(No Model.)

2 Sheets—Sheet 1.

J. A. WOODBURY, J. MERRILL & G. PATTEN.

HOT AIR ENGINE.

No. 324,060. Patented Aug. 11, 1885.

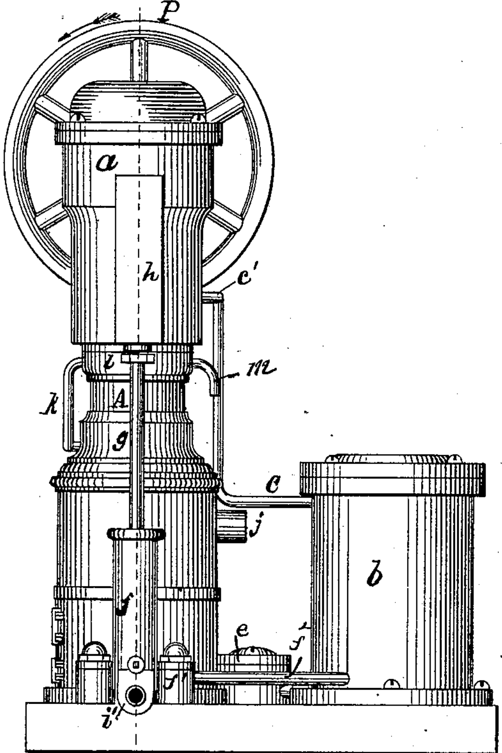


FIG. 2.

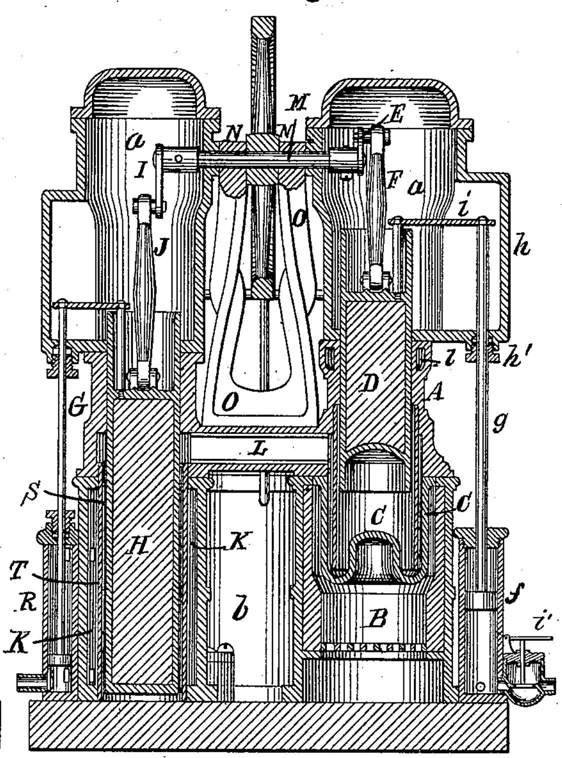
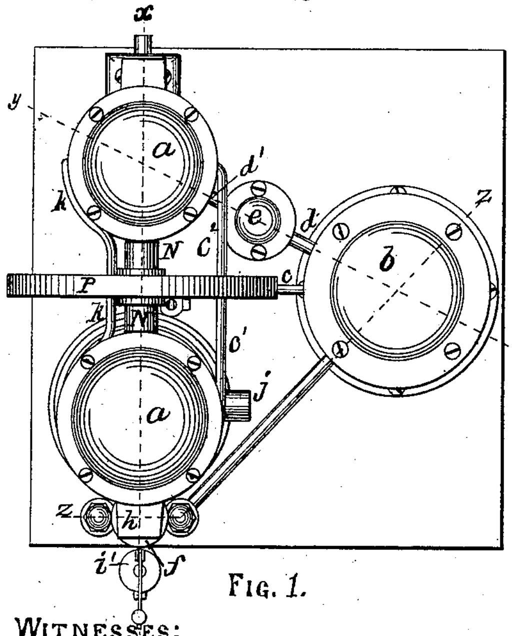


FIG. 3.



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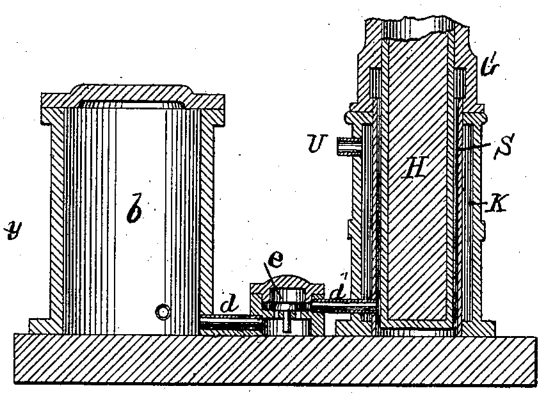

FIG. 4.

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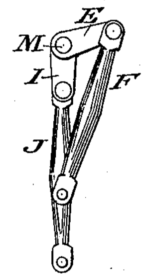
Fig. 7.



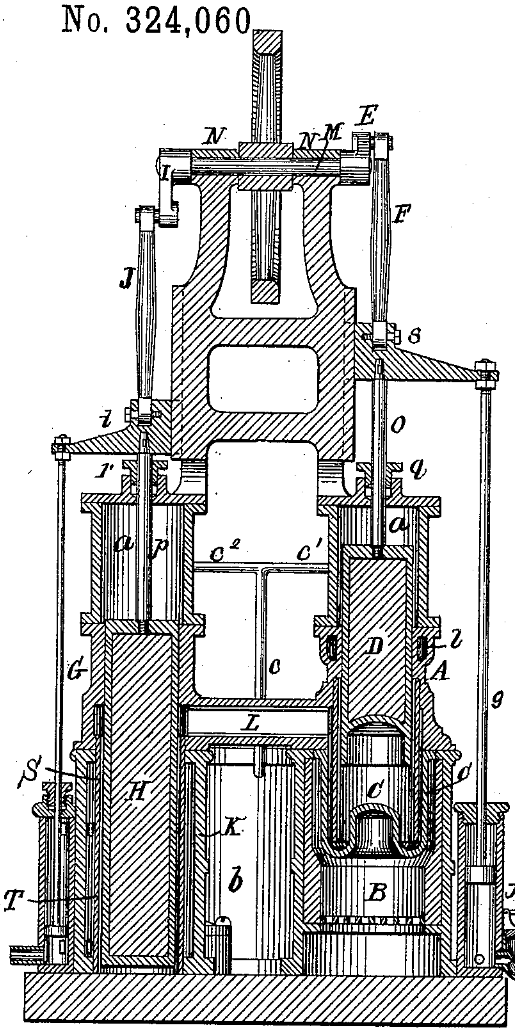


FIG. 6.

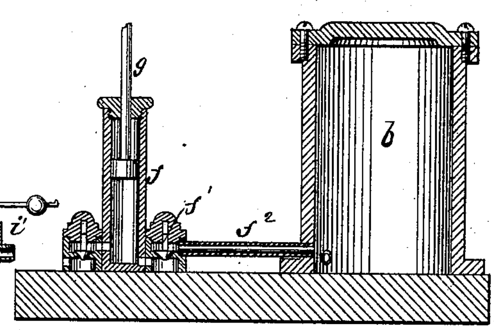


FIG. 5.

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UNITED STATES PATENT OFFICE.

JAMES A. WOODBURY, JOSHUA MERRILL, AND GEORGE PATTEN, OF BOSTON, MASSACHUSETTS.

HOT-AIR ENGINE.

SPECIFICATION forming part of Letters Patent, No. 324,060, dated August 11, 1885.

Application filed June 5, 1877.

To all whom it may concern:

Be it known that we, JAMES A. WOODBURY, JOSHUA MERRILL, and GEORGE PATTEN, all of Boston, in the county of Suffolk and State of Massachusetts, have jointly invented certain new and useful Improvements in Hot-Air Engines, of which the following, taken in connection with the accompanying drawings, is a specification.

Our invention relates to that class of engines in which two cylinders arranged side by side and connected together by a communicating passage and two tightly-fitting pistons are used, one of said cylinders having a heating apparatus beneath it and the other cylinder being provided with a refrigerating or cooling device, said pistons being operated by the alternate heating and cooling of air or other gas, or gaseous fluid, said air, gas or gaseous fluid being used continuously over and over again without being discharged therefrom, passing alternately from one cylinder to the other and requiring no renewal, except what may be necessary to supply deficiencies occasioned by leakage, and has for its object an increase of the power of an air-engine without a corresponding increase of consumption of fuel.

It is a well-known fact that atmospheric air is expanded or increased in volume by heat, and if confined so that it cannot expand, and heat is applied thereto, a pressure, in proportion to the degree of heat applied, is exerted upon the inclosing vessel, or, in other words, if the temperature of atmospheric air be raised to about four hundred and eighty degrees its volume will be doubled if free to expand, or if confined an outward pressure will be exerted upon the inclosing vessel of about thirty pounds per square inch, or double that exerted upon the exterior of the vessel by the atmosphere. It is also well known that the same result is produced by raising the temperature of confined air to about four hundred and eighty degrees, whatever may be the density of the confined air before the application of heat thereto—viz, to double the pressure possessed by the air before the application of heat. It has also been discovered that about the same number of units of heat that are required to raise the temperature of a cubic foot of atmospheric air in its normal condition to four hundred and eighty degrees and double its volume or pressure will raise to the same temperature any number of cubic feet of common air when compressed into the space of a cubic foot.

The object of our invention is the application of this principle to the operation of air-engines for the purpose of increasing their efficiency, and we have found by experiment, that if compressed air be supplied to both sides of the piston of an air-engine, and said compressed air is alternately heated and cooled upon one side of the piston, while upon the other side of the piston the air is kept at its normal temperature, and the same air is used over and over again without being discharged from the engine, passing alternately from one cylinder to the other, and requiring no renewal except what may be necessary to supply the loss by leakage, or, in other words, when the engine is worked by compressed air under precisely the same condition as when worked by atmospheric air in its normal condition, or at a pressure of fifteen pounds per square inch, a great increase of power is obtained without a material increase in the consumption of fuel.

Our invention consists in the combination of a working or power cylinder, provided with a heating apparatus located beneath it, a cooling-cylinder located parallel with and at one side of said working-cylinder and having free communication therewith through a connecting-passage, a piston fitted tightly in each of said cylinders and connected together by means of a shaft, suitable cranks and connecting-rods, and adapted to be worked by alternately heating the air under one piston and cooling it under the other piston, where the upper ends of both cylinders are closed by air-tight heads or covers, so as to adapt the chambers above the pistons to contain atmospheric air, gas, or gaseous fluid at a pressure greater than that of the ordinary atmosphere.

Our invention further consists in the combination of a working or power cylinder provided with a heating apparatus located beneath it, a cooling-cylinder arranged at one side of and parallel with said working-cylinder, and having free communication therewith through a connecting-passage, a piston fitted tightly in each of said cylinders and connected together by a shaft and suitable cranks and connecting-rods, and adapted to be worked by alternately heating the air, gas, or gaseous fluid under one piston and cooling it under the other piston, an air-tight chamber above each of said pistons adapted to contain air or other gas or gaseous fluid, at a pressure greater than that of the ordinary atmosphere, a pipe or pipes leading from the chamber above each of the pistons to the chamber beneath the piston in the cooling-cylinder, and a check-valve adapted to permit the free passage of the compressed air or gas from the chambers above the pistons to the chamber beneath the piston, when the pressure beneath the piston is reduced below that in the chambers above the pistons, and to prevent its return.

It further consists in the combination of a working-cylinder provided with a reciprocating piston, an air-pump adapted to force air into said cylinder under pressure, a furnace or other means of applying heat directly to said working-cylinder to heat the air contained therein, and a cooling or refrigerating device for cooling the air after it has been heated.

Our invention further consists in the use, in combination with a working-cylinder provided with a heating apparatus, and a compression-cylinder provided with a refrigerating or cooling device, and their respective pistons adapted to be worked by the alternate heating and cooling of the body of air contained beneath said pistons without discharging it from said cylinders, except from one cylinder into the other, and vice versa, of a tank or receiver filled with air compressed to the density of two, three, four, or more atmospheres, and communicating freely with air-tight chambers above the pistons of both cylinders, and, through a check-valve, with the cooling-cylinder beneath the piston, as will be further described.

Our invention further consists in the use, in combination with a working-cylinder provided with a heating apparatus, a compression or cooling cylinder, and a receiver filled with compressed air and communicating with both sides of the pistons of said cylinders, of an air-pump provided with suitable inlet and discharge valves, for the purpose of forcing air into said receiver to supply the loss which may be occasioned by leakage.

Our invention further consists in the combination of an engine adapted to be worked in an artificial atmosphere by the alternate heating and cooling of the compressed air upon one side of the piston, and the constant pressure of air compressed to the same density upon the other side of said piston or pistons, a receiver adapted to supply compressed air to both sides of the piston or pistons, a pump adapted to force air into said receiver to supply the loss by leakage, and a relief-valve applied to said pump and adapted to serve as a discharge for said pump when the pressure in the receiver is maintained at the desired point.

Figure 1 of the drawings is a plan of an air-engine illustrating our invention. Fig. 2 is a side elevation. Fig. 3 is a vertical section on line $x\ x$ on Fig. 1. Fig. 4 is a partial vertical section on line $y\ y$ on Fig. 1. Fig. 5 is a vertical section on line $z\ z$ on Fig. 1. Fig. 6 is a vertical section on line $x\ x$, illustrating a modification; and Fig. 7 is a diagram illustrating the positions of the cranks relative to each other and their comparative lengths.

A is the power or working cylinder situated directly over the fire-chamber B, and having attached to its lower flange the heater C.

D is the power piston, made in the form known as a "trunk" piston, and is connected directly to the crank E by means of the connecting-rod F, but it may be connected to a beam or lever, if preferred, when the engine is constructed according to the modification shown in Fig. 6.

G is a compression or cooling cylinder in which works the piston H, of the same area as the piston D, and connected in like manner to the crank I by means of the connecting-rod J. Both of the pistons D and H are fitted to work tightly in the upper portions of their respective cylinders, as shown in Fig. 3.

The crank E is made longer than the crank I, in about the proportion of nineteen to seventeen, and the cranks are so set upon the shaft M that the crank E leads the crank I about one hundred and five degrees, all as shown in Fig. 7. The cylinder G rests upon and is secured to the water chamber K, and is connected to the power-cylinder by the passage L.

M is the crank-shaft, mounted in bearings N N, formed upon the upper part of the frame O, and having secured thereto the fly-wheel P and the cranks E and I so set thereon that the crank E is about ninety-eight degrees in advance of the crank I.

R is a double-acting force pump adapted to use for pumping water for any desired purpose, the discharge from which communicates with the water space or chamber K, from which the water, after cooling the air in the cooling-chamber S, separated from the water-chamber K by the partition T, is discharged through the outlet-nozzle U, from which it may be conveyed by a suitable pipe or pipes to any desired point.

So far the engine shown is substantially like that illustrated and described in the Letters Patent, No. 167,568, granted Alexander H. Rider, September 7, 1875, to which reference may be had for further explanation of details.

We will now proceed to describe our improvements. To the upper end of each of the cylinders A and G is firmly secured an air-tight chamber, *a*, of suitable length and diameter to inclose the crank and connecting-rod of the engine, and permit a free movement thereof within said chamber, the crank-shaft M passing through the side wall of said chamber, the joint around said shaft being made tight by means of any suitable packing.

b is a cylindrical tank or receiver, which may be located at any convenient point relative to the engine, and communicating through the pipes *c*, *c'*, and c^2 with the chambers *a*, and through the pipes *d* and *d'* and check-valve *e* with the cooling-chamber beneath the piston H, and thence through the passage L, with the working-cylinder A and heater C beneath the piston D.

The receiver *b*, chambers *a a*, working-cylinder A, heater C, and cooling-chamber S are all filled with compressed air at any desired pressure, and at the normal temperature of common atmospheric air. This may be done by means of a hand-pump, or the engine may be started with common atmospheric air and pump itself up to the desired pressure, to which the valve *i'* is adjusted.

When a fire is built under the working or power cylinder, and the engine is started by imparting a rotation to the fly-wheel by hand in the usual manner, the engine works under the pressure of the artificial atmosphere precisely in the same manner that the engine would work under the pressure of the ordinary atmosphere, but developing a greatly increased power without material increase in the consumption of fuel, the same air being used over and over continuously. This might continue for an indefinite time without any additional supply of air whatever if the engine could be made absolutely tight, but as this is a very difficult thing to accomplish, especially when using the air at a very high pressure, an air-pump, *f*, is provided for the purpose of forcing air into the receiver to supply the place of that which passes through the pipes *d* and *d'* and check-valve *e* to the cooling-chamber S, and thence to the power-cylinder A, to supply the loss occasioned by leakage from said cylinders and maintain the pressure in the receiver *b* at a given and constant point.

The pump-rod *g* passes through the stuffing-box *h'* in the lower end of the extension *h* of the chamber *a*, and is worked by the arm *i*, attached to and moving with the piston D, as shown in Fig. 3. The pump R is operated in a similar manner from the piston H.

The air-pump *f* is provided with a relief or discharge cock or valve, *i'*, which may be arranged to open at a given pressure to which it may be adjusted so that the pump *f* will discharge into the receiver *b* through the valve *f'* and the pipe f^2, which connect the pump and receiver, as shown in Fig. 5, so long as the pressure in the receiver is below said given point, and, when said pressure is above said given point the pump will discharge through the valve *i'* into the atmosphere and relieve the engine from all work on account of the air pump, except what is due to friction.

j is the smoke-pipe leading from the fire-chamber B to the chimney, in a well-known manner.

k is a pipe leading from the water-chamber K to, and communicating with, an annular chamber, *l*, formed in the upper part of the cylinder A, through which a portion of the water pumped into the chamber K circulates to cool the cylinder and prevent the burning of the packing and lubricating material, said water being discharged through the pipe *m*, from which it may be conveyed to any desired point.

It is obvious that two or more of these engines may be connected to cranks mounted upon the same shaft, but set at different angles thereon for the purpose of more evenly distributing the power and overcoming the dead-point.

In the modification shown in Fig. 6, the cranks and crank-shaft are located above the chambers *a a*, the piston-rods *o* and *p* passing through stuffing-boxes *q* and *r*, and connected to the cross-heads *s* and *t* on the frame O, to which the connecting-rods F and J are connected, but the internal arrangements of the engine in other respects are precisely the same as heretofore described.

The operation of our invention is as follows: The several moving parts being in the positions shown in the drawings, and a suitable fire having been started in the furnace B, beneath the working-piston D, the operator to start the engines stands in front of the engine and pulls down upon the front side of the fly-wheel P to rotate it in the direction indicated by the arrow on Fig. 2 to impart thereto one or two revolutions, when the engine will start off and run without further assistance, if sufficiently hot.

The power of the engine is due to the difference of pressure in the chambers beneath the pistons, as compared with the chambers above the pistons, occasioned by the alternate heating and cooling the same body of compressed air over and over without exhausting it, together with the difference in length of the cranks and their angular positions upon the shaft M relative to each other.

As the piston D is being moved upward by the pressure of the heated air beneath it the piston H is being moved downward, thereby displacing the cold air in its cylinder and forcing it into the chamber beneath the piston D, where it is again heated to increase the pressure beneath the pistons, which, acting upon the piston D, continues to move it upward till it has reached the extreme of its upward movement and the crank E reaches its dead-center, when the crank I, having passed its dead-center, and the piston H having started on its upward stroke, the pressure of the heated air beneath the piston D, being transmitted through the passage L to the space below the piston H, reacts upon said piston to move it upward, and thus continue the rotation of the shaft M and move the piston D downward, thereby forcing the heated air again through the passage L to the space beneath the piston H, where it is cooled by contact with the cylinder T, which is surrounded by cold water in the annular chamber S, through which it is constantly circulated by the operation of the pump R.

I claim—

1. The combination of a working or power cylinder provided with a heating apparatus located beneath it, a cooling cylinder located at one side of and parallel, or nearly so, with said working-cylinder and having free communication therewith through a connecting-passage, a piston fitted to work tightly in each of said cylinders and connected together by a shaft and suitable cranks and connecting-rods, and adapted to be worked by alternately heating the air under one piston and cooling it under the other, the upper ends of both of said cylinders being tightly closed to adapt the chambers above the pistons to contain air, gas, or gaseous fluid at a pressure greater than that of ordinary atmospheric air, substantially as described.

2. The combination of a working or power cylinder provided with a heating apparatus located beneath it, a cooling-cylinder located at one side of said working-cylinder, having free communication therewith through a connecting-passage, a piston fitted to work tightly in each of said cylinders and connected together by a shaft and suitable cranks and connecting-rods, and adapted to be worked by alternately heating air under one piston and cooling it under the other, a chamber above each of said pistons adapted to contain gas or gaseous fluid at a pressure greater than that of the ordinary atmosphere, a pipe or pipes leading from the chambers above said pistons to the chamber beneath the piston in the cooling-cylinder, and a check-valve adapted to permit the passage of air, gas, or gaseous fluid from the chambers above the pistons to the space beneath the pistons and prevent its return, substantially as described.

3. The combination of a working-cylinder provided with a reciprocating piston, an air-pump adapted to force air into said cylinder under pressure, a heating apparatus for applying heat to said working-cylinder to heat the air contained therein, and a cooling or refrigerating device, all arranged and adapted to operate substantially as and for the purposes described.

4. The combination of a working-cylinder provided with a heating apparatus, a cooling-cylinder having free communication with the working-cylinder, a piston fitted to move in each of said cylinders and adapted to be operated by the alternate heating and cooling of the body of air contained beneath said pistons, the receiver *b*, having free communication through the pipes *c*, c', and c^2 with the chambers *a a*, above the pistons, and through the pipes *d* d' and check-valve *e*, with the spaces below the pistons, substantially as and for the purposes described.

5. In combination with a working or power cylinder provided with a heating apparatus, a cooling-cylinder having free communication with the working-cylinder, their respective pistons, and a receiver filled with compressed air and communicating with closed chambers upon both sides of said pistons, an air-pump connected by a suitable pipe or pipes with said receiver and adapted to force air into it under pressure, substantially as and for the purposes described.

6. In combination with an engine adapted to be worked in an artificial atmosphere by the alternate heating and cooling of the compressed air upon one side of the piston or pistons and the constant pressure of air compressed to the same density upon the other side of said piston or pistons, a receiver adapted to supply compressed air to both sides of the piston or pistons, an air-pump to force air into the receiver, and a relief-valve adapted to serve as a discharge for said pump when the pressure in the receiver is maintained at the desired point, substantially as described.

7. The combination of a working-cylinder of an air engine and its piston adapted to be operated by alternately heating and cooling the air contained upon one side of said piston, an air-pump adapted to force air into said cylinder under pressure, a receiver or reservoir placed between said pump and the working cylinder and having communication with the chamber above the working-piston, a pipe leading from said receiver to the chamber beneath said working piston, and a check-valve adapted to permit the free passage of air from the receiver to the chamber beneath the working-piston and prevent its return, substantially as described.

8. The combination of a working cylinder of an air-engine and its piston adapted to be operated by alternately heating and cooling the air contained upon one side of said piston, an air-pump adapted to force air into the chamber above the piston of said cylinder under pressure, a pipe leading from the chamber above said piston to the chamber beneath it, and a check-valve adapted to permit the free passage of air from the upper side of said piston to its under side and prevent its return, substantially as described.

9. In combination with an air-engine adapted to contain and be operated by air under pressure, a pump for forcing air into said engine, and a relief-valve adapted to control the pressure in the engine, substantially as described.

Executed at Boston, Massachusetts, this 25th day of May, A. D. 1877.

JAMES A. WOODBURY.
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Witnesses:
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JOSIAH DAVIDSON.