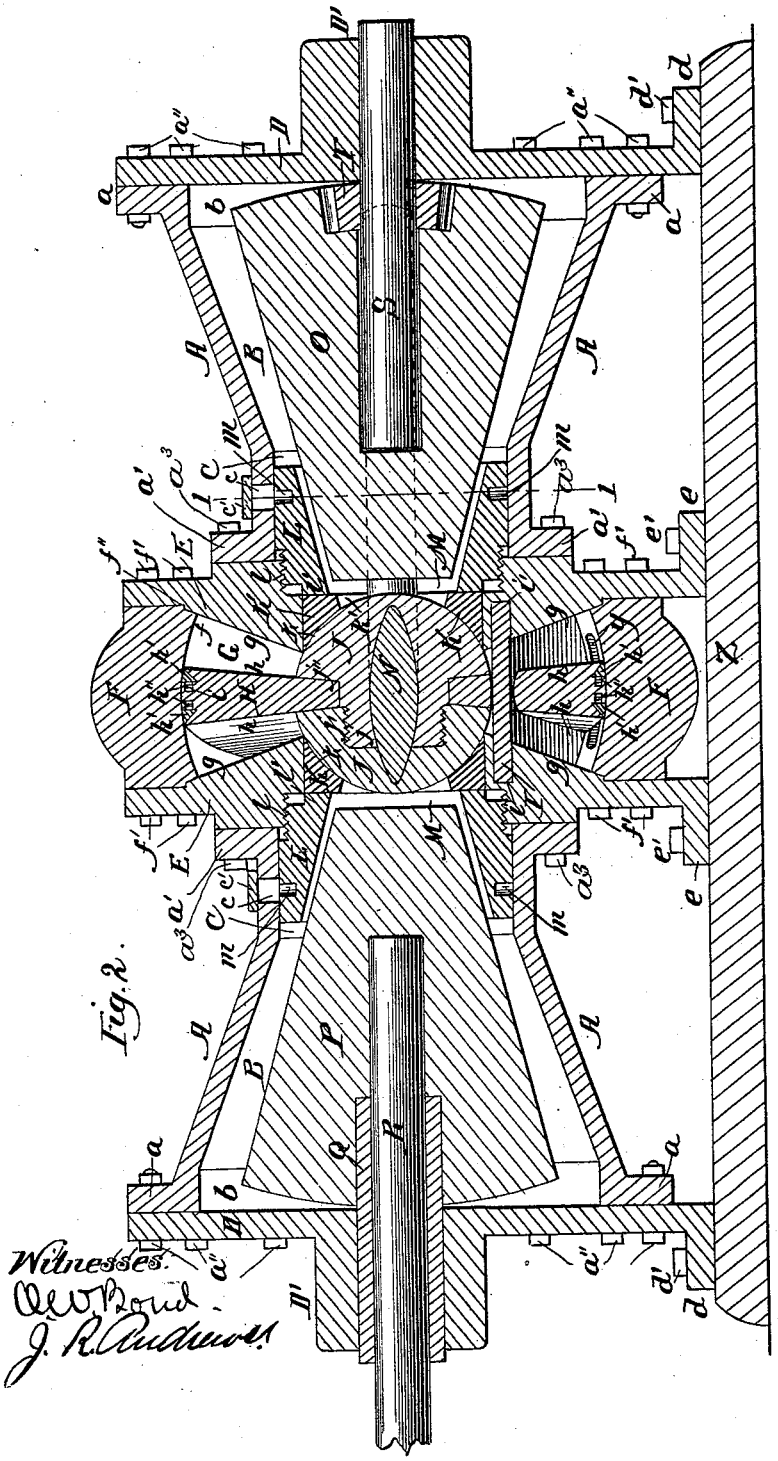

Fig. 2.

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Fig. 3.

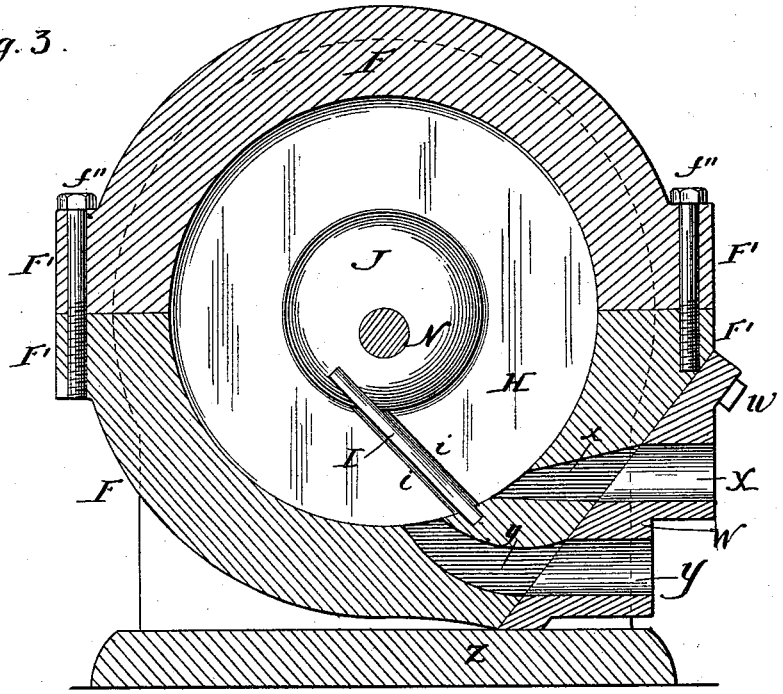

Fig. 4.

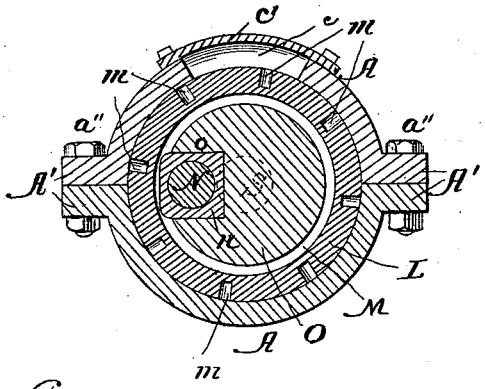

Fig. 5.

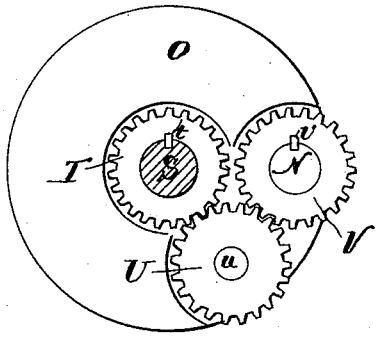

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Fig. 6.

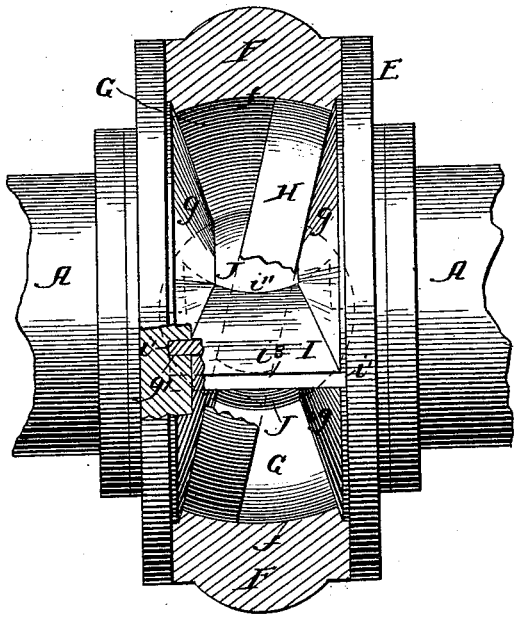


Fig. 9.

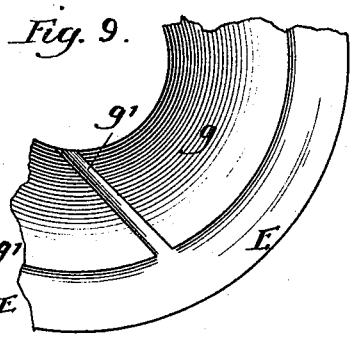


Fig. 7.

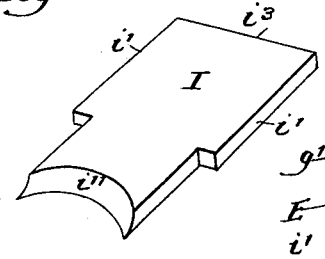
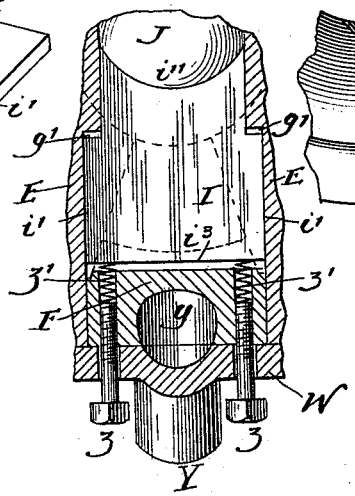


Fig. 8.



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L. M. SHAW.

PISTON ENGINE.

No. 455,061. Patented June 30, 1891.

Fig. 12.

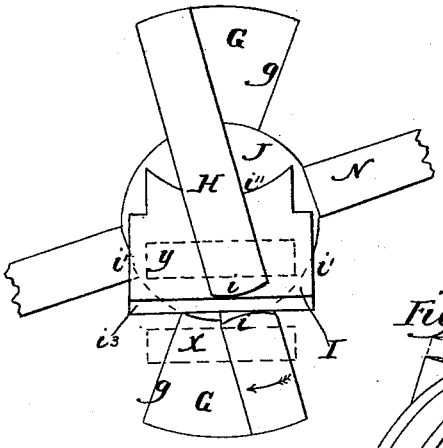


Fig. 11.

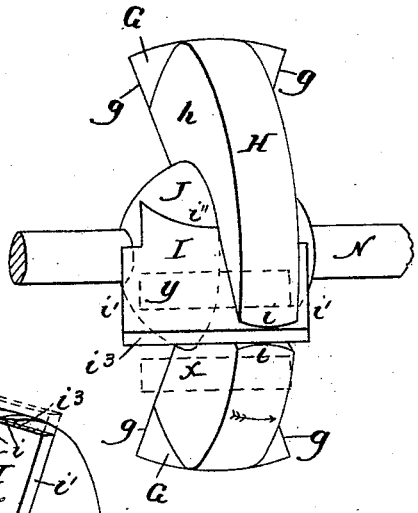


Fig. 14.

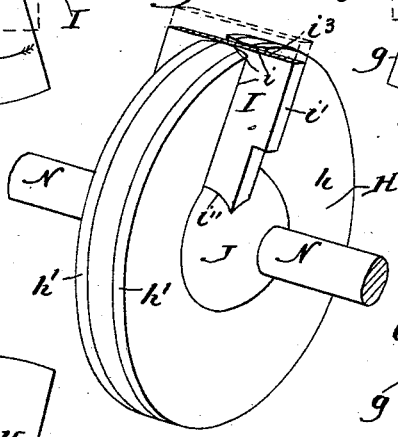


Fig. 10.

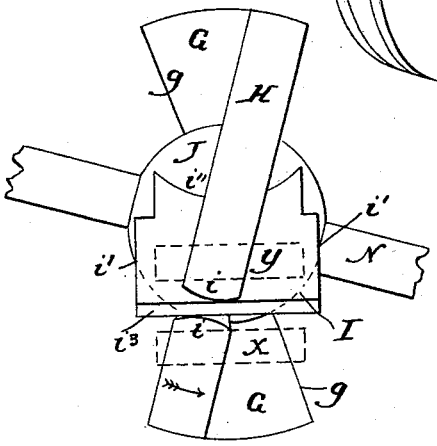
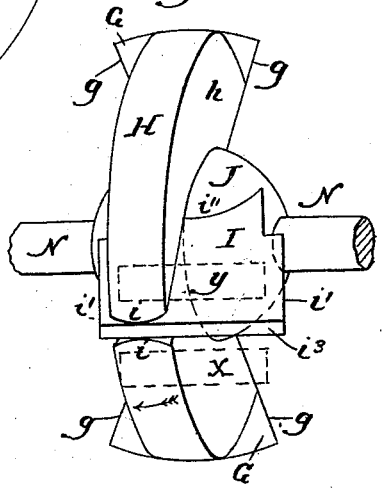


Fig. 13.



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C. W. Bond.
J. R. Andrews.

Inventor:
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UNITED STATES PATENT OFFICE.

LEVI M. SHAW, OF GYPSUM, KANSAS, ASSIGNOR TO HENRY C. STAVER, OF CHICAGO, ILLINOIS.

PISTON-ENGINE.

SPECIFICATION forming part of Letters Patent No. 455,061, dated June 30, 1891.

Application filed December 4, 1889. Serial No. 332,588. (No model.)

To all whom it may concern:

Be it known that I, LEVI M. SHAW, of Gypsum, in the county of Saline and State of Kansas, have invented certain new and useful Improvements in Piston-Engines; and I do hereby declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it pertains to make and use the same, reference being had to the accompanying drawings, forming a part hereof, in which—

Figure 1 is a longitudinal section in the central line of Fig. 2, with the shafts in elevation. Fig. 2 is a longitudinal section on the central line of Fig. 1, with the end shafts in elevation. Fig. 3 is a central cross-section through the steam-chest, with the piston and abutment in elevation. Fig. 4 is a cross-section on line 1 1 of Fig. 2; Fig. 5, an end elevation showing the gear for holding the piston-shaft in correct relation; Fig. 6, an elevation, partly in section, showing the steam-chest, the piston, and the abutment, with the piston and abutment partly broken away; Fig. 7, a perspective view of the abutment; Fig. 8, a detail in section showing the abutment and devices for pressing it onto the central ball; Fig. 9, a detail, being an elevation of the side wall of the steam-chest. Figs. 10, 11, 12, and 13 are outlines showing the relative positions of the piston-shaft and walls of the steam-chest at different points in the movement of the piston; Fig. 14, a perspective diagram view of the piston and abutment.

This invention relates to engines in which a piston is employed having a straight-line travel across the steam-chest and a rolling motion against the walls of the steam-chest, producing a compound movement, partly reciprocating and partly gyrating, and by which the end of the piston-shaft is made to describe a circle around a line-shaft with which the piston-shaft is connected for imparting a rotary motion to such line-shaft; and the objects of the invention are to give the piston a travel on the walls of the steam-chest, by which the contact between the walls and the piston will be always unbroken; to support the piston and its shaft against any unequal pressure of the steam on the piston and relieve the steam-packing of the piston of unequal wear; to control the piston in its relation to the steam-chest and prevent ill effects from any unequal pressure on the piston; to improve the connection between the piston-shaft and the shaft to be driven, so as to maintain the piston-shaft and the driven shaft always in the same line in their relation to each other; to control the piston in its relation to the steam-chest and have any point on the periphery of the piston pass in the same straight line across the steam-chest in both directions, and to improve generally the construction and operation of the engine as a whole; and its nature consists in the several parts and combinations of parts hereinafter described, and pointed out in the claims as new.

In the drawings, A represents the two ends of the case or shell, each end having an outer flange a and an inner flange a', as shown in Fig. 2, and each end A is formed in two halves or sections, each having a side flange A′, by means of which and suitable bolts a^4 the two sections are united together, so as to be steam-tight and form, in effect, a solid or continuous end.

B is a conical-shaped circular chamber in each end A, which chamber at its outer end has an annular flat face b in the construction shown.

C is a circular chamber with straight walls at the inner portion of each end A and communicating with the chamber B. The wall of the case A has a passage or opening c, closed by a cap or cover c', as shown in Fig. 2, which passage or opening leads through the wall into the chamber C.

D are the end plates for closing the outer end of each case A, each plate D being bolted securely to the flange a by means of bolts a'', so as to be steam-tight, and each plate or cover D has a side foot or lug d, through which bolts d' pass for attaching the engine as a whole to its base or support.

E are annular plates, one for each side of the steam-chest, each plate E being secured to the flange a' by bolts a^3, so as to make a steam-tight connection between the end cases A and the plates E, and each plate E has a

side foot or projection *e*, through which bolts *e'* pass for attaching the plates to the base or support of the engine.

F is a ring located between the inner faces of the plates E at the periphery of such plates and secured in position between the plates by bolts *f'*, and, as shown, in order to form a firm union between the plates E and the ring F, the plates are cut away around their periphery to form a shoulder or rest for the ring, and the inner face *f* of the ring is formed on the arc of a circle, as shown in Figs. 1 and 2. The ring F is formed of two half-rings, each having a flange F', by means of which and bolts *f''* the half-rings are united to make a continous ring.

G is the steam-chest formed between the inner face *f* of the ring F and the inner faces *g* of the plates E, and each face *g* of each plate E projects inward on an incline, so that the steam-chest G is wider at its periphery than at the center.

H is an annular flange, the periphery of which coincides with and fits the circle of the steam-chest G, and also conforms to the wall or face *f* of the ring F, and, as shown, in the periphery of the flange H is a triangular-shaped packing-ring *h'* on each side of the center of the flange, each packing-ring *h'* being held in place and forced outward by means of a spring *h''*, located in a recess adjacent to the recess for the packing-ring *h'*. The flange H has on each side an inclined face *h*, the inclination of which coincides with the inclination of the walls *g*, so that each side face *h* of the flange H is concave or has an inward flare, while the inner face *g* of each plate E is convex or has an outward flare, as shown in Figs. 1 and 2.

I is the abutment passing through the flange H, for which purpose the flange H has a slot or opening *i*, and cutting across the steam-chest to form a partition in the steam-chest G for separating the inlet and outlet ports for the steam, for which purpose the ports are located on opposite sides of the abutment, as shown in Fig. 3. Each side wall or face *g* of the steam-chest G has a groove *g'*, which groove *g'* is cut diagonally across the face or wall, as shown in Fig. 9, and these grooves *g'* receive the edges *i'* of the abutment I, by which the abutment I is located at one side of the center of the flange and in a diagonal plane running parallel with a radial line passing through the center of the flange, which plane in its passage cuts the radial lines of the flange, except the one with which it is parallel, as shown in Fig. 3, and this abutment is inclined in its relation to the line of contact of the flange with the wall of the steam-chest for the line of contact to pass from the exhaust to the supply side of the abutment with an unbroken support in passing from the inner to the outer end of the abument, and vice versa.

J is the ball, made in two parts, one of which has a screw-threaded neck or center *j*, which enters a screw-threaded hole *j'* of the other portion of the ball, as shown in Figs. 1 and 2, and this ball as a whole has a central annular recess *j''*, which receives the inner edge of the flange H, for which purpose the flange has a central hole of the same diameter as the neck *j*, so that the neck can be passed through such hole and the female portion of the ball be screwed into place, firmly connecting the flange H with its ball J, as shown in Figs. 1 and 2. The inner end of the abutment I fits against the face of the ball J, for which purpose this end has a circular concave face *i''*, conforming to the face of the ball, and, as shown, this inner end of the abutment is of a less width than the outer end to permit the abutment to pass through the packing-rings for the ball without cutting the packing-rings in two. The edges *i'* of the abutment I fit snugly in the grooves *g'* formed therefor in the inner face of each plate E, and the outer end *i*³ of the abutment fits snugly in a groove formed therefor in the inner face of the ring F, so that when the abutment is in place it will be steam-tight.

K are the packing-rings for the ball J, one located on each side of the flange H in a circular hole formed therefor at the center of each plate E, as shown in Figs. 1 and 2, and the bearing-face *k* of each ring K is on a concave to fit snugly against the ball J, and, as shown, each packing-ring K has a central hole *k'* for the passage of the piston-shaft.

L are followers, one for each end case A, located in the chamber C of such case, and each follower has a screw-threaded inner end *l* to enter a screw-threaded hole in the outer face of each plate E, and also has a rim or flange *l'* to abut against the face of the packing-ring K, so that by screwing in the follower the packing-ring will be advanced to fit snugly on the ball J. As shown, each follower has a series of holes *m*, which come in line with the opening *c*, so that by inserting a rod or a lever each follower can be screwed inward as required to advance the packing-rings and take up the wear.

M is a cone-shaped hole at the center of each follower L.

N is the piston-shaft, on which the ball J is firmly secured. This shaft passes centrally through the ball in the direction of the length of the case, but is made to stand at an angle for the side faces *h* of the flange H to lie in contact with the side faces *g* of the steam-chest G, by which means the flange is at an angle in relation to the center of the steam-chest and must be by reason of the inclination given to the shaft N.

O is a cone-shaped head lying within the chamber B and opening M at one end A of the case and receiving on one side the end of the shaft N, which shaft has thereon an outer and inner box *n*, each box entering a groove *o* in the face of the head O.

P is a cone-shaped head corresponding to O and located in the chamber B and opening

M at the other end A of the case and having a groove *p* to receive the boxes *n* on the end of the shaft N.

Q is a sleeve, the inner end of which enters the outer end of the head P, and this sleeve is held stationary in the boss D′ by a set-screw *q*, as shown, or in some other suitable manner.

R is the shaft to be driven, which shaft at its inner end passes through and has its bearing in the sleeve Q, and its extreme inner end has the head P secured thereto by a key *r*, so that the rotation of the head P from the shaft N will drive the shaft R.

S is a pin, on which is loosely mounted the head O, and this pin is locked or held stationary in the boss D′ by a set-screw *s*, as shown in Fig. 1. The shafts R and S are in the same central line, one with the other, which line is the center of the ball J, and the shaft N runs diagonal between the two shafts R and S, as shown in Fig. 1; and as the shaft N is supported at the ends by the boxes *n* and is likewise supported on each side of the ball J by the boxes *n*, and these boxes are in turn supported and held in position by the heads O and P, and these heads are held in line with a common center, it will be seen that the ball J is supported by the shafts N R and S in connection with the heads O and P, and thereby relieve the ball from unequal pressure and consequent unequal wear against the packing.

T is a gear-wheel attached to the supporting-pin S adjacent to the inner face of the cover D by a key *t*, so that this gear T is held stationary.

U is a gear meshing with the gear T and mounted on a pin *u* in the end of the head O.

V is a gear meshing with the gear U and attached firmly to the end of the shaft N by a key *v*, so that the shaft N and gear V will always have the same relation. The gear T is stationary. The gear U is free to revolve on its pin *u*, and the gear V is stationary on the shaft N, but has a circular motion with the shaft N, the result being that the gears U and V are carried around the gear T as a center, by which the shaft N will always be maintained in the same relation, as the gear U will travel on the gear T and likewise on the gear V, so that the gear V is held stationary and in the same direction, maintaining the shaft N in a corresponding relation. These gears T, U, and V prevent any revolving of the shaft N in describing the circle at its end and also prevent the shaft N from being thrown or carried out of line in relation to its position in connection with the ball J and flange H, by which the flange will always be carried in the same relation and will be held off the abutment.

W is a cap attached to the center of the engine on the ring F by suitable bolts *w*.

X is an opening in the plate or cap W for attachment of the steam-supply pipe, which opening coincides with a port *x*, forming the inlet-port for the steam to the chamber G on one side of the abutment I.

Y is an opening in the plate W for the attachment of the exhaust or outlet pipe for the steam, which opening coincides with an exhaust-port *y*, leading from the chamber G on the opposite side of the abutment I, as shown in Fig. 3.

Z is the base or support to which the engine is attached by the lugs *d e* and bolts *d′* and *e′*, as shown in Fig. 2. The abutment I is located between the ports *x* and *y*, as shown in Figs. 3 and 8, and this abutment is of a width to correspond to the width of the ring F, and is entered at its upper end i^3 in a groove in the ring, as shown in Fig. 8, and against the outer end of the abutment springs *z′* bear, which springs are held and adjusted by set-screws *z*, by means of which screws *z* and springs *z′* the abutment can be moved inward to take up the wear and properly hold the abutment at its ends *i″* on the ball J, as clearly shown in Fig. 8.

The parts are assembled by attaching the plates E to the inner end of each end case A by flanges *a′* and bolts a^3 and connecting the two parts of each end case A together by the flanges A′ and the bolts a^4. The packing-rings K are inserted in the openings therefor in each plate E, and the followers L are inserted in their respective chambers C. The head O is placed in the chamber B with its end in the opening M, and the shaft N, with the ball J and flange H thereon, is inserted for the end of such shaft with its boxes *n* to lie within the groove *o*. The central ring F is bolted to the plate E, and the two parts of the ring secured together by the flanges F′ and bolts *f″*. The abutment I is placed in position by entering its edge *i′* into the groove *g′* of the wall *g* and entering its end i^3 into the groove therefor in the ring F, and the other plate E is placed in the position for the groove *g′* of its wall *g* to receive the edge *i* of the abutment I, and then bolted to the ring F by the bolts *f′*. The head P is inserted in the chamber B, with its end in the opening M of the follower L, and its groove *p* receives the box *n* on the end of the shaft N. The end of the shaft R is inserted in the head P and locked by the key *r*, and the sleeve Q is slipped onto the shaft R and entered into the end of the head P, and the end plate D is then slipped into place on the sleeve Q and secured to the end case A by the flange *a′* and bolts *a″*. The gear V is secured to the end of the shaft N by the key *v*, and the gear U is mounted on its pin *u* on the head O to mesh with the gear V, and the shaft or pin S is entered into the end of the head O, and the gear T is keyed to the shaft S to mesh with the gear U, and the plate D is slipped over the shaft S and attached to the end case A by its flange *a* and the bolts *a″*. The heads O and P are advanced or moved inward by moving the sleeve Q and the pin S, and when properly adjusted the sleeve is locked by the set-

screw q, and the pin is locked by the set-screw s, holding the sleeve and pin both stationary. The plate W is attached to the side of the center of the engine by the bolts w in position for the openings X and Y to align with the ports x and y. After the abutment I is in position the springs z' are inserted to bear against the edge i^3, and after the plate W is attached the set-screws z are entered to bear against the springs z'. The several parts, after being assembled and connected together, are to be properly adjusted, and when adjusted the engine is ready for use by connecting a steam-supply pipe with the opening X and exhaust-pipe with the opening Y.

In use the steam entering the supply-port x will pass around in the steam-chamber to escape at the exhaust-port y, and such passage of the steam will carry the flange H back and forth across the steam-chamber G by reason of the steam acting first on one side of the flange H and then on the opposite side as such flange changes its position in relation to the supply-port. This changing of the flange from one side to the other of the steam-chamber causes the face h of the flange to roll against the wall g of the steam-chamber on both sides, and this rolling movement is had from the ball J turning in its packing-ring, and by this rolling movement a circular motion is given to both ends of the shaft N, and the position of the flange, the ball, the shaft, and the relation of the faces h of the flanges H and the faces or walls g of the steam-chamber in the movement of the crank in the circle which its ends describe is shown by the diagrams Figs. 10, 11, 12, and 13. The diagram Fig. 10 shows the flange in relation to the abutment and the position of the piston-shaft N when the flange has moved one-half of the distance across the abutment in the direction in which the flange is traveling toward the right, and in this position the contact-line of the flange with the walls of the steam-chest is one-quarter of the distance around, and in this position steam is supplied through the port x on both sides of the flange H, and steam is exhausted from both sides of the flange through the port y. The continued movement of the flange H in the direction of its travel to the right carries the flange over the abutment to the right-hand side of the abutment, as shown in Fig. 11, in which position the contact-line between the flange and the walls of the steam-chest has been advanced another quarter and the shaft N has been carried to the position shown in Fig. 11, and with the parts in this position the periphery of the flange on the right-hand edge has passed the inlet-port x and closed such port against the supply, and the exhaust-port on the opposite side of the abutment is closed by the periphery of the flange at the right hand, and at this point the flange begins its return movement across the steam-chest over the abutment I, and when the contact-line between the flange H and the walls g of the steam-chest G has been advanced another quarter the flange H has traveled across the steam-chest to the position shown in Fig. 12, and the shaft N is in the position shown in that figure, and with the parts in this position steam is supplied through the port x to both sides of the flange H, and steam is exhausted from both sides of the flange H through the port y, and the advance of the contact-line between the flange and the walls of the steam-chest for another quarter brings the parts into the position shown in Fig. 13, in which the flange has traveled back across the steam-chest and over the abutment to close the supply-port x on the left-hand side of the flange and to close the exhaust-port y on the left-hand side, shutting off the supply and closing the exhaust on these sides, respectively, and in this position the flange has made its entire return across the steam-chest and is ready to be carried back in the first direction of its travel again, and with this direction of travel the contact-line between the flange and the walls of the steam-chest, when carried around another quarter, will bring the parts into the position shown in Fig. 10, which is the position from which the start was made, and these movements of the flange across the steam-chest will continue as long as steam is supplied to the chamber G. The position shown in Fig. 10 may be regarded as having the contact-line between the flange and the steam-chest advanced one-quarter around from the starting-point, which is the abutment, and in this position the ends of the shaft N have described a quarter of the circle, and with the parts as shown in Fig. 11 the contact-line between the flange and the walls of the steam-chest has been advanced one-half of the distance around and the shaft N has described one-half of its circle, and with the parts as shown in Fig. 12 the contact-line between the flange and the walls of the steam-chest has been advanced three-quarters of the distance around and the shaft has described three-quarters of its circle, and with the parts as shown in Fig. 13 the contact-line between the flange and the walls of the steam-chest has completed its travel around and the shaft has described its circle, when the abutment is used as the starting-point; but to complete the circle illustrated the parts must be brought into the position shown in Fig. 10; or, in other words, the illustration in Fig. 10 shows a quarter, that of Fig. 11 a half, that of Fig. 12 three-quarters, and that of Fig. 13 a complete circle described by the shaft N.

It will be seen from the foregoing description and the diagram illustrations that, except at two points—namely, the limit of the travel of the flange in both directions across the steam-chest—steam is admitted to both sides of the flange at the supply-port at all times and travels around from the side of the abutment on which the supply-port is located in the space between the flange and the

side walls of the steam-chest on both sides of the flange to the exhaust-port, the result being a constant supply of steam, which travels continuously, moving the flange H to and fro across the steam-chest through pressure of the steam in the chest against the abutment on the supply side and against the wall of the steam-chest and the face of the flange, and it will be noticed that at the initial start in either direction the opening is very small, but gradually widens as the flange is carried across the steam-chest until half a circle is described, when the space gradually narrows for the remaining travel of the flange.

The flange H and the ball J constitute a piston, which piston is supported in the steam chamber or space G, and the abutment I forms a partition in the steam-chamber, separating the supply side from the exhaust side, and the piston as a whole is supported and held in position by the heads O P, in connection with the shaft N and the bearings of such shaft in the heads O P and the centering of the heads through the pin S and the driven shaft R, by which means the ball J is supported and held off from the packing-rings K in such manner as to have the packing-rings act without being subjected to unequal wear from any unequal pressure on the piston formed by the flange H and the ball J, the result being that the piston as a whole is supported in its chamber and held against unequal pressure, and consequently unequal wear, either on the ball and its packings or on the edge of the flange H and its contact-line with the walls *g* of the steam-chest.

The flange H should move over the abutment without contact, and this end is had by means of the train of gears T, U, and V, for the reason that, the gears T and V being stationary and the gear U being intermediate of the gears T and V and free to revolve, the travel in one direction on the gear T will counteract the travel on the gear V, maintaining an equality in the relation of the gear T to the gear V, by which these gears will be held in the same relation, one to the other, in the circle described by the gear V around the gear T, thereby holding the shaft N against self-revolving and maintaining the same point of this shaft always in the same relation to itself in the circle which the ends of the shaft describe.

The connection of the shaft N with the head O is by an inner and outer box, which constitutes in effect one box, the same as the single box by which the shaft N is attached to the head P, (shown in Fig. 1,) and a long box can be used at both ends of the shaft N for connection with the heads O P, or inner and outer boxes could be used at both ends for such connection, and the employment of boxes for making the connection is for the purpose of enabling a true alignment of the shaft N with the shaft R and the pin S to be had, as by using boxes a slight variation in the alignment can be readily taken up. The same result can be attained by dispensing with the boxes and making a connection with the heads by means of holes, through which the ends of the shaft could pass, such holes and the holes for the shaft R and pin S being in the same line.

The followers L enable the packing-rings K to be advanced uniformly at all points, thereby maintaining the packing-rings and the ball J in correct relation, and by these followers the packing-rings can be advanced to take up any wear, and by advancing the heads O and P through the sleeve Q and pin S these heads can be made to hold the shaft N at the inclination required for the side faces *h* of the flange H to impinge at the line of contact properly with the faces *g* of the steam-chest. The contact between the periphery of the flange H and the wall *f* of the steam-chest G is maintained steam-tight by means of the triangular-shaped packing-rings *h'*, which are held against the wall *f* by the action of the spring *h''*, preventing the passage of the steam from one side to the other of the flange H except at the opening *i* for the abutment I, and the passage of the steam at this point in no wise affects the operation of the piston as a whole, and by holding the flange H at the opening *i* clear of the abutment I in its passage to and fro over the abutment wear on the abutment is prevented, and consequently wear on the edge of the flange at the opening *i*.

The head O furnishes a support for the end of the shaft N, which does not perform any work, and this end of the shaft may therefore be termed a "non-driving end," while the end of the shaft at the head P may be termed the "driving end," as from the circle which it describes rotation is imparted to the shaft R, and the purpose of the head O and the end of the shaft N thereof is to furnish a connection for the train of gear through which the shaft N will be held in the same relation to itself in the circle which it describes, and thereby insure a straight reciprocation of the piston across the steam-chamber G—that is to say, a movement of the piston across the steam-chamber in the same straight line, thereby causing the piston to traverse over the abutment without coming in contact with the abutment, preventing wear on the piston and abutment

The case ends A, instead of being made in two halves or sections, can be formed continuous, in which event the side flanges A' and the securing-bolts a^4 are dispensed with, and the ring F, instead of being made of two half-rings, can be made of a continuous ring, dispensing with the flanges F' and the securing-bolts *f'''*, and instead of having the sleeve Q sliding into position the exterior face of this sleeve can be screw-threaded, and the hole therefor in the hub D' can be likewise screw-threaded, which will give the sleeve Q a better adjustment in advancing the head O.

The word "diagonal" is used in connection with "abutment" to define the position of the

abutment in relation to the flange and steam-chest as tangential, and a diagonal abutment is one having its outer starting-point in line, or nearly so, with the periphery of the ball and its inner or terminal point in or near a vertical line from the center of the ball for the line of the abutment to be outside of the piston-shaft, as clearly shown in Fig. 2, and standing at an angle of forty-five degrees, or approximately so, to a base-line horizontal otherwise. This diagonal abutment is not a straight-line radial abutment nor an inclined-line radial abutment, in both of which constructions the radiation is in a direct line from the center of the piston-shaft, and with such direct-line radiation the abutment is subjected to blows from the piston in its travel over the abutment because of the drop of the piston from the abutment, and the result of the continuous blows is a wearing out of the abutment at the center for an increased back swing of the piston, and such back swing produces a backlash of the piston-shaft, causing an uneven motion and not a true-circle traverse of the shaft, and the travel of the piston over the abutment is a broken or interrupted one by reason of the drop-off and the wearing of the abutment out at the center, and this produces more or less jar and concussion. The diagonal abutment obviates all these defects of a radial abutment, as it gives a continuous unbroken support over which the piston constantly travels without any drop, thus preventing back swing of the piston and backlash of the shaft and giving the shaft a true circle of rotation.

What I claim as new, and desire to secure by Letters Patent, is—

1. The combination, in an engine, of an annular steam-chest, a piston in the steam-chest formed of a flange and a ball, with the flange at the center of the ball traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, and a piston-shaft projecting on both sides of the piston and passing through the center of the ball transversely to the flange, substantially as and for the purposes specified.

2. The combination, in an engine, of a steam-chest, a piston in the steam-chest formed of a flange and a ball, with the flange at the center of the ball traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely to the flange and projecting on both sides of the piston, and revolving heads, one for each part of the piston-shaft, receiving and supporting the shaft on both sides of the piston at the outer and inner ends, substantially as and for the purposes specified.

3. The combination, in an engine, of a steam-chest, a piston formed of a flange and a ball, with the flange at the center of the ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely of the flange and projecting on both sides of the piston, revolving heads, one for each part of the piston-shaft and receiving and supporting the shaft on both sides at the outer and inner ends, and a center bearing for each revolving head, substantially as and for the purposes specified.

4. The combination, in an engine, of a steam-chest, a piston in the steam-chest formed of a flange and a ball, at the center of which the flange is located, and traversing the steam-chest on straight lines by rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely to the flange and projecting on both sides of the piston, revolving heads, one for each part of the piston-shaft and receiving and supporting the shaft at its outer and inner ends, a center bearing for each head, and a connection at the end of the non-driving part of the shaft with its head, substantially as and for the purposes specified.

5. The combination, in an engine, of a steam-chest, a piston in the steam-chest formed of a flange and a ball, with the flange at the center of the ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball and transversely to the flange, heads, one for each end of the piston-shaft, receiving and supporting the shaft ends, a driven shaft connected to one of the heads, and a pin on which the other head is mounted and revolves, substantially as and for the purposes specified.

6. The combination, in an engine, of a steam-chest, a piston in the steam-chest formed of a flange and a ball, with the flange at the center of the ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely of the flange and projecting at each end beyond the piston, heads, one for each end of the piston-shaft and receiving and supporting the shaft ends, a driven shaft connected with one of the heads at the center, a pin at the center of the other head and on which the head is mounted, and a connection between the shaft at this end and the head, substantially as and for the purpose specified.

7. The combination, in an engine, of a steam-chest, a piston in the steam-chest formed of a flange and a center ball traversing the steam-chest on straight lines and roll-

ing against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center ball and projecting on both sides of the piston, a revolving head receiving and supporting one part of the piston-shaft, and a connection between the head and the end of the shaft for maintaining the travel of the piston in straight lines across the steam-chest clear of the abutment, substantially as specified.

8. The combination, in an engine, of a steam-chest, a piston in the steam-chest formed of a flange and a center ball traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball and projecting on both sides of the piston, a head receiving and supporting one part of the piston-shaft and connected with a shaft to be driven, a head receiving and supporting the other side of the piston-shaft and mounted on a stationary pin, and a connection between the ends of the piston-shaft and the head for maintaining the flange in a straight-line travel across the steam-chest, substantially as and for the purpose specified.

9. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, and heads, one for each part of the piston-shaft and each receiving and supporting its part of the shaft at both its outer and inner ends, substantially as and for the purpose specified.

10. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, a head receiving and supporting non-driving part of the piston-shaft, and a connection between the end of the non-driving part of the shaft and its head for maintaining the piston in straight-line travel, substantially as specified.

11. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a head receiving and supporting one end of the piston-shaft, and a train of gear connecting the end of the shaft with the head, substantially as and for the purposes specified.

12. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a head receiving and supporting the end of the shaft, a stationary pin upon which the head is mounted, and a train of gear connecting the piston-shaft with the head, substantially as and for the purpose specified.

13. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a head receiving and supporting the piston-shaft at one end, a stationary pin on which the head is mounted, a stationary gear on the end of the piston-shaft, a stationary gear around the pin, and an intermediate gear connecting the two stationary gears and mounted on the end face of the head, substantially as and for the purposes specified.

14. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a head receiving and supporting one end of the piston-shaft, a shaft to be driven connected with the head, another head receiving and supporting the opposite end of the piston-shaft, and a pin on which the head is mounted for supporting the piston, substantially as and for the purposes specified.

15. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, and cone-shaped heads, one for each part of the piston-shaft and receiving and supporting the shaft on both sides of the piston for its full length, substantially as and for the purposes specified.

16. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft passing through the ball at the center and projecting beyond the piston on both sides, a cone-shaped head receiving and supporting the non-driving part of the piston-shaft, and a connection between the head and the end of the piston-shaft, substantially as and for the puposes specified.

17. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a cone-shaped head receiving and supporting one end of the piston-shaft, and a train of gear connecting the head with the end of the shaft, substantially as and for the purposes specified.

18. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a cone-shaped head receiving and supporting one end of the piston, a stationary pin on which the head is mounted, and a train of gear connecting the head with the end of the piston-shaft, substantially as and for the purposes specified.

19. The combination, in an engine, of a piston formed of a flange and a center ball, a piston-shaft projecting at each end beyond the piston and passing through the center of the ball, a cone-shaped head receiving and supporting one end of the shaft, a stationary pin on which the head is mounted, a stationary gear on the end of the piston-shaft, a sta-

tionary gear on the pin, and an intermediate gear mounted on the end face of the head and connecting the stationary gear, substantially as and for the purposes specified.

20. The combination, in an engine, of a piston formed of a flange and center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, a support for the non-driving part of the piston-shaft, and a traveling connection between the piston-shaft and its support operating to hold the piston-shaft against self-revolving and maintain the piston in a straight-line travel, substantially as specified.

21. The combination, in an engine, of a piston formed of a flange and a center ball, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, and revolving heads, one for each part of the shaft and receiving and supporting the shaft at both its outer and inner ends for preventing unequal wear on the piston, substantially as specified.

22. The combination, in an engine, of a piston-shaft, a head receiving and supporting the projected part of the piston-shaft, and a connection between the end of the piston-shaft and the head for maintaining the shaft always in the same relation, substantially as and for the purpose specified.

23. The combination, in an engine, of a piston-shaft, a head receiving and supporting the end of the piston-shaft, and a gear connection between the end of the piston and the head, substantially as and for the purpose specified.

24. The combination, in an engine, of a piston-shaft, a head receiving and supporting the end of the piston-shaft, a pin on which the head is mounted, and a gear connection between the end of the piston-shaft and the head, substantially as and for the purposes specified.

25. The combination, in an engine, of a piston-shaft, a head receiving and supporting the end of the piston-shaft, a pin on which the head is mounted, a stationary gear on the end of the piston-shaft, a stationary gear on the pin, and a movable gear mounted on the end face of the head and connecting the stationary gear, substantially as and for the purpose specified.

26. The combination, in an engine, of two stationary gears and a movable gear intermediate of and connecting the stationary gears for connecting the end of a piston-shaft and holding the shaft in the same relation with the same side always uppermost, substantially as specified.

27. The combination, in an engine, of a piston-shaft projecting on both sides of the piston and heads, one for each part of the shaft and receiving and supporting the shaft on both sides from the piston outward, substantially as and for the purposes specified.

28. The combination, in an engine, of a piston-shaft projecting on both sides of the piston and cone-shaped heads, one for each part of the shaft and each receiving and supporting its part of the shaft from the piston outward, substantially as and for the purposes specified.

29. The combination, in an engine, of a piston-shaft projecting on both sides of the piston, heads, one for each part of the shaft and each receiving and supporting its projected part of the shaft, and a connection for the end of the non-driving part of the shaft with its head for holding the shaft in the same relation, substantially as and for the purpose specified.

30. The combination, in an engine, of a piston-shaft projecting on both sides of the piston, and cone-shaped heads, one for each part of the shaft and each head receiving and supporting its part of the shaft, and a connection for the end of the non-driving part of the shaft with its head, substantially as and for the purpose specified.

31. The combination, in an engine, of a piston-shaft projecting at each end beyond the piston, heads, one for each end of the shaft and each head receiving and supporting its shaft end, and a train of gear connecting one end of the shaft with its head, substantially as and for the purposes specified.

32. The combination, in an engine, of a piston-shaft projecting at each end beyond its piston, cone-shaped heads, one for each end of the shaft and each head receiving and supporting its shaft end, and a train of gear connecting the shaft at one end with its head, substantially as and for the purpose specified.

33. The combination, in an engine, of a piston-shaft projecting at each end beyond its piston, a head receiving and supporting one end of the piston-shaft and attached to a shaft to be driven, another head receiving and supporting the opposite end of the piston-shaft, a pin on which the head is mounted, and a connection between the shaft end and its head, substantially as and for the purpose specified.

34. The combination, in an engine, of a piston-shaft projecting at each end beyond its piston, a cone-shaped head receiving and supporting one end of the shaft and attached to a shaft to be driven, another cone-shaped head receiving and supporting the opposite end of the piston-shaft, a pin on which the head is mounted, and a connection between the end of the shaft and the head, substantially as and for the purpose specified.

35. The combination, in an engine, of a piston shaft projecting at each end beyond its piston, a head receiving and supporting one end of the piston-shaft and attached to a shaft to be driven, another head receiving and supporting the opposite end of the piston-shaft, a pin on which the head is mounted, and a train of gear connecting the end of the piston-shaft with its head, substantially as and for the purpose specified.

36. The combination, in an engine, of a piston-shaft projecting at each end beyond its piston, a cone-shaped head receiving and supporting one end of the piston-shaft and attached to a shaft to be driven, another cone-shaped head receiving and supporting the opposite end of the piston-shaft, a pin on which the head is mounted, and a train of gear connecting the end of the piston-shaft with the head, substantially as and for the purposes specified.

37. The combination, in an engine, of a piston-shaft projecting at each end beyond its piston, a head receiving and supporting one end of the piston-shaft and attached to a shaft to be driven, another head receiving and supporting the opposite end of the piston-shaft, a pin on which the head is mounted, a stationary gear on the end of the piston-shaft, a stationary gear on the pin, and a movable gear mounted on the end face of the head and connecting the stationary gear, substantially as and for the purposes specified.

38. The combination, in an engine, of a piston-shaft projecting at each end beyond its piston, a cone-shaped head receiving and supporting the end of the piston-shaft and attached to a shaft to be driven, another cone-shaped head receiving and supporting the opposite end of the piston-shaft, a pin on which the head is mounted, a stationary gear on the end of the piston-shaft, a stationary gear on the pin, and a movable gear mounted on the end face of the stationary head and connecting the stationary gears, substantially as and for the purpose specified.

39. The combination, in an engine, of a steam-chest having convex side walls, a piston formed of a flange having concave side faces and a center ball, an abutment cutting the flange diagonally at one side of the center, and a piston-shaft projecting on both sides of the piston and passing through the center of the ball and supported on each side by a head, substantially as and for the purposes specified.

40. The combination, in an engine, of a steam-chest, a piston formed of a flange and a center ball, packing-rings receiving the center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, and heads, one for each part of the shaft and each receiving and supporting its part of the shaft at both the inner and outer ends, substantially as and for the purpose specified.

41. The combination, in an engine, of a steam-chest, a piston formed of a flange and a center ball, packing-rings receiving the center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, and cone-shaped heads, one for each part of the piston-shaft and receiving and supporting its part of the shaft at both the inner and outer ends, substantially as and for the purposes specified.

42. The combination, in an engine, of a steam-chest having a circular end wall and convex side walls, end casings, each having a cone-shaped chamber, a piston formed of a flange and a center ball, a piston-shaft projecting on both sides of the piston and passing through the center of the ball, and revolving heads receiving and supporting the piston-shaft at its inner and outer ends, substantially as and for the purposes specified.

43. The combination, in an engine, of a piston, a piston-shaft projecting on both sides of the piston, a support for each part of the piston-shaft, and a traveling connection for one end of the piston-shaft holding the piston-shaft against self-revolving and supporting and maintaining the piston in a straight-line travel, substantially as and for the purposes specified.

44. The combination, in an engine, of an annular steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces and a ball, with the flange at the center of the ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, and a piston-shaft projecting on each side of the piston and passing through the center of the ball transversely to the flange, substantially as and for the purposes specified.

45. The combination, in an engine, of a steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces and a ball, with the flange at the center of the ball, traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely to the flange and projecting on both sides of the piston, and revolving heads, one for each part of the piston-shaft, receiving and supporting the shaft in an inclined position, substantially as and for the purposes specified.

46. The combination, in an engine, of a steam-chest having convex contact-walls, a piston formed of a flange having concave side faces and a ball, with the flange at the center of the ball, traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely of the flange and projecting on both sides of the piston, heads, one for each part of the piston-shaft and each receiving and supporting its part of the shaft, and a center bearing for each head and around which each head revolves, substantially as and for the purposes specified.

47. The combination, in an engine, of a steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces and a ball, at the

center of which the flange is located, traversing the steam-chest on straight lines by rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely to the flange and projecting on both sides of the piston, heads, one for each part of the piston-shaft and each receiving and supporting its part of the shaft, a center bearing for each head, and a connection for one end of the shaft with its head, substantially as and for the purposes specified.

48. The combination, in an engine, of a steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces and a ball, with the flange at the center of the ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball and transversely to the flange, heads, one for each end of the piston-shaft, receiving and supporting the shaft ends, a driven shaft connected to one of the heads, and a pin on which the other head is mounted and revolves, substantially as and for the purposes specified.

49. The combination, in an engine, of a steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces and a ball, with the flange at the center of the ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball transversely of the flange and projecting at each end beyond the piston, heads, one for each end of the piston-shaft and receiving and supporting the shaft ends, a driven shaft connected with one of the heads at the center, a pin at the center of the other head on which the head is mounted, and a connection between the shaft at its end and the head, substantially as and for the purpose specified.

50. The combination, in an engine, of a steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces, and a center ball traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center ball and projecting at each end beyond the piston, a head receiving and supporting one end of the piston-shaft, and a connection between the head and the end of the shaft for maintaining the travel of the piston in straight lines across the steam-chest clear of the abutment, substantially as specified.

51. The combination, in an engine, of a steam-chest having convex contact-walls, a piston in the steam-chest formed of a flange having concave side faces and a center ball and traversing the steam-chest on straight lines and rolling against the walls of the steam-chest, an abutment cutting the flange diagonally at one side of the center of the piston, a piston-shaft passing through the center of the ball and projecting at each end beyond the piston, a head receiving and supporting one end of the piston-shaft and connected with a shaft to be driven, a head receiving and supporting the opposite end of the piston-shaft and mounted on a stationary pin, and a connection between the end of the piston-shaft and the head for maintaining the flange in a straight-line travel across the steam-chest, substantially as and for the purposes specified.

52. The combination, in an engine, of the steam-chest G, the flange H, and the ball J, forming a piston, the piston-shaft N, projecting on both sides of the piston and passing through the center of the ball J, and the heads O and P, one for each part of the piston-shaft and each receiving and supporting its part of the shaft at both the inner and outer ends, substantially as and for the purpose specified.

53. The combination, in an engine, of the steam-chest G, the flange H, and the ball J, forming a piston, the piston-shaft N, projecting at both ends beyond the piston and passing through the center of the ball, the head O, receiving and supporting one end of the piston-shaft, and the gears T, U, and V, connecting the end of the shaft N and its head O for maintaining the piston in straight-line travel, substantially as specified.

54. The combination, in an engine, of the steam-chest G, the flange H, and the ball J, forming the piston, the piston-shaft N, projecting at each end beyond the piston and passing through the center of the ball, the head receiving and supporting the piston-shaft at one end, the stationary pin S, on which the head O is mounted, the stationary gear V on the end of the piston-shaft, the stationary gear T around the pin, and the intermediate gear U, connecting the shaft and the head, substantially as and for the purposes specified.

55. The combination, in an engine, of the steam-chest G, the flange H, and the ball J, forming a piston, the piston-shaft N, projecting at each end beyond the piston and passing through the center of the ball J, the head P, receiving and supporting one end of the piston-shaft, the shaft R, connected with the head P, the head O, receiving and supporting the opposite end of the piston-shaft, and the pin S, on which the head O is mounted, substantially as and for the purposes specified.

56. The combination, in an engine, of the piston-shaft N, the head O, receiving and supporting the end of the piston-shaft, and a gear connection T, U, and V between the end of the piston-shaft N and the head O, substantially as and for the purpose specified.

57. The combination, in an engine, of the piston-shaft N, the head O, receiving and supporting the end of the piston-shaft, the pin S, on which the head is mounted, and the gear connection T, U, and V between the end of the piston-shaft and the head, substantially as and for the purposes specified.

58. The combination, in an engine, of the steam-chest G, the piston formed of the flange H and the center ball J, the diagonal abutment I, the packing-rings K, receiving the center ball J, the piston-shaft N, projecting on both sides of the piston and passing through the center of the ball, and the heads O and P, one for each part of the piston-shaft and each receiving and supporting its parts of the shaft from the piston outward, substantially as and for the purposes specified.

59. The combination, in an engine, of the steam-chest G, the piston formed of the flange H and the center ball J, the abutment I, the packing-rings K, the followers L, the piston-shaft N, projecting at each end beyond the piston and passing through the center of the ball, the heads O and P, receiving and supporting the piston-shaft, the shaft R, the pin S, and the gears T, U, and V, substantially as and for the purposes specified.

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Witnesses:
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