(No Model.)

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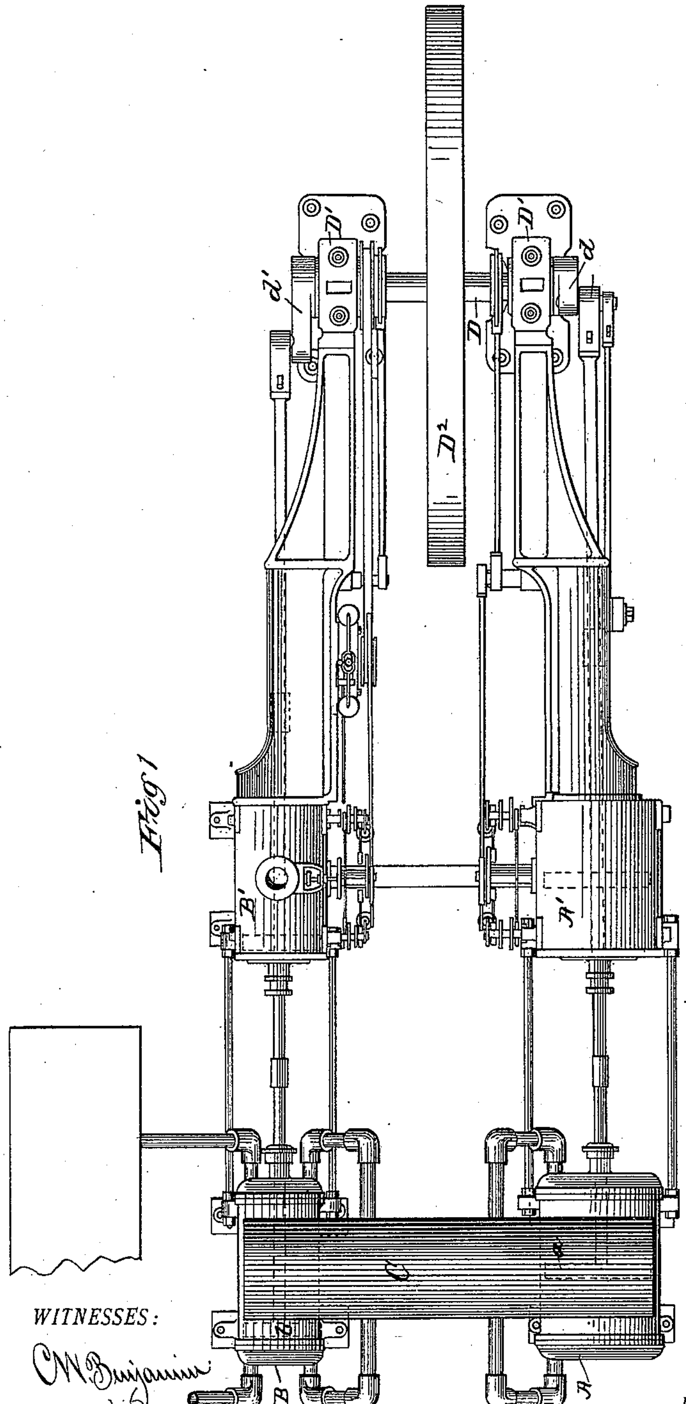
A. C. RAND & F. A. HALSEY.

AIR COMPRESSOR.

No. 421,611.

Patented Feb. 18, 1890.

Fig 1



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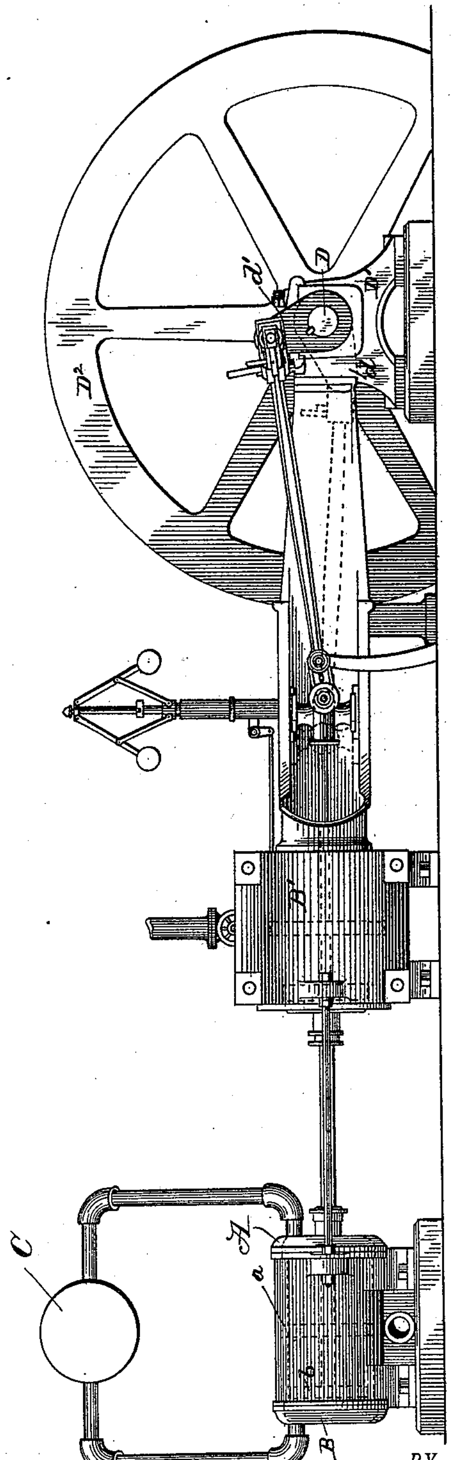

Fig 2

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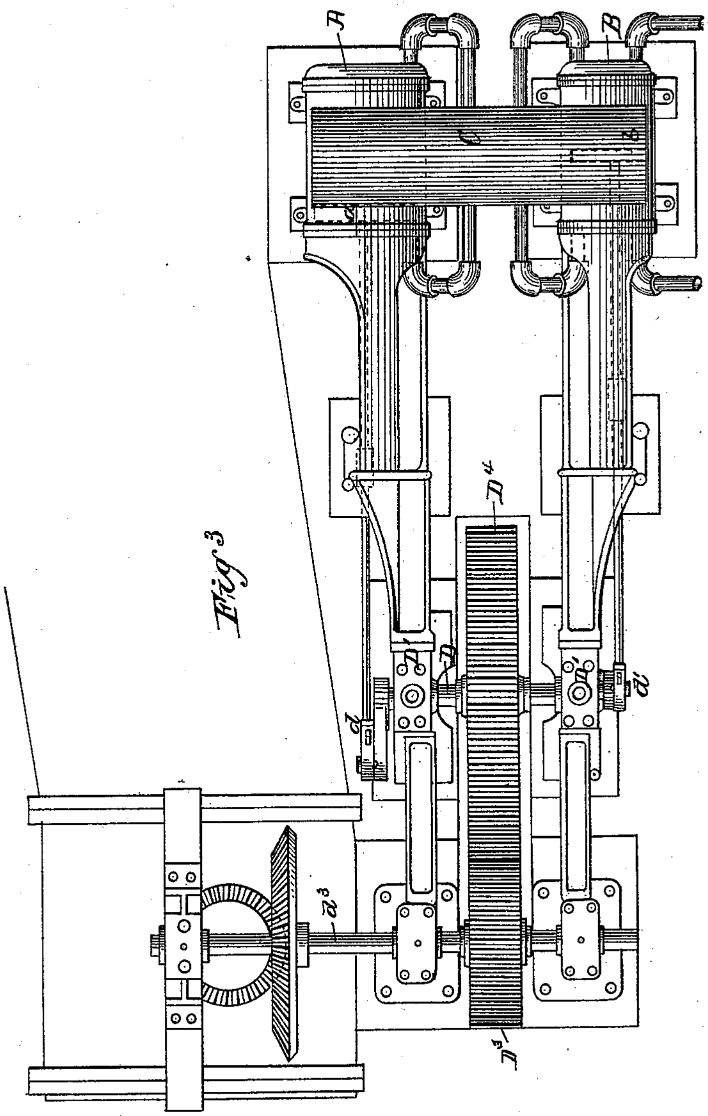

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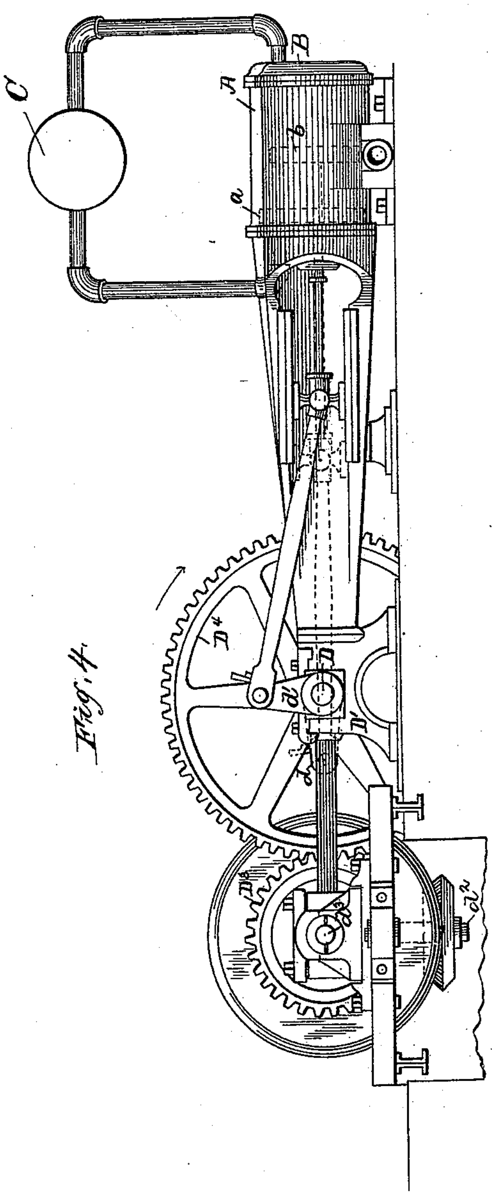

Fig. 4.

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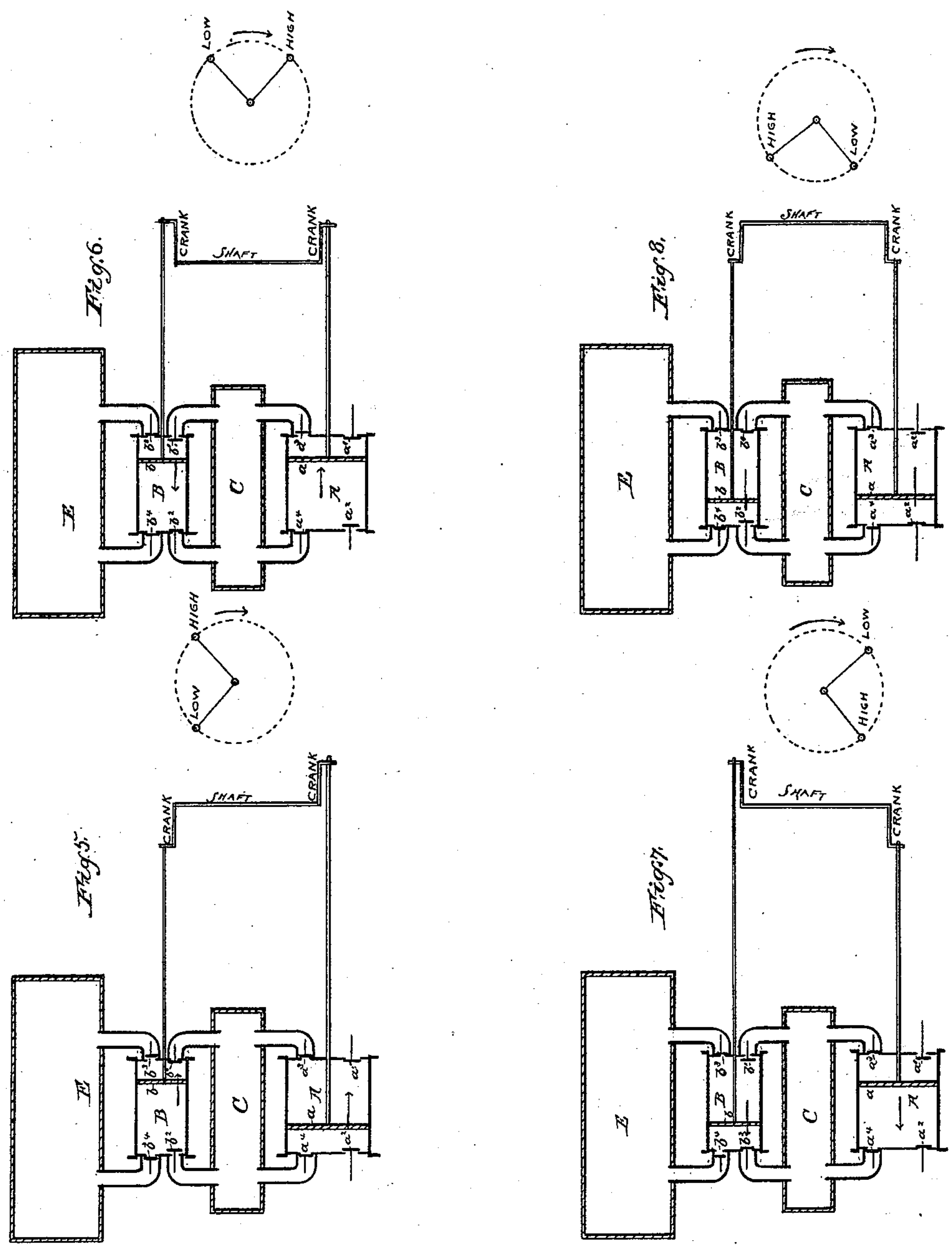

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UNITED STATES PATENT OFFICE.

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AIR-COMPRESSOR.

SPECIFICATION forming part of Letters Patent No. 421,611, dated February 18, 1890.

Application filed July 16, 1888. Serial No. 280,102. (No model.)

To all whom it may concern:

Be it known that we, ADDISON C. RAND, of the city of New York, county and State of New York, and FREDERIC A. HALSEY, of North Tarrytown, county of Westchester, State of New York, both being citizens of the United States, have invented certain new and useful Improvements in Air-Compressors, of which the following is a full, clear, and exact description, reference being had to the accompanying drawings, forming part of this specification.

Our invention relates to apparatus for compressing air; and our invention consists in a compound air-compressor composed of cylinders of differing volumes, the one an intake and the other a compression cylinder, and an air-connection discharging from the former into the latter, the respective pistons of said cylinders being adapted to move relatively to each other in making their strokes, so that when one piston approximates the limit of its stroke the other approximates mid-stroke, whereby the resistance of the air to both pistons is practically equalized throughout the entire strokes of both of said pistons, as hereinafter particularly set forth.

Figure 1 is a plan of a compound air-compressor embodying our invention and showing the same driven by a compound steam-engine as the motor. Fig. 2 is a side elevation of the same. Fig. 3 is a plan of our compound compressor, showing the same driven by gearing from an independent motor, such as a turbine water-wheel. Fig. 4 is a side elevation of the apparatus shown in Fig. 3. Figs. 5, 6, 7, and 8 are views in plan of the air-compression cylinders, the connection between them, and the compressed-air receiver, together with the valves thereon, and illustrative of the operation of the apparatus during the passage of air into and through the intake-cylinder and to and through the compression-cylinder, and thence to the receiver during the movement of the compressor-pistons.

In simple air-compressors having a single compression-cylinder driven by a single steam-cylinder by a direct piston-rod connection between the pistons of said cylinders the resistance to the compressor-piston at the beginning of the stroke is zero, or the minimum, while as the piston advances the resistance increases and becomes the maximum at a point in the latter portion of the stroke. Meanwhile the effort or power of the steam-piston is at its maximum at the beginning of the stroke thereof, and such effort gradually diminishes to the minimum at or during the latter portion of the stroke. The result of these conditions is obviously the exertion of the maximum effort against the minimum resistance and of the minimum of effort against the maximum of resistance throughout the concurrent strokes of the two pistons, and this result produces an inequality in the power and resistance, and hence irregularity of strain upon the operative parts during each piston-stroke, which can be remedied or overcome to only a minor degree by a fly-wheel on the engine crank-shaft. For the purpose of overcoming this inequality of power and resistance during the piston-stroke, the apparatus known as the "duplex" air-compressor has been hitherto devised. In this apparatus two similar compression-cylinders are employed, and their respective pistons are operated by cranks set at right angles to one another on a common shaft, the said shaft being usually driven by two similar steam-cylinders, the rods of the pistons of which are respectively connected to said cranks on said shaft. In this construction, when the resistance of the air to the pistons of either of the compression-cylinders is at its maximum, and the effort of the piston in the steam-cylinder in line therewith or operating the crank on the same side therewith in the machine is approaching its minimum, the piston of the other steam-cylinder is in position in its stroke to render assistance to the piston of said compression-cylinder through the said common shaft, the resistance to the piston of the compression-cylinder which is in line with the said last-named steam-cylinder being at its minimum; but while this described arrangement operates to approximately equalize the application of the effort of the motor-cylinders throughout the strokes of the compression-pistons, it does not secure an equalization of the resistance of the air to the pistons of the compression-cylinders during the strokes thereof, for the reason that the sum of such resistances to both pistons is at the maximum at or near the end of the stroke of either of said pistons. The inequality in the strain upon the operative parts during the piston-strokes thus still occurs in this construction. When the duplex compression-cylinders are driven by a turbine water-wheel or other equivalent motor developing a uniform continuous effort in place of the similar steam-cylinders, as stated, said turbine wheel being connected to the described common shaft by means of suitable gearing, the inequality of strain upon the gears consequent upon the inequality of resistance of the air during the strokes of the pistons of the compression-cylinders entails a serious disadvantage. In such case the comparatively instantaneous release of the compression-pistons from the maximum resistance of the air thereto at the end of the stroke of either produces an interruption in the movement of the compression-pistons, which is felt throughout the operative parts of the machine, and causes a jar or "back-lash" in the gearing, which is exceedingly liable to fracture the teeth thereof. The existence of these conditions necessitates the use of exceedingly heavy and strong gearing to withstand the shock thereto from the cause stated, besides causing a very appreciable loss of power.

Another construction of air-compressor which has been heretofore devised for the purpose of overcoming the disadvantages hereinbefore recited comprises two compression-cylinders of different diameters, having an air-connection leading from the larger to the smaller, the two cylinders being in line with each other, and being driven by the piston of a steam-cylinder, which is also in line with the compression-cylinders, the several pistons of said cylinders having a common or direct piston-rod connection, and moving synchronously and in relatively similar positions in their respective cylinders throughout their stroke. The compression-cylinders thus constitute a compound compressor, the cylinder of greater diameter, and hence larger area of piston, being the intake-cylinder, in which the air is only initially and partially compressed, and thence forced into the cylinder of lesser diameter, and hence smaller area of piston, wherein it is finally compressed to the desired tension. The areas of the pistons of the respective air-cylinders are of course so proportioned relatively to each other that the maximum resistances developed upon each by the air-compression are approximately equal; but in this construction an equalization of resistance by the air to the compression-pistons during their stroke is only partially obtained, for that the said pistons moving synchronously and in the same relative positions in their respective cylinders throughout their stroke the maximum of the sum of the resistances to both pistons is developed at the termination of their concurrent strokes, and the sole advantage secured is the reduction in the sum total of the resistances, due to the division of labor between the compound cylinders and the assistance given to the smaller piston in its advance by the pressure acting behind it, caused by the larger piston in forcing the air from the larger to the smaller cylinders under the pressure given said air in the larger or intake cylinder. Furthermore, no practical equalization of the effort of the steam-pistons to the resistances of the compression-pistons during the concurrent strokes thereof is afforded by this construction, as the effort of the steam-piston approximates its minimum when the resistances of the compression-pistons are approximating the maximum—namely, at the termination of the concurrent strokes. As a consequence of these stated conditions, an inequality in the strain upon the operative parts of the machine during each successive piston-stroke ensues.

By means of our invention, as hereinafter described, we attain a practical maximum of the equalization of the resistance of the air to the compressor-pistons throughout their strokes, and the effort or application of power by the motor is exerted uniformly and equally against the combined resistances of said pistons at all times during their strokes, whereby the strain upon the operative parts is practically equalized throughout said piston-strokes.

In carrying out our invention we employ two cylinders, constituting a compound compressor—namely, a cylinder A, which is of the greater diameter of the two, and which is the intake-cylinder, into which the air is initially drawn and therein only partially compressed, and a cylinder B, which is of the lesser diameter, and into which, through the connection C, the air, partially compressed in the intake-cylinder A, is forced under pressure and therein compressed finally to the desired tension. The respective pistons a and b of said cylinders are so proportioned in area relatively to each other that the maximum resistances developed upon each by the air-compression are approximately the same, or equal. These said pistons have strokes of equal length, and are adapted to move relatively to each other in making their strokes, respectively, so that when one piston is at the limit of its stroke, or substantially so, the other piston is substantially at midway of its stroke. To enable these essential conditions to be realized, the cylinders A and B are preferably placed or located alongside each other on a suitable bed or frame and at equal distances from a shaft D, common to both, which is provided with cranks d d' at right angles to each other thereon, and to which cranks the rods of the pistons are respectively connected, as shown.

The cylinders A and B, it will be understood, may be provided with the customary jackets for the circulation around them of water to keep them cool, such jackets not being indicated in detail in the drawings. It will also be understood that the cylinders have the usual inlet and outlet valves, whereby the air circulation and delivery are accomplished. The air-connection C may be and desirably is composed of a number of tubes, through which the air, partially compressed in the intake-cylinder A, passes on its way to the cylinder B, and a jacket inclosing said tubes adapted to permit a water-circulation through it. By this means the heated compressed air coming from the cylinder A is cooled and condensed on its way to the cylinder B. This construction of the connection C is not shown in detail, as it is well known, and no claim of novelty therefor is made herein. The shaft D may be given suitable bearings in ordinary pillow-blocks D′, as shown, and is provided with a fly-wheel D^2.

In Figs. 1 and 2 the described compound compressor-cylinders are shown as having their pistons operated, as described, by means of a compound steam-engine the cylinders of which are interposed between the compression-cylinders and the crank-shaft, and the pistons of which steam-cylinders have a direct rod-connection with the pistons of the compression-cylinders, respectively, and also with the described cranks d and d' by the usual pitmen. The expansion or low-pressure steam-cylinder A′ is in line and connection with the intake air-cylinder A, and the initial or high-pressure steam-cylinder B′ is in line and connection with the air-compression cylinder B. By this arrangement, when a steam-engine is employed as a motor, the piston of the cylinder B receives by direct action the effort or power of the piston of the cylinder B′, and the piston of the cylinder A receives similarly the effort or power of the piston of the cylinder A′, thus establishing conditions which attain the best results in our apparatus with steam as the motive power.

The shaft D may be driven by a turbine water-wheel, (not shown,) the shaft d^2 of which, by means of suitable gearing, may actuate a shaft d^3, having a gear D^3, meshing into a gear-wheel D^4 on said shaft D. This construction is illustrated in Figs. 3 and 5.

The passage or circulation of the air from its entrance to the intake-cylinder by one of its inlet-valves to and through the compression-cylinder and thence to the receiver is illustrated in Figs. 6, 7, 8, and 9. In Fig. 6 the piston a of the intake-cylinder A is advancing in the direction of the arrow and is approaching mid-stroke, while the piston b of the compression-cylinder is advancing in the same direction, as shown, and is approaching the limit of its stroke in such direction. The inlet-valve a^2 of the intake-cylinder is now admitting air behind piston a, as indicated. In front of said advancing piston a the air is being compressed; but as the pressure there has not yet reached the degree of the pressure in the intermediate connection C the discharge-valve a^3 in the cylinder and leading to the connection C has not yet opened. At the same time the inlet-valve b^2, leading from the connection C to the compression-cylinder B, is opened by the pressure in C, and the partially-compressed air from C is being admitted behind the piston b. As the connection C is now having no air pressed into it, its pressure is slowly falling, depending in rate of fall upon the size or capacity of said connection C. Meanwhile, the air in front of the advancing piston b, being compressed to or somewhat above the pressure in the main receiver E, has thereby opened the discharge-valve b^3, leading into the said receiver. In Fig. 7 piston b of compression-cylinder B has completed its advance stroke and is on its way to mid-stroke on the return, as indicated, while piston a of intake-cylinder A is approaching the end of its advance stroke, as shown. The inlet-valve a^2 of cylinder A is of course still open and admitting air to said cylinder back of piston a. The air in front of piston a, being now compressed to or slightly above the pressure in C, has thereby opened the discharge-valve a^3, and the air in front of said piston a is passing into C. Meanwhile the crank operating the piston b has passed the center, as indicated in diagrams on said figures, and the valves b^3 and b^2, released from the air-pressure, have been closed by springs in the usual way. Valve b' is now opened by pressure from C and is admitting air from C to the back of piston b, as shown. The cylinder A is therefore putting air into C, and the cylinder B is at the same time drawing air therefrom, and as cylinder A has the greater volume or capacity the pressure in C is rising slowly to compensate for the fall of the pressure therein, as hereinbefore stated. In Fig. 8 piston a of cylinder A has completed its advance stroke and is approaching to mid-stroke on its return-stroke, as indicated, while piston b of cylinder B is approaching the completion of its return-stroke. Inlet-valve a' of cylinder A is now admitting air behind piston a, and discharge-valve a^3, released from air-pressure, is closed by its spring, while discharge-valve a^4 has not yet been opened by pressure developed in front of piston a. In cylinder B the inlet-valve b' is still open, admitting air from C to behind piston b, and discharge-valve b^4 has been opened by the pressure in front of piston b, and air is thereby being discharged from cylinder B into the receiver E, while the pressure in C is again slowly falling, as before described. In Fig. 9 piston b has completed its return-stroke and is advancing to mid-stroke in the opposite direction again, while piston a is approaching the end of its said return-stroke. Inlet-valve a' is still admitting air to cylinder

A, and the pressure in advance of piston a has opened discharge-valve a^1 and air is passing from cylinder A to the connection C. The pressure in front of piston b has not yet opened discharge-valve b^3 of cylinder B, but inlet-valve b' is closed by its spring and inlet-valve b^2 is opened and air is passing from C to behind the piston b. When the piston b has again moved so as to approach the end of its stroke in the direction shown in Fig. 9, and the piston a has completed its stroke in the direction in said figure and has again reversed and is approaching mid-stroke, the pistons and valves will again be in the positions shown in Fig. 6.

By the described adaptation of the pistons a and b to move relatively to each other in making their respective strokes in their respective cylinders of the compound compressor, so that when the piston a is approximating the limit of its stroke the piston b is approximating mid-stroke, and vice versa, not only does the piston b have the assistance in its advance during each stroke of the effort back of it due to the pressure of the larger piston a in forcing the air from the cylinder A to the cylinder B, but the maximum resistance of the air to each piston during its stroke is developed alternately to the development of the maximum resistance of the air to the other piston, so that the sum of the resistances to both pistons at the beginning of the stroke of either is increased to its practical maximum, and hence the resistance throughout the entire of their strokes is practically equalized. It follows, therefore, that when the pistons are severally released from resistance in advance of them at the termination of their working-strokes and encounter the substantially equal resistance, which is then behind them at the beginning of their several return-strokes, the strain upon the operative parts will be substantially practically uniform throughout the piston-strokes, and no interruption of the movement of the pistons, nor jar upon the gearing or other operative parts, will occur. This enables a lighter construction to be employed, thus securing an economy in the cost of the apparatus.

By means of our compound compressor constructed, arranged, and adapted to operate as described it is futhermore evident that the motive power developed and applied to the crank-shaft D, so as to rotate the same with a uniformity of effort throughout the rotation thereof, will be consumed with a maximum of advantage by the pistons of the compound compression-cylinders in making their alternate strokes against the equalized resistance opposed thereto, thereby obtaining the maximum of economy of power.

What we claim as our invention, and desire to secure by Letters Patent, is—

1. A compound air-compressor composed of an intake-cylinder in which the air is initially and partially compressed, a compression-cylinder of less diameter or volume than said intake-cylinder, a connection between said cylinders through which air is discharged under pressure from the former into the latter, and the respective pistons of the said cylinders and their rods and cranks, adapted to move said pistons relatively to each other in making their working-strokes to approximate one piston at midway of its stroke when the other piston approximates the limit of its stroke, substantially as and for the purpose specified.

2. A compound air-compressor composed of an air-intake cylinder in which the air is initially and partially compressed, an air-compression cylinder of less diameter than said intake-cylinder, and a connection between said cylinders through which the air is discharged under pressure from the former into the latter, in combination with a driving-shaft having cranks at right angles to each other thereon, said cranks being connected, respectively, to the rods of the pistons of said respective cylinders, together with the cylinders of a compound steam-engine, the high-pressure cylinder thereof being in line and having its piston in connection with the piston of the air-compression cylinder, and the low-pressure or expansion cylinder thereof being in line and having its piston in connection with the piston of the air-intake cylinder, substantially as described.

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