F. SHUMAN.

STEAM ENGINE.

APPLICATION FILED MAR. 9, 1910. RENEWED AUG. 12, 1916.

1,218,219.

Patented Mar. 6, 1917.

3 SHEETS—SHEET 1.

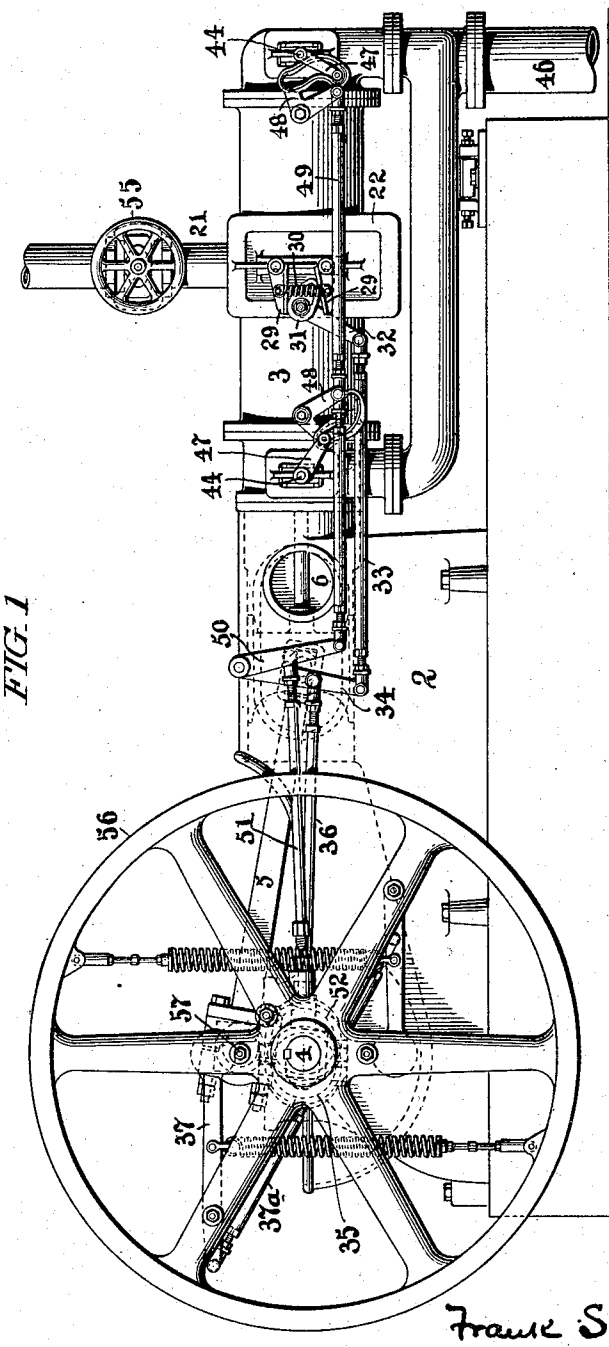

FIG. 1

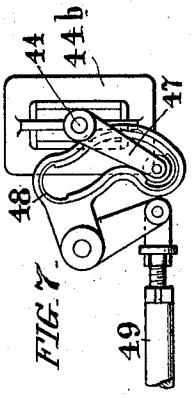

FIG. 7.

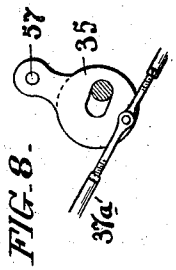

FIG. 8.

Witnesses

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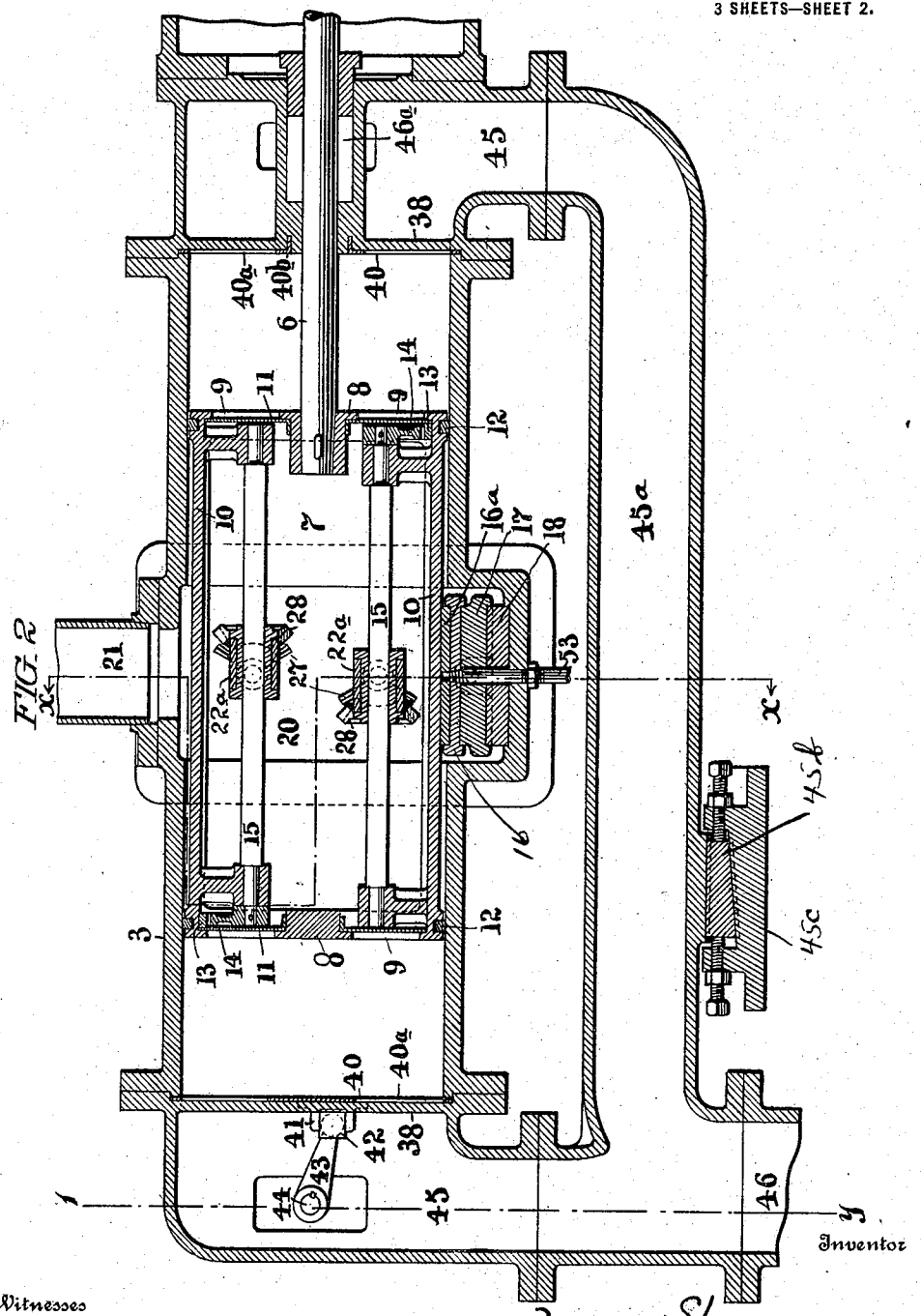
3 SHEETS—SHEET 2.

FIG. 2



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3 SHEETS—SHEET 3.

FIG. 3

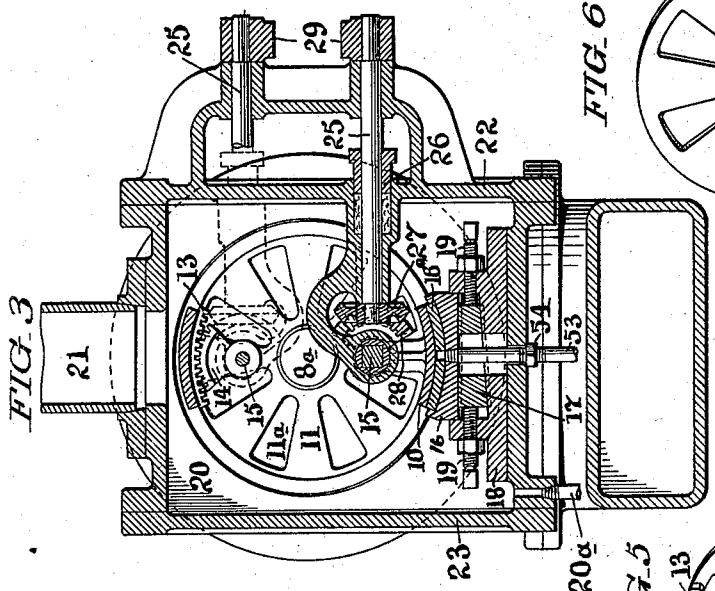


FIG. 6

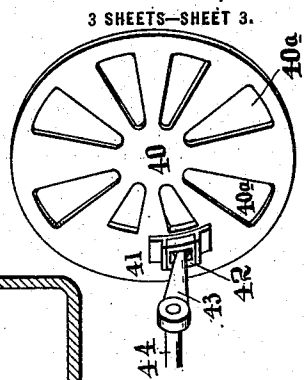


FIG. 5

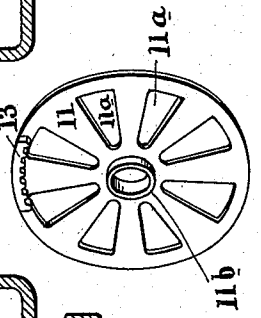
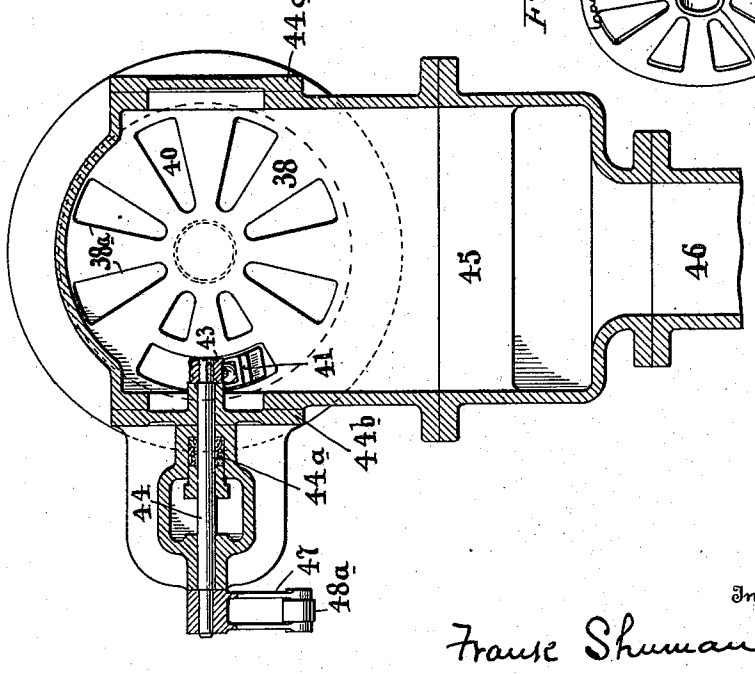


FIG. 4



Witnesses

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UNITED STATES PATENT OFFICE.

FRANK SHUMAN, OF PHILADELPHIA, PENNSYLVANIA.

STEAM-ENGINE.

1,218,219. Specification of Letters Patent. Patented Mar. 6, 1917.

Application filed March 9, 1910, Serial No. 548,154. Renewed August 12, 1916. Serial No. 114,626.

To all whom it may concern:

Be it known that I, FRANK SHUMAN, a citizen of the United States, and a resident of the city and county of Philadelphia, State of Pennsylvania, have invented an Improvement in Steam-Engines, of which the following is a specification.

My invention has reference to steam engines and consists of certain improvements which are fully set forth in the following specification and shown in the accompanying drawings which form a part thereof.

The object of my invention is to provide a construction of steam engine which shall have capacity for utilizing the kinetic energy of the steam to the highest practical degree, whereby great economy and efficiency may be secured.

My invention consists of certain improvements which are fully described hereinafter and more particularly defined in the claims. These improvements will be better understood by specific reference to the drawings, in which:

Figure 1 is a side elevation of a steam engine embodying my invention; Fig. 2 is a longitudinal sectional elevation through the cylinder of the same; Fig. 3 is a cross sectional view through the cylinder on line *x*—*x* of Fig. 2; Fig. 4 is a cross sectional elevation of the exhaust mechanism of the cylinder on line *y*—*y* of Fig. 2; Fig. 5 is a perspective view of one of the steam inlet valves; Fig. 6 is a perspective view of one of the exhaust valves; Fig. 7 is a plan view of one of the exhaust valve operating cams; and Fig. 8 is an elevation of the adjustable eccentric for operating the steam inlet valves.

2 is the housing of the engine and may be constructed in any suitable manner, being provided with the usual guides for the cross head; 3 is the cylinder and is bolted or otherwise secured to the end of the housing in any suitable manner; 4 is the crank shaft journaled in the housing and is operated by the connecting rod 5 by means of the piston rod 6 extending through a stuffing box 46ª. and secured at its inner end to the piston 7 located within the cylinder 3. The cylinder may be supported at its end most distant from the housing by adjusting wedge 45ᵇ and base 45ᶜ (Figs. 1 and 2). The general construction of these parts may be varied or modified to suit the ideas of the designer.

The steam cylinder 3 is provided at each end with a working tubular surface separated by what may be considered a steam receiver 20, the same being simply an enlarged box-shaped space centrally located with respect to the length of the cylinder and into which steam is supplied by the steam pipe 21, which may be provided with the throttle valve 55. The piston 7 is elongated and essentially composed of two steam tight heads 8, 8, connected by bars 10 which bridge the space formed by the receiver 20 and so locate the two piston heads that they are permitted to simultaneously reciprocate in the respective tubular or cylindrical parts of the cylinder. One of these heads is directly connected with the piston rod 6 and the other head transmits its power in one direction and is forcibly moved in the other direction by means of the bars 10 connecting the two piston heads. These piston heads are provided with suitable packing rings 12, and in the construction of my improved engine these packing rings may be a single ring for each piston head, as shown. The bar 10 is finished so as to act as a guide and rests upon a guide block 16 which may be provided with a replaceable wearing surface 16ª. The guide block 16 is supported in a shoe 18 resting upon the bottom of the receiver chamber 20, and is provided with an adjustable wedge 17 upon which the adjustable block 16 rests, and by which it may be adjusted vertically to support the weight of the piston, as will be readily understood by reference to Figs. 2 and 3. The adjustable wedge 17 may be adjusted by means of the adjusting screws 19 or other suitable devices accomplishing the same purpose. It is immaterial to my invention what particular means are employed for providing adjustment to the supporting block 16 for the piston. Secured to the block 16 and for delivering a lubricant to its surface in contact with the piston, I provide an oil supply pipe 53 which extends through the bottom of the casing of the receiver chamber and clamped in position by a clamping nut 54. In this manner lubricant may be

constantly supplied to the surfaces in working contact. It is evident that before adjusting the block 16 by the wedge 17 to take up wear, it will be necessary to loosen the nut 54 preliminary to said adjustment and tighten it after the adjustment has been made.

The heads 8 of the piston are provided over a large area of their surface with steam ports 9, the said ports being preferably formed by large radial openings leaving between them a structure resembling the spokes of a wheel. The outer faces of the piston heads are made flat and the inner surfaces are made flat in the form of annular bearings against which the annular valves 11 rest. These valves are preferably formed of sheet metal shaped substantially as indicated in Fig. 5, being provided with the lateral hub flange 11^b adjacent to the center and the radial apertures 11^a corresponding to the apertures 9 in the piston heads. These inlet valves 11 are journaled upon the central hubs 8^a of the piston heads 8 and rest flat against the annular surfaces of the said heads, and in operation are oscillated around their central bearings so as to bring the apertures 11^a in alinement with the apertures 9 in the heads for admitting steam, or bringing the said apertures 11^a in alinement with the radial bars of the head when it is intended to shut off the supply of steam. These valves 11 may be rocked in any suitable manner, and I have shown one means for accomplishing this purpose in a satisfactory way, said means comprising a curved rack 13 upon the valve 11, a gear segment 14 meshing with the rack and secured to a rock shaft 15 journaled within the piston and longitudinally arranged therein, said rock shaft being rocked at proper times for opening and closing the valve for controlling the admission of steam from the receiving chamber 20 into the cylinder beyond the piston, this operation being preferably under the control of suitable valve gear and automatic governor mechanism, which I will now describe.

Each of the inlet valves 11 are operated in the same manner and preferably from the same governor mechanism, but are alternately operated to correspond to the control of the steam valves in cut off engines in which the steam is employed expansively. Each of the valves is provided with its own rock shaft 15, and these rock shafts are preferably arranged one above the other within the piston. As shown, the rock shafts are square in cross section and sleeved upon them are the segmental gears 28, said gears being journaled in suitable bearings 22^a extending from one of the heads 22 of the steam chamber or receiver 20, as will be clearly understood by reference to Fig. 3. The segmental gears 28 are rocked by segmental gears 27, the latter being secured upon independent rock shafts 25 which are journaled in the aforesaid head 22 and extend through stuffing boxes 26 therein. The outer ends of these rock shafts 25 are respectively provided with arms 29 which may be drawn toward each other by a spring 30.

Journaled upon the head 22 is the cam 31, the said cam being located between the two arms 29 and when rocked by the operating arm 32 said cam alternately rocks the arms 29, and therefore, alternately operates the valves 11. This mechanism is such, that one of these valves 11 is always closed before the other valve opens, and the time of opening or closing either valve is independent of the opening of the other valve, as will be evident from the mechanism shown. The arm 32 is rocked by means of a rod 33 connected with a lever mechanism 34, the said lever mechanism being in turn rocked by means of an eccentric rod 36, the strap of which receives an adjustable eccentric 35 pivoted to the fly-wheel 56 at 57 and adjusted under the action of a governor 37 carried by the fly wheel, or any other well known construction. It will be understood that when the engine is running, the governor 37 will by rod 37^a adjust the eccentric which operates the steam valves 11, so that the time of cut off may be automatically varied to maintain a constant speed in the engine under varying loads. The particular mechanism which I have shown for accomplishing this automatic operation and adjustment of the steam inlet valves 11 may be greatly varied to suit the design of the engine to which my invention is applied, without departing from the essential characteristics of the invention. It will further be observed that the valve operating mechanism extends into the engine cylinder and forms a constant mechanical connection with the valves themselves, notwithstanding that the said valves are constantly shifting their positions to correspond to the position of the piston within the cylinder. It is evident that while the square rock shaft 15 is now employed, any other form of a sliding connection between the gears 28 and said shafts, such as the usual spline connection, may be employed in lieu thereof, this being an unimportant detail.

For convenience in securing access to the mechanism within the cylinder and piston, and especially to the mechanism within the steam receiver chamber 20, I provide a removable cover or head 23 therefor opposite to the head 22, as will be seen by reference to Fig. 3, the removal of which will at once permit access to the interior mechanism of the engine without disturbing any of the parts. The removal of this head 23 will

further permit the proper adjustments of all the interior mechanism during the setting up of the engine, and when adjusted to compensate for wear or for replacements caused by breakage. The cylinder heads 38 between the cylinders proper and the exhaust chambers 45 are made flat with radial apertures 38^a very similar to the radial apertures in the piston heads, the said construction being shown in Fig. 4. Working against the flat faces of the cylinder heads are the disk-shaped sheet metal valves 40, the said valves being guided in annular grooves between the cylinders and cylinder heads in which the perimeters of the valves are located; and the valves being flat, they rest against the flat surface of the cylinder heads. These valves 40 are likewise provided with radial apertures 40^a which have an area substantially the same as the area of the apertures 38^a in the cylinder heads, so that when the valves are rocked to bring their apertures 40^a in alinement with the apertures 38^a of the cylinder heads, there are numerous clear passages for steam constituting an aggregate area approximating about thirty per cent. of the total cross sectional area of the cylinder and extending from the inner walls of the cylinder nearly to the center. These exhaust valves may be operated in any suitable manner, one manner of operating said valves being herewith shown, and consisting of the following mechanism. The exhaust side of the valve near its perimeter is provided with a casting 41 in which is arranged an adjustable box 42 adapted to slide radially with respect to the valve. Journaled in the box 42 is a ball-shaped head of a rocker arm 43, said arm being secured to a rock shaft 44 extending through a suitable stuffing box 44^a and provided at its outer end with an operating arm 47 having at its free end a roller 48^a. The stuffing box 44^a as well as the bearings in which the rock shaft 44 is journaled are formed on a head 44^b secured to the side of the exhaust chamber (Fig. 4), whereby the parts are readily removable. Opposite to the said head 44^b may be arranged a second head 44^c which may be removed to provide access for observing the adjustment of the exhaust valve when setting up the engine or adjusting it for operation. Each of the arms 47 of the respective exhaust valve operating mechanism is rocked by means of a cam 48 which is pivoted to the engine cylinder, and so shaped as to provide the proper opening and closing of the exhaust valves during the operation of the engine. These cams are clearly shown in Figs. 1 and 7. These two cams 48 are connected by a link 49 so as to be simultaneously rocked and said rocking motion is accomplished by means of an eccentric 52 on the engine shaft 4 which operates an eccentric rod 51, the latter rocking an arm 50 which in turn is connected with the link 49 heretofore described as connecting the cams 48.

Cams 48 are arranged in right and left form so that when one exhaust valve is open, the other is closed, and vice versa. The cams are so shaped as to produce the required dwell when the valves are closed and when they are open, as will be readily understood. The valve mechanism for operating the exhaust valves shown is given by way of illustration only, and may be greatly varied to suit the ideas of the designer. It will be observed, however, that in this exhaust mechanism the exhaust valves are located within the steam cylinders and not in the chamber outside of the cylinder, as has heretofore been customary. Moreover, it will be observed that the exhaust valves being flat disks, the clearance between the piston and its valves and the exhaust ports and their valves may be reduced to a minimum, so that all available space within the cylinder between the steam inlet and exhaust valves is available for duty under the most advantageous conditions. On the cylinder head through which the piston rod 6 extends, it is evident that the exhaust valve must necessarily be provided with a central aperture through which the piston rod may pass, and because of this, I prefer to provide the central opening of the said exhaust valve with an annular flange 40^b which is received in an annular groove in the cylinder head, as shown in Fig. 2. In this way the exhaust valve is strengthened and journaled without contact with the piston rod. The exhaust chambers 45 at the ends of the cylinder are connected by a trunk 45^a, and their combined discharge is delivered into an exhaust pipe 46.

It is preferred that the interior space of the receiver 20 and piston as well as the supply pipe 21 between the boiler and the engine shall be as large as possible, so that they act as the joint receiver or reservoir from which the steam may be delivered directly through the steam valves 11 into the cylinders with the least possible wire-drawing of the steam. Furthermore, it will be evident that the construction is such that as the piston reciprocates within the cylinder it will be constantly bringing the live steam into contact with the interior surface of the cylinder and thereby raising it to the temperature of the steam immediately before the steam is admitted to the cylinder between the piston and exhaust valve and reducing the cylinder condensation to a minimum. The construction is such, that the live steam within the piston is brought alternately into contact with the tubular cylindrical inner surface of the cylinder on each side of the

receiver 20 so that the operation prepares the temperature of the inner surface of the cylinder for the proper reception of the steam with the least possible chance of condensation when performing its work by expansion, and thereby using the steam in a most efficient manner.

While I have shown my invention with an automatic governor mechanism whereby the cut-off may be automatically varied to maintain a given speed under variable loads, I do not confine myself to the use of such an automatic governor, as my invention may be employed with any of the usual constructions of valve operating means in which a fixed cut-off is employed in connection with the inlet valves. It is also evident that the valve mechanism may be modified or changed in various ways from that shown without departing from the essential characteristics of my improvements. The engine may be constructed as a horizontal or a vertical engine, and the general design may be greatly modified to suit the wishes of the designer, while employing the essential principles of my construction.

Any water of condensation which may collect within the steam chest or receiver chamber 20 may be drained off by a pipe 20^a (Fig. 3), if so desired, the said pipe being provided with a suitable control valve.

In this application I do not make claim to the specific form of the valves, as these will form subject matter of a divisional application, but have shown the said valve as being the best form in which to make them when embodied in the general construction of steam engine forming the subject matter of this application.

While I have illustrated my invention in a form which is excellently adapted for general commercial purposes, I do not restrict myself to the details, as these may be modified without departing from the spirit of the invention.

Having now described my invention what I claim as new and desire to secure by Letters Patent, is:—

1. In a steam engine, a fixed cylinder having a continually open steam inlet into it at its middle portion to fill the cylinder with live steam between the heads and exhaust chambers on each end separated from the cylinder space by heads each having a plurality of apertures in the line of movement of the piston, in combination with a piston having two steam tight heads secured together at a distance apart and between which the steam is supplied to fill the cylinder between said heads, valve devices within the piston and carried thereby for controlling the passage of steam through the piston heads into the cylinder spaces beyond them, and exhaust valves each having a plurality of apertures for controlling the passage of steam through the plurality of apertures in the cylinder heads.

2. In a steam engine, a fixed cylinder having a steam inlet opening into it at its middle portion and exhaust chambers on each end separated from the cylinder space by apertured heads in the line of movement of the piston, in combination with a piston having two steam tight heads secured together at a distance apart and between which the live steam is supplied to fill the cylinder between said heads, rotary valve devices within the piston and carried thereby for controlling the passage of steam through the piston heads into the cylinder spaces beyond them, means to operate the valves extending through the side of the cylinder, and exhaust valves for controlling the passage of steam through the apertured cylinder heads.

3. In a steam engine, a fixed cylinder having a steam inlet opening into it at its middle portion and exhaust chambers on each end separated from the cylinder space by heads each having a plurality of apertures in line with the movement of the piston, in combination with a piston having two steam tight heads secured together at a distance apart and between which the steam is supplied, valve devices within the piston and carried thereby for controlling the passage of steam through the piston heads into the cylinder spaces beyond them, and separate rotary exhaust valves in the cylinder head independent of the inlet valve devices within the piston for controlling the passage of steam through the apertures in the cylinder heads.

4. In a steam engine, a fixed cylinder having a steam inlet opening into it at its middle portion and exhaust chambers on each end separated from the cylinder space by apertured heads in the line of movement of the piston, in combination with a piston having two steam tight heads secured together at a distance apart and between which the steam is supplied, valve devices within the piston and carried thereby for controlling the passage of steam through the piston heads into the cylinder spaces beyond them, separate exhaust valves supported independently of the piston for controlling the passage of steam through the apertured cylinder heads, and automatic devices for operating the steam and exhaust valves from the crank shaft.

5. In a steam engine, a fixed cylinder having a continuously open steam inlet opening into it at its middle portion to fill the cylinder between the piston heads with steam and exhaust chambers on each end separated from the cylinder space by apertured heads in the line of movement of the piston, in combination with a piston

having two steam tight heads secured together at a distance apart and between which the steam is supplied to fill the cylinder between said heads, valve devices within the piston and carried thereby for controlling the passage of steam through the piston heads into the cylinder spaces beyond them, separate exhaust valves for controlling the passage of steam through the apertured cylinder heads, and mechanical connections extending through the cylinder and within the piston for operating and maintaining control of the steam valves in the heads thereof.

6. In a steam engine, a fixed cylinder having a continuously open steam inlet opening into it at its middle portion to fill the cylinder between the piston heads with steam and exhaust chambers on each end separated from the cylinder space by apertured heads in the line of movement of the piston, in combination with a piston having two steam tight heads secured together at a distance apart and between which the steam is supplied to fill the cylinder between said heads, valve devices within the piston and carried thereby for controlling the passage of steam through the piston heads into the cylinder spaces beyond them, separate exhaust valves for controlling the passage of steam through the apertured cylinder heads, mechanical connections extending through the cylinder and within the piston for operating and maintaining control of the steam valves in the heads thereof, and a governor device for varying the time of action of the steam valves alone to vary the point of cut-off during their reciprocation with the piston, and separate means for operating the exhaust valves.

7. In a steam engine, a fixed cylinder having a steam inlet intermediate of its ends, combined with a piston structure having widely separated heads arranged within the cylinder and respectively upon opposite sides of the inlet for the steam, valve devices arranged upon the two piston heads and seating outwardly upon internal seats for independently controlling the supply of steam from within the piston into the cylinder beyond the heads, and mechanical devices for operating the valves extending through the cylinder into the space between the two piston heads whereby the valves may be operated during the reciprocation of the piston.

8. In a steam engine, a fixed cylinder having a steam inlet intermediate of its ends, combined with a piston structure having widely separated heads arranged within the cylinder and respectively upon opposite sides of the inlet for the steam, valve devices arranged upon the two piston heads for independently controlling the supply of steam from within the piston into the cylinder beyond the heads, mechanical devices for operating the valves extending through the cylinder into the space between the two piston heads whereby the valves may be operated during the reciprocation of the piston, and a supporting guide for the piston intermediate of the piston heads for supporting the weight of the piston and removing the heavy frictional contact of the piston heads with the cylinder walls.

9. In a steam engine, a fixed cylinder having a steam inlet intermediate of its ends, combined with a piston structure having widely separated heads arranged within the cylinder and respectively upon opposite sides of the inlet for the steam, valve devices arranged upon the two piston heads for independently controlling the supply of steam from within the piston into the cylinder beyond the heads, mechanical devices for operating the valves extending through the cylinder into the space between the two piston heads whereby the valves may be operated during the reciprocation of the piston, a supporting guide for the piston intermediate of the piston heads for supporting the weight of the piston and removing the heavy frictional contact of the piston heads with the cylinder walls, a pipe opening into the guides for supplying oil thereto and adjusting devices for adjusting the guides to centralize the piston with respect to the axis of the cylinder.

10. In a steam engine, a fixed cylinder having a steam inlet intermediate of its ends, combined with a piston structure having widely separated heads arranged within the cylinder and respectively upon opposite sides of the inlet for the steam, valve devices arranged upon the two piston heads for independently controlling the supply of steam from within the piston into the cylinder beyond the heads, mechanical devices for operating the valves extending through the cylinder into the space between the two piston heads whereby the valves may be operated during the reciprocation of the piston, a supporting guide for the piston intermediate of the piston heads for supporting the weight of the piston and removing the heavy frictional contact of the piston heads with the cylinder walls, adjusting devices for adjusting the guides to centralize the piston with respect to the axis of the cylinder, and means for supplying a lubricant from the outside of the cylinder to the guide surface while the piston is in motion.

11. In a steam engine, a fixed cylinder having a central steam receiver chamber and two oppositely directed cylinder portions, combined with a piston structure having two widely separated piston heads one for

each cylinder portion and connecting means for said heads whereby they may be moved as a unit, valve devices on and moving with the piston heads for admitting steam from the steam receiver chamber through the piston heads into either of the cylinder portions beyond their respective piston heads, mechanical devices for operating the valves arranged within the receiver chamber and extending to the outside of the cylinder, and exhaust valves for the cylinder portions.

12. In a steam engine, a fixed cylinder having a central receiver portion for the steam and oppositely directed cylinder portions, a piston head of small thickness in each of the cylinder portions and said piston heads connected together so as to move as a unit whereby during the reciprocation of the piston heads the live steam is alternately brought into contact with the interior surface of the cylinders upon the surfaces of the cylinder portions adjacent to the receiver chamber to maintain a high temperature to the cylinder walls, valve devices arranged in and moving with the two piston heads to control the passage of steam from the receiver chamber through the piston heads into the cylinder portions beyond the piston heads, and valve operating devices for operating the valves extending from the receiver chamber to the outside of the cylinder and mechanically operated for moving the valves.

13. In a steam engine, a cylinder having a central receiver portion for the steam and oppositely directed cylinder portions, a piston head of small thickness in each of the cylinder portions and said piston heads connected together so as to move as a unit whereby during the reciprocation of the piston heads the live steam is alternately brought into contact with the interior surface of the cylinders upon the surfaces of the cylinder portions adjacent to the receiver chamber to maintain a high temperature to the cylinder walls, valve devices arranged in and moving with the two piston heads to control the passage of steam from the receiver chamber through the piston heads into the cylinder portions beyond the piston heads, valve operating devices for operating the valves extending from the receiver chamber to the outside of the cylinder and mechanically operated for moving the valves, and flat rotary valves of approximately the diameter of the cylinder at each end of the two cylinder portions for controlling the escape of the exhaust steam and reducing the amount of clearance between the piston heads and exhaust ports.

14. In a steam engine, the combination of a cylinder structure having a central steam receiver chamber and two oppositely directed cylinder portions, piston heads for each of the cylinder portions connected by an open frame work so as to permit live steam to fill the space between the piston heads at all times during their travel, rotary valves in each of the piston heads for permitting the flow of steam directly from the space between the piston heads through the piston heads into the cylinder spaces beyond the said piston heads, and exhaust valves of approximately the diameter of the cylinder portions arranged on the cylinder heads whereby the exhaust steam from the cylinders may freely escape, the construction being such that during the operation of the engine the steam from the steam receiving chamber passes into the cylinder space and from the cylinder space into the exhaust chamber beyond the exhaust valve in approximately straight directions and with the least possible resistance.

15. In a steam engine, the combination of a cylinder structure having a central steam receiver chamber and two oppositely directed cylinder portions, piston heads for each of the cylinder portions connected by an open frame work so as to permit live steam to fill the space between the piston heads at all times during their travel, rotary valves in each of the piston heads for permitting the flow of steam directly from the space between the piston heads through the piston heads into the cylinder spaces beyond the said piston heads, exhaust valves of approximately the diameter of the cylinder portions arranged on the cylinder heads whereby the exhaust steam from the cylinders may freely escape, the construction being such that during the operation of the engine the steam from the steam receiver chamber passes into the cylinder space and from the cylinder space into the exhaust chamber beyond the exhaust valve in approximately straight directions and with the least possible resistance, and means for operating the various valves, and an automatic governor for controlling the time of cut-off of the rotary valves in the piston devices.

16. In a steam engine a cylinder and piston therefor arranged to traverse approximately the entire cylinder space, combined with induction valves carried by the piston, and exhaust valves carried by the ends of the cylinder in direct line with the movement of the piston, the construction of the said valves being such that they form the inner faces of the ends of the cylinder and the operating faces of the piston, whereby the total amount of clearance space between the induction valves and exhaust valves is wholly within the cylinder proper.

17. A steam engine comprising in combination a cylinder and piston, induction and exhaust valves located wholly within and

traversely of the cylinder, means for separately operating the valves from without the cylinder, and automatic governor control means exterior to the cylinder for controlling the induction valves to regulate the operation of the engine.

18. In a steam engine, the combination of a cylinder, with a reciprocating piston having a steam chamber within the same, means for supplying steam to the steam chamber, valves in the ends of the piston and of a diameter approximately equal to the diameter of the piston whereby when said valves are open, the steam will rush into the cylinder in a direction parallel to but opposite to the motion of the piston to create a reactionary force, and means for automatically operating the valves in the piston at the proper times.

In testimony of which invention, I hereunto set my hand.

FRANK SHUMAN.

Witnesses:
S. A. BLEND,
A. G. MORRALL.