No. 625,758.

Patented May 30, 1899.

E. W. HARDEN.

COMPOUND ENGINE.

(Application filed Oct. 24, 1898.)

(No Model.)

2 Sheets—Sheet 1.

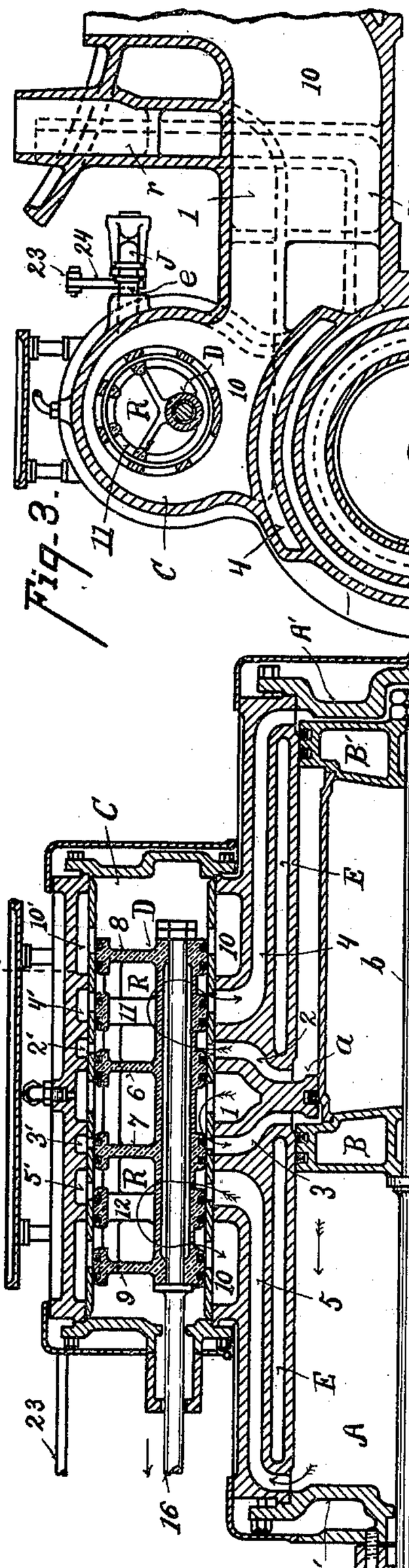

Fig. 3.

Fig. 2.

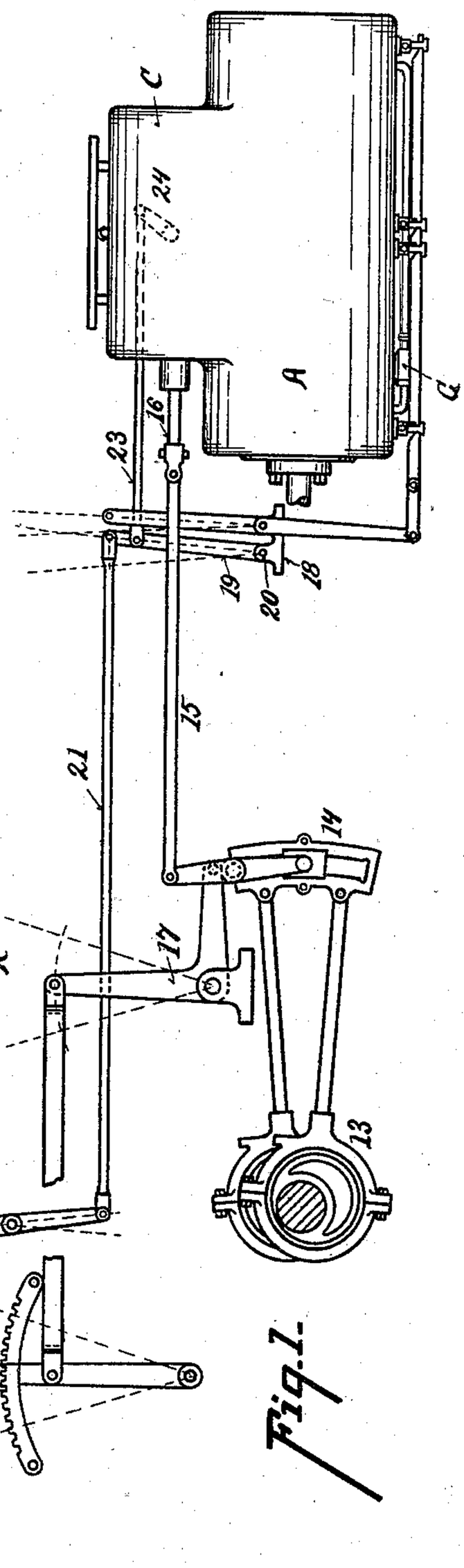

Fig. 1.

Witnesses
Oliver B. Kaiser.
W. R. Wood

Inventor
Edward W. Harden
By Wood & Boyd
Attorneys

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(No Model.) 2 Sheets—Sheet 2.

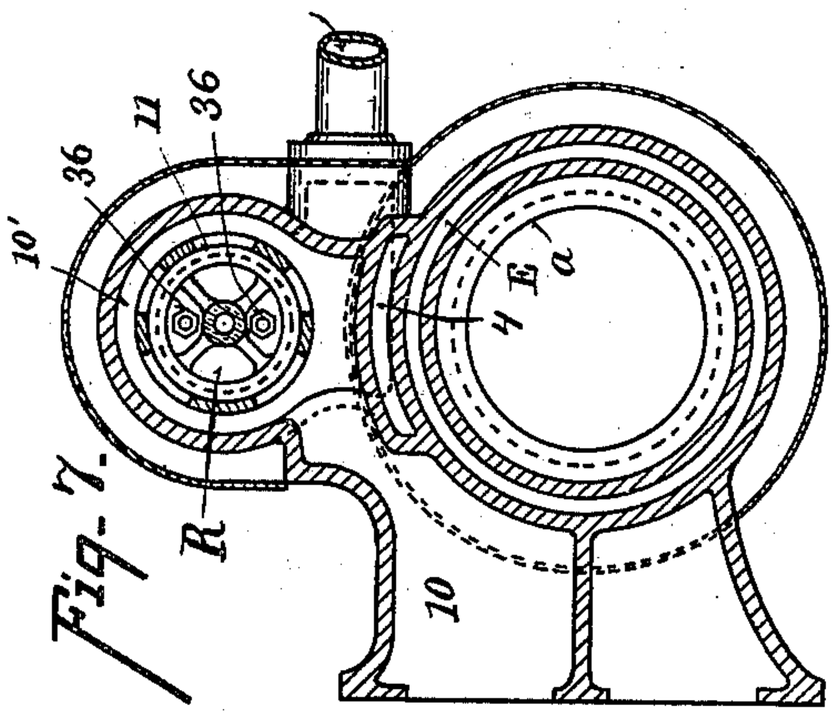

Fig. 7.

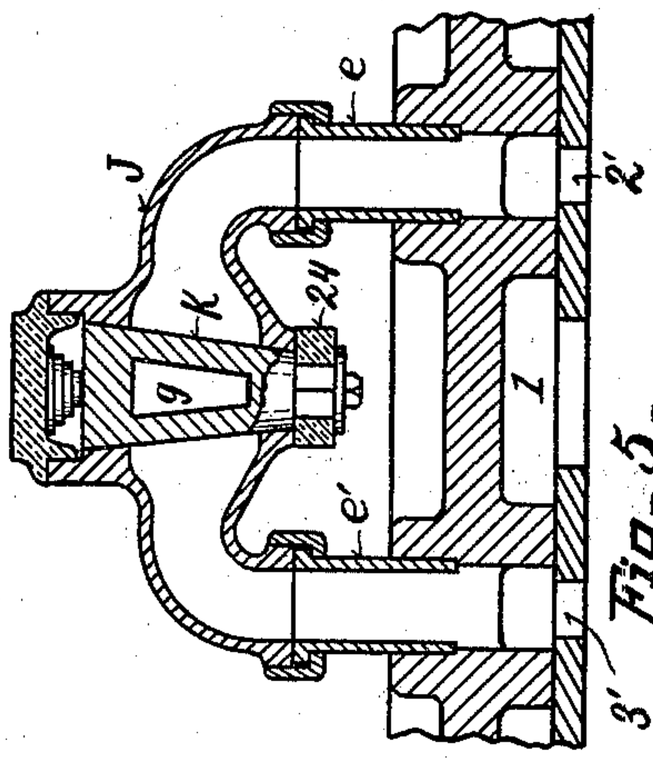

Fig. 5.

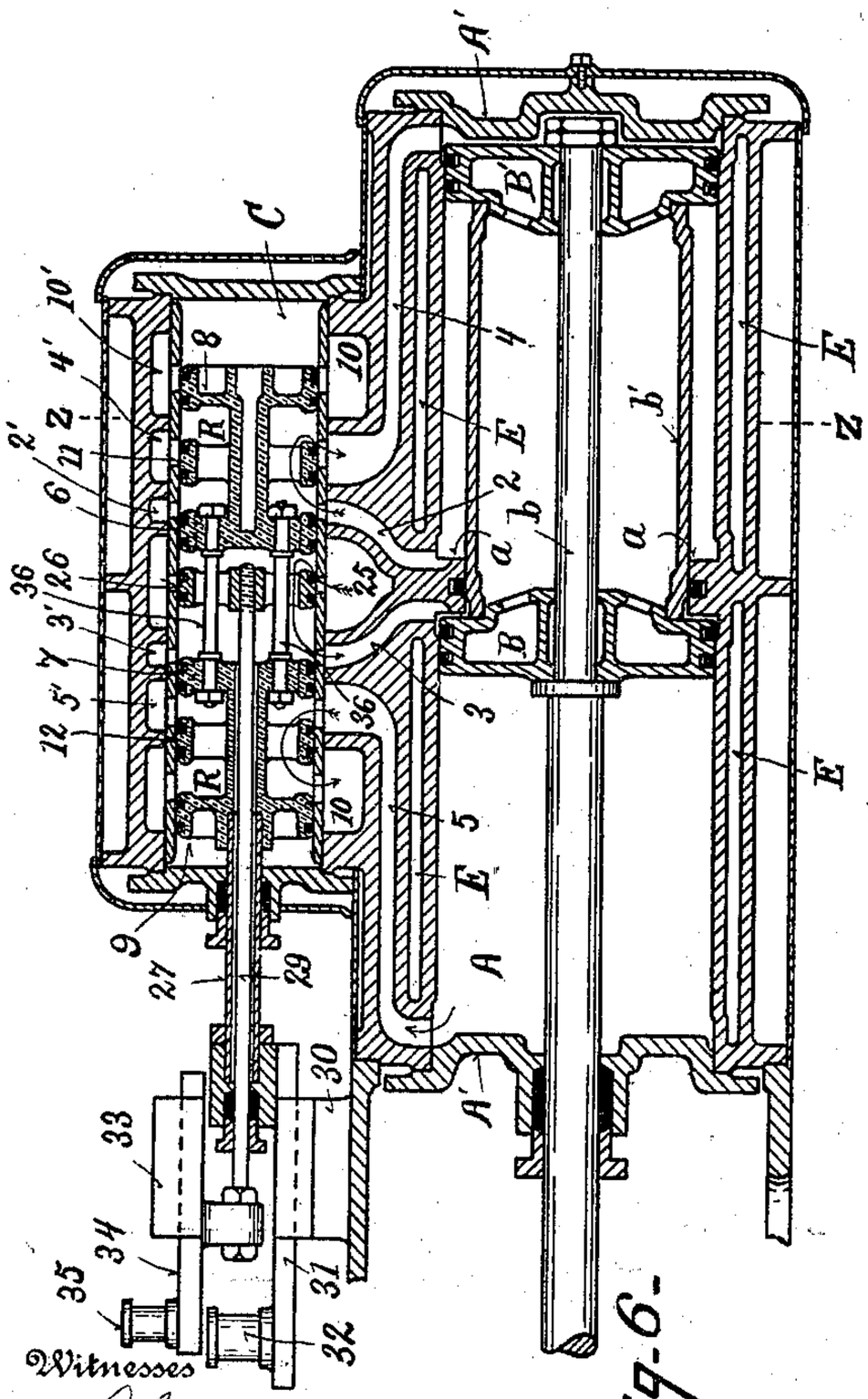

Fig. 6.

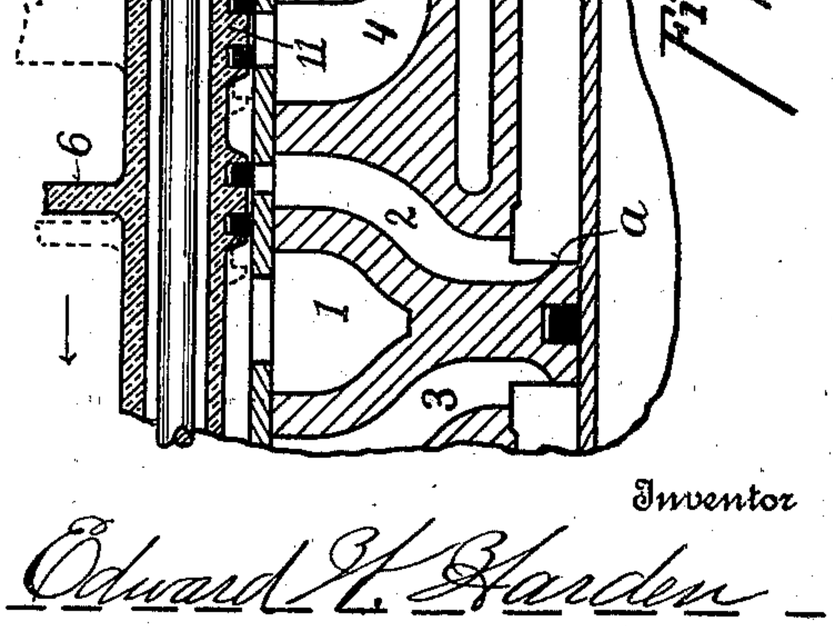

Fig. 4.

Witnesses
Oliver B. Kaiser.
N. R. Wood.

Inventor
Edward W. Harden
by Wood & Boyd
Attorneys

UNITED STATES PATENT OFFICE.

EDWARD W. HARDEN, OF CINCINNATI, OHIO, ASSIGNOR TO FREDERIC C. WEIR, OF SAME PLACE; LEVI C. WEIR EXECUTOR OF SAID FREDERIC C. WEIR, DECEASED.

COMPOUND ENGINE.

SPECIFICATION forming part of Letters Patent No. 625,758, dated May 30, 1899.

Application filed October 24, 1898. Serial No. 694,382. (No model.)

To all whom it may concern:

Be it known that I, EDWARD W. HARDEN, residing at Cincinnati, in the county of Hamilton and State of Ohio, have invented certain new and useful Improvements in Compound Engines, of which the following is a specification.

My invention relates to the novel construction of a compound engine of the general type shown in Letters Patent No. 597,433, granted October 24, 1893. This type of engines employs pistons the opposite faces of which are of different areas, the smaller one being acted upon by high-pressure steam, which is compounded upon the larger piston-face.

One of the objects of the present invention is to provide a piston-valve that will control in a novel manner the admission and release of the steam from the high and low pressure ports as well as the final exhaust.

In said Patent No. 597,433 the steam is admitted from the high-pressure port directly into the low-pressure port at the instant of opening said high-pressure port and without any means of controlling said steam except the high-pressure-port cut-off. I have found by experience that in order to have a speedy-acting engine it is desirable to release the steam in the high-pressure cylinder before the piston has reached the end of its stroke. In an engine of the present type if this release is made the steam would be admitted directly onto the larger face, and hence the piston would be acted upon by the steam upon both sides. I overcome this difficulty and accomplish the quick release by the form of valve here shown. This consists of three cut-off sections, one controlling the high-pressure port, one the final exhaust-port, and the other the intermediate or skeleton cut-off interposed between the other two and controlling the intermediate low-pressure port. I also utilize the space between the two outside cut-offs, which are solid disks, to form a reservoir or pocket to receive and hold the steam released from the high-pressure port until the time desired to compound it upon the larger piston. I have found by practical experience that this form of valve gives a better result as to the speed and power of the engine.

Another object of my invention is to employ a steam-jacket on this type of compound engine which is continually supplied with live steam direct from the boiler, thereby maintaining the temperature of the chamber of the cylinder approximately the same as the induction-steam in the high-pressure cylinder, and thereby preventing the cooling of the walls of the cylinder when the steam is compounded as low pressure on the piston.

Another object of my invention is to provide improved means for trapping off the steam from the jacket.

Another object of my invention is to provide improved means within the valve and valve-chamber for converting the compound engine into a simple engine. This is accomplished by introducing a converting-valve between the two high-pressure ports of such construction that when said converting-valve is open communication is established between the two high-pressure ports, but as one of these ports is alternately opened by the main valve and when open exhausts its steam on the other end of the piston it follows that direct steam will be acting on and in the same direction on the larger and smaller pistons. I have found it to be of material advantage to apply this converting-valve direct to the steam-chest in such a manner as to establish communication readily and at will between the two high-pressure ports for converting a compound into a simple engine.

Another object of my invention is to provide an independent piston-cut-off valve, located between the piston cut-offs, controlling the high-pressure ports of the main valve for controlling the initial admission of steam from the induction-ports.

The various features of my invention are more fully set forth in the description of the accompanying drawings, making a part of this specification, in which—

Figure 1 is a diagram showing an engine in side elevation with the eccentrics and starting and controlling levers. Fig. 2 is a central longitudinal section through the engine. Fig.

3 is a section on line *x x*, Fig. 2. Fig. 4 is a detail view showing a different position of the valve and piston from that shown in Fig. 2. Fig. 5 is a detail view of a converting-valve. Fig. 6 is a central longitudinal section through a modification adapted to be used as a stationary engine. Fig. 7 is a section on line *z z*, Fig. 6.

A represents a cylinder; A', the heads thereof.

a represents a bridge-wall which serves as a partition to divide the central portion of the cylinder into two compartments.

B B' represent piston-heads mounted upon the piston-rods *b*.

b' represents a cylinder or drum interposed between the two piston-heads.

C represents the steam-chest; D, a piston-valve mounted therein.

1 represents the induction-port; 2 3, the high-pressure-steam ports; 4 5, the low-pressure and exhaust steam ports and passages.

6 represents a piston cut-off controlling the high-pressure port 2.

7 represents a piston cut-off controlling the other high-pressure ports 3.

8 9 represent pistons controlling the final exhaust-ports 10.

11 12 represent the ring or skeleton cut-off controlling the ports 4 5, respectively. This ring or skeleton form is for the purpose of making the space between the disks 6 and 8 and 7 and 9 continuous, so as to form pockets or reservoirs in each half of the piston-valve, for a purpose which will be hereinafter explained.

It will be observed that each one of the ports 2, 3, 4, 5, and 10 is controlled by a separate cut-off or piston-face operated by a common valve-stem. It will be observed also that each end of the cylinder and piston is a duplicate of the other and has correspondingly-formed ports, so that a double or duplex engine is produced.

The mode of operation of the valve is as follows: In Fig. 2 the high-pressure port is shown as exhausting steam into the low-pressure port 4 at the initial movement of the return stroke, and that port 3 is supplying high-pressure steam to the piston B, and that the low-pressure port 5 is making a final exhaust through port 10, the valve moving at this period in the same direction as that of the piston. As before stated, it is desirable to release the steam from the high-pressure port before it is allowed to pass into the low-pressure port to be compounded. In practice the steam is cut off—say at the point *j* (shown in Fig. 4)—and the steam used expansively for the remainder of the stroke; but it is desirable to release the steam when the piston B' has arrived at the position shown in full lines, Fig. 4. If the connection between ports 2 and 4 were established at this time, the same steam would be acting on both sides of the piston and a loss of power would result. By providing the ring cut-off section 11 port 4 is kept closed until the piston B' has reached the end of its stroke, as shown in dotted lines. The valve in the position shown in Fig. 4 is moving in a direction opposite to that of the piston. Port 2 is open during the time the piston has traveled from the point shown in full lines to that shown in dotted lines, or the end of the stroke, and port 11 is kept closed. The steam from port 2 during this time fills the pocket or reservoir R, which is formed between the piston-disks 6 and 8, and when the valve has traveled in the direction shown by the arrow in Fig. 4 far enough to uncover port 4 the steam from pocket R and that which is being released by the return stroke of the piston is compounded on the larger piston-face. Of course the opposite end of the engine operates in the same manner, only alternately with the part just described.

In a compound engine of this type it is desirable to prevent the cooling of the cylinder due to the compounding of the steam on the same surface and to maintain a comparative temperature due to that of the initial heat of the high-pressure steam. To accomplish this, I provide a steam-jacket E, surrounding the cylinder and interposed between ports 4 and 5 and the walls of the cylinder. This jacket is supplied with high-pressure steam direct from the boiler by means of pipe *n*, as shown in Fig. 2. In order to remove the water of condensation, I provide a gutter F, opening into the lower side of the steam-jacket and depending below the same. This gutter is provided with a steam-trap G to carry off the water of condensation. This trap may be of any well-known form of construction. By having a gutter depend below the jacket and comparatively large area it is partially filled with steam, as well as condensed water, and assists in maintaining a higher temperature of the walls of the cylinder than could be obtained if the condensed water were allowed to rest within the steam-jacket itself. I obtain a new result by the use of this steam-jacket in a compound engine of the type which compounds the steam in the same chamber or cylinder in which the high pressure is utilized. When steam is expanded onto the piston, the temperature is reduced by the expansion of the steam, following "Mariotte's Law of Expansion P X V $\frac{17}{16}$." This reduction in temperature due to the compounding of the steam is materially greater and the initial condensation of the steam is proportionally larger than that due to the expansion of the high-pressure steam. By the use of a steam-jacket as herein shown and described, the inner wall of the cylinder is maintained approximately at the temperature of the high-pressure steam and consequently the expansion of the low-pressure steam instead of cooling the cylinder-surface to a larger extent than hitherto obtained, is heated by the walls of the cylinder,

thus preventing condensation, and maintaining a higher expansion-line than the "adiabatic curve," which would otherwise take place. The heat taken up from the walls of the cylinder is supplied and maintained by the constant supply of steam in the steam-jacket, and practically the entire condensation in the cylinder occurs in the gutter F within the steam-jacket, and a very high useful effect is obtained from the engine.

I have found by actual experiment that the amount of live steam employed in the steam-jacket and ultimately condensed in the gutter is very materially less in amount of condensed water than the water of condensation in the cylinder itself when no steam-jacket is employed.

It is sometimes desirable, and especially in locomotives, to convert a compound into a simple engine for the purpose of starting a train or going up a steep grade. I accomplish this by the converting-valve, applied direct in the steam-chest. This converting-valve is shown in Figs. 3 and 5, and the apparatus for operating the same is shown in Fig. 1. It will be observed in Fig. 2 that the ports 2, 3, 4, and 5 in the cylindrical steam-chamber each have an annulus upon the interior walls of the chest, of equal area to the several port-openings of the steam-chest, and these are indicated by figures 2′, 3′, 4′, and 5′, upon one side of the steam-chest. I mount pipe extensions *e e′*, which pipe extensions extend into the walls I of the steam-chest and communicate with the high-pressure annulus 2′ 3′. J represents an elbow-pipe rigidly secured to the pipes *e e′*. K represents a plug-valve; *g*, an opening formed through the plug. When this plug is turned so that its opening is coincident with the pipe-passages, live steam is admitted from port 3 into port 2, or vice versa, and when piston B is receiving direct steam piston B′ is receiving steam through port 4 from port 2. It follows that both pistons B B′ are being acted upon by the high-pressure steam and the engine is working simple. In Fig. 1 I have shown the method of operating this converting-lever. 13 represents the ordinary eccentrics; 14, the ordinary links; 15, the connecting-rod for operating the main-valve stem 16. 17 represents the bell-crank lever for reversing the main valve. 18 represents a fulcrum upon which is pivoted a link-arm 19. 20 represents a connecting-rod passing through and connecting with a duplicate link-arm on the opposite side of the engine. 21 represents a connecting-rod operated by lever 22. 23 represents a connecting-rod hinged to arm 19 and to crank-arm 24, which crank-arm is connected to the stem of plug-valve K, as shown in Figs. 3 and 5. By moving the lever 22 plug-valve K is rotated one-fourth of a revolution to open and close the same.

In Fig. 6 I have shown the form of piston-valve especially designed for stationary engines, or that type of engine employing an automatic cut-off. It is desirable to employ a piston-cut-off valve, and this is accomplished in the following manner: 25 represents the induction-port for admitting steam into the high-pressure ports 2 and 3. 26 represents a piston cut-off located between the piston-disks 6 and 7. The main piston-valve employs a hollow valve-stem 27, connected to the hub of disk 9. 29 represents the piston-rod of the cut-off valve, which journals and reciprocates within the sleeve piston-stem 27. 30 represents the guide for the slide 31; 32, the wrist-pin thereof. 33 represents the guide of the cut-off valve, 34 the slide, and 35 the wrist-pin of slide 34.

It will be observed that the construction of the cylinder piston-ports, piston-valve, and disk cut-offs shown in Fig. 6 is the same as that shown in Fig. 2 except the change of location of the valve-rod and its connection.

In the cut-off valve it is preferred to have the valve-rod centrally located, so as to better connect the duplex sections of the main valve, which is accomplished by means of the rods 36, that connect disks 6 and 7 together. This provides space for the independent movement of the cut-off valves between said disks.

It will be observed that each piston of my engine and the controlling parts thereof are duplicates one of the other and that consequently the main valve is a duplex piston-valve, the novel features of which consist in interposing a ring or skeleton cut-off between the disk and cut-off of the high-pressure port and final exhaust-port, and that this ring controls the low-pressure port located between the other two ports. I believe I am the first to provide the three cut-offs for each of said ports and the first to employ the space between the two disk cut-offs for a temporary pocket or reservoir, and I also believe I am the first to employ a converting-valve applied direct to a steam-chest to connect and disconnect the high-pressure ports of a compound engine, each of which admits steam into a duplex cylinder to operate upon pistons connected to a common rod, thereby obtaining a highly-useful effect. I also believe I am the first to employ a steam-jacket in an engine supplied with steam direct from the boiler, which is adapted to reheat the steam in the act of compounding, and I do not wish to limit myself in these respects to the specific devices herein shown and described.

I have shown in the drawings the gutter F of two steam-jackets connected together and a trap L connected to a pipe which taps each end of said gutter. It is obvious that the gutters of each of said steam-jackets need not be connected and that each can be emptied by a separate trap, if desired.

Having described my invention, what I claim is—

1. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, and an outside exhaust-port in each cylinder, the combination of a cylindrical steam-chest, a piston-valve, operating therein, and having a cut-off section for the high-pressure port, for the low-pressure port and for the exhaust-port, whereby the admission and escape of the steam of each of said ports is controlled by its respective cut-off, substantially as specified.

2. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, an outside exhaust-port in each cylinder, the combination therewith of a cylindrical steam-chest, the piston-valve operating therein, and having a disk cut-off section for the high-pressure port, a separate disk section for the exhaust-port, and a ring cut-off section intermediate between the said disk sections, and controlling the low-pressure port, and a temporary steam-receiving pocket formed between said outside disk cut-off sections for receiving steam from the high-pressure port in the manner substantially as described.

3. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, and an exhaust outside port in each cylinder, the combination therewith of a cylindrical steam-chest, and a piston-valve having cut-off sections controlling each of the said ports at each end of the steam-chest and operated by a common valve-stem, substantially as herein specified.

4. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, and an outside exhaust-port in each section, the combination therewith of a steam-chest, a duplex valve, provided with separate cut-off sections for controlling each steam-port and a converting-valve located in branch extensions of the two high-pressure steam-ports, means for operating said valve whereby live steam may be at pleasure simultaneously admitted into the two high-pressure ports, substantially as shown and described.

5. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, and an outside exhaust-port in each section, the combination therewith of a steam-chest, a duplex valve provided with separate cut-off sections for controlling each steam-port and a converting-valve located in branch extensions, tapping the two high-pressure ports, and extending outside of the steam-cylinder and connected together, a cut-off valve located at the junction of said extensions and means for operating the same whereby live steam admitted into one of said ports may be directly admitted through said extension into the other live-steam port, substantially as specified.

6. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, and an outside exhaust-port in each cylinder, the combination therewith of a steam-chest, a plural cut-off main valve provided with a hollow valve-stem and having cut-off sections for controlling the high-pressure and exhaust ports and an induction-port in the steam-chest located between the high-pressure ports and a cut-off valve controlling said induction-ports and operated by a valve-stem extending through the hollow stem of the main valve, substantially as specified.

7. In a compound engine having a duplex cylinder and a double piston for each cylinder, the opposing faces of each of which are of different areas, a live-steam port leading to the smaller piston-face, a low-pressure port leading to the larger piston-face, and an outside exhaust-port for each cylinder, the combination therewith of a cylindrical steam-chest, having a main piston-valve having a plurality of cut-off sections each controlling its respective ports and connected to a hollow valve-stem, an induction-port located between the two high-pressure ports and a piston-cut-off valve controlling said induction-port by means of a valve-stem reciprocating in the hollow stem of the main valve and connected to an independent wrist-pin, substantially as specified.

8. In a compound engine having a duplex cylinder and piston, a live-steam port, a low-pressure port and an exhaust-port in each cylinder, the combination therewith of an annular steam-jacket formed in the walls of the cylinder, a section of which is interposed between the low-pressure port and the inner periphery of said cylinder, means for supplying said steam-jacket with live steam direct from the boiler, means for trapping off the water of condensation whereby the steam being compounded upon the larger piston-face is maintained at a heat above the condensing-point

and the water of condensation of the engine is deposited in the steam-jacket outside of the piston-chamber, substantially as specified.

9. In a compound engine of the described type an annular steam-jacket, formed in the walls of each cylinder a section of which is inside of the low-pressure ports and provided with a gutter on one side thereof extending outside of the walls of the cylinder for receiving the water of condensation and means for trapping the water out of said gutters, substantially as specified.

In testimony whereof I have hereunto set my hand.

EDWARD W. HARDEN.

Witnesses:
OLIVER B. KAISER,
W. R. WOOD.