(No Model.) 4 Sheets—Sheet 1.

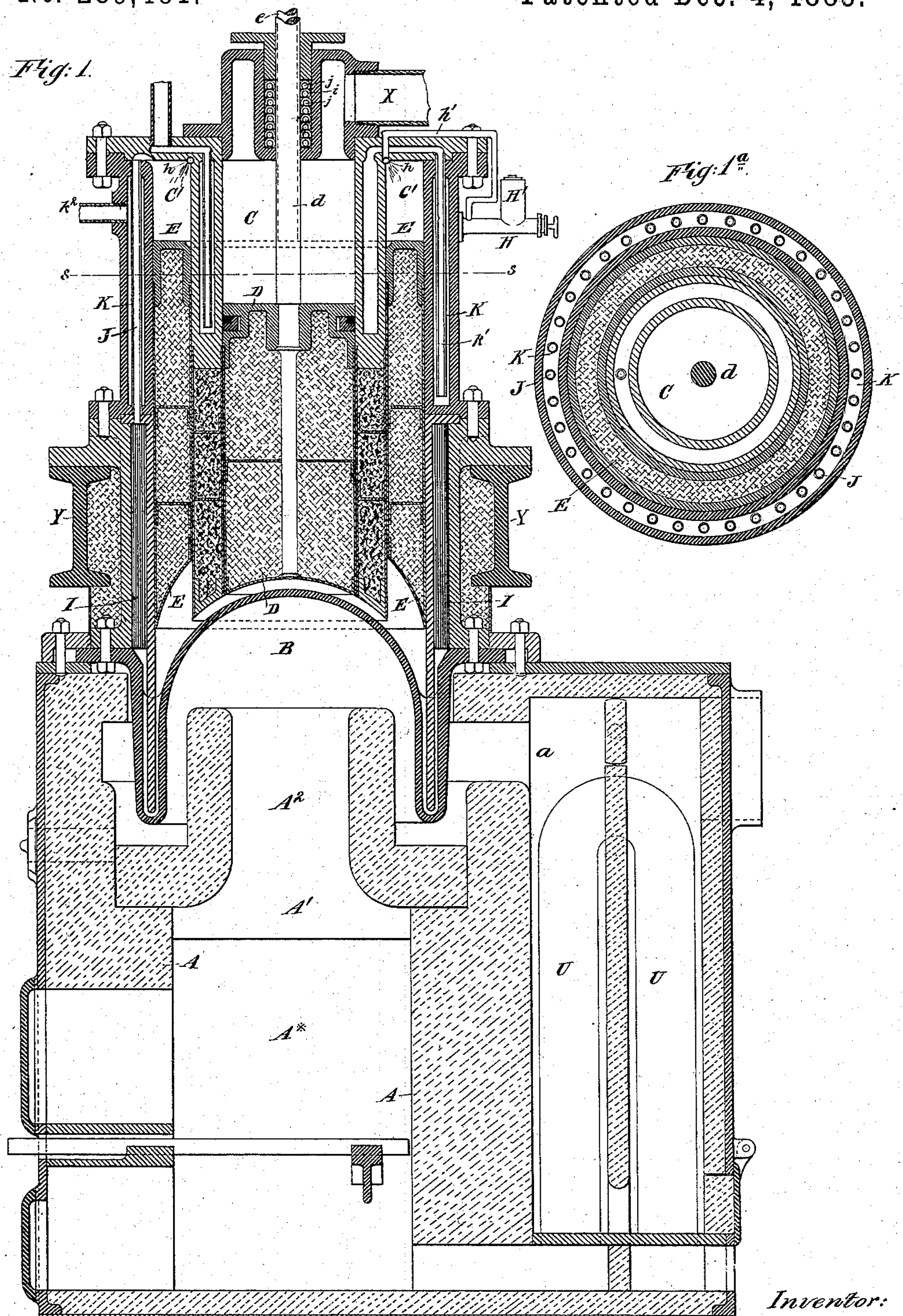
S. WILCOX.

HOT AIR ENGINE.

No. 289,481. Patented Dec. 4, 1883.

Fig. 1.

Fig. 1a.



Witnesses:
Charles R. Searle.
M. F. Boyle.

Inventor:
Stephen Wilcox
by his attorney Thomas D. Stetson

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.) 4 Sheets—Sheet 2.

S. WILCOX.

HOT AIR ENGINE.

No. 289,481. Patented Dec. 4, 1883.

Fig. 2.

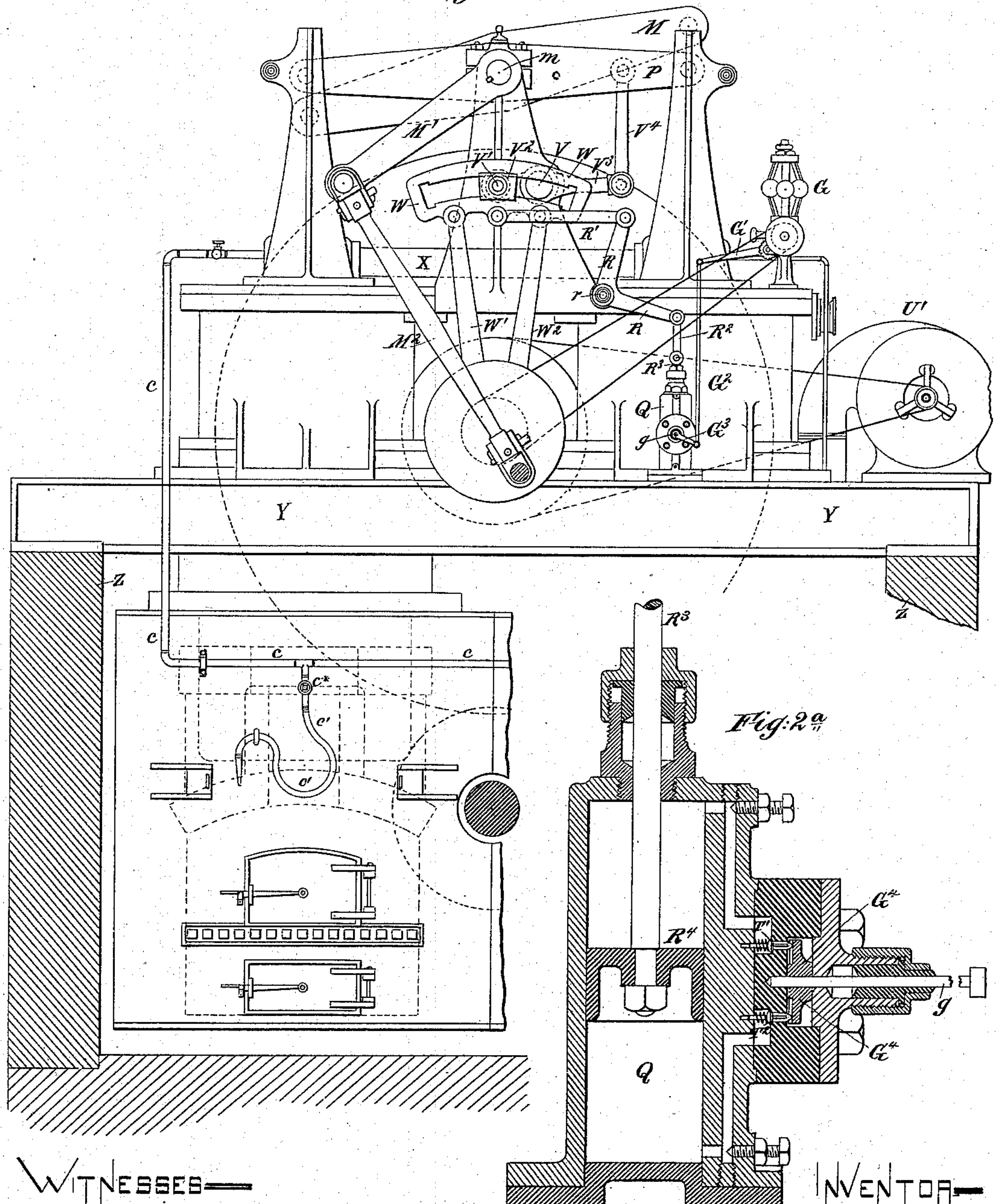


Fig. 2a.

WITNESSES—

Charles R. Searle.

M. F. Boyle.

INVENTOR—

Stephen Wilcox

by his attorney

T. D. Stetson

N. PETERS, Photo-Lithographer, Washington, D. C.

(No Model.) 4 Sheets—Sheet 3.

S. WILCOX.

HOT AIR ENGINE.

No. 289,481. Patented Dec. 4, 1883.

Fig: 3.

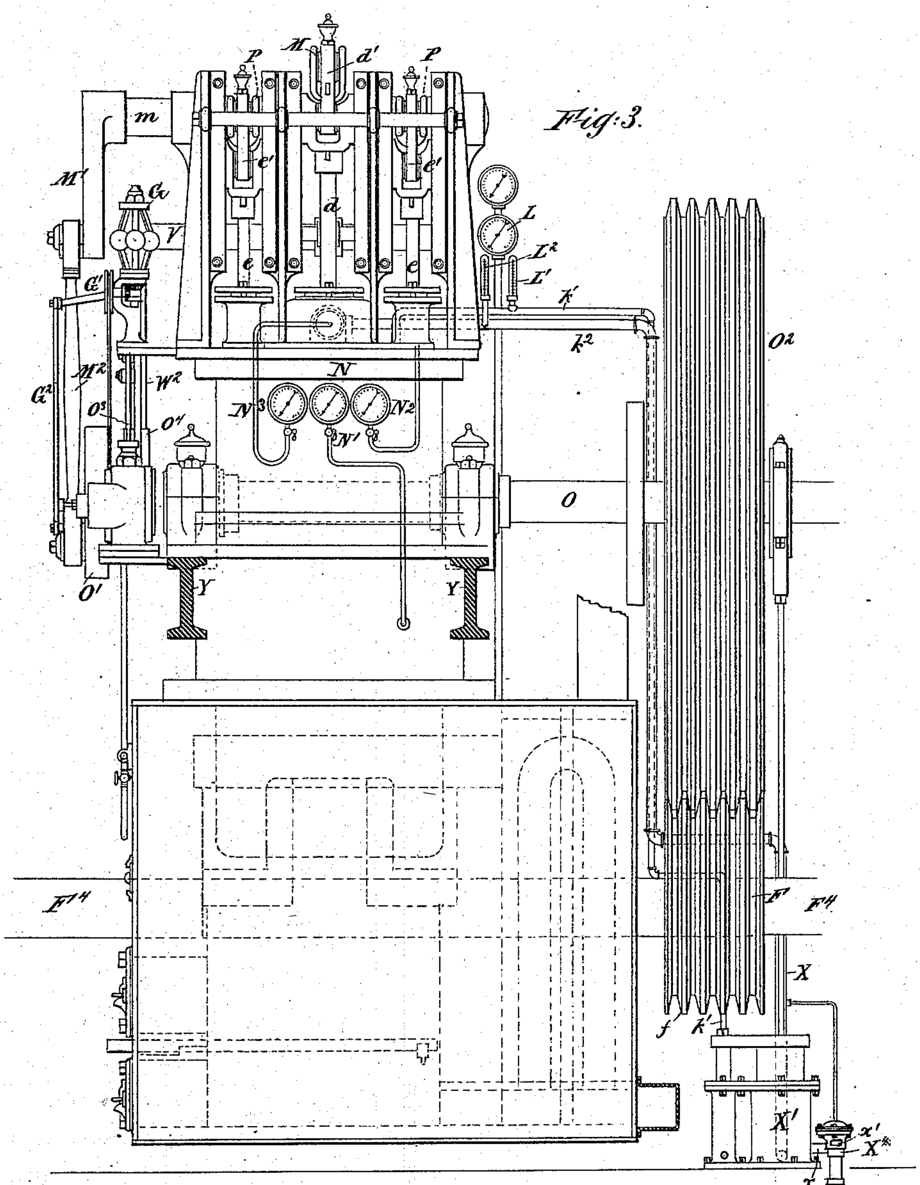


Fig: 8.

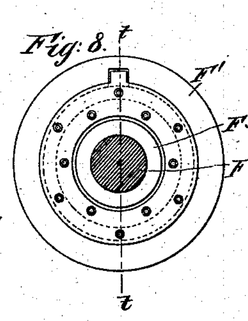
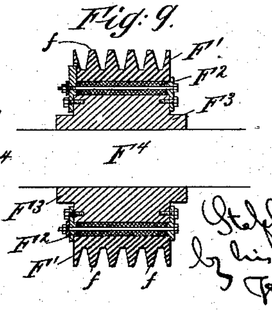


Fig: 9.



WITNESSES—

Charles R. Searle.
M. F. Boyle

INVENTOR—

Stephen Wilcox
by his attorney
T. D. Stetson

(No Model.)

4 Sheets—Sheet 4.

S. WILCOX.

HOT AIR ENGINE.

No. 289,481.

Patented Dec. 4, 1883.

Fig: 4.

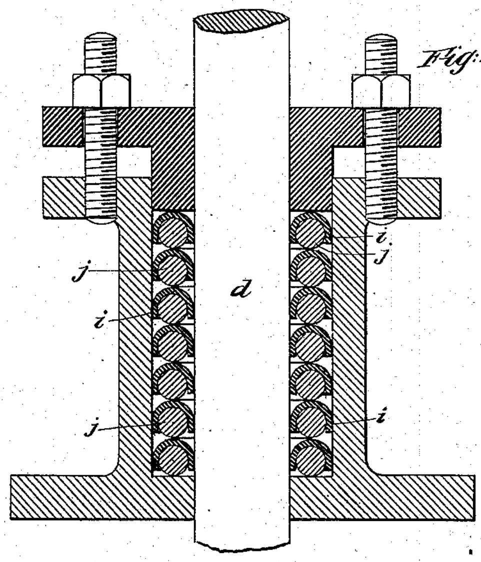


Fig: 7.

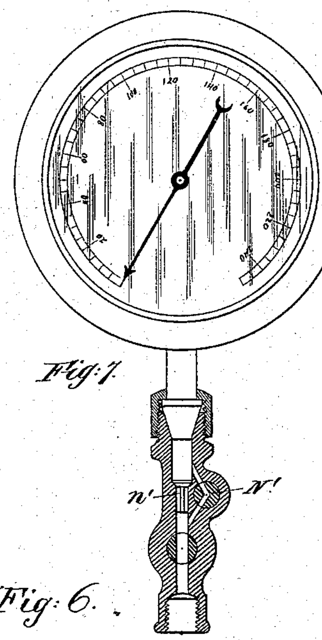


Fig: 5

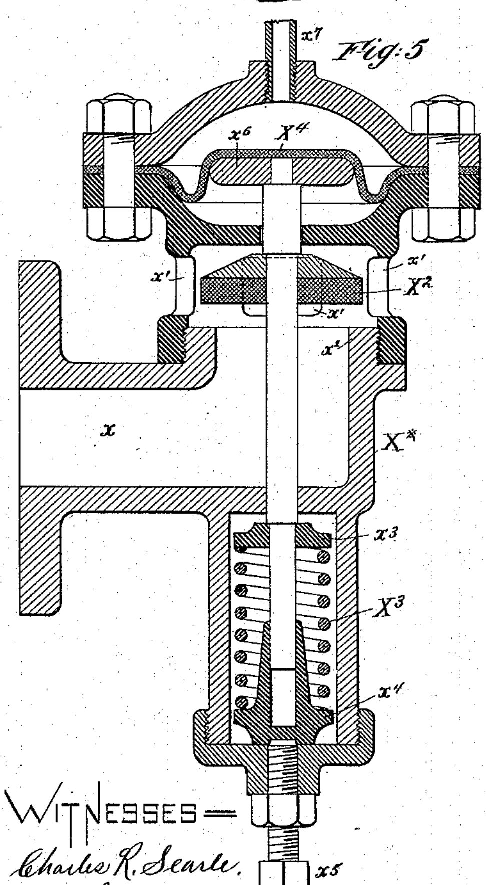
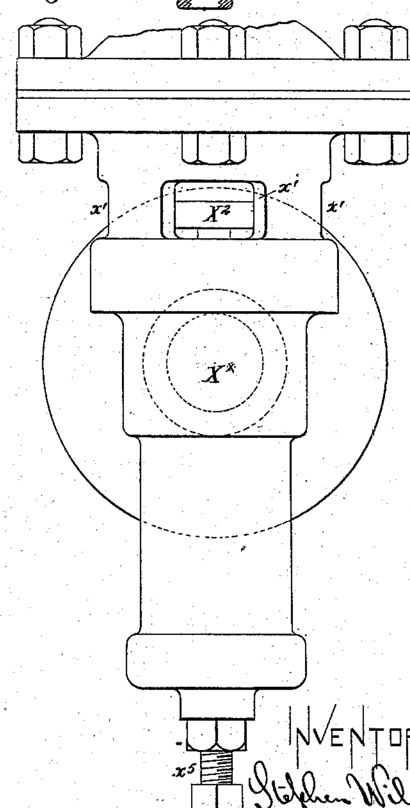


Fig: 6.



WITNESSES—
Charles R. Searle.
M. F. Boyle

INVENTOR—
Stephen Wilcox
by his attorney
Thomas D. Stetson

N. PETERS. Photo-Lithographer, Washington, D. C.

UNITED STATES PATENT OFFICE.

STEPHEN WILCOX, OF BROOKLYN, NEW YORK.

HOT-AIR ENGINE.

SPECIFICATION forming part of Letters Patent No. 289,481, dated December 4, 1883.

Application filed July 21, 1883. (No model.)

To all whom it may concern:

Be it known that I, STEPHEN WILCOX, of Brooklyn, Kings county, in the State of New York, have invented certain new and useful Improvements in Hot-Air Engines, of which the following is a specification.

I employ a cooling-jacket in connection with the regenerator, both arranged around the cylinder, by which the zones of low temperature are lowered in the regenerator, and the water cools not only the air which moves to and from the cool end of the cylinder, but also cools the cylinder itself. I automatically regulate the engine by means of a governor by shifting a link which moves the changing pistons. I provide peculiarly-adapted packing around the piston-rods and force air into the pipe connecting the tops of two opposite working-cylinders to compensate for leakage. By regulating this action automatically I maintain a uniform pressure. I have devised means for subtracting a large portion of the heat from the gases discharged from the furnace and for imparting it to the incoming air. A blower promotes the draft just sufficiently to overcome the resistance due to these provisions. I have also devised means for distributing oil in the upper portion of each cylinder. The engine has two cylinders and furnaces, fired independently, with the upper ends of the cylinders connected by an ample pipe and their several working and changing pistons joined by a vibrating beam, so that the weights shall balance. Two such pairs or any other number of pairs may be united to act on one shaft. I will describe one pair only.

The following is a description of what I consider the best means of carrying out the invention.

The accompanying drawings form a part of this specification.

Figure 1 is a central vertical section through one of the cylinders and immediately connected parts. Fig. 1ª is a horizontal section on the line *s s* in Fig. 1. Fig. 2 is an elevation, partly in section. Fig. 2ª is on a larger scale. It is a vertical section through the regulating-chamber for the automatic-link adjustment. Fig. 3 is an elevation at right angles to Fig. 2. The remaining figures are on a larger scale. Fig. 4 is a vertical section through one of the stuffing-boxes. Fig. 5 is a vertical section through the device for automatically controlling the effect of the air-pump, and Fig. 6 is an elevation of the same. Fig. 7 is a section, partly in elevation, showing the provisions for indicating the highest pressure. Fig. 8 is an elevation of the friction-pinion or jack-wheel. Fig. 9 is a section of the same on the line *t t* in Fig. 8.

Similar letters of reference indicate corresponding parts in all the figures where they occur.

A is the brick-work of a furnace, A*.

A′ is an arch, and A^2 a short funnel.

B is a dome-shaped double heater.

C is the working-cylinder.

D is the working-piston, and *d* the piston-rod.

E is the annular changing-piston, working in a cylinder, C′, larger than the working-cylinder, and arranged concentric thereto. Both pistons are of considerable depth. The changing-piston simply performs the function of shifting the air alternately from the cold to the hot portion of the apparatus and back again. Each working piston-rod, *d*, is connected by a link, *d′*, to one end of a working-beam, M, which is keyed onto a strong rocking shaft, *m*, having a crank-arm, M′, and mounted in fixed bearings. The two working-pistons and their connections balance each other. The connecting-rod M^2 extends from a pin on the crank-arm M′ to a pin in the crank O′ on the crank-shaft O.

Eccentrics O^3 O^4 connect by eccentric-rods W′ W^2 to a Stevenson link, W, which takes hold of a link-block, V^2, which is mounted on a pin, V′, carried on an arm fixed on a rocking shaft, V, supported in a fixed bearing in the framing. This shaft V has two arms, V^3, (only one of which is shown,) which carry, respectively, links V^4, (only one of which is shown,) connecting the arms to the changing-beams P, and by them operate the changing-pistons E. The two changing-pistons, connected to the opposite ends of the changing-beams by the rods *e* and links *e′*, balance each other. The link W has only to overcome the inertia and slight friction of the changing-pistons and the slight resistance of the air which the changing-pistons cause to be transferred rapidly between the hot and cold portions of the apparatus. The power is produced by the changes of temperature, and consequently of pressure, due to such transference, as will be readily understood.

I is a regenerator, composed of metallic plates set on edge and held a little distance apart. It is mounted in a sufficient annular space exterior to the changing-cylinder, and in communication with the hot-air space below the two pistons, and also through a cooler above with the relatively cold-air space above the changing-piston. The space above the working-piston is subject to a constant pressure from air pumped in, as will be fully explained further on.

K is the cooler. It is formed with thin metallic tubes J, allowing the air to flow up and down through them, and having cold water circulating in the spaces around them. The cooling-water enters through a pipe, k', and, after traversing this cooling-chamber and also another, which occupies an annular space between the working-cylinder and the changing-cylinder, is discharged through a pipe, k^2. The air-tubes J of the cooler communicate through passages at the top with the annular space over the annular changing-piston. The traversing of the air between the top and bottom of the apparatus in a thin annular space around the working-cylinder is of advantage in making the passage contracted and the amount of space in the passage small. The presence of the cooler insures that the upper edge of the regenerator, which is below it, shall be at a low temperature. The regenerator, with its several zones of temperature, varying from the hottest at the bottom to the coolest at the top, is a well-known adjunct of hot-air engines. It absorbs heat from the air as the hot air rises, and becomes heated thereby, its lower edge being heated the most. It imparts heat to the descending air and is itself cooled thereby, the upper edge being cooled the most. All the zones of heat are carried low on the cylinder by reason of the cooler above them. The ultimate effect is the confining of the heat in the cylinders and in all the parts to a limited domain at the base of the apparatus. By shifting the annular piston to the fullest possible extent theoretically, all the air is transferred alternately from the top to the bottom of the apparatus. This is the condition for the most effective working. I have adapted my engine to drive delicate machinery by providing an automatic regulation. It acts by reducing the extent of motion of the changing-pistons, and consequently the extent to which the air is transferred between the cool and hot portions.

When the link W holds the link-block V^2 in its center, as indicated in Fig. 2, there is little or no motion of the changing-pistons. By shifting the link W so that it receives and holds the block V^2 in one end of its curved slot, the changing-pistons E receive sufficient motion to cause them to traverse to the fullest extent and shift all the air. When the link W is held in some intermediate position, it induces a less amount of motion of the changing-cylinders. Under these conditions less air is transferred alternately between the cool and the hot end of the apparatus, less changes of pressure are induced, and less power is developed by the action of the air on the working-piston.

R' is a link which connects the Stevenson link W with a bell-crank lever, R, turning on a fixed center, r. This lever R connects by a link, R^2, and rod R^3 to a piston, R^4, in a small cylinder, Q. This latter is equipped with passages, arranged as shown, controlled by valves T' T^2, which, when the valves are held open, permit the fluid, which should be oil or some analogous inelastic fluid filling both ends of the cylinder, to shift from one end to the other.

The action of the engine communicated through the link W induces, by well-known laws, a tendency of the piston R^4 to shift alternately in one direction and the other. This tends to raise that piston during one portion and to lower it during another portion of each revolution of the main shaft. This tendency is resisted by the fluid; but the fluid can, under certain limitations, shift past the valves T' T^2. When these valves are both allowed to close, no such motion can occur. The piston R^4, and consequently the link W, is held against any shifting. It vibrates by the action of the eccentrics O^3 O^4, but does not shift to one side or the other. When, however, one of the valves T' T^2 is held open, the fluid in the cylinder Q may shift a little in one direction. The governor controls the opening of these valves. This control by the governor is effected through a lever, G', which is raised and lowered, either directly or indirectly, by the action of the governor G. It is connected by the link G^2 to the lever G^3. This lever rocks the spindle g and the rigidly-connected wheel G^4, and by means of face-cams formed on the latter forces open one or other of the valves T' T^2, one being released when the other is open—that is to say, when the lever G' rises it turns the wheel G^4 into such position that the uppermost valve, T', is held open. Under these conditions the fluid may flow from above the piston R^4 around into the space below said piston, the lowermost valve, T^2, opening automatically against the force of its gentle spring. Under these conditions the piston R^4 rises, and, acting through the connections, shifts the link W to the left and increases the power of the engine; but when the lever G' ascends it liberates the upper valve, T', and allows it to shut, thus resisting any tendency of the oil to escape from above the piston into the space below. The same movement opens and holds open the lower valve, T^2, and allows the oil to flow away from below the piston and to come into the space above it. This causes the piston R^4 to sink, and shifts the link W to the right, thus decreasing the power.

The piston-rods *d e* are surrounded by a series of rings, *i*, of good leather, shaped by wetting and stretching to the form shown in Fig. 4. These must be carefully kiln-dried at a moderate heat, after which they will endure the temperature without difficulty. The rings *j* are of vulcanized india-rubber of circular section. The stuffing-boxes are deep, and contain a number of these leathers, each partially inclosing its ring of rubber. The whole being gently compressed by the gland induces a gentle contact against the piston-rod *d*, and, becoming highly polished by the friction, reduces the leakage around the piston-rods to a very small amount, even if the pressure in the engine be as high as a hundred and fifty pounds per square inch. One hundred pounds per square inch I esteem about the best pressure to maintain above the working-piston. The packing in each working-piston allows some of the air above it to move down past it whenever the pressure below is less than that.

X′ is a constantly-acting force-pump, operated by the engine with a uniform stroke, and tending to receive and force into the spaces above the working-pistons a small uniform quantity of air at each revolution. The leakage is liable to vary, and I vary the admission of the air to this pump accordingly.

X* is a casing, having a nozzle, *x*, bolted on the induction-aperture of the pump. There are apertures *x′*, through which the air is drawn in freely; but the passage therefrom to the pump is controlled by a peculiarly-mounted valve, X^2, having a long stem, and capable of closing tightly upon a seat, x^2. It is held up and open by a coiled spring, X^3, acting between the collars x^3 and an adjustable abutment, x^4, controlled by a screw, x^5. On the upper end of the stem is a considerable button or disk, x^6, on which rests a flexible diaphragm, X^4, above which is a chamber connected by a pipe, x^7, with the connection X between the upper parts of the working-cylinders. So long as the pressure in the latter is sufficient the valve X^2 is, by the tension of the air on the diaphragm X^4, held down to its seat; but the moment the pressure becomes reduced by leakage the spring X^3 lifts the valve X^2 a little and allows the pump X′ to take in air and force it into the pipe X until the full pressure is restored, when it is again stopped by the refusal of the valve to rise. In practice the valve X^2 rises a little and the pump takes a little air at each stroke. Changing the screw x^5 determines the amount of pressure to be maintained in X.

The air to support the combustion in the furnace is received through inverted-**U**-shaped pipes U. These pipes, being exposed to the hot gases escaping from the furnace through the passage *a*, warm the air within, so that the fresh air therefrom entering the furnace, by being partially heated, contributes to the efficiency of the fuel and consequently the economy of the engine; but the passage of the air through these **U**-shaped pipes is resisted by friction. So, also, is the passage of the escaping gases from the furnace resisted by the effort required to flow through the chamber obstructed by these pipes. The consequence is a tendency to a retarded draft.

U′ is a blower driven by a belt from the engine and forcing the air strongly in its entrance through the pipes U. The effect of this blower should be sufficient to overcome the resistance of the fresh air in moving through the interior of the pipes U, and also to overcome the resistance of the hot gases in escaping from the furnace through the obstructed flue or chamber in which the pipes U are mounted. The combination of the blower with the pipes secures both economy and efficiency.

The changing-piston, although it need not be packed, and need not rub with much tightness against the surfaces on the exterior and interior, respectively, has large surfaces subject to friction, and parts are liable to rise to a high temperature under some conditions which cannot be conveniently insured against. I provide peculiarly efficient means for introducing oil to lubricate the parts.

H is a single-acting hand-pump, provided with a reservoir, H′, for receiving oil. It communicates by a small pipe, *h′*, with a perforated pipe, *h*, extending around in a recess provided in the top of the working-cylinder. Its perforations are arranged to allow the ejection of the oil upon the annular changing-piston. It spreads thereon and lubricates both the outer and inner edges.

L′ is a thermometer, the sensitive portion of which is immersed in the pipe *k′*, through which cold water enters the cooler K. L^2 is another thermometer, having its sensitive portion correspondingly immersed in the pipe k^2, which conveys away the warm water from the cooler. An inspection of these two thermometers shows, by direct comparison, the changes of temperature induced in the water of the heater. When the change of temperature is too small, it indicates that too much water is admitted to the cooler, and I partially close a controlling-cock, (not shown,) which lessens the quantity of water allowed to traverse the cooler. This is important when, as is frequently the case, the supply of cooling-water is small. When the difference of temperature of the two thermometers is unusually great, it shows that the water in the heater is allowed to become too much warmed, and consequently that the air is being too little cooled by the cooler. When this is observed, the attendant opens a cock (not shown) and allows the water to circulate through the cooler more freely.

L is a pyrometer, having its sensitive portion immersed in the hot gases filling the flue or chamber *a*. It has a dial mounted in position to be easily observed by the attendant.

When he sees that the heat in the flue is too low, he opens the damper and quickens the blower, or otherwise encourages the fire in the furnace. When he observes that the temperature of the pyrometer is too high, he closes the damper or decreases the action of the blower, or both, and consequently allows the fire to become less active. The several furnaces have each a separate pyrometer.

N is a pressure-gage. Its interior is subject to the influence of the pressure within the cylinder. This pressure varies widely between its greatest and its least during any given revolution. It also varies considerably in its absolute pressure at the period of greatest pressure. When the working-piston is being driven upward in its cylinder, my gage indicates the pressure at the highest. It is provided with a valve, n', opening freely upward, to allow the pressure of oil or other fluid acted on by the air to pass upward freely. When, during another portion of the revolution, the pressure in the working-cylinder is greatly reduced, this pressure-gage does not show the corresponding diminution of pressure. The pressure does not diminish in the gage except by a very small amount, that is due to a slow movement of the oil or other fluid past a stopcock, N', which communicates through small passages with the gage and with the source of pressure. At every revolution of the main shaft there is a period at which the high pressure is felt by the gage, the same being transmitted freely past the valve n'. The gage runs down a little, but only a little, in the intervals. It vibrates between indicating the highest pressure which obtains in the cylinder and a pressure only a pound per square inch, or thereabout, below such highest pressure.

N^2 is a pressure-gage working under opposite conditions. The valve is arranged to allow the oil to escape freely from the pressure-gage N^2 at each lowering of the pressure, and to rise only slightly during the period of high pressure. An additional gage, N^3, is of the ordinary construction, and is connected to the space above the working-piston. It is subject to a nearly-uniform pressure of air. The air in the upper end of one working-cylinder is transferred from the pipe X to the top of the opposite working-cylinder as the working-beam M vibrates and the two working-pistons alternately ascend and descend.

I communicate power from my engine through friction-gears peculiarly mounted. The fly-wheel O^2 is a large pulley having V-shaped grooves turned or otherwise produced in its periphery, adapted to transfer power by friction in the well-known manner.

F is a jack-wheel, certain portions being designated, when necessary, by additional letters of reference, as F' F^2. It has an iron periphery, F', equipped with V-shaped beads *f*, corresponding to the grooves in the wheel O^2; but instead of the whole jack-wheel being rigid and mounted fixedly upon the shaft F^4, the force is communicated through an annular mass, F^2, of vulcanized india-rubber, which is mounted between the hub F^3 and the annular rim F', and which, by its yielding, avoids the trembling due to ordinary friction-gear. It also allows the shafts to be slightly out of their true positions without inducing mischief. The false position is accommodated by the yielding of the rubber F^2.

I have shown in the drawings, Figs. 2 and 3, a flexible pipe, c', of india-rubber or analogous material, having a contracted nozzle at one end, and connected at the other to an iron pipe, *c*, which connects with the top of the working-cylinder C. On opening the cock c^* a strong blast of air is ejected from the nozzle, which, on opening one of the slides *b* and directing the current into the aperture thus exposed, clears the ashes and soot from the space around the base of the heater.

Y are the girders, which support the mechanism, resting on brick walls Z.

Modifications may be made in the forms and proportions. I can increase or diminish the width of the friction-gear wheels O^2 F. I can make the annular mass of rubber F^2 of greater or less diameter and thickness. Parts of the invention may be used without the whole. Instead of rubber, any other elastic material—as twisted wool or hair—may be employed as the part *j* to distend the formed leathers when the gland is pressed down.

Some of the advantages due to certain features of the invention may be separately enumerated as follows:

First, by reason of the fact that the cooler or water-jacket K surrounds the cylinder, as shown, with the regenerator I below it, the zones of low temperature are carried lower in the regenerator, and the upper end of the cylinder is maintained cooler than would be otherwise possible.

Second, by reason of the fact that the cylinder C forms the side of the water-jacket K, and also that the cooler is traversed by the pipes J, through which the air moves in its passage upward in coming to such cylinder and downward in flowing from it, the water performs the double function of cooling the air in its passages and also of bathing and cooling the cylinder.

Third, by reason of the combination of the governor G and its connections to the hydraulic cylinder Q, with its piston R^4 and connections to the rod R', controlling the link W, I am able to automatically regulate the extent of motion of the changing-pistons, and consequently the power of the engine, so as to maintain uniform speed.

Fourth, by reason of the continuously-acting pump X', valve X^2, spring X^3, and diaphragm X^4, the latter influenced, as shown, by the pressure obtaining on the upper faces of the working-pistons, I am able to automatically open the valve and allow air to be taken by the pump when the pressure is below a given point, and to automatically close the valve and prevent air from being taken when the pressure has reached and is maintained at the required standard.

Fifth, by reason of the blower U′, forcing air through the pipes U into the ash-pit, and thence through the furnace and escape-passage *a*, I am able to overcome the considerable frictional resistance due to the passage of the air through the pipes and to the passage of the escaping gases from the fire past such pipes, and maintain an active combustion and consequent efficiency of a given size of apparatus, combined with provisions for high economy.

Sixth, by reason of the perforated pipe *h* extending around over the changing-piston and connections *h′* to the pump H, with its oil-reservoir H′, I am able to conveniently introduce lubricating-fluid and to distribute it effectively in the upper portion of the annular changing-cylinder.

I claim as my invention—

1. The annular cooler or water-jacket K, arranged relatively to the cylinder C′ and to the annular regenerator I, substantially as herein specified.

2. The water-jacket K, with its pipes J, arranged as shown, and with suitable water-connections, *k′* k^2, arranged as shown, adapted to perform the double functions of cooling the cylinder C′ and of cooling the air in its passage to and from it, as herein specified.

3. The link W and suitable connections for receiving motion from the shaft and imparting it to the changing-piston, in combination with such piston and with the governor G, and with means for automatically shifting the link, as herein specified.

4. In a hot-air engine, the case X*, pipe *x*, and diaphragm X^4, in combination with a valve, X^2, controlling the admission of the air to the air-pump X′, so as to automatically maintain a uniform pressure, as herein specified.

5. In a hot-air engine, the blower U′, air-heating pipes U, furnace A*, and escape-flue *a*, combined and arranged for joint operation as herein specified.

6. In a hot-air engine, the oil-reservoir H′, pump H, and oil-distributing pipe *h*, in combination with each other and with the concentric cylinders C C′ and annular changing-piston E, arranged for joint operation, as and for the purpose herein specified.

In testimony whereof I have hereunto set my hand at New York city, N. Y., in the presence of two subscribing witnesses.

STEPHEN WILCOX.

Witnesses:
EDW. WM. FRANCIS,
WM. C. DEY.