(No Model.) 3 Sheets—Sheet 1.

E. HILL.

AIR COMPRESSOR.

No. 452,132. Patented May 12, 1891.

Fig. 1

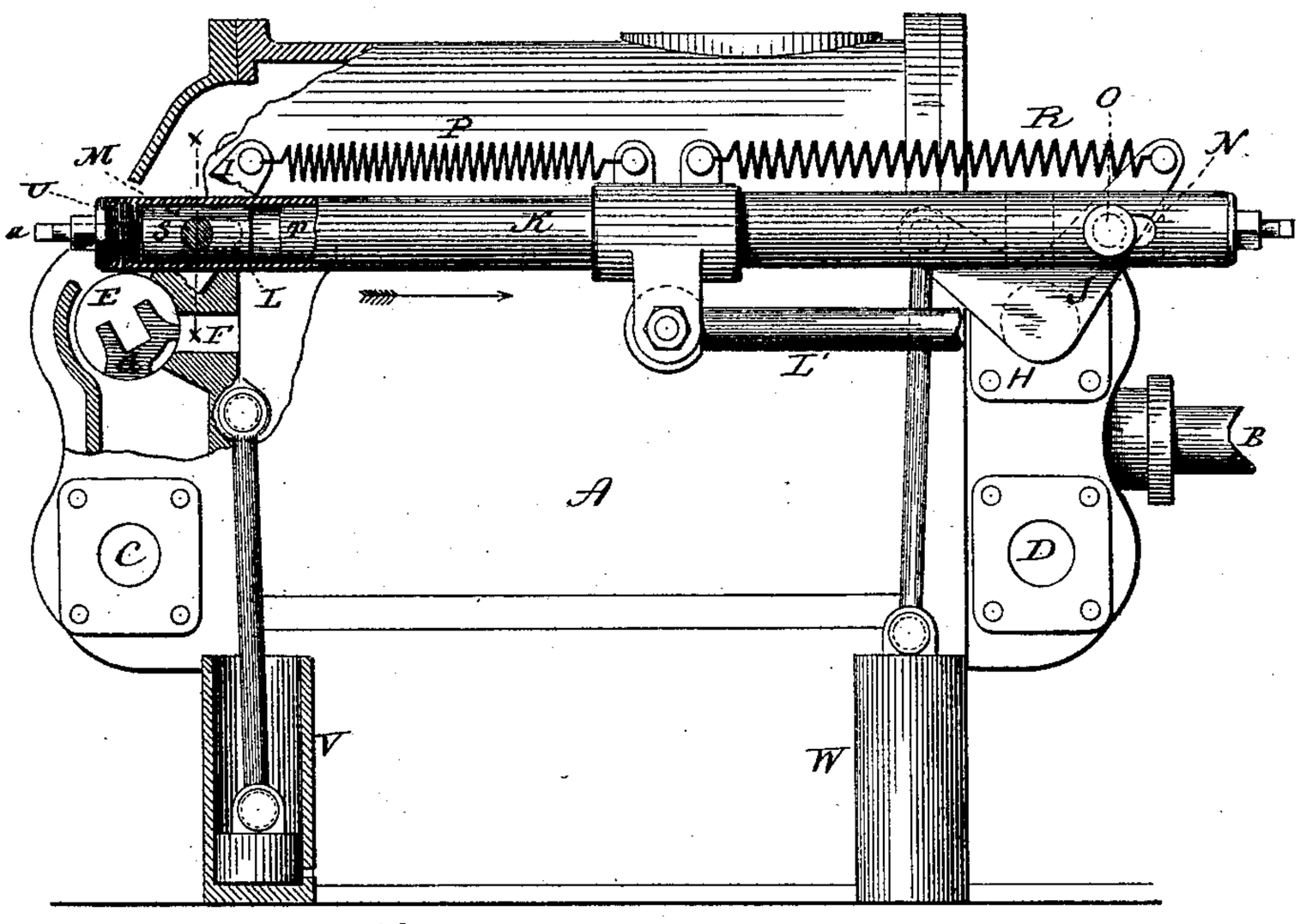


Fig. 4.

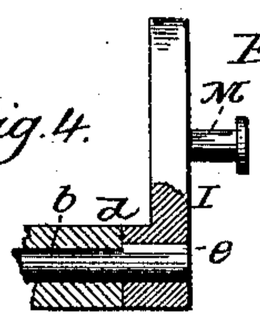


Fig. 3

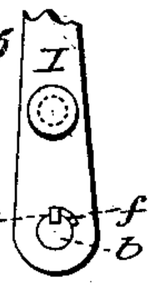
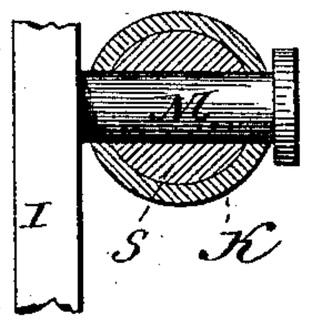


Fig. 2



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(No Model.) 3 Sheets—Sheet 2.

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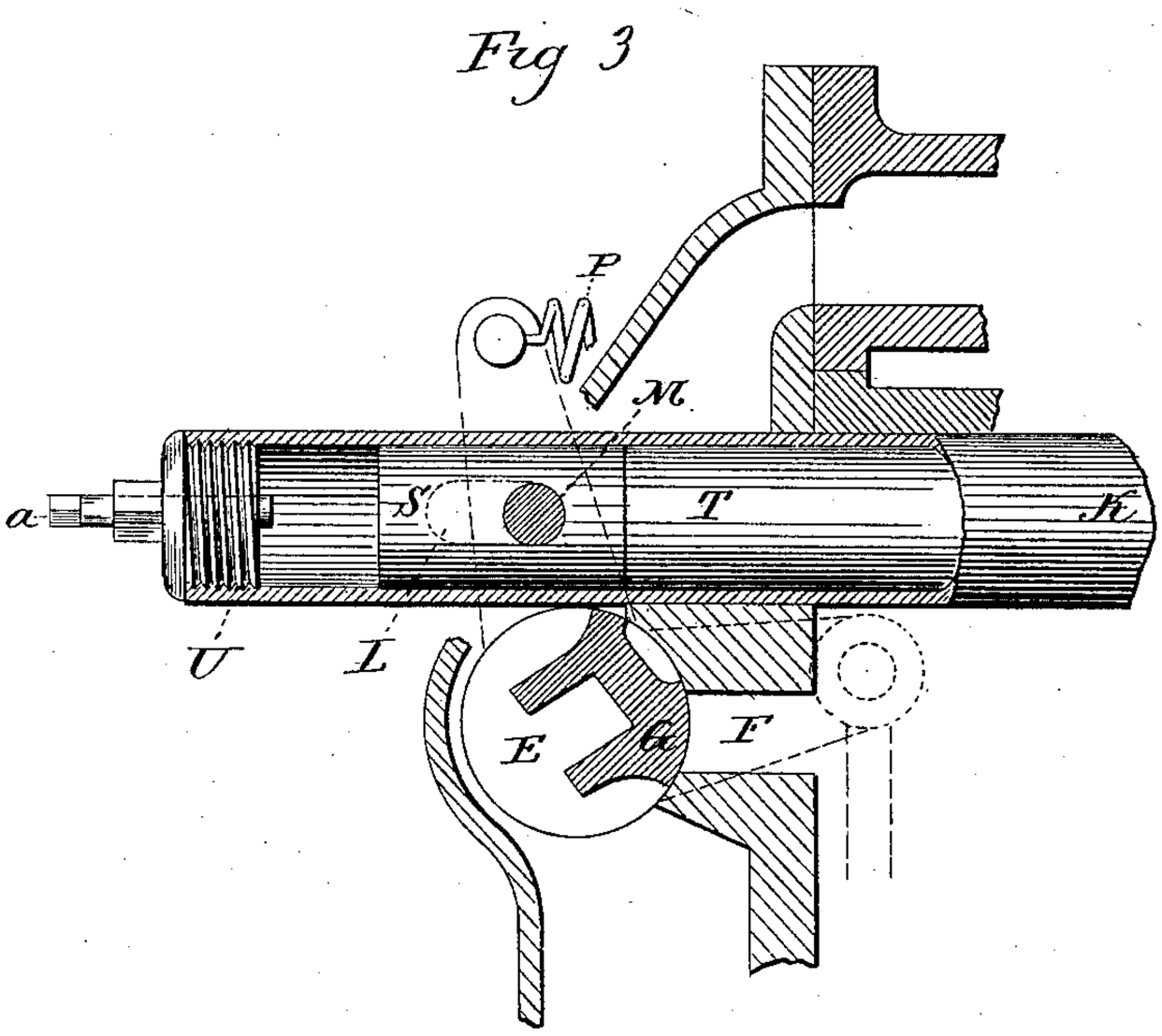
AIR COMPRESSOR.

No. 452,132. Patented May 12, 1891.

Fig 3



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(No Model.) 3 Sheets—Sheet 3.

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AIR COMPRESSOR.

No. 452,132. Patented May 12, 1891.

Fig 6

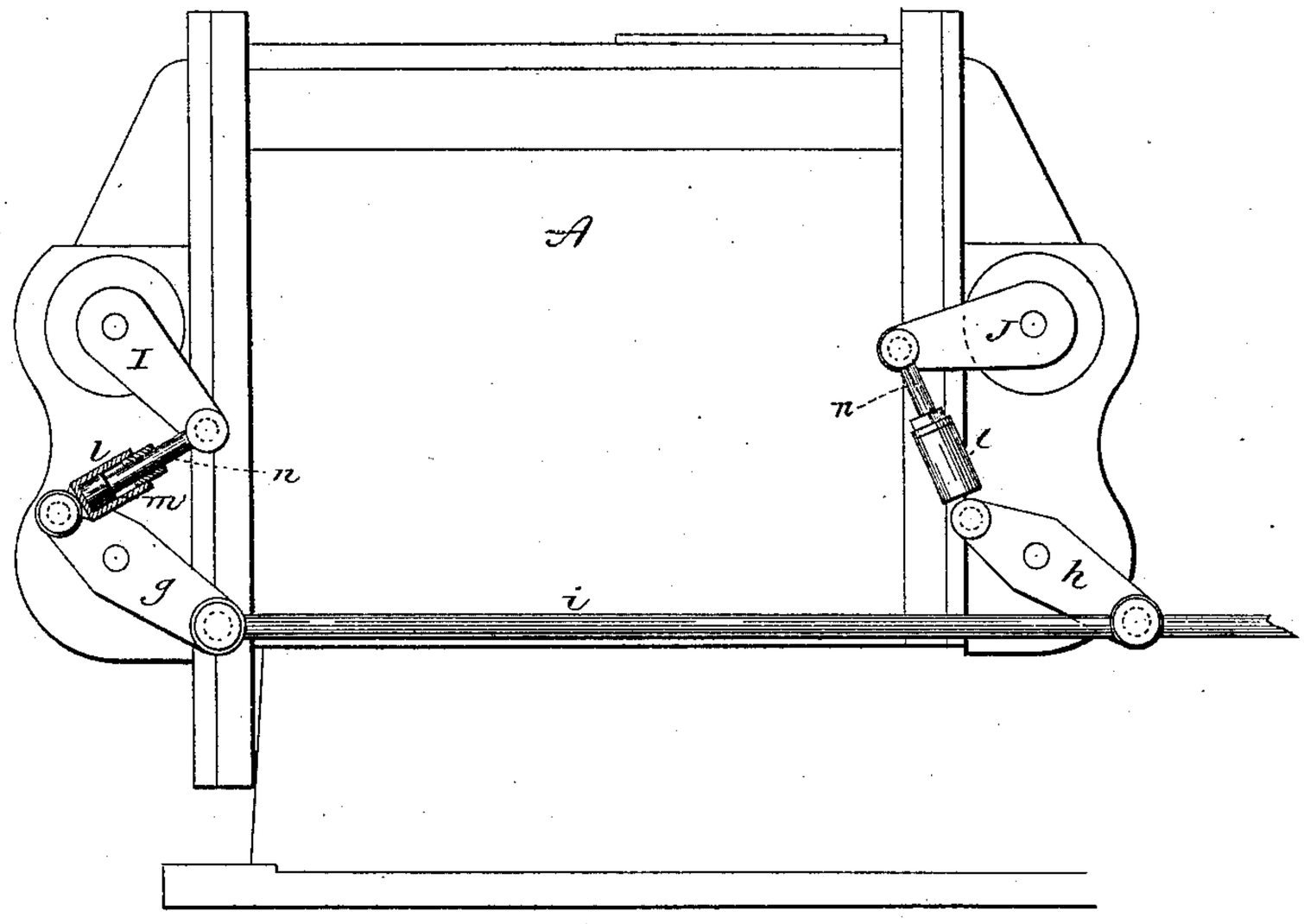


Fig. 7

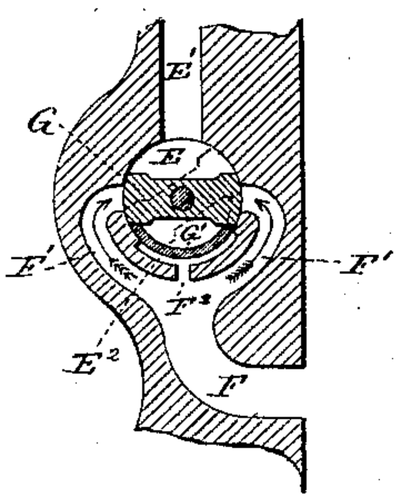
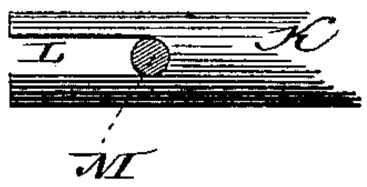


Fig. 8



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UNITED STATES PATENT OFFICE.

EBENEZER HILL, OF SOUTH NORWALK, CONNECTICUT.

AIR-COMPRESSOR.

SPECIFICATION forming part of Letters Patent No. 452,132, dated May 12, 1891.

Application filed March 25, 1889. Serial No. 304,622. (No model.)

To all whom it may concern:

Be it known that I, EBENEZER HILL, of South Norwalk, in the county of Fairfield and State of Connecticut, have invented new Improvements in Air-Compressors; and I do hereby declare the following, when taken in connection with accompanying drawings and the letters of reference marked thereon, to be a full, clear, and exact description of the same, and which said drawings constitute part of this specification, and represent, in—

Figure 1 a side view of the compressing-cylinder and the outlet mechanisms, portions broken away at one end of the cylinder to show the parts in section, the outlet-valve at the broken end of the cylinder being on the opening movement; Fig. 2, a transverse section through the rod K on line *x x*, showing the connection between the rod and the valve-crank enlarged; Fig. 3, a sectional view of the outlet-valve G and its connecting mechanism at the left-hand end of the cylinder as having just completed its closing movement, enlarged; Fig. 4, a longitudinal section through one of the crank-arm bearings; and Fig. 5 an end view of the same, showing a modification in obtaining the over motion between the valve-connection and the valve; Fig. 6, a side view of a cylinder and the valve-operating mechanism, illustrating a modification in the connection with the outlet-valves; Fig. 7, a modification in the formation of the frictional working surfaces for the valve; Fig. 8, another modification in the valve connections.

This invention relates to an improvement in that class of air-compressors in which the valves are mechanically operated for the escape of the compressed air from the cylinder. Under the more general construction of this class of air-compressors the valves are set so as to open at a predetermined point in the movement of the piston, and this point intended to be when the pressure in the cylinder shall have reached the pressure in the receiver. For illustration, suppose the pressure outside the valve in the receiver, or whatever it may be, is fifteen pounds. That pressure under ordinary circumstances will be attained in the cylinder when the piston has reached its half-stroke in the cylinder. Now, if, under this positive arrangement of the valve with relation to the piston, it be desired to reduce the pressure in the receiver or outside the valve—say to ten pounds—the continued action of the machine will still compress the air to the same extent in the cylinder and discharge it under a pressure of fifteen pounds, because the valve would not ordinarily open until the time when that pressure of fifteen pounds in the cylinder had been attained. On the contrary, if it be desired to increase the pressure in the receiver, the valve will open before the receiver-pressure has been reached in the cylinder. In the first case the valve is opened too late and in the latter case opened too early. The results of thus opening the valve are too well-known to require particular description. Hence when such change in pressure is desired a corresponding resetting of the valve is necessary to a perfect working of the machine.

The object of my invention is the construction of a valve-gear which will open or permit the valve to automatically open whenever the pressure upon the cylinder side of the valve shall equal or substantially equal the pressure upon the back of the valve, and so that the difficulties before mentioned will be overcome; and the invention consists in providing for an over-motion of the parts with which the valves are mechanically engaged and through which the power is applied to the valves and during which over-motion the valves are independent of the power, combined with means independent of such power, which, during such over-motion, may operate upon the valves to automatically open the valves when the valves are brought to an equilibrium by the pressure in the cylinder on the cylinder side of the valve equaling the pressure on the out or receiver side of the valve, the valve itself being held to its seat by the pressure of the air in the receiver or on the back of the valve.

In illustrating the invention I show only so much of an air-compressor as necessary to the understanding of the invention, and in this illustration I represent the valves as rotary valves.

A represents the compressing-cylinder; B, the piston-rod; C, the inlet-opening for one end of the cylinder, and D the inlet-opening for the other end of the cylinder. I do not

show the valve-gear for the two inlet-valves, as it is well known and unnecessary to the illustration of the invention.

E represents one outlet-valve chamber, to which a passage F leads from the cylinder. The valve-chamber is cylindrical, and in the chamber the valve G is arranged, which oscilates, within the chamber and so as to close and open the passage F. The peculiar characteristic of this valve is that it is held by abnormal friction—for illustration, as will be seen on reference to the valve in Figs. 1 and 2, in which the valve is provided with a much greater working-surface than is necessary for the opening and closing movement of the valve and so that as the valve is moved from the open position Fig. 1 to the closed position in Fig. 2, the valve is moved over a very much greater space than is necessary to simply close the valve. This increase of the surface of the valve produces the abnormal friction under the pressure of the air from the receiver on the back of the valve over what it would be were no provision made for such abnormal friction. The valve at the opposite end is of the same construction and arrangement for the outlet at that end of the cylinder, H representing the cap upon the chamber at that end.

The valve G is operated by an arm I outside the chamber, partly broken away in Fig. 1, and the valve at the other end by a similar arm J, there being a rocking movement imparted to these two arms to alternately open and close the valves, so that each valve will open for the proper discharge from its side of the piston. The two arms I J are connected by a rod K, and to this rod K a reciprocating movement is imparted from the eccentric through the eccentric-rod L′, and so that the reciprocating movement of this rod K is constant in both directions. If, therefore, the connection between the rod K and the two valves be unyielding the valves will open at a positive predetermined time with relation to the piston, and that time will be according as the eccentric is set with relation to the crank.

Instead of making the connections between the rod K and the respective arms of the valves positive, I make the connections through longitudinal slots in the rod, a slot L for the arm I, and into which slot the crank-pin M of the arm I extends. A like slot N is made at the opposite end of the rod K, into which the crank-pin O of the arm J enters. Fig. 2 represents a transverse section through the rod cutting through one of these slots and showing the engagement with the arm I. From these slots it follows that the rod moving in one direction—say, as indicated by the arrow in Fig. 1, which is the opening movement for the valve—the crank-pin M is bearing against the then active end of the slot L in the rod K, and so that the continued movement of that rod will produce the continued opening of the valve. The arm J of the other valve is at the same time being operated upon by the same end of its slot N, and will so continue to act until the valve G be wide open at its end of the cylinder and the valve at the opposite end of the cylinder will be fully closed. Now on the return of the rod K it will have a movement to the extent of the length of the slots before it will engage the respective valves; but when the now advancing end of the slot comes into engagement with the arms of the respective valves the valves will be returned until the valve G is closed and the valve at the opposite end opened. Thus I produce an over motion between the actuating-rod and the respective valves.

The valve G is exposed upon its back to the pressure of the air in the receiver, or whatever it may be, and when in the closed position—say as seen in Fig. 3—the valve is held to its seat by such pressure, the pressure producing a friction between the valve and its seat corresponding to such pressure, and this friction resists the opening movement of the valve.

The arm I of the valve G is provided with a spring P, the tendency of which is to turn the arm I and the valve G in the opening direction, and the other valve-arm J is provided with a like spring R, having the same opening tendency upon its valve. These springs are adjusted so as to substantially overcome the natural friction between the valves and their respective seats, and also to overcome the practical difference of pressure upon the two sides of the valve due to the difference of exposed area, so that the spring or auxiliary power itself will act upon the valve when the pressure is alike upon both sides of the valve. In rapid-running machines this auxiliary power should be a little greater than required to produce the movement of the valve when the equilibrium is actually produced in order that the valve may arrive at the point of opening the escape-passage just as the pressure in the cylinder has reached the pressure in the receiver or outside the valve, and so that if the valve were otherwise free the springs will operate to throw the valves to the open position.

When the valve G reaches its extreme closed position, as seen in Fig. 3, the rear end of the slot L is bearing against the crank-pin of the arm J. At this time the piston is on its return-stroke toward the valve G and the air-pressure upon the back of the valve is at its maximum. As the rod K commences its return the slot permits a considerable extent of movement of that rod K without action upon the valve. In due time, however, the other or forward end of the slot will come against the crank-pin of the arm I of the valve G, and then the movement of the valve will commence and continue during the movement of the rod K. Now the over-motion of the slot

L is on the opening side of its crank-pin, so that on that side the valve is free—that is to say, the valve is now free to be turned by some other power than that of the eccentric toward its open position. Therefore whenever the pressure on the cylinder side of the valve produced under the advancing movement of the piston shall have risen to an extent equal to the pressure upon the back of the valve, then the valve is free from the friction produced by the air-pressure. Now the valve-spring comes into action and will turn the valve in advance of the rod, the crank-pin of the valve passing forward in the slot of the rod, and this movement will occur whenever that equilibrium upon the valve is produced irrespective of the position of the piston in the cylinder. For illustration, suppose in the regular running of the machine fifteen pounds pressure is the pressure desired and that the slots will come into action when the fifteen pounds pressure is attained in the cylinder, or midway of the stroke of the piston. Now if the pressure on the back of the valve should from any cause be reduced, say, to ten pounds, the advancing piston will have produced that pressure of ten pounds before it reaches the said midway position, and when that ten pounds pressure is reached the valve will have been brought into equilibrium and the spring or auxiliary power will come into action upon the valve and throw it toward its open position, as I have described, and allow this air under ten pounds pressure to escape. This illustration will be sufficient to the understanding of the operation of the over-motion between the rod and the valves.

The operation is the same upon the valves at both ends of the cylinder, one valve opening as the rod moves in one direction, while the other one closes, and vice versa.

As the direct engagement of the rod with the respective valve-arms would produce a "thump," I introduce a cushion between the rod and the crank-arms to relieve the blow which would otherwise occur. In the best construction of such a cushion I make the respective ends of the rod K tubular and introduce therein a piston S. This piston has a limited amount of longitudinal movement in the rod and independent of the rod to the extent of the required over-motion. These pistons are connected with the respective arms, preferably by the crank-pin extending into the respective pistons. The tubular portion of the rods forms a cylinder within which the piston S works. The cylinder terminates in a head T at the rear end and a similar head U at the forward end, the heads being distant from each other greater than the length of the piston as much or little more than the extent of over-motion required between the connecting-rod K and the respective valves. The piston S fits closely, and as it works toward either head U or T cushions therein, and this cushioning is produced whether the valve be operated by power or whether through the rod itself. In the one case the piston cushions against the head in the rod and in the other case the head of the rod cushions upon the piston. Under this construction the slots in the rod may be of greater length than the required over-motion, the pistons S and their respective heads of the cylinders limiting the extent of over motion, and this extent may be adjusted, say, by the introduction of a set-screw *a*, which will form a stop to strike that head of the piston.

I represent dash-pots V W such as usually employed in this class of valve-gear as a cushion for the opening movement of the valves; but these are not essential to the invention.

Instead of making the over motion in the form of a slot in the rod, through which the crank-pin of the valve-arm works, the over motion may be attained between the crank-arm and the spindle or valve, as seen in Figs. 4 and 5. In this illustration I represents the crank-arm and *b* the valve-spindle projecting through a bearing *d*. The crank-arm fits the spindle, but is permitted a certain amount of rotation equal to the over motion required. This is produced by a spline or key *e* in the spindle *b* and an elongated recess *f* in the hub of the crank, so that the crank may engage the spindle at either end of the said recess, so that there will be the same interval of time between the engagement of the valve and the connecting mechanism as in the first illustration.

Under the illustration thus far the outlet-valves are represented as operated through an eccentric-rod independent of the rod which operates the inlet-valves; but the same result may be attained by a single rod, as seen in Fig. 6. In this illustration I represent the same outlet-valve arms I J. *g h* represent the crank-arms of the inlet-valves as on the same side of the cylinder as the crank-arms of the outlet-valves. These inlet-valve arms *g h* are connected by a rod *i*, which rod extends directly or indirectly to the single eccentric which is to operate the valves. The inlet-valve arm *g* at one end is connected with the outlet-valve arm I at the same end of the cylinder. This connection is in the form of a cylinder *l*, hung upon a projection from the arm *g* and a piston *m* in the cylinder, from which a rod *n* extends to and is hung to the crank-pin of the arm I. The piston M has a movement in its cylinder corresponding to the over-motion required for the outlet-valve, as before described.

As represented in Fig. 6, the valve-arm *g* is in the position of the inlet-valve closed and the valve-arm I in the position of the outlet-valve at the same end of the cylinder open. In this position the piston *m* rests upon the inlet-arm end of the cylinder. Then as the arm *g* is turned to open the inlet-valve its

movement is imparted to the arm I of the outlet-valve and produces the corresponding closing movement of the outlet-valve. On the return or closing movement of the inlet-valve *g* the cylinder will be free to move upon the piston without effect upon the arm I of the outlet-valve and until the other end of the cylinder comes into contact upon the opening-valve side of the piston. Then the opening of the outlet-valve will commence; but if in the meantime the pressure in the cylinder has produced the before-mentioned equilibrium of the outlet-valve, then the auxiliary power will come into action upon the valve and will remove it, forcing the piston *m* into the cylinder, thus operating in the same manner as does the piston in the connecting-rod K of the first illustration. This piston and cylinder in this modification also operates as a cushion, as described for that in the first illustration. The cylinder and piston connection is alike at both ends of the cylinder. The illustration which I have thus made with relation to a rotating or oscillating valve will be sufficient to enable others to apply this over-motion and auxiliary power to outlet-valves of other constructions with the same result.

I have represented the valve as an unbalanced valve and so that the pressure of the air upon the back of the valve serves to produce friction upon the seat of the valve to hold it in its place until the equilibrium is produced, that equilibrium being produced directly through the escape-port over which the valve works; but the power of the air upon the valve may be otherwise produced, and so as to employ what is commonly called a "balance-valve." This modification is illustrated in Fig. 7, in which E represents the cylindrical valve-chamber in which the valve G is arranged to oscillate. F represents the passage from the cylinder, which divides into two passages F′ F′, that lead through ports into the valve-chamber E at diametrically-opposite points. The valve is constructed with two working-surfaces for the said two cylinder-ports, and so that when in the closed position, as seen in Fig. 7, the pressure from the cylinder comes upon the valve at diametrically-opposite points, and thus counterbalance each other. The valve-chamber E leaves the opposite sides of the valve exposed in the chamber. E′ represents the outlet-passage to the receiver. The pressure from the receiver is therefore upon opposite sides of the valve alike. This will produce what is called a "balance-valve," because the pressure is alike upon the valve under all conditions, and the friction of the valve is not affected by such pressure.

To produce the necessary friction to hold the valve, a plate G′ may be introduced corresponding to the surface of the valve-chamber, and so as to lie in the chamber at one side of the valve, its inner surface exposed to the pressure of the chamber, and so that the pressure in the chamber will hold the plate against the surface of the chamber with frictional contact, according to such pressure. The said plate is adapted to engage the valve and so as to oscillate with the valve, as indicated in broken lines, Fig. 7. Hence there will be a friction opposed to the movement of the valves according to the friction between the said plate G′ and the surface upon which it works. To produce a counter-balance upon this plate, the surface of the chamber upon which the plate G′ works is recessed, as seen at E^2, and into this recess a passage F^2 leads from the cylinder-escape passage, and so that air from the cylinder under pressure will pass into the recess E and produce a pressure upon the plate G′ opposed to the pressure upon the reverse side of the plate from the receiver. The result of this will be substantially the same as when the pressure is directly upon the back of the valve. This illustration will be sufficient to indicate that the frictional surface to control the non-positive force to operate the valve may be the valve itself, or a surface substantially in connection with or so as to move with the valve.

I have illustrated the auxiliary power as springs; but it will be understood that such auxiliary power may be any of the known equivalents therefor, as a weight. For illustration, the piston of the dash-pot V W may be a weight sufficient to thus operate upon the valve without the employment of springs, or the weight of the valve itself may be so great that its own gravity will serve as the auxiliary power to throw the valve toward the open position when the valve is in a state of equilibrium.

The auxiliary power may be omitted and the valve moved positively when the connection shall have reached the extreme of the over-motion in the opening direction. Under this arrangement the opening movement of the valve will occur while the connection, under the action of the eccentric, is moving with its greatest velocity, so that the valve will be opened quickly, and the engagement between the connection and the valve for such opening will not occur until the pressure on the cylinder side of the valve substantially counterbalances that upon the back of the valve; hence the application of very slight power will be necessary to open the valve; or the opening movement of the valve may be produced entirely by the auxiliary power, while the closing movement will be positively produced by the eccentric connection, the slot or over-motion in the connection being of so great length that the connection will not come into engagement with the valve until after the before-mentioned equilibrium on the valve has been produced—say as seen in Fig. 8, where the slot L in which the crank-pin M works is made open at its outer end—so that contact between the rod K and the valve in the opening direction is impossible,

the opening movement of the valve being produced only by the auxiliary power, and this power will be applied, as before described, whenever the pressure upon the inside of the valve shall have produced the equilibrium of the valve. I have represented the cushions as produced by air; but it will be understood that any of the known substitutes for air to form the cushion may be employed.

The term "receiver," as used herein to indicate from whence the pressure comes on the back of the valve, is to be understood as not limited to an actual receiver where the air is to be stored, but includes all devices into which the air may be discharged from the air-compressor, and whereby the pressure of the air so discharged is brought to bear upon the back of the valve.

I am aware that air-compressors have been constructed in which a positive movement is imparted to the outlet-valve in the closing direction, with an auxiliary power to give to the valve its opening movement, and in which the opening movement of the valve will not occur until the pressure in the cylinder substantially equals the pressure in the receiver; but in such construction there has been combined a mechanism adapted to catch and positively lock the valve so soon as it reaches its closed position, and hold the valve so locked until such mechanism is disengaged through the operation of the pressure in the cylinder. I therefore do not wish to be understood as claiming, broadly, holding the outlet-valve of an air-compressor until the pressure in the cylinder substantially equals the pressure in the receiver, the essential feature of my invention being holding the valve upon its seat by friction produced by the differential pressures in the cylinder and receiver, and until those pressures have been brought into equilibrium, and whereby the before-mentioned locking or controlling mechanism is avoided and the valve left free and uncontrolled, except by said friction and the auxiliary force which produces the opening movement of the valve.

I claim—

1. In an air-compressor, a valve arranged to open and close the outlet-passage from the compressing-cylinder, the back of the valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, and whereby the said valve will be frictionally held substantially stationary upon its seat until the pressure upon its face equals the pressure upon its back, a connection from the eccentric to said valve, arranged to impart positive movement thereto in the closing direction, but the said connection substantially disengaged from the said valve in the opening direction, combined with an auxiliary power, substantially such as described, in connection with said valve, the said valve being otherwise uncontrolled, the said auxiliary power adapted to impart the opening movement to said valve when the pressure upon the face of the valve substantially equals the pressure upon its back.

2. In an air-compressor, a valve arranged to open and close the outlet-passage from the compressing-cylinder, the back of the valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, and whereby the said valve will be frictionally held by such pressure from the receiver substantially stationary upon its seat until the pressure upon the face of the valve from the cylinder substantially equals the pressure upon the back of the valve from the receiver, a connection from the eccentric to said valve arranged to impart positive movement thereto in both opening and closing, but said connection constructed with a space between its points of engagement with the valve in both opening and closing and so as to produce an over-motion of said connection independent of said valve, the said valve being uncontrolled during such over-motion except by the pressure upon its back and face, substantially as described, and whereby an independent movement of the valve is permitted during such interval of over-motion.

3. In an air-compressor, a valve arranged to open and close the outlet-passage from the compressing-cylinder, the back of the valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, and whereby the said valve will be frictionally held by such pressure from the receiver substantially stationary upon its seat until the pressure upon the face of the valve from the cylinder substantially equals the pressure upon the back of the valve from the receiver, a connection from the eccentric to said valve arranged to impart positive movemcnt thereto in both opening and closing, but the said connection constructed with a space between its points of engagement with the valve in both opening and closing and so as to produce an over-motion of said connections independent of said valve, combined with an auxiliary power, substantially such as described, in connection with said valve, and arranged to impart opening movement to said valve when the said equal pressure upon the back and face of the valve occurs, the said valve being uncontrolled as to its opening movement except as to its frictional contact and said auxiliary power, substantially as described.

4. In an air-compressor, a valve arranged to open and close the outlet-passage from the compressing-cylinder, the back of the valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, combined with a connection from the eccentric, with a cylinder and piston between the said valve and the said connection, the said piston and cylinder forming an over-motion between the said connection and the valve and also forming a dashpot between said connection and valve, substantially as described.

5. In an air-compressor, a valve arranged to open and close the outlet-passage from the compressing-cylinder, the back of the valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, combined with a connection from the eccentric, with a cylinder and piston between the said valve and the said connection, the said piston and cylinder forming an over-motion between the said connection and the valve, and also forming a dash-pot between said connection and valve, with an auxiliary power in connection with said valve independent of said eccentric connection, substantially as described, and whereby said auxiliary power will operate upon the said valve independent of the said eccentric connection when the pressure upon the valve shall be substantially equal upon both its back and face.

6. In an air-compressor, a valve arranged to open and close the outlet-passage from the compressing-cylinder, the back of the valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, combined with a connection from the eccentric, with a cylinder and piston between the said valve and the said connection, the said piston and cylinder forming an over-motion between the said connection and the valve, the end of the cylinder which produces the positive opening movement of the valve provided with an adjusting-screw, whereby the extent of over-motion between the connection and the valve may be adjusted, substantially as described.

7. In an air-compressor, a valve arranged to open and close the outlet-passage from each end of the compressing-cylinder, the back of the outlet-valve exposed to the pressure of the air in the receiver and the face of the valve to pressure from the cylinder, a rod K, connecting said valves and adapted to receive reciprocating movement from the eccentric, the said rod constructed with a cylinder at each end, a piston in each of said cylinders, the said pistons being in connection with said valves, and through which pistons the reciprocating movement of the rod is imparted to the respective valves to open and close the same, the said pistons permitting a predetermined amount of over-motion between said rod and the pistons, substantially as described.

8. In an air-compressor, a valve arranged to open and close the outlet-passage from each end of the compressing-cylinder, the back of the outlet-valve exposed to the pressure of the air in the receiver and the face of the valves to pressure from the cylinder, a rod K, connecting said valves and adapted to receive reciprocating movement from the eccentric, the said rod constructed with a cylinder at each end, a piston in each of said cylinders, the said pistons being in connection with said valves and through which pistons the reciprocating movement of the rod is imparted to the respective valves to open and close the same, the said pistons permitting a predetermined amount of over-motion between said rod and the pistons, combined with an auxiliary power applied to each valve independent of said rod, and whereby said auxiliary power is applied to open the valves independent of the rods when the said valves shall have been brought into equilibrium by the pressure from the cylinder on the face of the valve counterbalancing the pressure on the back of the valves.

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