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C. W. COOPER.

HYDRAULIC ENGINE.

No. 343,569. Patented June 15, 1886.

Fig. 1.

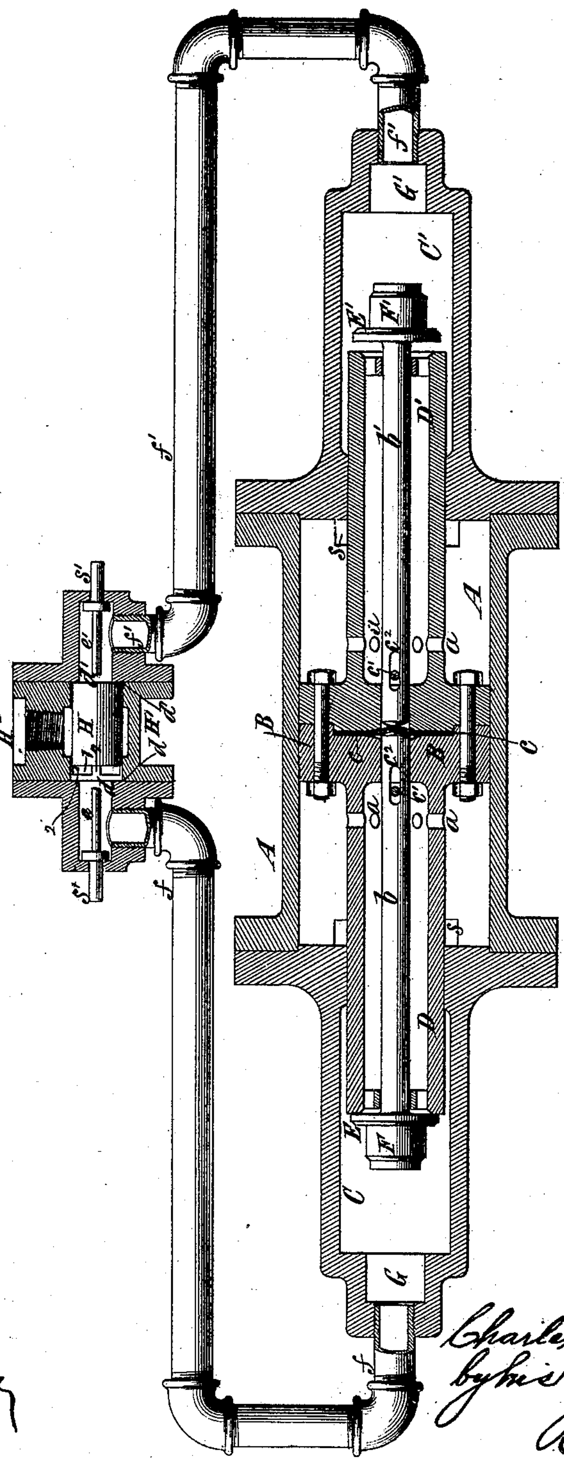

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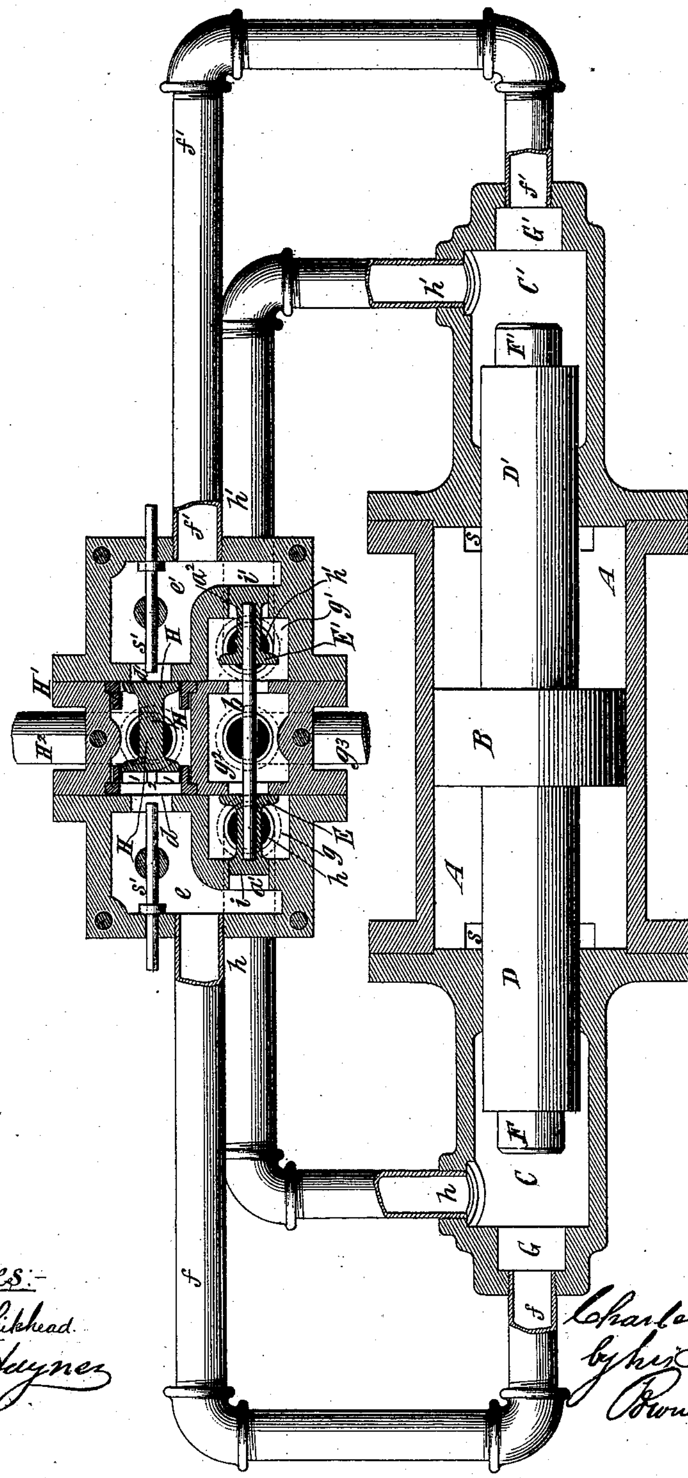
Fig. 2.



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HYDRAULIC ENGINE.

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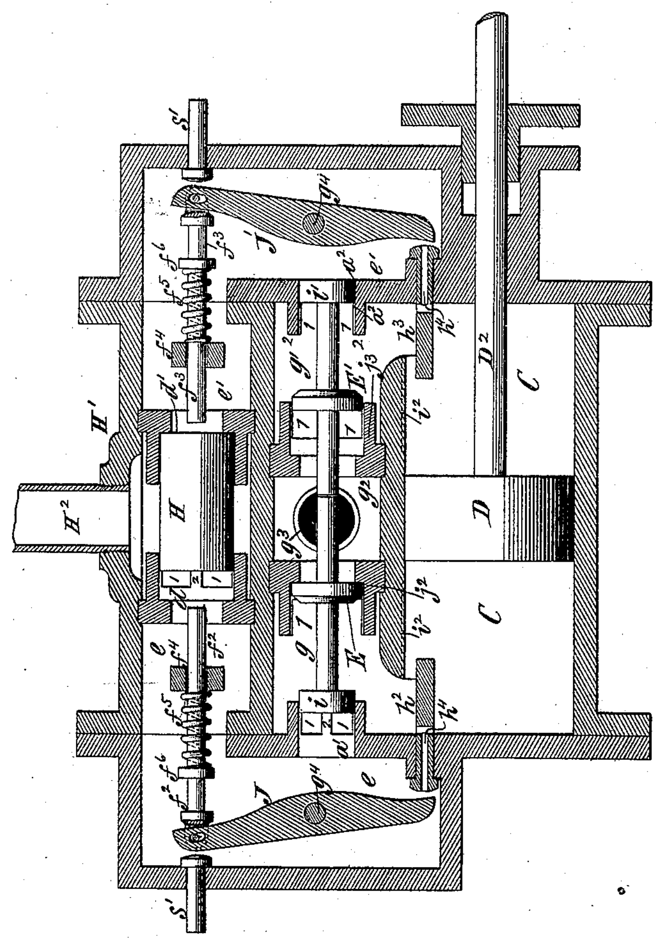
Fig. 3.



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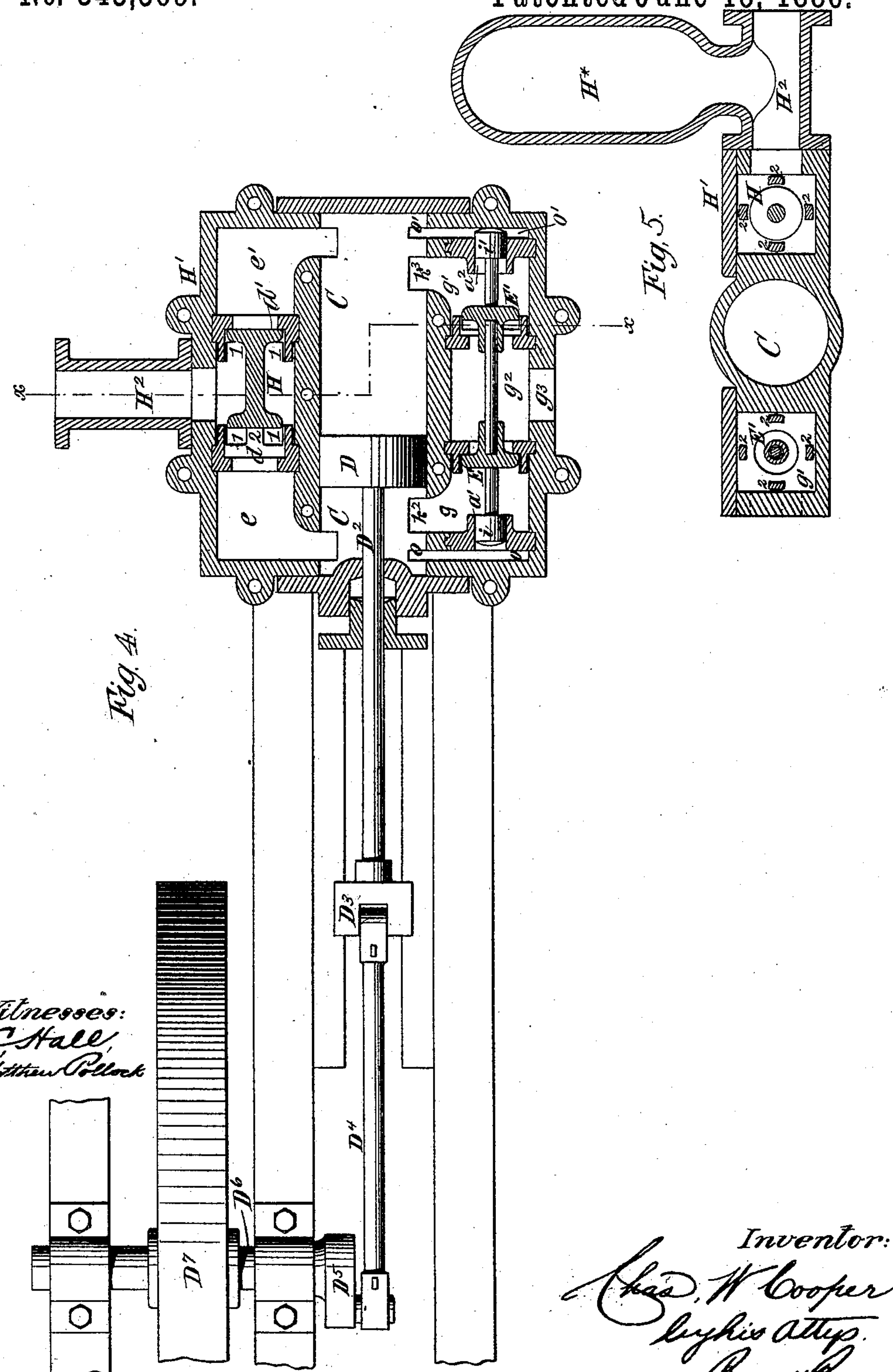
C. W. COOPER.

HYDRAULIC ENGINE.

No. 343,569.

Patented June 15, 1886.



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(No Model.) 5 Sheets—Sheet 5.

C. W. COOPER.
HYDRAULIC ENGINE.

No. 343,569. Patented June 15, 1886.

Fig. 7.

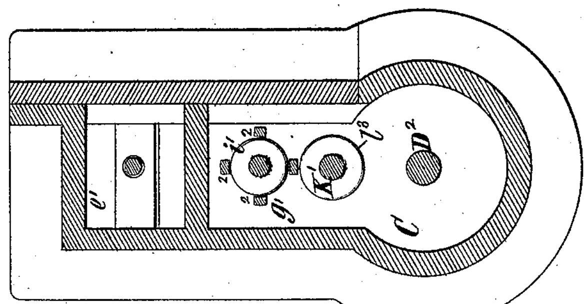
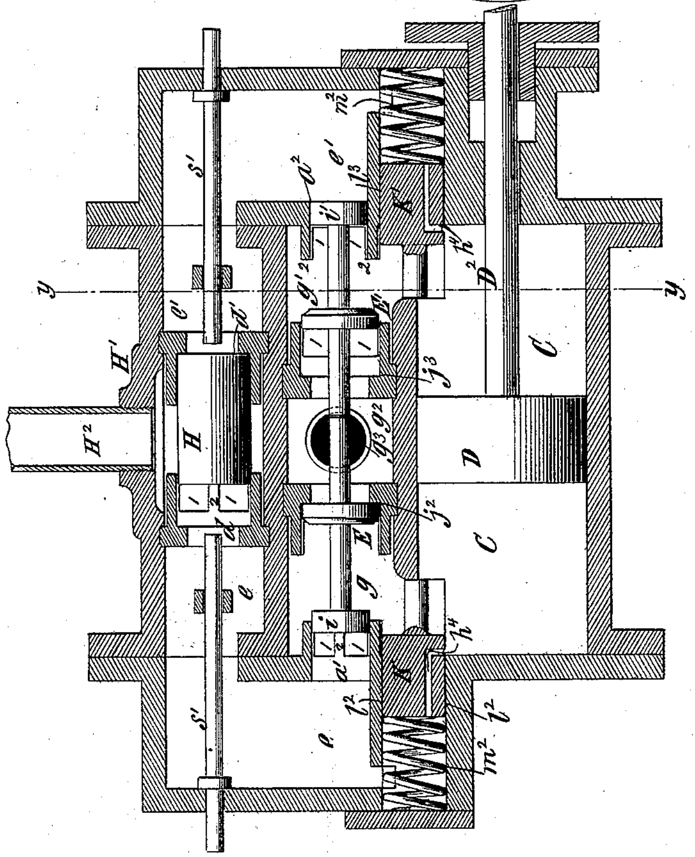


Fig. 6.



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UNITED STATES PATENT OFFICE.

CHARLES W. COOPER, OF BROOKLYN, NEW YORK.

HYDRAULIC ENGINE.

SPECIFICATION forming part of Letters Patent No. 343,569, dated June 15, 1886.

Application filed April 27, 1883. Serial No. 93,069. (No model.)

To all whom it may concern:

Be it known that I, CHARLES W. COOPER, of the city of Brooklyn, in the county of Kings and State of New York, have invented a new and useful Improvement in Hydraulic Engines, of which the following is a specification.

My invention relates, generally, to double-acting hydraulic engines, which are operated by water-pressure to drive pumps or other machinery, and which severally comprise a double-acting piston working in a cylinder. The water-pressure for operating the engine may be obtained from any natural source—as, for example, a waterfall—or from any artificial source—as, for instance, that which may be obtained from any kind of pump; but if a pump is employed to produce pressure for operating the engine a pump having a fly-wheel is preferable.

The invention relates to the construction and method or means of operating both the induction-valves which control the admission of water under pressure to an engine-cylinder, and the eduction-valves, which are independent of the induction-valves, and which control the exhaust or discharge of water from the engine-cylinder after performing its work therein.

In carrying out my invention I arrange the eduction-valves so that they close in the same direction in which water is to pass through them, and I connect them together so that the closing of one effects the opening of the other. I also arrange the induction-valves so that they close in the same direction in which the water is to pass through them, and also connect them together so that the opening of one insures the closing of the other.

The invention consists in the combination, with the main cylinder and piston of a double-acting hydraulic engine and induction-valves therefor, of eduction-valves independent of the induction-valves, closing in the same direction in which water is to pass through them, and connected as hereinafter described, whereby the closing of one effects the opening of the other, passages through which water passes from the induction-valves to the main cylinder, and auxiliary pistons connected with the eduction-valves and operative by the pressure of water in said passages to shift the eduction-valves.

The invention also consists in the combination, with the main cylinder and piston of a double-acting hydraulic engine and induction-valves closing in the same direction in which water is to pass through them, and connected together, as hereinafter described, whereby the opening of one insures the closing of the other, of passages through which water passes from the induction-valves to the main cylinder, the induction-valves when closed being acted upon by the pressure of water in said passages, eduction-valves independent of the induction-valves, closing in the same direction in which water is to pass through them, and connected together as hereinafter described, whereby the closing of one effects the opening of the other, and auxiliary pistons connected with the eduction-valves and operative by the pressure of the water in said passages to shift said eduction-valves.

In the accompanying drawings, Figure 1 is a longitudinal section of a double acting hydraulic engine embodying my invention. Fig. 2 is a similar section of an engine of modified form, also embodying the invention. Fig. 3 is a similar section of an engine of another form, also embodying the invention. Fig. 4 is a similar section of another engine, also embodying the invention. Fig. 5 is a transverse vertical section on the dotted line *x x*, Fig. 4. Fig. 6 is a longitudinal section of still another form of engine, also embodying the invention; and Fig. 7 is a transverse vertical section of the engine shown in Fig. 6 upon the dotted line *y y*.

In most of the figures of the drawings the engine is shown in combination with a pump which is driven by it; but neither the pump portion of the apparatus nor the combination of the engine and pump is to be considered as a part of my invention.

The invention relates only to the engine or driving portion of the machine, and the pump merely serves as an illustration of a useful purpose to which the power of the engine may be applied.

In the several figures of the drawings I have shown only such parts as are necessary to illustrate my invention; but have not fully illustrated all the details of construction—as, for instance, the pump-cylinders, valve-chambers, &c., and the bolts for securing the several parts together; but all such features will be readily understood by skilled mechanics familiar with hydraulic apparatus.

The engine shown in Fig. 1 includes two single-acting engine pistons and cylinders, which constitute the piston and cylinder for a double-acting engine and an intermediate double-acting pump piston and cylinder for raising a comparatively large quantity of water to a height or pressure less than that from which the engine derives its supply.

A designates the pump-cylinder, which may be provided with suitable suction and discharge valves. (Not here shown.) This cylinder is provided with inlet and outlet ports *s*, controlled by such valves.

B designates the pump-piston which works in said cylinder, and may be provided with any suitable packing. In this instance the ends of the cylinder A have secured to them engine-cylinders C C′, which together constitute the cylinder of the double-acting engine and which are of smaller diameter, and D D′ designate plungers or pistons attached to or formed with the piston B, and which work in said engine-cylinders C C′. These pistons or plungers are hollow, and communicate through holes *a* with the cylinder A on opposite sides of the piston B, and the passage through them is controlled by valves E E′, which have long stems *b b′*, extending through the pistons D D′ and abutting against each other in the piston B. The said stems do not come in absolute contact; but they are separated by a flexible diaphragm, *c*, in the piston B, which prevents leakage through the piston, and they are of such length that the valves E E′ can never be both closed at the same time. The opening movements of the valves E E′ are limited by pins *c′*, which enter slots c^2 in the valve rods or stems *b b′*.

Upon the backs of the valves E E′ are secured auxiliary pistons F F′, which have their outer ends of reduced diameter, for a purpose hereinafter described, and which are adapted to enter cylinders G G′ in the ends of the cylinders C C′. These auxiliary pistons should be about half the area of the pistons D D′.

H designates the induction-valve piece, which, as here shown, consists of a simple cylinder adapted to close on either of two seats, *d d′*, in a casing, H′, into which the inlet-pipe H^2 enters. The piece H therefore constitutes two valves. Each seat *d d′* is formed with side openings, 1, and ribs or guides 2, and at the ends of the casing H′ are chambers *e e′*, into one or the other of which the water passes when the valve is open, and from which pipes *f f′* lead to the ends of the auxiliary cylinders G G′. The chambers *e e′* and pipes *f f′* simply form passages, through which water passes from the valve to the engine-cylinders C C′. The valve-piece H always opens outward relatively to the engine-cylinders—as, for example, it moves toward the left hand to admit water to the right-hand clylinder C′, and vice versa. In starting the engine the valve-piece H may be operated manually by means of the push-rods *s′*. As shown in the drawings, the water enters through the valve-seat *d*, chamber *e*, and pipe *f*, to the left-hand engine-cylinder C, and forces the pistons D B D′ toward the right. The valve E is at this time closed, but the valve E′ is open, and the water in the cylinder C′ passes through said valve and the hollow piston D′ into the cylinder A on the right-hand side of the piston B, and augments the discharge therefrom. At the same time the cylinder A, on the left-hand side of the piston B, is being filled with water by suction. This movement continues until the piston F′ enters the cylinder G′, whereupon the water in that cylinder will be forced backward into the cylinder C′, while the smaller part of the piston F′ is entering and until the piston comes to so tight a fit that no water can pass. Then the pressure on the piston D will be partly balanced by the pressure on the smaller area of the piston F′, and before the pistons can move farther to the right the pressure, acting upon the difference in area between the pistons D and F′, must become great enough to do the work, because, as the pressure increases in the chamber C, it must necessarily become equally high in the pipe *f′* and chamber *e′* before the valve-piece H can be forced from its seat *d′* against that pressure. If a fly-wheel pump is employed to supply water under pressure through the pipe H^2, the momentum of the fly-wheel of said pump will cause the additional pressure to be obtained on the piston D the instant there is any check to the current supplied through the pipe H^2, and the movement of the pistons toward the right will continue until the pressure produced in the pipe *f′* and chamber *e′* by the movement of the small piston F′ into its cylinder G′, acting on the right-hand end of the induction-valve piece H, moves it away from the seat *d′* and closes it on the seat *d*. The water from the pipe H^2 then has free passage through the chamber *e′* and pipe *f′* into the auxiliary cylinder G′, and by reason of the momentum of the fly-wheel of the pump which supplies the water, or of the water itself, the pressure is increased in the cylinder G′ until it is sufficient, by acting through the valve-stems *b b′*, to move the valve E from its seat. The water in the cylinder C then has a free outlet through the hollow piston D into the cylinder A on the left-hand side of the piston. At the same time that the pressure on the auxiliary piston F′ opens the valve E it will close the valve E′, and if said valve is not entirely closed when the larger or tightly-fitting part of the piston F′ leaves the cylinder G′ the friction of the water in passing between the cylinder and the smaller part of the piston will retain a pressure behind the piston F′ sufficient to complete the closing of the valve E′. In point of fact the valve E′ would be entirely closed by the current, even if the piston should entirely leave the cylinder G′ before its closing movement is completed. A small quantity of water might, however, escape through the valve E′ before it is entirely closed, and to prevent this loss of power I make the pistons F F′ of reduced diameter at the ends, so that they may penetrate the cylinders farther in their entering movement before confining the water to reverse the stroke, and as a consequence will have sufficient movement on the reverse stroke to close the valves E E′ before leaving the cylinders. As soon as the piston F′ leaves the cylinder G′, the pressure immediately falls to that necessary to move the engine by acting on the larger area of the piston D′, and the pistons D′, B, and D are then all moved toward the left hand to make the return-stroke.

Although I have stated that the momentum of a fly-wheel on the pump which supplies the water through the pipe H^2 is depended on to increase the pressure automatically when the auxiliary pistons F F′ are entering and leaving their small cylinders G G′, the same result might be attained by the momentum of the water in the supply-pipe H^2, if the latter be long enough.

Although I have here shown two separate cylinders, C C′, and two pistons, D D′, they are each only single-acting—one piston, D, forcing the pump-piston B toward the right and the other piston, D′, forcing it toward the left—and therefore the two cylinders and their pistons form but one double-acting engine.

In the form of apparatus shown in Fig. 2 the construction and arrangement of the cylinder A and its ports *s*, the piston B, the cylinders C C′ G G′, and their pistons D D′ F F′ are the same as before described, except that there are no water-passages through the pistons D D′, and the auxiliary pistons F F′ are formed on or attached rigidly to them. The auxiliary pistons F F′ need not, however, be attached to the pistons D D′. They might be independent of said pistons D D′, but so arranged that the pistons D D′ would abut against and move them in terminating their movements. This latter arrangement might indeed be preferable, because the accurate alignment of the auxiliary cylinders G G′ with the cylinders C C′ will not be necessary.

The construction and arrangement of the casing H′, the induction-valve piece H, with its seats *d d′*, the inlet-pipe H^2, the chambers *e e′*, and pipes *f f′* are all as before described. The eduction-valves E E′ are arranged in chambers *g g′*, which communicate, through openings controlled by the said valves, with an intermediate chamber, g^2, from which leads a discharge-pipe, g^3. The valves E E′ are connected by a rod or stem, *b*, so that the closing of either valve effects the opening of the other, and the valve-chambers *g g′* are connected by pipes *h h′* with the ends of the cylinders C C′. Between the chambers *e e′* and the adjacent chambers, *g g′*, are openings or small cylinders *a′* a^2, in which work auxiliary pistons *i i′*, attached to or formed with the valves E E′, and by their movements controlling the opening and closing of said valves. The area of these pistons is somewhat smaller than the area of the valves. This arrangement of the induction and eduction valves is particularly desirable, because the chest or casing wherein they are all arranged may be placed in any suitable situation relatively to the engine and pump, and at a distance therefrom, if desired, and the pipes *f f′ h h′* may be prolonged and connected, as here shown, with the chambers *e e′ g g′*. As here shown, the valve H is closed onto the seat *d′*, and the water is entering the cylinder C through the pipe *f*, and forcing the pistons D B D′ toward the right, the water in front of the piston D′ exhausting through the pipe *h′* and chamber *g′*, valve E′, chamber g^2, and pipe g^3. This operation continues until the auxiliary piston F′ enters the small cylinder G′, and thereby increases the pressure in the pipe *f′* and chamber *e′* sufficiently to move the valve-piece H from its seat *d′*. By the pressure in the pipe *f′* and chamber *e′* the valve-piece H will be moved over sufficiently to close the side openings, 1, in the seat *d*, and hence the water from the pipe H^2 will no longer exert any tendency to hold said piece H against the seat *d*. As soon as this takes place, the chamber *e′* is, through the chamber *e*, pipe *f*, cylinder C, and pipe *h* in momentary communication with the chamber *g*, and hence the pressure in both the chambers *e′* and *g* is balanced; but as the area of the valve E is larger than that of the piston *i′*, said valve remains seated. As soon, however, as the valve-piece H, by the combined action of the pressure in the passage *e′* and from the inlet-pipe H^2, is forced onto its seat *d*, the pressure accumulates or increases in the chamber *e′* until it is sufficient, acting on the auxiliary piston *i′*, to open the valve E and close the valve E′. The piston D is thereupon relieved of pressure, and the increased pressure in the cylinder G′ forces the piston F′, together with the pistons D′ B D, toward the left. As soon as the piston F′ leaves the cylinder G′, the pressure of water falls, and, acting on the whole area of the piston D′, makes the return-stroke of the several pistons D′ B D. In this example of my invention, also, the two single-acting cylinders and pistons C C′ D D′ constitute a single double-acting engine.

In Fig. 3 I have represented a double-acting engine which may be employed for working pumps or for other kinds of work. In this case C designates the engine-cylinder and D the piston thereof, which transmits power through its rod D^2.

The arrangement of the induction-valve piece H, its chest or casing H′, provided with seats *d d′* and inlet-pipe H^2, is the same as previously described, and from the casing the water passes through either seat and into the passage or chamber *e* or *e′*. Opposite the ends of the induction-valve are arranged rods f^2 f^3, which are each adapted to slide in a bearing, f^4, and are moved away from the valve by springs f^5, arranged between the bearing and a collar, f^6, on each rod. Said rods are connected with the upper ends of levers or pivoted rocker-arms J J′, which are fulcrumed at g^4, and the lower ends of which are acted upon by push pins or plungers h^2 h^3, extending from the chambers e e' through the heads of the cylinder C, and against which the piston D may strike. Each pin or plunger has a hole, h^4, through it, and when in the position shown, where they are normally maintained by the springs f^5, or into which position they are forced by the pressure in the chambers e e', these holes afford communication between the chambers e e' and the cylinder C. The eduction-valves E E′ are connected together or push against one another, and are arranged in chambers g g', which communicate with an intermediate chamber, g^2, from which leads the outlet-pipe g^3. With the eduction-valves are connected auxiliary pistons i i', which work in cylinders a' a^2, and these cylinders are constructed with side openings, 1, and intermediate guides, 2, so that when the auxiliary piston is moved into the position of the piston i the water can pass freely from the chamber e into the chamber g, and thence to the cylinder C on the left side of the piston D. When the parts are in the position shown, water can pass freely from the inlet-pipe H² into the chamber e, and thence through the auxiliary cylinder a' into the cylinder C, to force the piston D toward the right, the valve E′ being at the same time open, so that the water can exhaust from the right-hand side of the piston D, through the valve E′, and out of the discharge or exhaust pipe g^3. This operation continues until the piston D strikes the plunger h^3, and when it does this, the plunger, is moved to cover its port h^4 and cut off communication between the chamber e' and cylinder C, and by its movement it acts on the rocker arm or lever J′, and pushing in the rod f^3 against the induction-valve piece H, moves the said valve-piece away from its seat d' and allows water to enter the chamber e'. The movement of the plunger h^3 into the passage or chamber e' increases by the amount of its bulk the pressure therein, and the increased pressure thus produced will suffice to start the valve-piece H from its seat d', and the rocker-arm J′ and rod f^3 are only to be employed, if desirable, to insure such starting movement of the valve-piece from its seat d'. As soon as the valve-piece H is thus moved over sufficiently to restrict the flow through the seat d and slightly open the seat d', the increased resistance offered to the downward movement of the water in the pipe H² by such restricted flow will cause the water by its momentum to increase the pressure in the passage or chamber e', and such increased pressure will complete the movement of the valve-piece H, and, by acting on the auxiliary piston i', will close the valve E′ and open the valve E. During the passage of the valve-piece H from one seat to the other the water-pressure per square inch on the closed eduction-valve E and on the right-hand side of the auxiliary piston i' is equal, and because of the greater area of the valve E it is still held to its seat until the valve-piece H completes its movement. If there were now a very slight leak from the left-hand end of the cylinder C past the piston D, the pressure on the valve E would be relieved, as there is no water entering on that side, and the pressure on the auxiliary piston i' would at once move it and effect the closing of the eduction-valve E′ and the opening of the opposite valve, E, without further increase of pressure. If such a leakage is deemed desirable, it may be provided for by grooving the cylinder C, as shown dotted at i^2. If, on the contrary, the piston D is absolutely tight, the pressure on the auxiliary piston i' will immediately increase by reason of the momentum of the column of water in the pipe H², which, after the valve-piece H is closed on the seat d, has no outlet until the piston i' moves, or by reason of the momentum of a fly-wheel on a pump which supplies water through the pipe H², and such increased pressure on the piston i' will overcome the pressure on the valve E and open the latter, and at the same time close the valve E′. A free exhaust is thus provided from the left-hand end of the cylinder C, and the water from the chamber or passage e' entering the right-hand end of the cylinder C, through the auxiliary cylinder a^2 into the cylinder C will effect the return-stroke of the piston D.

I have here shown the valve-seats for the valves E E′ as formed in casings or cylinders j^2 j^3, which are but slightly larger than the valves, and at a short distance beyond the valve-seats are formed with openings 1, like those before described. This is advantageous, because when one of the auxiliary pistons—the piston i', for example—has moved sufficiently to enable it to open the passage into the cylinder C the valve E′ will have nearly covered the openings 1 in its seat, and will have nearly stopped the flow of water, although it can still move far enough before it finally seats to allow a large water-passage through the auxiliary cylinder a^2 and past the piston i', to admit water to act on the piston D.

In Figs. 4 and 5 I have represented a very simple form of hydraulic engine, which is provided with a fly-wheel, and may be employed for any kind of work. The valves of this engine are automatically shifted by the momentum of the fly-wheel without the necessity of any mechanical connection between it and the valves.

C designates the cylinder, and D the piston, of a double acting hydraulic engine, the piston-rod D² being connected by a cross-head, D³, and connecting-rod D⁴, with a crank, D⁵, on a shaft, D⁶, said shaft being also provided with a fly-wheel, D⁷.

The induction-valve piece H, like those before described, is adapted to move between the seats d d', to control the passage of water from the inlet-pipe H² to the chamber e or e', which are in direct communication with the ends of the cylinder C.

Near the ends of the cylinder C are discharge-ports k^2 k^3, which communicate with chambers g g', wherein are eduction-valves E E', which control the passage of water to the intermediate chamber, g^2, and thence to the outlet-pipe, g^3. The valves E E' are connected so that when one is open the other is closed, and with them are connected auxiliary pistons i i', preferably of smaller area than the valves working in auxiliary cylinders a' a^2, to which ports o o' lead from the ends of the cylinder C. The ports k^2 k^3 are arranged at such a distance from the ends of the cylinder that the piston D will cover them as it terminates its stroke; but the ports o o' are arranged nearer the ends of the cylinder, and are never covered by the piston.

In the drawings the valve-piece H is moved away from the seat d, and water passes freely from the pipe H^2 into chamber e, and thence to the cylinder C, forcing the piston D toward the right. During this time the eduction-valve E' is open, and water can escape freely from the right-hand side of the piston D. As soon as the piston D in its movement passes the port k^3, the exhaust is cut off, and the pressure of the water on the right of the piston is increased instantly by the further movement of the piston, induced by the fly-wheel in completing the revolution of the crank D^5, and acts on the right-hand end of the valve-piece H, and on the auxiliary piston i'. The valve-piece H, having equal area at each end, is moved first, and is thrown over onto the seat d, opening the water-supply to the passage e' and right-hand side of the piston D. The auxiliary piston i' is also moved to close the valve E' and open the valve E, and the slight movement of the piston D toward the right after the valve-piece H is closed against the seat d, produces a sudden decrease of pressure on the valve E, which will allow of its opening instantly.

This engine should be provided with an air-chamber, H*, connected with the pipe H^2 as close as possible to the cylinder C, as shown in Fig. 5, and then the excess of water displaced by the piston D after the port k^3 is covered, and beyond what is required to move the valve-piece H will be driven back for the moment into the air-chamber before mentioned.

The fly-wheel of this engine may be made to turn in either direction. It will only be necessary to turn the wheel manually for half a turn in the direction desired, and it will then continue to rotate in that direction.

The engine shown in Figs. 6 and 7 is like that shown in Fig. 3, except that instead of the rods f^2 f^3 the levers J J' and the plungers h^2 h^3, for shifting the valve-piece H, I employ pistons K K', working in cylinders l^2 l^3, which communicate with the water passages or chambers e e', and are pushed toward the cylinder C by springs m^2. These pistons have apertures h^4 through them, as have the plungers h^2 h^3, so as to permit the escape of water from the passage e e' when the auxiliary pistons i i' are moved into their cylinders. When the piston D in its movement toward the right strikes the piston K', it will move the latter, and cause an increase of pressure in the water chamber or passage e' sufficient to start the induction-valve piece H in its movement toward the seat d'.

In all the examples of my invention above described I have shown, with slight differences in form, but one kind of induction and eduction valves; but obviously valves of other forms may be used, provided they are adapted to operate substantially as herein described.

I have described but one induction-valve piece for each engine; but this valve-piece is always used in connection with two seats, and is practically two valves, and always opens in an outward direction from the engine cylinder or cylinders. If two separate induction-valves connected by a beam or lever or by a rod were used, they would operate similarly to the single valve-piece H, and would be the equivalent thereof.

The combination of the induction-valve piece H with the casings containing the seats d d', and each comprising a cylindric portion close to the seat and openings 1 beyond or inward of said cylindric portion, is very desirable, because by the time the valve in moving begins to uncover the openings 1 adjacent to one seat it has nearly covered the openings adjacent to the other seat, and has nearly shut off the supply of water through the last-named seat, although it still has a considerable movement before finally seating. By this means I am better enabled to utilize the pressure of water directly from the supply-pipe for completing the movement of the induction-valve piece after its initial movement.

I do not limit myself to the construction of the valve-seats d d' above described, as the same result might be attained by employing valves and valve-seats of other constructions.

The eduction-valves are always connected or so constructed that the closing of one effects the opening of the other, and they will always open inward relatively to the ends of the cylinder which they control.

By way of recapitulation, and to better explain the principles that govern the changing of the induction-valve piece H, I will state that it is changed by the greater pressure in the passage e or e' than in the other, and that this greater pressure is produced at the proper times in this wise: The water passing, for example, through the seat d and passage e, acts upon the left-hand side of the piston D, and when it drives this piston so far to the right that the piston F' penetrates the cylinder G' in Figs. 1 and 2, or that the plunger h^3 is driven into the chamber e' in Fig. 3, or the plunger K' into the cylinder l^3 in Fig. 6, the water in the passage e' becomes confined and shut off from the right-hand chamber C, and consequently from communication through it with the exhaust through the valve E′, that is then open. Whenever the water becomes so confined in the passage e', it exerts a pressure upon the smaller plunger or piston F′, Figs. 1 and 2, and through it a backward pressure on the piston D′, and in effect reduces the area of the piston for driving purposes by an amount equal to the area of the piston F′. Whenever this occurs, a momentary slowing of the motion of the pistons in Figs. 1 and 2 takes place, which causes the pressure on the pipe H^2 to suddenly increase, first, by the momentum of the suddenly-checked water-column; secondly, by the reduction in the friction of water flowing through the said pipe, and, thirdly, by the momentum of the fly-wheel pump, if such a pump is used to force water through the pipe H^2. This increase in pressure serves to continue the motion of the piston, notwithstanding the reduction in effective area, until the valve-piece H is driven over onto the seat d by the water confined in the passage e'.

In Figs. 1 and 2 the increased pressure in the passage e' f' is produced, first, by the entrance of the auxiliary piston F′ into the cylinder G′, and as soon as the valve-piece H is moved sufficiently to restrict the flow through the seat d and slightly open the seat d' the momentum of the water in the pipe H^2, due to its flow through the seat d being restricted, will increase the pressure in the passage e' sufficiently to complete the movement of the valve-piece H, and close the valve E′ and open the valve E.

In Fig. 3 the movement of the plunger h^3 into the passage e' will produce an increase of pressure therein, and after the valve piece H is moved to restrict the flow of water through the seat d the momentum of the water in the pipe H^2 will still further increase the pressure in the passage e', and close the valve-piece upon the seat d.

Practical experience with one of these engines has shown that water obtained under pressure directly from city mains will serve to drive and reverse the engine without the aid of a fly-wheel pump.

In Fig. 4, when the piston D passes the opening k^3 and confines the water in the passage e', the full area of the piston is exposed to the backward pressure in that passage, and consequently any increase of pressure in the pipe H^2 acts equally on both sides of the piston, and does not serve to move it farther against the confined water in the passage e' to open the valve-piece H. Therefore a fly-wheel attached to the engine so that its momentum acts directly upon the piston D through its rod D^2, as already described, is necessary to continue the motion of the piston sufficiently to change the valve-piece H and reverse the stroke.

In all the engines it is essential that at the termination of any stroke the passage e or e' shall be shut off from communication with the exhaust end of the engine-cylinder, so that the water may be confined in that passage until the valve-piece H has been changed to the other seat, and the combination of these passages with the induction and eduction valves and auxiliary pistons arranged to operate as above described, I consider to be the important features of my invention.

It will be observed that in all examples of my invention which I have shown and described the eduction-valves are separate from the induction-valves.

The example of my present invention which is shown in Fig. 3, and in which the main piston as it nears the end of its stroke acts through suitable mechanical connections to start the induction-valve from its seat, is not specifically claimed herein, but forms the subject of my application for Letters Patent, Serial No. 201,047, filed May 4, 1886.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The combination, with the main cylinder and piston of a double-acting hydraulic engine and induction-valves therefor, of eduction-valves independent of the induction-valves, closing in the same direction in which water is to pass through them and connected together, as described, whereby the closing of one effects the opening of the other, passages through which water passes from the induction-valves to the main cylinder, and auxiliary pistons connected with the eduction-valves and operative by the pressure of water in said passages to shift the eduction-valves, substantially as herein described.

2. The combination, with the main cylinder and piston of a double-acting hydraulic engine and induction-valves closing in the same direction in which water is to pass through them, and connected together, as described, whereby the opening of one insures the closing of the other, of passages through which water passes from the said induction-valves to the main cylinder, the induction-valves when closed being acted upon by the pressure of water in said passages, eduction-valves independent of the induction-valves, closing in the same direction in which water is to pass through them, and connected together, as described, whereby the closing of one effects the opening of the other, and auxiliary pistons connected with the eduction-valves and operative by the pressure of water in said passages to shift said valves, substantially as herein described.

CHAS. W. COOPER.

Witnesses:

CHANDLER HALL,

FREDK. HAYNES.