(No Model.) 7 Sheets—Sheet 1.

M. W. HALL.

DUPLEX STEAM ENGINE.

No. 349,157. Patented Sept. 14, 1886.

Fig. 1.

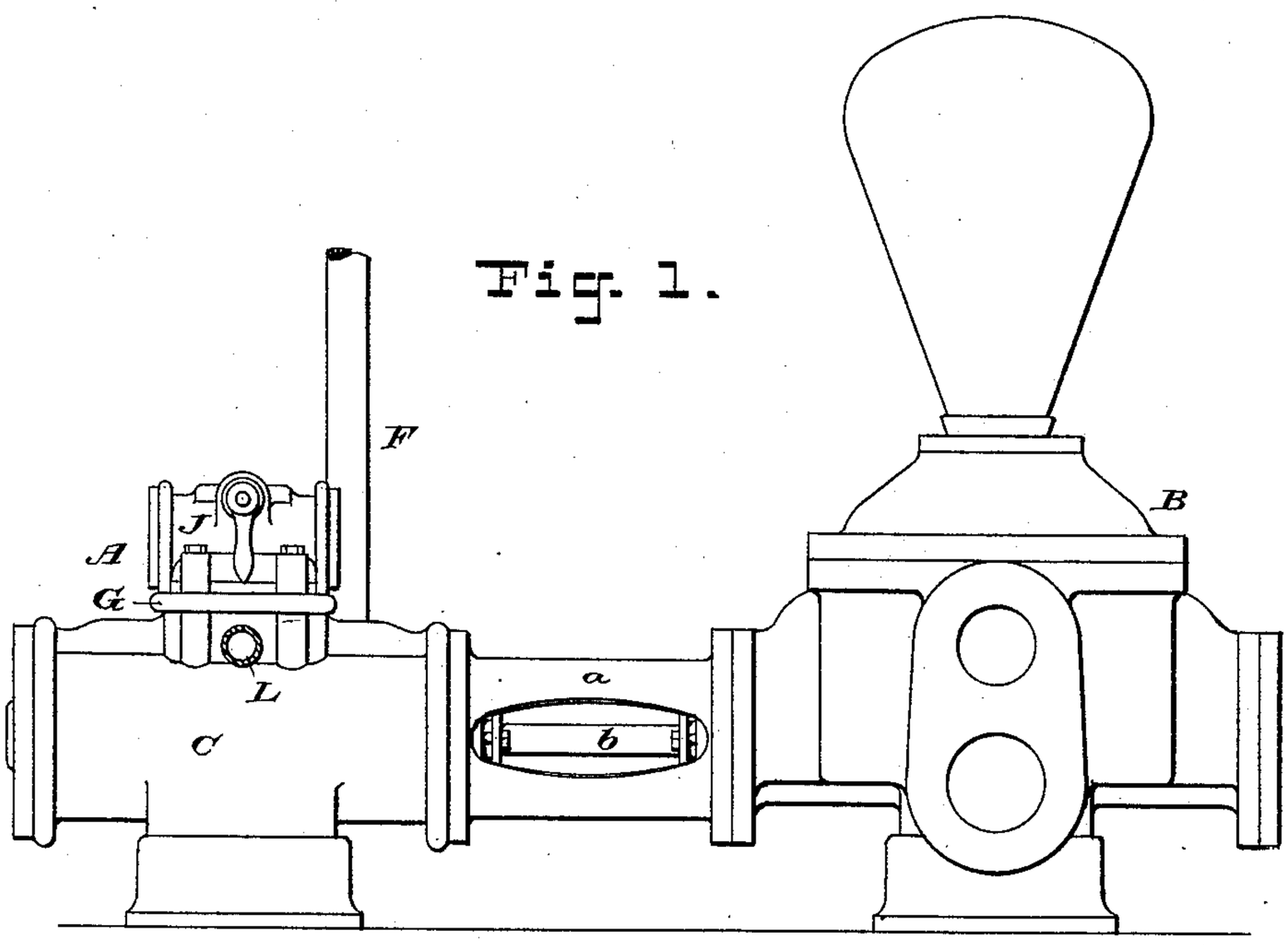
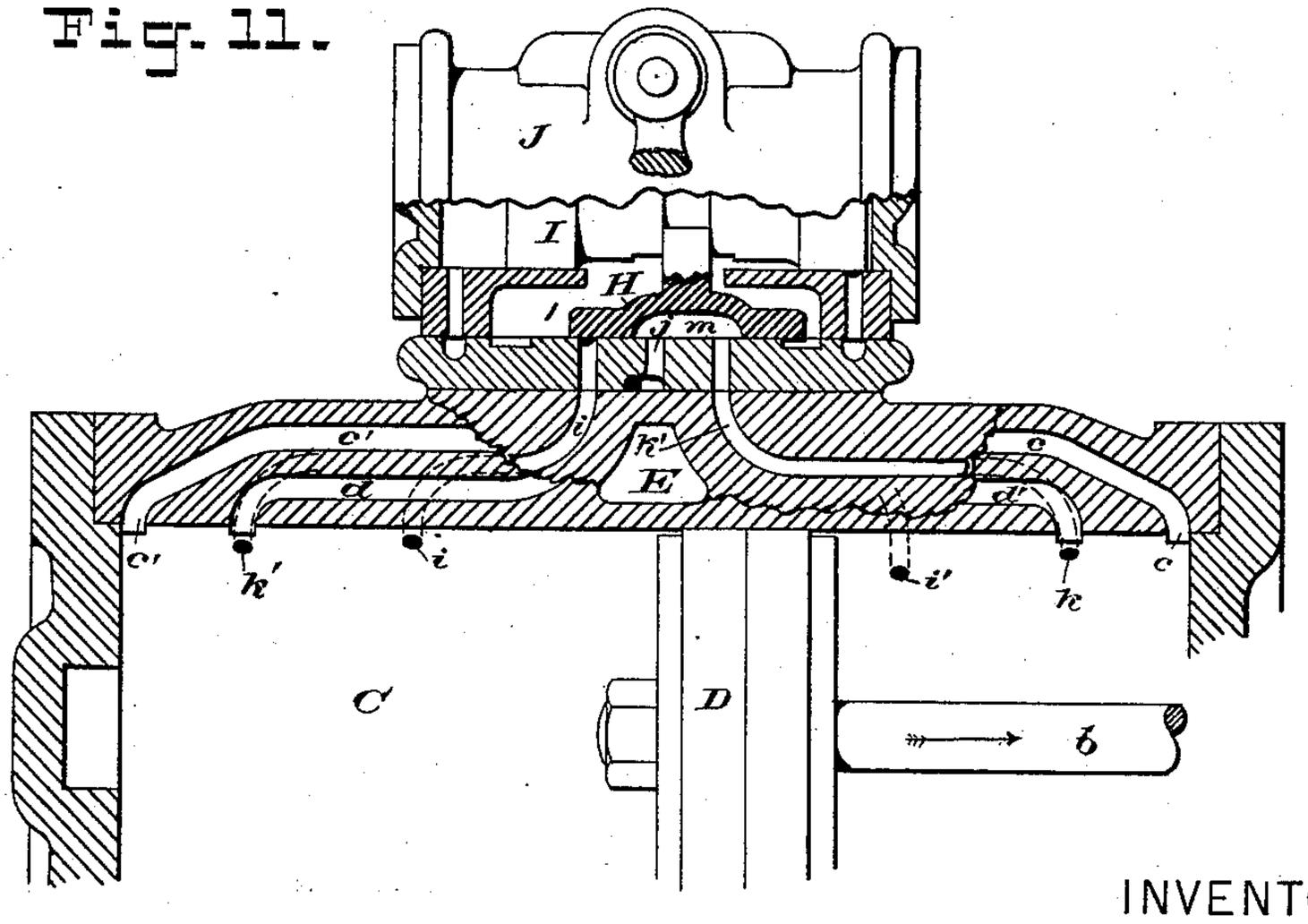


Fig. 11.



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By his Attorneys,

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(No Model.) 7 Sheets—Sheet 2.

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Fig. 2.

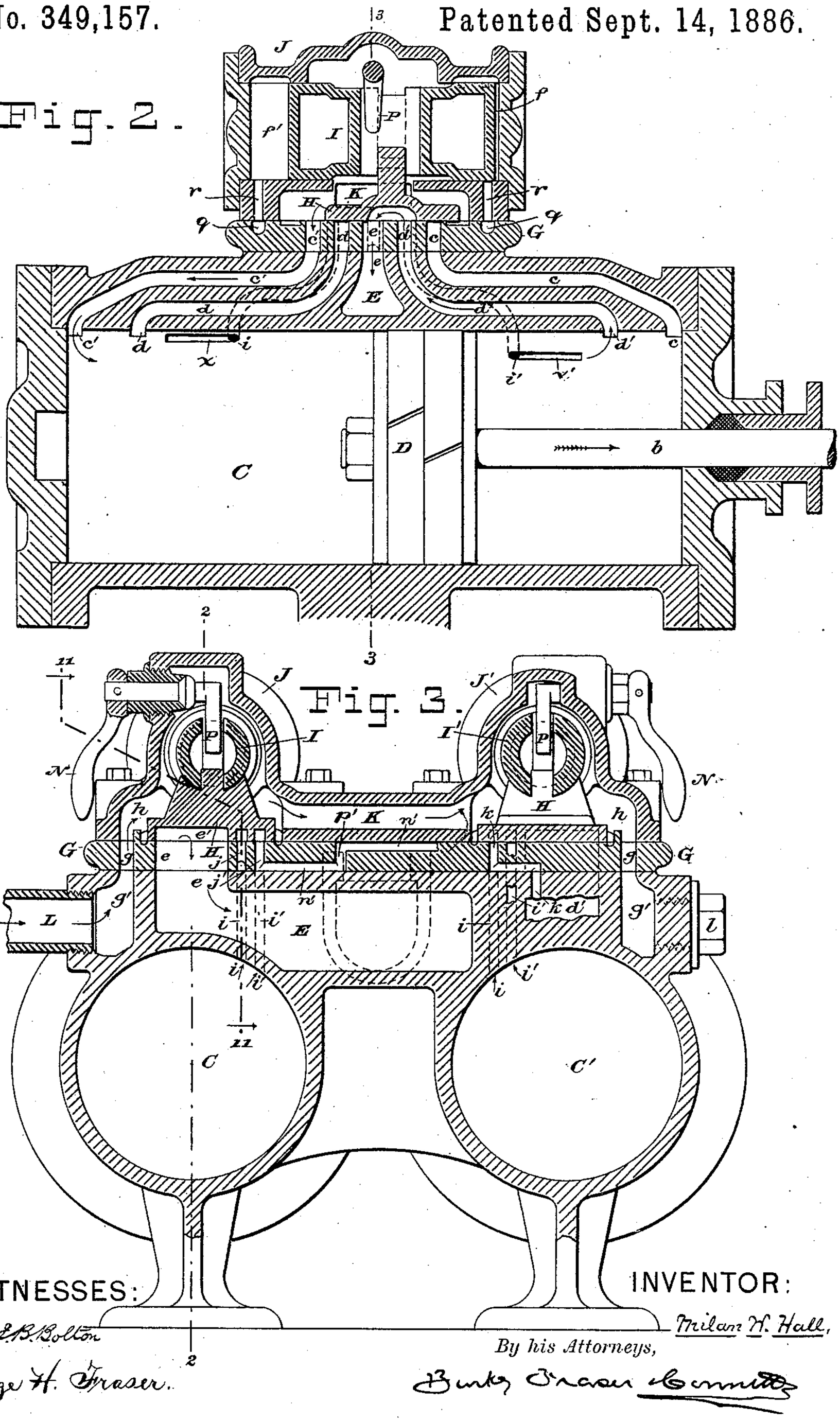

Fig. 3.

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N. PETERS, Photo-Lithographer, Washington, D. C.

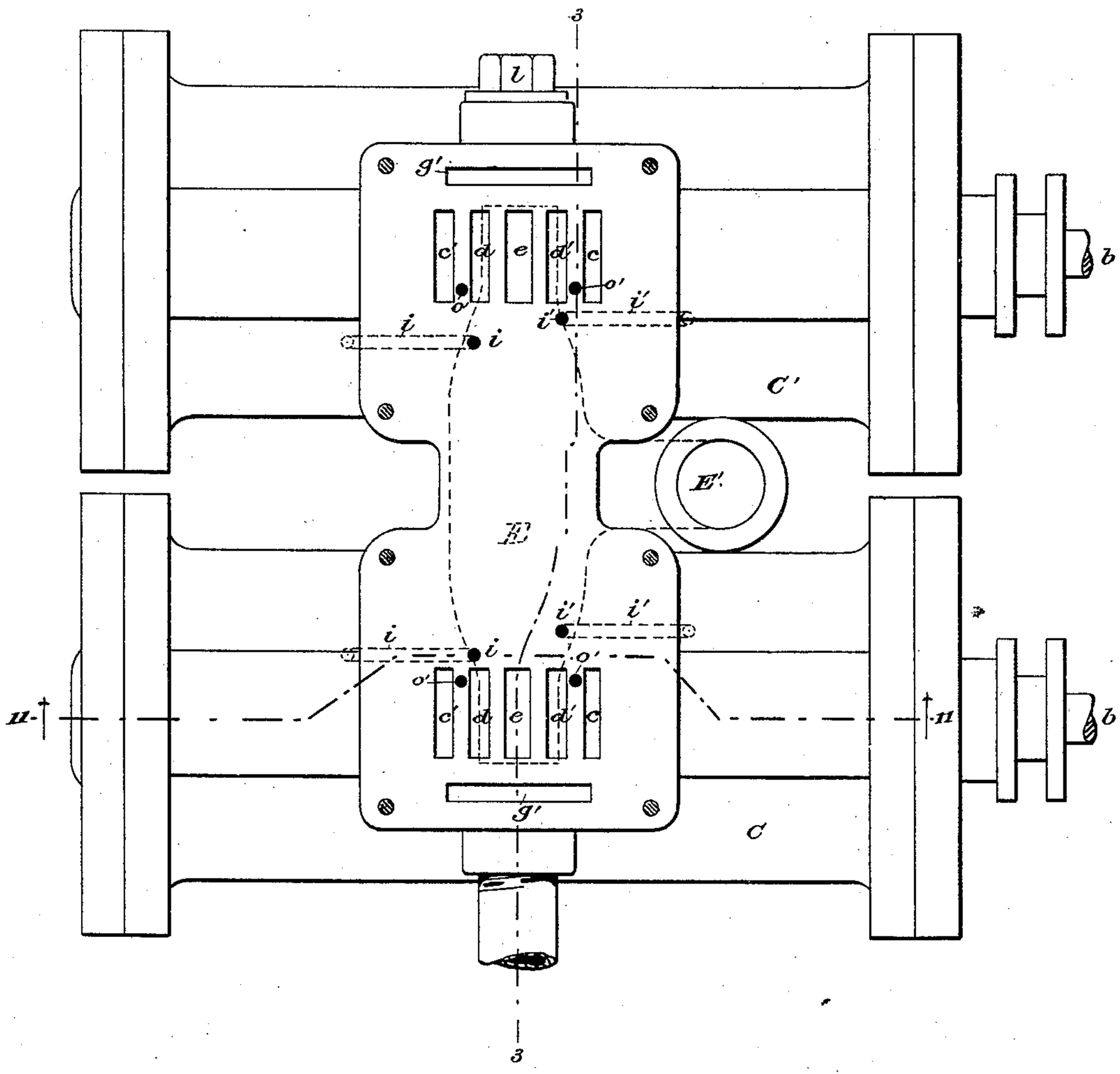
(No Model.) 7 Sheets—Sheet 3.

M. W. HALL.

DUPLEX STEAM ENGINE.

No. 349,157. Patented Sept. 14, 1886.

Fig. 4.



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(No Model.) 7 Sheets—Sheet 4.

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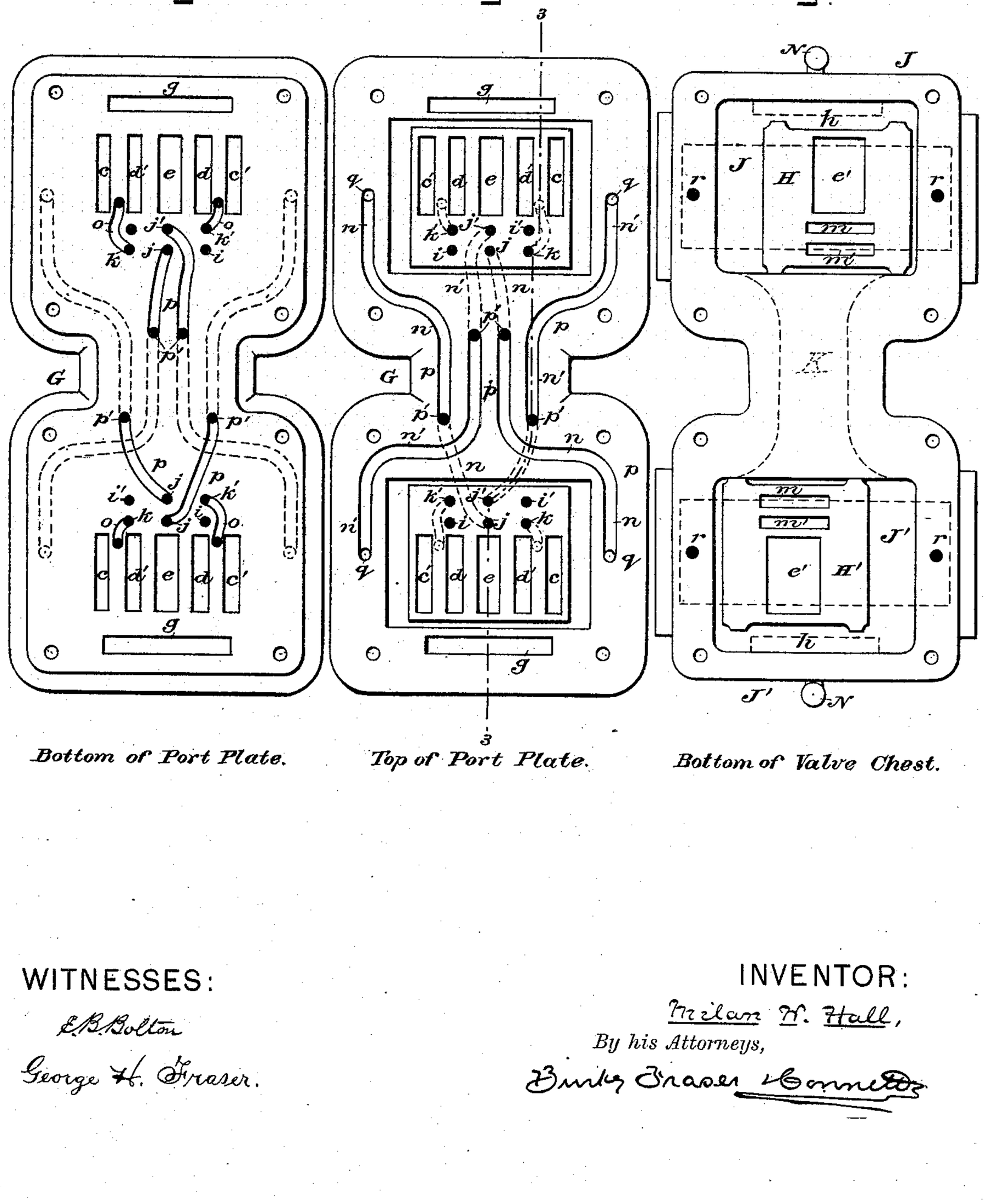
DUPLEX STEAM ENGINE.

No. 349,157. Patented Sept. 14, 1886.

Fig. 5. Fig. 6. Fig. 7.



Bottom of Port Plate. *Top of Port Plate.* *Bottom of Valve Chest.*

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(No Model.)

7 Sheets—Sheet 5.

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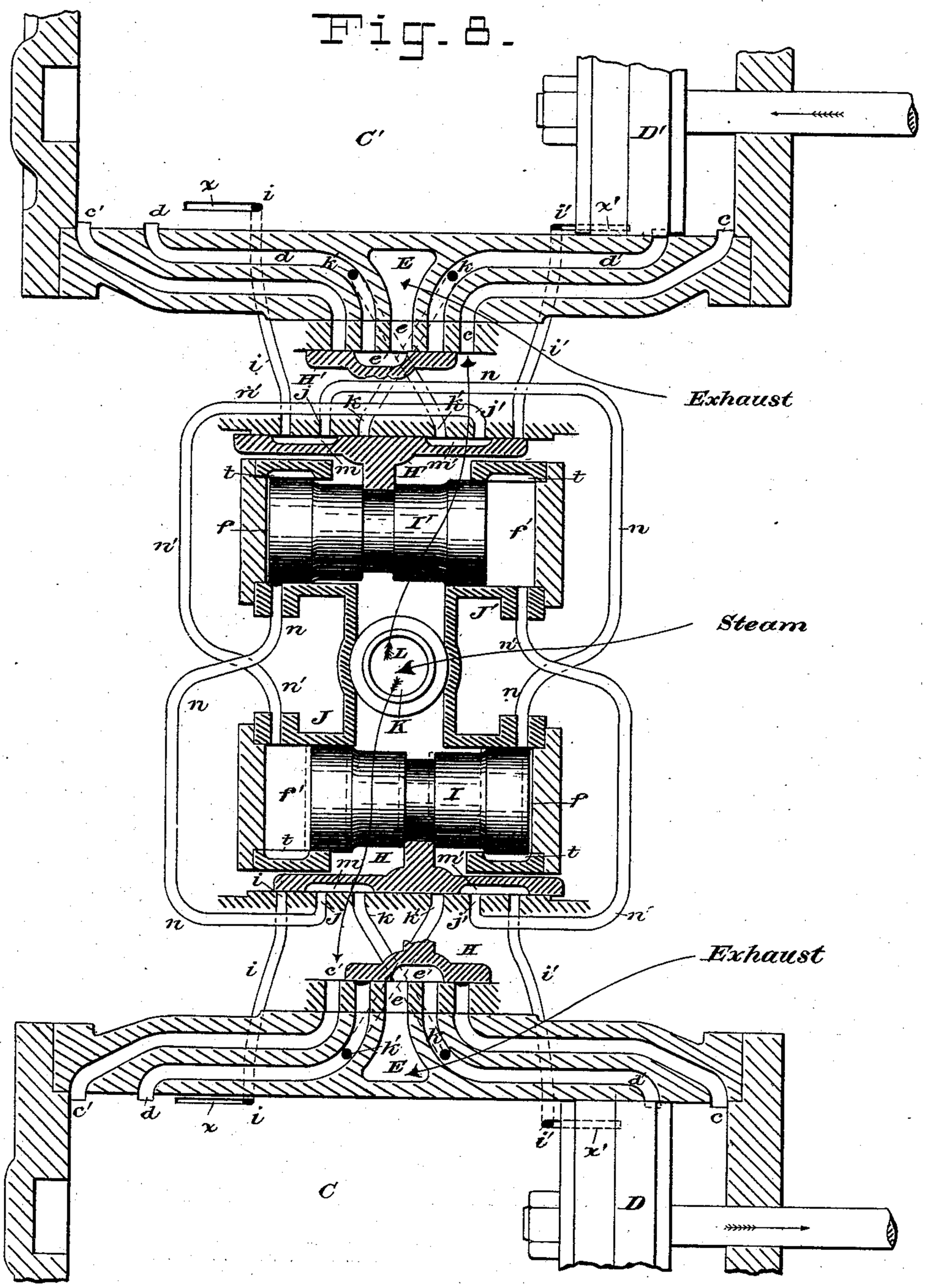
DUPLEX STEAM ENGINE.

No. 349,157. Patented Sept. 14, 1886.

Fig. 8.



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(No Model.) 7 Sheets—Sheet 6.

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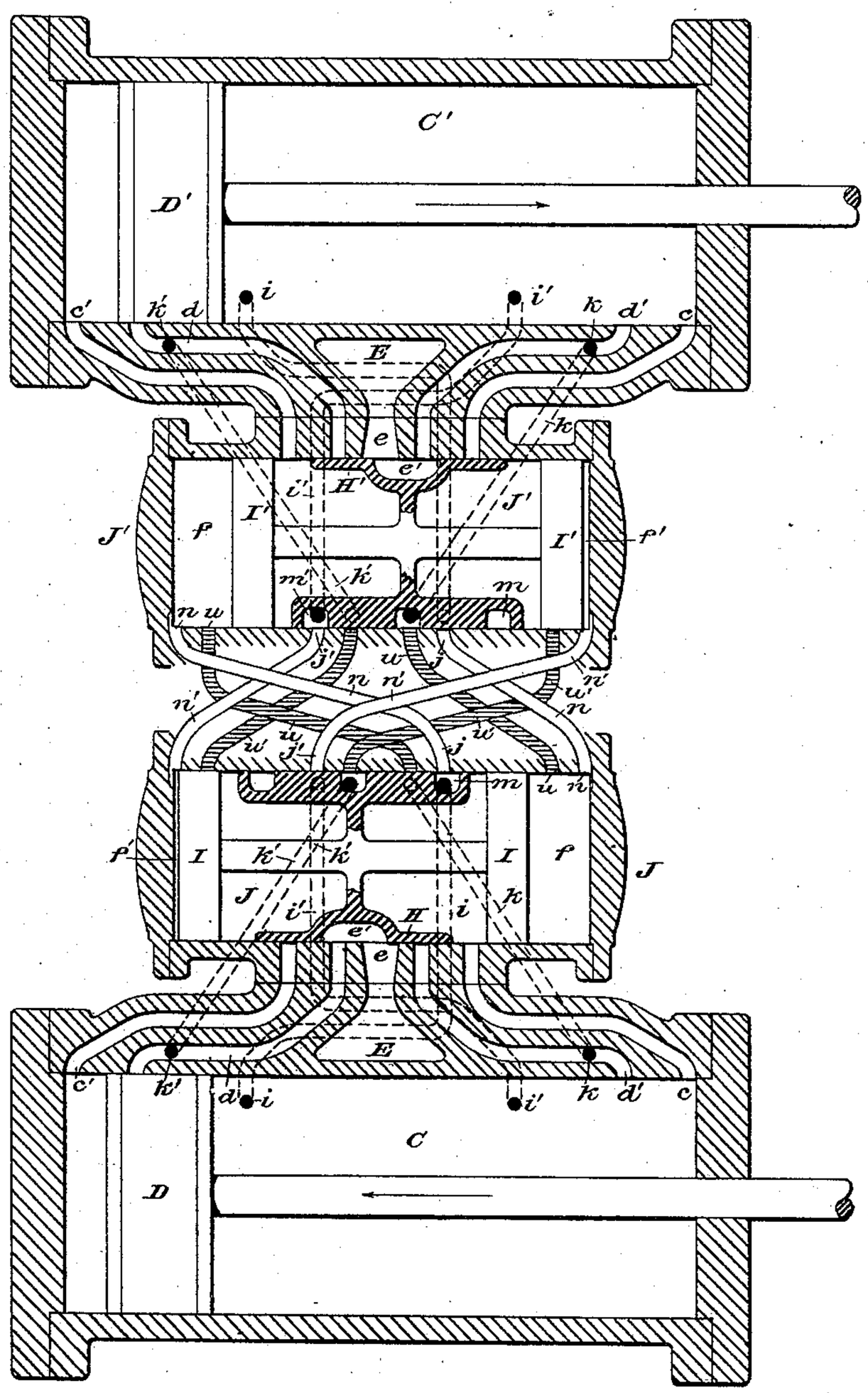
DUPLEX STEAM ENGINE.

No. 349,157. Patented Sept. 14, 1886.

Fig. 9.



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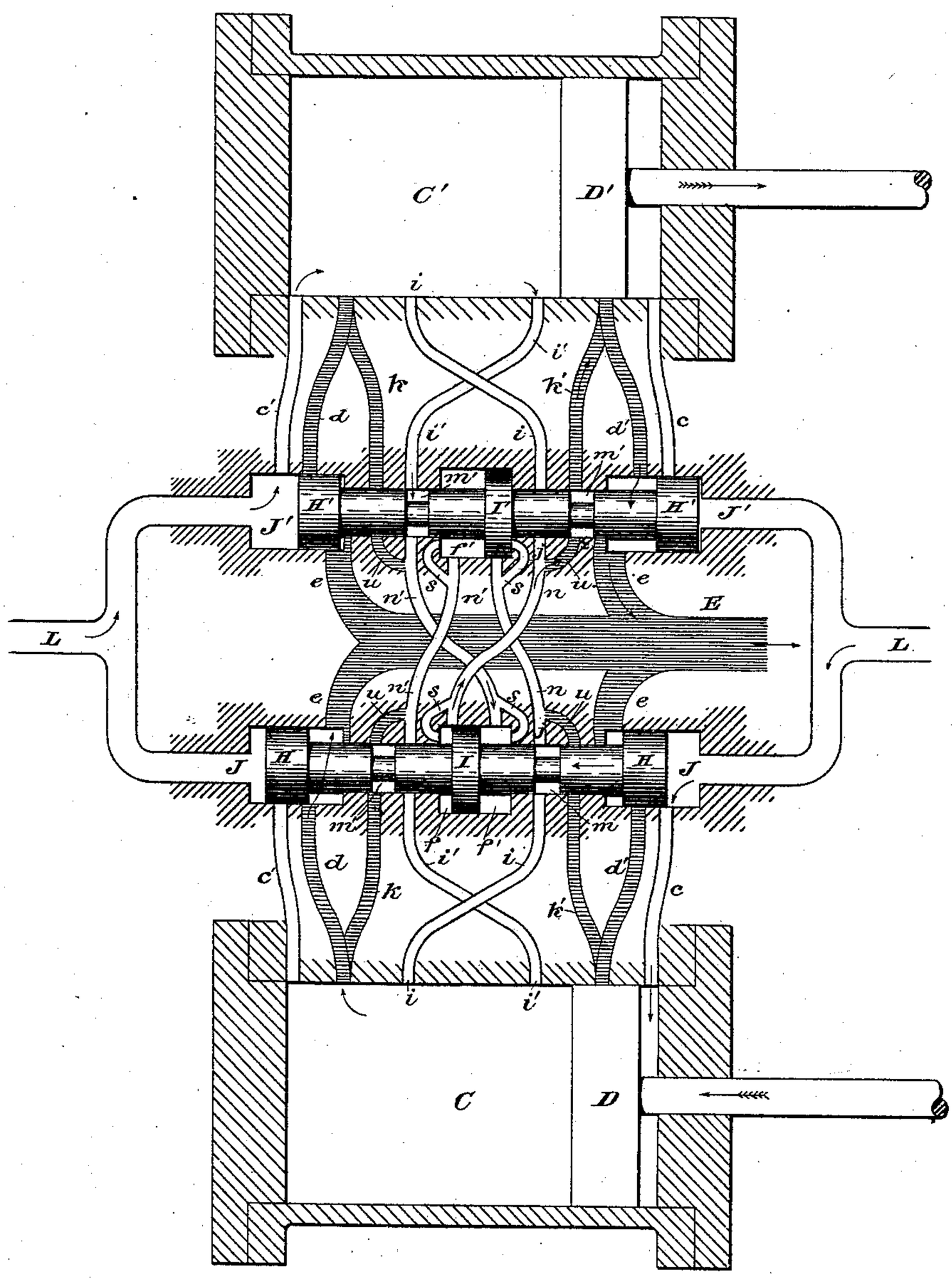
DUPLEX STEAM ENGINE.

No. 349,157. Patented Sept. 14, 1886.

Fig. 10.



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UNITED STATES PATENT OFFICE.

MILAN W. HALL, OF PLAINFIELD, NEW JERSEY, ASSIGNOR TO THE HALL STEAM PUMP COMPANY, OF SAME PLACE.

DUPLEX STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 349,157, dated September 14, 1886.

Application filed June 25, 1886. Serial No. 206,238. (No model.) Patented in France July 1, 1884, No. 163,084; in Germany July 2, 1884, No. 29,996; in England July 12, 1884, No. 10,097; in Belgium August 13, 1884, No. 66,018, and in Canada July 17, 1885, No. 22,049.

To all whom it may concern:

Be it known that I, MILAN W. HALL, a citizen of the United States, residing in Plainfield, Union county, in the State of New Jersey, have invented certain new and useful Improvements in Duplex Steam-Engines, of which the following is a specification.

This invention is the subject of patents in Great Britain, No. 10,097, dated July 12, 1884; in Germany, No. 29,996, dated July 2, 1884; in France, No. 163,084, dated July 1, 1884; in Belgium, No. 66,018, dated August 13, 1884, and in Canada, No. 22,049, dated July 17, 1885.

This invention relates to duplex engines of that class wherein the valves are actuated by steam-pressure alone, the two engines reciprocally controlling each other. It is most particularly an improvement upon the engine disclosed in my United States Patent No. 301,363, dated July 1, 1884. The chief distinguishing feature of the duplex engine described in that patent consists in the arrangement of steam-passages leading from the cylinder of each engine across to the valve-chest of the other engine, in order that steam from the cylinder of one engine shall cross over to the valve-chest of the other engine, and by direct impingement actuate the valve therein. Each valve controls the passage of steam from the cylinder of its own engine to actuate the valve of the other engine, and in like manner controls the passage of the exhaust-steam from the valve-chest of the other engine to the main exhaust. In operating the engine constructed according to that patent some trouble has been at times experienced, owing to the liability of the valves to move prematurely, thereby causing the pistons to make short strokes.

My present invention aims to overcome this defect; and to this end it involves two improvements on the engine shown in my said patent: first, such an arrangement of the steam and exhaust passages to and from the valve-chests that the "back-pressure" in the cylinders will be conducted equally to opposite sides of the valve-pistons, and, consequently, be impotent to move the valves prematurely; and, second, the "loading" of the steam-actuated valves to such extent that no mere inequality of back-pressure will suffice to move them, this requiring the direct pressure of the steam.

My invention also consists in certain important improvements in the mechanical construction of the engines, all as will be fully hereinafter described.

Figure 1 of the accompanying drawings is a side elevation of my improved duplex engine constructed as a pumping-engine. Referring to this figure, A is the duplex steam-engine, and B the pump. The two steam-cylinders are arranged in line with the two pump-cylinders, as is customary in duplex pumping-engines, and are connected by a yoke, *a*. Each engine has one piston-rod, *b*, which bears the steam-piston on one end and the pump piston or plunger on the other end. The pump B may be of any desired construction, and forms no part of this invention.

Figs. 2 to 7, inclusive, illustrate the preferred construction of my improved duplex engine. Fig. 2 is a vertical longitudinal mid-section of one engine, as denoted by the line 2 2 in Fig. 3. Fig. 3 is a transverse section through the two engines, as denoted by the lines 3 3 in Figs. 2, 4, and 6. Fig. 4 is a plan of the steam-cylinders alone, the valve-chests having been removed. Figs. 5 and 6 show the port-plate removed. Fig. 5 is a plan of the under side of this plate, and Fig. 6 is a plan of its upper side. Fig. 7 is a plan of the under side of the valve-chests and their connecting-passage. Fig. 8 is a diagram illustrating all the working parts and steam-passages in one view and nearly in the same plane. Figs. 9 and 10 are similar diagrams illustrating modifications. Fig. 11 is a fragmentary longitudinal section on lines 11 11 in Figs. 3 and 4, showing a slight modification.

Referring to Figs. 2 to 7, C C′ are the two steam-cylinders, and D D′ are their pistons fixed on the piston-rods *b b*. Each cylinder has two steam-ports, *c c′*, opening into it at its extreme ends, and two exhaust-ports, *d d′*, opening into it a short distance from its ends. (See Fig. 2.) These ports extend toward the middle, and between them is the exhaust-port

e, as usual, which opens into the main exhaust-passage E. This passage extends across between the ports *e e* of the two engines and leads to an outlet, E′, Fig. 4, where the exhaust-pipe F, Fig. 1, is to be connected. A port-plate, G, fits over the flat top of the two cylinders C C′, Figs. 2 and 3, and the several ports *c c′*, *d d′*, and *e* extend up through it. Over this plate works a flat slide-valve, H, Fig. 2, which operates in the usual way. It is moved back and forth by a plunger, I, the enlarged ends of which form pistons, which work in cylindrical chambers *f f′* in the steam-chest J. The valve H′, plunger I′, and steam-chest J′ of the other engine are of the same construction. The two steam-chests J J′ are connected by a steam-passage, K, Fig. 3, and they fit over the plate G, as shown. Through the ends of the plate G are formed two holes, *g g*, Figs. 5 and 6, which open into the steam-spaces *h h*, Fig. 3, in the steam-chests J J′, and coincide with two cavities, *g′ g′*, in the cylinder-casting beneath. One of these cavities is closed by a plug, *l*, and the steam-pipe L connects with the other. Thus the steam-pipe may be connected to either side of the engine, and the steam flows from it through the cavity *g′* and hole *g* into the interior of one steam-chest, and thence through the passage K to the other steam-chest.

Referring to Fig. 2, where the valve H is standing at the right, the steam flows from the steam-chest down the port *c′* into the cylinder C, where it drives the piston D toward the right, and the exhaust-steam escapes through the port *d′* under the valve A into the port *e* and exhaust-passage E. When the piston moves far enough to the right, it covers the exhaust-port *d′*, and the remaining steam in front of it acts as a cushion to stop the piston easily.

Referring to Figs. 2, 3, and 4, there are two small steam-ports, *i* and *i′*, in each cylinder-casting, which open into the cylinder, as shown. Holes or ports *i i′* are also formed through the plate G, coinciding with those in the cylinder-casting. These ports *i i′* open upward under the valve H or H′, and each is arranged in line with two other ports, as shown in Fig. 6. The six ports are thus arranged in two rows of three each, all covered by the valve. In one row is the cylinder-port *i*, a connection-port, *j*, and an exhaust-port, *k*. In the other row is the cylinder-port *i′*, a connection-port, *j′*, and an exhaust-port, *k′*. The valves H H′, Fig. 7, have each (in addition to the usual main exhaust-cavity, *c′*) two grooves, *m* and *m′*, which coincide with the two rows of ports. The connection-ports *j j′*, being in the middle, always communicate with these grooves *m m′*, and when the valve is at the right they are connected through the grooves with the ports *k* and *i′*, respectively, (the ports *i* and *k′* being then covered by the valve and closed,) and when the valve is at the left the ports *j j′* are connected, respectively, with the ports *i* and *k′*, (the ports *k* and *i′* being then closed.) The exhaust-ports *k* and *k′* pass down through the plate G, and extend into the exhaust-ports *d′* and *d*, respectively. They are formed by grooves *o o* on the under side of the plate, Fig. 5, and holes *o′ o′*, drilled in the cylinder-casting, Fig. 4. The connection-ports *j* and *j′* of each engine communicate through passages *n* and *n′*, respectively, with the chambers *f* and *f′*, respectively, in the steam-chest of the other engine. These four passages *n n′ n n′* are formed by grooves *p p* in the upper and lower faces of the plate G, as shown in Figs. 5 and 6. Where the passages *n n′* cross each other the respective grooves *p p* are on opposite sides of the plate, so that they do not interfere, and they connect through the plate by holes *p′ p′*. Where these grooves *p p* end at *q q q q*, Fig. 6, the passages *n n′ n n′* are continued upward by holes *r r r r*, Fig. 7, formed through the steam-chest J J′ into the chambers *f f′ f f′*, Fig. 2. All these ports and passages can be easily traced in the diagram, Fig. 8. The steam-pipe L is here shown in the center between the steam-chests. The valves H H′ are shown in two parts, one being a section through the exhaust-cavity *c′* and the other a section through the two grooves *m m′*, which are supposed to be arranged end for end instead of side by side. Referring to this figure, the operation will now be described. Steam enters cylinder C through port *c′* and drives piston D to the right. When the piston reaches nearly the end of its stroke it uncovers port *i′*, and live steam passes through that port, through groove *m′* in valve H into port *j′*, thence through passage *n′* to the chamber *f″* of the steam-chest J′, thus pressing the plunger I′ to the left, as shown, and shifting the valve H′ to the left. At the same time the steam in the chamber *f* at the other end of the plunger I′ escapes through passage *n*, port *j*, groove *m* in valve H, and passage *k* to the exhaust-passage *d′*, where it joins the exhaust-steam flowing out from cylinder C. The shifting of the valve H′ admits steam through the port *e* to cylinder C′, and starts piston D′ (which has been at rest) on its leftward stroke. When this piston uncovers port *i′*, no effect is produced, because this port is covered by the valve H′; but when it uncovers port *i* steam will flow through this port, through groove *m* or valve H′ into port *j*, and thence through passage *n* into chamber *f* of steam-chest J, where it will shift plunger I and valve H to the left. Meanwhile the steam in chamber *f′* at the left of plunger I will escape through passage *n′* to port *j′*, through groove *m′* of valve H′, and through port *k′* into exhaust-port *d* of cylinder C′. The shifting of the valve H to the left will start the piston D (which will previously have come to rest) on its leftward stroke, and the same series of operations will be repeated. The passages *n n′* enter the chambers *f f′* at a little distance from the ends of these chambers, thus leaving a cushioning-space beyond them in the ends of the chambers to stop the plungers I I′ gently.

A groove, *t*, is formed in the wall of each chamber *f f'*, and extends from the end of the chamber back a distance equal to the depth of the cushioning-space plus the width of the piston on the end of the plunger I or I'. When the plunger passes over and closes the opening *n* or *n'*, the groove *t* is opened to the pressure of steam in the middle of the steam-chest, and this stream flows through the groove into the cushioning-space, thus stopping the movement of the plunger. The plunger is then balanced with live steam at both ends. Assuming the plunger I to be at the right, as shown, as soon as the valve H' moves to the left, the chamber *f'* is opened to the exhaust, and the superior pressure of live steam in the chamber *f* will force the plunger I to the left a short distance, as shown in dotted lines in Fig. 8, sufficient to close the groove *t* and open the passage *n*. Then when the live steam from cylinder C' is admitted through the port *i* and passage *n* it will freely enter the chamber *f* and force the plunger I to the left. In case at any time the engine should fail to start when steam is turned on, it may be started by the hand-levers N N, Fig. 3, which are fixed to rocking bars, which pass into the tops of the steam-chests J J' and have arms P P, which hang down into the slots in the plungers I I'. By rocking the hand-levers the arms P P are caused to press against the ends of the slots and so move the plungers. These hand-levers form no essential part of the machine and may be omitted.

Prior to my present invention great difficulty has been experienced in all engines having steam-actuated valves, because of the tendency of the back-pressure in the cylinders when the valves are shifted to prematurely shift the valve pistons or plungers, and consequently derange the action of the valves. This derangement results in shortening the strokes of the engine-pistons, sometimes reducing them to such extent that the pistons execute merely a very short movement in the middle of their cylinders.

The action of the back-pressure may be made clear by reference to Fig. 8. The piston D is here about to stop. When it has remained stationary until the piston D' uncovers the port *i* in cylinder C', the plunger I and valve H will be shifted to the left. Previously the space in cylinder C to the left of piston D has been filled with live steam at high pressure. The shifting of the valve H connects this space with both chambers *f f'* of steam-chest J', and this pressure of steam escapes from cylinder C not only through the exhaust-port *d*, but also through the port *i* and passage *n* to chamber *f*, and through the port *d*, port *k'*, and passage *n'* to chamber *f'*. In my improved engine the same pressure passes from the cylinder C to both chambers *f f'*, so that the plunger I' is practically balanced; but in previous engines of this character the back-pressure has been permitted to pass from the cylinder to one chamber, *f* or *f'*, and the other chamber has had direct communication with the main exhaust, so that the pressures on opposite ends of the plunger I have been unequal, thus frequently shifting the plunger prematurely. This was the case to some extent with my former construction of engine, covered by my patent hereinabove referred to. In order that the change in that construction of engine which is necessary to apply my present invention may be readily understood, reference may be had to Fig. 10 of the accompanying drawings, which is a diagram very similar to the diagram Fig. 9 in my said patent. In both diagrams the passages used exclusively for exhaust-steam are tinted with horizontal lines. In my former patent the exhaust-passages from the valve-chests, after passing the grooves in the valve-stems, enter directly into the main exhaust. For instance, referring to Fig. 9 in my said patent, piston B' has just uncovered the port *i'*, and the valve D is being shifted toward the left. In so doing its grooves *h h* connect the passage *i* with the passage *j*, leading across to chamber L'. An instant previously the cylinder A to the left of piston B was filled with live steam at full pressure. The movement of the valve D uncovers the exhaust *b* at the left and the steam-inlet *a* at the right, both at the same instant. The pressure in cylinder A (known as the "back-pressure") then escapes through exhaust *b*, and also through passages *i* and *j* to chamber L', and presses upon valve-piston *g*, tending to force it to the left. From the main exhaust-passage it leads into passages P', thence through groove *h* and passages *i'* and *k* to chamber L', pressing against the piston *g* and tending to force it to the right; but the pressure thus exerted against the piston *g* is inferior to that against its opposite side, and consequently the piston is apt to be moved prematurely. This will occur whenever the preponderance of back-pressure from the cylinder A is sufficient to overcome the friction and inertia of the valve. That the two pressures are unequal may be clearly seen by tracing the respective paths which must be traversed by steam from both sides of the piston *g* before it can escape at the exhaust. Steam from the left side has only to pass through passages *k*, *l'*, and *p'* in order to reach the exhaust, while steam from its right side has to pass through passages *j'*, *j*, and *i*, cylinder A, exhaust-port *b*, and exhaust-passage *d* in order to reach the point where the passage *p'* joins the main exhaust, which is a far more circuitous passage. Furthermore, the back-pressure in cylinder A falls rapidly as the steam passes out to the exhaust, the pressure being at all times greatest in the cylinder and decreasing along the exhaust-passages; hence, while the right side of piston *g* is in direct communication with the high pressure in cylinder A, and the left side is in equally direct communication with the comparatively low pressure in the exhaust-passage, it is obvious that during the escape of the "back-press-

ure" from the cylinder there must be a much higher pressure against one side of piston *g* than against the other.

Referring now to Fig. 10 of the accompanying drawings, the essential change introduced by my present invention will be readily understood. The exhaust-passages *k k' k k'*, instead of joining the main exhaust E, as before, outside of the main valve, extend to the cylinders C C', respectively, or, what is substantially equivalent, to the exhaust-ports *d d' d d'*. Consequently the back-pressure from the cylinders has equally direct access to both sides of the pistons I I', and the latter are balanced by an equal pressure on opposite sides, and are no longer liable to be moved prematurely.

In my former construction the exhaust from the valve-piston chamber passed directly to the main exhaust outside of the main valve, where the back-pressure is much less than in the cylinder, or in the exhaust-port inside of the main valve. In my improved construction the exhaust from the valve-piston chamber passes either into the opposite cylinder or into the exhaust-port therefrom, and thence out through that port and through the main valve, being thus controlled and retarded by the main valve to the same extent as is the exhaust from the cylinder.

The construction shown in Fig. 10 is not preferred by me, for the reason that the valves H H', being balanced, are too easily moved in either direction, so that a very slight inequality of pressure will shift them. On this account I now use slide-valves, as already fully described, which are "loaded" by the pressure of steam holding them down to their seats. Sufficient friction is thus generated to resist any slight pressure; but when the full pressure of steam comes against the valve piston or plunger the valve is immediately shifted. This construction admits of some inequality of back-pressure on opposite sides of the valve-pistons without causing the premature shifting of the valves. Hence it is not necessary that the exhaust-passages from the valve-piston chambers shall actually enter the cylinders C C', and instead, for the sake of convenience and cheapness of construction, I cause the passages *k k'* to enter the exhaust-ports *d' d* at the position clearly shown in Fig. 8, or thereabout. In this case the ports *d d'* form continuations of the passages *k k'*, leading to the cylinders.

Fig. 11 shows a slight modification, wherein the exhaust-passages *k k'* actually enter the main cylinders. The section is chiefly through one exhaust-passage, *k*, and one steam-passage, *i*.

Another feature of my invention I will now describe. Where the ports *i i'* enter the cylinders, their open ends are designated by black dots. Formerly I provided only these openings, which were covered and uncovered by the piston in its movement. During the time that the piston is passing over one of these ports the port is covered up and all communication with the cylinder is cut off for an instant. I find it desirable that these ports shall always be in communication with the cylinder on one side or the other of the piston. In order to accomplish this to the same effect as though the piston were only as thick as the width of these ports, I form grooves *x x'* in the inner wall of the cylinder, extending from the open ends of the ports *i i'*, respectively, toward the ends of the cylinder for a length equal to the width of the piston, or rather for a distance equal to the width of the packing-rings, (the width of the openings *i* or *i'* being considered part of the length of the grooves,) as clearly shown in Figs. 2 and 8.

Fig. 9 is a diagram similar to Fig. 8, which shows a modified construction of the engine. The general operation is the same; but the passages *n n'* are used only for conducting the live steam to shift the plungers or pistons I I'. The exhaust-steam from the chambers *f f'* is conducted away by additional passages *u u'*, which are tinted in the figure. The cushioning-grooves *l l* are omitted, the plungers I I' being cushioned in the same way as the pistons D D'.

The plate G constitutes an important feature of my present invention, as it greatly improves and cheapens the construction of the engine and renders all the steam-passages readily accessible in case of necessity. It is not essential that the steam-passages crossing over from each cylinder to the opposite valve-chest shall be formed by grooves in the plate G, but only that they shall be formed by grooves along the joint between this plate and the valve-chests above and cylinders below. The grooves might be formed entirely in the jointing faces of the valve-chests and cylinders, or half in those parts and half in the plate.

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

1. A duplex steam-engine wherein the two engines reciprocally control each other by means of steam-actuated valves constructed with steam-passages and exhaust-passages extending from opposite sides of the valve-operating piston or plunger of each engine, and communicating with the cylinder of the other engine in such manner, as described, that the back-pressure in the cylinder shall be conducted equally, or nearly so, to opposite sides of the valve-operating piston or plunger, and consequently will be substantially balanced and impotent to move the piston or plunger prematurely, substantially as set forth.

2. In a direct-acting duplex steam-engine having its valves operated by direct steam-pressure, exhaust-passages leading from the opposite ends of the valve piston or plunger chambers into the end portions of the main cylinders, as described, each passage-way controlled by a valve, combined and arranged as described, as and for the purposes set forth.

3. In a direct-acting duplex steam-engine

having its valves operated by direct steam-pressure, exhaust-passages leading from the ends of the valve-plunger chambers and communicating with the exhaust-ports leading from the ends of the main cylinders to the main valves, each of said passages controlled by a valve, combined and arranged as described, as and for the purposes set forth.

4. A duplex steam-engine wherein the two engines reciprocally control each other by steam-actuated valves constructed with steam-passages and exhaust-passages leading from opposite sides of the valve-operating piston or plunger of each engine, and communicating with the cylinder of the other engine in such manner, as described, that the back-pressure from the cylinder shall be conducted equally, or nearly so, to the opposite sides of the valve piston or plunger, and the valves operated by said pistons or plungers constructed to be loaded by a pressure of steam forcing them against their seats, whereby sufficient friction is generated to resist the accidental shifting of the valves by any inequality of back-pressure transmitted through said passages, whereby said valves can be shifted only by the direct steam-pressure against their operating pistons or plungers, substantially as set forth.

5. The improved construction of duplex engines having steam-actuated valves, which consists of the combination of the main cylinders, the valve-chests, and an intervening plate, G, with the several steam and exhaust ports crossing between each engine and the valve-chest of the other, formed by means of grooves in the joints between said plate and the cylinders below and valve-chests above, substantially as set forth.

6. The improved construction of duplex engines having steam-actuated valves, which consists in the combination, with the main cylinders and valve-chests, of a port-plate, G, having grooves in its upper and lower faces, forming the passages crossing between each engine and the valve-chest of the other, substantially as set forth.

7. In a duplex engine, the combination of the two main cylinders, the valve-chests, the port-plate G between said cylinders and valve-chests, having grooves forming the passages crossing between the cylinder of each engine and the valve-chest of the other, and ports formed through it, and the steam-actuated slide-valves in said valve-chests, arranged to slide over said plate and to open and close the said ports therein, substantially as set forth.

8. In a duplex engine having steam-actuated valves, the combination, with the valves and their actuating pistons or plungers, of the valve-chests constructed with chambers *f f'* for said plungers, with ports *n n* entering the same near their ends, leaving a cushioning-space in the end of each chamber beyond the port *n*, and the cushioning-grooves *t t* in the said chambers, substantially as set forth, whereby when the plunger nears the end of its stroke and cuts off the exhaust through *n* it opens *t* and admits live steam in front of it to cushion against.

9. In a duplex engine having steam-actuated valves, the combination, with the main cylinders and pistons, of ports *i i'*, leading from the cylinder of each engine through the valve thereof to the valve-chest of the other engine, and grooves *x x'*, formed in the cylinders, extending from said ports toward the ends of the cylinders a distance equal to the effective length of the pistons, substantially as and for the purpose set forth.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

MILAN W. HALL.

Witnesses:

ARTHUR C. FRASER,

GEORGE H. FRASER.