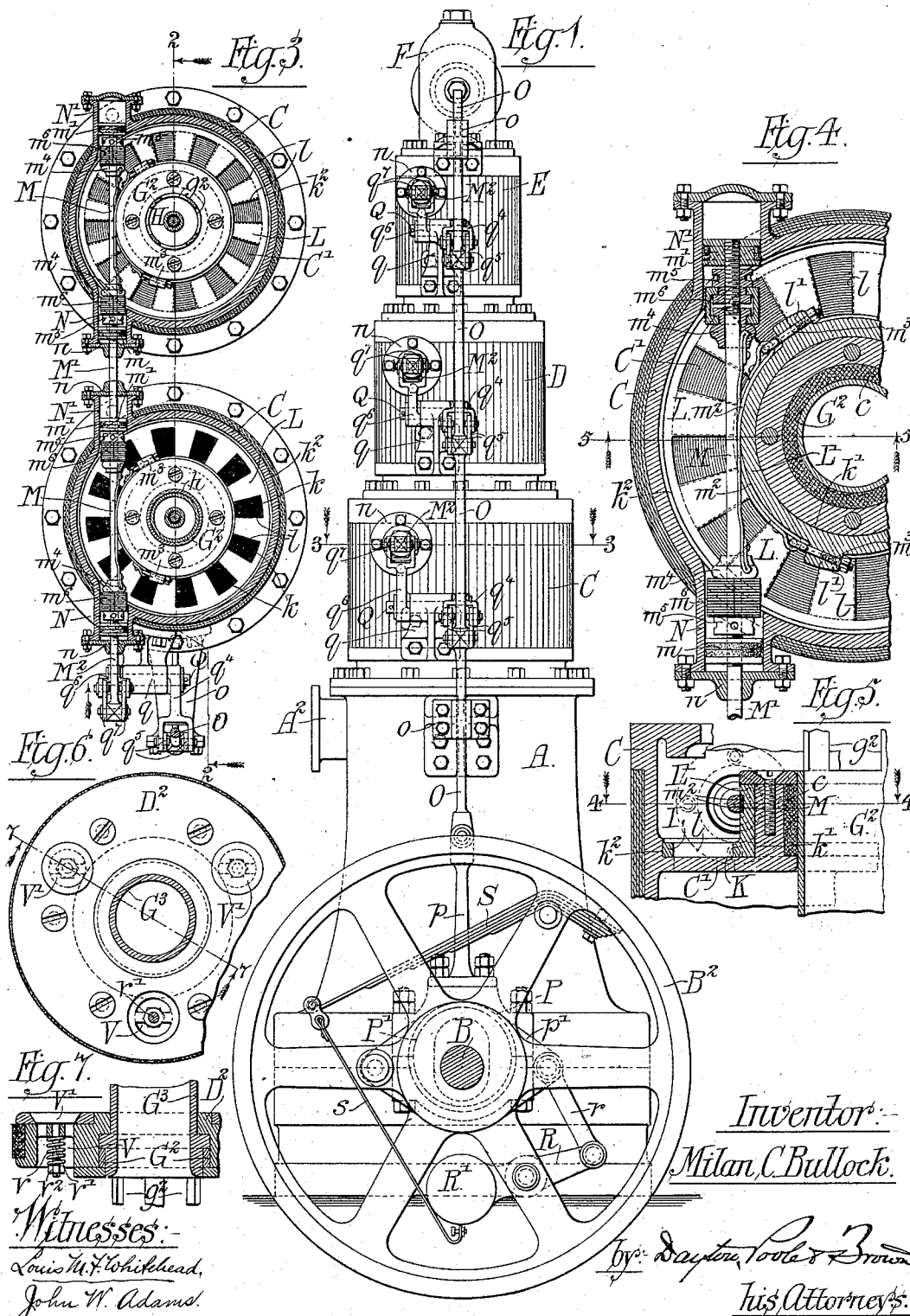


M. C. BULLOCK.
STEAM ENGINE.

No. 533,158.

Patented Jan. 29, 1895.



Inventor:
Milan C. Bullock.

by: Dayton, Fowler & Brown
his Attorneys.

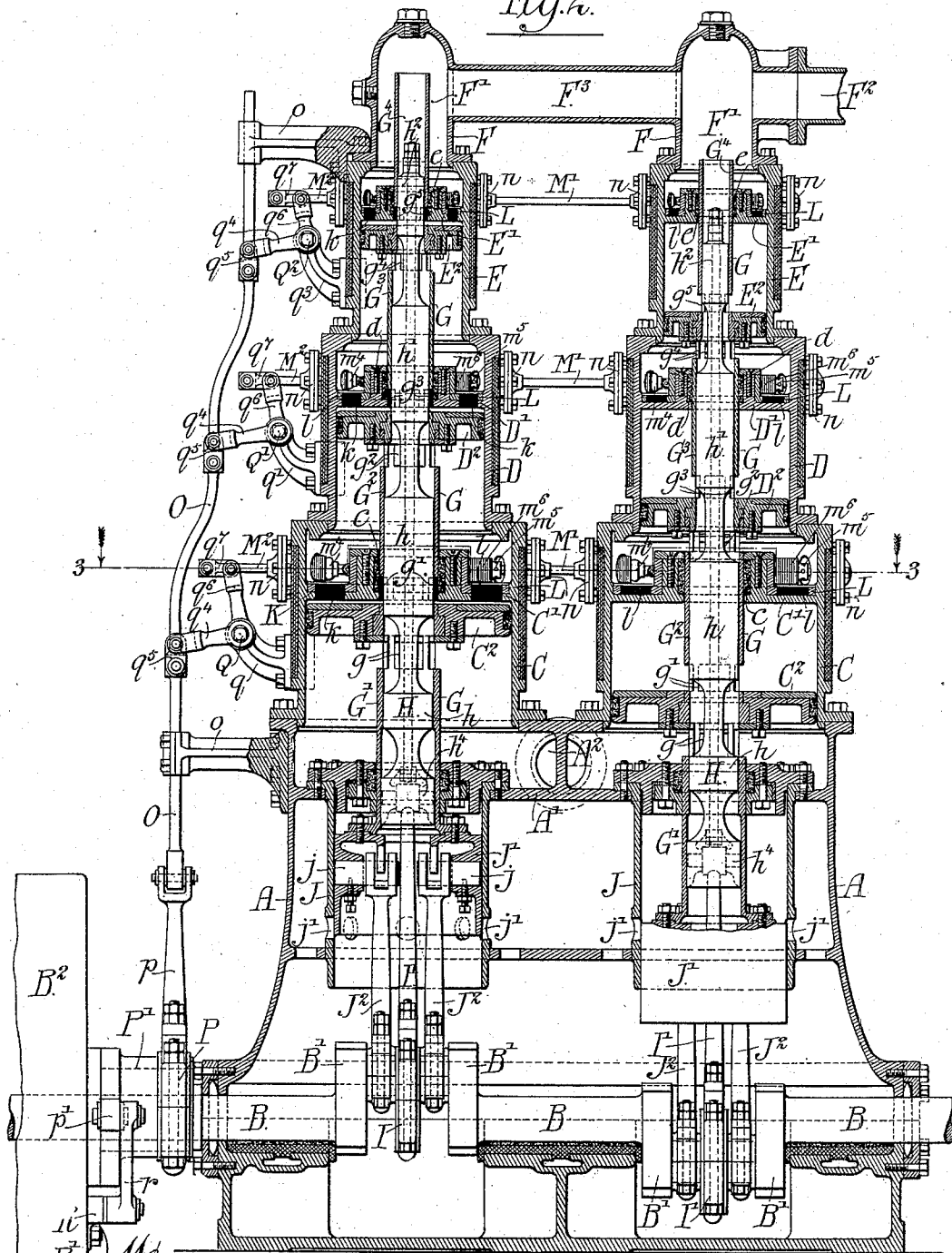
Witnesses:
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Fig. 2.



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STEAM ENGINE.

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Fig. 8.

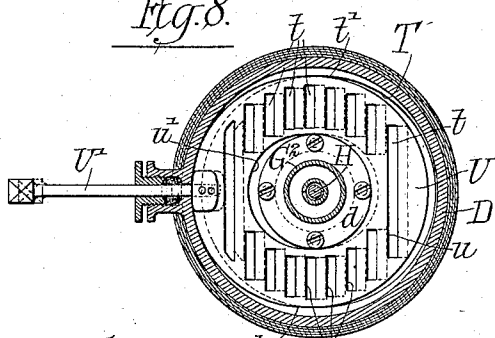


Fig. 9.

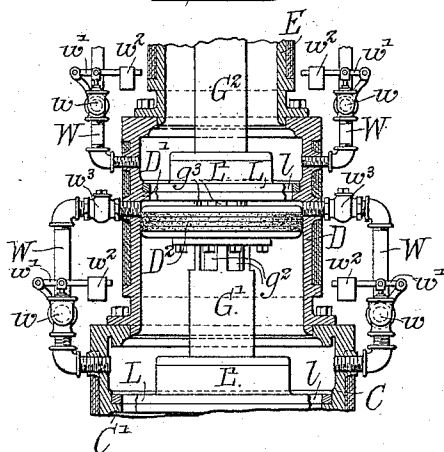


Fig. 10.

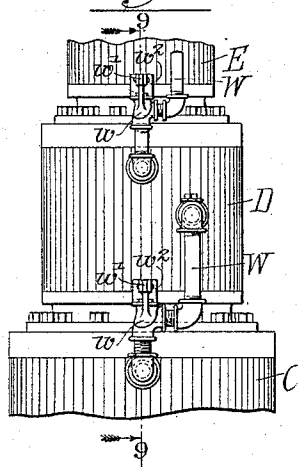
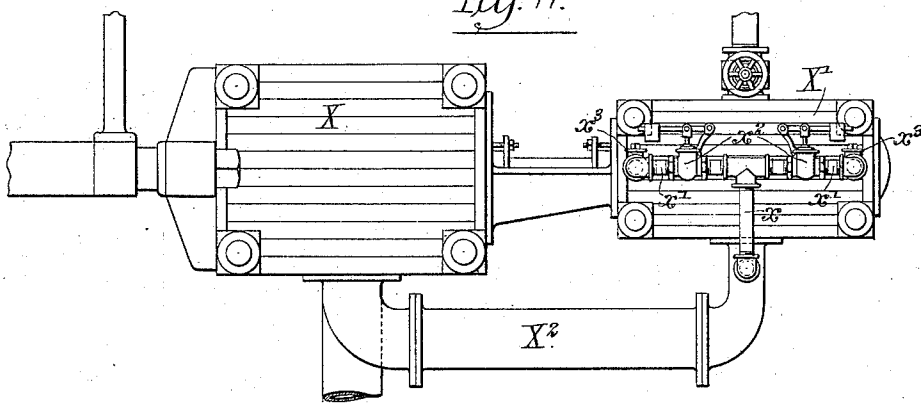


Fig. 11.



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UNITED STATES PATENT OFFICE.

MILAN C. BULLOCK, OF CHICAGO, ILLINOIS.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 533,158, dated January 29, 1895.

Application filed October 13, 1893. Serial No. 488,554. (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 reciprocating steam engines and it consists in the matters hereinafter described and pointed out in the appended claims.

The engine herein shown as embodying my invention is of that kind known as a single acting double tandem compound engine, the same having vertically arranged cylinders supported on a common base, a single crank-shaft mounted on said base and provided with two cranks, and pistons in the cylinders attached to the two piston rods which severally engage the cranks of the shaft; the engine illustrated being in its main features similar to that shown in the prior patent to P. W. Willans, No. 339,242, dated April 6, 1886.

In the accompanying drawings illustrating my invention: Figure 1 is a view in side elevation of an engine embodying my invention. Fig. 2 is a central vertical section thereof, taken axially through both sets of cylinders. Fig. 3 is a sectional plan view taken on line 3—3 of Figs. 1 and 2. Fig. 4 is an enlarged detail section of certain of the operative parts shown in Fig. 3. Fig. 5 is a detail cross-section taken on line 5—5 of Fig. 4. Fig. 6 is a plan view of one of the pistons, showing relief valves therein. Fig. 7 is a sectional view thereof, taken on line 7—7 of Fig. 6. Fig. 8 is a plan section through one of the cylinders above the steam valves thereof, showing a modified construction of said valve. Fig. 9 is a sectional view showing two cylinders and an intermediate receiver, with valved passages connecting the receiver with the cylinders. Fig. 10 is a side view of the same. Fig. 11 is a plan view of the high and low pressure cylinders and receiver of a double acting compound engine, showing valved passages connecting the receiver with the high pressure cylinder.

As shown in said drawings, Figs. 1 to 5, A indicates a hollow casting constituting the base of the engine in which the several cylinders and operative parts are mounted. Within the said base casting, at the lower part thereof, is mounted a horizontal crank-shaft B having two cranks B' B'.

C C indicate two upright cylinders affixed to the top of the base casting A and provided below their upper ends with integral partitions or diaphragms C' C' which constitute 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 latter is provided with openings in its top wall, preferably somewhat larger than the interior diameter of the cylinders C C, through which openings said cylinders communicate with the interior of the base casting. Said base casting is provided below its top wall with a horizontal partition or diaphragm A', which forms in the upper part of said base casting a receiver or exhaust passage for steam from the cylinders C C; said receiver being provided with an exit pipe A² for the discharge of exhaust steam from the engine. The said cylinders C C in their parts below the horizontal partitions or diaphragms C' C' constitute the low pressure cylinders of the engine.

D D are other cylinders which are smaller in diameter than the cylinders C C and are affixed to the tops of the latter. Said cylinders D D are provided at points below their upper ends with horizontal partitions or diaphragms D' D' forming the cylinder heads, and the parts of said cylinders below the diaphragm constitute the intermediate cylinders of the engine. Said cylinders D D are open at their lower ends and communicate with the upper parts of the cylinders C C above the diaphragms C' C' thereof.

E E indicate a third pair of cylinders which are still smaller in diameter than the cylinders D D and are affixed to the upper ends of the latter. Said cylinders E E are provided below their upper ends with horizontal partitions or diaphragms E' E' constituting the heads of said cylinders. The cylinders E E are open at their lower ends and communicate with the upper ends of the cylinders D

D above the diaphragms thereof. The parts of the cylinders E E below the diaphragms therein constitute the high pressure cylinders of the engine.

5 The upper ends of the high pressure cylinders E E are closed by means of castings or heads F F which form with the upper parts of said cylinders and the diaphragms or partitions E' E' steam chests or chambers F' F',
10 steam being supplied to said steam chests by means of a horizontal steam supply pipe F² which communicates with one of said castings F, the said castings being connected with each other by an intermediate pipe F³ forming in
15 effect a continuation of the steam pipe F².

The upper parts of the cylinders D D above the diaphragms D' D' constitute steam chambers or receivers between the high pressure cylinders E E and intermediate cylinders D D,
20 and, similarly, the upper parts of the cylinders C C above the diaphragms C' C' thereof constitute steam chambers or receivers between intermediate cylinders D D and the low pressure cylinders C C.

25 C² D² E² are pistons located severally within the cylinders C D and E, and G G are hollow or tubular piston rods which pass through the several cylinder heads or diaphragms C' D' and E' and to which the several pistons C² D²
30 and E² are attached. The diaphragms C' D' and E' are provided with glands or packings *c d e* to make tight joints around the piston rods. The said rods are herein shown as made in several separate parts or sections G' G² G³ and G⁴, of which the part G' is attached
35 to the lower piston C² and serves to connect the same with the crank-shaft. The part G² connects the piston C² with the piston D², and the part G³ connects the piston D² with the
40 piston E² and extends into the steam chest F'. The several parts or sections of the tubular piston rods are in open communication with each other through the pistons to which they are attached so that said piston rods are
45 adapted to serve as steam exhaust passages for the escape of steam from the several cylinders to the adjacent receivers below them.

The hollow piston rods are provided with steam ports *g g'* located respectively below
50 and above the lower piston C², with other steam ports *g² g³* located respectively below and above the intermediate piston D², and with steam ports *g⁴ g⁵* located respectively below and above the upper piston E². The ports
55 *g' g³ g⁵* constitute exhaust ports by which steam escapes from the several cylinders into the hollow piston rod, the exhaust steam passing from the same into the adjacent receiver through the ports *g g²* and *g⁴* which are located
60 below the several pistons. Within the hollow piston rods are located valve rods H H, which are adapted to move longitudinally within the piston rod and which carry valve
65 pistons which operate in connection with the several ports above described in the manner of ordinary slide valves to control the exit of exhaust steam from the cylinders. Each of

the valve rods H is herein shown as provided with four valve pistons, three of which, to wit, *h h' h²* act in connection with the valve ports
70 *g' g³ g⁵* to open and close the same at proper times in the operation of the engine. A valve piston *h³* which is located below the piston H serves merely to prevent the downward es-
75 cape of exhaust steam at the lower end of the hollow piston rod.

The valve rods H H travel or reciprocate with the piston rods in which they are located, but an endwise reciprocatory motion of the valve rods in the piston rods is produced by
80 means of eccentrics I I attached to the cranks B' B' and transmit motion to the piston rods by means of eccentric rods I' I' which extend into the lower open ends of the hollow piston
85 rods and are pivotally connected with the valve rods. As herein shown the said piston rods are attached at their lower ends to hollow guide pistons *h⁴ h⁴* which fit and slide within the lower parts of the hollow piston
90 rods and within which the eccentric rods are inserted and secured by transverse pivot pins.

Within the base casting A are two upright air cylinders J J arranged in alignment with the steam cylinders. Within said air cylinders are located pistons J' J' to which the
95 hollow piston rods G G are attached at their lower ends; said pistons being provided with central apertures for the passage of the eccentric rods I' I'. Said air cylinders are open at their lower and closed at their upper ends,
100 the piston rods passing through packing boxes or glands in the closed upper ends of said air cylinders. Each of the pistons J' J' is connected with the crank B' of the shaft by two connecting rods J² J² located one at each side
105 of the eccentric I and eccentric rod I' and engaged at their upper ends with transverse bearing pins *j j* secured in the piston J'. The air cylinders and pistons thus constructed take the place of the cross-head guides and
110 cross-heads commonly used in steam engines and also serve by the compression of the air within the upper ends of the cylinders in the upstroke of the piston rods to greatly retard the movement of said piston rods
115 and connected parts and to thereby absorb the momentum of the same and maintain the connecting rods in compression at all times during the upstroke. Said cylinders J J are provided with air inlet openings *j' j'*
120 *j'* to afford access of air to the cylinders at each down stroke of the pistons. As far as the air cylinders and eccentric connections for actuating the valve rods are concerned, the construction is like that shown in said
125 prior patent to P. W. Willans, hereinbefore referred to. In the engine herein shown, as in the engine illustrated in said patent to Willans, the pistons of the several cylinders are actuated by steam acting in the upper
130 ends of the cylinders only, while the exhaust steam from each cylinder in the upward stroke of the piston therein passes from the upper end of the cylinder through the hollow piston

rod to the steam space or receiver in the upper part of the larger cylinder below it. Each cylinder being in communication at its lower end with the upper compartment of the adjacent larger cylinder, exhaust steam entering the upper parts of the cylinders C and D in the upstroke of the several pistons will be free to enter the lower parts of the cylinders D and E below the pistons therein, so that the upper chambers of said cylinders D and E together with the lower parts of the cylinders D and E below the pistons in the latter will in effect constitute the steam chambers or receivers between the said cylinders.

As illustrated in said prior patent to Wilans, steam is supplied to the several cylinders through the hollow piston rods, but as herein shown steam passes from the steam chest in the several receivers directly through the cylinder heads to the upper ends of the several cylinders; steam inlet ports being provided in the several cylinder heads or diaphragms C' D' and E', and suitable valves being provided for controlling said ports. Said steam inlet ports and valves being alike in the several cylinders a description of the valve mechanism for one cylinder will serve for all; the valves, ports and parts of the valve mechanism connected with all of the cylinders being for convenience lettered in the same manner in the drawings.

Referring first to that form of valve shown in the main figures of the drawings (Figs. 1 to 5), the diaphragm or partition forming the cylinder head is provided outside of the gland or packing box therein with an annular valve-seat K in which is formed a series of ports or openings $k\ k\ k$ which extend through the said diaphragm or partition into the cylinder below, and are arranged at equal distances apart around the cylinder head. On the said valve seat K rests a valve ring L, which is provided with a plurality of ports $l\ l$ corresponding in number and angular arrangement with the ports $k\ k\ k$ of the cylinder head. Said annular valve ring preferably fits at its inner and outer margins against cylindric bearing surfaces $k'\ k'$ formed at the inner and outer margins of the valve seat K to more effectively prevent the escape of steam past the margins of the valve ring while enabling the same to rise under an excessive back pressure produced by water in the cylinder. The cylindric bearing surface k' at the inner margin of the valve seat is herein shown as formed on the exterior of the stuffing box which is located at the center of the diaphragm.

Devices are herein shown by means of which oscillatory motion is communicated to the several valve rings from a reciprocating part exterior to the cylinder as follows: The valve ring L is provided at its inner margin with an upwardly extending cylindric flange L' which fits upon the cylindric bearing surface k' of the valve seat. M is a horizontally arranged rod which extends through the steam space of the cylinder at a point oppo-

site the flange L', the ends of which are attached to pistons $m\ m'$, which pistons slide in horizontal cylinders N N' which are formed on or are attached to the exterior wall of the cylinder and open at their inner ends into the receiver or exhaust steam space. The pistons $m\ m'$ are adapted to slide within the cylinders N N' so as to permit endwise reciprocatory motion of the rod M and said pistons are provided with suitable packings serving to prevent the escape of steam past the pistons. The rod M is connected with the valve ring L by means of flexible metal strips $m^2\ m^2$ which are attached at their opposite ends respectively to the rod and to the flange L' of the ring; each strip being attached at one end to the rod and at its opposite end to the flange, and the strips being arranged to extend past or overlap each other so that movement of the rod in one direction will by tension on the strip turn the ring in the same direction, and movement of the rod in the opposite direction will similarly act to turn it in said opposite direction; the strips being arranged to rest upon and extend over the curved surface of the flange in their parts which are in contact therewith. As a means of attaching the ends of said strips $m^2\ m^2$ to the flange the latter is shown as provided with lugs l' (Fig. 4) through which are inserted bolts $m^3\ m^3$ which are provided with eyes engaged with loops formed on the ends of the strips, said bolts being provided with nuts by which the strips may be tightened. Each strip is adjustably attached to the rod through the medium of a sliding sleeve m^4 to which the ends of the strip is secured by a nut m^5 which engages a screw-thread on the rod and which is connected with the sleeve m^4 by means of a flange and connecting sleeve or thimble m^6 which engages annular grooves in the sleeve and nut so that the nut may be turned to effect endwise adjustment of the sleeve on the shaft without the turning of the sleeve. Said sleeve is shown as made in two parts or sections held together by a wrapping of wire whereby it may be readily detached and applied.

As herein shown the valve rods M M of the opposite cylinders of the engine or those which are side by side are arranged in alignment with each other and connected at their adjacent ends by means of a rod M' which passes through adjacent heads $n\ n$ of the cylinders N N' and is secured to the pistons $m\ m'$. The valve actuating rod M which is nearest the exterior valve actuating devices is connected with the same by means of a stem or rod M² which extends through the head n of the cylinder N in the manner illustrated in Fig. 3.

As a means of giving motion to the several actuating rods of the steam inlet valves, devices are herein provided as follows:

O is a rod which is arranged vertically at one side of the engine and is given a vertically reciprocatory motion through the medium of an eccentric P with which it is connected by

an eccentric rod p . The rod O slides at its opposite ends in brackets $o o$ attached, in the instance shown, to the base casting and high pressure cylinder of the engine.

5 $Q Q'$ and Q^2 are three rock-shafts which are mounted in brackets $q q' q^2$ attached to the cylinders $C D$ and E and through the medium of which motion is transmitted from the rod O to the several valve actuating rods $M^2 M^2$
 10 M^2 . Each of the rock-shafts $Q Q' Q^2$ is provided with a horizontal arm q^4 which is connected at its outer end with the rod O by links $q^5 q^5$, through the medium of which oscillatory motion is transmitted to the said arm and the
 15 rock-shaft to which it is attached. Each of said rockshafts is, furthermore, provided with an upwardly extending arm $q^6 q^6 q^6$ which is forked at its upper end and connected with the outer end of the adjacent rod M^2 by
 20 means of links $q^7 q^7$. The construction described obviously affords a simple means of communicating horizontal oscillatory movement to the several valve rods from the eccentric P on the main shaft.

25 The eccentric P is herein shown as mounted to turn on the shaft and as actuated by a governing device whereby the movement of the several valves may be automatically controlled.

30 In the particular construction illustrated the eccentric P is actuated by means as follows: The said cam P is attached to or formed on a sleeve P' which is mounted on the shaft B adjacent to the belt pulley B^2 which is attached to the shaft adjacent to the said eccentric. Pivotaly mounted at one side of the pulley B^2 is a lever R , Fig. 1, which carries at one end a weight R' and is connected at its opposite end by a rod r with a rigid arm
 40 p' on the sleeve P' . A spring S is attached to the wheel rim at one end and is connected at its opposite end with the weighted end of the lever R by means of a strap or cord s . This spring serves to hold the weight normally at the inward limit of its movement and the
 45 parts are so adjusted that when the weight is held at its inward position by the spring the eccentric will be in position to give a maximum admission of steam to the several cylinders. As the speed of the engine increases
 50 the weight R' will move the lever in opposition to the action of the spring and will thereby turn the eccentric so as to cut off the steam supply at such point in the stroke of the engine as may be determined by the speed
 55 of the same.

The actuating device for the valves which is here illustrated is only one of a number of such devices which may be used for this purpose and is herein shown merely for the purpose of illustrating one convenient and practical way of giving motion to the valves.

60 In the operation of the engine illustrated it is obvious that the several valves of the three connected cylinders $C D$ and E will be moved at the same time to admit steam to the several cylinders, so that while the steam

at boiler pressure is acting on the high pressure cylinder, steam previously exhausted from the high pressure and intermediate cylinders will be acting on the pistons of the said intermediate and low-pressure cylinders. It will be observed, furthermore, that inasmuch as the steam inlet ports lead directly through the cylinder heads or partitions, steam will pass from the steam chest or receivers to the adjacent cylinders by the shortest possible path and without coming in contact with any extended steam passages, or in contact with steam passages through which exhaust steam has previously passed, so that loss by condensation is greatly lessened. It will also be noted that the steam inlet ports may by the construction described be made of ample size to give the utmost freedom of delivery and prevent possibility of wire drawing of the steam; it being obvious that a large part of the area of the cylinder head may be utilized for the valves and valve ports.

In Fig. 8 I have shown a construction in the steam inlet valve adapted to produce substantially the results obtained by the valve hereinbefore described, but containing a reciprocating plate or gridiron valve instead of an oscillatory ring valve. As shown in said figure, the cylinder head is provided with a flat valve seat T having a plurality of narrow and elongated valve ports tt arranged parallel with each other. On the said valve seat rests a valve plate U which is adapted to be reciprocated in a direction transverse to the valve ports tt and is provided with ports uu corresponding in number and location with said ports tt . Lateral guide surfaces $t' t'$ are provided for engagement with the side margins of the valve plate and the latter is provided with a central aperture u' through which passes the piston rod, said aperture being made of sufficient width to extend around the central hub formed by the stuffing box. A valve stem U' is shown as attached to one side of the valve plate and as extending outwardly through a stuffing box in the wall of the steam chest or receiver, said valve stem serving to connect the valve with a suitable actuating device, such, for instance, as that illustrated in Figs. 1 to 5.

It is obvious that the closing of the several steam admission valves under the action of the automatic governing device at the time of a sudden increase in the speed of the engine will result in a considerable compression of the steam within the receivers owing to the fact that the descent of the pistons in the cylinders will produce a decrease of the steam area of the receivers and a consequent increase of pressure therein. The back pressure on the pistons thus produced will obviously have the effect of retarding the movement of the pistons and thus promptly decrease the speed of the engine, and will thereby be of great benefit in securing promptness of action in the governing devices. Inasmuch, however, as the steam com-

pression thus produced in the receivers will be produced mainly by the inertia of the moving parts, it may in some cases become excessive or dangerous, as for instance when the steam is suddenly cut off at an early point in the stroke of the piston, and in order to avoid liability of breakage at such time and at the same time to secure a means of more accurately regulating the action of the governing devices and the speed of the engine, I employ passages leading from the receivers to the cylinders and provide the said passages with relief valves opening toward the cylinders from the receivers, said relief valves being held closed by springs or weights adapted to yield to allow the opening of the relief valves when the pressure within the receivers becomes excessive. In the form of engine shown in Figs. 1 to 5, such valved relief passages may be located in the pistons D^2 and E^2 of the cylinders D and E, and in the detail views Figs. 6 and 7 I have shown the construction of a piston containing such passages and valves. In this instance relief passages are indicated in the drawings by V, the upwardly opening valve disks for closing the passages by V' , and the springs which hold closed the valves by v ; said springs having the form of coiled springs surrounding a stem v' on the valve disk. A nut v^2 on the valve stem enables the tension of the spring to be regulated so that the valve will open at a greater or less pressure as desired. It is obvious that in the operation of the parts thus constructed any excess of pressure in the receiver above that which is desirable for the purpose of checking or retarding the speed of the engine, will result in the opening of the relief valves referred to and the upward passage of steam from the receivers into the cylinders, so that excessive steam pressure will be avoided, while at the same time there will be no loss of energy by the escape of steam from the engine.

Another, and in some respects a preferable construction, in means for providing relief passages for the purpose referred to is shown in Figs. 9 and 10. In this instance said relief passages instead of being made in the pistons are formed by means of pipes W W located outside of the cylinders and leading from the receivers upwardly to the upper ends of the cylinders above the same. The pipes W W are provided near their lower ends with relief valves $w w$ which are held closed by means of levers w' having sliding weights w^2 in the manner of an ordinary safety valve. These weights will be adjusted on the levers to permit the opening of the relief valves at any pressure which may be best adapted for the purpose. In this instance as in the case of the spring actuated relief valves shown in Figs. 6 and 7, it is thought that the valves will be set to open at a pressure of from five to fifteen pounds persquare inch, this giving as much back pressure on the pistons as it is thought will be usually desirable for check-

ing the speed of the engine; it being of course understood that the pressure within the receiver will ordinarily be much greater than this and that the valves will open when the pressure in the receiver exceeds that within the cylinder above it to the degree indicated. It will of course be understood, however, that the valves may under some circumstances be set to open at a less or greater pressure than is included within the limits indicated. I have shown at the upper ends of the pipes W W secondary relief or check valves w^3 which will serve merely to prevent said pipes from being filled by steam from the cylinders and thus avoid an excessive amount of steam space or clearance. The construction shown in Figs. 9 and 10 wherein the relief passages are outside of the cylinders has the advantage over that in which the relief valves are formed in the pistons of enabling access to be had to the valves at all times for the purpose of adjusting the same as may be required to secure a most favorable action of the regulating or governing devices as a whole.

While the employment of valved relief passages such as are above described is of especial advantage in connection with single acting compound engines, the same principles of construction may also be applied with advantage to a double acting compound or multiple expansion engine. In an engine of this kind while there is no diminution of the area of the receiver such as is produced by the down stroke of the piston in a single acting engine of the type herein shown, yet the closing of the several steam admission valves at an early point in the stroke of the piston in such double acting engine is liable to similarly produce an excess of pressure in the receiver by reason of the fact that all escape of steam from the receiver is thereby prevented while the exhaust steam within both ends of the cylinder will be forced into the receiver in the back stroke of the piston in both directions.

In Fig. 11 I have shown two cylinders X X' of a compound engine, an intermediate receiver X^2 and a pipe x leading from the receiver and provided with branches $X' X'$ which communicate with the opposite ends of the high pressure cylinder X'. The pipes x' are provided with weighted relief valves x^2 and also with check valves x^3 corresponding in construction and function with the relief and check valves shown in Figs. 9 and 10. In a construction of this kind it is obvious that when the steam admission valves of both cylinders are closed at an early point in the stroke of the piston by the action of the governing devices upon a sudden increase in the speed of the engine, occasioned by a decrease of load, it will result in a considerable increase of pressure in the receiver, but that any excess of pressure within the receiver over that for which the relief valves are set will result merely in the passage of steam through the relief passages into each end of

the cylinder behind the piston as the latter moves in both directions; the steam merely passing from one side of the piston to the other in the motion of the same in each direction so as to prevent any pressure within the receiver greater than that within the cylinder plus the pressure required to open the relief valves. The back pressure thus produced on the piston obviously serves to retard its motion in both directions and to thus promptly check the speed of the engine while at the same time excessive or dangerous pressure in the receiver is avoided.

The employment of relief passages for preventing excess of pressure in the receiver is of advantage in both single and double acting engines for the reason that it avoids excessive pressure within the receiver at the time the admission valves are open for the escape of steam to the low pressure cylinders, so that the admission of steam under high pressure to the low pressure cylinders at the time a decrease in the speed of the engine is desired is avoided; it being obvious that without such relief valves the steam will be under the greatest compression in the receiver at the time the steam admission valves are opened.

It is to be understood that the construction described in the relief passages is for use only under exceptional circumstances and for the purpose of controlling the engine under quick or great variations of load, and in order that the compression of the steam in the receivers shall have no undue retarding effect in the usual working of the engine, the area of each receiver will be so proportioned to that of the cylinder with which it communicates that the steam pressure within the receiver will not materially exceed that of the steam within the cylinder at any time during the travel of the piston; it being obvious that at the end of the stroke the exhaust valve will be opened with the result of establishing an equality of pressure at opposite sides of the piston. This may be better understood by consideration of the fact in connection with the single acting engine shown in Figs. 1 to 5 that at the time the steam valves are closed by the governing devices in the usual running of the engine, the steam pressure within the receiver will be materially less than that in the cylinder from which it receives steam, so that a considerable movement of the piston must take place after the admission valves are closed before the steam in the receiver is compressed to a degree sufficient to make the pressure in the receiver equal to that within the cylinder. By so proportioning the size of the receiver to that of the cylinder that the pressure within the receiver will not equal or exceed that within the cylinder at any time during the stroke of the piston when the engine is running at normal speed and with the load for which it is designed, the expansive action of the steam will be effective for doing work throughout the full stroke of the piston.

As far as above stated, the conditions pre-

vailing in the usual working of the engine have been considered, but when the automatic governing device is brought into service the conditions will be somewhat different because in such case the excessive speed of the engine will be checked by the closing of the several steam valves at an early point in the stroke or when little or no steam has been admitted to the cylinders. When the steam supply is thus cut off from the several low pressure cylinders for the purpose of checking the speed of the engine, it is obvious that a larger quantity of steam will be contained within the receiver at the moment when the admission valves are closed than when the engine is running at normal speed. It follows that under these circumstances the steam pressure within the receiver will be greatly increased by the compression and were it not for the presence of the relief passages described, might greatly exceed that within the cylinders. When the relief passages are present however, the excess of pressure at the receiver side of the piston under such circumstances will only be such as is found desirable or necessary for promptly checking or retarding the speed of the engine. When the pressure within the receiver is less than that required for opening the relief valves the retarding pressure on the piston will obviously be greater or less according to the point at which the steam is cut off; it being obvious that where the admission valves are quickly closed under a great diminution of load the pressure in the receiver will be great and the retarding effect considerable, while if the decrease of load is only slight the admission valves will be closed at a later point in the stroke, the amount of steam confined will be less and the retarding pressure will be correspondingly small. The construction described, therefore, affords a certain and reliable means of regulating the speed of compound engines by which is avoided the slowness and uncertainty of action which necessarily results where the governing devices are applied to the steam admission valves of the high pressure cylinder only in which case several strokes of the engine must take place before the shutting off of the steam supply can have its full effect in decreasing the speed of the engine; it being obvious that under such circumstances the steam already admitted to the high pressure cylinder must exercise its expansive force step by step in all of the cylinders before its energy is exhausted.

In this connection it is to be noted that in an engine provided with regulating devices constructed as herein described, excessive or retarding pressure in the receiver is not likely to occur except when the governing device is operated to control the engine under a sudden change of load; it being obvious that when the engine is running continuously under a light load and the steam is cut off at an early point in the stroke of the piston, any

great pressure in the receiver is not likely to occur because under these conditions only a small quantity of steam will be admitted to the cylinder before the valve is closed, and the steam thus admitted will expand greatly on entering the receiver, so that a relatively small pressure will exist in the receiver notwithstanding the relatively great reduction of the steam area of the receiver occasioned by the movement of the piston after the valves are closed. It is therefore only under exceptional circumstances that excessive pressure will be present in the receiver and then only at times when such pressure will be useful for the purpose of retarding the speed of the engine.

I claim as my invention—

1. The combination with a cylinder and an adjacent steam chest or receiver, of a piston in the cylinder, a hollow piston rod attached to the piston and provided with exhaust ports, a valve for controlling the passage of exhaust steam through said piston rod, a cylinder head or diaphragm separating the cylinder from the said steam chest or receiver and provided with steam inlet ports, a valve acting in connection with the said inlet ports to control the admission of steam to the cylinder, and means for actuating the said steam inlet and exhaust valves, substantially as described.

2. The combination with a cylinder and an adjacent steam chest or receiver, of a piston in the cylinder, a hollow piston rod attached to the piston and provided with exhaust steam ports, a valve for controlling the passage of exhaust steam through said piston rod, a cylinder head or diaphragm dividing the cylinder from the said steam chest or receiver and provided with steam inlet ports, a valve acting in connection with the said inlet ports to control the admission of steam to the cylinder, the steam admission valve being actuated by an eccentric on the crank-shaft, and the exhaust valve being actuated by an eccentric on the crank pin of said shaft, substantially as described.

3. The combination with high and low pressure cylinders and an intermediate receiver separated from the low pressure cylinder by a partition or diaphragm, of pistons in said cylinders, a hollow piston rod carrying said piston, said piston rod being provided with exhaust ports, a valve for controlling the passage of exhaust steam through said piston rod, steam inlet ports located in said partition or diaphragm, a valve acting in connection with said steam inlet ports to control the passage of steam from the receiver to the low pressure cylinder, and means for actuating said exhaust and steam inlet valves, substantially as described.

4. The combination with single acting high and low pressure cylinders and a receiver located between the same and in open communication with the adjacent end of the high pressure cylinder, of pistons within the cylin-

ders, a single piston rod to which said pistons are attached steam admission and exhaust valves for the cylinders, means for positively actuating the exhaust valves, and means for actuating the steam admission valves, embracing an automatic cut-off governor, substantially as described.

5. The combination, with high and low pressure cylinders, and an intermediate receiver in open communication with the high pressure cylinder, of pistons within the cylinders, a single piston rod to which said pistons are attached, exhaust valves for the cylinders, a cylinder head or diaphragm separating the low pressure cylinder from the receiver and provided with steam inlet ports, a valve for closing said inlet ports, means for actuating the inlet and exhaust valves, and an automatic governor controlling the movement of the inlet valves, substantially as described.

6. The combination with high and low pressure cylinders and an intermediate receiver separated from the low pressure cylinder by a partition or diaphragm, of pistons in said cylinders, a hollow piston-rod carrying said pistons, said piston-rod being provided with exhaust ports, a valve for controlling the passage of steam through said piston-rod, steam inlet ports located in said partition or diaphragm, a valve for closing said inlet ports, and an automatic governor controlling the latter valves, substantially as described.

7. The combination with high and low pressure cylinders, and a receiver located between the same, of pistons within the cylinders, steam admission and exhaust valves for the cylinders, means for actuating the valves, an automatic governor controlling the movement of the admission valves, and a valved relief passage connecting the receiver with the high pressure cylinder, whereby excessive pressure in the receiver due to the early closing of the admission valves will be relieved by discharge into the high pressure cylinder, substantially as described.

8. The combination with high and low pressure cylinders, and a receiver located between the same and in open communication with the adjacent end of the high pressure cylinder, of pistons within the cylinders, steam admission and exhaust valves for the cylinders, means for actuating said valves, an automatic governor controlling the movement of the admission valves, and a valved relief passage connecting the receiver with the high pressure cylinder, whereby excessive pressure in the receiver, due to the early closing of the steam admission valves, will be relieved by discharge into the high pressure cylinder, substantially as described.

9. The combination with high and low pressure cylinders, and a receiver located between the same, and in open communication with the high pressure cylinder, of pistons within the cylinders, steam admission and exhaust valves for the cylinders, means for actuating said

valves, an automatic governor controlling the
movement of the admission valves, and a
valved relief passage in the high pressure pis-
ton, whereby excessive pressure in the re-
ceiver, due to the early closing of the admis-
sion valves, will be relieved by discharge into
the high pressure cylinder, substantially as
described.

In tetimony that I claim the foregoing as
my invention I affix my signature in presence 10
of two witnesses.

MILAN C. BULLOCK.

Witnesses:

C. CLARENCE POOLE,
TAYLOR E. BROWN.