(No Model.) 2 Sheets—Sheet 1.

W. M. HENDERSON.

STEAM ENGINE.

No. 347,874. Patented Aug. 24, 1886.

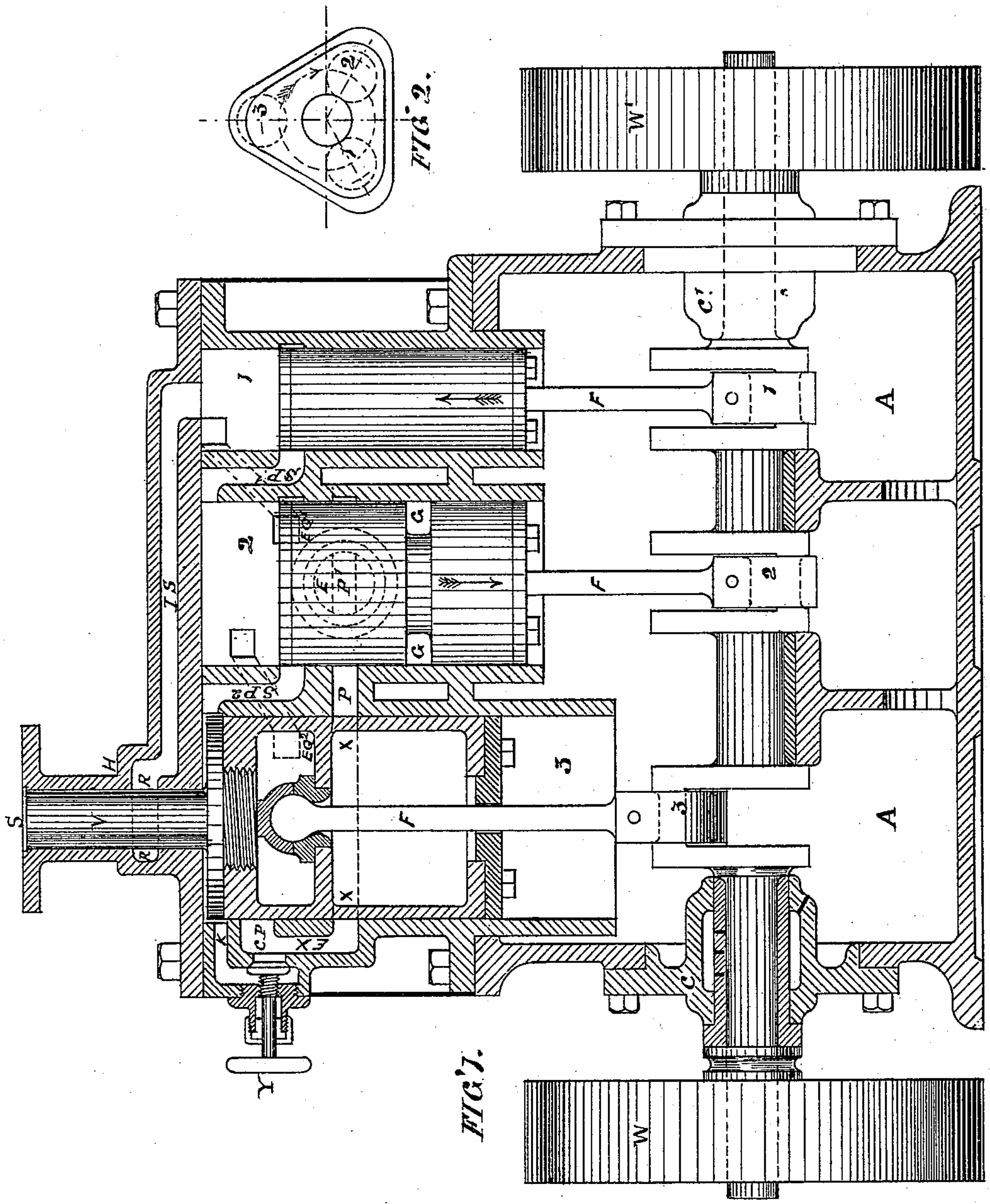

FIG. 2.

FIG. 1.

WITNESSES.

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(No Model.) 2 Sheets—Sheet 2.

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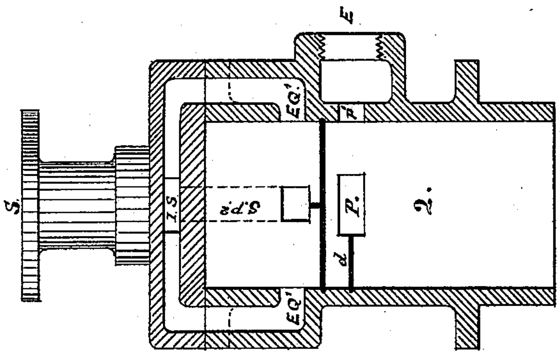

FIG. 4.

FIG. 5.

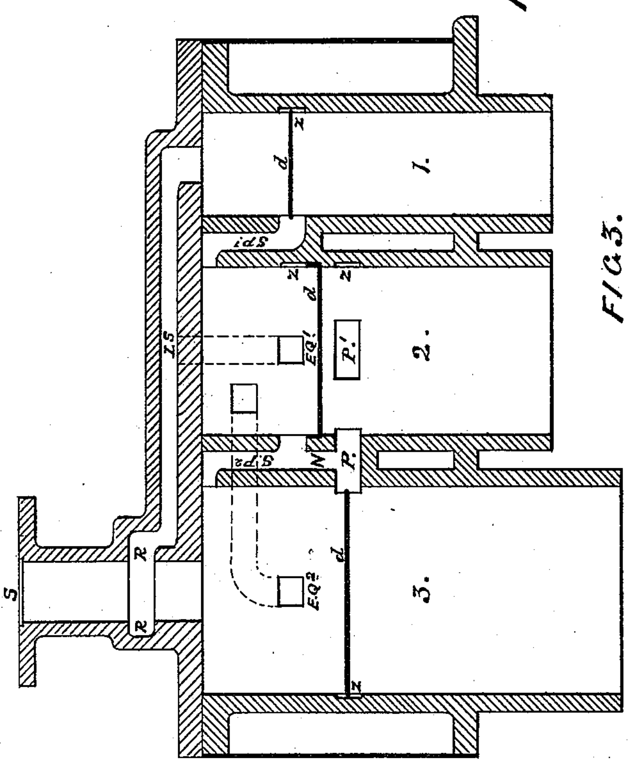

FIG. 3.

WITNESSES.

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UNITED STATES PATENT OFFICE.

WILLIAM M. HENDERSON, OF MORTON, PENNSYLVANIA.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 347,874, dated August 24, 1886.

Application filed April 16, 1886. Serial No. 199,101. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM M. HENDERSON, a citizen of the United States, residing at Morton, in the county of Delaware and State of Pennsylvania, have invented a new and useful Improvement in Steam-Engines; and I do hereby declare the following to be a full, clear, and exact description of the invention, which will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings.

This invention is intended as an improvement upon the English patent granted to J. A. and A. C. F. Franklin, No. 457 of 1871, for compound engines, where three cylinders are used of unequal diameters, placed side by side, their pistons coupled to crank-pins set one hundred and twenty degrees apart on a common crank-shaft; and the object is to do away with the eccentrics and sliding valves there used, and employ no valve-gear other than what is derived from the motion of the pistons themselves, after the manner subsequently brought out by P. W. Willans, of Lewisham, England, combining in one machine the advantages to be derived from the continuous steam expansion afforded by Franklin's system, with the simplicity pertaining to Willans' method of dispensing with all valve-gear. In order to produce an effective working engine by this combination certain new arrangements in the manner of forming the several steam and exhaust ports and passages in relation to the movements of the several valvular pistons, and to the forms of the pistons themselves, have to be devised, and means taken to prevent side thrust on the pistons by the action of the steam pushing on them through the several lateral ports piercing the bore of the cylinder, all of which will hereinafter be fully described and set forth.

Figure 1 represents a longitudinal section taken through the center line of the cylinders and engine. Fig. 2 is an end view of the crank-shaft. Fig. 3 is a longitudinal section through the line of cylinders, showing a modification in the arrangement of the ports and passages. Fig. 4 is a transverse section of Fig. 3, through the center line of cylinder No. 2, and Fig. 5 is a detail.

A is an inclosed crank case or housing for the engine, containing the lubricating material required for the running parts, upon which are mounted the three working cylinders 1 2 3.

B is the crank-shaft, the crank-pin centers being arranged one hundred and twenty degrees apart, as shown by Fig. 2. The journals of the shaft run in long phosphor-bronze bearings, secured in the heads C C′, which heads are bolted to the crank-case, as shown. The shaft is further supported by intermediate bearings, D D′.

F shows a form of connecting-rod which may be used, and W W′ are the balance-wheels.

Cylinder No. 1 is the high-pressure cylinder, or the first to which the steam from the boiler is admitted. Cylinder No. 2 is the second cylinder in the series, of somewhat larger diameter, receiving steam from the first, and cylinder No. 3 is of still larger dimensions, and receives its steam from the second. The expansion of the steam being progressive and continuous from the first cylinder to the last, in conformity with the design exemplified by Franklin. The relative proportions of the cylinders may be varied to suit any requirement, either in having increased diameters, or longer strokes, or both together, in order that the steam from the first cylinder shall expand in the second, and shall again expand from the second to the third, a principle well known and recognized in the art of building compound engines.

In order to give a working example I have in the acccompanying drawings made the high-pressure cylinder three inches diameter and three inches stroke, the second or intermediate cylinder four and a half inches diameter and three inches stroke, and the third or low-pressure cylinder six inches diameter; but in order to introduce the final exhaust-passage P from cylinder No. 3, and which exhaust is controlled by a circular groove cut in piston 2, the stroke of this cylinder is made four inches. These proportions give an expansion of the steam, allowance being made for clearance-space of five times.

The three-throw crank in its application to three-cylinder engines as an expedient to do away with all valve-gear, has been fully demonstrated and recognized. By reference to Fig. 2 it will be seen that the relative positions of the crank-pin centers 1 2 3 are just where the centers of eccentrics should be to admit steam at the commencement of the stroke and cut it off at three-fourths of the stroke on the piston connected to the next following crank. Thus the piston connected to crank-pin 2 would give steam to the piston attached to crank 3 when that piston arrives at the top of its stroke, (the position it now occupies on Fig. 1,) the position of the cranks at this time being, as shown by Fig. 2. Piston 2 is descending and about to uncover the steam-port S P^2, leading to the top of cylinder No. 3. Piston No. 1 is proceeding upward, and has just cut the steam off from cylinder No. 2, which at this time has completed three-fourths of its downward stroke. Crank 3 would come into position to give steam by the piston-valve V to the piston No. 1 at the commencement of its stroke, and crank No. 1 in its turn would operate the piston connected to it as the valve for No. 2. Such is the general property of the three-throw crank; but in order to make it effective here, certain other provisions have to be made, which I will now describe.

S is where the steam connects from the boiler, and E is the final exhaust-outlet. First, it will be seen that above the cylinder No. 3 there is attached to the cylinder-head, which covers the tops of the cylinders, a cylindrical chamber, H, having a recessed circular port, R, connecting with the initial steam-port I S, leading to the top of cylinder No. 1, in which chamber works a piston-valve, V, projecting from the large piston 3. This valve is so arranged that when piston 3 descends to its lowest point the valve will be carried down, fully uncovering the entrance to port I S. The depth of the circular recess R does not agree with the usual requirements of the three-throw crank, giving steam to piston 1. When it arrives at the top of its stroke, it is only three-fourths of the depth required for that purpose, and the consequence is that crank No. 1 is allowed to pass its center about one-fourth of an inch, giving some leverage for action before the steam is admitted to piston 1. No advantage is gained by admitting steam to a piston directly on its dead-center, which only produces an injurious thrust on the crank-pin. This is an incidental advantage, but not the one aimed at, which will be noted further on.

S P′ is a steam-port. The upper edge, leading out of cylinder No. 1, is three-fourths of the stroke down, and the lower edge on the stroke-line, so that when piston 1 reaches its lowest point, it fully uncovers this steam-port. The other end opens into the top of cylinder No. 2. Another similar port, S P^2, leads from cylinder No. 2 to the upper end of cylinder No. 3.

E Q′ is an equilibrium-passage leading from the upper end of cylinder No. 1 and opening into cylinder No. 2, its upper edge in cylinder No. 2 being about three-sixteenths of an inch less than the three-fourths part of the stroke, as shown. Another equilibrium-passage, E Q^2, leads from one-fourth the stroke down in cylinder No. 2 and opens into cylinder No. 3, its upper edge in cylinder No. 3 being about three-sixteenths of an inch less than the three-fourths part of the stroke of piston 3. These passages E Q may be formed in other ways. (See Fig. 3.)

E X is an exhaust-passage leading from the upper part of cylinder No. 3 and communicating with the circular recess X X at the bottom of the stroke of that cylinder, and by the passage P, leading to the port P′, which latter opens into the final exhaust-outlet E, situated on the back of cylinder No. 2, as shown by Fig. 4.

Y is a regulating-valve for controlling the degree of compression on the return stroke upon piston 3.

Operation: The position of the pistons, as shown by the drawings, Fig. 1, and by the position of the crank-pins represented in Fig. 2, shows that piston 3 is at the top of its stroke. Piston 1 has already completed its downstroke and is ascending. It has just closed steam-port S P′, and the steam is thereby cut off from cylinder No. 2. Now, it is manifest that unless some provision is made the end of further steam expansion has been reached, and the compression above piston 1 would soon stall the engine; but piston 2 is at this time descending, and has already uncovered the upper edge of the equilibrium-passage E Q′, opening an avenue for the steam to flow uninterruptedly from above piston 1 to cylinder No. 2, which continues to descend by virtue of its greater area over that of the back pressure on piston 1, and presently will admit the steam to piston 3 by the steam-port S P^2. It will reach its lowest point, and return to the position it now occupies, at which time piston 3 has descended three-fourths of its stroke, and will have uncovered the upper edge of the equilibrium-passage E Q^2, through which the steam from cylinder No. 2 will continue to flow to cylinder No. 3, until the upper edge of piston 2 in ascending closes the opening to passage E Q^2, which will occur when piston 3 has completed its downward stroke. The steam remaining above piston 2 is required there for the purpose of cushioning. By measurement it will be seen that when piston 3 reaches its lowest point, its upper edge descends about one-eighth of an inch below the exhaust-recess X X, and permits of a supplementary exhaust. By this time the circular groove G in piston 2 will, in ascending, have established a connecton between itself and the exhaust-passage P, communicating by means of the recess X X and the passage E X and port C P with the upper end of cylinder No. 3, and a free exhaust will continue through the port P′ and exhaust-outlet E, until the groove G in piston 2 in descending again passes the passage P, which will occur at one-fourth of its downstroke. At this time piston 3 will have completed three-fourths of its upward stroke, and would at the same time have closed the port C P, when compression above piston

3 will set in. Some compression will be required to keep a thrust on the head of the piston, and prevent knocking when running at high speeds, and to adjust the amount required an additional opening, K, is made above the port C P, having a regulating-valve, Y, opening a communication back again to the exhaust-passage E X. The course of the steam through the cylinders is as follows: Connection with the boiler is made at S, and when crank 1 has passed its center about one-fourth of an inch the piston-valve V will have descended into position to admit steam to piston 1 by the descent of piston 3, which will then be three-fourths of an inch from the end of its stroke. Completing this and returning the steam will be cut off by the piston-valve V in cylinder No. 1, when its piston has made about two-thirds of its downward stroke. At three-fourths of the downstroke piston 1 will admit steam to cylinder No. 2, the piston of which has just arrived at the top of its stroke, and the steam will expand from cylinder No. 1 into cylinder No. 2. The steam will also expand on piston 1, carrying it to the end of its stroke. On returning, piston 1 will close the steam-port S P′; but steam will continue to flow through the equilibrium-passage E Q′, that channel being previously uncovered by piston 2 in its descent. At the same time that piston 1 closes the steam-port S P′ piston 2 commences to pass the expanding steam to cylinder No. 3 by the steam-port S P^2, the piston of cylinder No. 3 being then at the top of its stroke. The steam will now expand from cylinder No. 2 into cylinder No. 3, and will also act expansively on piston 2, carrying it to the end of its stroke. Piston 3 will be three-fourths down when piston 2 in ascending closes the steam-port S P^2. The steam will, however, continue to flow from cylinder No. 2 to cylinder No. 3 by the equilibrium-passage E Q^2, which was previously opened by the piston 3 and maintained to near the end of the stroke. When this is reached, the circular groove G in piston 2 will commence to exhaust the steam from above piston 3 by the exhaust-passage E X, circular recess X X and passage P being by the groove G put into communication with the exhaust-port P′ and exhaust-outlet E; and this exhaust will continue until piston 3 reaches to the point of one-fourth from the end of its upstroke, when compression will set in above piston 3 by the combined action of the groove G passing downward the passage P and by the piston itself closing the port C P leading to the exhaust-passage E X. The compression on piston 3 after the point has been reached is regulated by the adjusting-valve Y, as before explained.

It will be observed that by the peculiar disposition of the steam-ports S P^2 and equilibrium-passage E Q′ in relation to the movement of pistons 2 and 3 the steam communication between cylinders 1 and 3 remains open until the end of the useful expansion has been reached, which will occur when piston 3 has completed about seven-eighths ($\frac{7}{8}$) of its downward stroke. Another point to be noticed is that piston 2 in ascending will close the equilibrium-passage E Q′ just before steam is admitted to cylinder No. 1, the admission being purposely held back until piston 1 has passed its center, as before explained, giving time for this to take place. Otherwise the steam would pass to the top of piston 2 and block the engine. It will also be observed that the area presented by the piston-valve V tends to equalize the pressure on the pistons by reducing the effective area of the high-pressure piston 1, which is the most powerful, and assisting the low-pressure piston 3, the least powerful, and is further valuable in relieving the engine from dead-points, so that it will start whenever steam is turned on, without the necessity of priming or turning over by hand as generally required, for should the engine stop with the piston-valve V raised above the circular port R, excluding the steam from the leading cylinder No. 1, the first action of the steam admitted by the throttle-valve will be to push the valve V and piston 3 downward, opening the port R, and allowing the steam to pass by port I S to the piston of cylinder No. 1, which in its descent will pass it to cylinder No. 2, and from No. 2 it will be transmitted to cylinder No. 3, causing the engine to revolve. In any other position, where the top of piston-valve V is below the circular port R the engine will start, because the steam then will be properly admitted.

Referring to Figs. 3 and 4, it is manifest that the upper end of equilibrum-passage E Q′ may be brought direct from the initial steam-port I S, and that by having one on each side of the cylinder, as shown on Fig. 4, the pressure of the steam on the piston, when moving across the openings made in the cylinder, will balance the piston from side thrust. The passages E Q^2 being also in duplicate, the pressure comes equally on each side of the piston in cylinder No. 3. The upper openings of E Q^2, in cylinder No. 2, it will be seen, are not in the center line of that cylinder; but when the piston 2 is traversing them the lower openings in cylinder No. 3 are open to the atmosphere, and no pressure is experienced.

The steam-ports S P′ S P^2 and exhaust-port P are counterbalanced by casting an impression of the port about one-eighth of an inch deep, (marked Z,) opposite each port, and leading thereto, a semicircular steam-duct, *d*, of about one-sixteenth of an inch in diameter, which will convey the same pressure of steam from each port to its corresponding counter-relief recess, resulting in a restored equilibrium. The port P′ always being open to the atmosphere requires no attention. The recesses primarily act as a counter-relief. They are also advantageous to the production of a true bore. The tool in its revolution then always encountering the same resistance, the tendency to spring toward the open port is avoided.

The importance of balancing the pistons from side thrust is a matter that cannot be overrated, for it will be seen that if a port pierces one side of a cylinder traversed by a piston, piston-valve, or trunk-piston the steam will press on the piston sidewise with a force equal to the area of such port multiplied by the pressure of the steam, which force will push the piston over to the opposite side, producing, in the first place, excessive friction, and in the second place will open an avenue on the pushed side for the steam to escape past the piston and cause a loss of steam, besides being generally objectionable. As a means to prevent this, it has become a common practice, in the construction of engines having piston-valves, to continue the width of the ports over which such pistons travel in a circular direction clear around the piston. Such an arrangement is shown in the patent to Thomas L. Davis, No. 39,125, of July 7, 1863; but it has the defect of increasing the waste-steam space, the contents of such circular counter-bore having to be added to the waste space of the ports. It will be seen that the device shown upon the drawings accompanying this specification is equally effective, and that the loss from waste space is restricted to that contained in a mere recessed impression of the port to be counteracted, located directly opposite, the larger part of the passage being supplanted by a duct of relatively small proportion, which duct will invariably convey the same pressure to the recess as exists at any time in the port. Again, there are situations where the full width of port cannot be carried around as commonly practiced, as in the case where two ports to be balanced occur in the same plane, performing different duties, for then the steam would pass where it was not wanted. With my arrangement of distinct counter-relief recesses and ducts this is perfectly feasible. The recesses can be placed in proper position opposite the ports, and the ducts led up and down, avoiding contact entirely.

By simply cutting the bottom of the steam-port S P^2 through to the exhaust-port P, as indicated by N on Fig. 3, all the ports on the other side of cylinder No. 3 may be dispensed with, depending upon the constant steam-pressure on valve V to provide the thrust necessary to prevent knocking, and by making the port P ⅂ shaped, as shown by Fig. 5, and lowering the groove in piston 2 to suit, the stroke of all three cranks can be made alike.

A steam-jacket may or may not be used encircling the cylinders, as provided for in the original patent granted to Franklin, referred to.

Having thus described the nature of my invention, what I claim therein as new, and desire to secure by Letters Patent, is—

1. In a continuous-expansion compound engine, the combination of the cylinders 1 2 3, of unequal size, placed side by side, and having their pistons coupled to crank-pins arranged one hundred and twenty degrees apart on a common crank-shaft, the pistons performing the functions of the steam-valves, admitting the steam directly and consecutively from one to the other by means of steam-ports I S S P′ and S P^2, substantially in the manner shown and described.

2. The steam, equilibrium, and exhaust ports and passages arranged, as shown, with the valvular pistons, and means for operating them, substantially as set forth.

3. The combination of the high-pressure cylinder No. 1 and its piston with the low-pressure piston 3, piston-valve V, cylindrical chamber H, and initial steam-passage I S, arranged substantially as shown and described.

4. The combination of the intermediate expansion-cylinder, No. 2, and its piston with the high-pressure valvular piston 1, steam-port S P′, and equilibrium-passage E Q′, arranged substantially as shown and described.

5. The combination of the low-pressure cylinder No. 3 and its piston with valvular piston 2, steam-port S P^2, and equilibrium-passage E Q^2, arranged substantially as shown and described.

6. The combination of the low-pressure cylinder No. 3 and its piston with the grooved valvular piston 2, exhaust-passage E X, P, and P′, and exhaust-outlet E, the groove G, matching exhaust-passage P and exhaust-port P′ on its upstroke, substantially as shown and described.

7. The combination of the low-pressure cylinder No. 3 and its piston with the grooved valvular piston 2, exhaust-ports C, P, and K, and compression-valve Y, exhaust-passages E X, P, and P′, and exhaust-outlet E, arranged substantially in the manner shown and described.

8. The combination of the low-pressure cylinder No. 3 and its piston with the grooved valvular piston 2, steam-port S P^2, with outlet N, opening into exhaust-port P, substantially as shown and described.

9. The combination, in cylinder No. 2, of the steam-port S P^2 and equilibrium-passage E Q′ with the valvular piston 2, substantially as shown and specified.

10. The combination of the pistons 1 2 3 with the ports, counter-relief recesses, and connecting-ducts, arranged substantially in the manner for the purpose represented.

11. In a cylinder, the combination, with a moving piston, of a lateral port, a corresponding counter-relief recess, and a pressure-duct joining the two, arranged substantially in the manner for the purpose herein set forth and described.

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Witnesses:

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H. R. SHULTZ.