(No Model.) 7 Sheets—Sheet 1.

U. CUMMINGS.

AIR COMPRESSOR.

No. 412,474. Patented Oct. 8, 1889.

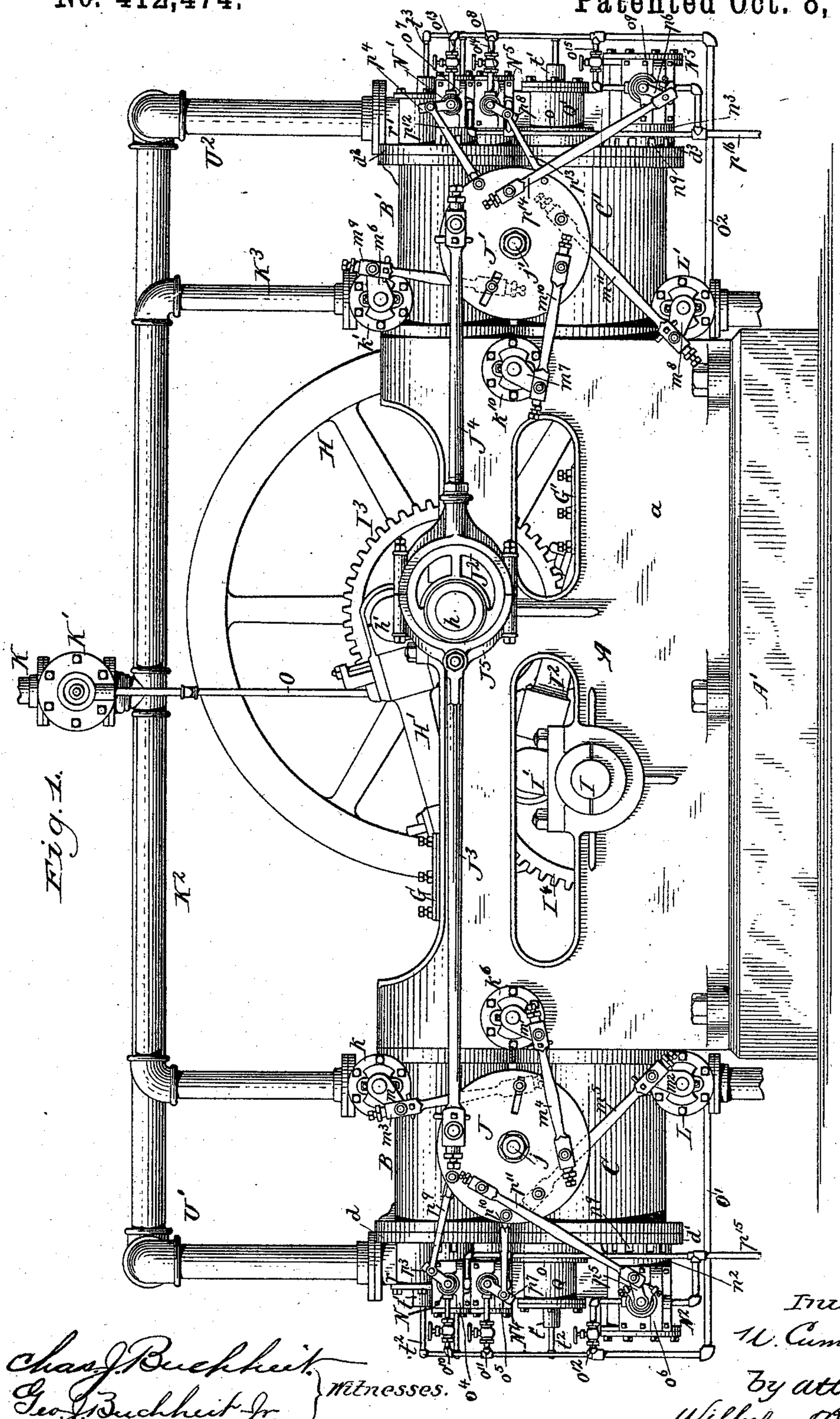

Fig. 1.

Witnesses.
Chas. J. Buchheit.
Geo. J. Buchheit Jr.

Inventor:
U. Cummings
By Attorney's.
Wilhelm Bonner

(No Model.)

7 Sheets—Sheet 2.

U. CUMMINGS.

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No. 412,474. Patented Oct. 8, 1889.

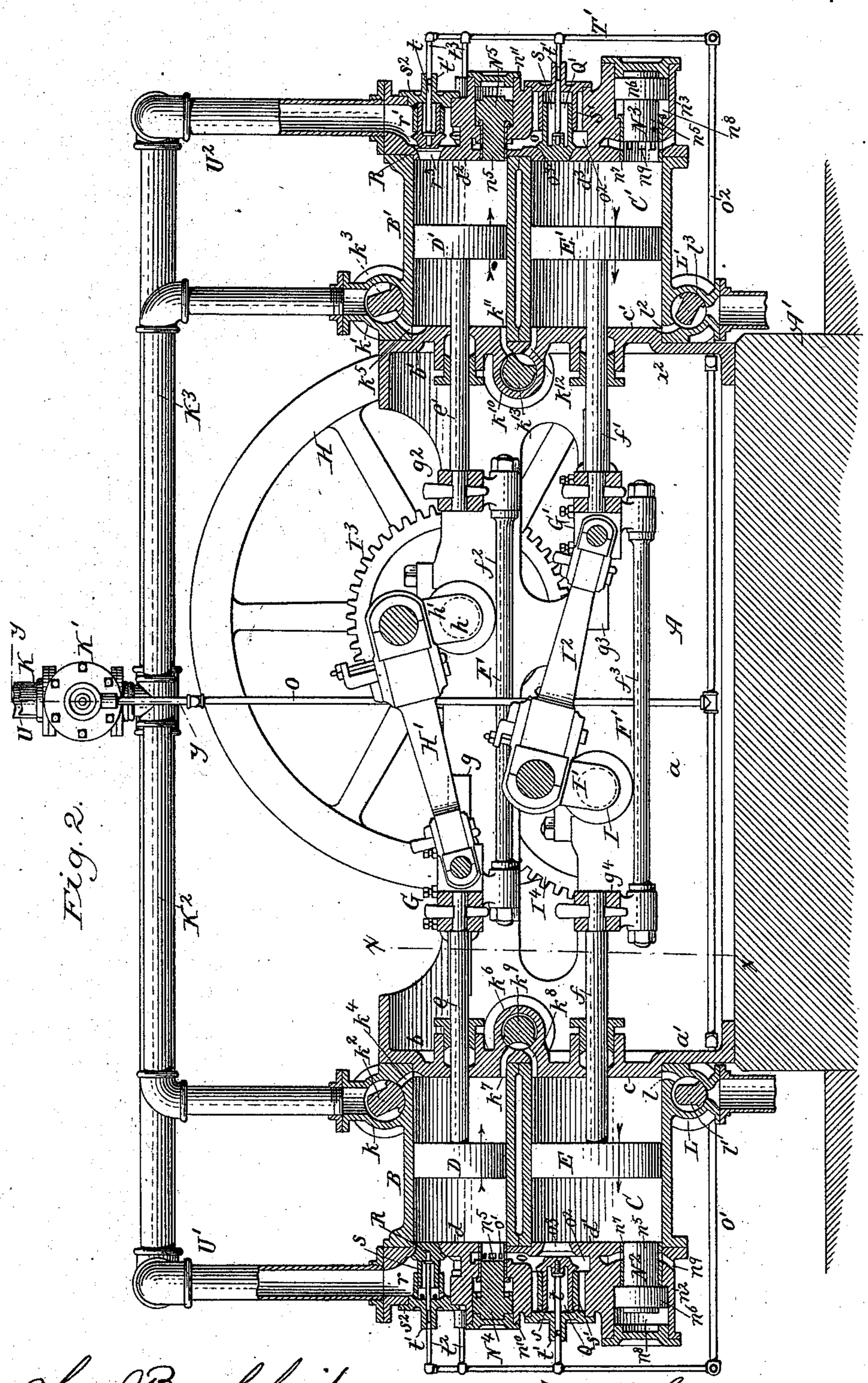

Fig. 2.

Witnesses.
Chas. J. Buchheit.
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(No Model.) 7 Sheets—Sheet 3.

U. CUMMINGS.

AIR COMPRESSOR.

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Fig. 3.

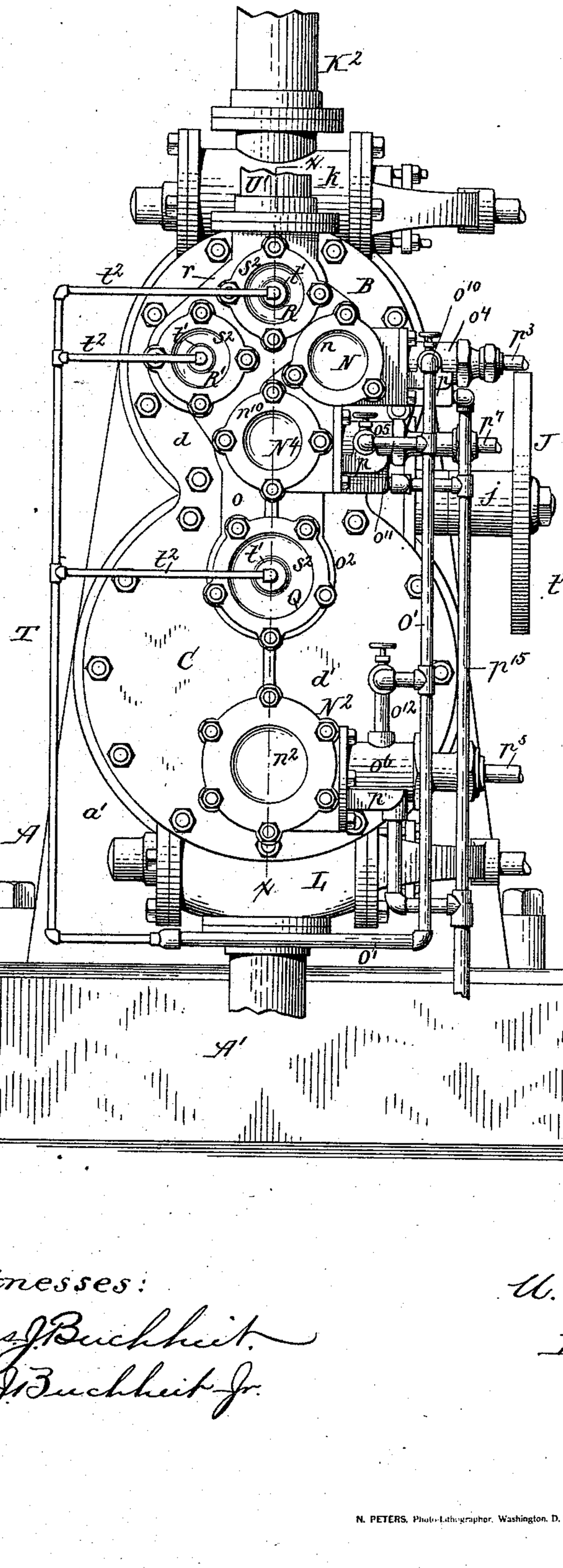
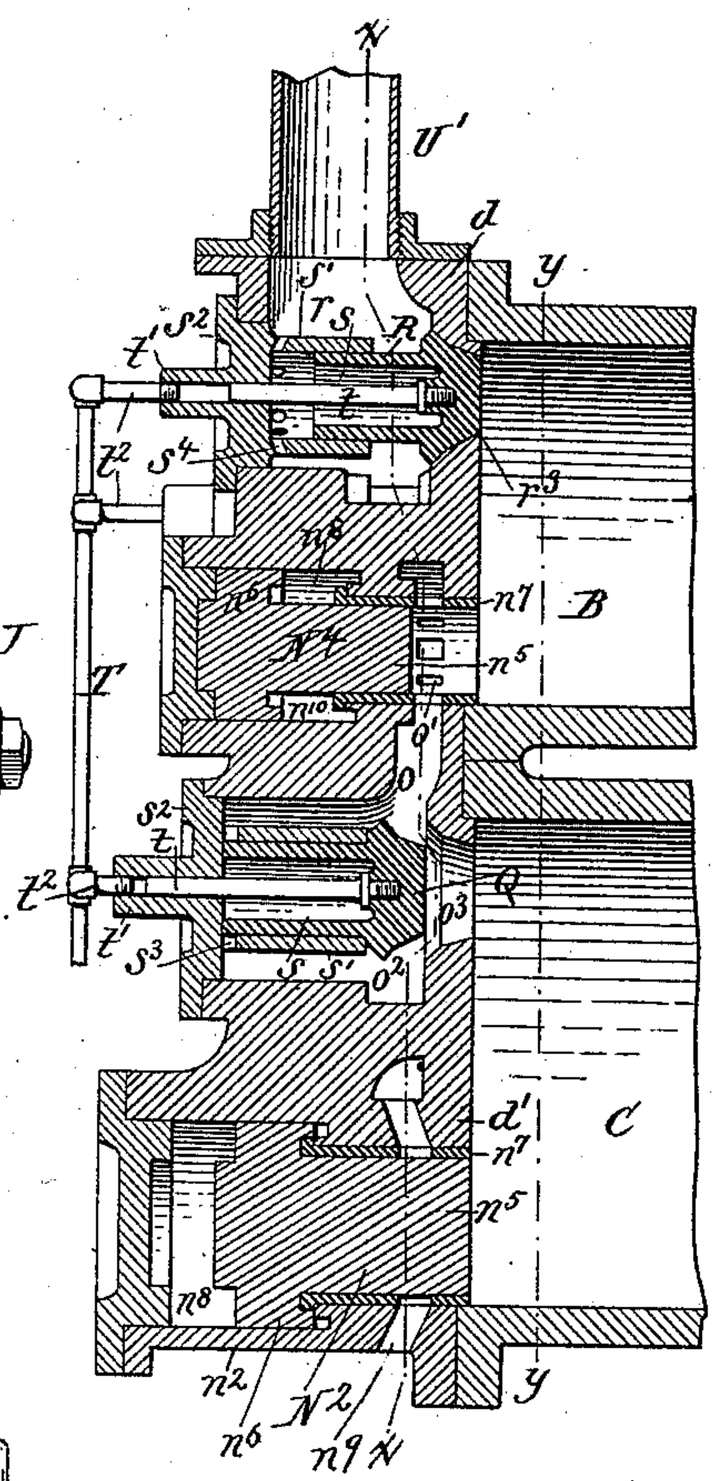


Fig. 4.



Witnesses:
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(No Model.) 7 Sheets—Sheet 4.

U. CUMMINGS.

AIR COMPRESSOR.

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Fig. 5.

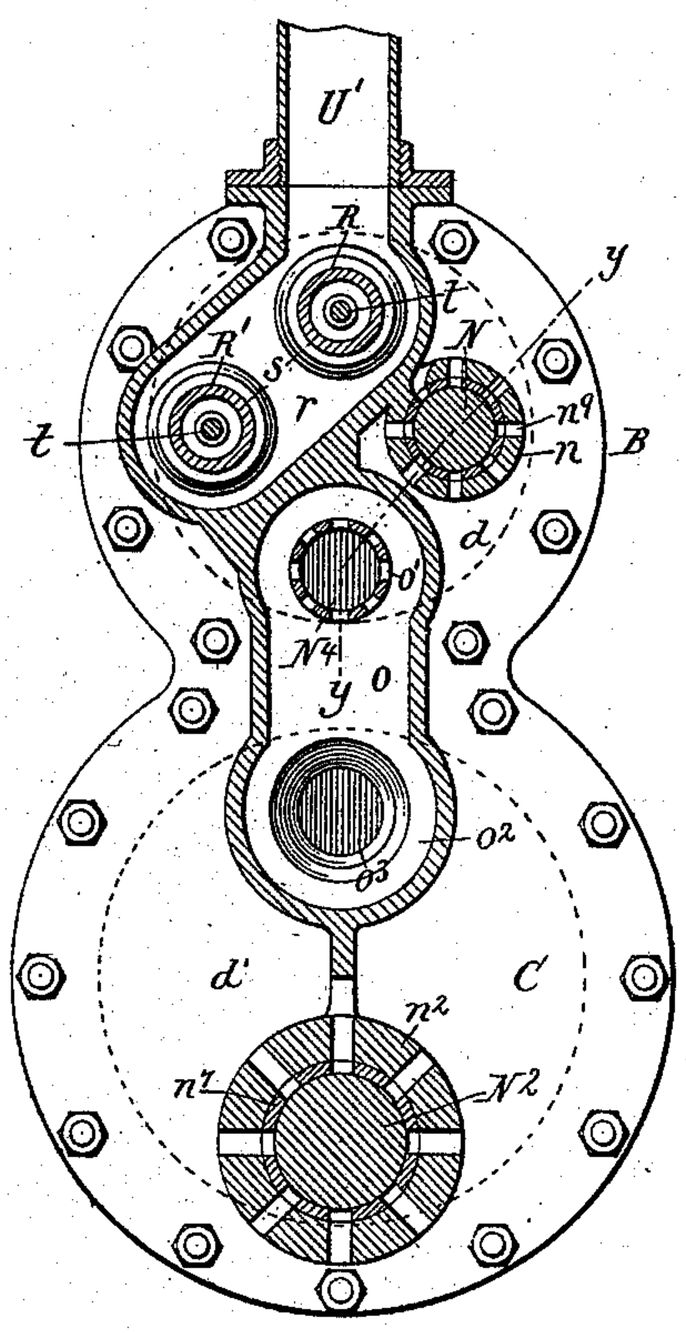


Fig. 6.

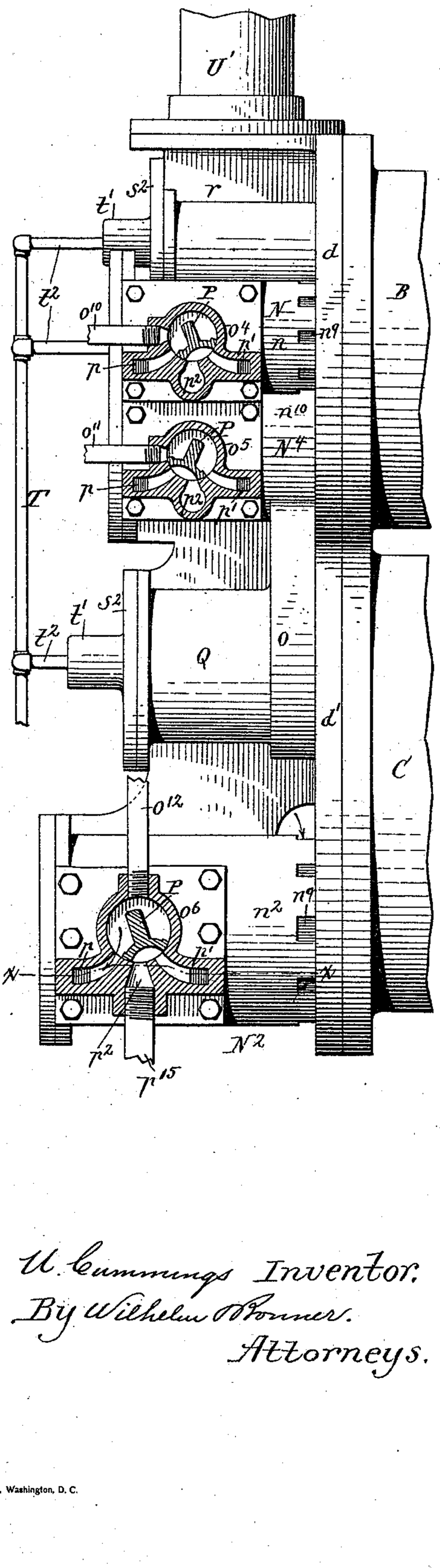
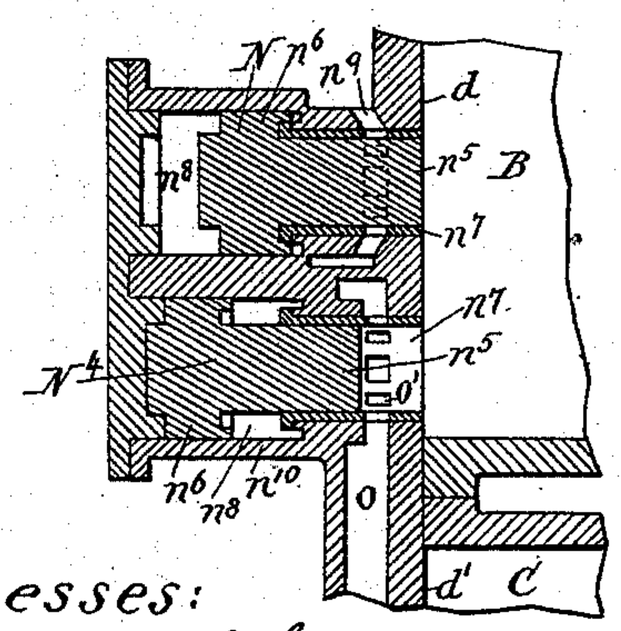


Fig. 7.



Witnesses:
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(No Model.) 7 Sheets—Sheet 5.

U. CUMMINGS.

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Fig. 8.

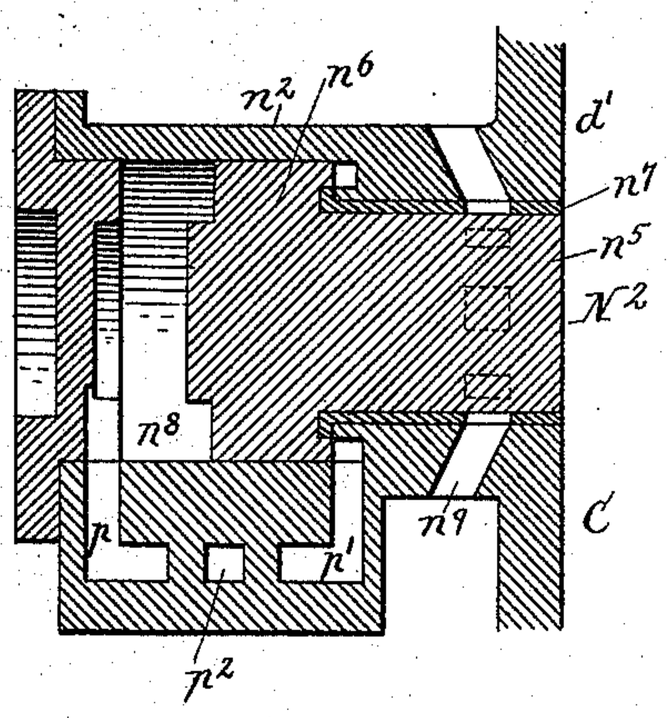


Fig. 9.

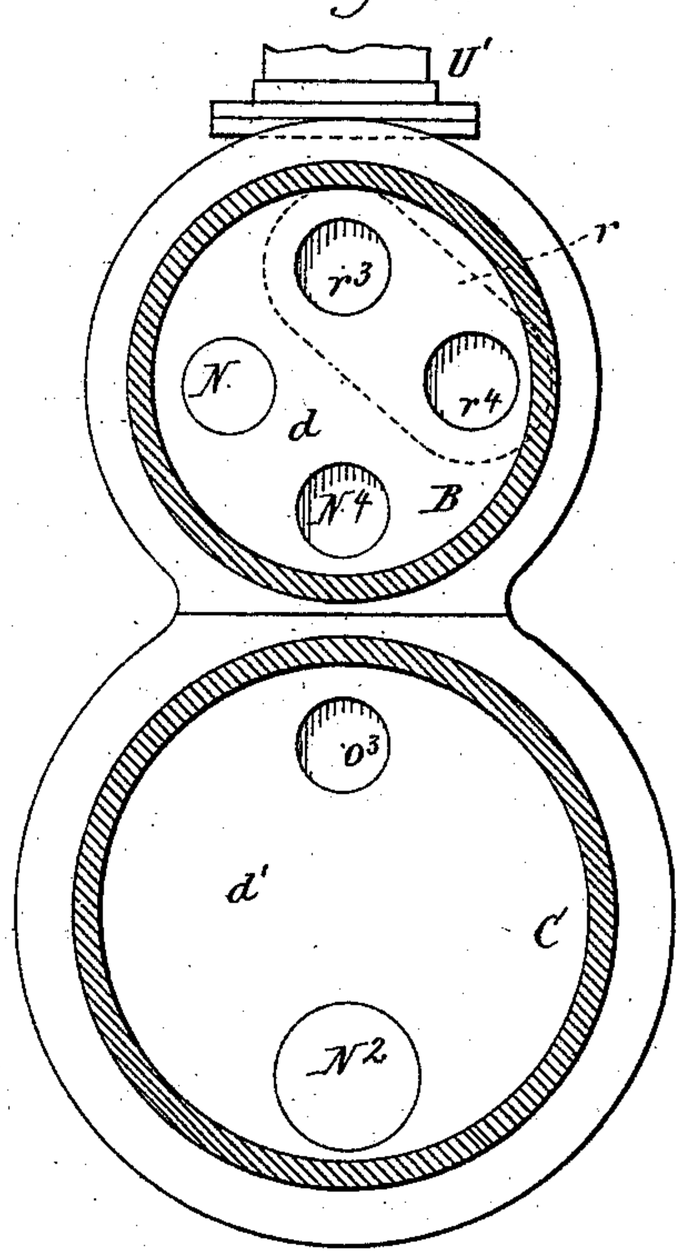
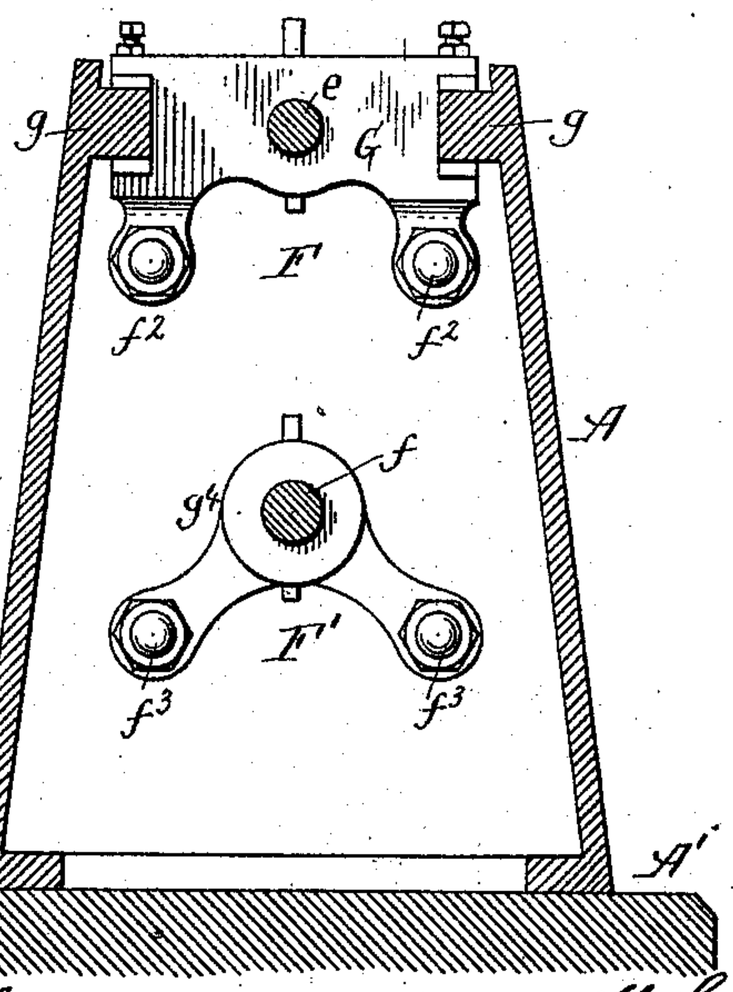


Fig. 14.



Witnesses:
Chas. J. Buchheit
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(No Model.) 7 Sheets—Sheet 6.

U. CUMMINGS.

AIR COMPRESSOR.

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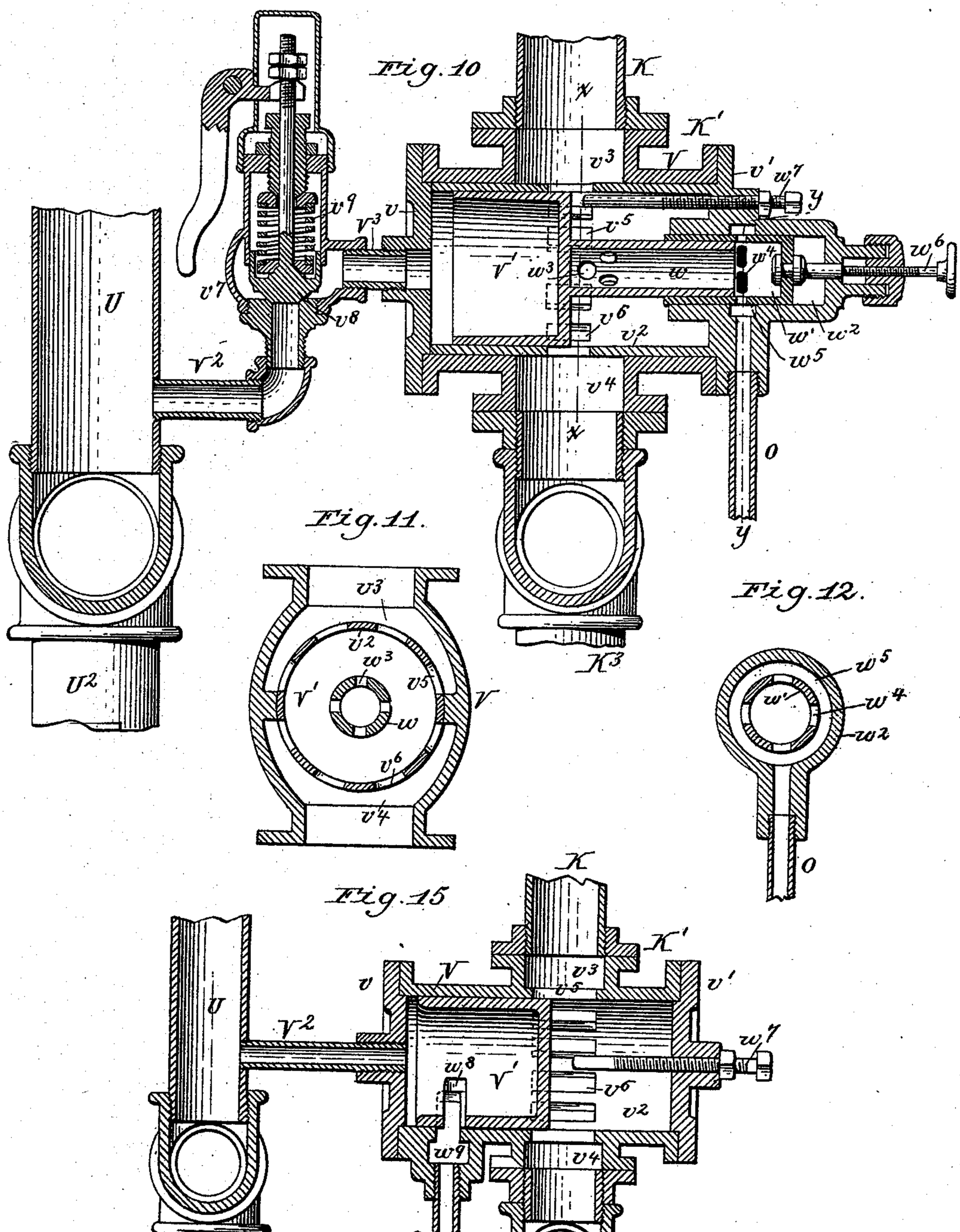

Fig. 10

Fig. 11.

Fig. 12.

Fig. 15

Witnesses:
Chas. J. Buckheit
Geo. J. Buckheit Jr.

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(No Model.)

7 Sheets—Sheet 7.

U. CUMMINGS.

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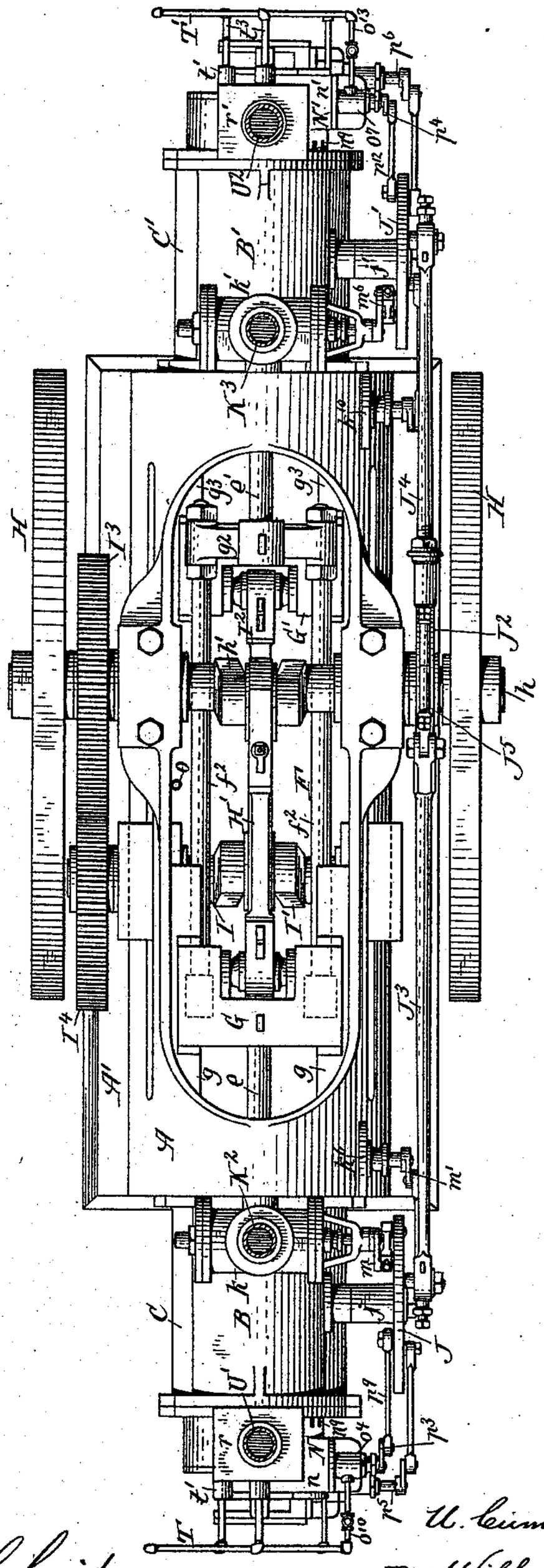

Fig. 13.

Witnesses:
Chas. J. Buchheit.
Geo. J. Buchheit Jr.

U. Cummings Inventor.
By Wilhelm & Bonner.
Attorneys.

UNITED STATES PATENT OFFICE.

URIAH CUMMINGS, OF BUFFALO, NEW YORK.

AIR-COMPRESSOR.

SPECIFICATION forming part of Letters Patent No. 412,474, dated October 8, 1889.

Application filed May 23, 1888. Serial No. 274,774. (No model.)

To all whom it may concern:

Be it known that I, URIAH CUMMINGS, of the city of Buffalo, in the county of Erie and State of New York, have invented new and useful Improvements in Air-Compressors, of which the following is a specification.

This invention relates to that class of air-compressors which are employed for compressing air to a high pressure by a reciprocating piston moving in a cylinder.

The objects of my invention are to produce an air-compressor which contains compound cylinders for the steam and air, and which can be run at a high rate of speed to increase the compressing capacity of the compressor and effect a corresponding saving of fuel; to improve the construction of the air-valves and their actuating mechanism, and to improve the automatic regulator by which the supply of steam to the compressor is controlled.

My invention consists to these ends of the improvements which will be hereinafter fully described, and pointed out in the claims.

In the accompanying drawings, consisting of seven sheets, Figure 1 is a side elevation of my improved air-compressor. Fig. 2 is a longitudinal sectional elevation of the same. Fig. 3 is an end elevation on an enlarged scale. Fig. 4 is a vertical sectional elevation of one end of the cylinders and connecting parts in line *x x*, Fig. 3. Fig. 5 is a cross-section in line *x x*, Fig. 4. Fig. 6 is a side elevation of one end of the cylinders and connecting parts, on an enlarged scale, showing the steam-valves of the air-valve mechanism in section. Fig. 7 is a longitudinal section in line *y y*, Fig. 5. Fig. 8 is a horizontal section in line *x x*, Fig. 6, on an enlarged scale, showing the arrangement of the steam-ports. Fig. 9 is a cross-section in line *y y*, Fig. 4, looking outwardly. Fig. 10 is a cross-section of the regulating mechanism in line *y y*, Fig. 2, on an enlarged scale. Fig. 11 is a cross-section in line *x x*, Fig. 10. Fig. 12 is a cross-section in line *y y*, Fig. 10. Fig. 13 is a top plan view of the compressor with the steam and air pipes removed. Fig. 14 is a vertical cross-section in line *x x*, Fig. 2, on an enlarged scale. Fig. 15 is a sectional elevation of a modified construction of the automatic regulator.

Like letters of reference refer to like parts in the several figures.

A represents the frame of the compressor, secured at its base to a bed or foundation A′, and having longitudinal side walls *a* and vertical end walls *a′ a²*.

B B′ represent the high-pressure cylinders arranged in line and secured at their inner ends on opposite ends of the frame A to the upper ends of the vertical walls *a′ a²*, respectively.

C C′ represent the low-pressure cylinders arranged in line and secured at opposite ends of the frame A to the end walls *a′ a²* below the cylinders B B′, respectively. The inner ends of the cylinders B B′ C C′ are closed by heads *b b′ c c′*, preferably formed on the vertical end walls *a′ a²* of the frame A.

d d′ represent heads, which close the outer ends of the cylinders B C, respectively, and which are preferably formed in one piece, as shown in Figs. 3 and 5.

d² d³ represent heads, which close the outer ends of the cylinders B′ C′, respectively, and which are also preferably formed in one piece.

The high-pressure cylinder B and low-pressure cylinder C are arranged at one end of the frame A, and the high-pressure cylinder B′ and low-pressure cylinder C′ are arranged at the opposite end of this frame.

D D′ represent the pistons of the high-pressure cylinders B B′, and *e e′* represent the piston-rods, which are respectively connected with the pistons D D′, and which pass through stuffing-boxes in the heads *b b′* of the cylinders B B′.

E E′ represent the pistons of the low-pressure cylinders C C′; and *f f′* represent the piston-rods, which are respectively connected with the pistons E E′, and which pass through stuffing-boxes in the heads *c c′* of the cylinders C C′.

F represents a yoke arranged between the longitudinal side pieces *a* of the frame A, and connecting the piston-rods *e e′* of the high-pressure cylinders B B′; and F′ represents a similar yoke arranged below the yoke F and connecting the piston-rods *f f′* of the low-pressure cylinders C C′. The upper yoke F is provided at one end with a cross-head G, which is connected with the piston-rod *e* of

the high-pressure cylinder B, and which moves on guides g, secured to the main frame, while the opposite end of the yoke F is provided with an upwardly-projecting head g^2, to which the piston-rod e', of the high-pressure cylinder B′ is attached. The lower yoke F′ is provided at one end with a cross-head G′, which is arranged below the head g^2 of the upper yoke, and to which the piston-rod f' of the low-pressure cylinder C′ is attached. This cross-head G′ moves on guides g^3. The opposite end of the lower yoke is provided below the cross-head G with an upwardly-projecting head g^4, to which the piston-rod of the low-pressure cylinder C is attached. The bodies of the yokes F F′ consist each of two parallel rods f^2 f^3, respectively, having their ends screw-threaded and attached to the cross-heads G G′ and heads g^2 g^4 by screw-nuts, which permit of a nice adjustment of the pistons in the cylinders.

h represents the main driving-shaft of the compressor arranged transversely in the frame A, between the high-pressure cylinders; and H represents the fly-wheels secured to opposite ends of the shaft.

h' represents a crank formed on the shaft h centrally between the side walls of the frame A, and connected with the cross-head G of the upper yoke F by a rod H′.

I represents a crank-shaft arranged between the low-pressure cylinders and having its crank I′ connected with the cross-head G′ of the lower yoke F′ by a rod I^2.

The two longitudinal rods constituting the main portion or body of each yoke are arranged sufficiently apart laterally to enable the crank and connecting-rod to move freely between them, and, as both bars of the yoke are arranged on the same side of the shaft with which they are connected, the parts of the yoke are arranged more closely together than when the two parts of the yoke are arranged on opposite sides of the same shaft, whereby a more compact construction is obtained and lighter bars can be used.

I^3 represents a gear-wheel secured to the main shaft h between one of the fly-wheels H and the frame A, and meshing with a similar gear-wheel I^4, secured to the lower shaft I, and whereby motion is transmitted from the main shaft to the lower shaft in such manner that the pistons D D′ of the high-pressure cylinders move in a direction opposite to that of the pistons E E′ of the low-pressure cylinders.

J represents a vertical wrist plate or disk arranged at one end of the machine on one side of the cylinders B C, and mounted on a stud j, secured to the cylinders B C.

J′ represents a similar disk arranged at the opposite end of the machine on the same side of the cylinders B′ C′, and mounted on a stud j', secured to these cylinders.

J^2 represents an eccentric secured to the main shaft h, and J^3 J^4 represent eccentric-rods connected at their inner ends to opposite sides of the ring J^5 on the eccentric J^2, and at their outer ends to the disks J J′, respectively, whereby the latter are actuated.

K represents the main steam-supply pipe connected with the upper end of a regulating device K′, which will be hereinafter more fully described; and K^2 K^3 represent branch steam-pipes connected at their upper ends with the lower portion of the regulating device K′, and at their lower ends with the valve-chambers k k' of the high-pressure cylinders. These valve-chambers are arranged on the upper inner ends of the high-pressure cylinders B B′ and contain induction-valves k^2 k^3.

k^4 k^5 represent the induction-ports connecting the valve-chambers k k' with the upper inner ends of the high-pressure cylinders B B′, respectively, and formed partly in the lower portions of the valve-chambers and partly in the inner heads of the cylinders.

k^6 represents a valve-chamber formed on the end wall a' of the main frame between the high-pressure cylinder B and the low-pressure cylinder C.

k^7 is a port leading from the high-pressure cylinder B to this valve-chamber k^6, and k^8 is a port leading from this valve-chamber to the low-pressure cylinder C.

k^9 is a valve arranged in this valve-chamber k^6, whereby the flow of steam from the high-pressure cylinder to the low-pressure cylinder is controlled.

k^{10} represents a similar valve-chamber arranged on the opposite end of the machine between the high-pressure cylinder B′ and the low-pressure cylinder C′, and provided with similar ports k^{11} k^{12} and a valve k^{13}.

L represents the exhaust-chamber formed on the lower inner end of the low-pressure cylinder C, with which it communicates by a port l.

l' represents the exhaust-valve arranged in the chamber L.

L′ represents the exhaust-chamber formed on the low-pressure cylinder C′, and provided with an exhaust-port l^2 and valve l^3.

m m' m^2 represent arms secured to the stems of the valves k^2, k^9, and l', respectively; and m^3 m^4 m^5 are rods connecting the wrist-plate J with the valve-arms m m' m^2, respectively.

m^6 m^7 m^8 represent arms secured to the stems of the valves k^3, k^{13}, and l^3, respectively; and m^9 m^{10} m^{11} represent rods connecting the wrist-plate J′ to the valve-arms m^6 m^7 m^8, respectively.

When the pistons are moving in the direction of the arrows in Fig. 2, the induction-valve k^2 of the high-pressure cylinder B and the exhaust-valve l' of the low-pressure cylinder C are closed, and the intermediate valve k^9 is open and allows the steam to pass from the upper cylinder B to the lower cylinder C, while the induction-valve k^3 of the high-pressure cylinder B′ and the exhaust-valve l^3 of the low-pressure cylinder C′ are open, and

the intermediate valve k^{13} is closed and cuts off communication between the cylinders B′ and C′. When the pistons have reached the limit of their movement, the valves k^2, k^9, and l' of the cylinders B C are moved by the eccentric-rod J³, wrist-plate J, and connecting-rods m^3 m^4 m^5 so as to open the induction-valve k^2 of the cylinder B and close the intermediate valve k^9 and open the exhaust-valve l' of the low-pressure cylinder C, while the valves k^3, k^{13}, and l^3 of the cylinders B′ C′ are moved by the eccentric-rod J⁴, wrist-plate J′, and connecting-rods m^9 m^{10} m^{11} so as to close the induction-valve k^3 of the cylinder B′ and open the intermediate valve k^{13} and close the exhaust-valve l^3 of the low-pressure cylinder C′, ready for a return-stroke of the pistons.

N N′ represent steam-actuated air-inlet valves arranged in chambers n n', formed on the outer side of the heads d d^2 of the high-pressure cylinders B B′, respectively; and N² N³ represent similar air-inlet valves arranged in chambers n^2 n^3, formed on the outer heads d' d^3 of the low-pressure cylinders C C′, respectively.

As clearly shown in Figs. 2, 4, 7, and 8, each of the air-inlet valves N N′ N² N³ is composed of a cylindrical portion n^5 and an enlarged piston portion n^6. The cylindrical portion n^5 moves in a bore n^7, formed in the casing of each valve-chamber and connecting at its inner end with its respective cylinder. The enlarged outer or piston portion n^6 moves in a cylinder n^8, forming part of the valve-chamber.

n^9 represents radial air-inlet openings formed near the inner end of each of the valve-chambers n n' n^2 n^3, and through which air is admitted to the respective cylinders when the valves N N′ N² N³ are moved outwardly far enough to uncover these openings, and which are closed so as to cut off the supply of air to the cylinders when these valves are moved inwardly to the position shown in Fig. 8.

N⁴ N⁵ represent steam-actuated intermediate air-valves arranged in chambers n^{10} n^{11}, which are formed on the lower portions of the heads d d^2 and connect at their inner ends with the high-pressure cylinders B B′, respectively. The valves N⁴ N⁵ alternately open and close the communication between the high and low pressure cylinders, and are constructed similar to the valves N N′ N² N³. Each of these valves is provided with a cylindrical portion n^5, moving in a perforated sleeve or bore n^7, and an enlarged outer or piston portion n^6, moving in a cylinder n^8, formed in the outer ends of the chambers n^{10} n^{11}. The bores in which these valves move are preferably provided with bushings, as represented in the drawings.

o represents passages formed in the heads d d^2 of the high-pressure cylinders B B′, respectively, and partly in the heads d' d^3 of the low-pressure cylinders C C′, respectively. The upper ends of the passages o communicate with the high-pressure cylinders B B′ through a series of opening o', formed in the sleeves n^7 of the valves N⁴ N⁵, and at their lower ends with a chamber o^2, formed in the upper portion of the heads d' d^3 of the low-pressure cylinders C C′, respectively. The chambers o^2 are connected with the high-pressure cylinders C C′ by openings o^3, arranged in the heads d' d^3 opposite the central portions of the chambers o^2.

o^4 o^5 o^6 represent valve-chests secured to the chambers of the air-valves N N⁴ N², respectively, on one side of the machine; and o^7 o^8 o^9 represent similar valve-chests secured to the chambers of the air-valves N′ N⁵ N³, respectively, on the other side of the machine.

O represents a steam-pipe connected to one end of the regulating device K′, and extending downwardly on the inner side of one of the side walls a of the main frame. This pipe is provided at its lower end with two branch pipes O′ O², which pass outwardly through the end walls a' a^2, and thence forwardly and upwardly. The valve-chests o^4 o^5 o^6 on one end of the machine are connected with the branch pipe O′ by branches o^{10} o^{11} o^{12}, respectively, and the valve-chests o^7 o^8 o^9 on the opposite end of the machine are connected with the branch pipe O² by branches o^{13} o^{14} o^{15}, respectively, as shown in Figs. 6 and 8. Each of the valve-chests o^4 o^5 o^6 o^7 o^8 o^9 is provided with steam-ports p p', leading to opposite ends of the cylinders, in which the valves move, and with an exhaust-port p^2, as shown in Fig. 6.

P represents rock-valves, one of which is arranged in each of the valve-chests o^4 o^5 o^6 o^7 o^8 o^9, and whereby steam is admitted alternately to opposite sides of the pistons n^6 of the valves N N′ N² N³ N⁴ N⁵, so as to actuate the latter.

As clearly shown in Fig. 1, p^3 p^4 p^5 p^6 p^7 p^8 are arms secured, respectively, to the stems of the rock-valves P of the air-inlet valves N N′ N² N³ and the intermediate air-valves N⁴ N⁵, respectively.

p^9 p^{10} p^{11} represent rods connecting the wrist-plate J with the arms p^3 p^7 p^5, respectively; and p^{12} p^{13} p^{14} represent similar rods connecting the wrist-plate J′ with the arms p^4 p^8 p^6, respectively.

p^{15} represents an exhaust-pipe arranged at one end of the compressor and connected with the exhaust-ports p^2 of the valve-chambers n n^{10} n^2; and p^{16} represents a similar pipe arranged at the opposite end of the compressor and connected with the exhaust-ports p^2 of the valve-chambers n' n^{11} n^3.

Q Q′ represent check-valves arranged in the air-chambers o^2 of the low-pressure cylinders C C′, respectively, and which are adapted to seat themselves in the opening o^3 of the low-pressure cylinders C C′, and close said openings when the pistons E E′ move inwardly, while these valves are moved away from their seats when the pistons E E′ approach these valves.

r r' represent air-chambers arranged near the upper ends of the high-pressure cylinders B B′, respectively. Each of these chambers is provided with two check or air-discharge valves R R′, which are adapted to seat themselves in outlet-openings r^3 r^4, formed in the heads d d^2, and which connect the chambers r r' with the high-pressure cylinders B B′. The valve R is arranged near the top of the cylinders B B′, and the valve R′ below the valve R on one side thereof, as clearly shown in Figs. 3 and 5. Each of the check-valves Q Q′ and R R′ is provided on its back with a horizontal hollow sleeve s, which moves in a cylinder s', formed on a head s^2. The latter is arranged opposite the air-outlet opening of the respective cylinder and closes the outer end of the check-valve chamber. The cylinders s' of the valves Q Q′ are provided near the inner sides of the heads s^2 with openings s^3, which connect the air-chambers o^2 with the interior of these cylders s', so as to cause the back-pressure to act upon the sleeves of the valves and keep the valves closed. The cylinders s' of the check-valves R R′ are provided with similar opening s^4 for the same purpose. Each of the check-valves Q Q′ R R′ is provided with a rod or stem t, arranged centrally on the back of the valve. The outer end of this stem enters a small steam chamber or cylinder t', formed in the head s^2 of the valve-chamber. The outer ends of the steam-chambers t', arranged at one end of the compressor, are connected to a steam-supply pipe T by branches t^2. The steam-pipe T is connected at its lower end to the branch O′ of the steam-pipe O. The steam-chambers t' of the heads s^2, arranged at the opposite end of the compressor, are connected to a steam-pipe T′ by branches t^3, which latter are also tapped into the outer ends of the steam-chambers t'. The pipe T′ is connected at its lower end to the branch O² of the steam-pipe O. By thus connecting steam-pipes to the chambers t' of the valves Q Q′ R R′ a sufficient pressure is brought to bear upon these valves to insure a rapid inward or closing movement of the valves without the use of springs, and whereby a clean and sharp cut-off is effected, thereby greatly increasing the duty of the compressor.

U represents the main air-discharge pipe, having branches U′ U², which are connected, respectively, with the upper ends of the air-chambers r r' of the high-pressure cylinders B B′, respectively.

The regulator K′, by which the steam-supply to the compressor is automatically controlled, is provided with a casing V, closed at its ends by heads v v', and a cylinder v^2, arranged within said casing.

v^3 represents the steam-inlet chamber, which is mounted on the upper portion of the casing V, and connected with the steam-supply pipe K.

v^4 represents the steam-outlet chamber arranged on the lower side of the casing V, and connected with the pipes K² K³, leading to the compressor.

v^5 represents slots or openings formed in the upper portion of the cylinder V, and through which the steam passes from the inlet-chamber v^3 to the interior of the cylinder v^2; and v^6 represents similar openings arranged in the lower portion of the cylinder v^2, and through which the steam passes from the cylinder v^2 to the outlet-chamber v^4 and branch pipes K² K³.

V′ represents a piston-valve, which moves in one end of the cylinder v^2 and regulates the supply of steam from the main steam-pipe K to the branches K² K³ by opening and closing the openings v^5 v^6, connecting the inlet-chamber v^3 with the lower outlet-chambers v^4.

V² represents a pipe leading from the main air-discharge pipe U to the regulator. This pipe is connected with a casing v^7, in which is arranged a valve v^8, which closes the pipe V² and prevents the air from passing to the regulator through the connecting-pipe V³ until the air-pressure in the pipe U has reached a certain predetermined point, to which the valve v^8 is loaded by a spring v^9, or otherwise. When the air-pressure exceeds this point, the valve v^8 is raised and the air passes through the pipe V³ to the regulator. The valve v^8 allows the air-pressure to be raised higher than the steam-pressure before the air is admitted to the regulator. The connecting-pipe V³ is provided with a pin-hole, through which the air between the valve v^8 and the piston-valve V′ is allowed to escape very slowly. The pressure in the air-pipe U is thus thrown against one side of the piston V′, so that the air-pressure tends to move the piston in the direction in which it is required to move in order to close the openings v^5 v^6, while the steam entering the cylinder v^2 presses against the opposite side of the piston-valve.

w represents a hollow stem formed centrally on the inner end of the piston-valve V′ and entering a longitudinally-adjustable sleeve w'. The latter is arranged in a chamber w^2, formed on the head v' of the casing V.

w^3 represents perforations which are formed in the stem w near the valve V′, and through which the steam enters the hollow stem.

w^4 represents perforations which are formed in the sleeve w' near the end of the valve-stem w and opposite a steam-chamber w^5, surrounding the sleeve w' at this point. This steam-chamber is connected at its lower end to the steam-pipe O, which supplies steam to the cylinders of the air-valves and check-valves, as before described. Steam passes from the cylinder v^2 to the pipe O, through the perforations w^3 of the stem w, the perforations w^4 of the sleeve w', and the steam-chamber w^5.

w^6 represents a screw-stem connected with the outer closed end of the sleeve w', and whereby the latter can be adjusted so as to

cause the openings w^4 to be closed by a greater or less movement of the sleeve w', as may be necessary.

w^7 represents an adjustable stop whereby the closing movement of the piston-valve is limited.

When the air-pressure in the air-discharge pipe U exceeds the normal, the valve V′ of the regulating device K′ is moved inwardly by the air-pressure, so as to partially cut off the supply of steam from the main pipe K to the branch pipes K^2 K^3, and whereby the speed of the compressor is correspondingly reduced. Should the air-pressure still exceed the normal after the speed has been reduced, (which may be the case when the compressed air is not used in sufficient quantities,) the air-pressure continues to move the valve V′ inwardly until its hollow stem w covers the openings w^4 of the sleeve w', whereby the supply of steam to the chamber w^5, and consequently to the steam-cylinder of the air-inlet valves N N′ N^2 N^3 and the intermediate valves N^4 N^5, is cut off. The steam-pressure being so removed from these valves, they simply move outward when the actuating-pistons D D′ E E′ next approach the valves, and then remain in this outward position, leaving the air-inlet passages open, so that the air enters the cylinders and is expelled therefrom through these passages. Should the air-pressure fall below the normal, the steam-pressure against the back of the valve V′ forces the latter outwardly, and thereby increases the flow of steam from the main to the branch pipes and correspondingly increases the speed of the machine.

When the valve V′ is in its extreme inward position, it does not entirely cut off the supply of steam, but admits only enough steam to the cylinders to produce a very slow movement of the machine, so that the latter will always be ready for duty should the air-pressure be reduced. The openings w^4 of the sleeve w' are so located with reference to the stem w of the valve V′ that when the latter is moved inwardly by the steam-pressure sufficiently to again produce an active speed in the machine the openings w^4 are also again opened to admit steam to the cylinders of the air and check valves, so as to again render these valves operative.

When the piston D of the high-pressure cylinder B and the piston E′ of the low-pressure cylinder C′ are in position ready to begin their inward stroke, and the piston D′ of the high-pressure cylinder B′ and the piston E of the low-pressure cylinder C are in position ready to begin their outward stroke, the valves of the several cylinders are in the following position: The steam-valve k^3 is open and allows the steam to pass through the port k^5 into the high-pressure cylinder B′ back of the piston D′, the intermediate steam-valve k^9, between the high-pressure cylinder B and low-pressure cylinder C, is open and allows the steam to exhaust from the high-pressure cylinder B into the low-pressure cylinder C back of the piston E, the air-inlet valve N of the high-pressure cylinder B is open and the air-inlet valve N′ of the high-pressure cylinder B′ is closed, the air-inlet valve N^2 of the low-pressure cylinder C is closed, and the air-inlet valve N^3 of the low-pressure cylinder C′ is open, and the intermediate air-valves N^4 N^5, connecting the high and low pressure cylinders B C and B′ C′, respectively, are closed. The steam acting upon the diagonally-opposite pistons D′ and E of the high-pressure cylinder B′ and low-pressure cylinder C causes these pistons to move in opposite directions, as indicated by the arrows in Fig. 2, whereby the air contained in the high-pressure cylinder B′ is compressed and expelled through the check-valve chamber r' and branch air-pipe U^2, the high-pressure cylinder B and the low-pressure cylinder C′ are taking in air through the open air-valves N N^3, respectively, and the air contained in the low-pressure cylinder C is being compressed therein. The air-inlet valve N^3 of the low-pressure cylinder C′ remains open until the piston has reached the end of its inward stroke, so as to allow the cylinder to become filled with air, and the intermediate valve N^5 and the air-inlet valve N′ of the high-pressure cylinder B′ will remain closed until all the air contained in the high-pressure cylinder B′ has been expelled therefrom. The air-inlet valve N of the high-pressure cylinder B remains open only long enough to allow this cylinder to become filled with external air until its piston D has made about one-half its backward stroke, when the air-inlet valve N is closed. Immediately after this occurs the intermediate valve N^4 is opened, so as to allow the compressed air in the low-pressure cylinder C to be forced into the high-pressure cylinder B through the air-chamber o. The intermediate valve N^4 now remains open until the piston D has reached the end of its inward stroke and the piston E the end of its outward stroke, and all the air contained in the cylinder C has been forced into the high-pressure cylinder B. The steam behind the piston E of the low-pressure cylinder C escapes through the exhaust-port l during the backward stroke of the piston. At the moment that the pistons D D′ and E E′ reverse their movement the several valves are shifted as follows: The steam-valve k^3 of the high-pressure cylinder B′ is closed and the intermediate steam-valve k^{13} is opened and allows the steam in the high-pressure cylinder B′ to pass into the low-pressure cylinder C′, behind the piston E′, and the exhaust-valve l^3 is closed. The steam-valve k^2 of the high-pressure cylinder B is opened and admits the steam to the cylinder B behind the piston D thereof and the intermediate valve k^9 is closed, so as to prevent the steam from passing into the low-pressure cylinder C, and the exhaust-valve of the latter is opened to allow the steam contained therein to escape.

The air-inlet valve N of the high-pressure cylinder B remains closed. The air-inlet valve N′ of the high-pressure cylinder B′ is opened. The air-inlet valve N^2 of the low-pressure cylinder C is opened. The air-inlet valve N^3 of the low-pressure cylinder C′ is closed, and the intermediate air-valves N^4 N^5, connecting the high and low pressure cylinders B C and B′ C′, respectively, are also closed. The steam now acts upon the diagonally-opposite pistons D and E′ of the high-pressure cylinder B and low-pressure cylinder C′ and moves the same outwardly, whereby the compressed air contained in the high-pressure cylinder B is expelled therefrom through the chamber *r* and branch pipe *u*, while the opposite high-pressure cylinder B′ and the low-pressure cylinder C are taking in air through the open air-valves N′ N^2, respectively, and the air contained in the low-pressure cylinder C′ is compressed therein. The air-inlet valve N^2 of the low-pressure cylinder C now remains open until the piston E has reached the end of its inward stroke, so as to allow this cylinder to fill with air, and the intermediate valve N^4 and the air-inlet valve N′ of the high-pressure cylinder B remain closed until all the compressed air contained in the high-pressure cylinder B has been expelled therefrom, while the air-inlet valve N′ of the high-pressure cylinder B′ remains open only long enough to allow this cylinder to fill with external air, or until its piston D′ has made about one-half its backward or inward stroke, when the air-inlet valve N′ is closed. Immediately after the valve N′ is closed the intermediate valve N^5 is opened, so as to allow the compressed air contained in the lower cylinder C′ to be forced into the high-pressure cylinder B′ through the air-chamber *o*. The intermediate valve N^5 now remains open until the piston D′ has reached the end of its inward stroke and the piston E′ the end of its outward stroke, and the air contained in the low-pressure cylinder C′ has been forced into the high-pressure cylinder B′. The various valves will now again be shifted back to their former position, ready for the return-stroke, as first above described. In this manner each cylinder operates alternately as a steam-cylinder and as an air-cylinder, and each cylinder is supplied with steam at every other stroke, whereby the contact-surfaces of the cylinders and pistons are at short intervals supplied with moisture, which insures the smooth running of the machine and prevents the parts from becoming overheated. The low-pressure cylinders are made, preferably, about twice as large in area as the high-pressure cylinders, and the latter take external air during about half of the stroke, so that the aggregate volume of air which is compressed at one stroke of the high-pressure cylinder-piston is about two and a half times as large as the capacity of the high-pressure cylinder, whereby the compressing capacity of the machine is largely increased. The external air, which is admitted into the high-pressure cylinder, also serves to cool this cylinder. This admission of external air to the high-pressure cylinder is rendered possible by the action of the intermediate air-valves N^4 N^5, which prevent the compressed air in the low-pressure cylinders from entering the high-pressure cylinders until the pistons of the latter have made about half of their return-stroke.

The air-valves are flush with the cylinder-heads when closed, whereby dead-air spaces are avoided. The air-valves, which are provided with actuating-pistons, are held fully open while the air passes into the cylinders, and are opened and closed instantly by the pressure of the steam against these pistons. This avoids loss of time in opening, which takes place when such valves are opened against spring-pressure and prevents the wire-drawing of the air when such valves are actuated by eccentric or other mechanism from the shaft. The pistons of these valves are so much larger in diameter than the valves themselves that the steam-pressure on their pistons overcomes the air-pressure in the cylinders.

By arranging the high-pressure and low-pressure cylinders side to side, or one above the other, as shown, instead of end to end, the length of the connecting steam and air passages is reduced to a minimum and a very compact construction of the valve mechanism is obtained.

The air-valves may be actuated by compressed air, instead of steam, by providing the piston-valve V′ with a port w^8, which supplies the compressed air to a chamber w^9. In this case the pipe O, leading to the cylinder of the air-valves N N′ N^2 N^3 and the intermediate valves N^4 N^5, is connected with the chamber w^9, and the port w^8 is so arranged that it cuts off the air-pressure when the piston-valve has reached the end of its closing movement. In this construction, which is represented in Fig. 15, the intermediate valve v^8 is omitted.

I claim as my invention—

1. The combination, with a high-pressure and a low-pressure actuating cylinder and the pistons working in the same, of steam-valves whereby steam is admitted into the high-pressure cylinder, exhausted therefrom into the low-pressure cylinder, and discharged from the low-pressure cylinder, air-valves whereby the air is admitted into the low-pressure cylinder and from the latter into the high-pressure cylinder and discharged from the latter, a fly-wheel shaft rotated from said pistons, and valve mechanism, substantially as described, whereby the steam-valves are actuated from said shaft, substantially as set forth.

2. The combination, with the high-pressure cylinder and the low-pressure cylinder arranged side to side, pistons working in the same, and connecting mechanism, substantially as described, whereby the pistons are caused to move in opposite directions, of a

steam-induction valve, an intermediate steam-valve, and a steam-exhaust valve, all arranged at one end of said cylinders, and an air-inlet valve, an intermediate air-valve, and air-discharge valve, all arranged at the opposite ends of said cylinders, substantially as set forth.

3. The combination, with a pair of high-pressure and low-pressure cylinders arranged side to side at each end of the machine and the pistons working in said cylinders, of two geared shafts arranged between the two pairs of cylinders, one shaft connected with the pistons of the high-pressure cylinders and the other shaft with the pistons of the low-pressure cylinders, steam-induction valves, intermediate steam-valves, and steam-exhaust valves arranged at the inner ends of the cylinders, and air-inlet valves, intermediate air-valves, and air-discharge valves arranged at the outer ends of the cylinders, substantially as set forth.

4. The combination, with a compressing-cylinder provided with a cylindrical air-inlet passage having air-inlet openings in its side, of a cylindrical air-valve arranged in said passage and provided at its outer end with an enlarged piston, a cylinder in which said piston moves, a valve-chamber, ports connecting said valve-chamber with the piston-cylinder on opposite sides of the piston, and a valve arranged in said valve-chamber, whereby a fluid under pressure can be admitted to the cylinder on either side of the piston, substantially as set forth.

5. The combination, with the low-pressure cylinder provided with an air-inlet valve, a high-pressure cylinder, a positively-controlled intermediate valve whereby the compressed air is excluded from and admitted to the high-pressure cylinder, and a check-valve arranged in the air-passage between the intermediate valve and the low-pressure cylinder, substantially as set forth.

6. The combination, with the low-pressure cylinder provided with an air-inlet valve, a high-pressure cylinder, a positively-controlled intermediate valve whereby the compressed air is excluded from and admitted to the high-pressure cylinder, a check-valve arranged in the air-passage between the intermediate valve and the low-pressure cylinder, and an air-inlet valve connected with the high-pressure cylinder and admitting external air thereto, substantially as set forth.

7. The combination, with the compressing-cylinder, of an air-inlet valve provided with an actuating-piston, a cylinder in which said piston moves, a valve whereby the flow of the actuating-fluid to and from opposite ends of the valve-cylinder is controlled, valve-gear whereby said valve is actuated, and an automatic regulator whereby the fluid-pressure can be shut off from said valve, thereby suspending the action of the air-inlet valve and allowing it to be opened and to remain open for the passage of air in both directions until the fluid-pressure is again applied, substantially as set forth.

8. The combination, with the air-compressor and its steam-supply pipe, of the regulator-casing connected with the steam-supply pipe and provided with steam-inlet openings v^5 and steam-outlet openings v^6, a piston-valve adapted to open and close said openings and receiving the steam-pressure in the casing on its front side, and the air-pipe V^3, admitting the compressed air to the valve-casing on the rear side of the valve, substantially as set forth.

9. The combination, with the compressor and its steam-supply pipe, of a regulator-casing receiving steam from said pipe, a piston-valve arranged in said casing, and whereby the steam-passage is opened and closed, an air-pipe connecting said casing with a conduit containing compressed air, whereby the air-pressure tends to move the valve in the direction in which the steam-passage is closed, while the steam-pressure tends to move the valve in an opposite direction, and a stop whereby the closing movement of the valve is limited, substantially as set forth.

10. The combination, with the compressor, its steam-supply pipe and its air-valves and their actuating mechanism, of the regulator-casing connected with the steam-supply pipe and provided with steam inlet and outlet openings, a piston-valve arranged in said casing, an air-pipe admitting compressed air to the casing on one side of said valve, a hollow stem projecting from the opposite side of said valve and receiving steam from the casing, a chamber receiving the steam from the hollow stem, and a pipe conducting this steam to the actuating mechanism of the air-valves, substantially as set forth.

11. The combination, with the compressor, its steam-supply pipe, its air-valves, and their actuating mechanism, of the regulator-casing provided with steam inlet and outlet openings v^5 v^6, and an air-pipe V^3, a piston-valve arranged in said casing and provided with a hollow stem w, having steam-inlet openings w^3, an adjustable sleeve w', surrounding the open end of the hollow stem and provided with steam-passages w^4, a steam-chamber surrounding said steam-passages, and a pipe O, connecting said chamber with the actuating mechanism of the air-valves, substantially as set forth.

Witness my hand this 10th day of May, 1888.

URIAH CUMMINGS.

Witnesses:
CHESTER D. HOWE,
CARL F. GEYER.