(No Model.) 5 Sheets—Sheet 1.

J. DOW.

HIGH SPEED ENGINE.

No. 521,706. Patented June 19, 1894.

Fig. 1.

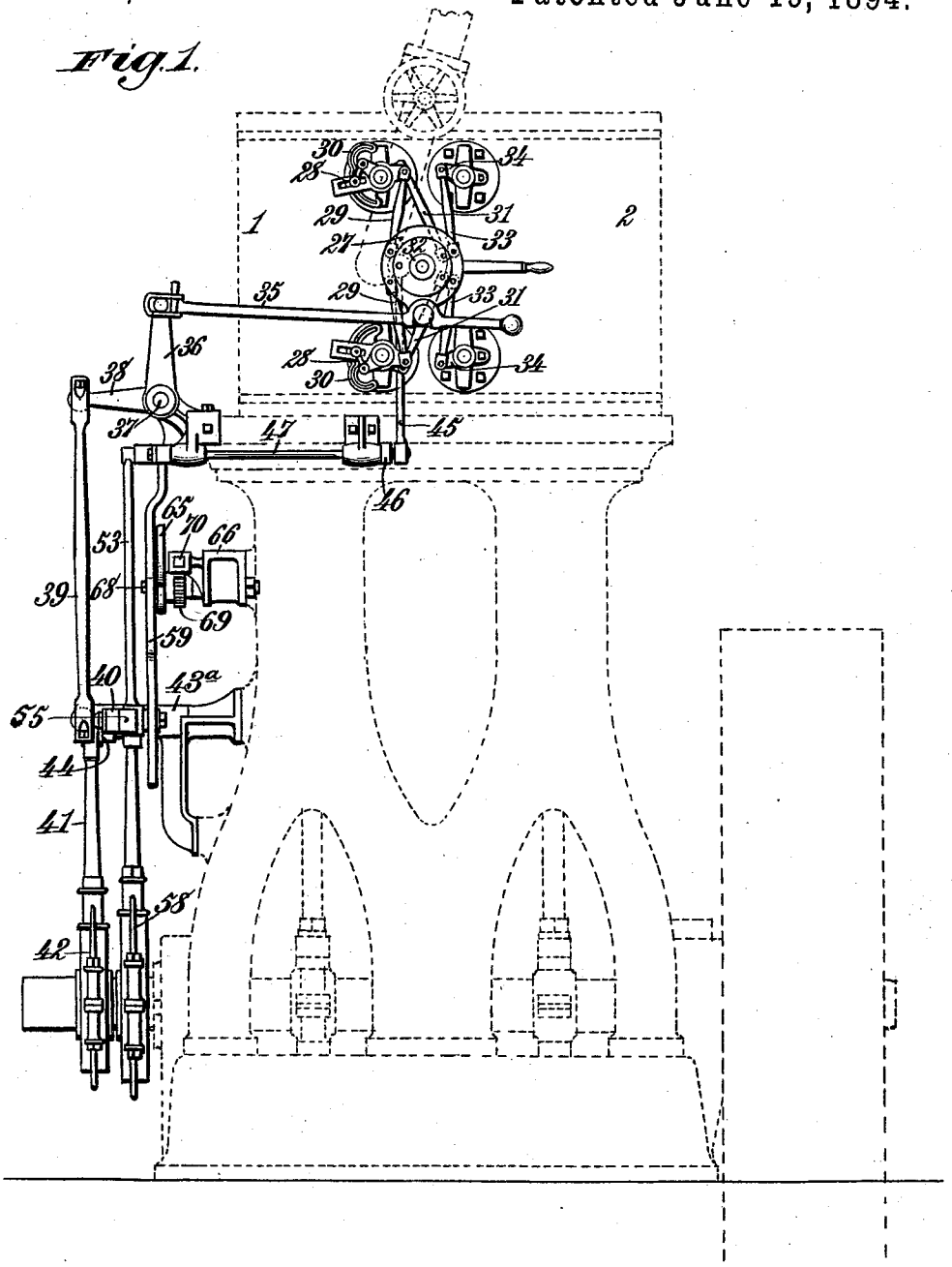

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Fig. 2.

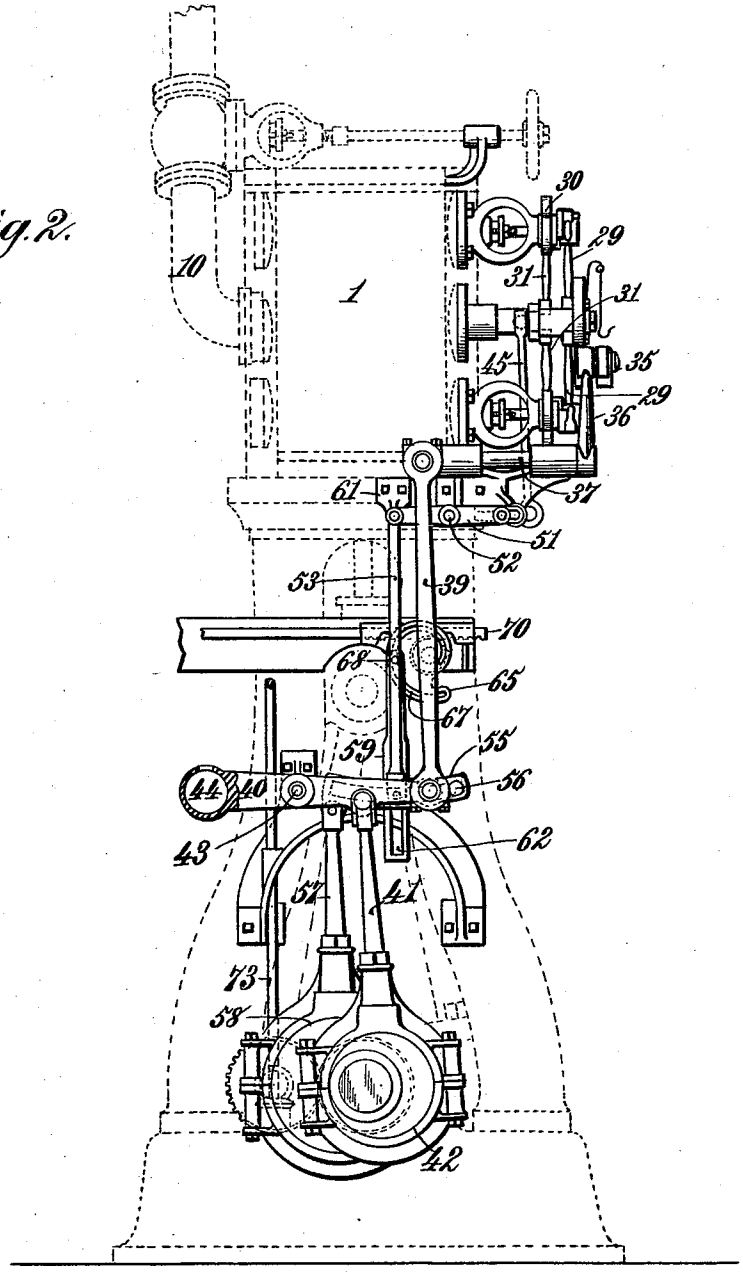

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Fig. 3.

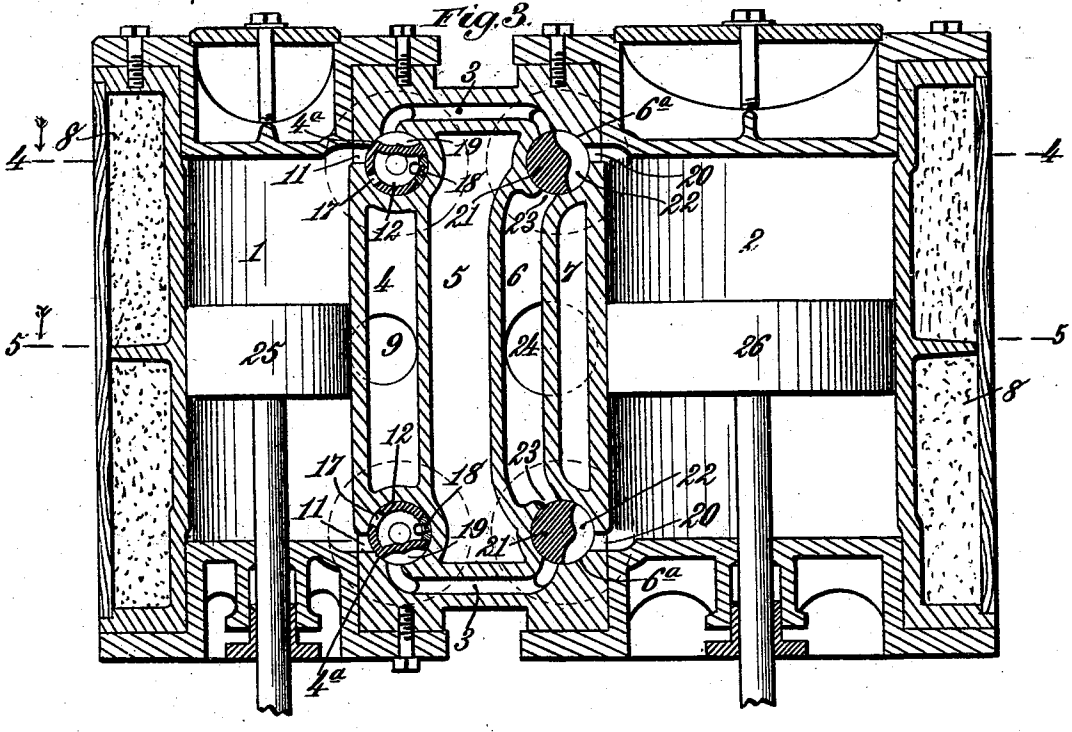

Fig. 4.

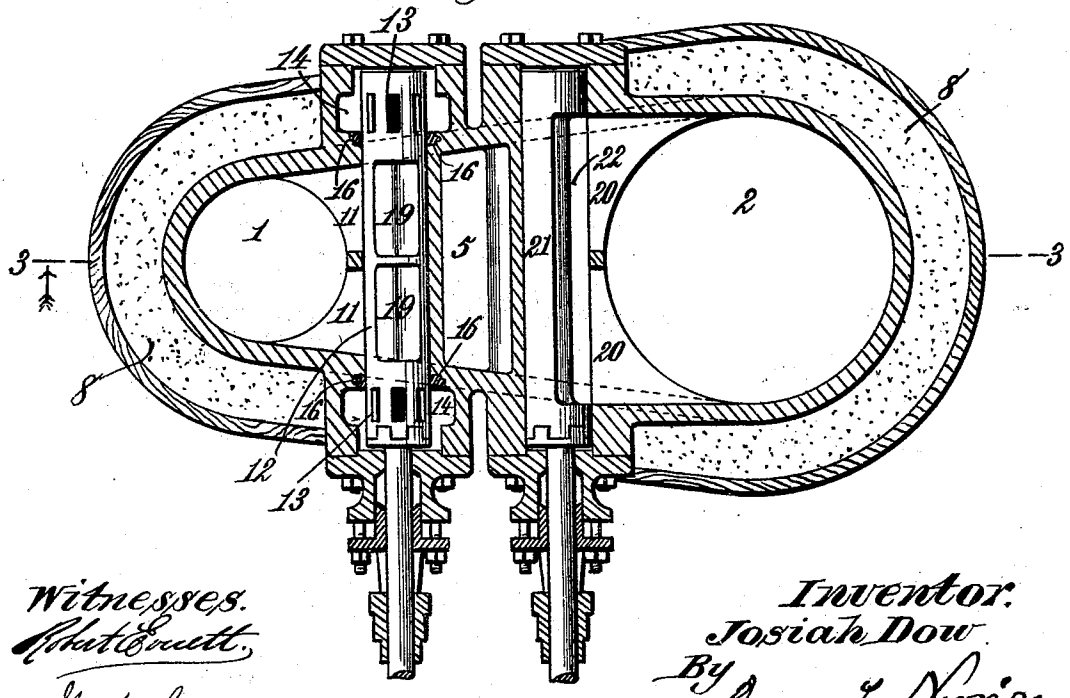

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Fig. 5.

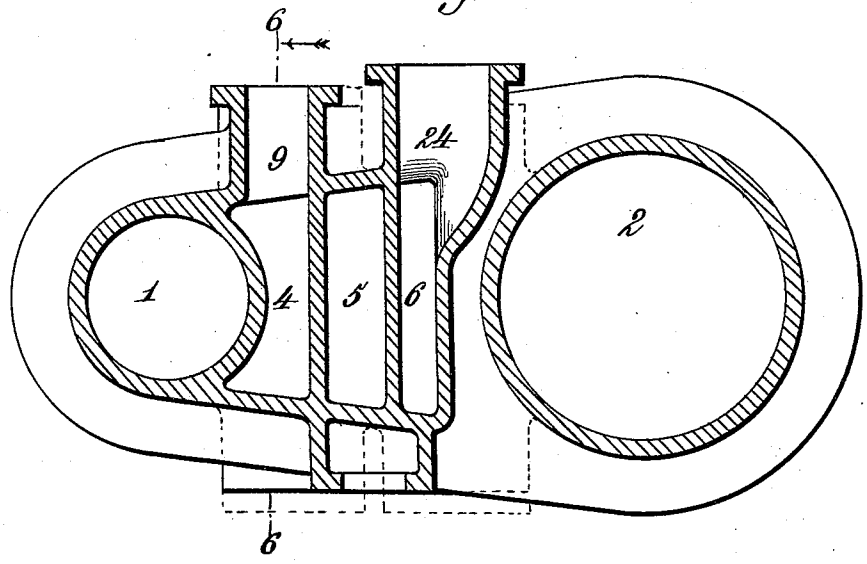

Fig. 6.

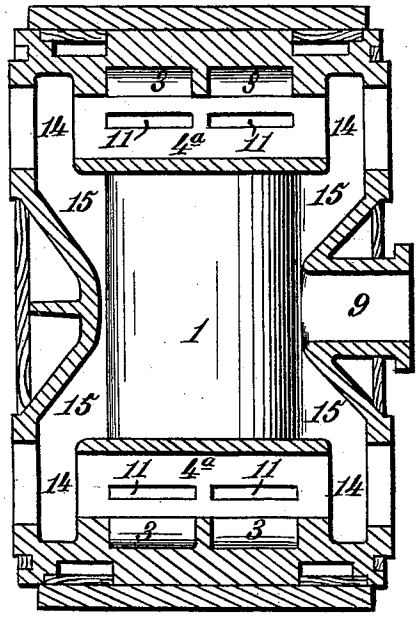

Fig. 7.

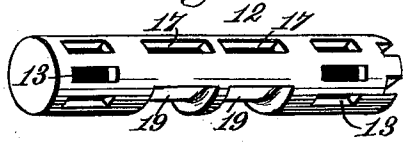

Fig. 8.

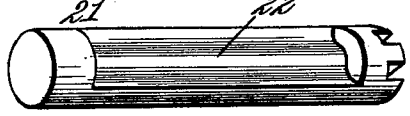

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Fig. 9.

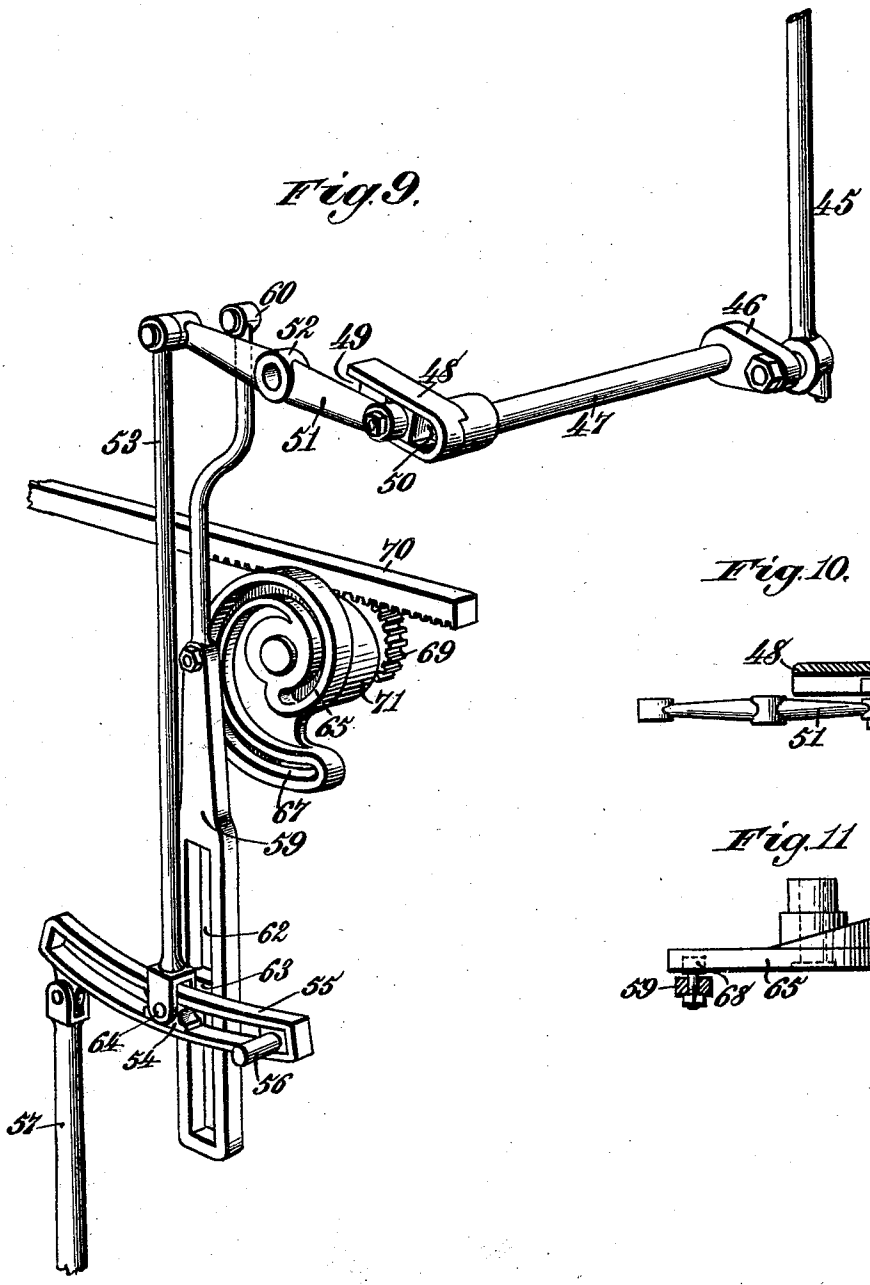

Fig. 10.

Fig. 11.

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UNITED STATES PATENT OFFICE.

JOSIAH DOW, OF PHILADELPHIA, PENNSYLVANIA.

HIGH-SPEED ENGINE.

SPECIFICATION forming part of Letters Patent No. 521,706, dated June 19, 1894.

Application filed December 14, 1893. Serial No. 493,620. (No model.)

To all whom it may concern:

Be it known that I, JOSIAH DOW, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented new and useful Improvements in High-Speed Engines, of which the following is a specification.

My invention relates to high speed vertical compound steam engines and consists in several novel features in the construction, arrangement and combinations of parts and devices as hereinafter described and more particularly pointed out in the claims.

It is one of the objects of my invention to place the high pressure and low pressure engine cylinders in such compact and close relation to each other that simple steam passages located at opposite ends of the cylinders, and only the width of the ports, will directly conduct the whole of the steam from the exhaust of the high pressure cylinder to the low pressure cylinder, whereby the clearance between the cylinders and through their valves may be made far less than has been heretofore practicable in engines of this class.

Another object of the invention is to control the admission of steam to the low pressure cylinder by means of the valve of the high pressure cylinder which preferably combines both inlet to and outlet from the said high pressure cylinder, the opening of the exhaust from the high pressure cylinder becoming the steam opening for the low pressure cylinder and determining the lead of steam thereto.

Another object of my invention is to provide mechanism for working both sets of valves, the high pressure and the low pressure, from one wrist plate.

Another object of the invention is to provide an improved and reliable governor-controlled mechanism for actuating the cut off plates to determine the point of cut off and equalize the motion of the valves at both ends of the high pressure cylinder.

Another object of the invention is to so arrange the main rocker arm and its connection with the engine shaft as to correct the angular advance of the rocker arm eccentric and rod with relation to each other and cause the high pressure and low pressure valves to have the same movements in both the up and down strokes.

Another object of the invention is to provide throughout the engine a perfect balance—as by part against part where most convenient, or otherwise by counter-balancing at suitable points, so that everything will be balanced from the pistons, rods and cranks to the valve gear, and its actuating mechanism, the governor-controlled cut off devices and every detail of parts concerned in the distribution of steam and the working of the engine.

In the annexed drawings illustrating the invention—Figure 1, shows, in dotted lines, an elevation of the frame and cylinders of a vertical compound engine, while in full lines are shown the valve gear, cut off and wrist plate connections and, also, my improved balanced or counter-balanced mechanism for operating the valves of the high pressure and low pressure cylinders from the engine shaft and controlling the point of cut off by the action of a governor driven from said shaft. Fig. 2, is a similar elevation at a right angle to the view shown in the preceding figure. Fig. 3, is an enlarged vertical section, on the line 3—3, Fig. 4, through the high pressure and low pressure cylinders, initial steam chamber, exhaust chamber, closed intervening spaces, valves and steam passages, with the pistons and piston rods in elevation. Fig. 4, is a horizontal section on the line 4—4 of Fig. 3. Fig. 5, is a section on the line 5—5 of Fig. 3, with the pistons removed. Fig. 6, is a vertical transverse section on the line 6—6 of Fig. 5, through the steam inlet and initial steam chamber. Fig. 7, is a view of one of the valves of the high pressure cylinder. Fig. 8, is a view of one of the valves of the low pressure cylinder. Fig. 9, is an enlarged perspective of the governor controlled mechanism for equalizing the action of the high pressure valves and determining the point of cut off. Figs. 10 and 11, are partly sectional detail views of parts of said governor controlled cut off mechanism.

Referring, first, to Figs. 1, 2, 3, 4, 5 and 6, the numeral 1, designates the high pressure cylinder and 2 the low pressure cylinder. These cylinders, as shown, are placed verti-

cally and in such relation to each other that a simple steam passage 3, only the width of the cylinder ports, serves to conduct the whole of the steam from the exhaust of the high pressure cylinder to the induction of the low pressure cylinder, the admission of steam to the low pressure cylinder being controlled by the exhaust valve of the high pressure cylinder. The engine may, however, be preferably built with each valve at the high pressure cylinder combining both inlet to and outlet from that cylinder. It will be observed that the cylinders are placed close together and may be constructed practically integral and in compact close relation to each other with the steam passages 3, at top and bottom, formed in the casting and extended from the valves of the high pressure cylinder to the valves of the low pressure cylinder. The valves of the two cylinders are thus connected by simple and direct passages without any intermediate chambers or intermediate receiver or pipe.

Next to the high pressure cylinder 1, is the initial steam chamber 4; then a closed air space 5, either filled with non-conducting material or not; then the exhaust chamber 6 from the low pressure cylinder 2 and then, between the exhaust chamber and the low pressure cylinder, another air space 7 that may, or may not, be filled with non-conducting material. As shown in Figs. 3, 4 and 5 the cylinders 1 and 2 may be partly or wholly surrounded by a jacket 8, filled with magnesia, asbestus or other non-conducting substance.

The initial steam chamber 4 is provided on one side with a steam inlet 9 to which a suitable valved steam inlet pipe 10 will be connected, as indicated in Figs. 1 and 2.

At the ends of the initial steam chamber 4, adjacent to the top and bottom of the high pressure cylinder 1, are transversely arranged cylindrical valve seats 4^a each of which communicates on one hand through a port or ports 11 with one end of the high pressure cylinder and on the other hand with the passage 3 leading to the corresponding valve of the low pressure cylinder. Each port 11 is controlled by a cylindrical oscillatory balanced valve 12 constructed in the manner described and claimed in Letters Patent No. 498,635, granted to me May 30, 1893. This valve 12 is hollow and has steam admitted into the interior only through annular series of peripheral openings or ports 13 at its two ends, as shown in Figs. 4 and 7. Surrounding the ends of these valves 12 are steam chambers 14 communicating with the initial steam chamber 4 through passages 15, Fig. 6. When the valves 12 are in place the steam chambers 14 have a steam tight separation from the valve seats 4^a by means of packing rings 16, Fig. 4, resting closely around the valves and in the inner sides of said chambers.

Each hollow oscillatory valve 12 at the high pressure cylinder is provided on one side, between its peripheral end ports 13, with a narrow port, or ports 17, Figs. 3 and 7 to permit steam to pass through the interior of the valve into the high pressure cylinder 1 when the valve port 17 is brought into coincidence with the cylinder port 11, hereinbefore mentioned. In the opposite side of each valve 12 is a packed balance port 18, Fig. 3, and between is the ports 17 and 18 is an exterior cut away or depressed portion or pocket 19 to form an exhaust port or passage so that when the valve is moved into proper position to present one side of said pocket or port 19 to the cylinder port 11 and the other side to the passage 3, between the cylinders, a direct channel is afforded through which the exhaust steam from the high pressure cylinder passes to the valve of the low pressure cylinder.

The construction and operation of the cylindrical oscillatory valve 12 are substantially the same as the valve described in my above named prior patent. It will be observed that steam is not allowed to pass around the valve and that no steam actually passes out of the valve through the balance port. The outside of the valve being thus isolated from the pressure of steam, the excess of pressure at the balance port 18 over that at the port 17, through which steam passes to the cylinder, is only sufficient to hold the valve closely upon its seat at both steam and exhaust passages and thus render the valve as nearly perfectly balanced as may be consistent with a firm seat.

The opposite ends of the low pressure cylinder 2 are provided with ports 20 that communicate with cylindrical valve seats 6^a in each of which is placed a solid cylindrical two-way valve 21 having its exterior cut away longitudinally on one side to form a port or passage 22, Figs. 3, 4 and 8, similar to the old Corliss exhaust valve. The cylindrical valve seats 6^a communicate with the connecting passages 3 between the two cylinders and also by exhaust ports 23 with the exhaust chamber 6 that is provided at or about its center with an exhaust outlet 24, Figs. 3 and 5, leading off to one side. The cut away portion, port or passage 22 of each oscillatory low pressure valve 21 works first to the adjacent steam connecting passage 3 and then to the exhaust.

In the operation of the engine the valve action begins by the steam valve 12, say at the upper end of the high pressure cylinder, admitting steam above the piston 25 of that cylinder. Then the "cut off" takes place and the steam is allowed to expand as usual to very near the end of the downward stroke of the piston. In the meantime the piston 26 in the low pressure cylinder moves upward exactly as the other piston 25 moves downward, they being balanced in stroke one against the other both in movement and weight, that is, the two cranks, pistons and rods are always in exactly opposite positions in stroke. When the low pressure piston in moving upward, reaches the point for com-

pression and just before compression is to begin the valve 21 at the upper end of the low pressure cylinder closes the exhaust port or passages. It will be noted that as this valve does not for another portion of the stroke open to the connecting passage 3 between the cylinders that passage, in the reverse motion of the valve, has been closed during the downward stroke the same length of time before exhaust took place and consequently the passage 3 contains steam at higher pressure than that of exhaust, and, therefore, as the low pressure piston 26 moves upward against compression it reaches, or about reaches, the pressure in the connecting passage at the time when the valve 21 opens to it. Then the compression continues in the low pressure cylinder 2 until the period for exhaust lead from the high pressure cylinder which is thus added to the compression at the end of the stroke in the low pressure cylinder. This gives three stages to the compression in the low pressure cylinder and insures a perfect balance of the steam between the two cylinders, at the beginning of each stroke. These three stages are, first, the closing of the exhaust port from the low pressure cylinder; second, the opening of the low pressure cylinder port to the connecting passage 3 between the cylinders, and, third, the opening of the exhaust from the high pressure cylinder 1 which becomes really the steam opening for the low pressure cylinder 2 and determines the lead of steam for that cylinder.

The length of the low pressure cylinder port 20 and cut-away portion 22 of the valve 21, as shown in Fig. 4, are each greater than the corresponding ports at the high pressure cylinder, as the low pressure cylinder itself is of much greater diameter than the other cylinder. Thus the connecting passage 3 between the two cylinders tapers from the valve seat of one to that of the other and affords a very free outlet for steam from the high pressure cylinder to the low pressure cylinder.

The close and compact arrangement of the cylinders 1 and 2, initial steam chamber 4, exhaust chamber 6 and closed interspaces 5 and 7 and the employment of the oscillatory valves 12 and 21 in the connection and relation to each other as hereinbefore described, with the simple and direct connecting passages 3 between the two cylinders and the high pressure exhaust lead controlling the low pressure steam lead, may be noted as important features of the present invention. The clearance between the cylinders and through the valves, it will be observed, is greatly reduced and made much less than has heretofore been accomplished in engines of this general character. This is a very valuable point in compounding. Both sets of valves, namely, the high pressure and the low pressure, are worked from one main wrist plate 27, Fig. 1. The valve gear 28 and wrist plate connections 29 for the oscillatory high pressure valves 12, and also the grooved or slotted cut off plates 30 and their connections 31 with a quadrant or auxiliary wrist plate 32, movable upon the same axis with the main wrist plate but entirely independent from it, are all substantially the same as shown, described and claimed in Letters Patent No. 498,634, granted to me May 30, 1893, except that a connection, in some places, takes hold outside its bearing instead of inside, to better accommodate the action of the parts to the vertical condition. The main wrist plate 27 is connected by rods or connections 33 to rigidly attached arms 34 on the stems of the low pressure valves.

The high pressure valves 12 and low pressure valves 21 are oscillated from the main wrist plate 27 which receives its motion through a rod 35 that connects with the free end of an arm 36 on a rock-shaft 37, Figs. 1 and 2. This rock-shaft 37 is provided with another arm 38, Fig. 1, having a ball and socket connection with one end of a rod 39 that connects at its other end with a counter-balanced and weighted main rocker arm 40 to which motion is communicated through a rod 41 from an eccentric 42 on the main shaft of the engine. The counter-balanced main rocker arm 40 is fulcrumed to the engine frame at 43, intermediate the ends of said arm. On the engine frame, as shown in Fig. 1, is a bracket 43^a by which the fulcrum of the rocker arm is supported. The rod 39 is pivotally connected with the main rocker arm 40 near one end of the said arm and the other end of the rocker arm is provided with a counter-balance 44 preferably in the form of an integral hollow ball or other suitably shaped chamber or cavity to be filled with lead or other weighty material, as needed. The rod 41 from the main eccentric 42 to the counter-balanced main rocker arm 40 has its connection on the rocker arm at a point between and sufficiently below a direct line between the centers of the fulcrum 43 and end of the rod 39, on the line of an arc through where the connection to eccentric rod would ordinarily be, to correct the angular advance of the eccentric and rod in relation to each other and bring the movement of the valve gearing into the same time for reaching each degree of its advance in either direction, or going from the center in either way of movement. This, therefore, makes the movements of the valves the same in both the up and down strokes.

The "cut off" at the high pressure valves 12 is effected through the quadrant or auxiliary wrist plate 32 that is movable upon the same axis as the main wrist plate but entirely independent thereof. This auxiliary wrist plate 32 is actuated through a rod 45, Figs. 1, 2 and 9, one end of which has a ball and socket connection with a crank arm 46 on one end of a rock shaft 47 supported in suitable bearings on the engine frame. To the other end of the rock shaft 47 is secured

a crank arm or equalizer lever 48, Figs. 9 and 10, the outer side of which is provided with a longitudinal groove 49 in which slides a pin or block 50 carried by one end of an auxiliary, or cut off, rocker arm 51 that is fulcrumed at 52, about midway its length, to the engine frame. It will be seen that the groove 49 and pin or block 50 form a variable connection between the equalizer 48 and one end of the auxiliary rocker arm. To the other end of this auxiliary rocker arm or lever 51 is pivotally attached one end of a rod 53 the other end of which is bifurcated to receive a slide block 54 that is pivotally supported therein, as shown in Fig. 9. This slide block 54 is loosely engaged in a segmental slotted link 55 one end of which is fulcrumed, through a pin 56, to the unweighted end of the counter-balanced main rocker arm 40, as shown in Fig. 2. To the other end of the slotted link 55 is pivotally attached a rod 57 that is connected to and actuated from the cut off eccentric 58 on the engine shaft.

As in other engines of the Corliss type the point of "cut off" is determined by a governor. The mechanism through which this is effected will now be described. A pendulum lever 59, Figs. 1, 2 and 9, is suspended at 60 from a bracket 61 on the engine frame immediately behind the center of movement of that end of the rocker arm 51 to which is attached the rod 53 connecting with the slide block 54 in the slotted link 55 that is actuated from the cut off eccentric. The lower end of the pendulum 59 is provided with a longitudinal slot 62, Figs. 2 and 9, in which plays up and down a subsidiary slide block 63 mounted on the extended end of a pin 64, passed through the link slide block 54, and by which the two slide blocks are connected. This allows full play up and down for the slotted link 55, while the position in it of the slide block 54 for determining cut off is held secure. For the purpose of shifting the link slide block 54 to and from the link fulcrum 56 to vary the point of cut off the pendulum 59 is moved into proper position by an oscillatory plate 65, Figs. 9 and 11, pivotally supported from a bracket 66, Fig. 1, on the engine frame. In the face of the oscillatory plate 65 is a helical cam groove or slot 67 that engages with a pin or roller 68 on the pendulum. To the rear side of this oscillatory plate 65 is secured a pinion 69 engaged with a reciprocating rack bar 70 through which the helical cam plate 65 and pendulum 59 are actuated from any suitable governor. The shorter end of the oscillatory cam plate 65 may be counter-balanced at 71 as shown in Figs. 9 and 11. By suspending and arranging the pendulum 59 in the manner shown and described it is afforded a range of movement at all times directly in line with the rod 53 connecting the auxiliary rocker arm 51 with the link slide block 54 through the position of which in the slotted link 55 is determined the point of cut off for the valves of the high pressure cylinder. The plate 65 with its helical cam groove or slot 67 is oscillated in one direction or the other by the rack 70, actuated from the governor, and the pendulum 59 is thus moved one way or the other, controlled by the pin 68 in the cam groove 67, and carries with it the link block 54 to a longer or shorter position for cut off. As the pin 68 fitting in the helical cam groove 67 is in direct line with the pivotal bearing of the pinion 69 and plate 65 the resistance is against that bearing and does not have any appreciable tendency to react upon the governor.

I may employ a governor driven directly from the main shaft of the engine through gearing 72 and upright shaft 73, Fig. 2, but as the particular form of the governor is not essential and forms no part of my present invention its illustration here is not deemed necessary.

It will be observed that the balancing, throughout the engine, is part against part where practicable and otherwise counter-balanced. This balance of the several parts includes everything from the pistons, rods and cranks to the valve gear and wrist plate connections, the rocker arms, the equalizing and governing mechanism for the "cut off" and, also, the smallest minutiæ of the distribution of steam.

What I claim as my invention is—

1. In a compound engine, the combination of a high pressure cylinder and a low pressure cylinder placed side by side in compact close relation to each other and provided at both ends with direct steam connecting passages formed in the cylinder casting and leading from the exhaust of the high pressure cylinder to the induction of the low pressure cylinder, an initial steam chamber and an exhaust chamber intermediate said cylinders, and cylindrical oscillatory valves at both ends of both the high pressure and the low pressure cylinders and located between the said cylinders, each valve adapted to control both the induction and eduction of its cylinder and the valves at the ends of the high pressure cylinder being also adapted to control the lead of steam to the low pressure cylinder, substantially as described.

2. In a compound engine, the combination of a high pressure cylinder and a low pressure cylinder placed side by side in compact close relation to each other and provided with direct steam connecting passages leading from the exhaust of the high pressure cylinder to the induction of the low pressure cylinder, an initial steam chamber and an exhaust chamber intermediate said cylinders and each provided at both ends with cylindrical valve seats, and cylindrical oscillatory valves located in said valve seats at the high pressure cylinder and low pressure cylinder, respectively, and each adapted to control both the induction and eduction of its cylinder, the valves at the high pressure cylinder

being arranged to govern the admission of steam to the low pressure cylinder from the exhaust lead of the high pressure cylinder, substantially as described.

3. In a compound engine, the combination of a high pressure cylinder and a low pressure cylinder placed side by side in compact close relation to each other, an initial steam chamber and an exhaust chamber intermediate said cylinders and alternating with intervening closed spaces, both ends of the cylinder-casting being provided between the cylinders with cylindrical valve seats located at the high pressure and low pressure cylinders and with direct steam connecting passages leading from the exhaust of the high pressure cylinder to the induction of the low pressure cylinder, and cylindrical oscillatory valves located in said valve seats at both ends of and between the cylinders, each valve being adapted to control both the induction and eduction of its cylinder and the valves at the high pressure cylinder controlling also the lead of steam to the low pressure cylinder, substantially as described.

4. In a compound engine, the combination with a high pressure cylinder and a low pressure cylinder placed in compact close relation to each other and having direct steam connecting passages tapering from the ports of the high pressure cylinder to the ports of the low pressure cylinder, whereby the clearance between the cylinders and through the valves is reduced and a free outlet afforded for the passage of steam from the high pressure cylinder to the low pressure cylinder, of valves located between said cylinders and each adapted to control both the induction and eduction of its cylinder, the valves at the high pressure cylinder being also adapted to control the lead of steam at the low pressure cylinder, substantially as described.

5. In a compound engine, the combination of the high pressure cylinder and the low pressure cylinder placed side by side in compact close relation to each other and provided at both ends with direct steam connecting passages and with cylindrical valve seats located at both ends of and between the cylinders, cylindrical oscillatory valves for both ends of each cylinder, located in said valve seats between the cylinders and each adapted to control both the induction and eduction of its cylinder, a single main wrist plate intermediate the cylinders, and valve gear and wrist plate connections through which all the said valves controlling the ports of both the high pressure and low pressure cylinders are actuated, substantially as described.

6. In a compound engine, the combination with the high pressure cylinder and the low pressure cylinder placed in compact close relation to each other and having direct steam connecting passages, of an initial steam chamber and an exhaust chamber located between said cylinders and having cylindrical valve seats at their ends, oscillatory valves located in said valve seats at the ports of both the high and low pressure cylinders and between the same, each of said valves adapted to control both the induction and eduction of its cylinder, the valves at the high pressure cylinder controlling both the exhaust from that cylinder and the lead of steam at the low pressure cylinder, a single main wrist plate intermediate the cylinders and through which the said valves controlling the ports of both the high and low pressure cylinders are actuated, and suitable valve gear and wrist plate connections, substantially as described.

7. In a compound engine, the combination with the high pressure cylinder, the low pressure cylinder, their cylindrical oscillatory valves, a single main wrist plate and the valve gear and wrist plate connections, of a counter-balanced main rocker arm actuated from an eccentric on the engine shaft, a rock shaft provided with arms, a rod connecting one arm of said rock shaft with the main rocker arm on one side of its fulcrum and at a point opposite its counter-balanced end, and a rod connecting the other arm of said rock-shaft with the main wrist plate, substantially as described.

8. In a compound engine, the combination with the oscillatory valves, the main wrist plate, and the valve gear and wrist plate connections, of a counter-balanced main rocker arm fulcrumed intermediate its ends, a rock shaft provided with arms, a rod connecting one arm of said rock shaft with the main rocker arm at a point opposite its counter-balanced end, an eccentric rod extended from an eccentric on the engine shaft and connected with said counter-balanced main rocker arm at a point between and below the rocker arm fulcrum and the attachment of the rod connecting with the rock shaft arm, and another rod connecting the other arm of said rock shaft with the main wrist plate, substantially as described.

9. In a compound engine, the combination with the oscillatory valves, the main wrist plate and the valve gear and wrist plate connections, of a counter-balanced main rocker arm actuated from an eccentric on the engine shaft and connected with the said main wrist plate, a slotted link carried by said main rocker arm and actuated from the cut off eccentric, a block adapted to slide in said link, a cut off mechanism connected with and actuated from said block, a slotted pendulum, a block adapted to slide in the slot of the pendulum and connected with the slide block of the slotted link, an oscillatory plate having a cam groove or slot engaged with a pin on the pendulum, and rack and pinion gearing for actuating said cam plate and pendulum from a governor to vary the position of the link slide block and determine the point of cut off, substantially as described.

10. The combination with an oscillatory valve, a main wrist plate, the valve gear and wrist plate connections, a counter-balanced

main rocker arm connected with the said main wrist plate and actuated from an eccentric on an engine shaft, a slotted link fulcrumed to said main rocker arm and actuated from a cut off eccentric, and a block adapted to slide in said link, of a balanced centrally fulcrumed auxiliary rocker arm having one end connected with said block, a pivotally supported equalizer lever having a varying connection with the other end of said auxiliary rocker arm, and cut off mechanism connected with said equalizer lever, substantially as described.

11. The combination with an oscillatory valve, the main wrist plate, a valve gear and wrist plate connections, of a counter-balanced main rocker arm actuated from a main eccentric rod, a two armed rock shaft intermediate the main wrist plate and main rocker arm and connected with both by rods, a slotted link carried by the main rocker arm and actuated from the cut off eccentric rod, a slide block supported in said link, governor mechanism connected with the said slide block to control its position in the slotted link and determine the point of cut off, a balanced auxiliary rocker arm having one end connected with the link slide block, an equalizer lever having a varying connection with the other end of the auxiliary rocker arm, and a quadrant or auxiliary wrist plate connected with said equalizer and with the cut off plate that controls the action of the valve gear, substantially as described.

12. The combination with an oscillatory valve, a main wrist plate, the valve gear and wrist plate connections, the cut off plate and its auxiliary wrist plate, of a counter-balanced main rocker arm actuated from a main eccentric and connected with the main wrist plate of the valve gear, a link carried by said main rocker arm and actuated from the cut off eccentric, an auxiliary balanced rocker arm intermediate said link and the auxiliary wrist plate, a link slide block connected with one end of the auxiliary rocker arm, equalizer mechanism intermediate of and connected with the auxiliary rocker arm and auxiliary wrist plate, and governor mechanism connected with the link slide block to determine the point of cut off, substantially as described.

13. The combination with an oscillatory valve, its valve gear, main wrist plate and wrist plate connections, of a counter-balanced main rocker arm fulcrumed intermediate its ends and connected with the main wrist plate and main eccentric rod, a link carried by said main rocker arm and actuated from the cut off eccentric rod, a block adapted to slide in or on said link and controlled by a governor, a centrally fulcrumed and balanced auxiliary rocker arm having one end connected with said block, an equalizer lever having a varying connection with the other end of said auxiliary rocker arm, and means for connecting the equalizer lever with a cut off quadrant or auxiliary wrist plate through which the cut off is controlled, substantially as described.

14. The combination with an oscillatory valve, its valve gear and wrist plate connections, a main rocker arm connected with a main wrist plate and actuated from the main eccentric rod, a link carried by the main rocker arm and actuated from the cut off eccentric rod, and a link slide block, of a centrally fulcrumed and balanced auxiliary rocker arm connected with the link slide block and with a cut off mechanism, a slotted pendulum lever, a slide block located in the slot of the pendulum and connected with the link slide block, an oscillatory plate having a helical cam groove or slot engaged with a pin or roller on the pendulum, and rack and pinion gearing actuated from a governor to oscillate the cam plate and pendulum for shifting the link slide block and controlling the point of cut off, substantially as described.

15. The combination with the cylinders, balanced pistons, cranks, rods, valves and valve gear of a compound engine, of a counter-balanced main rocker arm connected with the main wrist plate of the engine valve gear and actuated from the main eccentric rod, a link carried by said main rocker arm and actuated from the cut off eccentric, a link slide block, a balanced and centrally fulcrumed auxiliary rocker arm having one end connected with the link slide block and its other end with an equalizing mechanism through which the cut off devices are actuated, a pendulum provided with a slide block that is engaged with the link slide block, a counter-balanced oscillatory cam plate engaged with the pendulum, and gearing for actuating said cam plate and pendulum from a governor to vary the position of the link slide block and control the point of cut off, substantially as described.

16. The combination with a valve, its valve gear, a cut off plate that controls the action of the valve gear, a rocker arm actuated from a main eccentric and connected with the valve gear, a link carried by said main rocker arm and actuated from a cut-off eccentric, a block adapted to slide in or on said link, and connections from said block to the cut off plate, of a slotted pendulum, a block adapted to slide in the slot of the pendulum and connected with the link slide block, an oscillatory plate having a cam groove or slot engaged with a pin on the pendulum, and rack and pinion gearing for actuating said plate and pendulum from a governor, to vary the position of the link slide block and determine the point of cut off, substantially as described.

17. The combination with a valve, its valve gear and cut off connections, a main rocker arm connected with the valve gear and carrying a link that is actuated from a cut off eccentric and provided with a link slide block for controlling the cut off connections, of a pendulum for shifting the position of the link slide block to control the point of cut off, and

an oscillatory cam plate engaged with the pendulum and actuated from a governor, substantially as described.

18. The combination with a valve and its valve gear and cut off devices comprising a link slide block for controlling the point of cut off, of a slotted pendulum, a slide located in the slot of the pendulum and connected with the link slide block, an oscillatory plate having a helical cam groove or slot engaged with a pin or roller projecting from the pendulum, and means for actuating said cam plate and pendulum from a governor to shift the link slide block and vary the point of cut off, substantially as described.

19. In a compound engine, the combination with a high pressure cylinder and a low pressure cylinder placed close together and having direct steam connecting passages leading from the exhaust of the high pressure cylinder to the induction of the low pressure cylinder, of induction and eduction valves located between said cylinders, the valves at the high pressure cylinder controlling the lead of steam to the low pressure cylinder from the exhaust lead of the high pressure cylinder and the valves at the low pressure cylinder controlling the exhaust therefrom, pistons located in said cylinders and balanced in stroke one against the other, both in movement and weight, valve gear and wrist plate connections, and a governor controlled cut-off, whereby the lead and compression of steam are determined and a balancing of steam pressure is obtained through and between the cylinders and connecting passages at beginning and end of each stroke, substantially as described.

20. The combination with the cylinders, balanced pistons, cranks, rods, valves, valve gear and cut-off devices of a compound engine, of a slide through which the point of cut-off is controlled, a pendulum connected with and adapted to shift said slide, a cam connected with and actuating the pendulum, and means for oscillating said cam from a governor to control the movements of the pendulum and slide and vary the point of cut-off, substantially as described.

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

JOSIAH DOW.

Witnesses:
I. ALTZ GATES,
CHARLES H. WEISS.