(No Model.)

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M. C. BULLOCK.

STEAM ENGINE.

No. 533,157. Patented Jan. 29, 1895.

Fig. 3.

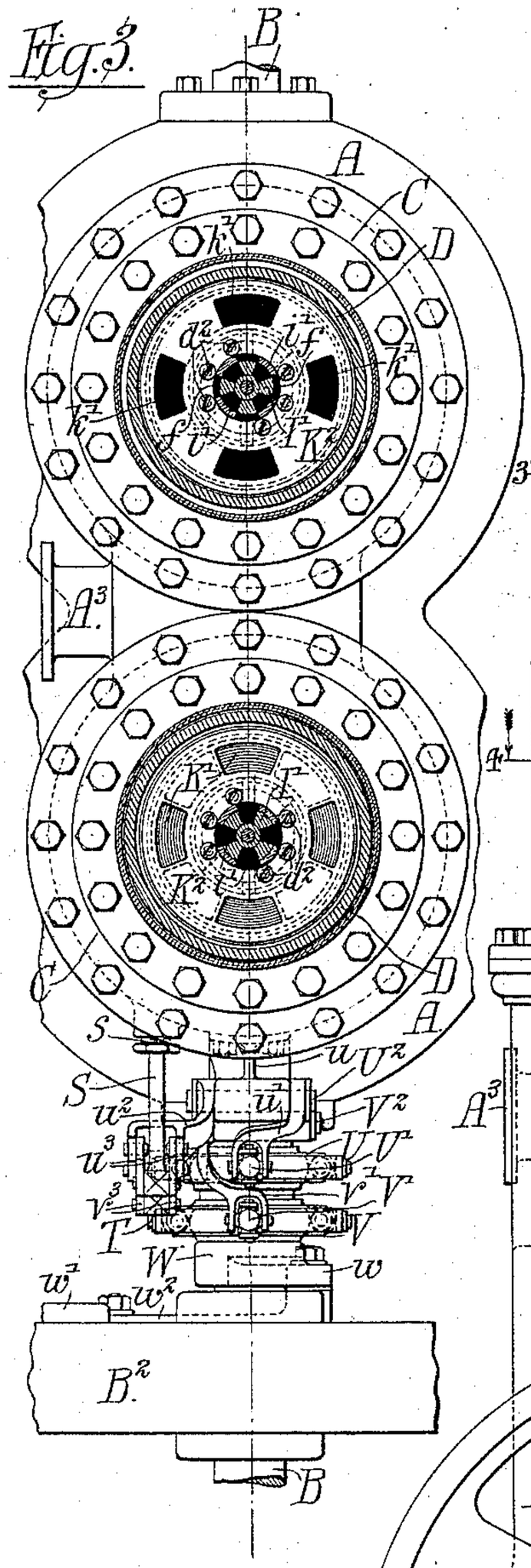


Fig. 1.

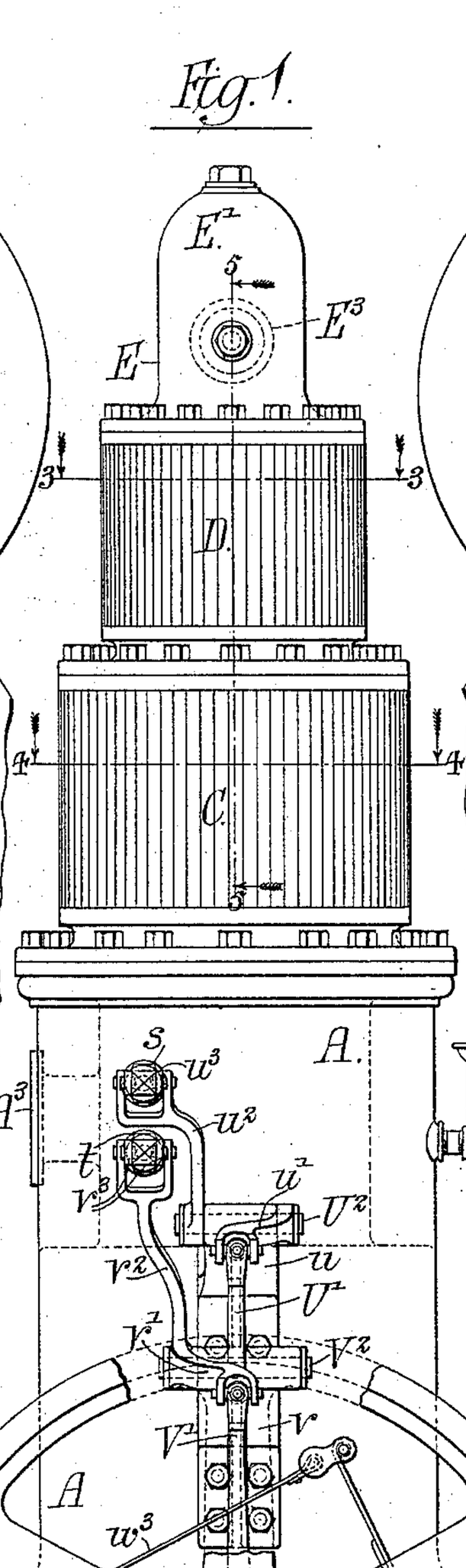
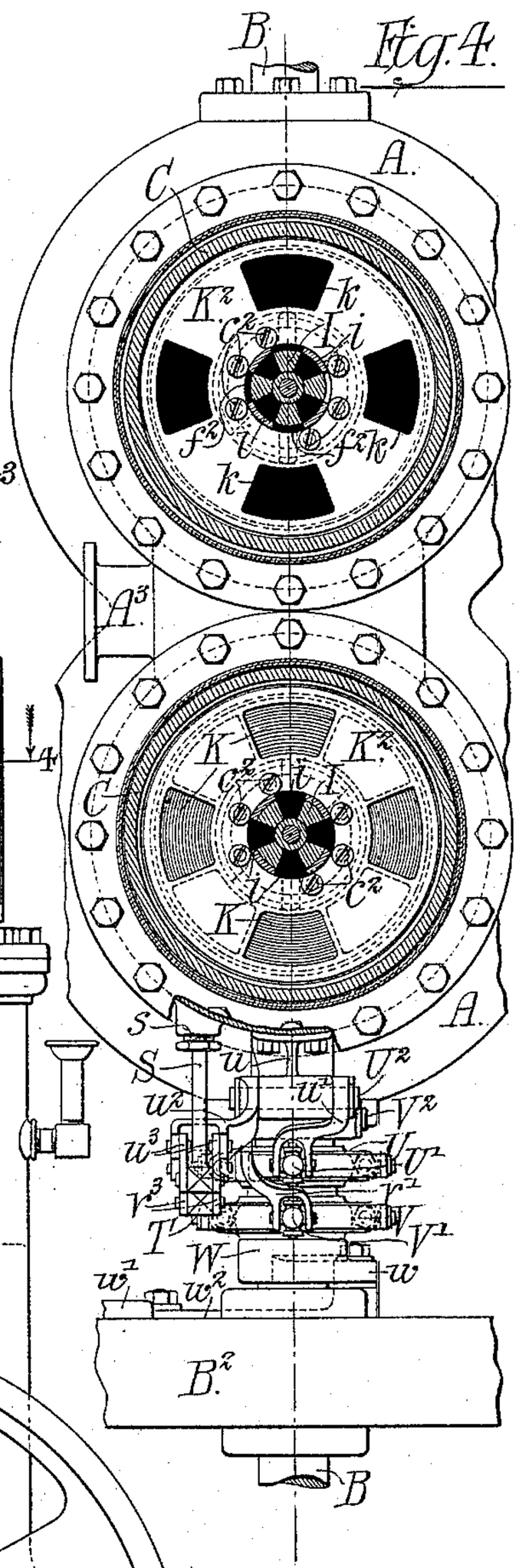
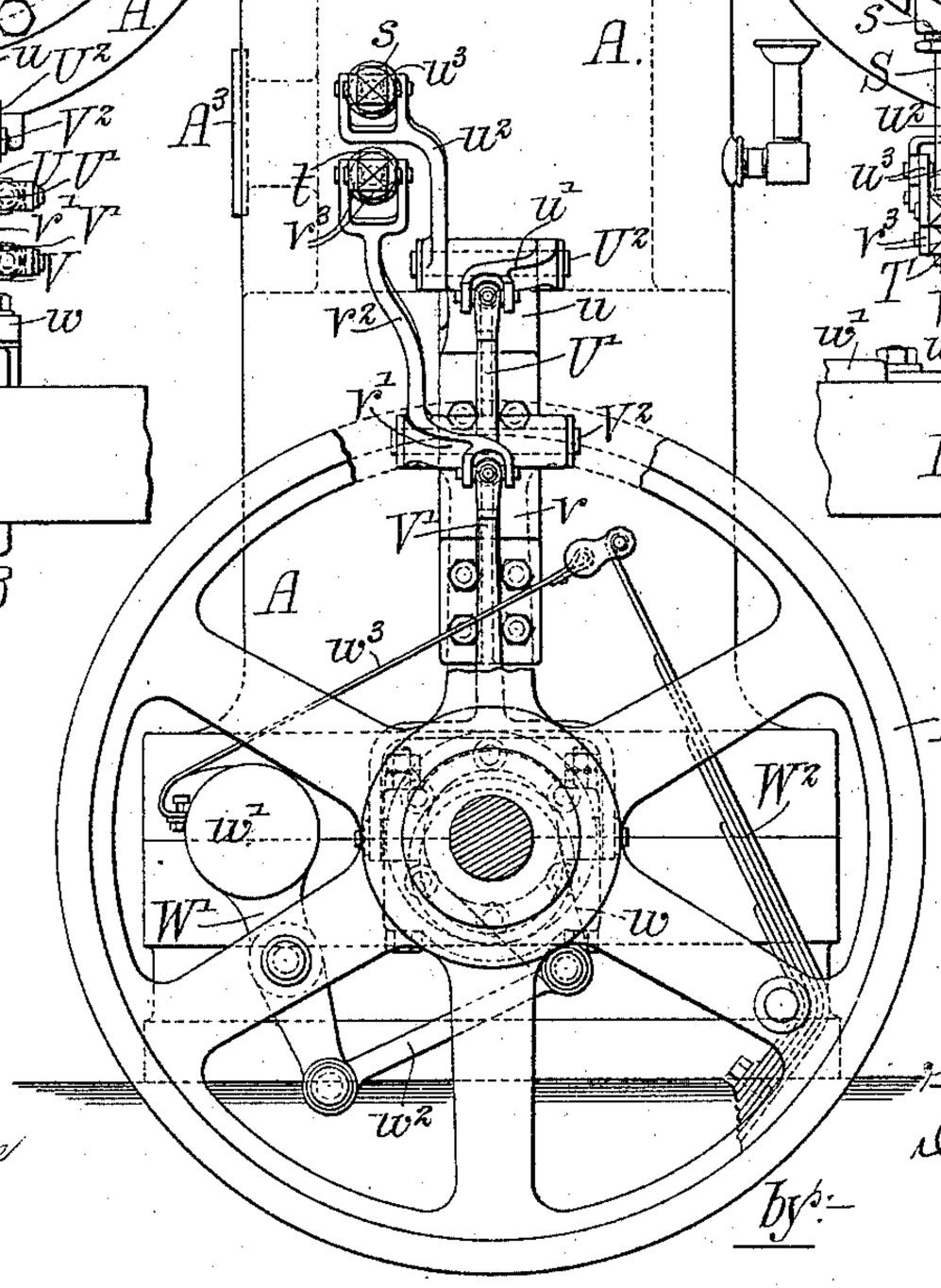


Fig. 4.





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His Attorneys

(No Model.) 4 Sheets—Sheet 2.

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Fig. 2.

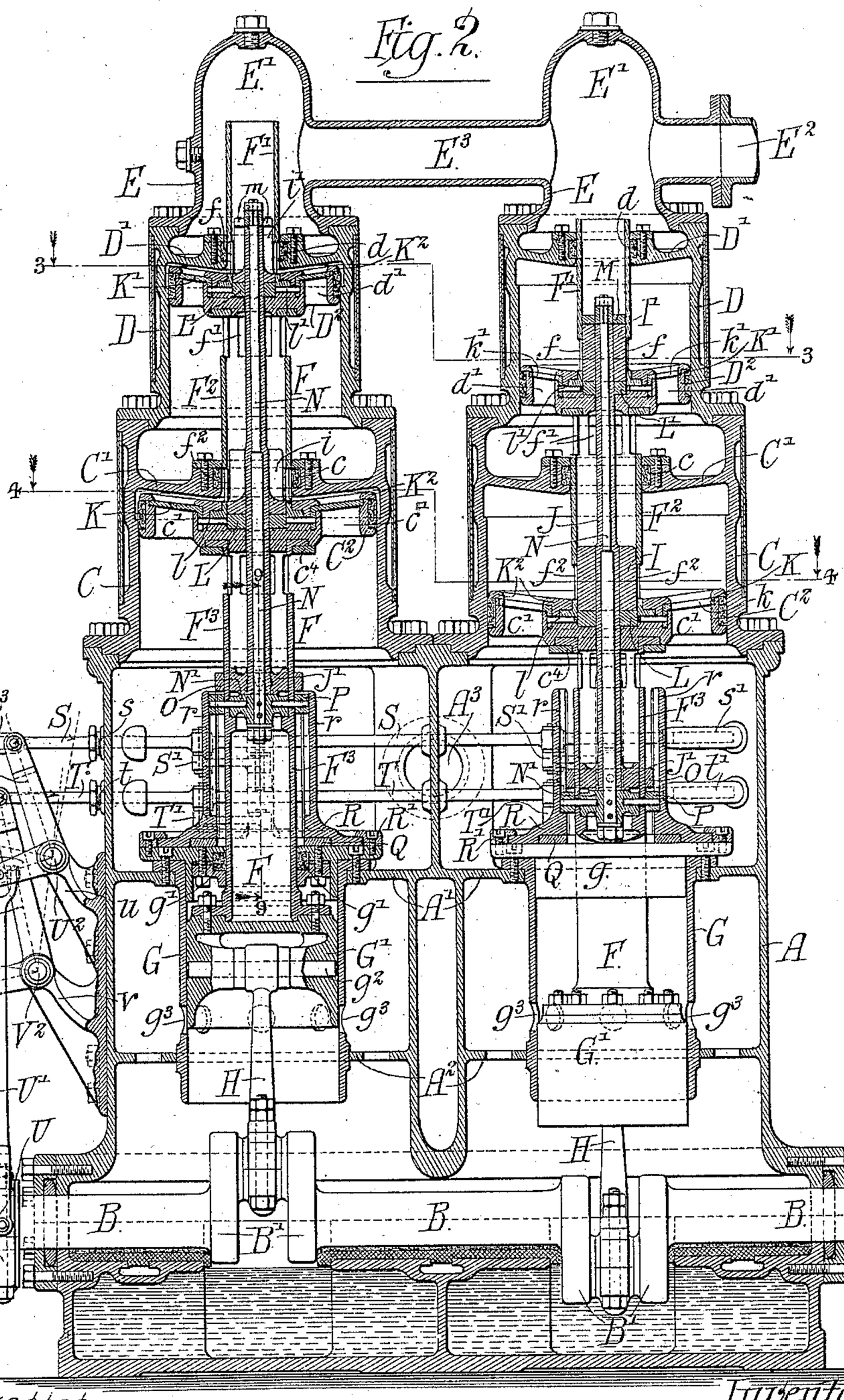

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Fig. 5.

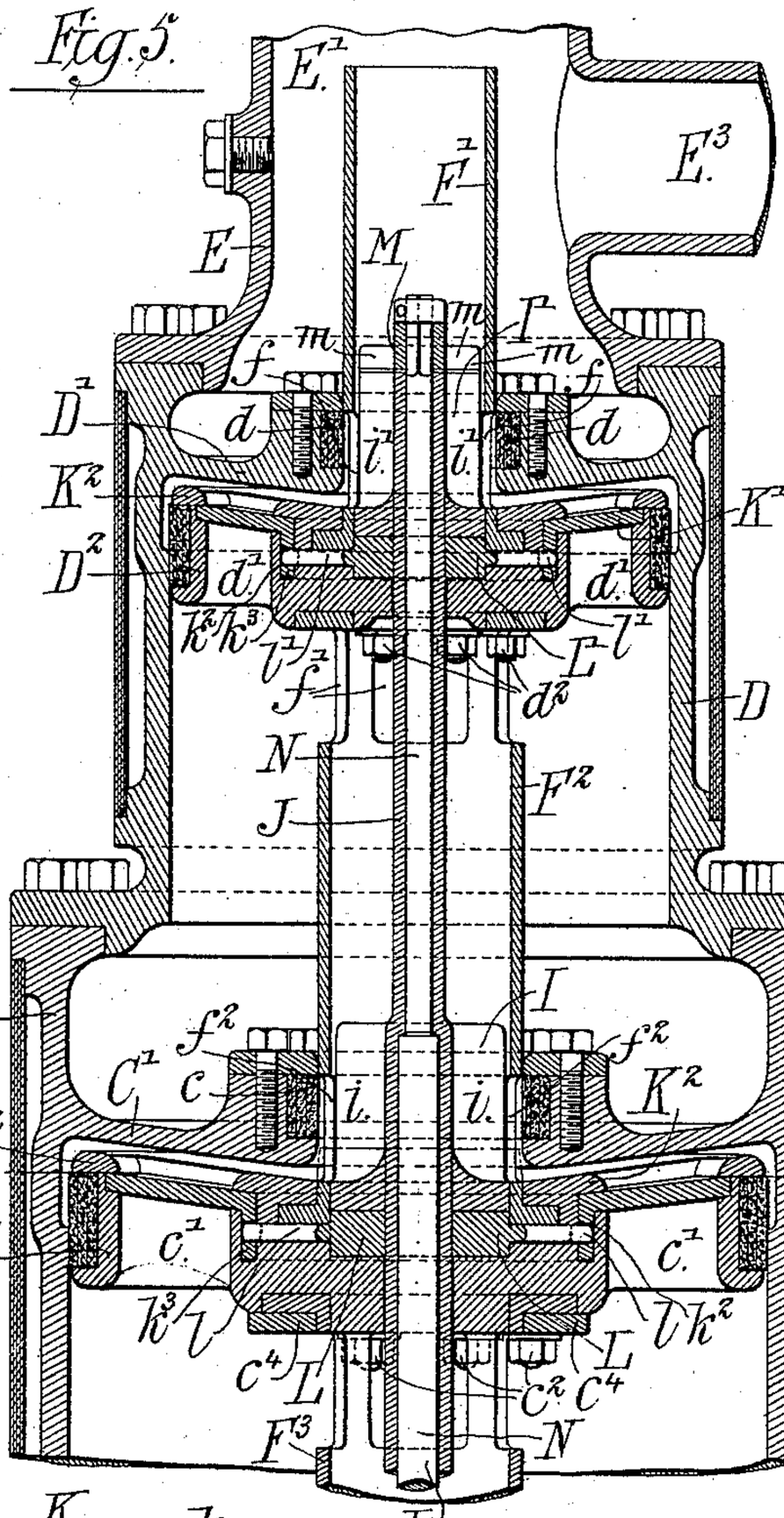


Fig. 7.

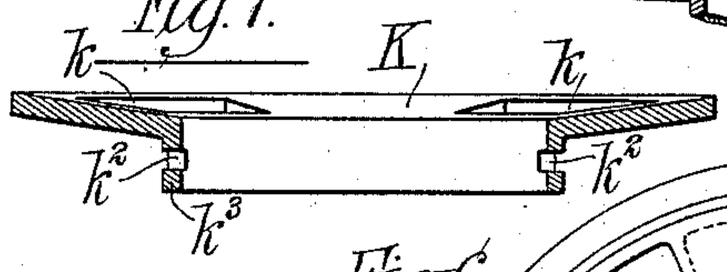


Fig. 8.

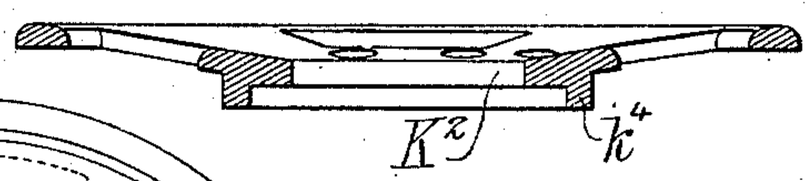
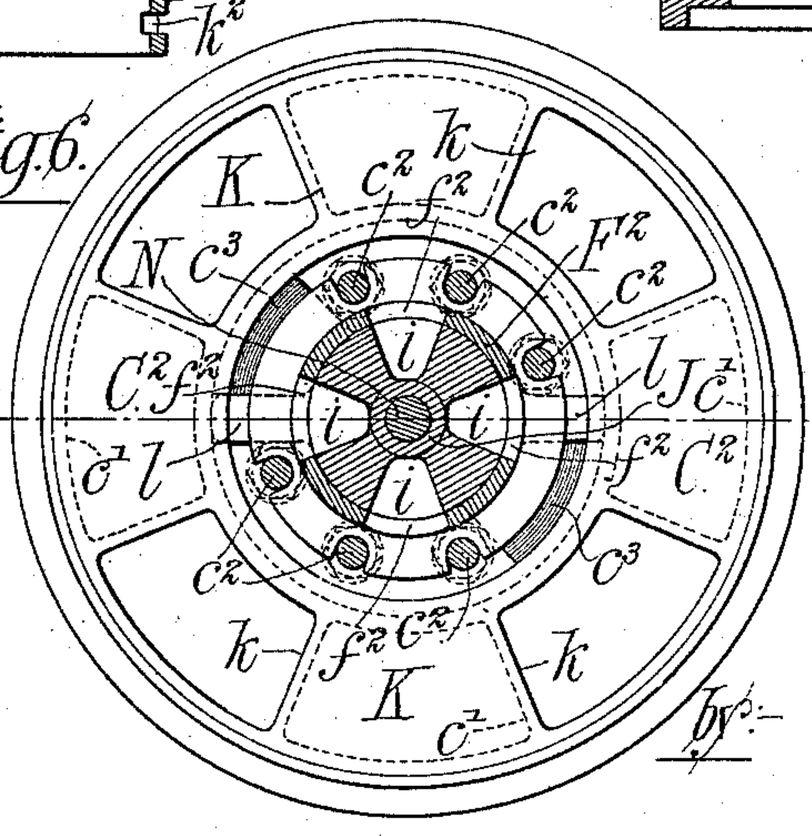


Fig. 6.



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(No Model.) 4 Sheets—Sheet 4.

M. C. BULLOCK.

STEAM ENGINE.

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Fig. 9.

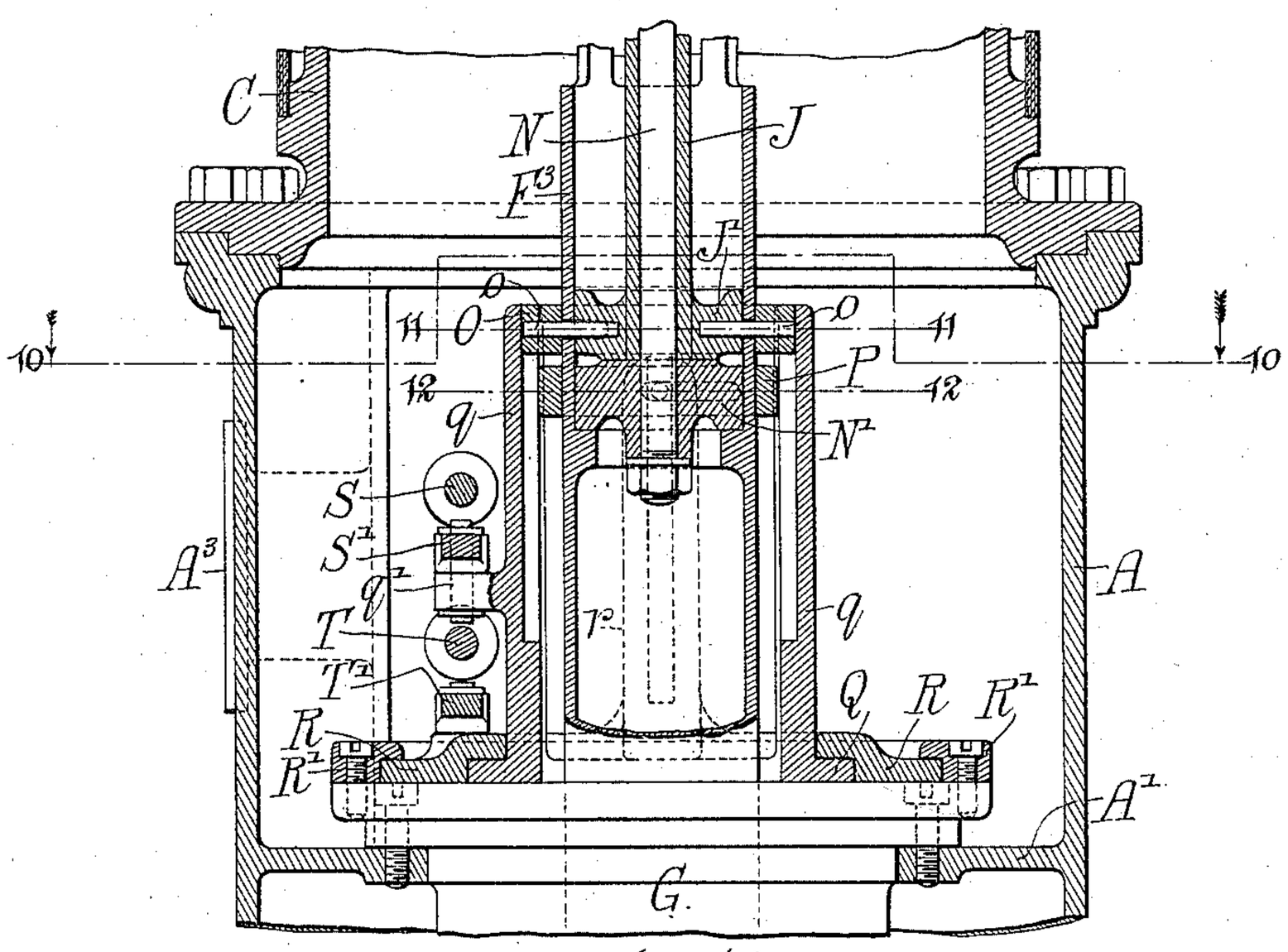


Fig. 10.

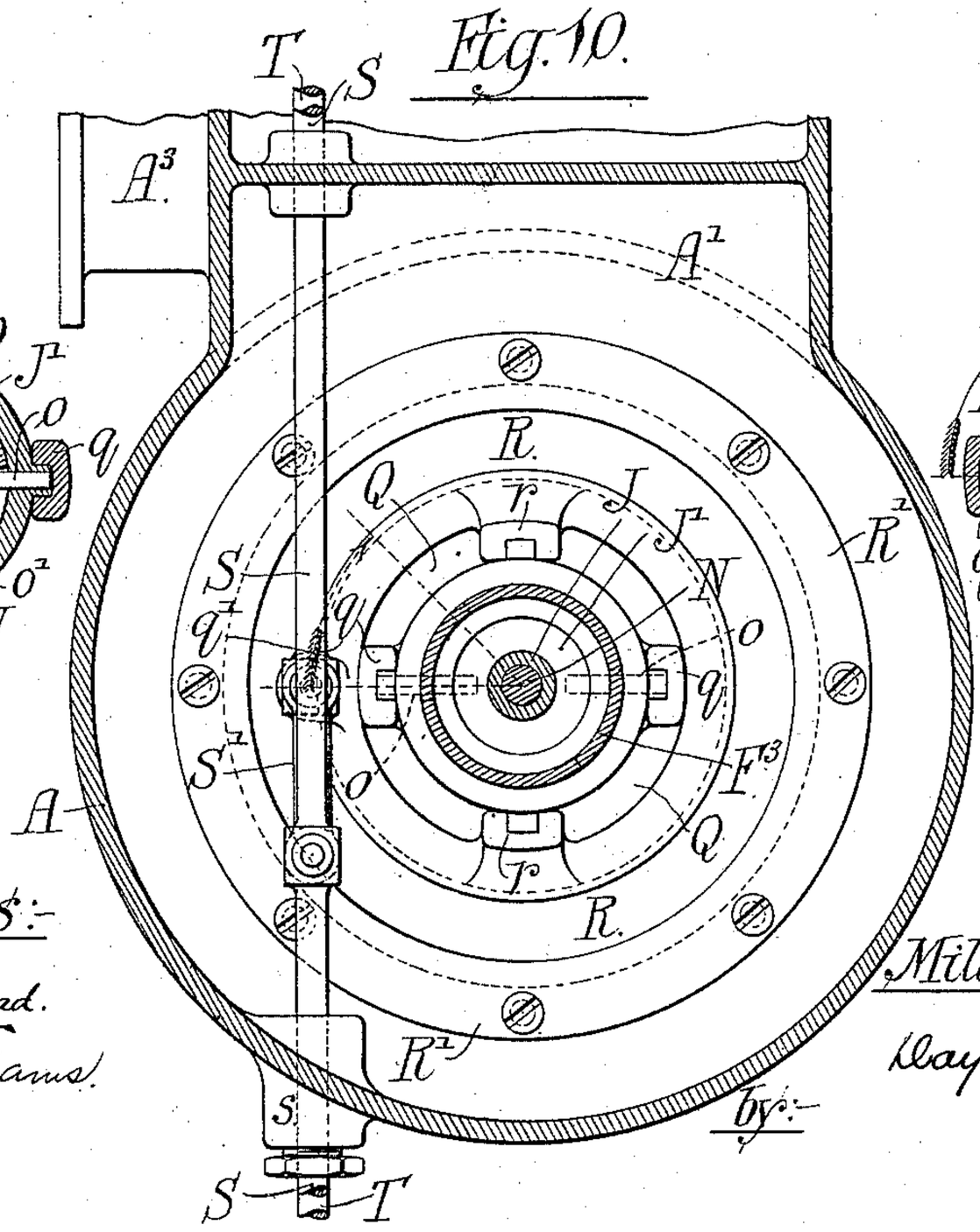


Fig. 11.

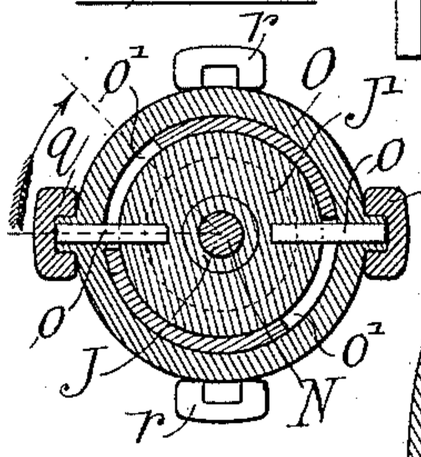
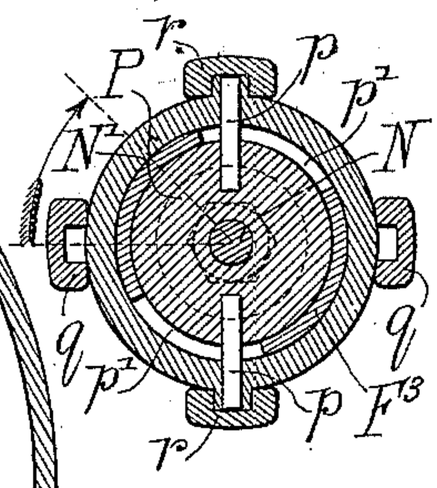


Fig. 12.



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UNITED STATES PATENT OFFICE.

MILAN C. BULLOCK, OF CHICAGO, ILLINOIS.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 533,157, dated January 29, 1895.

Application filed August 8, 1893. Serial No. 482,669. (No model.)

To all whom it may concern:

Be it known that I, MILAN C. BULLOCK, of Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Steam-Engines; and I do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the accompanying drawings, and to the letters of reference marked thereon, which form a part of this specification.

This invention relates to improvements in reciprocating steam engines of that class known as single-acting engines, or those in which the steam acts on one side of the piston only.

The engine herein shown as embodying my invention is of that kind known as a double tandem compound engine, the same embodying vertically arranged, single acting cylinders, supported on a common base, two piston rods carrying the pistons which operate within the cylinders, and a single crank-shaft provided with two cranks on which the two piston rods severally act. The pistons being moved in one direction only by the steam pressure within the cylinders as in other single-acting engines and the return stroke of each piston rod being accomplished by the action of the crank-shaft.

In the accompanying drawings illustrating my invention, Figure 1 is a view in side elevation of a double expansion engine embodying the same. Fig. 2 is a central vertical section, taken axially through both cylinders. Fig. 3 is a sectional plan view taken through both cylinders on lines 3—3 of Figs. 1 and 2. Fig. 4 is a similar sectional view taken on lines 4—4 of Figs. 1 and 2. Fig. 5 is an enlarged detail section of the upper cylinder and adjacent part of the lower cylinder of the engine. Fig. 6 is a detail plan section of the lowermost piston, taken on line 6—6 of Fig. 5. Fig. 7 is a detail section of the exhaust valve ring shown in Fig. 6. Fig. 8 is a detail section of the plate which covers the exhaust valve ring. Fig. 9 is a detail section through the lower or base part of the engine, showing devices for giving motion to the steam inlet valves, the same being taken on line 9—9 of Fig. 2. Fig. 10 is a plan section of the parts shown in Fig. 9, taken on line 10—10 of said figure. Fig. 11 is a detail section taken on line 11—11 of Fig. 9. Fig. 12 is a similar section taken on line 12—12 of Fig. 9.

As illustrated in said drawings, the base of the engine on which the cylinders and other parts are supported consists of a hollow casting A, within which is mounted the crank-shaft B, which is arranged horizontally within said base and has suitable bearings therein, and is provided with two cranks B′ B′. Attached to the top of the base casting A, side by side, are two upright cylinders C C, which constitute the low-pressure cylinders of the engine, and which are provided below their upper ends with integral horizontal partitions or diaphragms C′ C′ forming the heads of the cylinders proper. Said cylinders C C are open at their lower ends and communicate with the interior of the hollow base casting A, which is provided in its horizontal top wall with openings preferably somewhat larger than the interior diameters of the cylinders; the cylinders being bolted to the said base casting in the manner illustrated. Said base casting is provided at some distance below its top wall with a horizontal partition or diaphragm A′, which forms a passage or receiver for exhaust steam from the low pressure cylinders C C. Said base casting is also provided above the diaphragm A′ with an exit pipe A^3 communicating with the said exhaust passage or receiver and permitting the discharge of the exhaust steam from the engine.

Affixed to the upper ends of the cylinders C C are other smaller cylinders D D, which constitute the high pressure cylinders of the engine. Said cylinders D D open at their lower ends into the cylinders C C, above the diaphragms C′ C′ of the latter, and are provided at points below their upper ends with horizontal partitions or diaphragms D′ D′ which form the cylinder heads. The upper ends of said cylinders D D are closed by means of castings or heads E E, which form with the upper parts of the said cylinders above the diaphragms or partitions D′ D′ steam chests or chambers E′ E′, which are supplied with steam by means of a steam supply pipe E^2 leading to one of said chambers, and a horizontal steam pipe E^3 which connects the said chambers with each other. As herein shown and as preferably con-

structed, the steam pipe E^3 is cast integral with the heads E E.

The upper parts of the cylinders C C above the diaphragms C′ C′ constitute steam chambers or receivers between the high and low pressure cylinders, and inasmuch as the cylinders D D open at their lower ends into the said steam chambers or receivers, the lower parts of said cylinders D D below the pistons constitute in effect portions of said receivers. Similarly, the lower parts of the low pressure cylinders C C open into and form parts of the receivers or exhaust space in the upper part of the base casting.

C^2 D^2 indicate severally pistons which are located within the cylinders C and D, and F F are hollow or tubular piston rods which pass through the several cylinder heads or diaphragms C′ D′ and to which the several pistons C^2 D^2 are attached. The said piston rods are herein shown as made in several separate parts or sections F′ F^2 F^3, of which the part F′ is attached to the upper piston D^2 and extends upwardly through the partition D′ into the steam chest. The part F^2 is attached at its opposite ends to the pistons C^2 and D^2, and the part F^3 is attached to the piston C^2 and serves to connect the same with the crank-shaft. The several diaphragms C′ and D′ are provided with glands or packings *c d* to make tight joints around the piston rods where the latter pass through said diaphragms. The piston rods F are provided above the piston D^2 with ports *f* for the admission of steam to the cylinders D and below said piston with other ports *f′* for the admission of steam from the receivers to the interior of the hollow piston rod, and similarly said hollow piston rod is provided above the piston C^2 with steam ports f^2 for the admission of steam to the low pressure cylinders C.

Within the base casting A are located two vertically arranged air cylinders G G which are in axial alignment with the low pressure steam cylinders C C, said air cylinders being closed at their upper and open at their lower ends. Within the air cylinders G G are located pistons G′ G′ to which the lower ends of the piston rods F F are rigidly secured. The lower parts or sections F^3 F^3 of the piston rods F F pass through glands or packing boxes *g′ g′* in the heads *g g* of the air cylinders, which glands or packing boxes form tight joints about the piston rods to prevent the escape of air past the cylinder heads. The pistons G′ G′ of the air cylinders are connected with the cranks B′ B′ of the crank-shaft by means of connecting rods H H which are pivotally connected with the pistons and are engaged with the crank-pins in the usual manner. Said pistons G′ G′ have preferably the form of hollow cylinders closed at their upper ends, the upper ends of the connecting rods H H being located within the same and pivotally connected therewith by bearing pins g^2 g^2 which are inserted transversely through the opposite side walls of the pistons.

The air cylinders and the pistons described serve the same purpose as the cross-head guides and cross-heads commonly employed for the purpose of guiding the piston rods of steam engines. Said air cylinders and pistons also serve as a means of taking up the momentum of the pistons and piston rods during their up-stroke and to thereby maintain the connecting rods compressed at all times during such stroke; it being obvious that compression of the air in the air cylinders in the up-stroke of the pistons will gradually retard the movement of the piston rods and connected parts. The energy expended in thus compressing the air is not lost for the reason that during the subsequent down stroke of the pistons the expansive action of the air is added to the effect of the steam pressure. Said air cylinders G G are shown as provided with air inlet openings g^3 g^3 for the purpose of admitting air to the cylinders at each down stroke of the pistons.

In the particular construction shown the air cylinders are secured at their upper ends in the partition A′, the heads *g g* being secured to the cylinders by bolts which also connect the cylinders to the said partition. A horizontal partition A^2 located at some distance below the partition A′ is provided with apertures in which the lower ends of the air cylinders closely fit and by which they are held accurately in place.

Steam enters the upper ends of the several cylinders through the hollow or tubular piston rods F F and act on the upper surfaces of the pistons to force the same downwardly or toward the open ends of the cylinders and the cranks being set opposite each other or at an angle of one hundred and eighty degrees one piston is at the limit of its down stroke at the time the other piston is at the limit of its up stroke, so that the up stroke of each piston rod is accomplished by the action of the crank-shaft only. In the up stroke of the piston rod and pistons attached thereto exhaust steam from the upper ends of the high and low pressure cylinders escape into the receivers between said cylinders and below the low pressure cylinders through apertures or steam ports formed in the pistons themselves; suitable valves being provided in connection with said ports in the pistons to close the same except when they are open for the passage of exhaust steam. The passage of steam through the hollow piston rods to the several cylinders is controlled by valves located within the hollow piston rods which valves are operated by actuating devices which extend through the hollow piston rods, and which also serve to actuate the valve plates by which the exhaust ports within the pistons are also actuated. Steam supplied to the steam chests E′ E′ enters the open upper ends of the piston rod sections F′ F′ and is delivered to the high pressure cylinders D D through the ports *f f* which are located adjacent to the upper pistons. Steam from the receivers between the

high and low pressure cylinders enters the intermediate piston rod sections F^2 F^2 through the ports f' f' at the upper ends thereof, and is delivered to the low pressure cylinders through the ports f^2 f^2 adjacent to the lowermost pistons. Inasmuch as both the high and low pressure cylinders open at their lower ends into the adjacent receivers beneath them, the exhaust steam which passes through the pistons as the latter rise enters directly into the said receivers so that at the end of each up stroke of the pistons the steam which previously filled the cylinders above the pistons will have passed through the pistons and will fill the lower portions of the cylinders as well as the receivers which in the case of the high pressure cylinders is formed by the space above the diaphragm C' of the low pressure cylinder and in the case of the low pressure cylinder is formed in the upper part of the base casting.

As far as the construction herein shown of the devices for admitting steam to the several cylinders is concerned, these parts are constructed as follows: The movable parts of the several valves consist of valve-plugs I I' which are located within the hollow piston rod and are attached to a common valve stem J, which extends centrally through the hollow piston rod and is adapted to turn or rotate with the valve plug. Said valve plugs are arranged to operate in connection with the ports f f^2, and are for this purpose located within the hollow piston rods above the pistons C^2 and D^2 and are arranged to fit closely within said piston rods. The several valve plugs are provided with ports or passages i i i' i' which open through the sides and upper ends of the plugs and correspond in width and angular arrangement with the ports f f f' f', in connection with which they operate. Inasmuch as the several ports i i i' i' of the valve plugs open at their upper ends into the hollow piston rods, said ports are at all times in communication with the source of steam supply and it follows that when the ports are turned into position to bring the said ports opposite to ports f f f^2 f^2 of the piston rod, steam will pass from the piston rods to the cylinders, but when the plugs are turned to bring the said ports opposite the spaces between said ports f f f^2 f^2, then the passage of steam will be cut off. As herein shown, the ports f f' of the piston rod are four in number, while the valve plugs are also provided with four ports i i', and it follows that in the operation of the valve the plug is swung or oscillated through an angular distance equal to one eighth of an entire revolution, an oscillatory movement through this distance obviously serving to alternately open and close the valve ports.

As shown in the drawings, Figs. 5 and 6, the valve plugs are in position for the admission of steam to both cylinders, the steam at such time passing from the space within the upper piston rod section downwardly through the ports or passages i i and then laterally outward through the ports f f to the space within the cylinders above the piston D^2, while similarly, steam which enters the piston rod section F^2 through the ports f' passes downwardly through the ports i' i' and then laterally outward through the ports f^2 f^2 to the space above the piston C^2.

In order to provide ample area for the passage of steam with a minimum of oscillatory movement in the valve, the ports f are made of considerable length vertically and relatively narrow, this construction having the advantage also of giving sufficient area in the ports without unduly weakening the piston rod. The said ports when thus made of considerable vertical length will extend upwardly into the piston head or diaphragm when the piston is at the upward limit of its stroke, as seen at Fig. 5, but this is of no consequence in the operation of the engine for the reason that only a small supply of steam is required for starting the piston in its downward movement and as soon as the piston has moved far enough to acquire any considerable speed the ports will have been entirely uncovered and an ample supply of steam thus afforded as soon as required.

The exhaust ports or passages c' d' which are formed in the pistons are arranged at equal distances apart around the pistons and separated from each other by spaces somewhat greater in length circumferentially than the ports themselves, while the annular valve plates or rings K K' are provided with correspondingly arranged apertures k k k' k', these ports being so arranged that by turning the valve plate through an angular distance equal to one half of that between the centers of two adjacent ports said ports will be alternately opened and closed. The pistons and valve plates are herein shown as provided with four ports or openings, the same corresponding in number with those of the steam inlet valve, so that both the steam inlet and exhaust valves may be operated by the same actuating devices.

Means for connecting the said valve plates K K' with the valve stem J are herein shown as provided as follows: Attached to the said valve plate below the valve plugs I I' are disks L L' which are provided with radial arms l l l' l', which latter extend outwardly through suitable slots or passages formed in the pistons and engaged at their outer ends with recesses k^2 k^2 which are formed in a downwardly extending flange k^3 on the valve plate; said disk and arms thereon partaking of the oscillatory movement of the stem J. It follows that the valve plates K K' will be moved or oscillated with the valve plugs I I', so that when the steam admission valves are closed the exhaust valves will be opened and vice versa. It follows from this construction that when the valve plugs are turned in one position steam will be admitted simultaneously to both the high and low pressure cylinders, and when the several plugs are turned in the

opposite direction the steam will be cut off simultaneously from both cylinders and exhaust steam will be allowed to escape through the pistons from the spaces above to the spaces below the same.

The upper valve plug I′ is provided on its top surface with a valve disk M, which is interposed between the ports of said valve plug and the steam space of the steam chest and forms the movable part of the cut off valve for controlling the steam supply to the high pressure cylinder in quantities corresponding with the work being done by the engine, thereby securing the results produced by other cut off valves. Said valve disk M rests directly upon the top of the plug I′ and is provided with a plurality of ports *m m* corresponding in size and angular distance apart with the ports or passages *i′ i′* of the said valve plug. Said cut off valve is attached to a valve stem N which passes downwardly through the valve-stem J of the main valve, which latter valve stem is made hollow for this purpose.

Inasmuch as the valve stems J and N of both the main and cut off valves are located within and moved longitudinally with the piston rod, devices for turning or giving oscillatory movement to said valve stems must obviously be connected to the same by devices permitting free reciprocation of the said stems with the piston rod while maintaining constantly such engagement as is necessary for turning or giving oscillatory movement to the said stems. The devices herein shown as employed for this purpose are located within the base A of the engine and are adapted to engage with the lower ends of said valve stems which extend past the lowermost piston C^2 into the part of the hollow piston rod below the said lower piston.

To now describe more specifically the devices shown for giving motion to the valves, the main valve stem J is attached at its lower end to a disk J′ which is adapted to turn freely within the hollow piston rod, while the valve stem N is attached to a similar disk N′ located below and preferably adjacent to the disk J′. Outside of the hollow piston rod and surrounding the same are two rings O P, the ring O being attached to the disk J′ by means of pins *o* extending through horizontal slots *o′ o′* in the piston rod and secured in said disk J′ (Fig. 11). The ring P is similarly attached to the disk N′ by means of pins *p p* which pass through horizontal slots *p′ p′* in said piston rod. Q is an oscillating ring mounted on the top wall of the air cylinder G concentrically with the piston rod, and R is a similar ring located outside of the ring Q concentrically therewith. The ring Q is shown as held in place by engagement with the ring R which is arranged to overlap the same, while said ring R is shown as held in place by an external bearing ring R′ secured to the margin of the air cylinder head in the manner shown. The ring Q is provided with two vertical arms *q q* (Figs. 9 and 11) which arms are provided with grooves to engage outwardly extending lugs on the ring O, so that said ring has vertically sliding but non-rotative connection with the said arms. The ring R has similar upwardly extending arms *r* (Figs. 10 and 12) which arms have grooves on their inner faces engaging lugs on the ring P, so that said ring P has vertically sliding engagement with the arms *r* but is held in rotative engagement therewith. The vertically sliding but non-rotative connection of the arms *q q* and *r r* with the rings O and P obviously enables the oscillatory movement given to the rings Q and R to be transmitted to the disks J′ and N′ and thence to the valve stems at all times notwithstanding the rapid reciprocatory motion of the piston rod and said valve stems.

S. and T are two horizontally arranged actuating rods through the medium of which motion is given to the rings Q and R, and which are themselves actuated by suitable connections with the main shaft of the engine. Said rods S and T are shown as extending through the base casting at one side of the piston rods and as passing through packing boxes *s t* at the points where they enter the base casting. At their opposite ends said rods are supported in guides *s′ t′* attached to the wall of the base casting within the same. The actuating rods S T are connected with the oscillating rings Q and R by means of short connecting rods or links S′ T′; the link S′ being pivoted to the connecting rod and to an outwardly projecting lug *q′* on one of the arms *q* of said ring Q, while the link T′ is pivoted directly to the top surface of the ring R. It is obvious that with this construction endwise reciprocatory motion given to the two actuating rods S and T will transmit oscillatory motion to the rings Q and R for the purpose of actuating the main and cut off valves in the manner above described.

Means for giving motion to the actuating rods S and T of the main and cut off valves are provided as follows: On the main crankshaft B are mounted two eccentrics U and V, of which the eccentric U is rigidly attached to the shaft and the eccentric V is loosely mounted thereon so that it may be turned or partially rotated relatively to the shaft. In connection with the eccentric V is employed a governing device, herein shown as having the form of a fly-wheel governor; said governing device being arranged to turn the eccentric in one direction or the other, according to the speed of the fly-wheel. With the eccentrics U and V are connected in the usual manner, two eccentric rods U′ and V′, the upper ends of which are connected with and give motion to two rock-shafts U^2 V^2, (which rock-shafts are mounted in brackets *u v* attached to the base casting A) and are provided with horizontal arms *u′ v′* to the outer ends of which the eccentric rods U′ V′ are connected. The rock-shaft U^2 is provided

with an upwardly extending arm u^2 which at its upper end is connected with the outer end of the valve actuating rod S; the means of connection shown consisting of two pivot links u^3 u^3. Similarly the rock-shaft V^2 is provided with an upwardly extending arm v^2 the upper end of which is connected with the valve actuating rod T by means of two pivot links v^3 v^3. The rock-shafts and arms thereon arranged as described constitute obviously, bell-crank levers by which the vertical motion of the eccentric rods is changed to horizontal motion for actuating the rods S and T. The connecting devices constructed as described ovbiously serve to transmit motion continuously and uniformly from the eccentrics U and V to the valve actuating rods S and T at all times during the operation of the engine.

The fly-wheel governor hereinbefore mentioned is shown as applied to the belt pulley B^2 of the engine and is constructed as follows, to wit: The eccentric V is attached to a sleeve W which surrounds and turns on the shaft B and is provided with a rigidly attached radial arm w, Fig. 1. Pivotally mounted at one side of the pulley is a lever W′ carrying a weight w' at one end and connected at its opposite end by a link w^2 with the arm w of the eccentric sleeve. A spring W^2 attached to the wheel rim is connected at its free end with with the weighted end of the lever W′ by means of a strap or cord w^3; the spring being arranged to hold the weight normally at the inward limit of its movement. The parts of the governor are arranged in the usual manner so that the spring will tend to hold the eccentric normally in the position giving a maximum admission of steam to the high pressure cylinder, while the outward movement of the weight produced by the increased speed of the engine acts to shift the eccentric in a manner to move the cut off valve relatively to the main valve in a direction to decrease the steam supply.

The attachment of the piston rod sections to the pistons and the details of construction in the pistons by which suitable bearings or seats are provided for the valve plates or rings K K′ may be of any suitable character, the details of construction in these parts herein provided for convenience in the construction illustrated being as follows: The pistons each consist of a single casting made without any passage or opening at its center excepting a bearing aperture for the passage of the valve stem J. Both adjacent ends of the piston rod sections above and below the piston are provided with an outwardly extending flange, and the piston rod sections are secured to the piston by vertical bolts c^2 d^2 (Figs. 5 and 6) which pass through said flanges and the central part or hub of the piston in a direction parallel with the axis of the piston rod. The arms l l by which the valve plates are connected with the valve stems are inserted beneath the flanges of the upper piston rod sections and between the same, the body of the piston being cut away to form segmental slots or recesses c^3 c^3 through which said arms may pass when oscillated. The said flanges of the upper piston rod being in contact with the piston in its parts only which are located between the said recesses, as clearly seen in Fig. 6. Inasmuch as said segmental slots or recesses extend through an angular distance equal to somewhat more than one eighth of a circle at each side of the center of the piston, I have found it desirable to arrange the bolts c^2 c^2 close together in the spaces between the ends of said recesses, as clearly seen in said Fig. 6. Said bolts c^2 c^2, furthermore, are shown as engaging at their lower ends holding rings c^4 placed in contact with the flange of the lower piston rod section and as engaged at their upper ends with a plate K^2 which extends over the valve ring K and covers the top of the piston; said plate being extended inwardly to overlap the flange of the upper piston rod section and thus form a holding ring for the same. A depending flange k^4 on the plate K^2 serves to fill the space between the inner margin of the valve ring and the flange of the upper piston rod section, as clearly seen in Figs. 5 and 6.

I claim as my invention—

1. The combination with single acting high and low pressure cylinders and an intermediate receiver in open communication with the high pressure cylinder, of a piston in the latter cylinder provided with exhaust ports extending directly through the piston, and a valve for controlling said exhaust ports, substantially as described.

2. The combination with single acting high and low pressure cylinders and an intermediate receiver in open communication with the high pressure cylinder, of a piston in the latter cylinder provided with exhaust ports extending directly through the piston, a valve for controlling said exhaust ports, and means for actuating said valve embracing parts which extend through the piston rod, substantially as described.

3. The combination with a single acting cylinder and an adjacent receiver into which the cylinder opens at one end, said cylinder being provided with a steam inlet port and a valve for controlling the same, of a piston in the cylinder provided with exhaust ports extending directly through the same and with a valve for controlling said exhaust ports consisting of a valve plate having port openings corresponding with those of the piston, substantially as described.

4. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports and with a valve for controlling said exhaust ports the movable part of which is adapted to turn about an axis coincident with the central longitudinal axis of the cylinder, substantially as described.

5. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve for controlling the passage of steam through said ports, the movable part of which is adapted to turn about an axis coincident with the central axis of the cylinder, a hollow piston-rod attached to the piston, and valve-actuating devices extending through the hollow piston-rod and connected with the movable part of the valve, substantially as described.

6. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve for controlling the passage of steam through said ports, the movable part of which is adapted to turn about an axis coincident with the central axis of the cylinder, a hollow piston-rod attached to the piston, and valve-actuating devices embracing a stem which extends longitudinally through the rod and moves endwise with the same, and means having sliding but non-rotating connection with the said rod for giving motion thereto, substantially as described.

7. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve for controlling the passage of steam through said exhaust ports, a hollow piston-rod provided with steam ports and a valve for controlling the passage of steam through said piston-rod, substantially as described.

8. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve for controlling the passage of steam through said exhaust ports, a hollow piston-rod provided with steam ports, a valve controlling the passage of steam through said piston-rod and means for actuating both of said valves embracing a valve stem which extends through the hollow piston-rod and is connected with the movable port of both valves, substantially as described.

9. The combination with a cylinder and an adjacent receiver with which the cylinder communicates, of a piston in the cylinder provided with steam ports, a valve for controlling said steam ports, the movable part of which is adapted to turn about an axis coincident with the central axis of the cylinder, a hollow piston-rod provided with steam ports a valve for controlling the passage of steam through said piston-rod, the movable part of which is also adapted to turn about an axis coincident with the central axis of the cylinder and means for actuating both of said valves, embracing a valve stem which extends through the hollow piston-rod and is connected with the movable part of both of said valves, substantially as described.

10. The combination with a cylinder and an adjacent receiver with which the cylinder communicates at one end, of a piston in the cylinder provided with steam ports, a valve for controlling said steam ports, the movable part of which is adapted to turn about an axis coincident with the central axis of the cylinder, a hollow piston-rod provided with steam ports, a valve for controlling the passage of steam through said piston-rod, the movable part of which is also adapted to turn about an axis coincident with the central axis of the cylinder, and means for giving motion to both of said valves, embracing a valve rod or stem mounted to turn within the hollow piston-rod and movable endwise with the same, the actuating devices having sliding but non-rotative connection with said rod or stem, substantially as described.

11. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve ring or plate operating in connection with said ports to form a valve for controlling the passage of steam through the said piston, a hollow piston-rod, a valve stem mounted to turn within the hollow piston-rod and connected with the said valve ring, and means for actuating said valve stem comprising parts having sliding but non-rotative connection with the same, substantially as described.

12. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve ring operating in connection with said valve ports, a hollow piston rod provided with a steam valve, the movable part of which is adapted to turn about an axis coincident with the central axis of the cylinder, and means for actuating said valves embracing a valve stem mounted to turn in the said hollow piston-rod and connected with the movable part of said steam valve and with the said exhaust valve ring, substantially as described.

13. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve ring operating in connection with said valve ports, a hollow piston-rod provided with steam ports, a valve for controlling said steam ports, the movable part of which is adapted to turn about an axis coincident with the central axis of the cylinder, and means for actuating said valves, embracing a valve-stem mounted to turn in the said hollow piston-rod and connected with the movable part of said valve and with the said valve ring, and embracing also a part having longitudinally sliding but non-rotating connection with the said valve stem, substantially as described.

14. The combination with a cylinder and an adjacent receiver into which the cylinder opens at one end, of a piston in the cylinder provided with exhaust ports, a valve ring operating in connection with said exhaust ports,

a hollow piston-rod provided with steam ports, a valve-plug turning in the hollow piston-rod and controlling said steam ports, and means for actuating the said valves embracing a valve stem mounted to turn in said hollow piston-rod and connected with said valve plug and with the valve ring of the exhaust valve, substantially as described.

15. The combination with high and low pressure cylinders and an intermediate receiver separated from the low pressure cylinder by a diaphragm or partition forming the cylinder head, of pistons within said cylinders, said pistons being provided with exhaust ports, valves controlling said exhaust ports, a hollow piston-rod attached to the said pistons and passing through said cylinder head, said piston-rod being provided with steam ports, valves for controlling the passage of steam through the hollow piston-rod, and means for actuating the said valves embracing a valve rod or stem mounted to turn within the hollow piston-rod and connected with the movable parts of said valves, substantially as described.

In testimony that I claim the foregoing as my invention I affix my signature in presence of two witnesses.

MILAN C. BULLOCK.

Witnesses
C. CLARENCE POOLE,
ALBERT H. GRAVES.