(No Model.) 3 Sheets—Sheet 1.

J. H. EICKERSHOFF.

COMPOUND ENGINE.

No. 441,947. Patented Dec. 2, 1890.

Fig. 1.

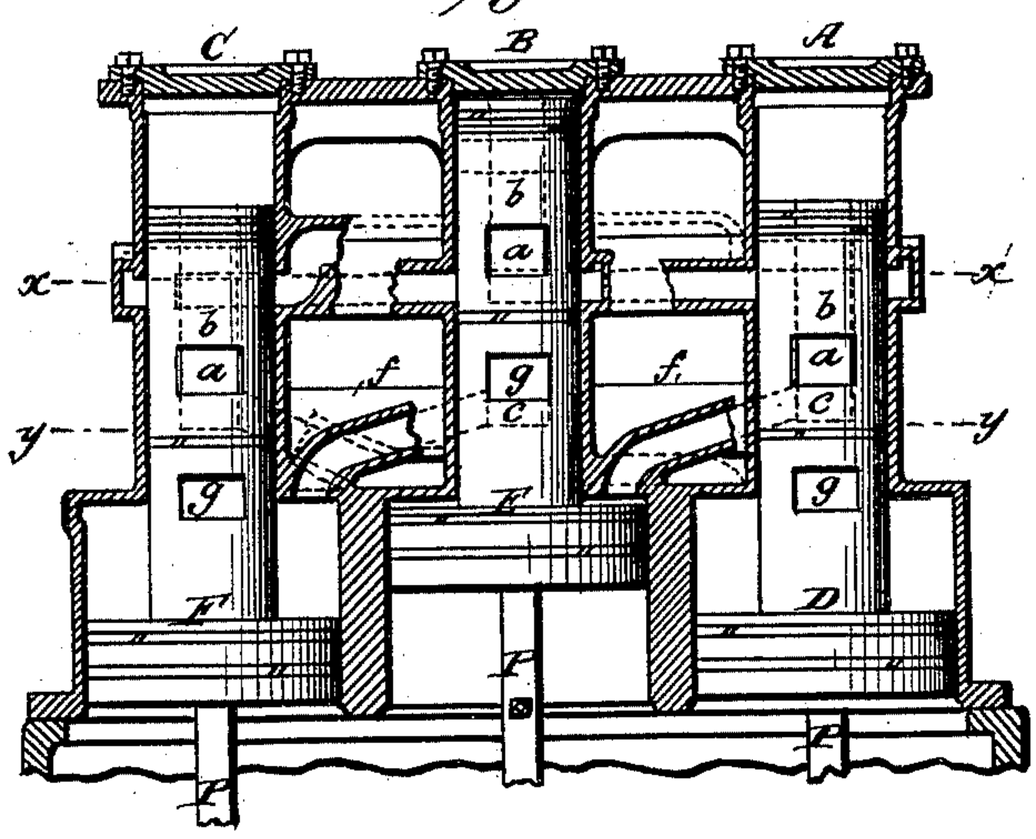
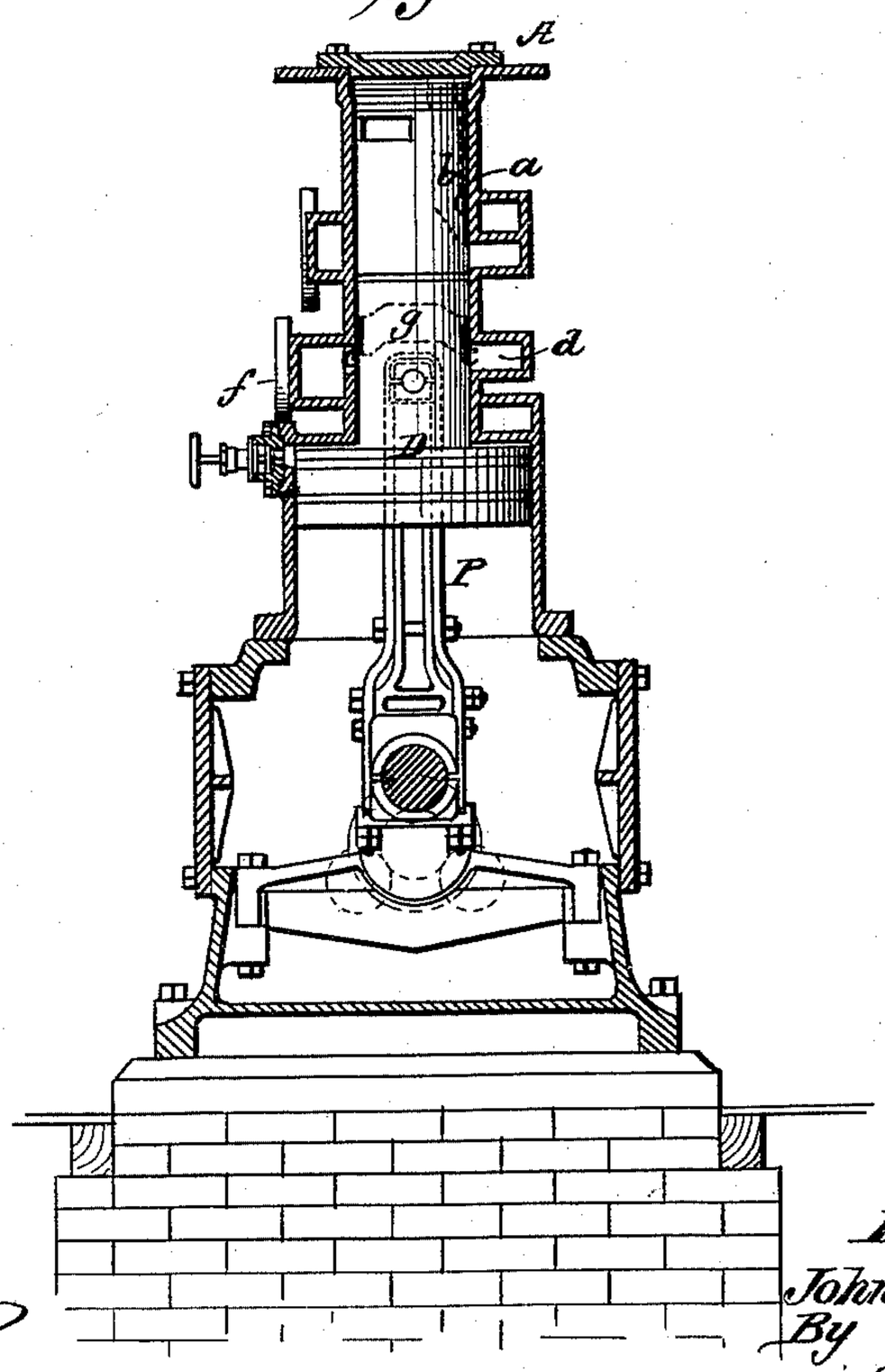


Fig. 2.



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(No Model.) 3 Sheets—Sheet 2.

J. H. EICKERSHOFF.

COMPOUND ENGINE.

No. 441,947. Patented Dec. 2, 1890.

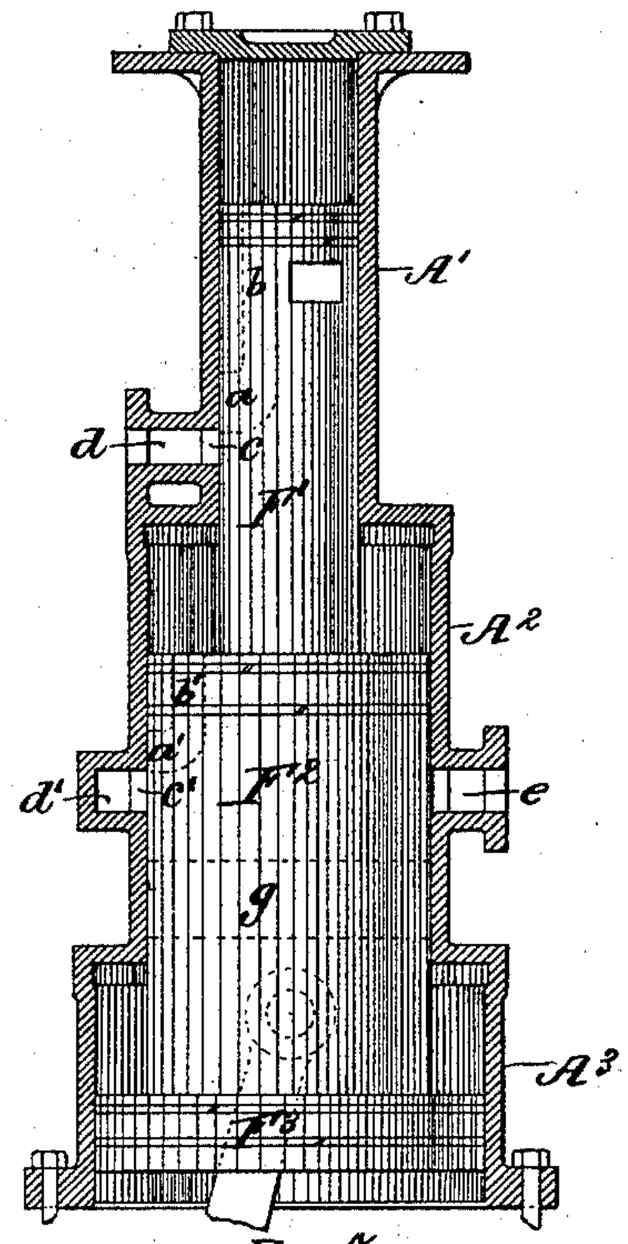


Fig. 5.

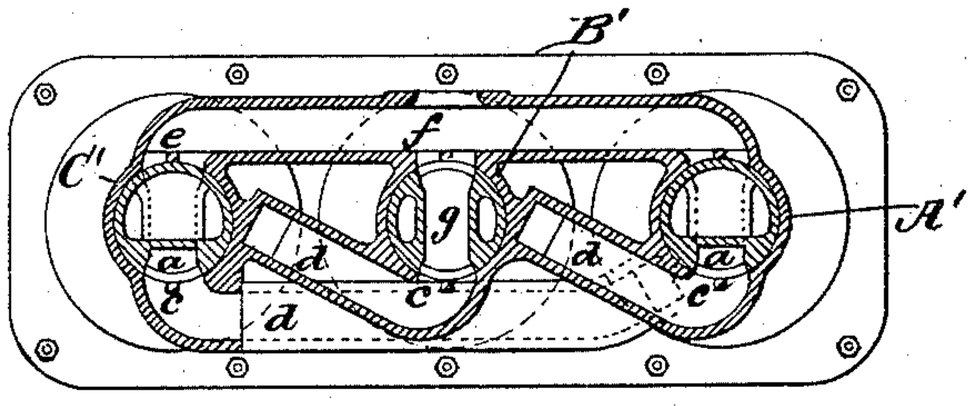
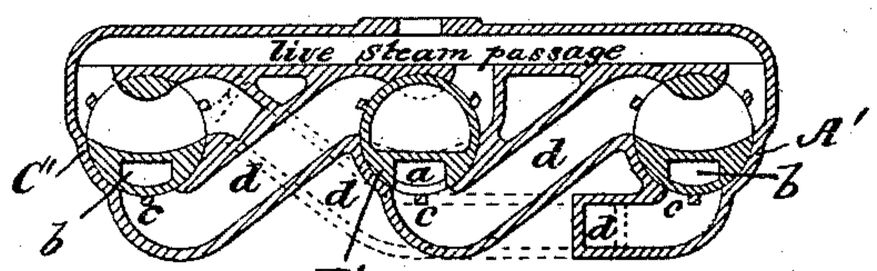


Fig. 4.



B' Fig. 3.

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(No Model.) 3 Sheets—Sheet 3.

J. H. EICKERSHOFF.

COMPOUND ENGINE.

No. 441,947. Patented Dec. 2, 1890.

Fig. 6.

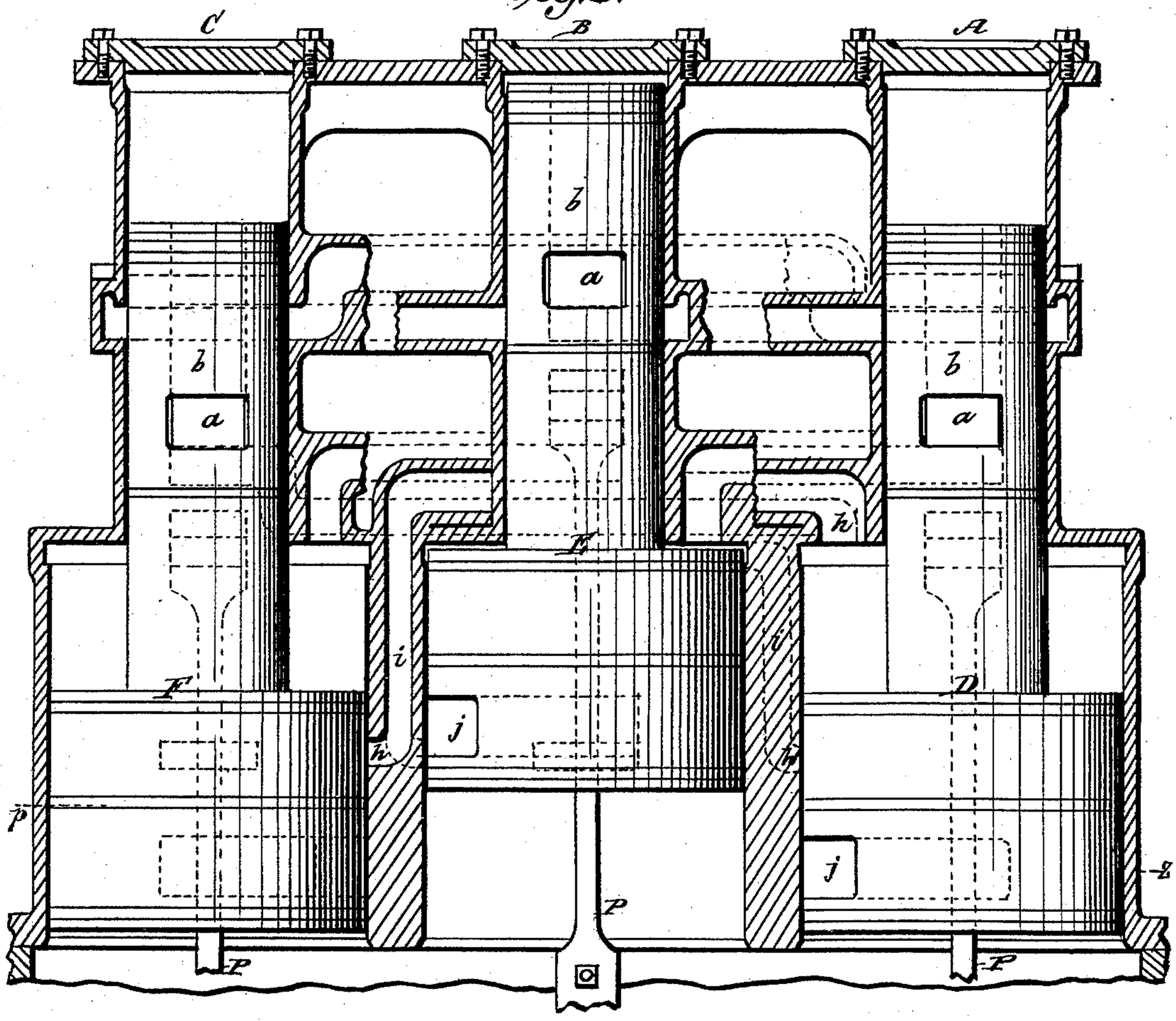
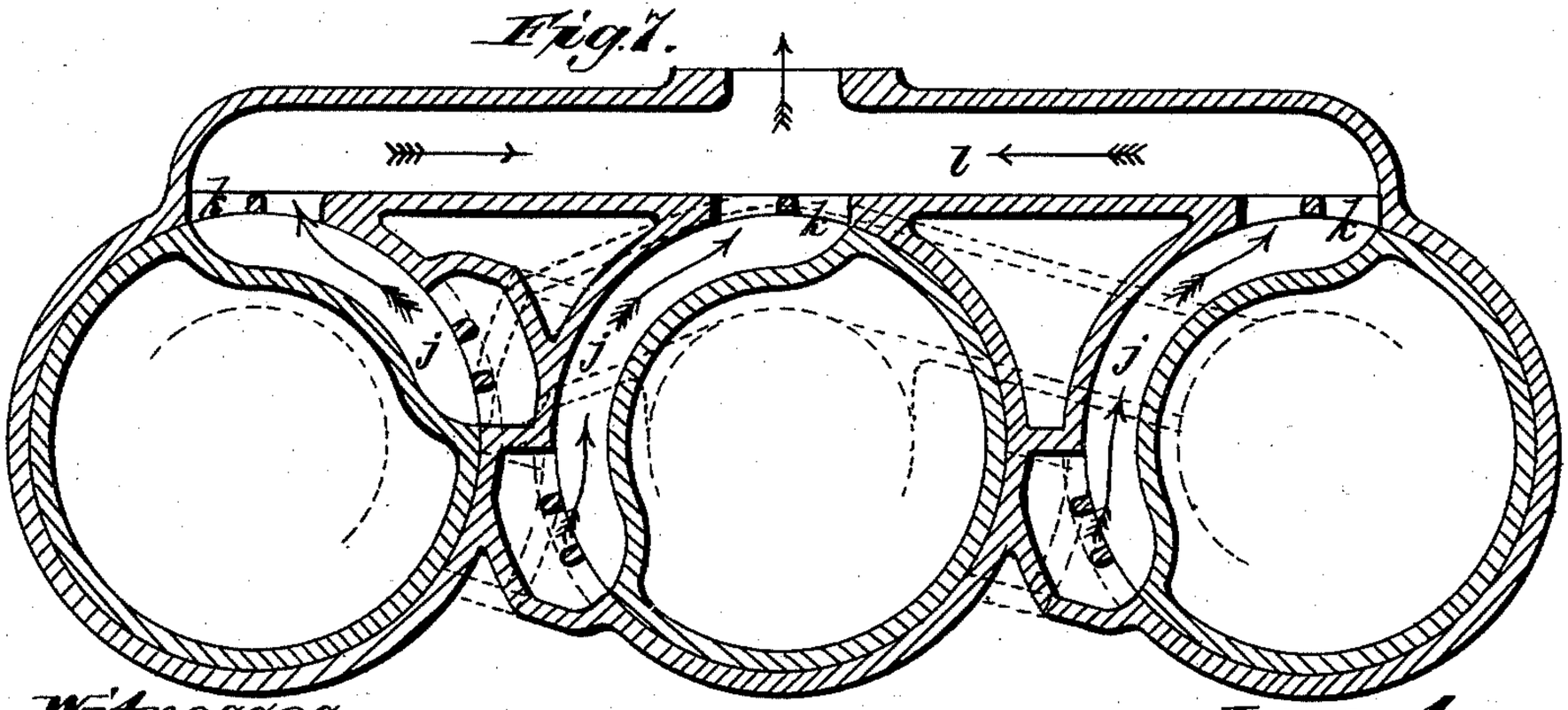


Fig. 7.



Witnesses.
Robert Everett,
J. A. Rutherford

Inventor.
John H. Eickershoff.
By
L. C. Uhl Atty.

UNITED STATES PATENT OFFICE.

JOHN H. EICKERSHOFF, OF CINCINNATI, OHIO, ASSIGNOR TO THE TRIUMPH COMPOUND ENGINE COMPANY, OF SAME PLACE.

COMPOUND ENGINE.

SPECIFICATION forming part of Letters Patent No. 441,947, dated December 2, 1890.

Application filed January 30, 1890. Serial No. 338,600. (No model.)

To all whom it may concern:

Be it known that I, JOHN H. EICKERSHOFF, a citizen of the United States, residing at Cincinnati, Ohio, have invented new and useful Improvements in Compound Engines, of which the following is a specification.

My invention relates to compound engines of the single-acting type, in which two or more cylinders are employed in similar relations to a common crank-shaft. In such engines, and especially in the type fully described by me in Letters Patent No. 407,184, issued July 16, 1889, the final exhaust of each low-pressure cylinder was into the crank-case, excepting only in those cases where independent valve-gear operated in the ordinary manner by the main shaft was provided. The expense and complexity of outside valve-gear renders the same objectionable. It is also found objectionable to carry the exhaust-steam into the crank-case on account of the exposed pitman-connections in the pistons, which suffer in respect to lubrication, besides which in the latter case a condenser cannot be employed.

The object of my present invention is to obviate these difficulties; and it consists in an application of the principle of the "valveless" construction illustrated in my aforesaid patent (as there applied to the initial use and expansion of steam—that is to say, of perforating the pistons and utilizing them, in connection with suitable lateral ports in the cylinder, to govern the distribution of steam to and between the cylinders) to the final exhaust of the steam outward into the atmosphere or condenser, whereby the exhaust from one cylinder is controlled by the piston of an adjacent cylinder without the employment of other valves or driving-gear. The construction attains greater economy in first cost, besides greater durability in maintenance, in avoiding wear of external parts. It also, when applied in preferred form, somewhat promotes economy in the use of steam.

My invention is applicable with best results in the type of single-acting compound engines having cylinders of differential diameter, such as illustrated in the accompanying drawings, in which—

Figure 1 is a vertical elevation of three cylinders of an engine of the type indicated, sectioned in the common axial plane of the cylinders, constructed according to my present improvement; Fig. 2, a vertical axial section of the central cylinder transverse to the plane of Fig. 1; Figs. 3 and 4, horizontal sections, respectively, in the planes *x* and *y* of Fig. 1. Fig. 5 is an axial cross-section of a similar cylinder of a "triple-expansion" engine, showing the principle of the invention applied thereto; Fig. 6, a vertical section, in the common axial plane of the three cylinders, of a slight modification in structure designed more particularly to facilitate the application of the present improvement to an existing engine of the same general type having its exhaust into the crank-case, the application being, by way of alteration, without radical changes of structure; and Fig. 7, a horizontal section in the plane *z* of Fig. 5 in further illustration of the construction last referred to.

The class of engines within the general type referred to which I have selected for the illustration of my invention is represented by a three-cylinder double-expansion single-acting engine; but it may be employed with equal facility and benefit in engines of any number of expansions, and, indeed, in other types of single-acting compound engines.

The general features of the engine are three cylinders A, B, and C, each of differential diameters in successive axial portions of their length, provided with plunger-pistons D E F, of corresponding differential diameters, operating steam-tight in the cylinders, respectively, and carrying a pitman P, pivoted within each piston and operating through its open end upon one of the cranks of a common crank-shaft in a crank-case in which the crank-shaft is journaled. The cranks are of course set at equal radial angles apart.

The general construction of the engine in respect to the admission of steam to the respective cylinders and its expansion from one

initial cylinder in which it has completed its primary work over into the enlargement or expansion portion of an adjacent cylinder is the same as I have already described in the Letters Patent referred to. I need not, therefore, particularize in detail as to those features already fully described. Suffice it here to say that the steam from the boiler being admitted through a transverse aperture in one of the smaller pistons upon duly registering with opposite side ports of its cylinder to a passage leading to a side port of an adjacent similar cylinder is by a side opening and connecting vertical passage in the second piston permitted to flow into said last-named cylinder above the piston, there to exert its initial pressure in driving said piston downward. In descending, the same piston side opening by which the live steam was admitted to said second cylinder registers with another side port (termed the "expansion-port") of said cylinder in line below the first (or "admission") port, and the steam-content of the cylinder, having performed its initial work, now flows downward through the same piston-passage and opening by which it entered through the now registering cylinder-port and an "expansion-passage" extending over to the top of the larger or expansion end of the third cylinder in series, where it operates by further expansion upon the lower and larger section of said third piston. In said former construction, as I have already intimated, the final exhaust of steam took place directly into the crank-case or by means of outside valve-gear controlling separate eduction valve or valves into the atmosphere or condenser. My present improvement, however, governs the exhaust in practically the same manner as above described for the admission, but in reverse, as I will now describe.

Referring now to the drawings, *a* designates the side port of the high-pressure piston, extended by a vertical passage *b* within and through the top of the piston, through which live steam is primarily admitted to the high-pressure cylinder and subsequently on the downstroke expanded over through the side or expansion port *c* of the cylinder and its extending passage *d* to the adjacent low-pressure cylinder.

In my present improvement I provide a port *e*, opposite to and corresponding with the expansion-port *c*, opening, however, into a common exhaust-passage *f*, which may lead to a condenser or into the atmosphere. Through the piston below its admission-opening *a* and in a position to register with the cylinder-ports *c* and *e* when near the upper limit of its stroke I provide a transverse passage *g*. Thus when the piston-passage *g* connects the opposite cylinder-ports *c* and *e* a free opening to the exhaust is afforded for the adjacent expansion-cylinder backward through its receiving expansion-passage *d* for the exhaust of the steam after its work is completed in the expansion-cylinder. As the cranks are set one hundred and twenty degrees apart, it will be seen that as one piston completes its downstroke and is in position to begin the exhaust the adjacent piston begins the last third of its upstroke, and that while the exhausting-piston is traveling from the beginning to the end of its return or exhaust stroke the adjacent piston travels the last third of its upstroke and the first third of a succeeding downstroke, covering only the upper one-third of its cylinder in the time occupied by the entire travel of the exhausting-piston. An opportunity is thus given for utilizing each piston as a controlling-valve for the final eduction of steam from an adjacent cylinder, and this opportunity I avail myself of in the present improvement. I utilize for this purpose the expansion-port *c* and passage *d*, thereby economizing in the initial cost of construction both in labor and material. The duration of the opening and the point of closure for compression may be exactly regulated by duly proportioning the vertical and lateral dimensions of the port-apertures and their relative vertical position in relation to the limits of stroke.

In order to economize space in the passage *d*, I place the cylinder-port *c* as low down as possible, which, as it affects the position of the piston-passage *g*, may bring said passage somewhat into the larger or expansion cylinder at the extremity of the downstroke, as shown in the right and left hand cylinders of Fig. 1; but this is not detrimental, since the opening enters the cylinder at about the point of time when the expansion ceases and the exhaust begins. I further proportion the parts so that a final compression on the upstroke of the expansion-piston fills the passage *d* to a pressure equal to that of the next succeeding expansion, so that the space is practically neutralized so far as it might otherwise be detrimental in unduly enlarging the expansion-space. This also effects a slight gain in economy over the former structures on which this is an improvement, as there are no separate exhaust-spaces to be filled by the expansion-steam; consequently a higher compression is obtainable.

In applying the construction principle of the invention to triple-expansion engines each cylinder and piston is constructed as illustrated in Fig. 5, in which a third enlargement of both cylinder and piston is added, as at A^3 and F^3. In this case an additional steam-passage *d'* is provided, entering the side of the intermediate cylinder A^2 at a port *c'*, and a piston side port *a'* is provided, opening by a vertical passage *b'* through the top of the intermediate plunger F^2. The exhaust-passage *g* in this instance is carried through the intermediate plunger-piston F^2 and the exhaust-passage *e* correspondingly located in the intermediate cylinder A^2. This construction being a practical reduplication of that al-

ready described as applied to the added parts, the mode of operation will be obvious without further description.

The construction exhibited in Figs. 6 and 7, being merely a mode of application of the invention to existing structures of the general type, presupposes the existence of an exhaust-port *h* at one side of each expansion-cylinder and also a passage *i* leading thence to the top of the adjacent expansion-cylinder, the exhaust taking place in such case from the top of one expansion-cylinder downward through the passage *i* and port *h* (as the latter was uncovered by the rise of its governing-piston) through the open lower end of the adjacent cylinder into the crank-case.

The change to my improvement consists, first, in lengthening the expansion-piston by an additional section, as indicated in the drawings, from the dotted line *p* downward a sufficient distance to maintain a packing-ring always below the side exhaust-port *h*, which is thus never uncovered by the lower edge of the piston in rising. The additional section of the piston is provided with a lateral circumferential open passage *j*, (shown in Fig. 6,) extending around to the rear of the piston, where (and corresponding to the port *h*) a port *k* is cut in the cylinder (constituting the second change) and suitable pipe attachments made to a common exhaust-pipe *l*. The construction is clearly shown in Fig. 6, wherein the cylinders are sectioned through both ports *h k* and the pistons are sectioned through the connecting-passage *j*.

It may be that the lengthening of the piston, as described, will cause it to project into the crank-case in its downward stroke and carry the exhaust-passage *j* into the crank-case; but this is not material. While the construction is a practical realization of my invention, that first described is to be preferred for new work for obvious reasons of economy in construction and maintenance.

It will be apparent that the control of the exhaust by the pistons in the manner indicated may be employed independently in engines of this general type where the admission and expansion of steam are controlled by independent valves. It will also be understood that the invention may be applied to horizontal engines, to any number of cylinders, or engines having provision for any number of expansions.

I claim as my invention and desire to secure by Letters Patent of the United States—

1. In a multiple-expansion steam-engine embodying three cylinders, each of differental diameters, ports and passages connecting said cylinders for the initial distribution and intermediate expansion of steam, ports and passages for the final outward exhaust of steam wholly independent of the crank case, and plunger-pistons fitted to said cylinders and provided with corresponding ports and passages, combined with triple crank-shaft and pitman connections, whereby the distribution, expansion, and final exhaust of steam outward independently of the crank-case are wholly effected and controlled by said plunger-pistons, substantially as set forth.

2. In a multiple-expansion single-acting engine of two or more cylinders, each of two or more diameters in successive portions of the length and fitted with corresponding pistons, an exhaust-opening at the receiving end of the ultimate enlargement of a cylinder, a passage connecting the same with a port in the side of an adjacent cylinder, a second port in said last-named cylinder, and a passage in or through the piston of said last-named cylinder, bridging and connecting said last-named ports simultaneously at a given portion of the stroke, substantially as and for the purpose set forth.

3. In a multiple-expansion single-acting engine of two or more cylinders, each extended by successive enlargements into expansion-cylinders, a port in the side of the last intermediate expansion-cylinder extended by a passage to the receiving end of an adjacent ultimate expansion-cylinder, a second port at the side of the intermediate expansion-cylinder, and a transverse passage in or through the piston adapted to register with and connect the said two cylinder-ports with the extension-passage on the upstroke of the piston, substantially as set forth.

4. In a multiple-expansion single-acting engine of two or more main cylinders, each extended by successive enlargements constituting expansion-cylinders, an expansion-port in the side of a last intermediate expansion-cylinder extended by a passage to the receiving end of the ultimate enlargement of an adjacent main cylinder, a plunger-piston in each main cylinder adapted to its successive enlargements and having a passage in the last intermediate enlargement adapted to register with said expansion-port and effect the expansion from a last intermediate expansion-cylinder into an ultimate enlargement of an adjacent main cylinder on the upstroke of the piston, an exhaust-port at the side of said intermediate expansion-cylinder, and a transverse passage in or through said intermediate piston enlargement beyond and in line with the expansion port or passage therein, adapted to register with and connect the cylinder expansion-port and the opposite exhaust-port on the instroke of the piston, substantially as set forth.

5. In a double-expansion single-acting engine of two or more main cylinders, each of two differential diameters, having corresponding plunger-pistons operating a common crank-shaft, a side opening in the high-pressure piston extended within and through its top, a corresponding side port in the high-pressure cylinder for the admission of live steam on the upstroke through the side opening of the piston, an expansion-port in said cylin-

der, a passage connecting said expansion-port with the next adjacent low-pressure cylinder, a second cylinder-port in the high-pressure cylinder opening to the exhaust-passage, and a transverse passage through the high-pressure piston beneath the steam-admission opening, adapted to register on the upstroke with and connect the expansion-port and exhaust-ports of the cylinder, substantially as set forth.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

JOHN H. EICKERSHOFF.

Witnesses:
JAMES C. HOBART,
L. M. HOSEA.