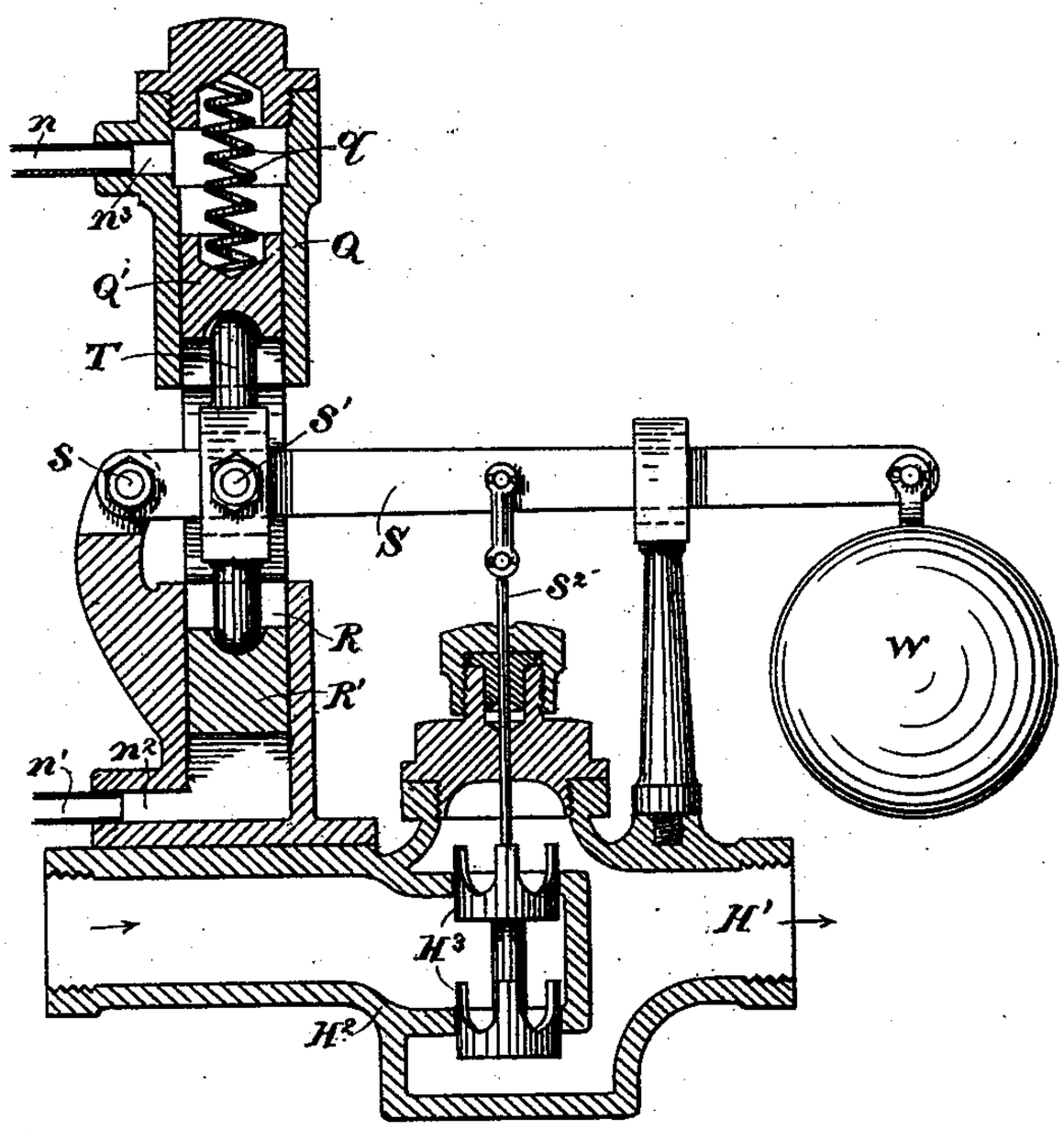
(No Model.) 2 Sheets—Sheet 1.

C. CUMMINGS.

GOVERNOR FOR AIR COMPRESSORS.

No. 603,425. Patented May 3, 1898.

Fig. 1.



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(No Model.) 2 Sheets—Sheet 2.

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Fig. 2.

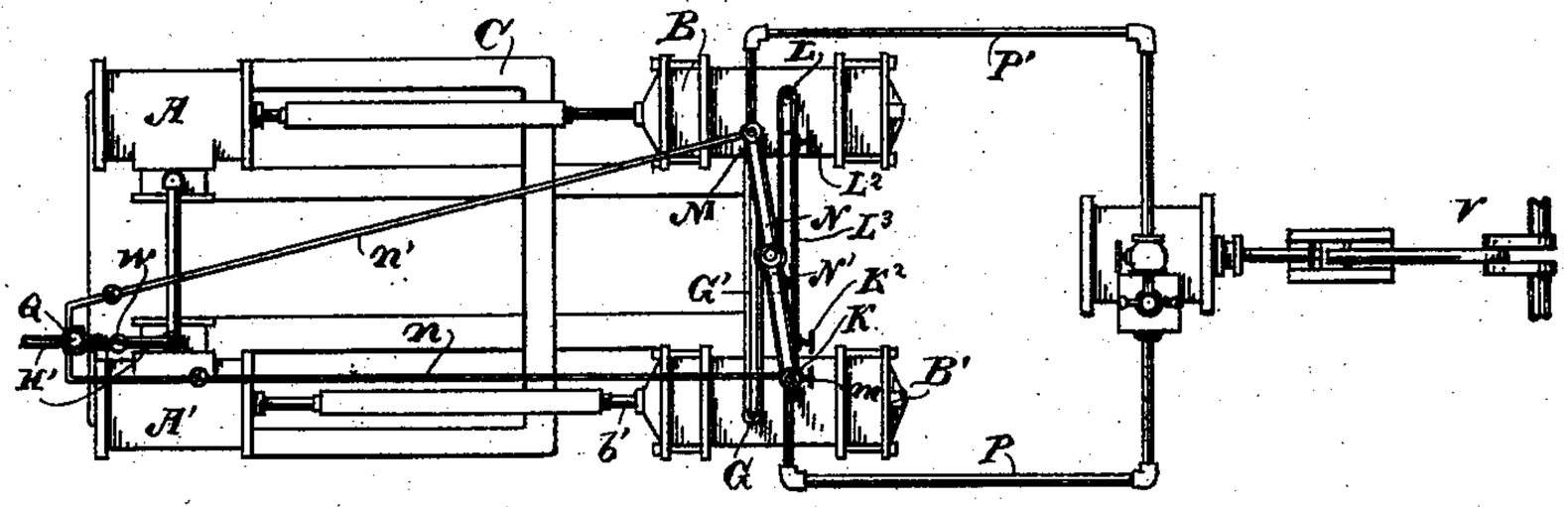


Fig. 3.

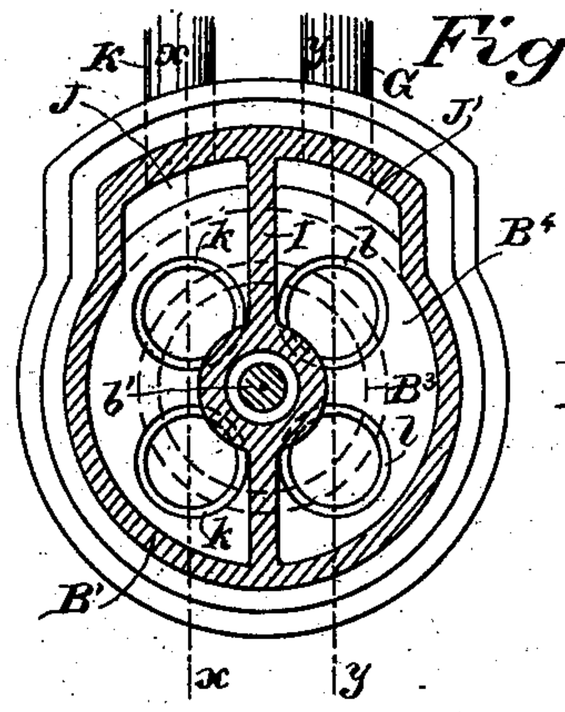


Fig. 4.

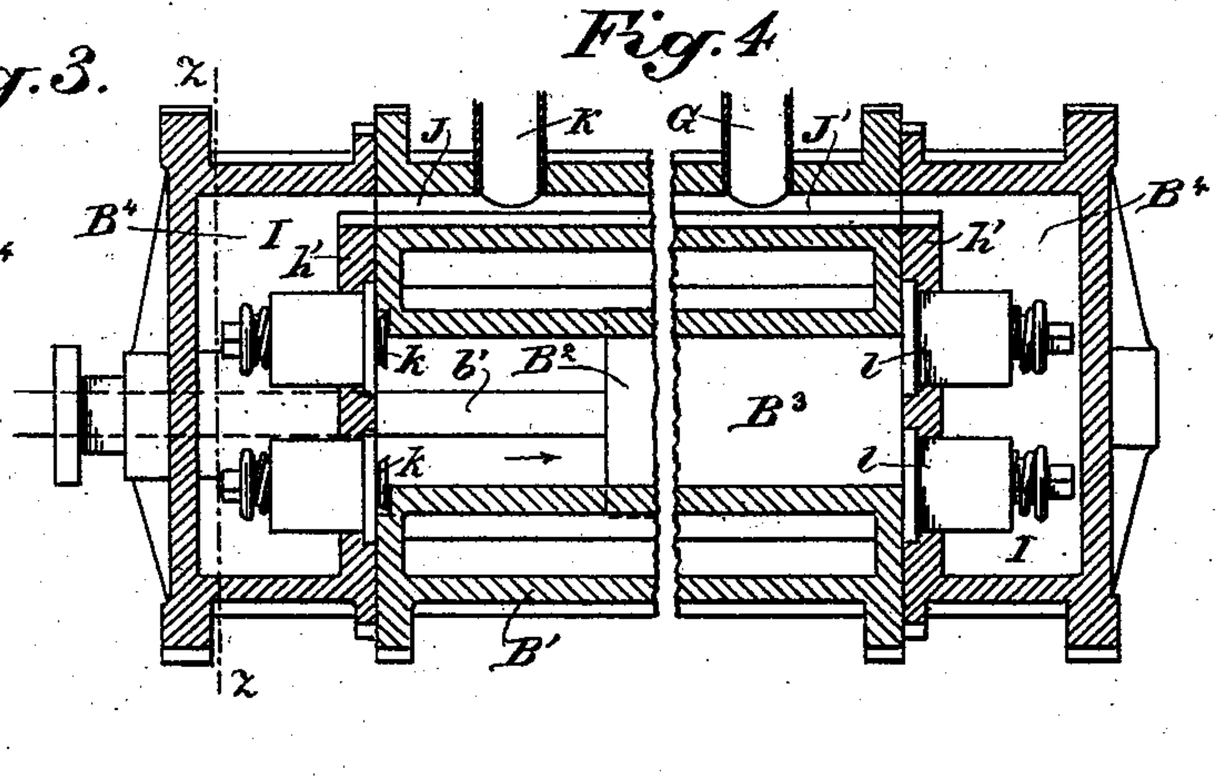
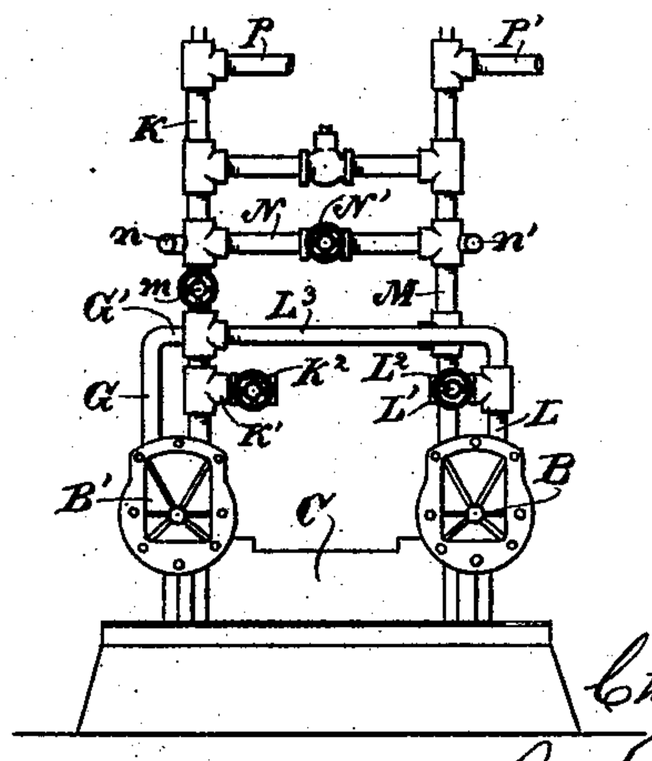


Fig. 5.



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UNITED STATES PATENT OFFICE.

CHARLES CUMMINGS, OF OAKLAND, CALIFORNIA, ASSIGNOR TO THE PNEUMATIC POWER COMPANY, OF SAN FRANCISCO, CALIFORNIA.

GOVERNOR FOR AIR-COMPRESSORS.

SPECIFICATION forming part of Letters Patent No. 603,425, dated May 3, 1898.

Application filed October 29, 1896. Serial No. 610,440. (No model.)

To all whom it may concern:

Be it known that I, CHARLES CUMMINGS, a citizen of the United States, residing at Oakland, county of Alameda, State of California, have invented an Improvement in Governors for Air-Compressors; and I hereby declare the following to be a full, clear, and exact description of the same.

My invention relates particularly to that class of air-compressing machinery in which are employed two unequal pressures of air or other gas or fluid, both above the normal atmospheric pressure, circulating in a closed system, and it relates particularly to a governing apparatus for controlling automatically the action of the air-compressing machinery.

My present invention is designed to be applied more particularly to that system for the transmission of power by means of compressed air which is described and illustrated in Letters Patent of the United States No. 456,941, granted to me August 4, 1891, to which said patent reference is hereby particularly made for a more perfect understanding of the present invention, as I deem it unnecessary in this case to illustrate and describe that system with that degree of particularity and detail which is given in said patent, as I can make my present invention plain by a more brief description and illustration. In that former patent an apparatus is disclosed for transmitting power by means of compressed air or other gas or fluid circulating in a closed system at two unequal pressures, both above the normal atmospheric pressure, and a governor is therein shown and described for keeping the geometrical ratio of the two pressures constant and regulating the speed of the compressor in proportion to the work to be done by the driven machine. It is well known to pneumatic engineers and others that the efficiency reached at the sea-level by the ordinary single-pipe air-compressor is materially reduced when working at a higher elevation, and for any given working pressure becomes less with the decrease of the atmospheric or the initial pressure of the air to be compressed. It is also well known that the theoretical efficiency varies inversely as the ratio of the initial to the final pressure of the air; but with the initial pressure furnished by the atmosphere a large ratio of compression is necessitated in order to obtain the comparatively large working or unbalanced pressure required for the transmission of power for industrial purposes. It is easy to see that with a higher initial pressure of air than the atmosphere affords any given working or unbalanced pressure could be had with a less degree of compression, and consequently with an increase of efficiency, and as a consequence the size of the compressor would be very materially reduced for any given work to be performed.

The apparatus of my prior patent provides means for increasing and maintaining any desired initial pressure, limited only by the strength of materials used in construction, and permits the choice of any convenient working pressure and a ratio of compression that will give the highest efficiency attainable.

The governor shown in my previous patent is so constructed as to maintain practically constant any geometrical ratio of the initial to the final pressure that the governor has been proportioned for. It is immaterial as to what the initial pressure may be. The governor will maintain the same ratio of the initial to the final pressure that the area of the high-pressure piston of the governor has to that of the low-pressure piston. The working pressure available for working will be always the difference between the initial and the final pressure, and if for any reason the initial pressure varies the working or unbalanced pressure also changes with it; but by the action of the governor the ratio of the initial to the final pressure remains practically constant; but where power is to be transmitted for the purpose of actuating, for instance, a mining-pump it is generally desirable to maintain a constant working pressure upon the air-piston of the pump. To meet this requirement is the object of my present invention. By its use a practically constant difference of pressure between the initial and final pressure of the air or other gas to be compressed will be maintained, or, in other terms, a constant working pressure will be had, notwithstanding the initial pressure may be made greater or less. This con-

stant difference of pressure may be termed the "arithmetical ratio" between the two pressures, which ratio is sought to be kept constant by my present invention, as distinguished from the geometrical ratio between the two pressures of my former governor. It also controls the speed of the compressor to the work required of it, equally well increasing the speed when more work is required, and vice versa. The weight *w* remaining unchanged, increasing the quantity of air circulating in the system, reduces the ratio of the initial to the final pressure and increases the efficiency correspondingly. Diminishing the quantity of air in the circuit has a contrary effect. These changes have no effect upon the working or unbalanced pressure. The difference of the two pressures of air in the circuit will remain practically constant under any change in pressures that can be made.

Assuming that the quantity of air circulating in the system is kept practically constant, increasing the weight *w* (other parts of the governor unchanged) increases the ratio of the initial to the final pressure of the air acted upon. The initial pressure will become less, the final pressure will become greater, and the efficiency will be correspondingly impaired. The working or unbalanced pressure will become greater proportionally to the increase of the weight *w*. Decreasing the weight *w* under similar conditions has a directly opposite effect.

My invention may therefore be stated to consist generally in an apparatus for transmitting power by means of compressed air or other gas or fluid circulating in a closed system at two unequal pressures, both above normal atmospheric pressure, said apparatus having a governor with connected pistons of equal pressure area for keeping the difference in pressures or the arithmetical ratio between the two pressures constant and for regulating the speed of the compressor in proportion to the work to be done by the driven machine.

It also consists in the novel construction of the governor, which is herein shown in its best form.

Referring to the accompanying drawings, Figure 1 is a vertical section of my governor. Fig. 2 is a general plan of an air-compressor to which my governor is attached and with which it is combined. Fig. 3 is a vertical section on line *z z* of Fig. 4. Fig. 4 is a sectional view of one of the air-compressor cylinders, there being two separate sectional planes, the one on the left being on the line *x x* of Fig. 3 and the one on the right being on the line *y y* of Fig. 3. Fig. 5 is an elevation of the pipe connections.

Before describing the governor forming the essential subject-matter of the present application it will be necessary to briefly describe the apparatus which this governor is intended to control and with which it is used in combination, though it is to be understood that this apparatus, as far as the present case is concerned, simply represents one form of an apparatus for transmitting power by means of compressed air or other gas or fluid circulating in a closed system of two unequal pressures. This apparatus as now described is practically a synopsis of that shown and described in my former Letters Patent above referred to.

C is the frame or bed of the machine.

B and B′ are two cylinders of the air-compressor. These are here shown as being driven by a steam-engine, of which A and A′ denote the cylinders. Piston-rods of these cylinders are suitably connected with the piston-rods of the air-compressor cylinders. The air-compressor cylinders are alike, and a description of one will answer for both. The piston of one of these cylinders has a piston-rod *b′*.

B^3 is the bore of the cylinder, and the cylinder is provided at each end with hollow heads B^4, each of which is divided by a vertical partition I into two compartments, and in the main body of the cylinder are two horizontal channels J and J′, divided by a longitudinal partition or wall in line with the partitions I I in each head, so that the chambers in the heads, in conjunction with these channels J and J′, which communicate therewith, form two separate and distinct longitudinal compartments. The bore B^3 has heads *h′*, each of which is provided with four openings, two of which lie on one side of the partition I and two on the other side. Two of these openings in each head and on one side of the partition are provided with suction-valves *k*, and the other two in each head on the other side of the partition are provided with discharge-valves *l*. The suction-valves in both heads communicate with a passage J, which I call the "low-pressure" passage, and the discharge-valves communicate with passage J′, which I call the "high-pressure" passage.

From the foregoing description it will be evident that when the piston B^2 moves to the right in the direction of the arrow shown in Fig. 4 the two suction-valves in its rear, which lead from the low-pressure passage, will be opened to permit air to flow in behind the piston. The two discharge-valves in the rear of the piston, which communicate with the high-pressure passage, are at this time closed, while the two suction-valves in front of the moving piston will be closed, the air being compressed against them; but the two discharge-valves which lead into the high-pressure passage in front of the moving piston will when the air is compressed against them be opened, allowing the air at a higher pressure to enter the passage of higher pressure. When the compression-piston reverses its movement, a similar operation will take place, the air now entering through the other two suction-valves, while the air in advance of the piston is delivered in a compressed condition into the high-pressure passage through the other pair of discharge-valves.

K is a pipe which discharges air into the low-pressure passage J.

G is a pipe which receives air from the high-pressure passage J′.

The pipe K has a short branch K′, provided with a valve K^2, said branch pipe opening into the atmosphere. Pipe K is therefore an air-induction pipe for delivering air to the cylinder and pipe G an air-eduction pipe for withdrawing the air from the cylinder, the former being a "low-pressure" pipe, so called, and the latter a "high-pressure" pipe, so called.

The function of the pipe K, when the valve K^2 is opened, is to deliver atmospheric air to the cylinder. The other air-cylinder B is likewise entered by induction and eduction pipes.

L is the induction or low-pressure pipe of this cylinder, and M is the eduction or high-pressure pipe of the same cylinder.

The pipe L has a short horizontal branch L′, which is provided with a valve L^2, serving the same purpose as the valve K^2. The pipes L and K, having a similar function, both being low-pressure pipes, are connected together by a horizontal pipe L^3, and likewise the pipes G and M, both being high-pressure pipes, are connected together by the horizontal pipe G′. The pipes K and M, being the main low and high pressure pipes, are connected together above by a horizontal pipe N, having a valve N′, adapted to be operated by hand.

From the upper end of the low-pressure pipe K issues a pipe P, which extends to the driven apparatus, and from the upper end of the high-pressure pipe M a pipe P′ likewise leads to the driven apparatus. In the low-pressure pipe K is a valve *m*.

V represents generally the driven apparatus, which is here shown in the form of an engine and with the cylinder of which the pipes P and P′ communicate on opposite sides of its piston.

The operation of this apparatus is as follows: The valves K^2 and L^2 will be opened to admit atmospheric-pressure air into the pipes K and L, and thence into the compressing-cylinders. The valve N′ will be opened and the valve *m* closed. Then the compressor will be set to work and air will be drawn from the atmosphere into the compressing-cylinders, compressed therein, and sent through the pipes G M N K above valve *m* and through pipes P and P′. The compressed air in the entire system will be now at the same pressure. The operation of compressing will be continued until a pressure is reached of, say, one hundred pounds, supposing this to be the lesser of the two unequal pressures. Then the operator will close valve N′. This will separate the system of low-pressure pipes from the system of high-pressure pipes, leaving the pressure in the former fixed permanently at one hundred pounds. The operation of the compressor will continue until the air in the high-pressure pipes has attained a pressure of two hundred pounds, when the inlet-valves K^2 and L^2 will be closed, preventing the admission of any more air, and the valve *m* will be opened, allowing air at a pressure of one hundred pounds to be delivered to the compressor-cylinders. The closed system is now complete, and when in action the air circulates between the compressor and the motor. The air in one part of the system is at one hundred pounds pressure and the air in the other part at two hundred pounds pressure. These are the two unequal pressures, the difference between which is, for the purpose of my present invention, to be kept constant—that is to say, the arithmetical ratio between the pressures is to be kept constant. The governing apparatus which I employ to effect this result consists of two cylinders Q and R. In the cylinder Q is a piston Q′, and in the cylinder R is a piston R′. Unlike the governor of my previous patent, which had these pistons of unequal area of pressure in order to maintain constant the geometrical ratio between the two pressures, my present pistons Q′ and R′ are equal in pressure area, as is shown. A spring *q* is seated in the cylinder Q and bears upon the piston Q′. The pipe *n*, which leads from the low-pressure pipe K, extends to and is entered in the opening n^3 in the cylinder Q above the piston Q′, and the pipe *n*′ from the high-pressure pipe M leads to and enters the opening n^2 in the cylinder R below the piston R′. These pressures, as in the former case, do not bear directly upon the pistons, but upon a body of oil or other suitable material, the effect being the same as if the pressure bore directly on the pistons.

S is a lever with its short arm pivoted at *s* to a suitable bracket.

T is a bearing-piece between the two pistons Q′ and R′, said bearing-piece having its ends rounded, and the pistons are slightly recessed to receive them. The air-pressures on the piston keep them firmly against the ends of the bearing-piece. The latter is slotted to allow the lever S to pass through, and a pin *s*′ connects the two parts, as shown.

From the long arm of the lever S a weight W is suspended. Attached to the lever, between the weight and the fulcrum, is the valve-stem s^2, carrying the balanced valve H^3, which is seated in the valve-casing H^2, interposed in the steam-pipe H′, which leads from the boiler to the steam-engine, supposing the compressor to be actuated by steam. Thus the governor is between the air-compressor and the steam-generator.

The spring *q* above the piston Q′ is for the purpose of securing a gradual movement of the pistons Q′ and R′ from one extreme to the other of their movement.

The office of this governor is to maintain within narrow limits a constant difference of pressure between the two pipes of the air-compressing system and at the same time to regulate the speed of the compressor, so as

to furnish more or less compressed air when the work to be performed varies, shutting off the steam entirely when no power is required and turning on the steam again to actuate the compressor when work is resumed. Its operation is as follows:

The system having been charged with air compressed from the atmospheric pressure to any desired extent—for example, say fifty pounds pressure per square inch in the low and one hundred pounds in the high pressure pipe—and supposing it be decided that an unbalanced pressure of fifty pounds per square inch is sufficient to perform the work in hand, then in such case a constant difference of fifty pounds per square inch is required to be maintained and the speed of the compressor to be regulated in accordance with the work required to be done within the limits of its capacity. The areas of the pistons Q′ and R′ being equal, and say, for example, that they are one square inch each, then the cylinder Q, being connected with the low-pressure pipe of the compressed-air system, will have a pressure of fifty pounds upon its piston, and the cylinder R, being connected with the high-pressure pipe, will have a pressure of one hundred pounds. The excess of fifty pounds on this piston is counterbalanced by the weight W, the moving parts of the governor being thus held in equilibrium. In this condition a slight excess of pressure in the high-pressure pipe, for example, caused by the speed of the compressor being greater than required for the power used, will cause the piston in the cylinder R to rise, and thus shut off a part of the steam by closing the steam-valve H^3 and so reducing the speed of the compressor. If, on the contrary, the speed of the compressor should from any cause be less than that required to furnish the power necessary, the pressure in the high-pressure pipe would decrease and that in the low-pressure pipe increase, which would tend to press downwardly the piston in cylinder Q, and thus to open the steam-valve H^3 and increase the speed of the compressor until the supply of steam is sufficient to do the work required. If the pressure in the low-pressure pipe—that is, the initial pressure of the air to be compressed—is increased or decreased, the working or unbalanced pressure will not be affected thereby, but a constant difference of pressure, or, in other words, the arithmetical ratio between the two pressures in the two pipes, will be maintained by the action of the governor and will be equal to the pressure exerted upon the piston R′ by the weight W. For example, if the initial pressure is reduced to, say, forty pounds per square inch this pressure in addition to that caused by the weight W will rest upon the piston R′, being together ninety pounds. Then to balance this there must be ninety pounds pressure in the high-pressure pipe, and the difference is fifty pounds, as before, or if the initial pressure be increased, say, to one hundred pounds per square inch this added to that caused by the weight exerts a pressure of one hundred and fifty pounds on the piston R′, to balance which there must be a pressure of one hundred and fifty pounds in the high-pressure pipe of the system, the difference or working pressure being still fifty pounds. These changes of pressures in the two pipes do not affect the governor in its power to regulate the work of the compressor, that function being as well performed under any and every initial and final pressure that can be practically used.

Changing the initial pressure of air to be compressed varies the ratio of the initial to the final pressure, and the efficiency of the system is thereby increased or decreased according as the initial pressure is made greater or less. Increasing the initial pressure increases the efficiency, and vice versa.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In an apparatus for transmitting power by means of compressed air or other gas or fluid circulating in a closed system at two unequal pressures, both above normal atmospheric pressure, a means for automatically keeping an arithmetical ratio or a constant difference of pressure between the two unequal pressures, said means varying the speed of the compressor so that it will generate, as required, more or less energy for the work to be done by the driven machine.

2. In an apparatus for transmitting power by means of compressed air or other gas or fluid circulating in a closed system at two unequal pressures, both above normal atmospheric pressure, the combination of a compressor, a machine to be driven thereby, air-conduits between the compressor and the machine and containing air at the unequal pressures, and a means for automatically keeping an arithmetical ratio or a constant difference of pressure between the two unequal pressures, said means varying the speed of the compressor in proportion to the work to be done by the driven machine.

3. In an apparatus for transmitting power by means of compressed air or other gas or fluid circulating in a closed system at two unequal pressures, both above normal atmospheric pressure, a governor for keeping an arithmetical ratio or a constant difference of pressure between the two unequal pressures, and regulating the speed of the compressor in proportion to the work to be done by the driven machine, said governor comprising connected pistons of equal pressure areas, acted upon by the unequal pressures, means for counterbalancing the difference in pressure and holding the pistons in equilibrium and means operated by said connected pistons for controlling the compressor-driving medium.

4. In an apparatus for transmitting power by means of compressed air circulating in a

closed system at two unequal pressures, a governor for keeping an arithmetical ratio, or a constant difference of pressure between the two unequal pressures, and regulating the speed of the compressor in proportion to the work to be done by the driven machine, said governor having two pistons connected and moving in unison, the pistons being of equal pressure areas, said pistons receiving respectively the pressures of the high and low air-pressures, a weight connected with the pistons for counterbalancing the difference in pressure and holding the pistons in equilibrium, and a valve controlling the supply-pipe leading to the motor which actuates the compressor, said valve being regulated by the movement of the governor-pistons.

5. In an apparatus for transmitting power by means of compressed air circulating in a closed system at two unequal pressures, a governor for keeping an arithmetical ratio or a constant difference of pressure between the two unequal pressures and regulating the speed of the compressor in proportion to the work to be done by the driven machine, said governor having two pistons connected and moving in unison, the pistons being of equal pressure areas, said pistons receiving respectively the pressures of the high and low air-pressures, a weighted lever connected with and operated by the pistons for counterbalancing the difference in pressure and holding the pistons in equilibrium, and a valve controlling the supply-pipe leading to the motor which actuates the compressor, said valve being connected with the weighted lever and regulated by the movement of the governor-pistons.

6. In an apparatus for transmitting power by means of compressed air circulating in a closed system at two unequal pressures, the combination of a compressor, a suitable motor for actuating it, a machine to be driven by the power of the compressed air, two air-conduits between the compressor and the driven machine and containing air at unequal pressures, a governor having two pistons connected and moving in unison and whose pressure areas are equal, a pivoted lever connected and operated by the movement of said pistons and carrying a weight to balance said pistons and hold them in equilibrium, a valve controlling the supply-pipe leading to the motor which actuates the compressor and a valve-stem connecting the valve with said lever whereby it is operated, a low-pressure pipe running from the low-pressure conduit to the low-pressure end of the governor, and a high-pressure pipe running from the high-pressure conduit to the high-pressure end of the governor.

In witness whereof I have hereunto set my hand.

CHARLES CUMMINGS.

Witnesses:
FAIRFAX HENRY WHEELAN,
HENRY J. LANG.