(No Model.) 2 Sheets—Sheet 1.

G., O. & W. EIMECKE.

DOUBLE ACTING HOT AIR ENGINE.

No. 270,036. Patented Jan. 2, 1883.

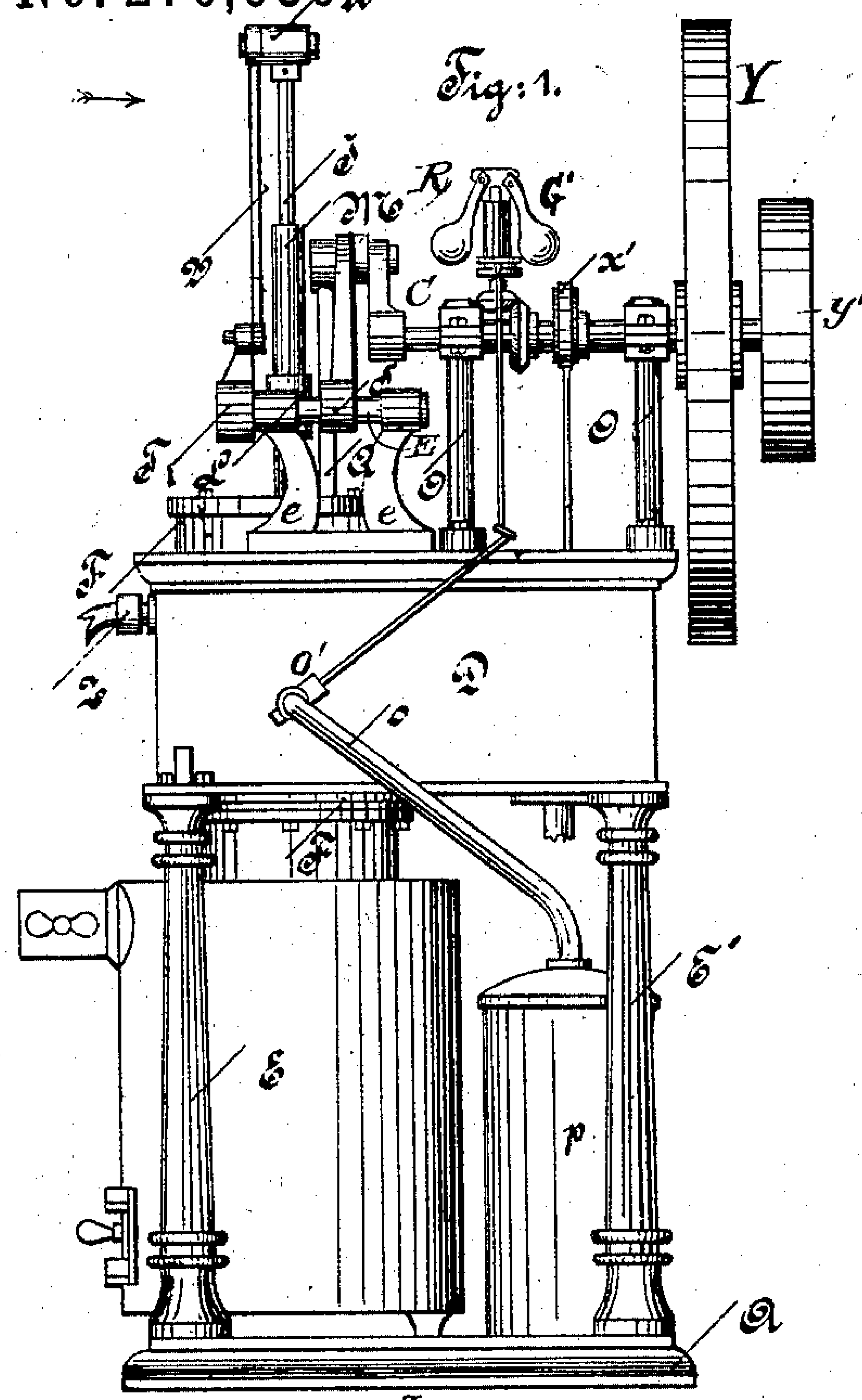

Fig: 1.

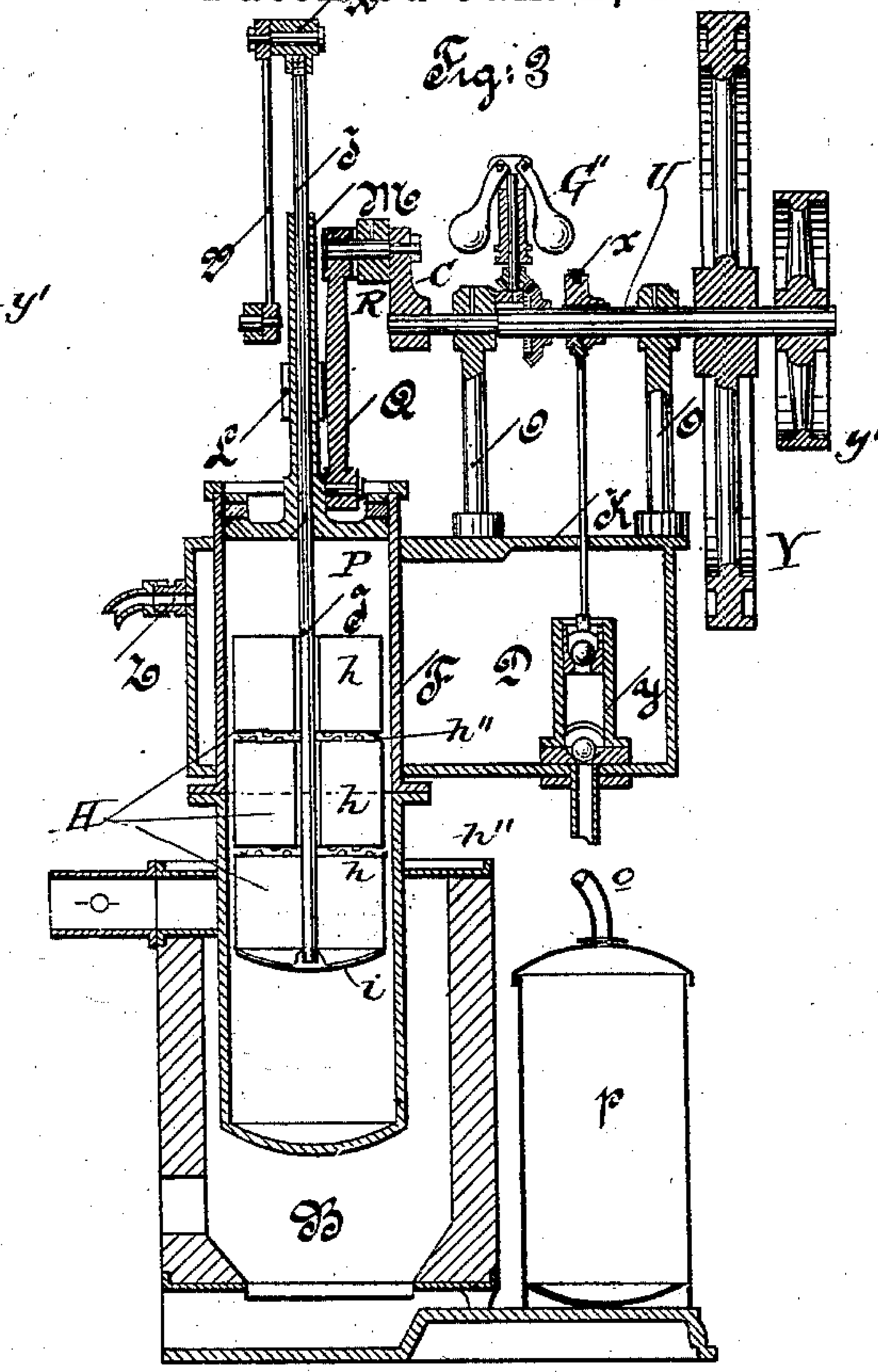

Fig: 3

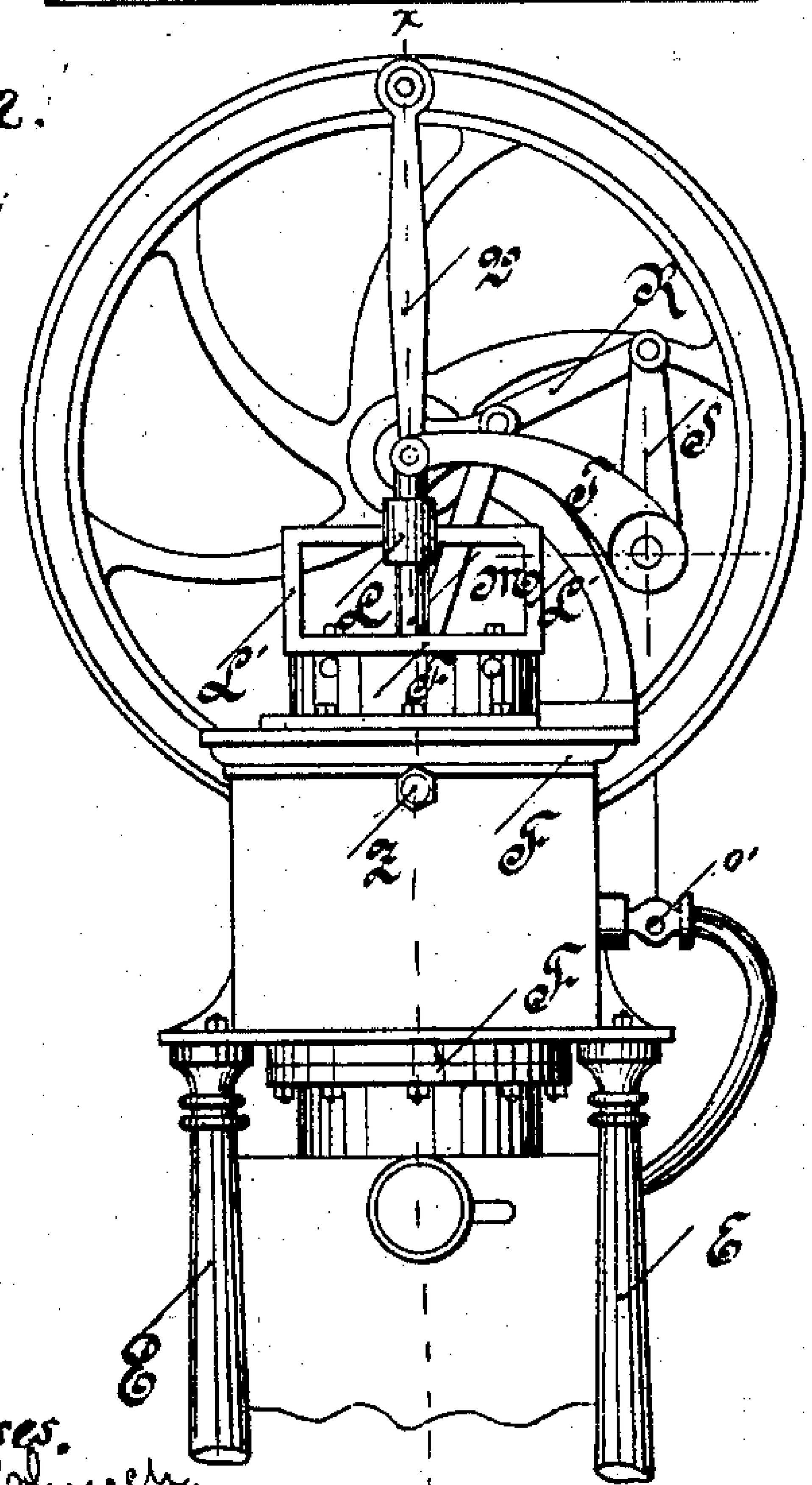

Fig: 2.

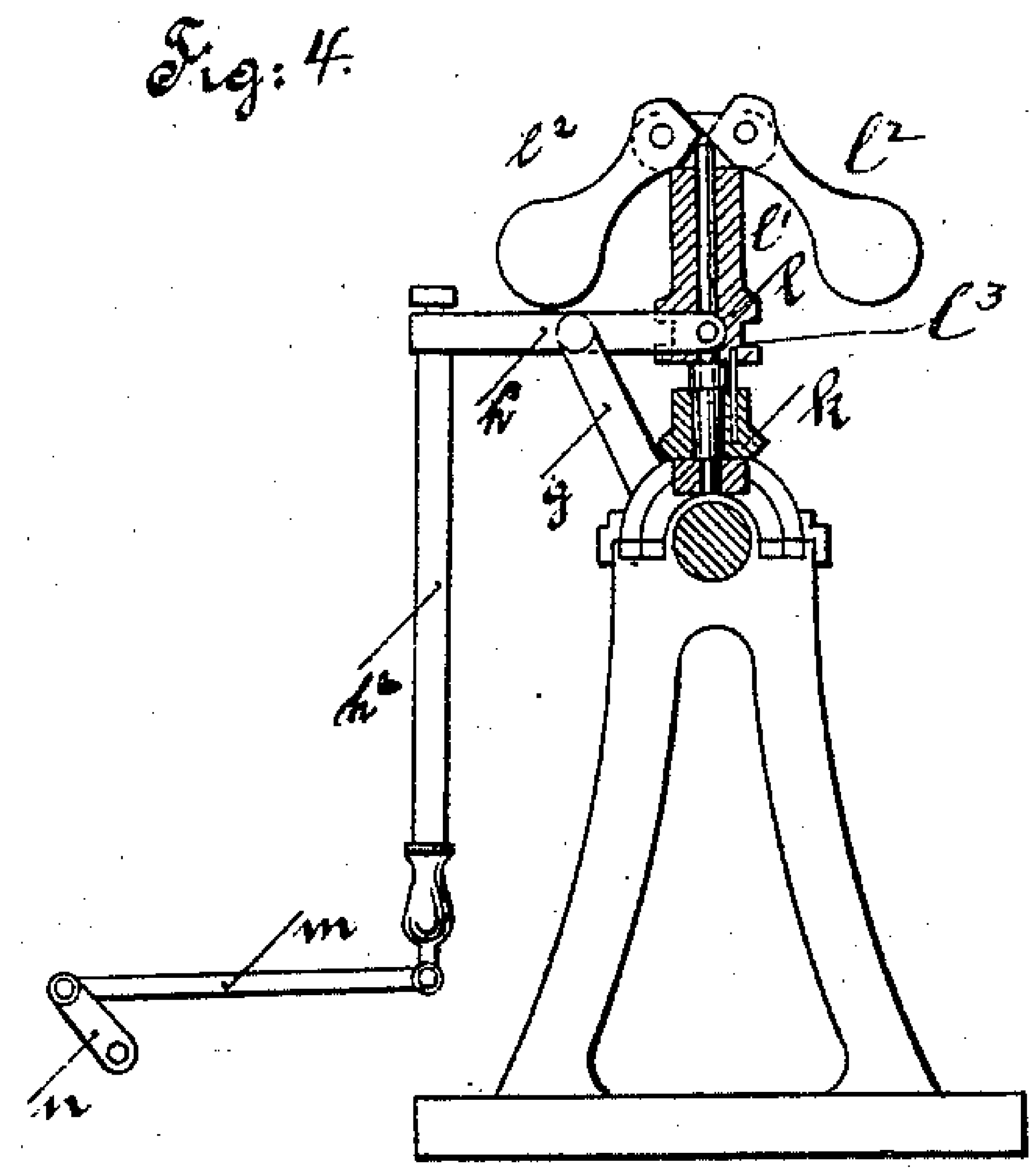

Fig: 4.

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(No Model.)

2 Sheets—Sheet 2.

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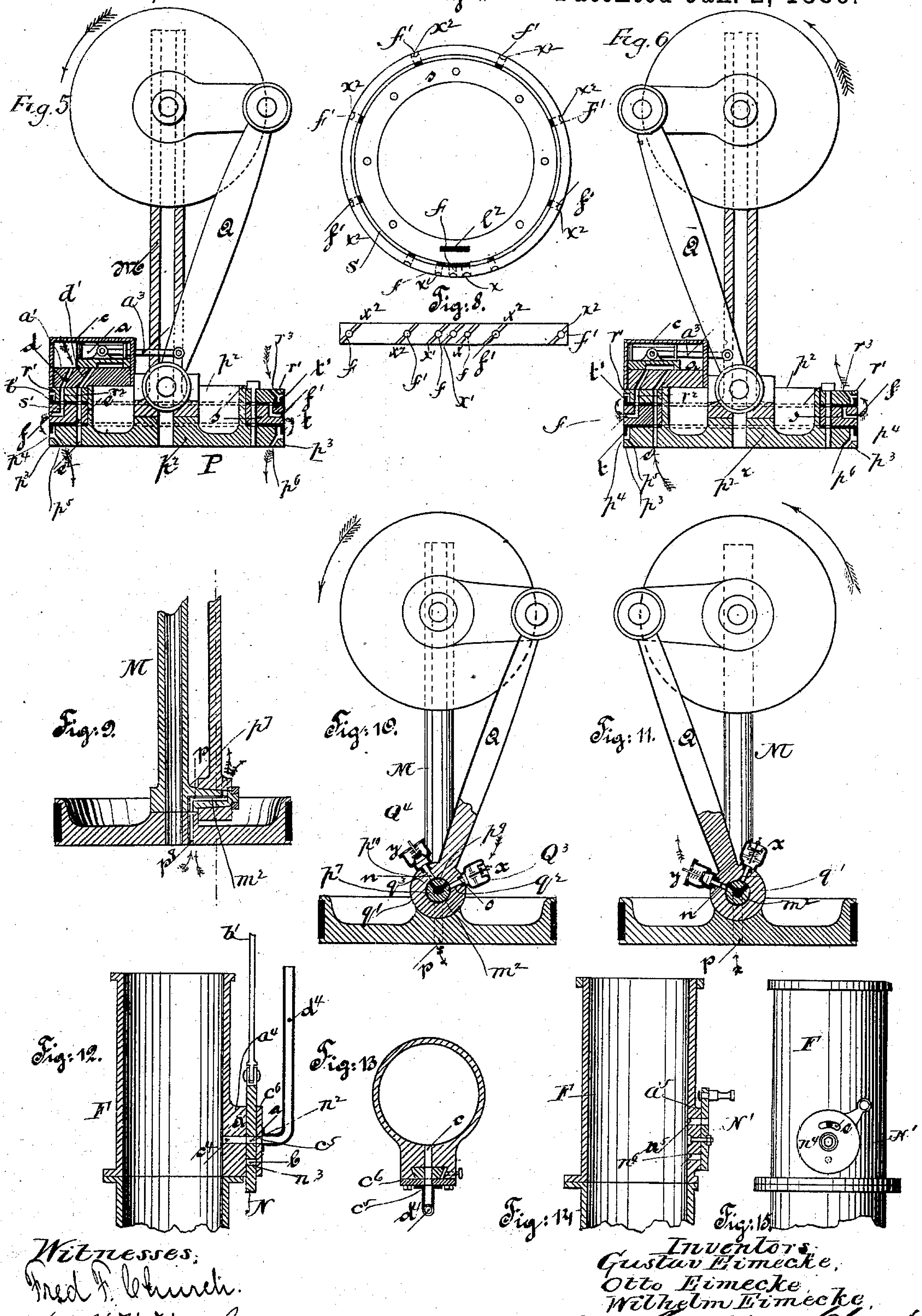

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UNITED STATES PATENT OFFICE.

GUSTAV EIMECKE, OTTO EIMECKE, AND WILHELM EIMECKE, OF BRUNSWICK, GERMANY, ASSIGNORS TO SAMUEL SUDHEIM, OF CASSEL, PRUSSIA, GERMANY.

DOUBLE-ACTING HOT-AIR ENGINE.

SPECIFICATION forming part of Letters Patent No. 270,036, dated January 2, 1883.

Application filed January 6, 1882. (No model.)

To all whom it may concern:

Be it known that we, GUSTAV EIMECKE, OTTO EIMECKE, and WILHELM EIMECKE, subjects of the Duke of Brunswick, and residents of Brunswick, in the Dukedom of Brunswick, German Empire, have invented certain new and useful Improvements in Hot-Air Engines; and we do hereby declare the following to be a full, clear, and exact description of the same, reference being had to the accompanying drawings, forming part of this specification, and to the figures and letters of reference marked thereon.

This invention relates to that class of hot-air engines in which one end of the working cylinder is arranged to be heated by a furnace, while the other end is by suitable means kept cool or at a comparatively low temperature, the air within the cylinder being changed from one end to the other alternately by the action of a displacer, which is caused to change its position within the cylinder in accordance with the movements of the piston.

The objects of the invention are to provide a simple and accurately-operating combination of devices for effecting the changes of position of the displacer; to prevent the undue heating of the displacer, and a consequent disadvantageous communication of the heat thereby to the air in the cold end of the cylinder; to obviate the hitherto existing retarding effect of partial vacuum and compressions during certain portions of the stroke of the piston, and to insure an evenness of speed and force in the operation of the engine.

With these objects in view the invention consists in certain novel constructions and combinations of devices, which will be hereinafter described with reference to the accompanying drawings, in which—

Figure 1 is a side elevation of a hot-air engine constructed according to my invention. Fig. 2 is an end elevation of the same, the view being taken in the direction indicated by the arrow at the left of Fig. 1. Fig. 3 is a view mainly in vertical section on the line $x\,x$ of Fig. 2. Fig. 4 is a detached view of devices for operating a valve to relieve the cylinder of overpressure. Fig. 5 is an enlarged diametric section of the piston and its slide-valve and a view of the connecting-rod and crank in elevation, the parts being shown as when the piston is commencing the latter half of its outstroke. Fig. 6 is a similar view, showing the parts as when the piston is commencing the latter half of its instroke. Fig. 7 is a detached top view of a ring forming a part of the piston and containing air-passages, the arrangement and purpose of which will be hereinafter explained. Fig. 8 is an edge view of the said ring. Fig. 9 is a diametric section of the piston and attachments, illustrating a modified arrangement of air-passages for permitting access and egress of air to and from the cylinder through the piston. Figs. 10 and 11 are views mainly in section at right angles to the plane of section in Fig. 9, illustrating further the modified arrangement of air-passages and showing the valves controlling the same. Fig. 12 is a vertical section, and Fig. 13 a transverse section, showing the cylinder provided at its side with a direct-acting slide-valve for permitting access and egress of air; and Fig. 14 is a vertical section, and Fig. 15 a side elevation of the cylinder, showing the same provided with a rotary slide-valve for the same purpose.

Referring to Figs. 1, 2, and 3, the letter F designates the working cylinder, the lower portion of which is arranged within a furnace, B, while the upper portion extends through a cold-water reservoir, D, mounted on pillars E′, provision being thus made for heating the lower and cooling the upper portion of said cylinder.

P is the piston, which plays in the cylinder F, and Q is a connecting-rod by which the piston is connected to the crank-pin of a crank, C, which is fixed upon one end of a driving-shaft, U, mounted in bearings at the top of standards O O, standing upon the top plate of reservoir D, said shaft carrying the fly-wheel Y and the belt-pulley y'. The piston P is provided with a hollow piston-rod, M, through which plays snugly a rod, I, extending into the cylinder and carrying thereon the displacer H, the particular construction of which will be presently described and explained. The piston-rod plays through a guide-bearing, L, supported in a frame, L', mounted upon the upper end of the cylinder.

The upper end of the rod I carries a cross-head, W, to which is pivoted one end of a link, V, the other end of which is pivoted to the end of an arm, T, projecting laterally from a short shaft, E, mounted in bearings on standards *e e*, the feet of which are secured to a base-plate attached to the top plate of reservoir D.

Projecting upwardly from the shaft E is an arm, S, the upper end of which is pivoted to one end of a link, R, having its other end pivoted on the crank-pin of crank C, said pin being long enough to properly hold both the said link and the connecting-rod Q.

The main operative parts of the engine have now been described, and to cause their operation a fire must be kept up in the furnace B and a constant supply of cold water maintained in the reservoir D and surrounding the upper portion of the cylinder F. The supply of cold water is provided by a pump, *y*, located in the reservoir, and having its plunger-rod connected with an eccentric, *x*, on the shaft U, an overflow-pipe, Z, carrying off the surface-water. To start the engine after the lower part of the cylinder has become properly heated, the fly-wheel is turned by hand until the piston is at the limit of its instroke and the displacer elevated. The air, becoming heated and expanded in the lower portion of the cylinder, will then force the piston upward. It will be seen that when the piston rises in the cylinder rotary motion will be communicated to the shaft U through connecting-rod Q and crank C, and at the same time a rocking motion will be communicated to shaft E from crank C through link R and arm S, causing the shaft E to vibrate the arm T, which, through the link V, causes a vertical reciprocating motion of the rod I through the hollow piston-rod M, the movement of the rod I being so timed that it will carry the displacer H alternately to opposite sides of the cylinder, to cause changes of the bulk of the air therein with proper relation to the movements of the piston—that is, when the piston commences the upper half of its outstroke the displacer begins to descend, displacing the hot air from the lower portion of the cylinder and causing it to flow up between the displacer and cylinder to the upper portion of the latter, where it will become cooled and lose its tension so far that its resistance to the instroke of the piston will be overcome by the momentum of the fly-wheel. The cooling of the air will also produce a tendency toward a vacuum, which will enable the external pressure upon the piston to assist in impelling it through the instroke. The displacer continues to descend until the piston has completed the first half of its instroke, and then begins to ascend, displacing the cooled air from the upper portion of the cylinder and driving it to the lower portion, where by the time the piston completes its instroke it will have become heated and expand to such a degree as to force said piston upward again on its outstroke at the proper time, in which, as already explained, the displacer will begin to descend and repetition of the actions, as described, will continue as long as the opposite portions of the cylinder are respectively kept hot and cold. Motion may be transmitted from the engine to other machinery by a belt passing around the pulley *y'* in the usual manner.

During the operation of the engine variations in the furnace-heat are liable to produce increase or decrease of pressure in the cylinder, and leakage of air from the cylinder may so reduce the volume therein that its expansion will not give full force to the piston on its outstroke. To provide against such occurrences an equilibrator or air-reservoir, *p*, is arranged alongside the furnace and connected with the upper portion of the working cylinder by means of a pipe, *o*, in which, at *o'*, is arranged a suitable valve, which may be opened and closed as required by connections with a governor, G', in the usual manner. When the pressure in the cylinder, and consequently the speed of the engine, is too great, the governor, being connected by bevel-gears with the driving-shaft, will operate in the usual manner and through the intermediate connection open the valve *o'*, thus permitting a portion of the air to escape from the cylinder to the equilibrator or reservoir *p*, and when through leakage or otherwise the volume of air in the cylinder becomes so far reduced as not to act efficiently upon the piston the speed of the engine will be reduced and the governor act in the opposite direction to again open the valve *o'* and permit a sufficient supply of air to enter the cylinder to restore a proper working volume.

In the partly-sectioned view, Fig. 4, are illustrated the connecting devices between the governor and the valve. The sleeve *l* plays vertically upon the stem *l'*, and has pivoted to its upper end the ball-arms l^2 l^2, the inner ends of which bear upon the top of the stem. The sleeve is circumferentially grooved at l^3, and into the groove project the pins from the embracing prongs of the bifurcated lever *h'*, which is fulcrumed at the top of an arm, *g*. Depending from the lever *h'* is a rod, h^2, connected at its lower end with a link, *m*, which is pivoted to one end of a lever, *n*, the other end of which may be connected to a valve to open and close the same.

The displacer H is formed of hollow air-tight cylindrical sheet-metal sections *h h h*, each having a tubular passage through its center to fit loosely around the rod I. The lower section rests upon a supporting-plate, *i*, carried by the rod I, and the sections are separated from each other by intervening spaces, each of the upper sections resting upon slight spurs h'', projecting from the top of a next lower section. By this construction it will be seen that the heat will be very slow in transmission from the bottom section to those above it, and when the top section enters the upper portion of the cylinder it will remain cool, notwithstanding that the bottom section is subjected to a very high heat, and the air in the upper portion of the cylinder will not be heated, as by old forms of displacers.

At the latter part of its outstroke, in an air-engine as ordinarily constructed, the piston, in enlarging the air-space of the cylinder, produces a partial vacuum, which has a serious retarding effect, and a similar effect results from the compression of the air in the cylinder during the latter part of the instroke. In order to obviate the retardation resulting from such partial vacuum and compression, we provide our engine with an automatic relief-valve, which at proper times will permit air to escape from the cylinder as required.

Referring to Figs. 5 and 6, the piston P is shown as formed of a central portion, p^2, from the bottom of which projects a flange, p^3, which fits the cylinder. This flange is recessed around its upper edge, as shown at p^4, and from this recess oblique passages p^5 lead inwardly and downwardly through the flange. Upon the top of the flange is arranged a flexible packing-ring, t, the outer margin of which is folded down and extends partially across said recess, the flap or folded portion being thin enough to have a slight lateral play in said recess. Upon this packing-ring rests a metallic ring, s, a plan view of which is shown in Fig. 7 and an edge view in Fig. 8. This ring has an annular recess, s', extending downwardly from its upper surface, and from the bottom of this recess radial passages f lead through the ring and intersect oblique grooves x' x' x', formed across its periphery.

Upon the top of the ring s is placed a flexible packing-ring, t', and upon the top of this packing-ring is placed an annular cover-plate, r', which is recessed around its lower edge, and upwardly into the recess is folded the margin of the packing-ring t', in the same manner that the packing-ring t is folded into the recess of flange p^3. The cover-plate has formed through it a vertical passage, r^2, which communicates at its lower end with the annular recess s' in the ring s, an aperture being cut in the packing-ring t' to permit such communication. The upper end of the passage r^2 connects with a port, d, formed through the seat a' of a slide-valve, a, arranged to play in a valve-box, c, mounted upon the top plate, r', and having an opening in its top. A port, d', is also formed through said valve-seat, and communicates at its lower end with a passage, e^2, which is formed through the top plate, r', ring s, flange p^3, and the intermediate packing-rings. The slide-valve a has its rod a^3 pivoted to it at one end, the other end of said rod being pivoted to the connecting-rod Q, so that the vibrations of the connecting-rod will communicate a reciprocating motion to the valve.

In Fig. 5 the piston is represented as commencing the latter half of its outstroke, at which point of its movement it begins "to draw a vacuum," which would impede its motion; but at this point the valve a has been moved to open its port d, and thereby establish communication between the cylinder-space below the piston and the external air, so that air enters through the valve-box c, port d, passage r^2, annular recess s', lateral passages f f f, and grooves x' x' x', and, forcing the flap of the packing-ring t inwardly, passes through the recess p^4 and oblique passages p^5 to the space below the piston, thus counteracting the tendency toward a vacuum. In Fig. 6 the piston is represented as commencing the latter half of its instroke, at which time it would commence to produce a compression of the air in the cylinder, and be thereby retarded were such an effect not provided against; but at this point of the movement of the piston the bridge-shaped slide-valve a has been moved to open the port d' and passage e^2, and air is thus permitted to escape from the cylinder and through the valve-box in sufficient quantities to prevent any resistance to the piston by compression of air below it.

In order to further facilitate the escape and ingress of air, additional oblique grooves, x^2, are formed at intervals about the periphery of ring s and intersect additional lateral passages, f', leading from the annular recess s'. When air enters through the valve-seat it will, besides passing through the annular passage s' and lateral passages f, also flow around through said annular passage and under the packing-ring t' to the additional passages f', and thence down through the additional grooves x^2, forcing aside the flap of packing-ring t and entering the cylinder through additional oblique passages, p^5, in the flange p^3.

It will be seen that the bridge-valve, while opening port d', also puts it in communication with port d, and a portion of the air escaping from the port d' may pass down through port d and passage r^2 to annular passage s', and, following said passage around, it will find exit through the additional passages f', the upper portions of additional grooves, x^2, and, forcing aside the flap of packing-ring t', will escape through the recess in the cover-plate r' and oblique passages r^3, formed inwardly and upwardly through the cover-plate from said recess. The compression below the piston will prevent such air from flowing downward through the oblique grooves x^2 and back to the cylinder. It will be understood that any air flowing against the backs of the packing-ring flaps will force said flaps outward against the cylinder-wall, so that they will prevent the further passage of such air toward the oblique grooves, and no air, therefore, can pass these flaps unless it comes in the proper direction, as heretofore described.

In Figs. 9, 10, and 11 the piston P′ has its periphery unbroken except by the formation of a seat for the ordinary packing-ring. From the piston-rod M, however, there projects a hollow trunnion, p^7, the passage m^2 through which is closed at its outer end, but connected at its inner end with a passage, p^8, formed through the piston. From the passage m^2 radial passages p^9 and p^{10} extend divergently through the trunnions, said trunnions being embraced by a collar, q', at the lower end of the connecting-rod Q. This collar is provided with passages q^2 and q^3, which connect with the casings of check-valves Q^3 and Q^4, respectively, the former being arranged to open inwardly and the latter outwardly. In Fig. 10 the piston having begun the latter half of its outstroke, the passages p^9 of the trunnion and q^2 of the collar q' are in line and the external air-pressure will open check-valve Q^3 and air will flow into the cylinder through said passages and the passages m^2 in the trunnion and p^8 in the piston, thus counteracting the tendency toward the formation of a vacuum in the cylinder. When the piston begins the latter half of its instroke, as shown in Fig. 11, the passages p^{10} of the trunnion and q^3 of the collar are in line, and air will flow from the cylinder through the passages p^8 of the piston and m^2 and p^{10} of the trunnion, and thence through the passage q^3 of the collar, and will force the valve Q^4 open and escape in sufficient quantity to prevent any retarding effect upon the piston by compression.

In Figs. 12 and 13 we illustrate another modified arrangement of the relief-valve. Upon the side of the cylinder F is formed a valve-seat, a^4, having a port, c^4, formed through it to the interior of the cylinder, and a corresponding port, c^5, through the top plate, c^6, of the valve-casing connects with an air-pipe, d^4. A direct-acting slide-valve, N, plays between the top plate and the valve-seat, and has two ports, n^2 and n^3, which may be alternately brought in line with the ports c^4 and c^5. The slide-valve is pivoted to a rod, the upper end of which may be connected with an eccentric on the driving-shaft, so timed that one of the ports n^2 or n^3 will be opened to permit the passage of air when the piston is beginning the last half of its outstroke and the other when it is beginning the last half of its instroke, for the purpose already stated.

In the modification of the relief-valve shown in Figs. 14 and 15 a seat, a^5, for the rotary valve N′ is formed on the side of the cylinder, said seat having two through-ports, n^5 and n^6, diametrically opposite each other, and communicating with the cylinder. The rotary valve N′ is pivoted centrally on the seat, and is provided with an elongated port, n^4, which as the valve is rotated will come opposite the ports n^5 and n^6 alternately. This valve may be connected with an eccentric on the driving-shaft or other suitable motive device to cause it to open the ports of the valve-seat alternately, in order to prevent retardation of the piston by the causes before referred to.

Having now fully described our invention and explained the operation thereof, we wish it to be understood that we do not confine ourselves to any of the specific constructions or arrangements of devices shown and described, but may vary the same in any manner within the practice of engine-building, or by the substitution of equivalents, while not departing from the true spirit and scope of our invention.

Having thus described our invention, we claim—

1. The combination, with the cylinder, the piston having the hollow piston-rod, the displacer within the cylinder, the rod I, carrying said displacer at its lower end, the link V, arm T, and suitable intermediate connections for communicating a vibratory motion to said arm from the crank C, of the driving-shaft connected with the piston, substantially as described.

2. In a hot-air engine, the combination, with the cylinder and piston, of a relief-valve, arranged to open when the piston begins the latter part of both its outstroke and instroke, and devices connected with the moving part of the engine for automatically and positively operating said valve, for the purpose set forth.

3. In a hot-air engine, the combination, with a working cylinder, of a connected air-reservoir and an automatically-operating valve, arranged to establish communication between the cylinder and reservoir at proper times, substantially as described, and for the purpose set forth.

4. The combination, with the cylinder, air-reservoir or equilibrator, the connecting-pipe, and valve arranged therein, of the governor operated by the driving-shaft, and suitable intermediate connections between the valve and the governor for operating said valve, substantially as described.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses.

GUSTAV EIMECKE.
OTTO EIMECKE.
WILHELM EIMECKE.

Witnesses:
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JOHS. KRACKE.