(No Model.)

3 Sheets—Sheet 1.

S. T. RICHARDSON.

STEAM ENGINE.

No. 456,848. Patented July 28, 1891.

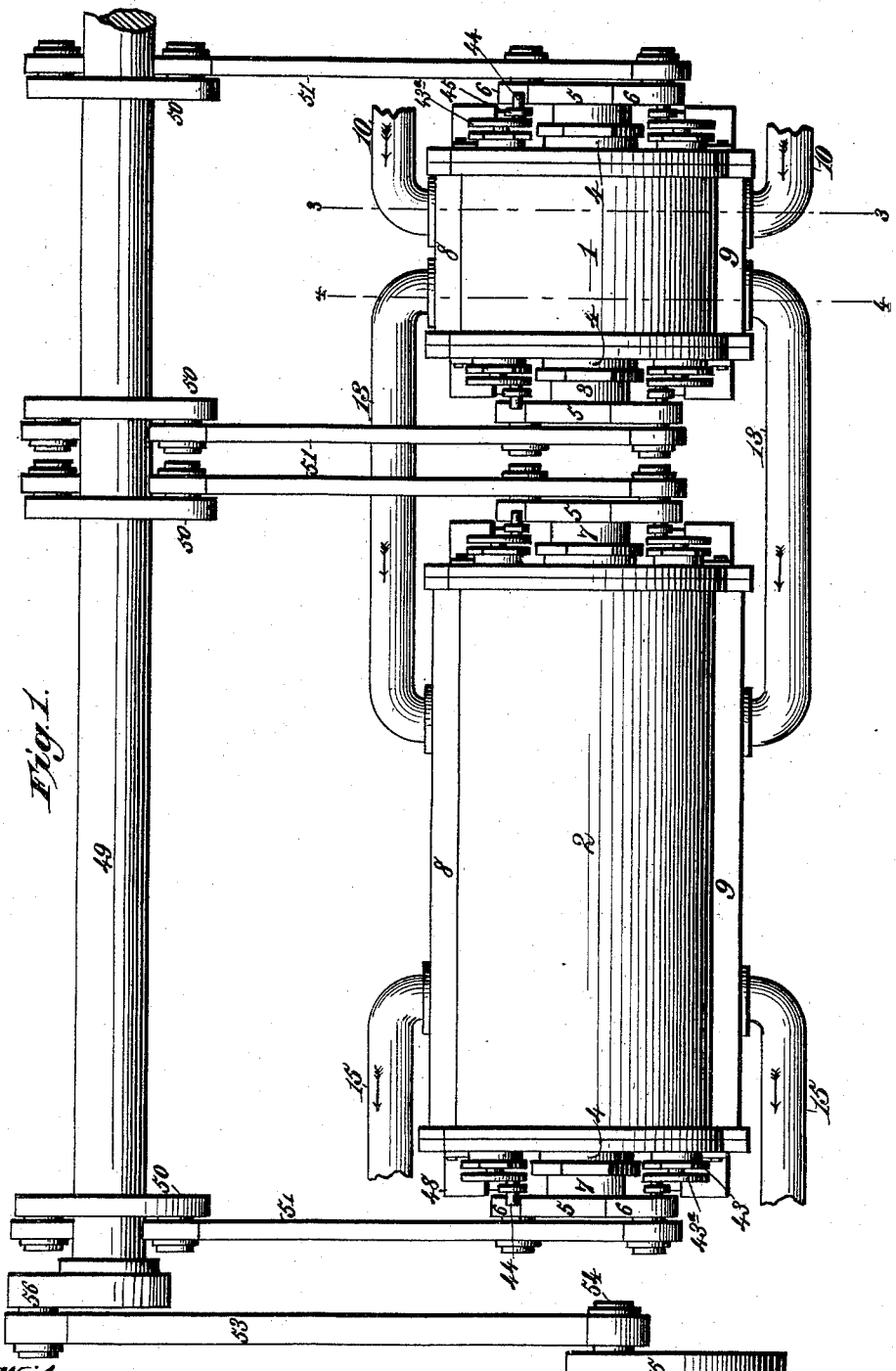


Fig. 1.

Witnesses.
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Inventor.
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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

(No Model.) 3 Sheets—Sheet 2.

S. T. RICHARDSON.

STEAM ENGINE.

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Fig. 2.

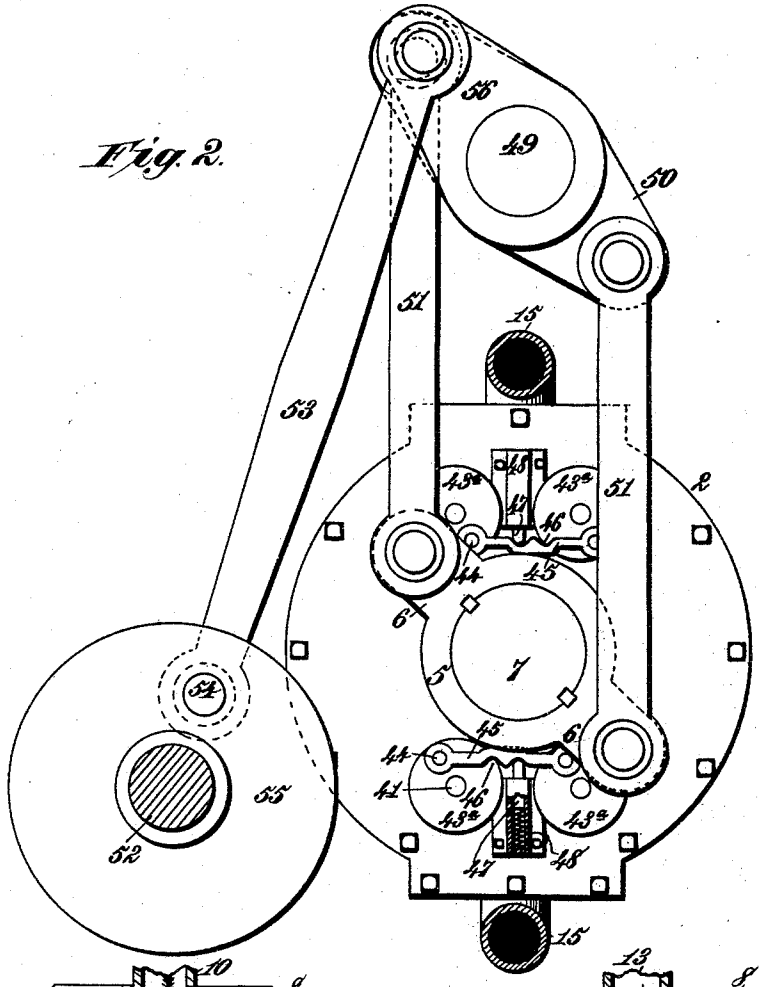


Fig. 3.

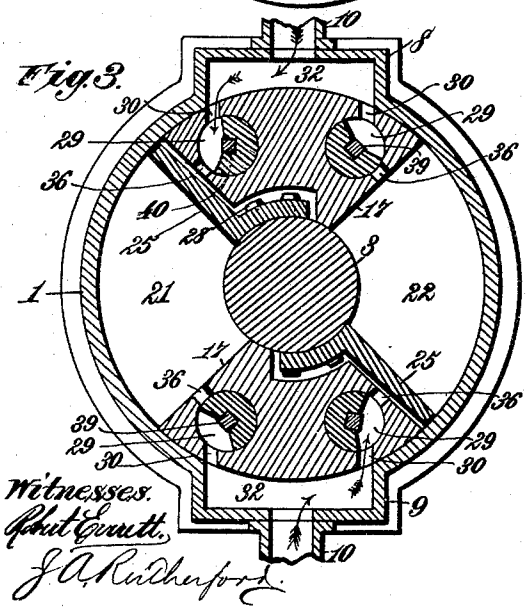
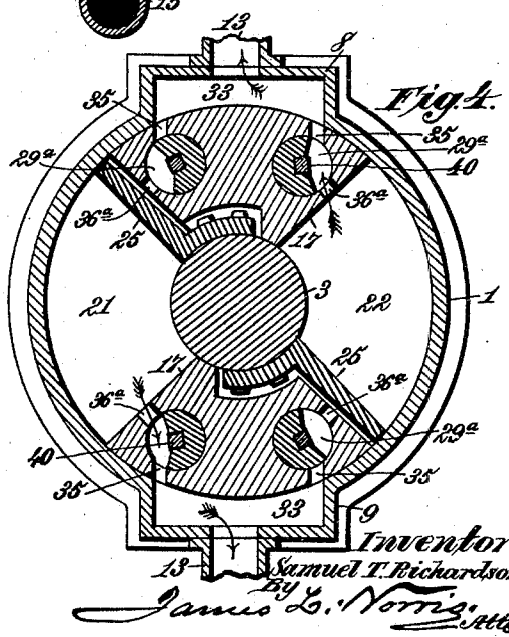


Fig. 4.



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(No Model.) 3 Sheets—Sheet 3.

S. T. RICHARDSON.

STEAM ENGINE.

No. 456,848. Patented July 28, 1891.

Fig. 5.

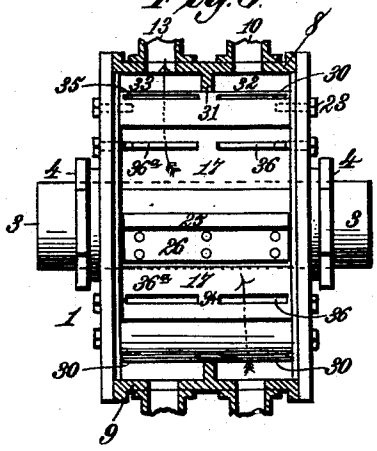


Fig. 6.

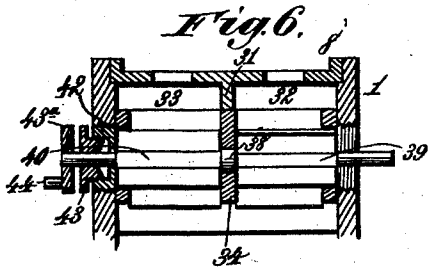


Fig. 7.

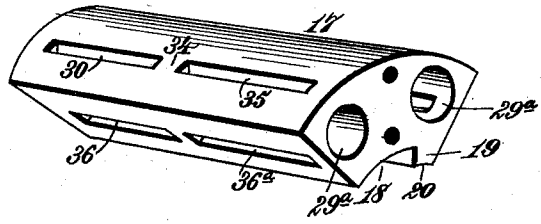


Fig. 8.



Fig. 9.

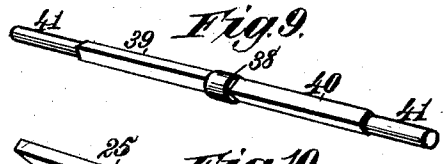
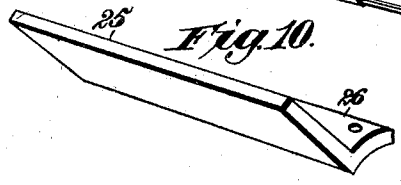


Fig. 10.



Witnesses.
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UNITED STATES PATENT OFFICE.

SAMUEL T. RICHARDSON, OF BALTIMORE, MARYLAND, ASSIGNOR TO THE RICHARDSON ENGINE AND STEAMSHIP COMPANY, OF SAME PLACE.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 456,848, dated July 28, 1891.

Application filed December 18, 1890. Serial No. 375,134. (No model.)

To all whom it may concern:

Be it known that I, SAMUEL T. RICHARDSON, a citizen of the United States, residing at Baltimore, State of Maryland, have invented new and useful Improvements in Steam-Engines, of which the following is a specification.

My invention relates to that class of steam-engines in which vibrating wings or pistons are mounted upon an oscillating shaft extending through the cylinder and having its axis concentric therewith.

It is the purpose of my invention to provide a steam-engine of this type in which the piston-rod is replaced by a shaft which is extended throughout the cylinder and provided with wings or plates which practically form the pistons, and to combine with the working-chambers, in which the pistons vibrate, means whereby the live steam shall be admitted thereto from independent ports and caused to expand and push against the alternately-opposite faces of the wings or pistons to move them to a point where the expanded steam will be discharged and fresh steam admitted from other independent ports to force the pistons back to their original position, thereby causing an oscillation of the shaft, upon which they are oppositely mounted. It is my object, in other words, to provide a steam-engine having an oscillating shaft concentric with the cylinder, which shall move easily and without the jarring and heavy strain which is incurred in direct-acting engines, whereby an equal pressure of live steam shall be exerted upon the opposite pistons, and whereby, also, a considerable increase in the horse-power developed may be obtained without a corresponding increase in the space required for the accommodation of the steam mechanism and without increasing the steam-pressure.

It is my further purpose to provide a steam-engine having a shaft extending through and concentric with the cylinder and provided with opposite wings, constituting pistons, which vibrate in opposite sector-shaped chambers, and to combine therewith means whereby live steam shall be admitted to both of said chambers at the same moment, or substantially so, in such manner that it shall push against the alternately-opposite faces of the opposite pistons with like force, each piston having its own independent live-steam and exhaust ports.

It is my purpose, also, to combine with a high-pressure cylinder a shaft extending centrally through the center of the cylinder and provided with opposite wings or pistons rigidly mounted on the shaft and vibrating under steam-pressure in sector-shaped chambers, to which live steam is admitted in opposite directions to push against the alternately-opposite faces of the opposite pistons with an equal or balanced pressure on each and a second low-pressure cylinder having a similar central shaft independent of the shaft of the high-pressure cylinder, but vibrated by similar devices, the low-pressure cylinder being so arranged as to receive the exhaust-steam from the high-pressure cylinder and the independent vibrating shafts of both cylinders being connected to the same counter-shaft by pitmen.

It is my purpose, also, to provide a steam-engine having an oscillating shaft substituted for the piston-rod and extended through the cylinder from end to end, said shaft being provided with opposite wings, constituting the pistons, and arranged to vibrate in sector-shaped chambers formed by oppositely-arranged metallic filling-pieces or sector-blocks having live-steam and exhaust ports in each and containing valve-chambers communicating with the steam-chest, and to combine therewith simple and novel means for giving movement to the valves, whereby each piston shall have its own live-steam and exhaust ports, the live steam being supplied by independent ports to the alternately-opposite faces of the pistons at the same time and with a balanced pressure.

It is my purpose, finally, to simplify and improve the construction of steam-engines of this class; to decrease materially the weight of the metal forming the pistons as compared with those of direct-acting engines to diminish the *vis inertiæ* which must be overcome by the steam before power can be obtained; to increase the ease and smoothness with which the engine is operated and to avoid the jar and strain ordinarily caused by the sudden reverse movement of the heavy piston-heads used in direct-acting engines; to pro-

vide a novel construction of the valves opening and closing the steam-ports and to combine therewith simple and novel means for effecting the valve movement; to combine together a high-pressure and a low-pressure cylinder arranged in the same axial line, each having an independent shaft extending centrally through its cylinder and oscillated by opposite wings constituting the pistons, said shafts having vibrating cross-heads connected by parallel links to cross-heads on a counter-shaft, while the counter-shaft has a crank-arm connected to a wrist-pin on the power-shaft by a pitman, and to provide an engine of the type specified with an arrangement of steam-ports whereby the travel of the live steam and exhaust-steam shall be diminished to such a degree that the expansive power shall be materially increased, while condensation is avoided in a corresponding degree.

To these ends my invention consists in the several novel features of construction hereinafter fully set forth, and then more particularly pointed out and defined in the claims following this specification.

To enable others skilled in the art to which the said invention pertains to make, construct, and use the same, I will proceed to describe said invention in detail, reference being had to the accompanying drawings, in which—

Figure 1 is a side elevation of an engine embodying my invention with its several connections, showing the intermediate or counter-shaft and a portion of the power-shaft. Fig. 2 is an end elevation of the engine, the view being taken from the low-pressure end of the engine in Fig. 1. Fig. 3 is a transverse or vertical section of the high-pressure cylinder in Fig. 1, the section plane being upon the line 3 3 in said figure. Fig. 4 is a similar section upon the line 4 4, Fig. 1. Fig. 5 is a sectional elevation of the high-pressure cylinder, the casing and a portion of the steam-pipes being in vertical section and the interior parts in elevation. Fig. 6 is a longitudinal section of the high-pressure cylinder, the section plane being in the line 6 6, Fig. 4. Fig. 7 is a detail perspective of one of the sector-blocks containing the valve-chambers and steam-ports. Fig. 8 is a detail perspective of one of the duplex valves. Fig. 9 is a similar view of the valve-stem with the duplex valves removed. Fig. 10 is a detail perspective of one of the wings or pistons removed from the oscillatory shaft.

In the several figures of the drawings the supporting frame-work of the engine and its several connections have been wholly omitted, in order to render the illustration more easily understood and to avoid the confusion which would be caused, in some degree, by the union of the operative parts with their supports.

The frame of the engine may be of any known or preferred construction and forms no part of my present invention.

In the said drawings, the reference-numeral 1 indicates the engine-cylinder, which, if the engine is of the compound type, will be the high-pressure cylinder.

While I have shown the invention embodied in a compound engine in the drawings of this application, in which the numeral 2 denotes the low-pressure cylinder, it should be clearly understood that said invention is not limited to this or to any specific type of engine, as it may be applied to steam or other engines of any class. It should be remembered, also, that the steam mechanism of the low-pressure cylinder in the compound engine shown is precisely identical with that of the high-pressure cylinder, the parts being duplicates one of another. For this reason, also, I have illustrated the construction of the parts inclosed by the cylinder 1, only the cylinder 2, containing the mere duplicates of said parts, differing therefrom in area alone. The cylinders 1 and 2 are preferably arranged in such manner that their axes are coincident with one and the same straight line, and in the cylinder 1 is placed a central shaft 3, extending through the interior of the cylinder and having its ends projecting through glands 4 in the opposite heads of said cylinders. Upon each outwardly-projecting end of the shaft 3 is mounted a duplex crank, consisting, usually, of a ring 5, keyed or otherwise fastened upon the shaft and having oppositely-projecting arms 6, the construction being identical with that shown in Fig. 2. The cylinder 2 of the compound engine is provided with a similar but independent shaft 7, having upon its projecting ends duplex cranks of the form already described, the function of which will be shown hereinafter. Each cylinder is provided with duplex or divided steam-chests 8 and 9, coextensive with the length of the cylinder upon which they are formed or mounted, and having a diametrically-opposite arrangement one with the other, as seen in Figs. 1 to 4, inclusive. A pipe 10 for the live steam enters the chest 8 of the high-pressure cylinder at or near its end, and a second or similar pipe 10 enters the opposite steam-chest 9 at a corresponding point. From a point at or near the other end of each steam-chest 8 and 9 of the cylinder 1 pipes 13 extend to the steam-chest of the low-pressure cylinder to convey the steam from the cylinder 1 after its first expansion therein to the low-pressure cylinder 2, where it undergoes a second expansion and is exhausted through pipes 15.

Within the cylinders 1 and 2 are arranged sector-blocks 17. (Shown in detail in Fig. 7.) These sector-blocks have convex outer faces, which coincide with the interior circular face of the cylinder, while their inner or opposite faces are partly removed to form recesses 18, extending longitudinally the whole length of the block. The portion 19, which remains after the formation of the recess 18, is provided with a concave face 20, concentric with

the outer face of the block, which is of such thickness that the concave face will rest upon the shaft 3 and form a close joint. The breadth of the outer or convex face of the block is such that when arranged within the cylinder directly beneath the steam-chest 8, or above the steam-chest 9, a marginal longitudinal portion of the convex face will have contact with the circular interior of the cylinder upon opposite sides of the steam-chest, as shown in Figs. 3 and 4. Two of these sector-blocks are arranged in each cylinder diametrically opposite each other and covering the open steam-chests, their longitudinal marginal portions forming close joints with the circular inner face of the cylinder on each side of the steam-chest. It will be seen that by this opposite arrangement of these sector-blocks the interior of the cylinder is divided into two opposite working-chambers 21 and 22 of substantially the same shape in cross-section as the sector-blocks 17. The parts last named are supported and fastened by means of bolts 23. The construction and arrangement of these sector-blocks are such that the longitudinal recesses 18, by which a portion of the concave or inner face of each block is removed, have their open sides turned in opposite directions, as shown in Figs. 3 and 4.

The reference-numeral 25 denotes the wing or plates which constitute the pistons of each cylinder. These pistons, which are usually formed of a single piece of metal, as shown in detail in Fig. 10, each consist, essentially, of two members or parts, one being a flat, oblong, and rectangular plate of suitable thickness and having a length and width equal, respectively, to the interior length of the cylinder and the radial distance between the surface of the shaft 3 to the inner surface of the cylinder. Upon its inner edge is formed a foot-plate 26, curved in such manner that its inner face shall be concentric with the shaft 3 and provided with openings to receive bolts 28, by which it is fastened in place. The angle between this curved plate and the flat plate or wing 25 is such that when the former is placed upon the shaft 3 a diametrical line drawn through the cylinder shall substantially coincide with a line drawn centrally from the inner to the outer edge of the plate or wing. The piston-plates are mounted on the shaft diametrically opposite one to the other, their fastening-plates 26 lying in the recesses 18 in the sector-blocks made to receive them, whereby the alternately-opposite faces of the pistons are enabled to closely approach the flat faces of the sector-blocks, which lie in planes substantially parallel with the adjacent faces of the pistons when the latter are in the position shown in Figs. 3 and 4.

In the sector-block 17 upon each side of the diametrical line of the cylinder are formed circular valve-chambers 29, extending longitudinally from the end of the sector-blocks to a central septum, hereinafter described. Communicating with these valve-chambers are two similar live-steam ports 30, both formed in the same half of the sector-block and having connection with the steam-chest 8, which is divided by a central partition 31, lying between the live-steam inlet and the outlet for the low-pressure steam into two equal steam-chambers 32 and 33, the former having communication with the live-steam pipe 10 only, while the latter is in connection with the pipe 13. The live-steam ports 30, which enter the valve-chambers 29, are each separated by a central septum or wall 34 in the center of the sector-block 17 from ports 35, formed in the other end of the sector-block and communicating with the steam-chamber 33 in the chest 8, said chamber being upon the opposite side of the partition 31, the edge of which makes a close fit and forms a tight joint with the outer or convex surface of the sector-block between the ports 30 and the ports 35.

The live-steam ports 30 and valve-chamber 29 communicate with the working-chambers 21 and 22 by steam-ports 36, preferably formed at a right angle with the flat faces of the sector-blocks, as shown in Fig. 3.

Upon the other side of the central septum or wall 34 are ports 36^a, communicating with the working-chambers 21 and 22 and having connection also with valve-chambers 29^a, having their axes coincident with the axes of the valve-chambers 29. The ports 35, which enter the valve-chambers 29^a, have communication with the steam-chamber 33 in the divided steam-chest.

In each of the valve-chambers 29, and extending through each valve-chamber 29^a, is a duplex-valve stem, which passes through an opening in the septum or wall 34, the stem being provided with a central circular enlargement 38, which closely fits the opening in the septum 34.

Upon each side of the central enlargement 38 of the valve-stem is an angular portion. (Shown in the drawings, Figs. 3, 4, 8, and 9, as of rectangular form in cross-section.) The angles of one portion 39 do not, however, coincide with the similar angles of the other portion 40, as shown in Fig. 9, the two angular portions having such relative arrangement that the angles of one alternate with those of the other.

When the valve-stem is introduced within the valve-chambers 29 and 29^a in both sector-blocks 17, with its central enlargement 38 closely fitting the opening in the septum 34, the valves are placed in the following manner: Each stem carries two separate rotary valves having substantially similar form, each being composed of a metallic body having in cross-section a shape resembling a crescent, the exterior surface of each valve closely fitting the inner surface of the valve-chamber in which it is inserted, a central opening or longitudinal channel being formed in the inner or concave face for the reception of the angular portion of the stem. Each valve,

also, is of the same length as the valve-chamber in which it lies, so that its one end abuts against the central enlargement 38 of the stem and the central septum 34, while its other end is flush with the end of the sector-block. The stem is supported by journals 41, projecting beyond the outer ends of the angular portions 39 and 40, these journals having bearings in bushings 42, set in the ends or heads of the cylinder and packed therein by a suitable packing-nut 43. The journals project beyond the outer faces of the packing-nut and receive disks 43ª of similar size, each disk being provided with a wrist 44, for a purpose hereinafter described.

By reference to Fig. 3 or Fig. 4 it will be seen that the live-steam ports 30 and 36 are so arranged with relation to each other, and that the inner faces of the rotary valves lying in the valve-chambers 29 are so concaved that both ports 30 and 36 may be thrown open and a continuous channel or passage formed for the live-steam chamber 32 in the steam-chest 8 to the working-chamber 21, where it expands between the piston 25 and the adjacent flat face of the sector-block 17, through which the port 36 is cut. At the same time the other duplicate portion of the valve lying beyond the other side of the central enlargement 38 closes the port 35, which opens into the low-pressure steam-chamber 33 of the chest 8.

The construction of the valves, valve-chambers, and steam-ports in the opposite or lower sector-block 17 is the same as that described, and these ports have communication with the two chambers in the lower chest 9 in the same manner already set forth in connection with the devices in the upper sector-block. There is this difference, however, between the two—viz., that the live-steam ports open upon alternately or diagonally opposite faces of the two sector-blocks, in order that the steam may be thrown and caused to push against the alternately-opposite faces of the pistons 25, as shown by the position of the valve described above, and the alternately-opposite live-steam valve open below and admitting live steam to push against the face of the piston 25, Fig. 3, thereby balancing the pressure upon both sides of the shaft 3. The means by which this movement of the independent valve is automatically produced will be described hereinafter, it being sufficient to state at this point that the four valves and ports delivering live steam to the working-chambers 21 and 22 have such arrangement that when one of the upper valves is opened the lower valve on the same side of the shaft is closed, while the lower valve on the other side of said shaft is opened simultaneously while the other upper valve is closed.

I will now show how the steam which has already expanded in the working-chambers 21 and 22 and brought the pistons 25 into the position shown in Fig. 3 finds an exit from said chambers, and is either exhausted or passes to the low-pressure cylinder.

Referring to Fig. 3 it will be remembered that one of the parts of the duplex valve is set upon its portion 39 of the stem in such manner that it will act upon the ports entering its duplex-valve chamber at different times as compared with the other part of the duplex valve. For example, if the two-part valve shown in Fig. 8 is inserted in the valve-chambers 29 and 29ª lying above the recess 18, as shown in Figs. 3 and 4, and if the valve-stem be turned to open the live-steam ports 30 and 36, the other part of the valve in the chamber 29 will still cover the port 35, as shown in Fig. 4, thereby preventing the escape of live steam to the chamber 33 and thence to the low-pressure cylinder. In order, however, to allow the expanded steam which has already done its work to pass out of the working-chambers 21 and 22, the alternately or diagonally opposite valves in the lower left-hand valve-chamber 29ª and the upper right-hand chamber 29ª in Fig. 4 are both opened, while the valves carried by the same stems, but lying in the valve-chambers 29 on the other side of the central septa 34, are both closed, as shown in Fig. 3. It will be seen from the above description that each piston has its own inlets and exits for the live steam and expanded steam, respectively, and that these are arranged upon the same side or face of the piston when acting successively and upon opposite sides or faces thereof when acting at the same time.

The disks 43ª upon the projecting journals of the valve-stems are connected by link-bars 45, Fig. 2, whereby both valve-stems lying in the duplex-valve chambers in the same sector-block shall be compelled to rotate or oscillate in the same direction simultaneously. In the link-bar 45, upon each side of its middle part is formed a notch 46, with one or the other of which the end of a spring-latch 47 engages as the link-bar reaches its opposite limits of movement. The spring operating said latch is arranged within a housing 48, mounted on the end of the casing.

The valve movement is produced by the oscillation of the arms 6 of the duplex cranks keyed upon the ends of the shaft 3. The ends of the wrists 44 project somewhat beyond the outer surface of the link-bars 45, and at each oscillation of the duplex crank the upper edge of one of said crank-arms 6 strikes one of the said projecting wrists and forces it to move horizontally, the spring-latch 47 being disengaged by the movement of the link-bar at right angles to its own line of movement and by the rounded form of its engaging head, which enables it to lift with ease from the notches 46, the function of these parts being not to lock the valves positively in either position, but to provide means by which accidental displacement may be prevented. At the same moment that the upper

edge of either crank-arm makes contact with the projecting end of one of the wrists 44 on either disk 43 the lower edge of the opposite crank-arm 6 is brought against the similar wrist projecting from the face of the alternately-opposite disk, Fig. 2, or mounted upon one of the valve-stems in the lower sector-block, and thus the two upper duplex valves are oscillated in one direction, thereby bringing the valves which control the entrance of live steam into the position shown in Fig. 3, and at the same time moving the valves by which the steam has exit to the position shown in Fig. 4; or, in other words, opening the live-steam ports of the upper left-hand valve-chamber in Fig. 3 and closing the similar ports of the valve-chamber horizontally opposite and effecting an alternately-opposite position of the live-steam valves in the valve-chambers in the lower sector-block.

Arranged above the engine and having support in any suitable bearings is an intermediate or counter shaft 49, of any suitable length, its axis being in the same vertical plane as the axis of the shaft 3 of the high-pressure cylinder and that of the independent shaft of the low-pressure cylinder. At suitable points upon this counter-shaft are rigidly mounted duplex cranks 50—duplicates in all essential respects—of the similar devices upon the ends of the oscillating shafts, to which they are pivotally connected by parallel link-bars 51. I prefer to mount the duplex cranks upon both ends of each independent cylinder-shaft and connect the same to duplex cranks on the counter-shaft, in order to balance the frictional resistance to obtain a perfect equilibrium of pressure and produce a smoother and easier action of the engine; but I do not confine my invention to such an arrangement.

Power is communicated to the working shaft or power-shaft 52 by a pitman 53, connected at one end to a wrist 54, carried by a disk 55, rigid on the power-shaft, and at its other end to a crank-arm 56 on the power-shaft.

My invention is applicable to any engine operated by steam, gas, hot or compressed air, or other expanding medium. In all large reciprocating or direct-acting engines of these several species the weight of the piston-head, which reciprocates within the cylinder, is very considerable in proportion to the area of the cylinder. For example, in a cylinder of sixty inches diameter, having an area of two thousand eight hundred and twenty-seven square inches and forty-four hundredths of an inch, the weight of the piston-head is ordinarily about three thousand one hundred and thirty-nine pounds, independent of the weight of the piston-rod. If the stroke is two feet in length and the number of revolutions one hundred per minute, it will be perceived that the piston travels four hundred feet per minute and that the direction of movement of this heavy mass of metal is changed diametrically two hundred times. The enormous strain thus exerted upon the parts by these forces is readily apparent, and the jarring of the mechanism, caused by this constant and rapidly repeated change of movement of this great weight, is a great damage, in continued use, to the mechanism itself and to the structure or fabric containing it. Moreover, when a direct-acting engine has a vertical stroke the descent of the piston will be assisted by gravity and its reverse movement will be resisted by the same force, thus increasing the injurious effects referred to. My invention avoids these objections by reason of the fact that said invention provides a balanced piston oscillating upon an axis, which is in substantially perfect equilibrium at all times and in all positions in which it can be placed. As this balanced piston takes steam in opposite directions upon the alternately-opposite faces of the wings constituting said piston, and takes said steam at the same moment on both of said faces and from the same steam-generator, the pressure or push of the steam is also balanced upon each side of the axis of oscillation, thereby rendering the movement of the parts far smoother and easier, avoiding in a great measure, if not entirely, the jar of the mechanism and increasing the possible horse-power developed. It should be noted, also, that by my invention the live steam from each steam-chest has the minimum distance to travel in order to reach the working-chambers. In fact, it may be said that practically it has no travel, because the opening of the valve exposes the steam-faces of the vibrating wings, against which the live steam expands without any material travel. Moreover, after its first expansion it exhausts in the same direct manner through an exit-port lying in the same plane with the live-steam port and opening through the same face. It is due to these facts that there is but an extremely small loss of expansive force, and that a largely-increased power is developed in the low-pressure cylinder as compared with other engines of the same type. By attaching the wings 25 directly to the piston-rod 3, in contradistinction to mounting them upon a piston-cylinder surrounding the shaft, a much greater steam-face is given and a corresponding power is gained without any increase in the diameter of the cylinder. In marine engines, where the available space is limited, this advantage is of the highest importance. It will be seen, also, that in my invention the steam is thrown simultaneously against the alternately-opposite faces of the opposite wings and acts successively upon both faces thereof, thereby balancing the power upon the opposite sides of the shaft, the cylinder being provided with steam-chests upon opposite sides for this purpose. Finally by my construction I am able to turn out the steam-face of the cylinder and thereby secure a good steam fit.

What I claim is—

1. In a steam or other engine, the combination, with a cylinder having two working-chambers arranged upon opposite sides of the longitudinal axis, of an oscillating shaft having its axis coincident with that of the cylinder and independent duplex or two-part valves to open and close the separate inlets for live steam pushing against wings or pistons oppositely mounted on the shaft and to open and close the exit-ports for the steam, substantially as described.

2. In a steam or other engine, the combination, with a cylinder having a central longitudinal shaft provided with opposite wings which constitute pistons adapted to vibrate in working-chambers upon opposite sides of the shaft, of independent oscillating valves controlling the admission of live steam to the working-chambers, and similar but differently-timed valves carried by the same stems and controlling the exit of the expanded steam, substantially as described.

3. In a steam or other engine, the combination, with a cylinder having sector-shaped working-chambers upon opposite sides of the axis of the cylinder, of a central shaft having its ends packed through the ends or heads of the cylinder and provided with opposite wings constituting pistons, oscillating valves controlling the live steam from steam-chambers in oppositely-arranged and centrally-divided steam-chests on the cylinder, and differently-timed oscillating valves on the same stems governing the outlet-ports on the same side of each piston, substantially as described.

4. In a steam or other engine, the combination, with a cylinder having opposite steam-chests centrally and transversely divided, of sector-blocks having convex faces closing the communication of the steam-chests with the cylinder, but provided with duplex-valve chambers separated by a central septum, a duplex or two-part valve mounted on a single stem lying in both valve-chambers, and a central shaft having opposite wings which constitute pistons, each sector-block being provided with live-steam ports and exit-ports having connection with the duplex-valve chambers and through the latter with working-chambers on opposite sides of the shaft, whereby a simultaneous push is communicated to both pistons in opposite directions, substantially as described.

5. In a steam or other engine, the combination, with a cylinder having a central shaft provided with opposite radial wings which constitute pistons adapted to vibrate in working-chambers on opposite sides of the central shaft, of duplex-valve chambers formed in the sector-blocks separating the working-chambers and each having an inlet and an exit port for the live steam and expanded steam, respectively, said ports being separated by a central septum, the live-steam ports communicating with steam-chambers in opposite and divided steam-chests and the exit-ports having communication with outlet-chambers in said steam-chests, duplex or two-part valves lying in said valve-chambers having their parts differently timed but oscillated by the same stems, the valve-stems in each sector-block being connected by a link, and duplex cranks mounted on the ends of the central oscillating shaft and moving the link connections of the upper and lower valves in opposite directions simultaneously at each vibration of the crank-arms, substantially as described.

6. In a steam or other engine, the combination, with a central shaft having wings vibrating in opposite working-chambers, of independent inlet and outlet ports adjacent to each face of each piston, and duplex or two-part valves opening and closing said ports, whereby the steam introduced through an inlet-port finds exit through a port adjacent to the same face of the piston, substantially as described.

7. In a steam or other engine, the combination, with a cylinder, of a central oscillatory shaft having opposite wings or plates directly mounted thereon and vibrating in the opposite sector-shaped chambers, and live-steam and exhaust valves mounted on a single stem and alternately delivering steam to and exhausting it from the face of each wing, substantially as described.

8. In a steam or other engine, the combination, with a cylinder having opposite working-chambers separated by sector-shaped blocks, of a central oscillatory shaft upon which said blocks have bearing, said shaft being provided with opposite wings or plates, and a live-steam and exhaust valve rigidly mounted on a single stem and arranged in valve-chambers in each sector-block between the steam-chest and the working-chamber, substantially as described.

In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

SAMUEL T. RICHARDSON.

Witnesses:
JAMES L. NORRIS,
A. H. NORRIS.