No. 811,520. PATENTED JAN. 30, 1906.

E. REYNOLDS.

STEAM ENGINE.

APPLICATION FILED AUG. 20, 1900. RENEWED JAN. 9, 1905.

11 SHEETS—SHEET 1.

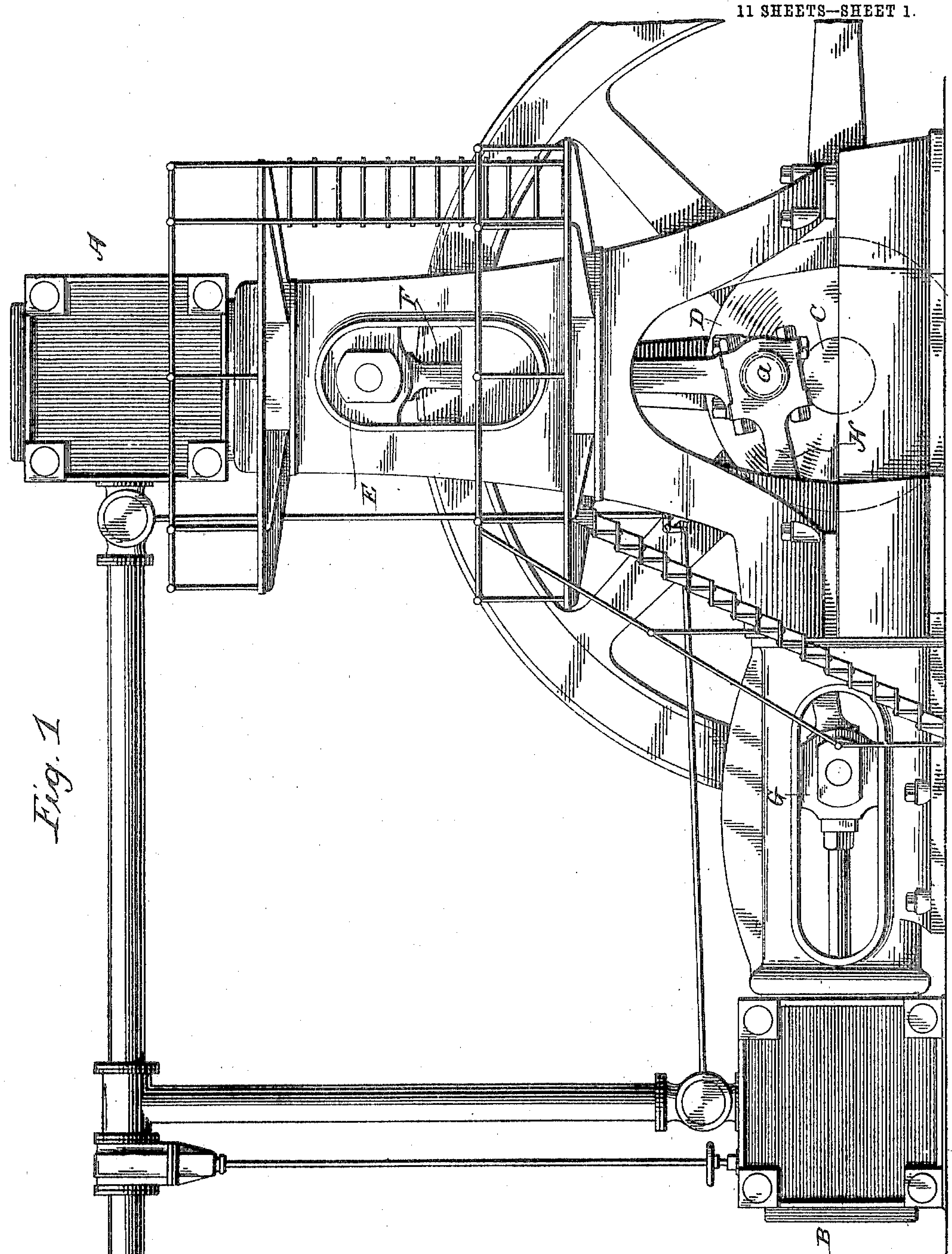

Fig. 1

Witnesses

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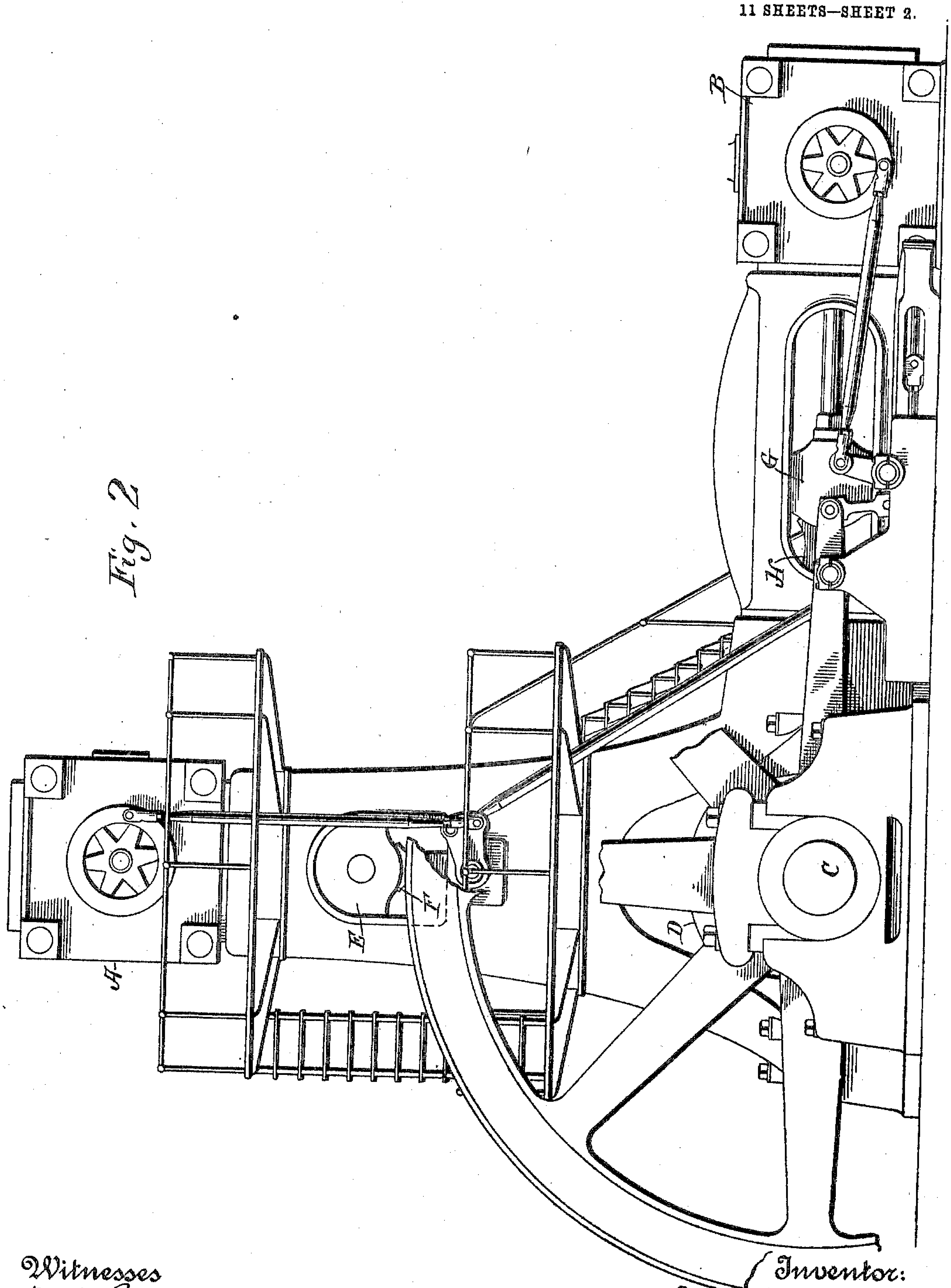
11 SHEETS—SHEET 2.

Fig. 2



Witnesses

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11 SHEETS—SHEET 3.

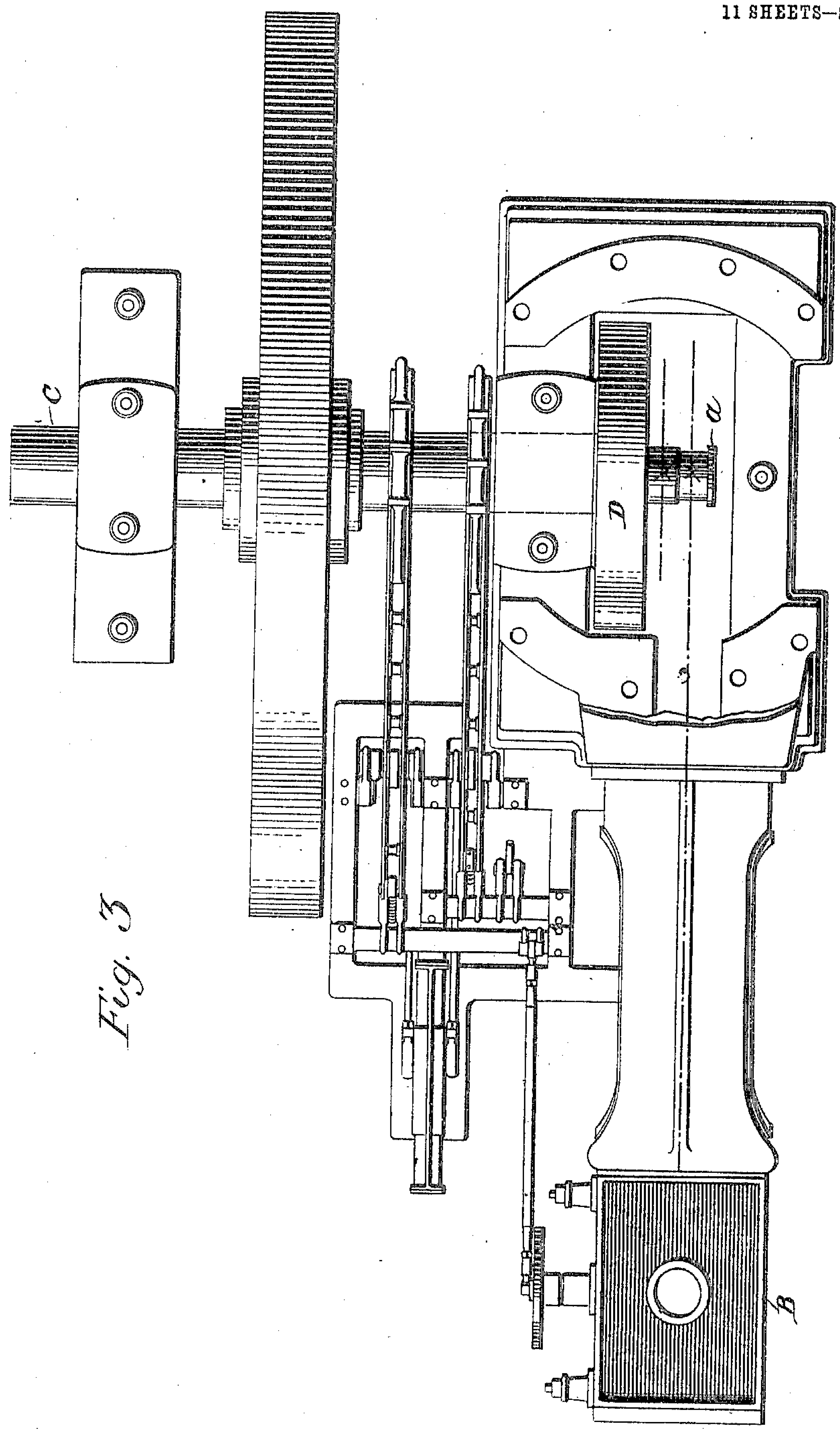

Fig. 3

Witnesses
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11 SHEETS—SHEET 4.

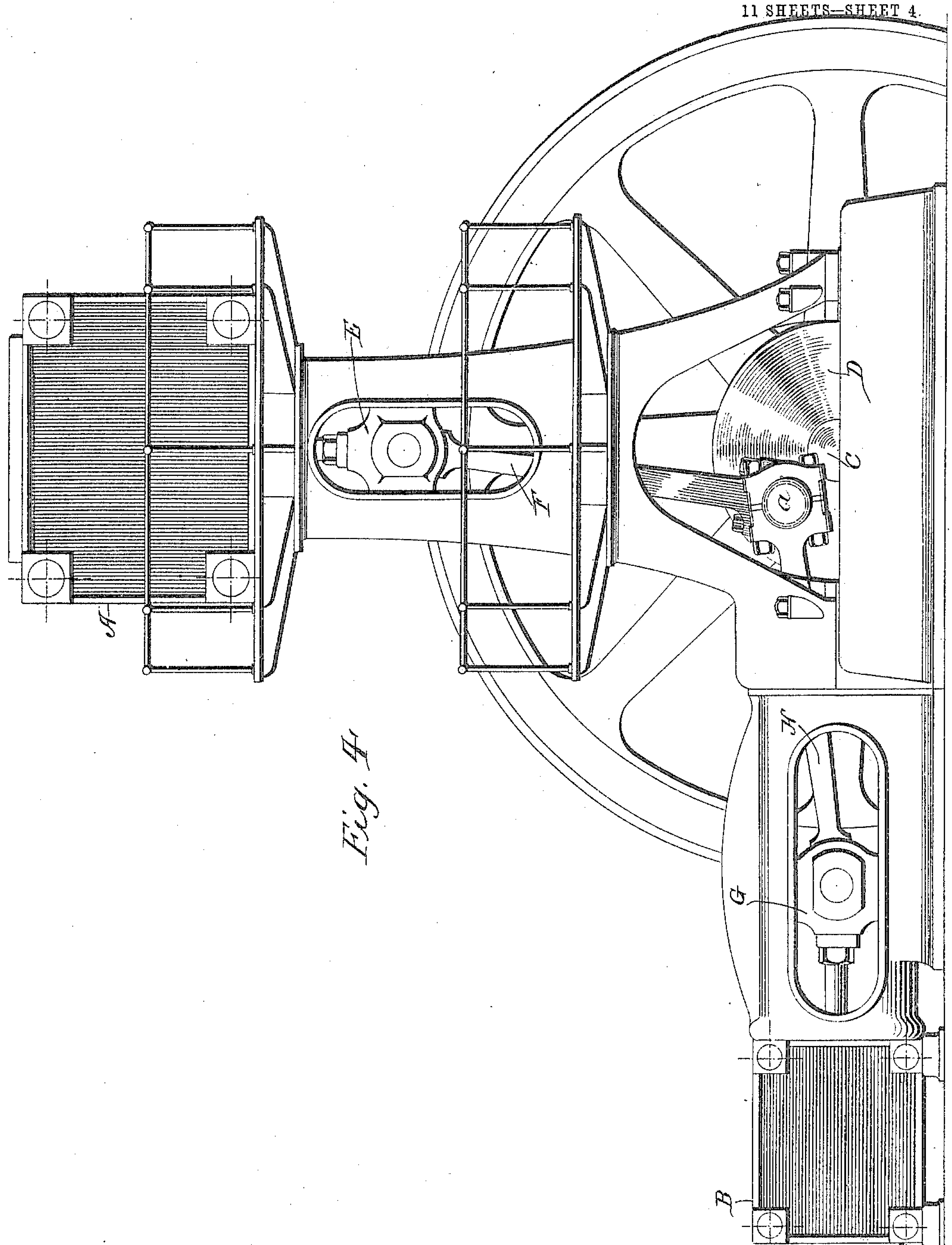

Fig. 4

Witnesses

D. C. [illegible]

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11 SHEETS—SHEET 5.

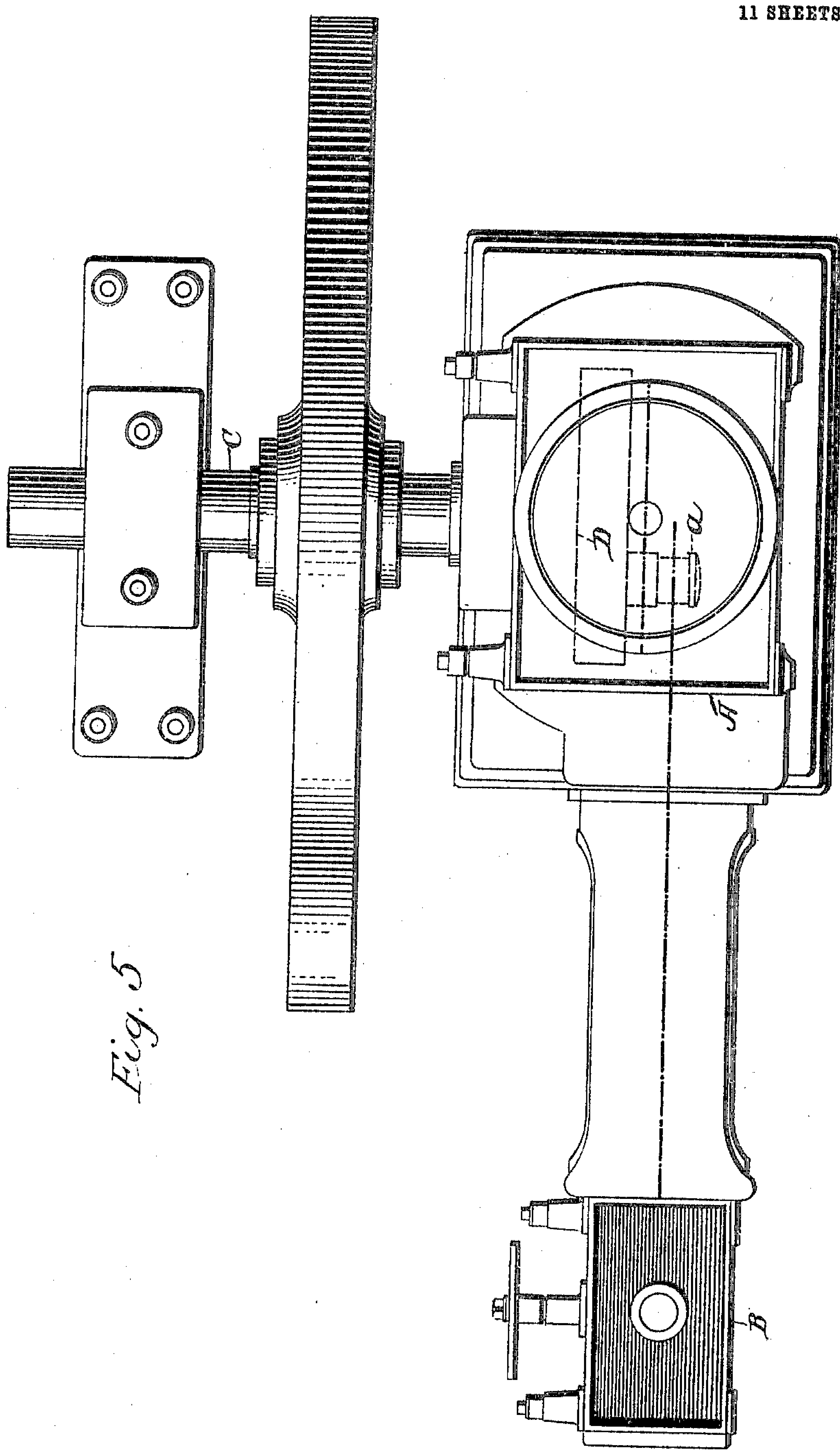

Fig. 5

Witnesses
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11 SHEETS—SHEET 6.

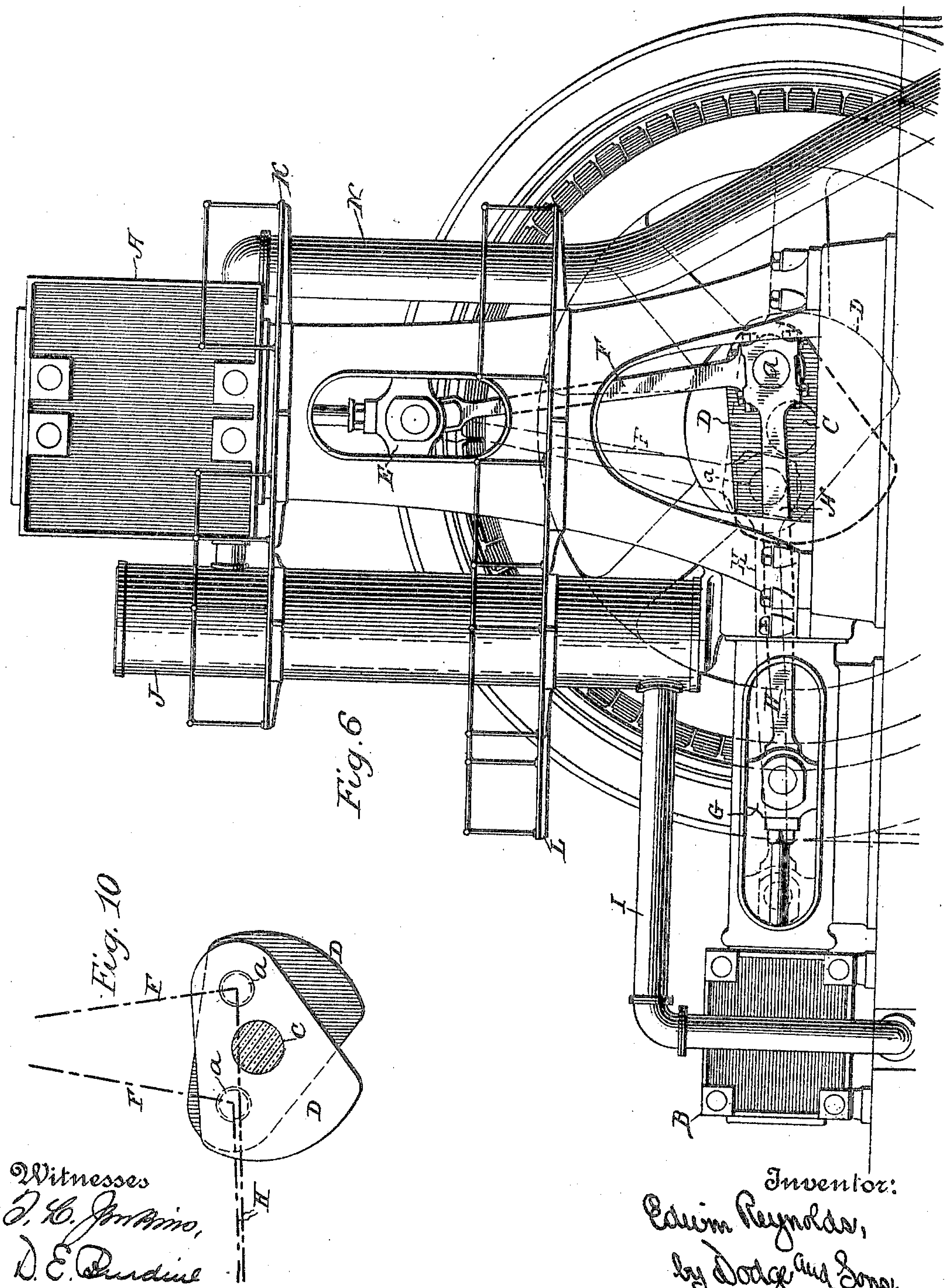

Fig. 6

Fig. 10

Witnesses
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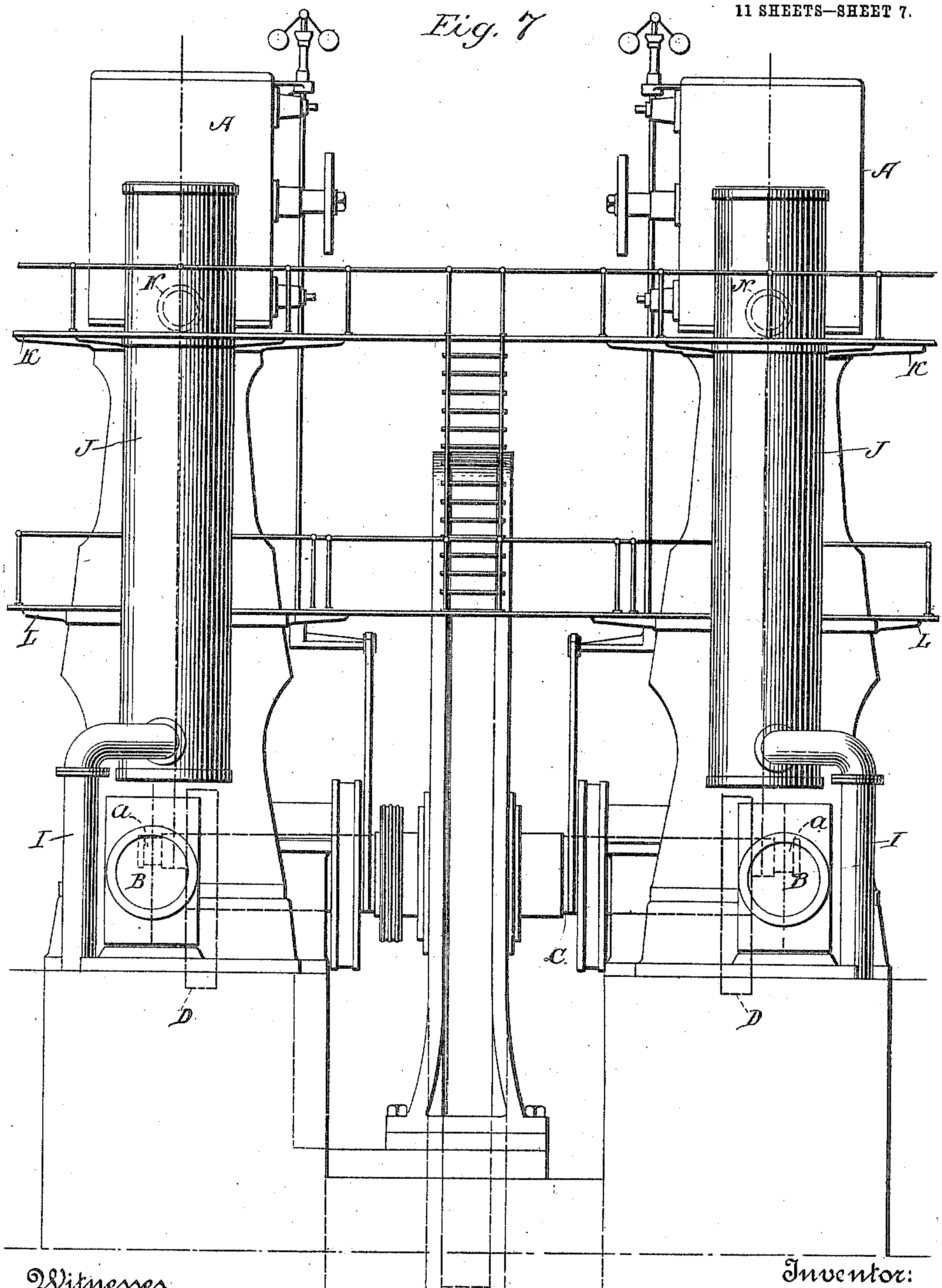
11 SHEETS—SHEET 7.

Fig. 7



Witnesses

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11 SHEETS—SHEET 8.

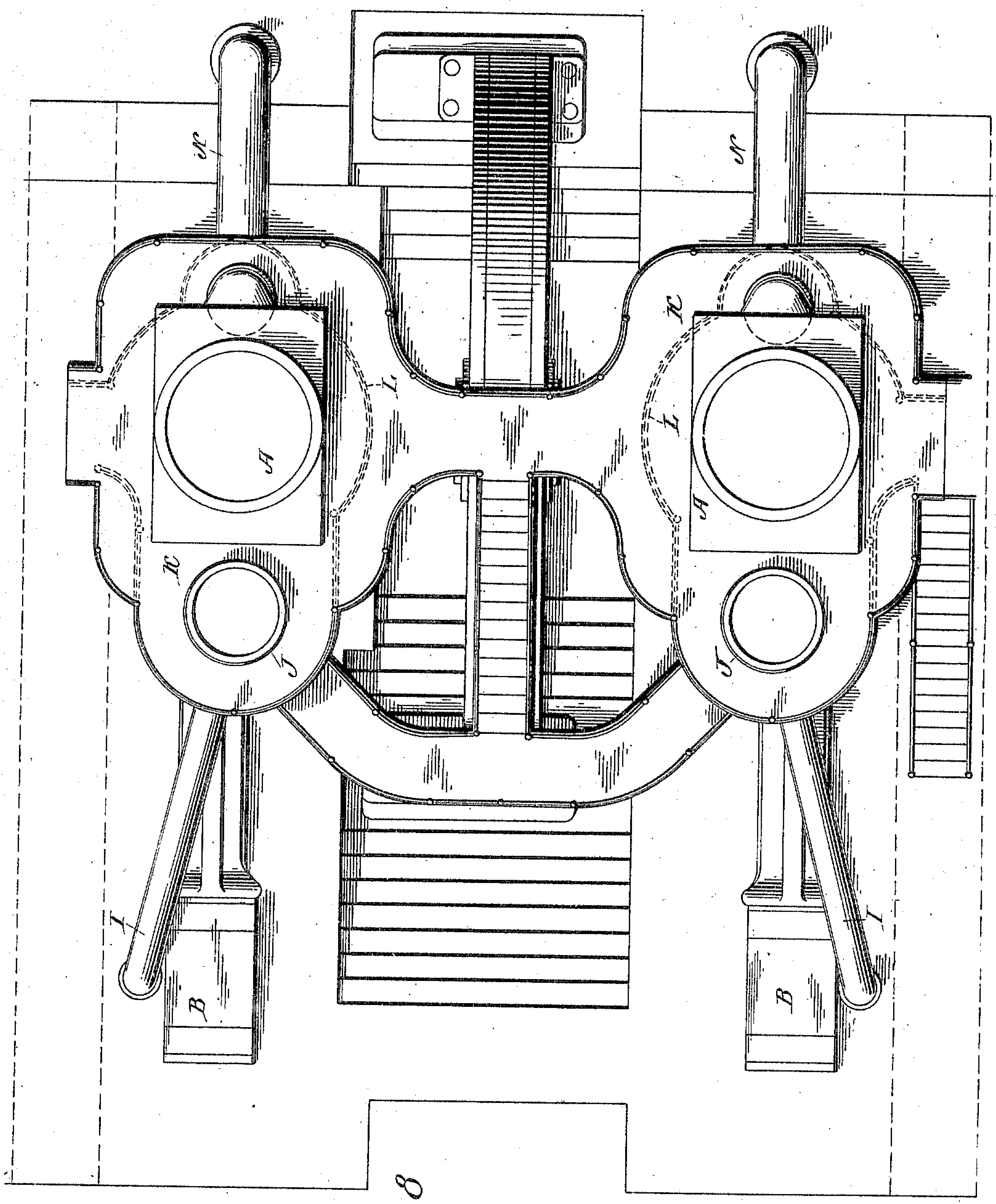

Fig. 8

Witnesses
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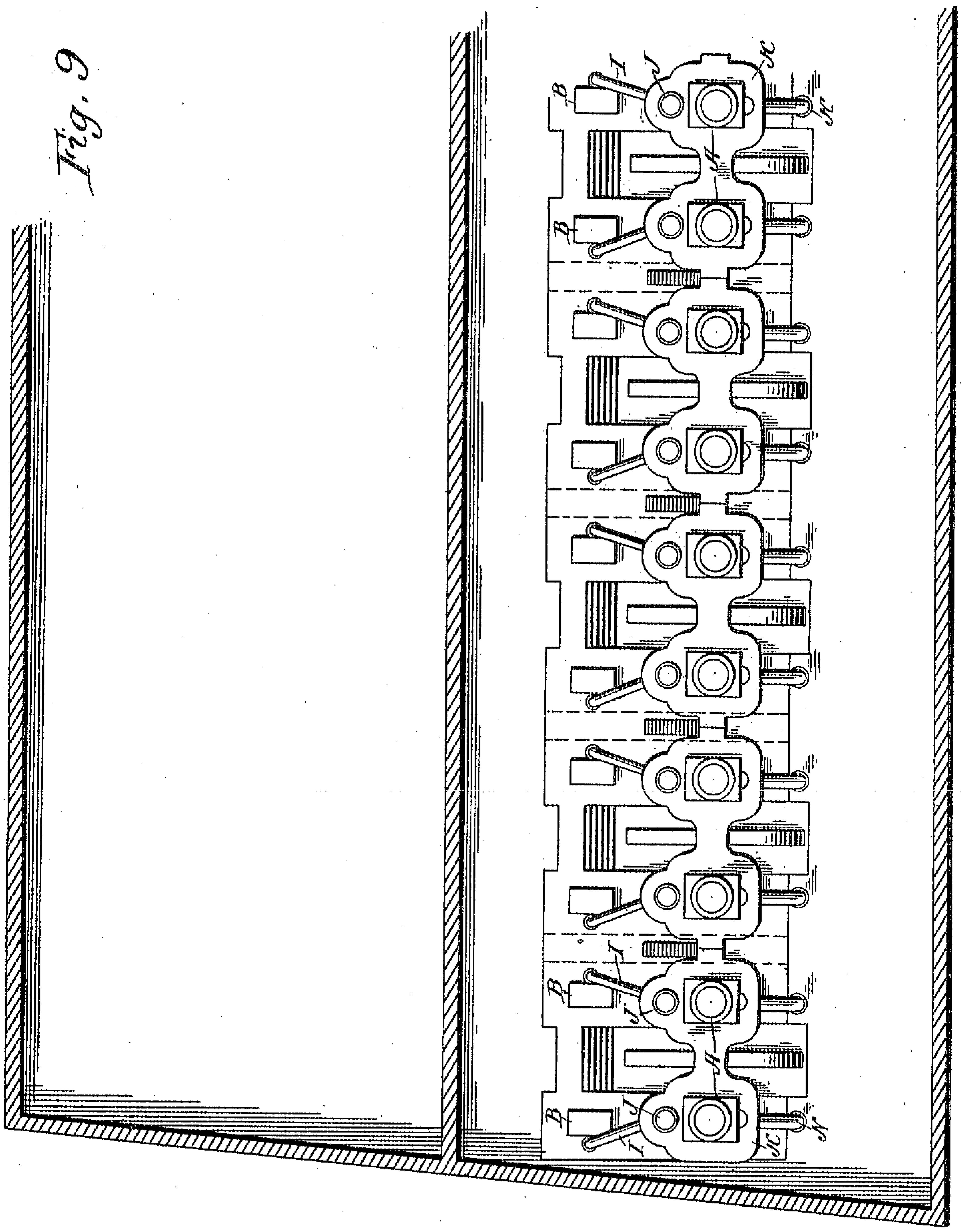
11 SHEETS—SHEET 9.

Fig. 9



Witnesses

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11 SHEETS—SHEET 10.

Fig. 11

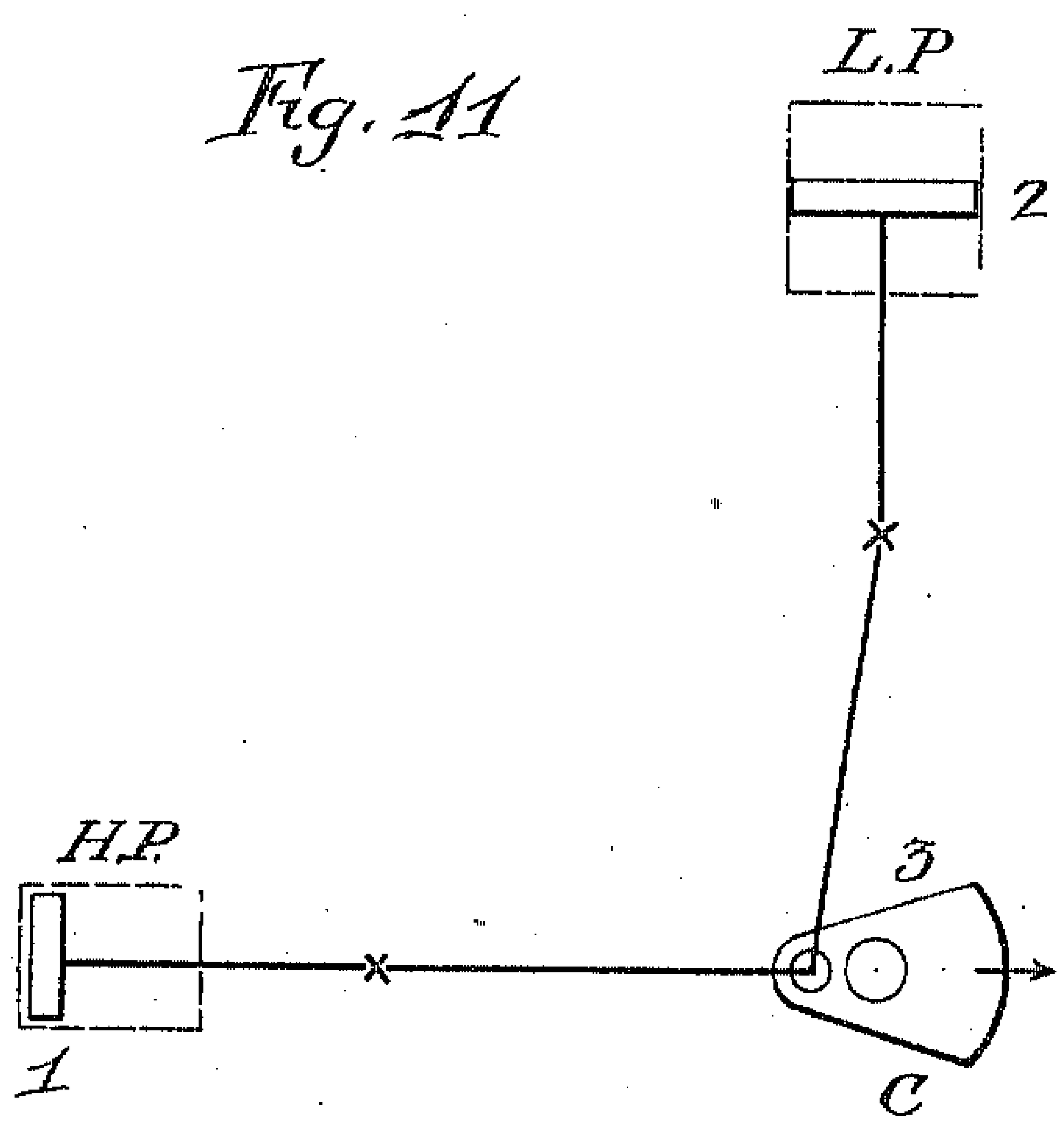


Fig. 12

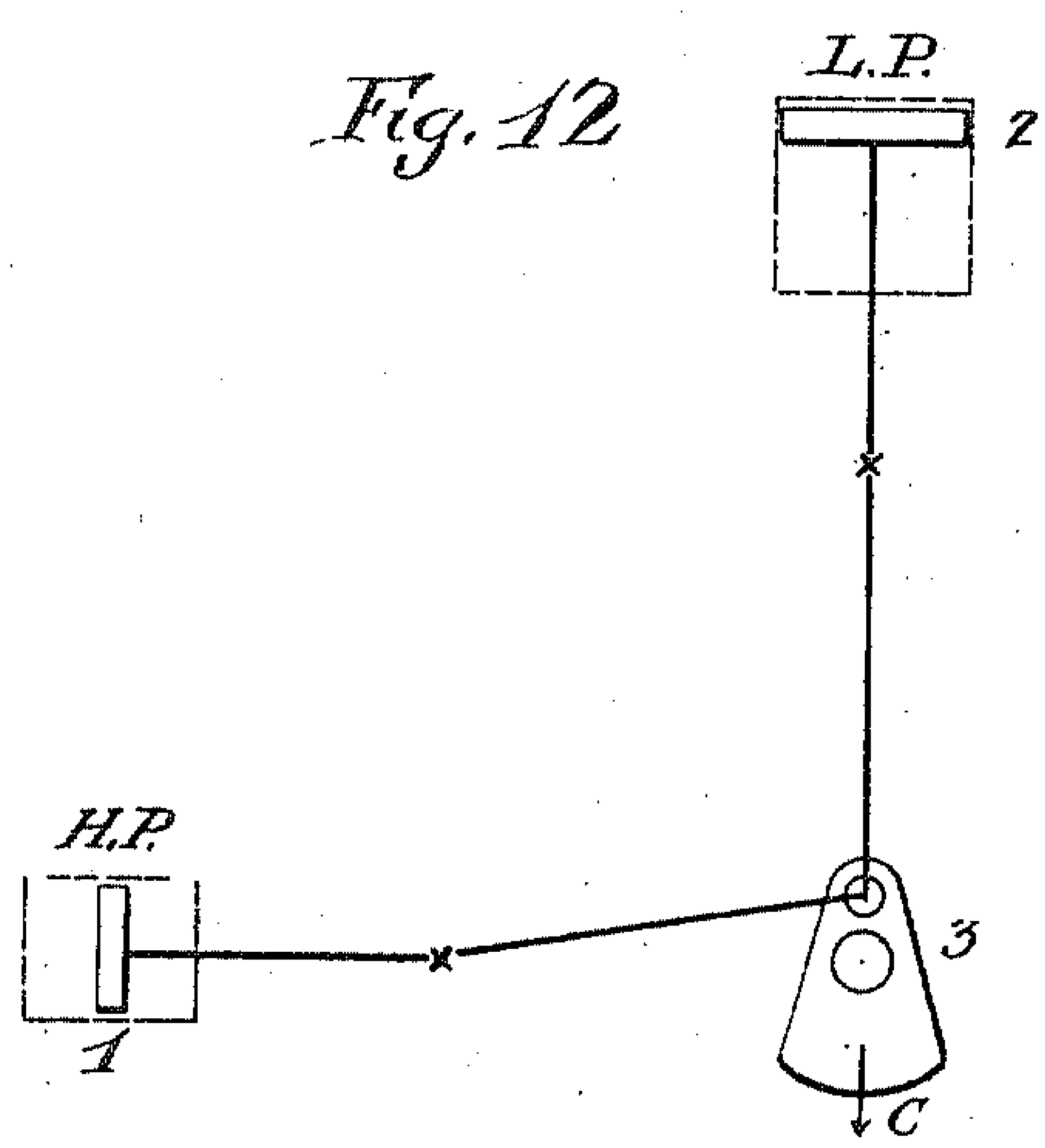


Fig. 13

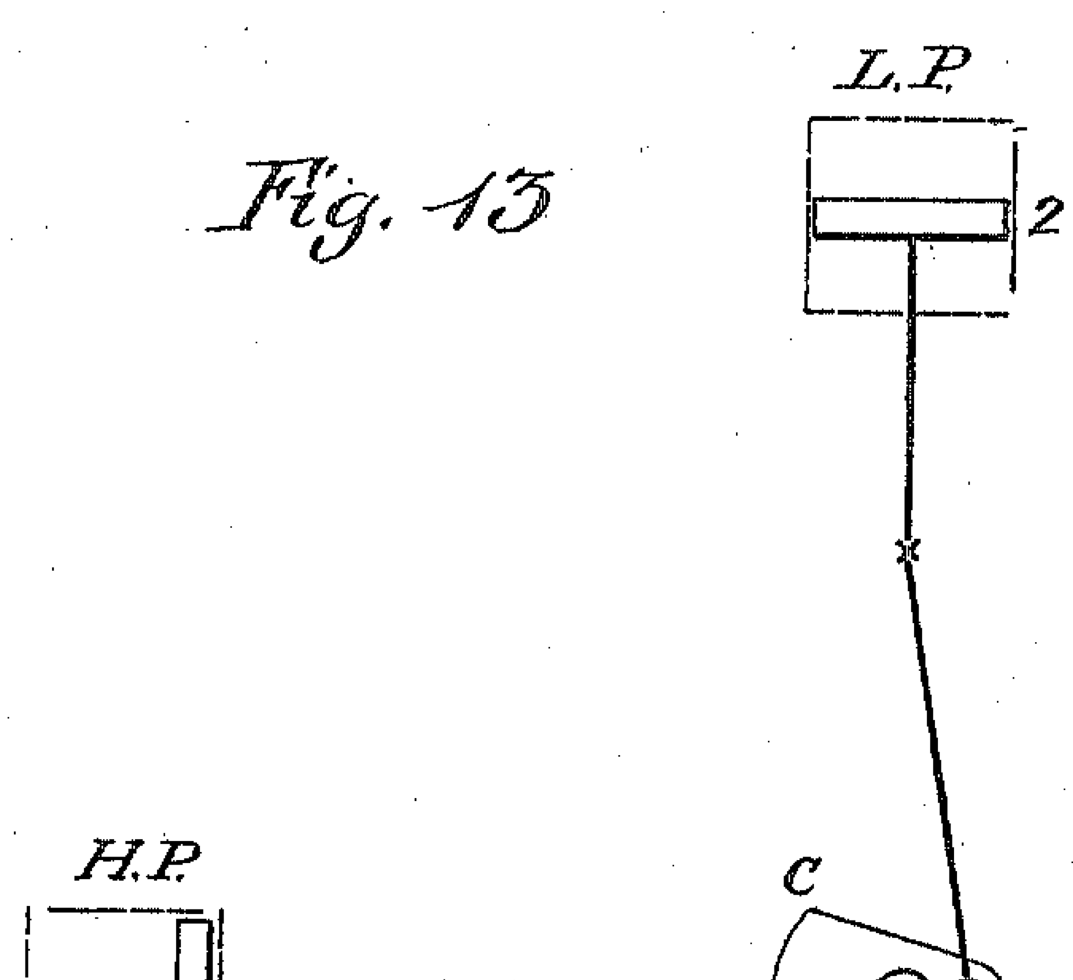
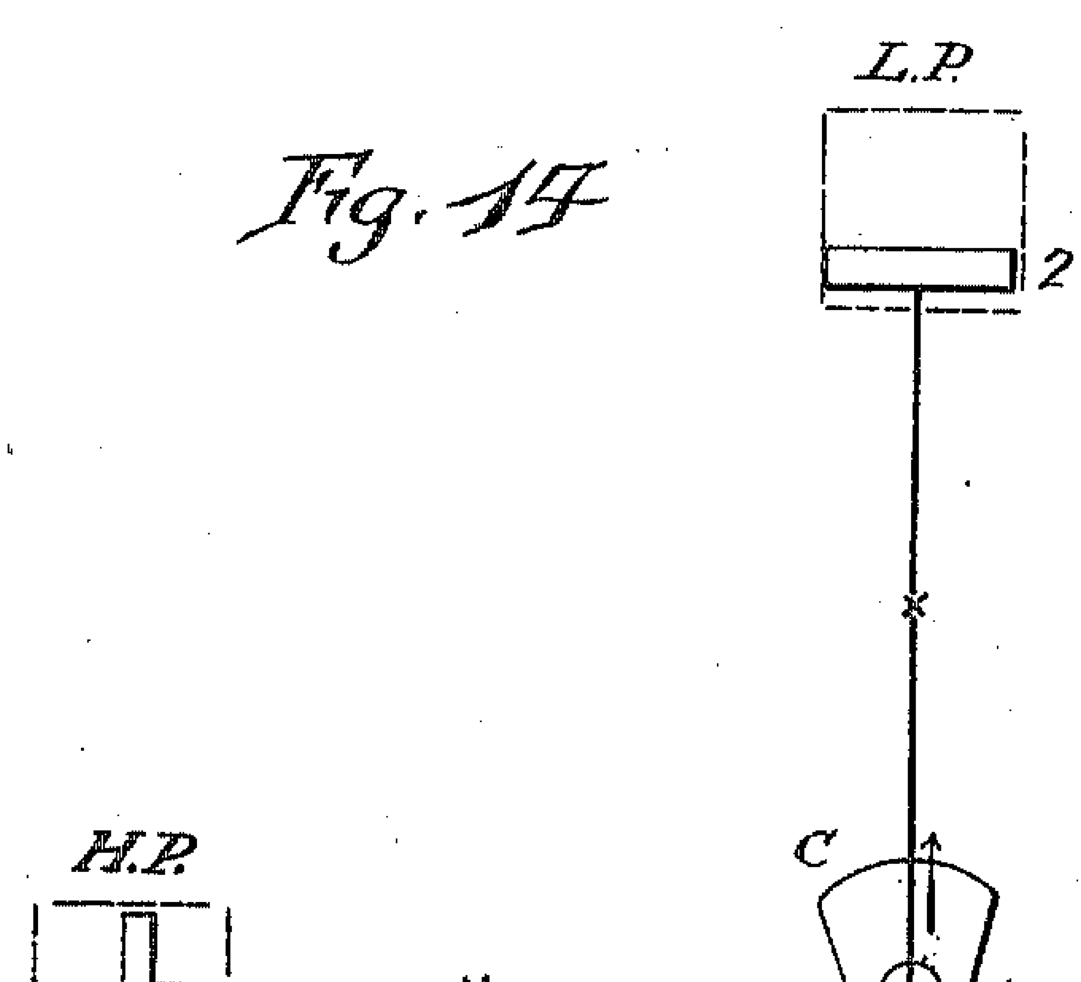


Fig. 14



Witnesses
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11 SHEETS—SHEET 11.

Fig. 15.

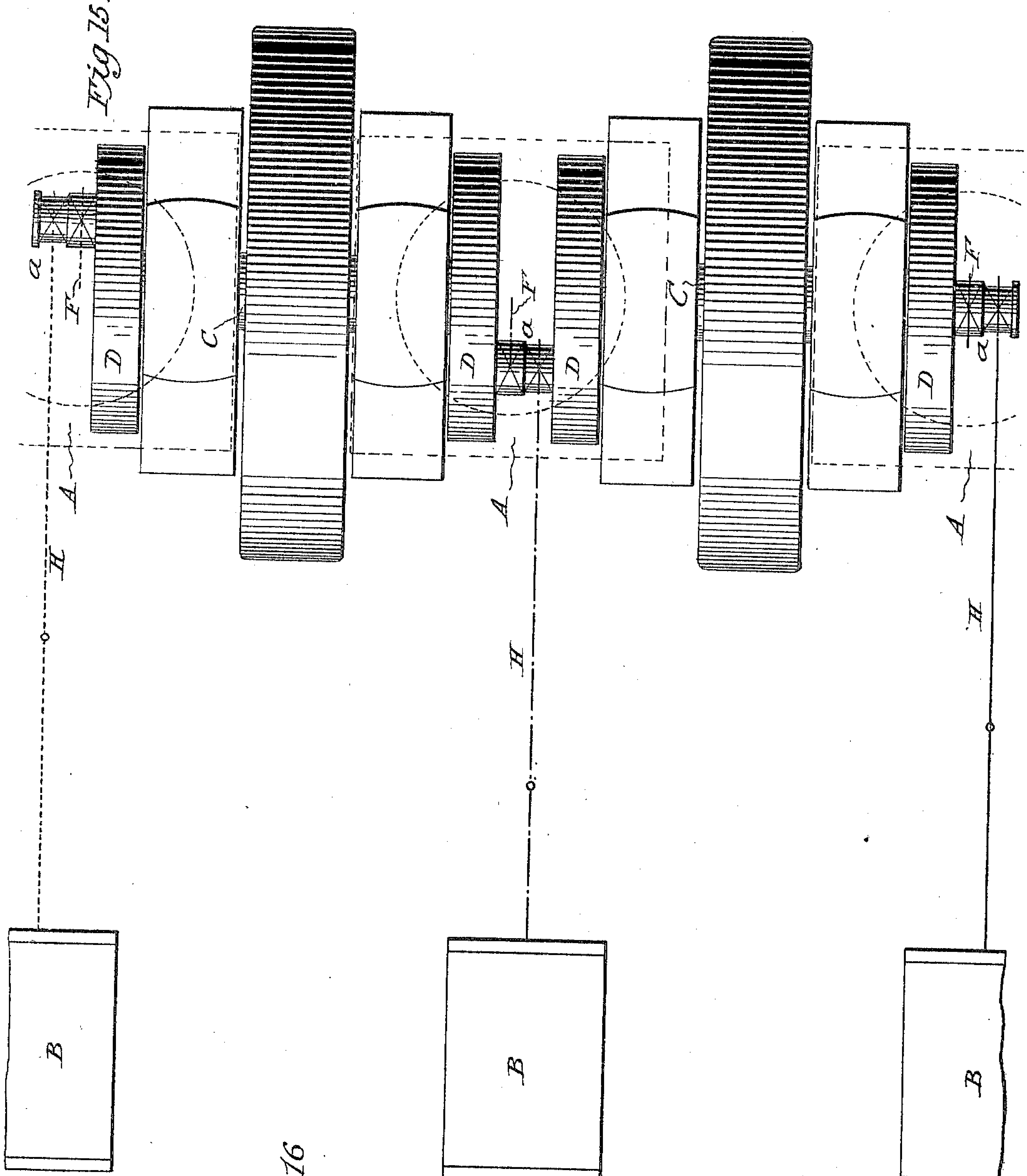
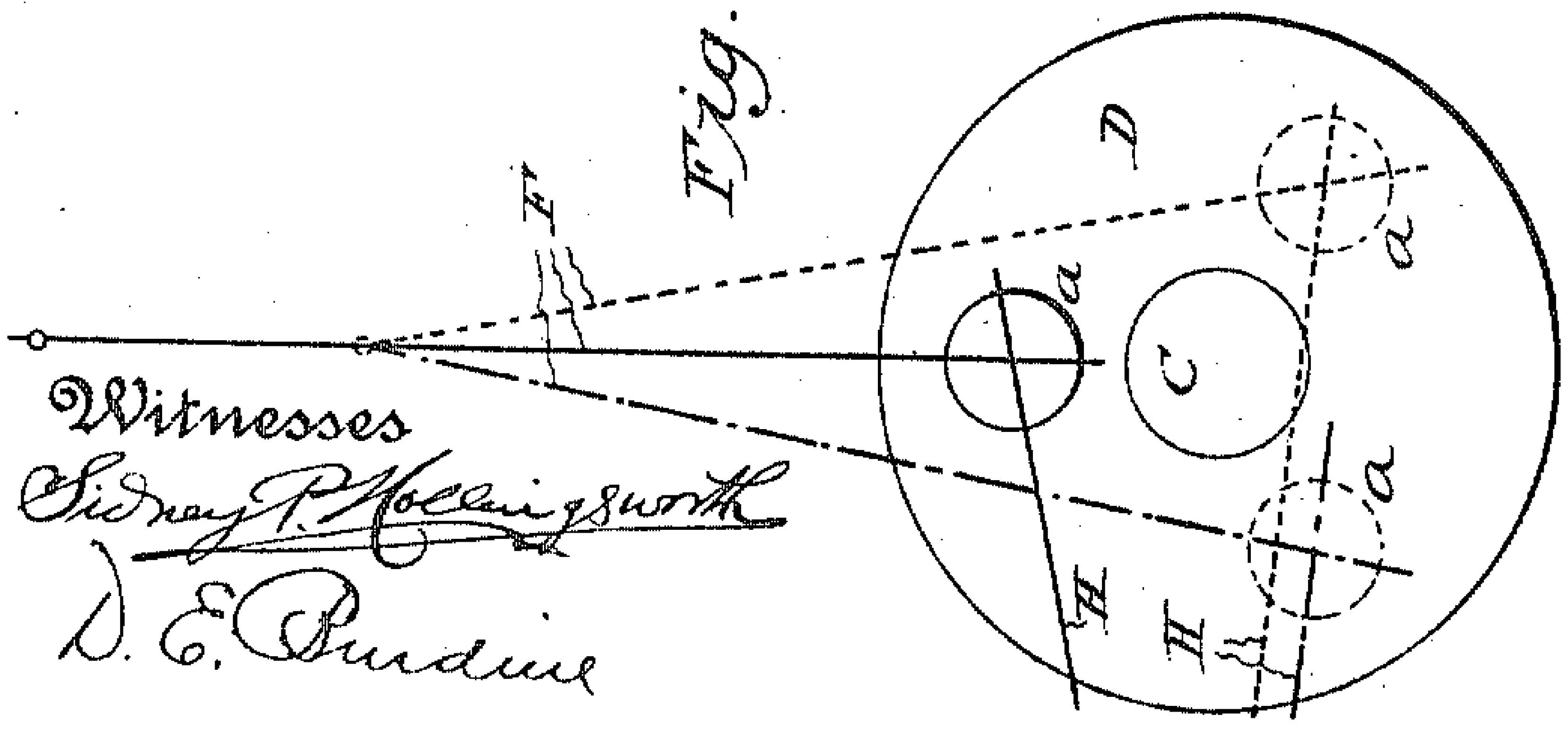


Fig. 16



Witnesses
Sidney P. Hollingsworth
D. E. Burdine

Inventor:
Edwin Reynolds,
by Dodge and Sons,
Attorneys.

UNITED STATES PATENT OFFICE.

EDWIN REYNOLDS, OF MILWAUKEE, WISCONSIN, ASSIGNOR TO ALLIS-CHALMERS COMPANY, OF CHICAGO, ILLINOIS, A CORPORATION OF NEW JERSEY.

STEAM-ENGINE.

No. 811,520. Specification of Letters Patent. Patented Jan. 30, 1906

Application filed August 20, 1900. Renewed January 9, 1905. Serial No. 240,236.

To all whom it may concern:

Be it known that I, EDWIN REYNOLDS, a citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Steam-Engines, of which the following is a specification.

My invention pertains to steam-engines; and it consists in novel combinations of vertical and horizontal engines, simple or compound, and in various features, details, and combinations incident to or connected with the union of such vertical and horizontal engines, as hereinafter explained, and pointed out in the claims.

Among the objects sought may be mentioned uniformity of turning effect, static balance of the engines in all positions or at every point in the stroke, facility of coupling or connecting the engine or engines directly to the machinery to be driven, compact and convenient arrangement of a series of such combined engines in line with each other, and proper distribution of stresses, weights, &c. These several results are obtained, speaking broadly, by a system of units, the unit being in this case a combination comprising a vertical and a horizontal engine coupled in a manner hereinafter explained.

The invention is illustrated in different embodiments in the accompanying drawings, in which—

Figures 1 and 2 are respectively side elevations of two simple engines, one vertical and the other horizontal, combined and coupled in accordance with my invention; Fig. 3, a plan view of the same with portions omitted to better illustrate certain features hereinafter described; Fig. 4, a side elevation of a compound engine comprising vertical and horizontal cylinders combined and coupled in accordance with the present invention; Fig. 5, a top plan view of the same with portions omitted as before; Fig. 6 a side elevation, Fig. 7 a front or face elevation, and Fig. 8 a top plan view, of a double compound engine constructed in accordance with the present improvements; Fig. 9, a top plan view illustrating a series of double compound engines of the type illustrated in Figs. 6, 7, and 8 arranged in one line and showing the compactness of arrangement incident thereto; Fig. 10, a view illustrating the arrangement of counterbalances employed in connection with the double compound engine; and Figs. 11 to 14, both inclusive, diagrammatic views illustrating the arrangement and operation of counterbalances employed in connection with vertical and horizontal engines for effecting and maintaining a static balance of the moving parts at all points in the stroke of the engines; Figs. 15 and 16, views illustrating a three-unit arrangement in which the cranks bear the relation of one hundred and twenty degrees to one another.

Broadly speaking, it is not new to combine a vertical and a horizontal engine or to employ in one engine coacting vertical and horizontal cylinders and pistons. The practical application or embodiment of this idea, however, has not hitherto been made in the most advantageous way, as I beleve, and the purpose of the present invention is so to make this combination as to secure the highest return in efficiency, durability, and in uniformity or steadiness of motion.

The peculiarities and advantages of the different features of construction and arrangement will be pointed out in connection with the description of such construction and arrangement as represented in the drawings.

Referring first to Figs. 1, 2, and 3, A indicates the cylinder of a vertical engine; B, the cylinder of a horizontal engine; C, the main engine-shaft; D, the crank-disk, and *a* the crank-pin of said disk. The cross-head E of the piston of the vertical cylinder is provided with a pitman F, which connects with the crank-pin *a* in that portion of the length of said pin immediately adjacent to the face of the crank-disk D.

The cross-head G, to which is attached the piston-rod of the piston of the horizontal cylinder B, is connected with the crank-pin *a* by a pitman H at a point outside of the pitman F or farther from the crank-disk D. To attain or permit this result, the longitudinal axes of the respective cylinders and their piston-rods are placed in parallel planes, which, however, are not coincident, the distance between said planes being equal to one-half the width of the brasses of the pitman F plus one-half the width of the brasses of the pitman H, with whatever slight space may be between the proximate ends or sides of said brasses, if any. The purpose of this special arrangement is to bring the weight of the upper piston, its rod, cross-head, and pitman, which are directly sustained by the crank-pin, as close to the base or point of support of said crank-pin as possible, where said pin is best capable of sustaining the weight and the strain incident to the support and movement of said parts.

The direct weight of the horizontally-moving piston, its rod, and cross-head, and in great measure that of the pitman H, being supported by the horizontal cylinder and the cross-head guides, said parts bring less weight upon and offer less strain to the crank-pin than the vertically-moving members. Hence these parts may be attached to and moved by the outer or unsupported end of the crank-rod with comparative safety and advantage. This arrangement of the vertical and horizontal cylinders in parallel but non-coincident planes constitutes one feature of my invention. By setting the two cylinders with their axes at an angle of ninety degrees each to the other and coupling them to a common crank-pin I am enabled to start the engine in any position that the pistons may occupy, and consequently the arrangement is well adapted for reversing engines. Accordingly I have represented in Fig. 3 reversing-gear applied to the engine.

The coupling of two pistons to the common crank-pin in the manner set forth gives greater uniformity of turning moment than would otherwise be attainable. The horizontally-moving piston is at mid-stroke under full pressure and working at its out angle at the time that the vertically-moving piston is at the end of its stroke, and consequently exerting practically no tangential effect.

The specific means for perfectly counterbalancing the weight of the moving parts in all positions will be later explained.

Referring now to Figs. 4 and 5, which illustrate a two-cylinder compound engine or an engine having one high and one low pressure cylinder, it will be observed that the same features of construction are present as in Figs. 1, 2, and 3. It will be further noted, however, that the low-pressure cylinder, which is of course the larger one, is the vertical and the high-pressure cylinder the horizontal one. This construction is adopted for the reason that the weight of the large piston and its attendant parts is so considerable that if said parts be arranged horizontally an excessive amount of friction is produced, involving rapid wear of the cylinder and piston or piston-packing. When the cylinder and piston are vertically arranged, this friction is in great measure eliminated, and by making the crank-pin proportionately strong and heavy and giving it adequate area to prevent heating and cutting the low-pressure piston may be advantageously carried thereon in a vertical plane. As the arrangement of parts is the same in this as in Figs. 1, 2, and 3, the same reference characters are employed.

In Figs. 6, 7, and 8 I have shown two compound engines each having one high-pressure and one low-pressure cylinder, the said engines directly connected to the armature-shaft of an electric generator placed between the two engines. This arrangement produces an extremely compact and rigid structure and permits direct connection of both engines with the shaft. It permits the disconnecting of any one cylinder of the four in case of accident or the disconnection of one unit to allow the remaining unit to be worked at best economy when delivering half the power of the generator. It allows the concentration of great power in one shaft with but moderate power in each cylinder, which becomes very important in powers of six-thousand-horse power and upward. There are only two bearings in the shaft, which makes it much easier to keep the engines in alinement, as with the great weight of generator and fly-wheel required a certain amount of deflection in the shaft is unavoidable, which makes it extremely difficult to keep the bearings in good shape when there are more than two bearings. Finally, there are no double-throw cranks, which are always a source of expense and weakness. In these figures the parts which are common to the several embodiments of the invention here illustrated are again lettered, as in other figures. Thus A indicates the low-pressure cylinder, and B the high-pressure cylinder, of each engine; C, the main shaft, which in this case constitutes also the armature-shaft; D D, the crank-disks, and *a a* their respective crank-pins. Each engine also has the vertically-movable cross-head E and pitman F and the horizontally-movable cross-head G and pitman H. I indicates the exhaust-pipe, through which the steam escapes from each high-pressure cylinder B. Each pipe I connects with a receiver J, supported upon the main frame of the engine and rising vertically in front of said frame, its upper end being connected with the upper or low-pressure cylinder, as best seen in Fig. 6. This receiver J, thus located, occupies space that is not otherwise needed, and it serves not only as a receiver of ample capacity, but also serves as a steam-pipe, reducing the amount of piping and consequent loss from radiation. The platform or galleries K and L pass about the receiver and about the exhaust-pipe N of the low-pressure cylinder, as shown. The arrangement is peculiarly compact and economical in point of construction and as regards loss from radiation.

In Figs. 7 and 8 the two sides or sections of the engine are shown alike, or, in other words, there are two compound engines, each having one high-pressure and one low-pressure cylinder; but, if desired, I may construct the engines for triple or quadruple expansion, in which event the exhaust-pipe of one cylinder will connect with the supply valve or chamber of the next cylinder, and so on throughout the series in the usual and well-known way. The extent to which and the manner in which the engines shall be compounded are matters variable at will and according to the requirements of each case.

In order that the two sides or units of the double or twin engine shown in Figs. 7, 8, and 9 may be used either conjointly or independently, I may divide the shaft C and introduce between its sections clutches or couplings by which said sections may be joined or disconnected at will; but I deem this less desirable than to disconnect either power unit from its crank-disk, as desired. This combination of engines is peculiarly advantageous in connection with dynamo-electric generators, since it not only produces a peculiarly compact and rigid structure subject to only a minimum of vibration, but it permits of direct connection of each double engine with the armature-shaft, and this without the use of double cranks.

By employing two compound engines arranged as set forth I am enabled to set the respective cranks so that the engines may act to the best advantage or with the greatest efficiency in securing a uniform and steady rotation of the shaft.

The valve-gear, governors, throttle-valves, and all similar parts and devices not herein specifically described may be of any usual or approved construction, these constituting no part of the present invention.

Mention has been above made of the counterbalancing of the engines, so as to preserve static balance in every position or at every point in the stroke of the engines and to produce uniformity of turning moment. In the case of the double engine shown in Figs. 6, 7, and 8 this counterbalance is effected by making the crank-disk D of each unit or engine pair of such form that the weight is distributed as represented in Fig. 10, the crank-pin *a* being in the smaller end, while the opposite larger or wider portion is made of such dimensions and weight as to form an effective counterbalance.

Referring now to Figs. 11 to 14, inclusive, and assuming for purposes of explanation that the vertically-moving or low-pressure piston and its connected moving parts equal in weight the horizontally-moving high-pressure piston and its connected moving parts and that the counterbalance C is of such weight that the moment of the force balances the moment due to the reciprocating parts, it will be seen that the action and effect are as follows: In the position shown in Fig. 11 the force 1 is a maximum in one direction, as indicated by the arrow, while the force due to counterbalance 3 is equal and opposite in direction, giving practically perfect balance as regards horizontal forces. The vertical force due to 2 is zero, (disregarding the effect due to the angular position of the connecting-rod or pitman.) Hence the total for this position is zero. With the parts in the position indicated in Fig. 12 the low-pressure piston is represented as passing its center, and the counterbalance 3 now exactly balances the forces due to the weight 2, while 1, having reached mid-stroke, is *nil* or zero. In like manner in the positions indicated in Figs. 13 and 14 the engine, it will be seen, is in perfect running balance. This of course indicates only the one side of the engine or one unit; but the same arrangement being duplicated for the other side its parts will be similarly placed in perfect running balance. In the case of the twin or double engine it is desirable to set the crank-pins in different angular relation to the shaft—advisably at forty-five degrees or at some odd multiple of forty-five degrees, avoiding positions of ninety degrees and one hundred and eighty degrees. At forty-five degrees or any odd multiple thereof there will be eight impulses during one revolution instead of four, and hence great uniformity of movement. It is found that the weight of fly-wheel required for this four-cylinder engine with cranks at one hundred and thirty-five degrees is exactly one-half that which would be required for a cross compound engine, either vertical or horizontal, with cranks at ninety degrees.

In Fig. 10 I have shown the pins *a* one hundred and thirty-five degrees apart. It will be seen that under this arrangement the parts of each unit or engine couple are placed in proper running balance. In view of the fact that in the case of compound engines—that is, of engines employing high and low pressure cylinders—the low-pressure cylinder possesses greater weight than the high-pressure cylinder it may be necessary to make the counterbalance of such weight that its moment shall be intermediate that of the respective pistons with their connected parts. In such case the balancing of the engine would be approximately performed at all parts of the stroke.

In Figs. 15 and 16 I have illustrated a three-unit arrangement—that is to say, three horizontal and vertical units—connected to one shaft. Each unit consists of one upright and one horizontal cylinder with pistons, rods, &c., the two pitmen of each unit or couple connecting to a common crank-pin and the two cylinders having their longitudinal axis at ninety degrees to each other, or thereabout. With this three-unit arrangement the cranks will be arranged at angular distances apart divisible by thirty degrees, being preferably equally spaced or at one hundred and twenty degrees to one another. By this arrangement twelve impulses are imparted to the shaft during or in the course of each revolution, and the turning moment is thereby rendered so much more uniform than under former arrangements that the fly-wheel weight required may again be reduced one-half as compared with the arrangement described in connection with Figs. 11 to 14, inclusive. In other words, it need be but twenty-five per cent. of that required under ordinary arrangements of parts.

As indicated in Fig. 15, this three-unit plan involves the employment of four bearings; but the center crank-pin may be rigidly connected to a disk on one side and work in a loose box in the disk on the other side, which arrangement allows freedom and makes compensation for any relative deflection of the two shaft-sections, and hence obviates any difficulty in keeping the four bearings in exact alinement.

As above explained, the main shaft may be, and in practice it is preferred that it shall be, divided so that each engine unit may be run independently of another or others. This arrangement has the further advantage also that each section of the shaft will be permitted to deflect under and in accordance with its own load. This will be better understood in connection with Fig. 15. Here it will be seen that the power of the vertical cylinder in the central unit is transmitted to the left and that of the horizontal cylinder of said unit is transmitted to the right and that neither of the outside units transmits any power through the crank-pins of the central unit. There is consequently no power transmitted through any crank-shaft or crank-shaft section by an engine not directly connected thereto.

Having thus described my invention, what I claim is—

1. In an engine of the class described, the combination of a frame, a rotatable crank-shaft mounted therein and provided with a single crank disk or arm having a single wrist-pin, high and low pressure cylinders the axes of which are arranged in horizontal and vertical planes respectively and substantially at an angle of ninety degrees each to the other, so that their longitudinal axes meet substantially at the crank-shaft, a reciprocating piston in each of said cylinders provided with outwardly-extending piston-rods, and a connecting-rod for each of said piston-rods connected with the single wrist-pin independently and in parallel arrangement, substantially as described.

2. In an engine of the class described, the combination of a frame portion, a rotatable crank-shaft mounted therein and provided with a single crank disk or arm having a single wrist-pin, a horizontally-arranged high-pressure and a vertically-arranged low-pressure cylinder set substantially at an angle of ninety degrees each to the other so that their longitudinal axes meet substantially at the crank-shaft, a reciprocating piston in each of said cylinders provided with an outwardly-extending piston-rod, and a connecting-rod for each of said piston-rods connected with the single wrist-pin independently and in parallel arrangement, substantially as described.

3. In an engine, the combination of a frame; a shaft provided with crank disk or arm and crank-pin; a vertical low-pressure cylinder and piston; a horizontal high-pressure cylinder and piston; connections between the respective pistons and the common crank-pin, the low-pressure piston connection being nearest the crank arm or disk; and a counterweight carried by the shaft and serving to counterbalance both the vertically and the horizontally moving parts.

4. In an engine, the combination of a frame having a shaft provided with crank disk or arm and crank-pin; a high and a low pressure cylinder set at an angle of ninety degrees each to the other, the low-pressure cylinder being vertically placed; pistons carried by the respective cylinders; connections between said pistons and the common crank-pin, the low-pressure piston connection being nearest the crank arm or disk; and a counterweight common to both the vertically and the horizontally moving members, and set in relation thereto substantially as described, whereby when either piston is at its extreme throw from the shaft, the counterweight shall be at its extreme throw on the opposite side of said shaft.

5. In an engine, the combination substantially as herein set forth, of a frame; a shaft provided with two crank arms or disks each having a crank-pin; and two pairs of engines each comprising a vertical cylinder, piston, piston-rod, and pitman, and a horizontal cylinder, piston, piston-rod, and pitman, the vertically and horizontally moving pistons of one engine pair or unit being connected to the crank-pin of one crank arm or disk, and the vertically and horizontally moving pistons of the other engine pair or unit being connected to the crank-pin of the other crank arm or disk, and the power of the engine being applied at a point between the two units, substantially as and for the purposes set forth.

6. In an engine, the combination substantially as herein set forth, of a frame; a shaft provided with two crank arms or disks each having a crank-pin; two pairs of engines each comprising a vertical cylinder, piston, piston-rod, and pitman, and a horizontal cylinder, piston, piston-rod, and pitman, constituting one unit, the vertically and horizontally moving pistons of one engine pair or unit being connected to the crank-pin of one crank or disk, and the vertically and horizontally

moving pistons of the other engine pair or unit being connected to the crank-pin of the other crank arm or disk; and counterbalances applied to said shaft one for each engine pair, each counterbalance arranged to make its extreme throw on one side of the shaft at the instant that the piston on the opposite side of the shaft reaches its extreme throw in a direction opposite said counterbalance, the power of the engine being applied at a point intermediate the two units.

7. In an engine, the combination of a plurality of units or engine couples, each comprising an upright and a horizontal cylinder with its piston, rod, &c.; and a crank-shaft having a crank-pin for each unit or engine couple, the two cylinders of each couple being set at substantially ninety degrees to each other, and the several cranks being set at such angular distances apart that the time interval between successive impulses imparted to the shaft shall be equal to the time of one revolution divided by twice the number of coöperating cylinders, the crank-shaft of each unit or engine couple being formed separate from that of other units or couples, whereby each crank-shaft or section of the common crank-shaft is permitted to deflect or spring under and in accordance with its own load.

8. In an engine, the combination of a plurality of engine couples, each comprising an upright and a horizontal cylinder with its piston, rod, &c., and a crank-shaft having a crank-pin for each unit or engine couple, the two cylinders of each couple being set at substantially ninety degrees to each other, and the several cranks being set at angular distances apart equal to thirty degrees or multiples thereof, and in general so set that the time interval between successive impulses imparted to the shaft shall equal the time of one revolution divided by twice the number of cylinders in this combination, the crank-shaft being divided into sections one for each engine couple or unit, whereby each is permitted to deflect or spring in accordance with its own load.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

EDWIN REYNOLDS.

Witnesses:

B. A. Brennan,

E. T. Adams.