No. 890,595. PATENTED JUNE 16, 1908.

E. BELKNAP.

EXPANSION ENGINE.

APPLICATION FILED JAN. 23, 1906.

3 SHEETS—SHEET 1.

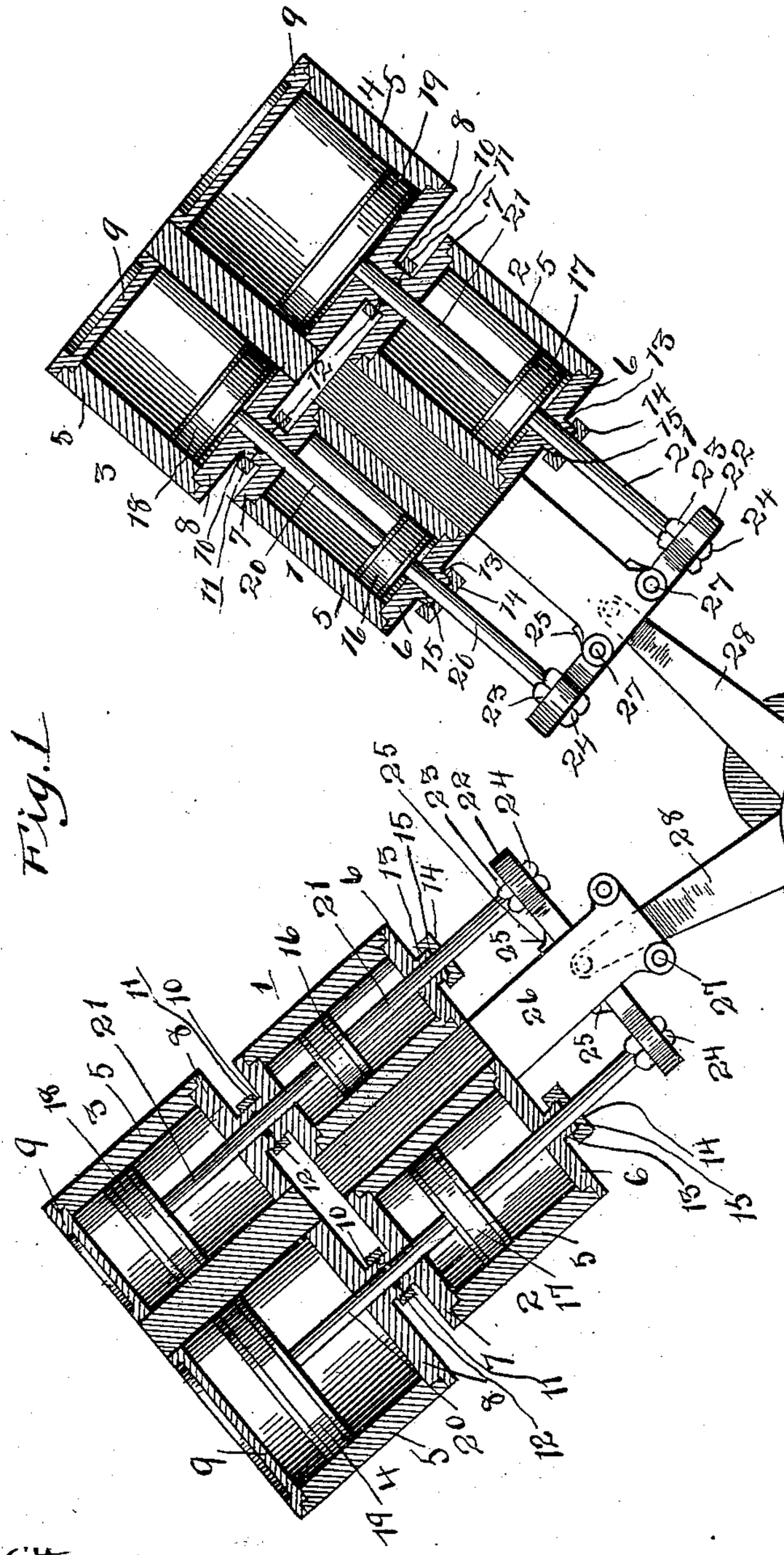

Fig. 1

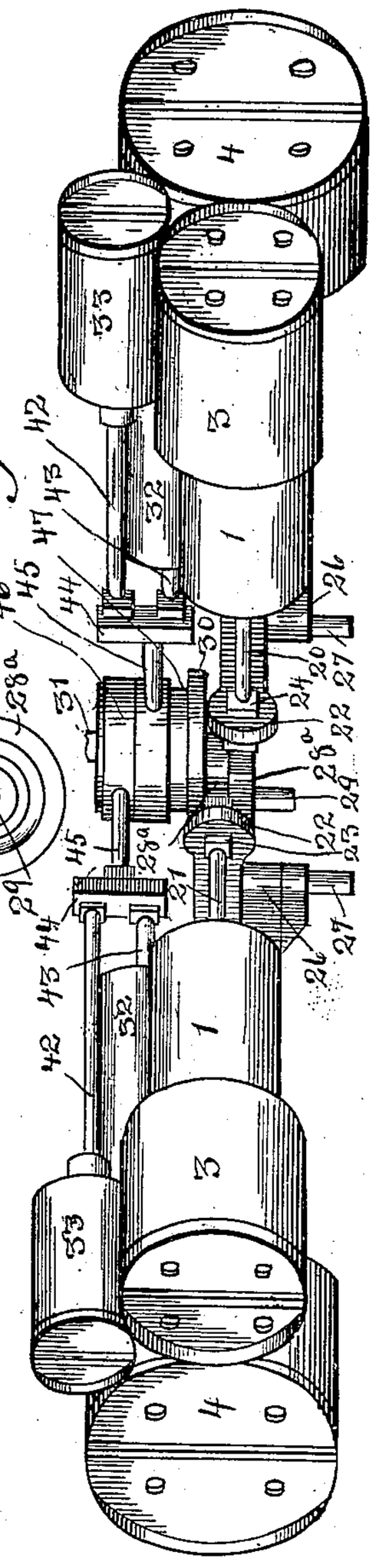

Fig. 2

Witnesses:
Wm. P. Bond
Oscar W. Bond

Inventor:
By Ellsworth Belknap,
Banning & Banning
Attys.

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3 SHEETS—SHEET 2.

Fig. 3

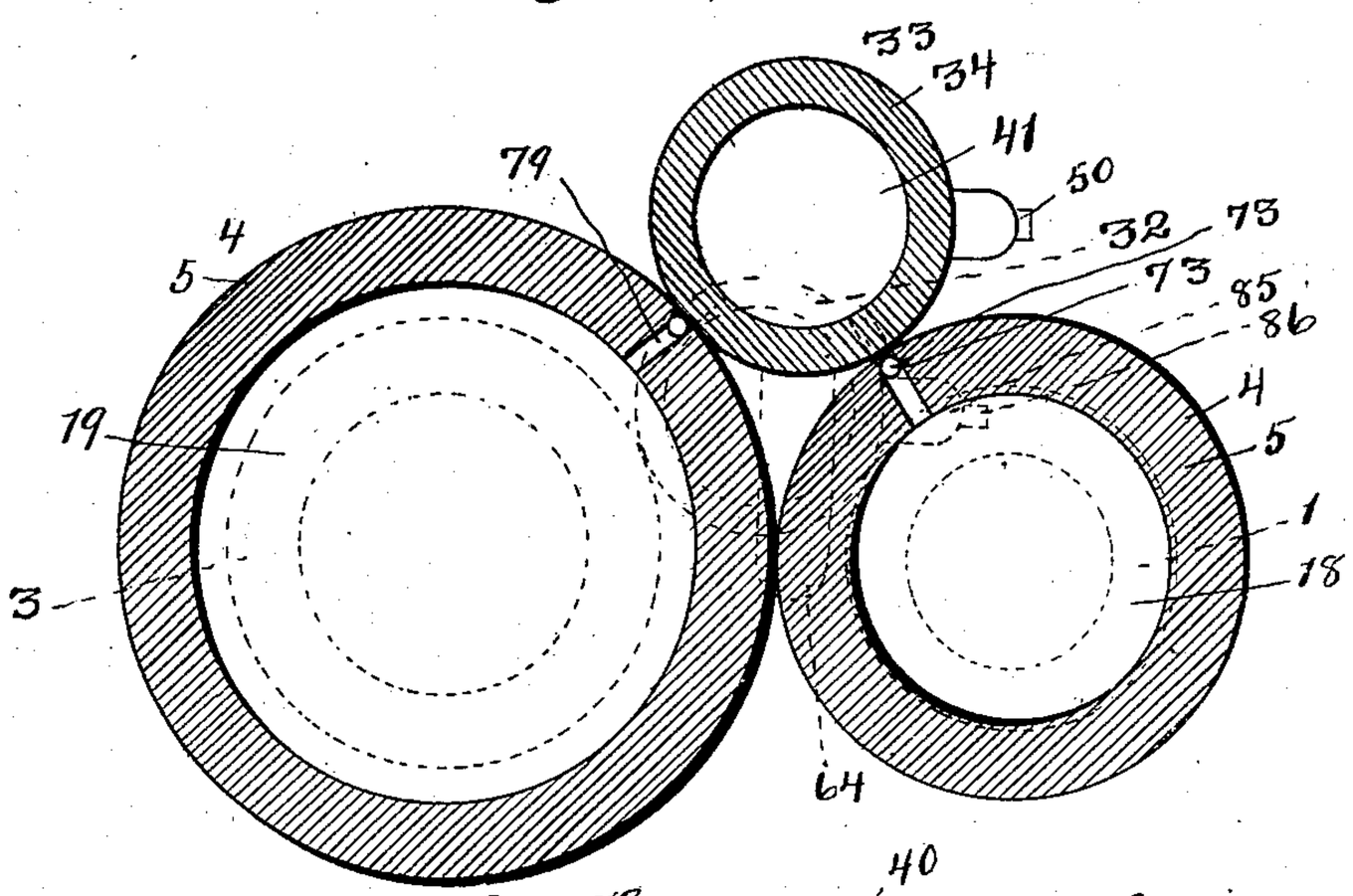
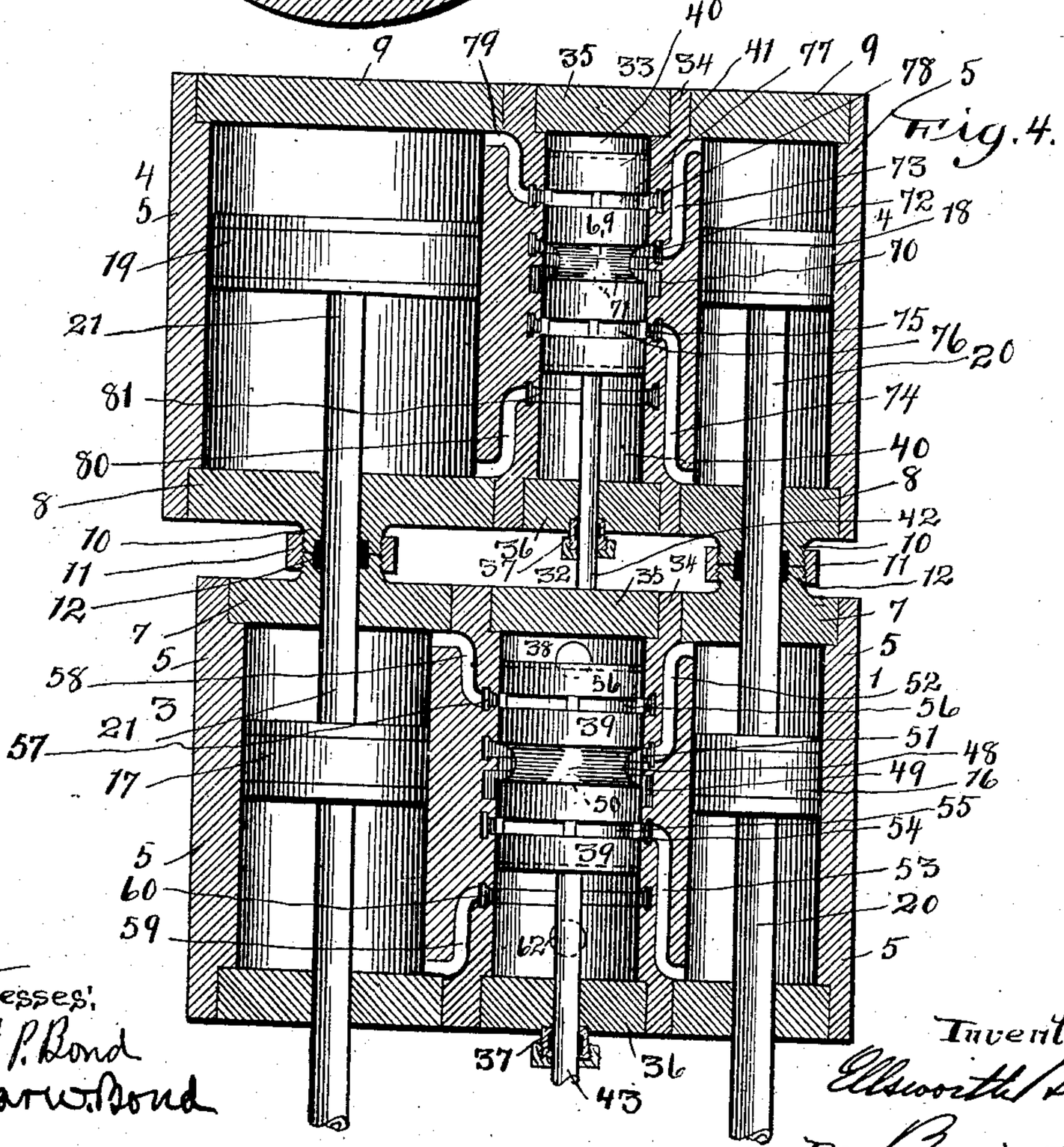


Fig. 4.



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Ellsworth Belknap
By Benning & Benning
Attys.

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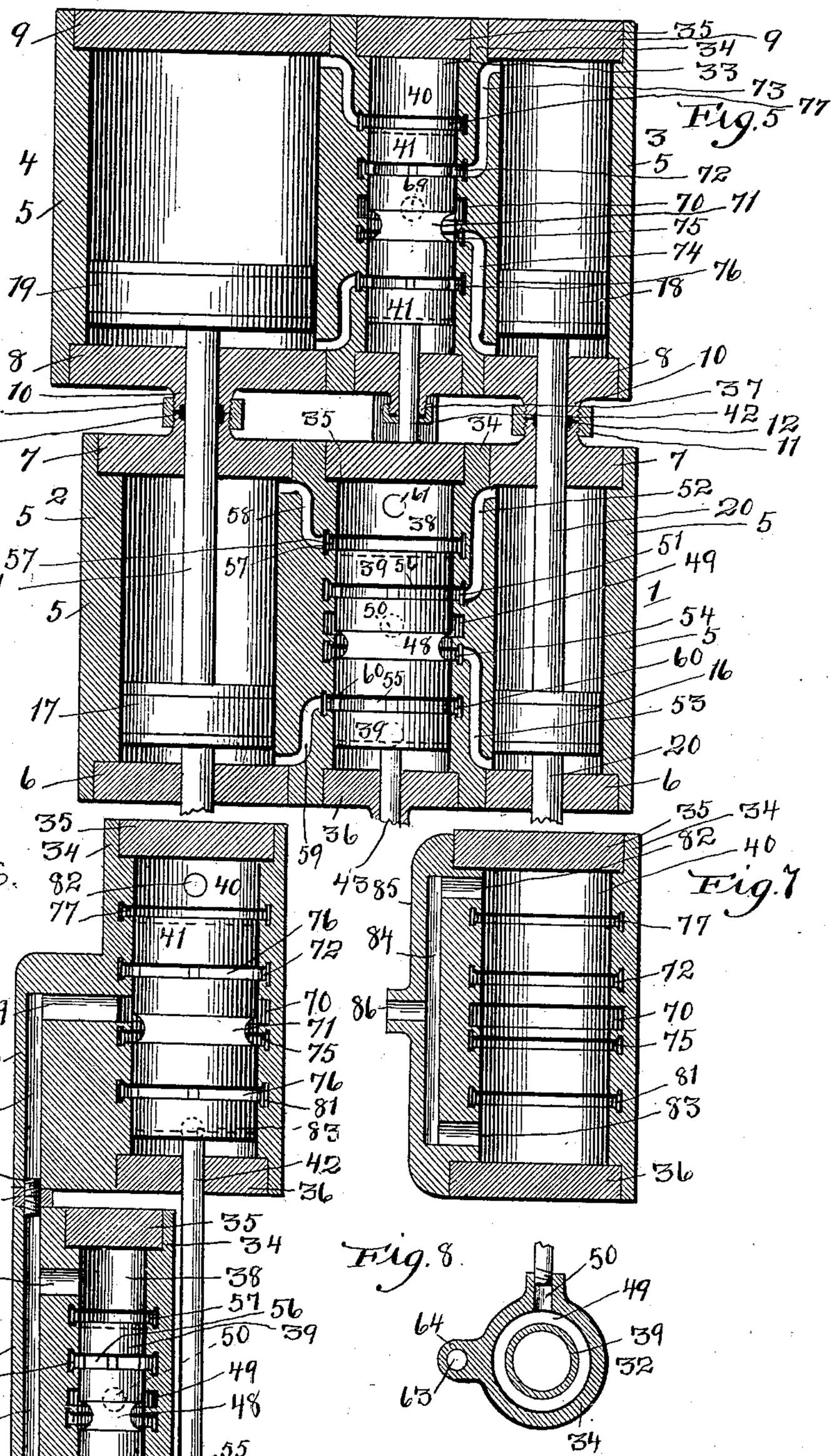

Fig. 6.

Fig. 5

Fig. 7

Fig. 8.

Witnesses:
Wm. P. Bond
Oscar W. Bond

Inventor:
Ellsworth Belknap
By Banning & Banning
Attys:

UNITED STATES PATENT OFFICE.

ELLSWORTH BELKNAP, OF POLO, ILLINOIS.

EXPANSION-ENGINE.

No. 890,595. Specification of Letters Patent. Patented June 16, 1908.

Application filed January 23, 1906. Serial No. 297,519.

To all whom it may concern:

Be it known that I, ELLSWORTH BELKNAP, a citizen of the United States, residing at Polo, in the county of Ogle and State of Illinois, have invented certain new and useful Improvements in Expansion-Engines, of which the following is a specification.

The invention has for its objects to construct an expansion engine having cylinders and pistons of small diameters and giving an increase of power from the pressure of the actuating fluid; to combine eight cylinders in coöperative relation for imparting power to a driving or other shaft and have the arrangement of the power cylinders compact and standing in an angling relation for the four cylinders of each battery of cylinders; to connect the pistons of the four cylinders of each battery of cylinders to a common cross head, which, in turn, is connected with a crank disk or crank fixed on a driving shaft to supply the fluid pressure under full head to the initial power cylinder to be transmitted therefrom successively to the remaining cylinders of the battery of cylinders; to control the passage of the fluid pressure between the cylinders by a reciprocating valve and communicating ports and passages, whereby the fluid pressure will be simultaneously admitted to all four of the battery of cylinders and also simultaneously exhausted from all four of the battery of cylinders; to actuate the controlling valve for the cylinders of the two batteries of power cylinders so that the cylinders of one battery will be brought into use to actuate the pistons before the pistons on the other battery of cylinders have completed a full stroke in either direction, and in such manner as to maintain a continuous drive for the power shaft; and to improve generally the construction and arrangement of the several appliances entering into the formation of the engine as a whole.

The invention consists in the features of construction and combinations of parts hereinafter described and claimed.

In the drawings Figure 1 is a sectional elevation showing the preferred form of arrangement for the two batteries of cylinders; Fig. 2 a top or plan view of the arrangement shown in Fig. 1; Fig. 3 a cross section through the upper cylinders and steam or other fluid pressure chest of a battery of cylinders; Fig. 4 a sectional elevation of the battery of cylinders taken on diagonal lines running respectively through the centers of the upper and lower cylinders and the centers of the upper and lower steam or other fluid pressure chest; Fig. 5 a similar view to Fig. 4 showing the pistons to the limit of the down stroke in the power cylinders, and the controlling valve for the fluid or steam chest in its lower position—Fig. 4 showing the controlling valve in its upper position; Fig. 6 an elevation in section showing the steam or fluid pressure chests and the controlling valves with the connecting passages for steam or other fluid between the pressure chests; Fig. 7 a detail in elevation showing the upper or final fluid pressure or steam chest and its passage; and Fig. 8 a cross section of the lower or initial fluid pressure or steam chest and its inducting and educting passages.

The engine, preferably, is constructed with two batteries of power cylinders, each battery comprising four cylinders and the two batteries standing, as a whole, at an angle of 90 degrees so as to enable the engine to be compactly arranged and to occupy but a small space in comparison with the space occupied by eight power cylinders differently arranged. Each battery of cylinders has an initial cylinder 1, a second cylinder 2, a third cylinder 3, and a fourth cylinder 4, arranged for the first and third cylinders to be in axial alinement, and for the second and fourth cylinders to be in axial alinement, as shown in Fig. 1. Each cylinder has a wall 5, and the cylinders 1 and 2 each have a head 6 at one end, and a head 7 at the opposite end, both heads being screw threaded, or bolted, or otherwise firmly fixed in the ends of the two cylinders. The cylinders 3 and 4 each have at one end a head 8 and at the other end a head 9, and the heads 8 and 9 are screw threaded, or bolted, or otherwise firmly secured to the ends of the two cylinders. The abutting ends of the cylinders 1 and 3 and the abutting ends of the cylinders 2 and 4 each have a boss or neck 10 to receive a ring or coupling nut 11, having a right and left hand screw thread, by means of which and the necks the adjacent cylinders are united firmly together endwise, and, as shown, the necks 10 have a recess to receive a packing 12 surrounding the piston rods of the pistons in the two alining cylinders. The lower end head 6 of the cylinders 1 and 2 each have a neck or boss 13 onto which is entered a cap nut 14, and in the cap nut is a recess for the

reception of a packing 15 to form a tight joint for the piston rods of the two lower power cylinders.

The cylinder 1 has located and operating therein a piston 16; the cylinder 2 has located and operating therein a piston 17; the cylinder 3 has located and operating therein a piston 18; and the cylinder 4 has located and operating therein a piston 19. The pistons 16 and 18 are connected together by a piston rod 20 passing through the necks or bosses 10, and the heads 7 and 8 of the cylinders 1 and 3; and the pistons 17 and 19 are connected together by a piston rod 21 passing through the necks 10 and the heads 7 and 8 of the cylinders 3 and 4, so that the pistons 16 and 18, and the pistons 17 and 19 move in unison. The piston rod 20 and the piston rod 21 continue through the heads 6 and through the stuffing boxes on the heads, and the two piston rods are connected together by a cross head 22, through the ends of which the piston rods pass and are adjusted, as to length, by means of adjusting nuts 23 and 24 on opposite sides of the cross head, as shown in Fig. 1. The cross head has a bearing 25, which reciprocates in a pathway or channel therefor, formed in a plate 26 attached to or integral with the heads 6; and, as shown, at the end of each plate 26 are rods or studs 27 forming bolts for securing an inclosed casing, not shown, around the power cylinders and the operative parts of the engine. Each cross head 22 has pivotally attached to its center the end of a pitman or drive rod 28, each pitman or drive rod having a head 28^a mounted on a wrist-pin 29 located off center on a disk 30 fixed to the driving or power shaft 31 of the engine. It will be noted that the location of the wrist- or crank-pin 29, and the relation of the pitman or drive rods 28 are such that when the pistons of one battery of power cylinders are at the end of the down-stroke the pistons of the cylinders of the other battery of cylinders have completed only approximately a quarter of the down-stroke, so that when one set of pistons has completed a stroke, the other set of pistons continue the stroke, thereby giving a continuous application of power to the driving or power shaft, when the two batteries of cylinders are in operation.

The lower cylinders of each battery of cylinders have a common fluid pressure or steam chest 32, and the two upper cylinders of each battery of cylinders have a common fluid pressure or power chest 33, and the two chests have communication with their respective power cylinders, so that steam or other fluid pressure entered into the initial or first cylinder will pass to all of the cylinders to be finally discharged at the last or fourth cylinder. Each chest 32 and 33 has a surrounding wall 34, integral with the walls 5 of the respective power cylinders; and each chest, at the upper end, has a closing head 35 screw threaded, bolted, or otherwise fixedly secured in the end of the chest or cylinder; and each chest or cylinder at its lower end, has a head 36 screw threaded, bolted, or otherwise fixedly secured in the end of the chest or cylinder; and each head 36 has a stuffing box 37 for the passage of the valve rods for the valves of the respective chests or cylinders 32 and 33; and as the chests or cylinders 32 and 33 are not in axial alinement the valve rod of the chest or cylinder 33 clears the exterior face of the chest or cylinder 32, as shown in Figs. 2 and 6.

The chamber 38 of the lower chest or cylinder 32 has located and operating therein a hollow piston valve 39, closed at each end, as shown at the dotted lines in Figs. 4, 5 and 6, and the chamber 40 of the upper chest or cylinder 33 has located and operating therein a hollow piston valve 41, closed at each end, as shown by dotted lines in Figs. 4, 5 and 6 for the valves 39 and 41 to control inducting and educting fluid pressure, between the fluid pressure or steam chest and their respective power cylinders. The piston valve 41 has a rod 42 passing through the stuffing boxes 37, and the piston valve 39 has a rod 43 passing through the stuffing box 37, so that both valve rods are protected against the escape of pressure therearound. The two valves rods 42 and 43 are connected to a common cross head 44, with adjusting nuts to regulate the throw of the respective piston valves, and each cross head 44 is connected by a rod or stem 45 with a ring 46 of an eccentric 47 by which the position of the piston valves for the two batteries of power cylinders is shifted in the usual manner of eccentrics for moving the controlling valve of fluid pressure to a cylinder.

An inlet 48 admits steam or other fluid pressure into the lower cylinder 32, and this inlet is in communication with a circumferential passage 49 formed in the interior face of the chest or cylinder 32, which passage, with the reciprocation of the piston valve 39, through a circumferential channel 50 can be brought into communication with conducting passages leading to the power cylinders 1 and 2 respectively.

The piston valve 39, in the position shown in Fig. 4, through the channel or passage 50 furnishes communication between the passage 49 and a passage 51, leading from which to the upper end of the cylinder is a passage 52, and with the piston valve 39, in the position shown in Fig. 4, a passage 53, leading from the lower end of the chamber of the cylinder 1 and in communication with a circumferential passage 54, is brought into communication with a passage or opening 55 formed in the wall of the piston valve 59 at one end thereof, so that fluid pressure or steam from the lower end of the cylinder 1

can enter the chamber of the hollow piston valve 39 as the piston of the cylinder 1 descends. The opposite end of the hollow piston valve 39 has a passage or opening 56 which, with the valve in the position shown in Fig. 4, communicates with a circumferential passage 57 in the wall of the cylinder or chest 32; and this passage, through a passage 58, communicates with the upper end of the cylinder 2, so that fluid pressure can pass from the exhaust side of the piston 16 as the piston descends, and, by means of the passages 53, 54, hollow piston valve 39, and passages 57 and 58, enter the cylinder 2 to act against the piston of said cylinder and force such piston to descend. A passage 59 leads from the lower end of the cylinder 2 and communicates with an annular passage 60 in the wall of chest 32, which passage, when the piston valve 39 is in the position shown in Fig. 4, is open for the fluid pressure or steam to escape into the chamber 38, below the piston 39 so as to exhaust therefrom.

A port 61 is formed in the wall of the chest or cylinder 32 adjacent to the upper end thereof, and a port 62 is formed in the wall of the chest or cylinder 32 adjacent to the lower end thereof. The ports 61 and 62 are opened as the piston valve is depressed or raised, and these ports open into a passage 63 formed in a wall 64 on the exterior of the chest or cylinder 32; and the passage 63 is in alinement with a passage 65 formed in a wall 66 on the exterior of the chest or cylinder 33, so that the fluid pressure exhausted from either end of the chamber 38 can flow into the passage 63 and enter the passage 65 for admission to the chamber of the chest or cylinder 33 and its passage be controlled by the piston valve 41 in said chamber. The passages 63 and 65 are connected together by a short tube 67 having a right and left screw thread, on which tube is a nut or head 68 by means of which the tube can be secured in position forming free communication between the passages 63 and 65 for the flow of pressure through the passages.

A port or passage 69 leads from the end of the passage 66 and is in communication with a circumferential passage 70, formed in the inner face of the wall of the chest or cylinder 33, with which passage a circumferential passage 71 on the exterior of the piston valve 41 is in communication. A circumferential passage 72 is formed in the inner face of the wall of the chest or cylinder 33 which can be brought into communication with the passage 70 by the passage 71, and from the passage 72 a passage 73 opens into the upper end of the chamber of the power cylinder 3 for admitting pressure to such end of the cylinder, when the hollow piston valve is in the position shown in Fig. 4, such pressure coming from the exhaust pressure from the power cylinder 2. A passage in the wall of the power cylinder 3 leads from the lower end of the chamber of said cylinder, and this passage 74 is in communication with a circumferential passage 75 formed in the inner face of the wall of the chest or cylinder 33. The passage 75, when the hollow piston valve 41 is in the position shown in Fig. 4, is in communication with a passage or opening 76 cut through the wall of the hollow piston valve 41 so that pressure can enter the interior of the valve. A passage or opening 77 is formed through the wall of the hollow piston valve at the opposite end of the passage or opening 76, and this passage or opening, when the valve is in the position shown in Fig. 4, is in communication with a circumferential passage 78, formed in the inner face of the wall of the chest or cylinder 33, and from the passage 78 a passage 79 leads and opens into the upper end of the power cylinder 4 for admitting pressure to the upper end of the power cylinder. A passage 80 is formed in the wall of the cylinder 4 and opens into the lower end of the chamber of the cylinder, and this passage 80 is in communication with a circumferential passage 81 formed in the inner face of the wall of the cylinder 33. A port or passage 82 leads from the upper end of the chest or cylinder 33, and a port or passage 83 leads from the lower end of the chest or cylinder 33, and these ports or passages 82 and 83 both open into a passage 84 formed in a wall 85 on the exterior of the chest or cylinder, and from the passage 84 a port or passage 86 opens to the atmosphere.

It will be understood that the construction of hollow piston valve and arrangement of ports and passages apply to both of the batteries of power cylinders, that is each of the two cylinders of the two batteries of cylinders has a controlling valve with the ports and passages as described. The piston valve for the two cylinders of each pair of cylinders, when in the position shown in Fig. 4, opens communication for the fluid pressure to enter the cylinder 1 initially through the passage 52, and exhaust from such cylinder through the passage 53 to enter the interior of the hollow piston valve 39 and pass into the upper end of the cylinder 2 through the passage 58 and exhaust from the lower end of the cylinder 2 through the passage 59 to flow through the exhaust port 62 into the passage 63 and, by means of the passages 63 and 65 and port or passage 69, enter the chamber of the chest or cylinder 33 to pass through the passage 73 into the upper end of the chamber of the cylinder 3 and exhaust at the lower end of the chamber of the cylinder 3 through the passage 74 and enter the hollow piston valve to flow through the passage 79 into the upper end of the chamber of the cylinder 4 and exhaust from the lower end of the chamber of such cylinder through the passage 80 and escape through the port 83

into the passage 84 and finally exhaust to the air through the port or passage 86. This admission of fluid pressure to the various cylinders drives the pistons of the respective cylinders toward the lower end by reason of the pressure exerted on the upper face of the pistons, and at the same time exhausts fluid pressure from the under side of the pistons.

The flow of pressure into the upper portion of the chambers of the several power cylinders continues until the hollow piston valve is shifted into the position shown in Fig. 5, in which position the admission of fluid pressure to the chambers of the respective cylinders is reversed. The initial pressure enters the lower end of the chamber of the cylinder 1 through the passage 53 and exhausts from the upper end of the chamber of the cylinder 1 through the passage 52 and enters the interior of the hollow piston valve and discharges from such valve into the passage 59 to enter the lower end of the chamber of the cylinder 2 and exhausts from the upper end of the chamber of the cylinder 2 through the passage 58 and escape through the port 61 into the passage 63 and enters the passage 65 to pass through the port or passage 69 into the chamber of the chest or cylinder 33, and from its point of admission into such chamber flow through the passage 74 into the lower end of the chamber of the cylinder 3 and exhaust from the upper end of such chamber through the passage 73 to enter the interior of the hollow piston valve and pass into the passage 80 to enter the lower end of the chamber of the cylinder 4 and exhaust from the upper end of the chamber of the cylinder 4, through the passage 79 and flow out through the port or passage 82 into the passage 84 and pass through the port or passage 86 to the atmosphere. It will thus be seen that, with the hollow piston valves 39 and 41 in the position shown in Fig. 4, the fluid pressure passes to the upper end of the four cylinders of the battery of power cylinders to drive the pistons of the respective cylinders down; and, with the hollow piston valves in the position shown in Fig. 5, the fluid pressure enters the lower end of the cylinders composing the battery of cylinders and operates to drive the pistons of the respective cylinders up, so that, as the position of the hollow piston valves is changed by the eccentric, the fluid pressure is directed alternately into the upper and lower ends of the power cylinders and is exhausted alternately from the lower and upper end of the power cylinders, thus enabling pressure initially entering the first power cylinder to exhaust through the intermediate power cylinders and the final power cylinder, and escape to the atmosphere after the complete expansion thereof.

It will be noticed that the ports or passages 61 and 62 and 82 and 83 each open into the ends of the respective chests or cylinders 31 and 33, and that the ports or passages 61 and 62 are in communication with the passage 63, so that the fluid pressure exhausting from either end of the chest or cylinder 1 is free to enter both ends of the chest or cylinder 31 to act on the hollow piston valve in the chest or cylinder 31, and balance the controlling valve; and it will also be seen that the fluid pressure exhausting from the power cylinder 3 is free to enter both ends of the chest or cylinder 33 and exert a pressure on the hollow piston valve in the chest or cylinder 33 to balance such valve.

The operation will be understood from the foregoing description. The pressure initially entered into the smaller power cylinder 1 passes to the power cylinder 2 where it is expanded; and from the power cylinder 2 passes to the power cylinder 3 where it is again expanded, and from the power cylinder 3 passes to the power cylinder 4 where it is finally expanded and exhausted to the air. The admission of the fluid pressure to either end of the power cylinders is controlled by the position of the hollow piston valve, as is also the exhaust of the fluid pressure from the power cylinders. The engine, consisting of two sections, each section composed of a battery of four power cylinders, furnishes a great power, and enables the engine as a whole to occupy but a small space, making an engine very desirable for use with automobiles, auto-trucks, or on cars, where a high power is desired and only a limited space is furnished in which to locate the engine, boiler, and other appliance. The controlling valves do not move in unison, owing to the connection with the eccentric, and their movements are so graduated that when one set of controlling valves is fully opened for the full admission of fluid pressure to the battery of cylinders the other set of controlling valves is initially opened while the pistons of the power cylinders of the first set of controlling valves are moving in the direction of their full stroke either way, thus enabling fluid pressure to be applied to the two batteries of power cylinders in such manner as to maintain a constant pressure for driving the shaft. The pressure exhausted from the initial and intermediate cylinders is free to enter the chambers of the two controlling valves for the power cylinders at both ends, so as to maintain the controlling valves in balance, and the controlling valves for the cylinders of the two batteries of power cylinders are so actuated as to simultaneously admit pressure to and exhaust pressure from the four cylinders during the stroke of the pistons of the cylinders, thus insuring a perfect and continuous action for the pistons.

The battery of cylinders can be made up of a plurality of cylinders and can be of two, three, four or more cylinders as may be de-

sired with a controlling valve for each battery of cylinders.

What I regard as new and desire to secure by Letters Patent is:

1. In an expansion engine, the combination of two companion batteries of power cylinders standing at right angle relation, each battery composed of a plurality of cylinders gradually increasing in diameter from the first cylinder to the last, with the cylinders in pairs and the cylinder of each pair side by side and the two cylinders tandem, for the cylinders of the rear pair of cylinders to be in end alinement with the cylinders of the front pair of cylinders, a fluid pressure receiving chest for each pair of cylinders of the battery of cylinders, located between and parallel with the cylinders and one chest in advance of the other, a central circumferential fluid supply passage for the interior of each chest, inner circumferential passages in the connecting wall of each chest and its cylinders and opening into the interior of the chest, one on each side of the central circumferential fluid supply passage, outer circumferential passages in the connecting wall of each chest and its cylinders and opening into the interior of the chest one at each end of the chest, longitudinal passages in the connecting wall on each chest and its cylinders on one side, one passage for each inner circumferential passage of each pressure receiving chest, the passages leading to opposite ends of the first cylinder of the pair of power cylinders in the chest, a longitudinal passage in the connecting wall of each chest and its cylinders on one side, one passage for each outer circumferential passage of the pressure receiving chest, the passages leading to opposite ends of the second cylinder of the pair of power cylinders of the chest, an exhaust port at each end of the chest, a passage in the wall of the chest in communication with the exhaust ports for inducting and educting pressure into and from each pair of power cylinders, a hollow piston valve for each chest, each valve closed at each end and having an exterior circumferential central passage, and a passage through its wall on each side of the exterior passage and leading into the interior of the valve for controlling the induction and eduction of pressure into and from the pair of power cylinders, and means for reciprocating the valves in unison, substantially as described.

2. In an expansion engine, the combination of two companion batteries of power cylinders standing at right angle relation, each battery composed of four cylinders gradually increasing in diameter from the first cylinder to the last, a fluid pressure receiving chest for each pair of cylinders of the four cylinders, a central annular passage in the inner face of the wall of each pressure receiving chest, a port leading into the central passage, an annular passage in the inner face of the wall of each pressure receiving chest on each side of the central passage therein, passages leading from the last named annular passages to the opposite ends of the power cylinders, an eduction port at each end of each pressure receiving chest, an eduction passage common to the two eduction ports of each pressure-receiving chest, a hollow piston valve for each pressure-receiving chest, an exterior circumferential passage for each valve in communication with the central annular passage of the chest, and a passage at each end of each valve opening from the interior of the valve and adapted to open communication with the passages in the chest on each side of the central passage, substantially as described.

3. In an expansion engine, the combination of two companion batteries of power cylinders standing at right angle relation, each battery composed of four cylinders gradually increasing in diameter from the first cylinder to the last and having two of the four cylinders in axial alinement with each other, a piston in each power cylinder, a piston rod common to two cylinders in axial alinement, a cross head for the two piston rods, a pitman for each cross head, a crank pin, a disk carrying the crank pin, a driving shaft having the disk fixed thereon, a fluid pressure-receiving chest for each pair of cylinders of the four cylinders, passages leading to the opposite ends of each cylinder from the pressure-receiving chest for inducting and educting pressure into and from the power cylinders, and a hollow piston valve for each pressure-receiving chest controlling the induction and eduction of pressure into and from the four cylinders, substantially as described.

4. In an expansion engine, the combination of two companion batteries of power cylinders standing at right angle relation, each battery composed of four cylinders gradually increasing in diameter from the first cylinder to the last and having two of the four cylinders in axial alinement with each other, a piston in each power cylinder, a piston rod common to two cylinders in axial alinement, a cross head for the two piston rods, a pitman for each cross head, a crank pin, a disk carrying the crank pin, a driving shaft having the disk fixed thereon, a fluid pressure-receiving chest for each pair of cylinders of the four cylinders, a central annular passage in the inner face of the wall of the pressure-receiving chest, a port leading into the central passage, an annular passage in the inner face of the wall of the pressure-receiving chest on each side of the central passage therein, passages leading from each last named annular passage to the opposite ends of the power cylinders, an eduction passage common to the two eduction ports of each

pressure-receiving chest, a hollow piston valve for each pressure-receiving cylinder, an exterior circumferential passage for each valve in communication with the central annular passage of the chest, and a passage at each end of each valve opening from the interior of the valve and adapted to open communication with the passages in the chest on each side of the central passage, substantially as described.

5. In an expansion engine, the combination of two companion batteries of power cylinders standing at right angle relation, each battery composed of four cylinders gradually increasing in diameter from the first cylinder to the last and having two of the four cylinders in axial alinement with each other, a piston in each power cylinder, a piston rod common to two cylinders in axial alinement, a cross head for the two piston rods, a pitman for each cross head, a crank pin, a disk carrying the crank pin, a driving shaft having the disk fixed thereon, a fluid pressure-receiving chest for each pair of cylinders of the four cylinders, a central annular passage in the inner face of the wall of the pressure-receiving chest, a port leading into the central passage, an annular passage in the inner face of the wall of the pressure-receiving chest on each side of the central passage therein, passages leading from each last named annular passage to the opposite ends of the power cylinders, an eduction passage common to the two eduction ports of each pressure-receiving chest, a hollow piston valve for each pressure-receiving cylinder, an exterior circumferential passage for each valve in communication with the central annular passage of the chest, a passage at each end of each valve opening from the interior of the valve and adapted to open communication with the passages in the chest on each side of the central passage, a piston rod for each hollow piston valve, and an eccentric and connection for actuating the piston valves through their respective piston rods, substantially as described.

6. In an expansion engine, the combination of four power cylinders gradually increasing in diameter from the first cylinder to the last arranged in tandem pairs with the cylinders of each pair side by side, and having the two cylinders of the rear pair of cylinders in axial alinement with the two cylinders of the front pair of cylinders, a fluid pressure receiving chest for each pair of cylinders of the four cylinders, each chest located between its pair of cylinders and one chest in advance of the other, a central circumferential fluid supply passage for the interior of each chest, inner circumferential passages in the connecting wall of each chest and its cylinders and opening into the interior of the chest, one on each side of the central circumferential fluid supply passage, outer circumferential passages in the connecting wall of each chest and its cylinders and opening into the interior of the chest at each end of the chest, longitudinal passages in the connecting wall of each chest and its cylinders on one side, one passage for each inner circumferential passage of the pressure-receiving chest, the passages leading to opposite ends of the first cylinder of the pair of power cylinders of the chest, longitudinal passages in the connecting wall of each chest and its cylinders on one side, one passage for each outer circumferential passage of the pressure-receiving chest, the passages leading to opposite ends of the second cylinder of the pair of power cylinders of the chest for inducting and educting pressure into and from the four power cylinders, an exhaust port at each end of the chest, a passage in the wall of the chest in combination with the exhaust ports, and a hollow valve in each pressure-receiving chest, each valve closed at both ends and having an exterior circumferential central passage and a passage through its wall on each side of the exterior passage and leading into the interior of the valve for controlling the induction and eduction of pressure into and from each pair of power cylinders, and means for reciprocating both valves in unison, substantially as described.

7. In an expansion engine, the combination of a battery of power cylinders composed of four cylinders gradually increasing in diameter from the first cylinder to the last arranged in tandem pairs with the cylinders of each pair side by side, with the smaller cylinder in axial alinement with the second intermediate cylinder and the larger cylinder in axial alinement with the first intermediate cylinder, the smaller cylinder and the first intermediate cylinder constituting the rear pair of cylinders, and the second intermediate cylinder and the larger cylinder constituting the front pair of cylinders, a primary fluid pressure-receiving chest for the rear pair of cylinders, a central circumferential fluid supply passage for the interior of the chest, inner circumferential passages in the connecting wall of the chest and cylinders and opening into the interior of the chest one on each side of the central circumferential fluid supply passage, outer circumferential passages in the connecting wall of the chest and cylinders and opening into the interior of the chest one at each end of the chest, longitudinal passages in the connecting wall of the chest and smaller cylinder, one passage for each inner circumferential passage of the pressure-receiving chest, the passages leading to opposite ends of the cylinder, congitudinal passages in the connecting wall of the chest and first intermediate cylinder, one passage for each outer circumferential passage of the pressure-receiving chest, the passages leading to opposite ends of the cyl-

inder, an exhaust port at each end of the chest, a passage in the wall of the chest in communication with the exhaust ports, a fluid pressure-receiving chest for the front pair of cylinders in end alinement with the chest of the rear pair of cylinders, a central circumferential fluid supply passage for the interior of the chest, in communication with the exhaust passage of the primary chest, inner circumferential passages in the connecting wall of the chest and second intermediate power cylinder and opening into the interior of the chest one on each side of the central circumferential fluid supply passage, outer circumferential passages in the connecting wall of the chest and the larger power cylinder and opening into the interior of the chest one at each end of the chest, longitudinal passages in the connecting wall of the chest and intermediate second power cylinder, one passage for each inner circumferential passage of the pressure-receiving chest, the passages leading to opposite ends of the second intermediate power cylinder, longitudinal passages in the connecting wall of the chest and the larger power cylinder, one passage for each outer circumferential passage of the pressure-receiving chest, the passages leading to opposite ends of the larger power cylinder for inducting and educting pressure into and from the respective power cylinders, an exhaust port at each end of the chest, a passage in the wall of the chest in communication with the exhaust ports, and a valve for each pressure-receiving chest, each valve closed at both ends and having an exterior circumferential central passage and a passage through its wall on each side of the exterior passage and leading into the interior of the valve for controlling the induction and eduction of pressure into and from the pair of power cylinders cooperating with the respective chests, and means for reciprocating both valves in unison, substantially as described.

ELLSWORTH BELKNAP.

Witnesses:
HUGH W. SHAY,
JOSEPH A. DAVISON.