4 Sheets—Sheet 1.

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

Air-Engine.

No. 228,713. **Patented June 8, 1880.**

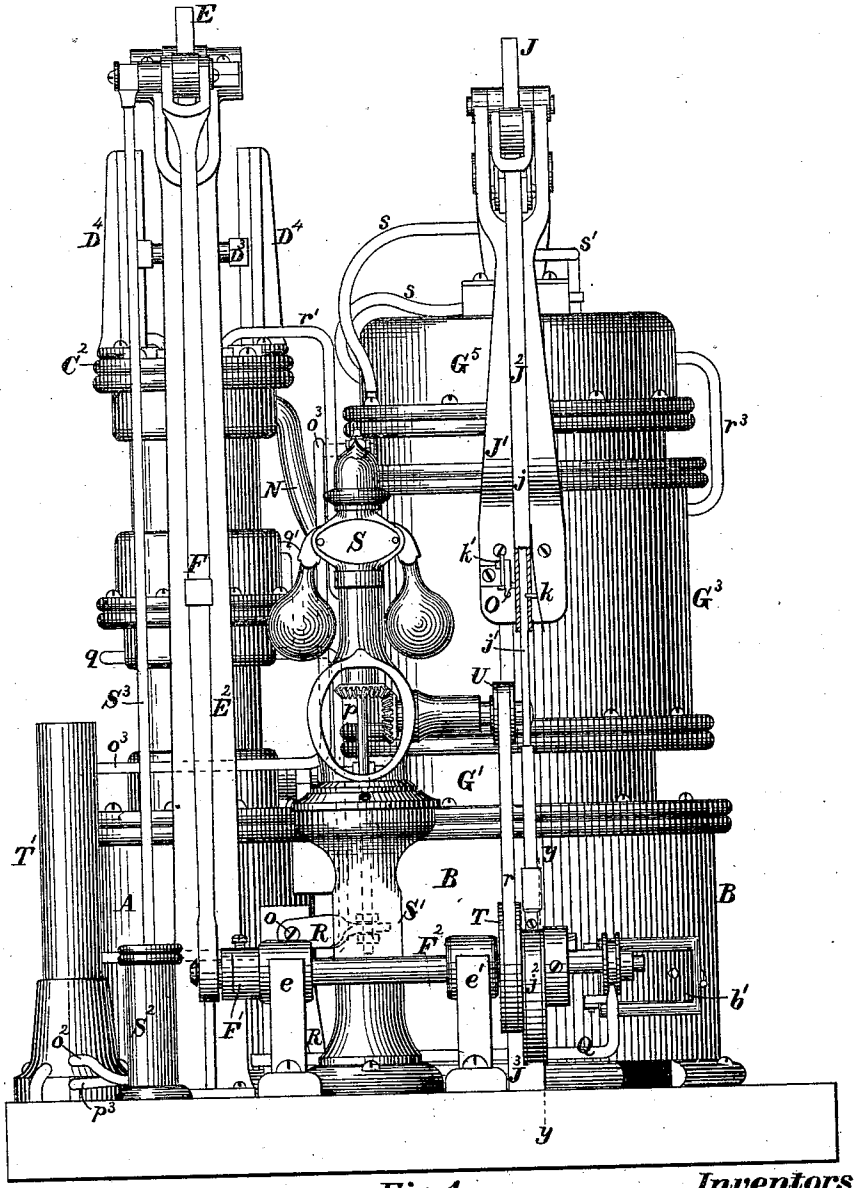

Fig. 1.

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4 Sheets—Sheet 2

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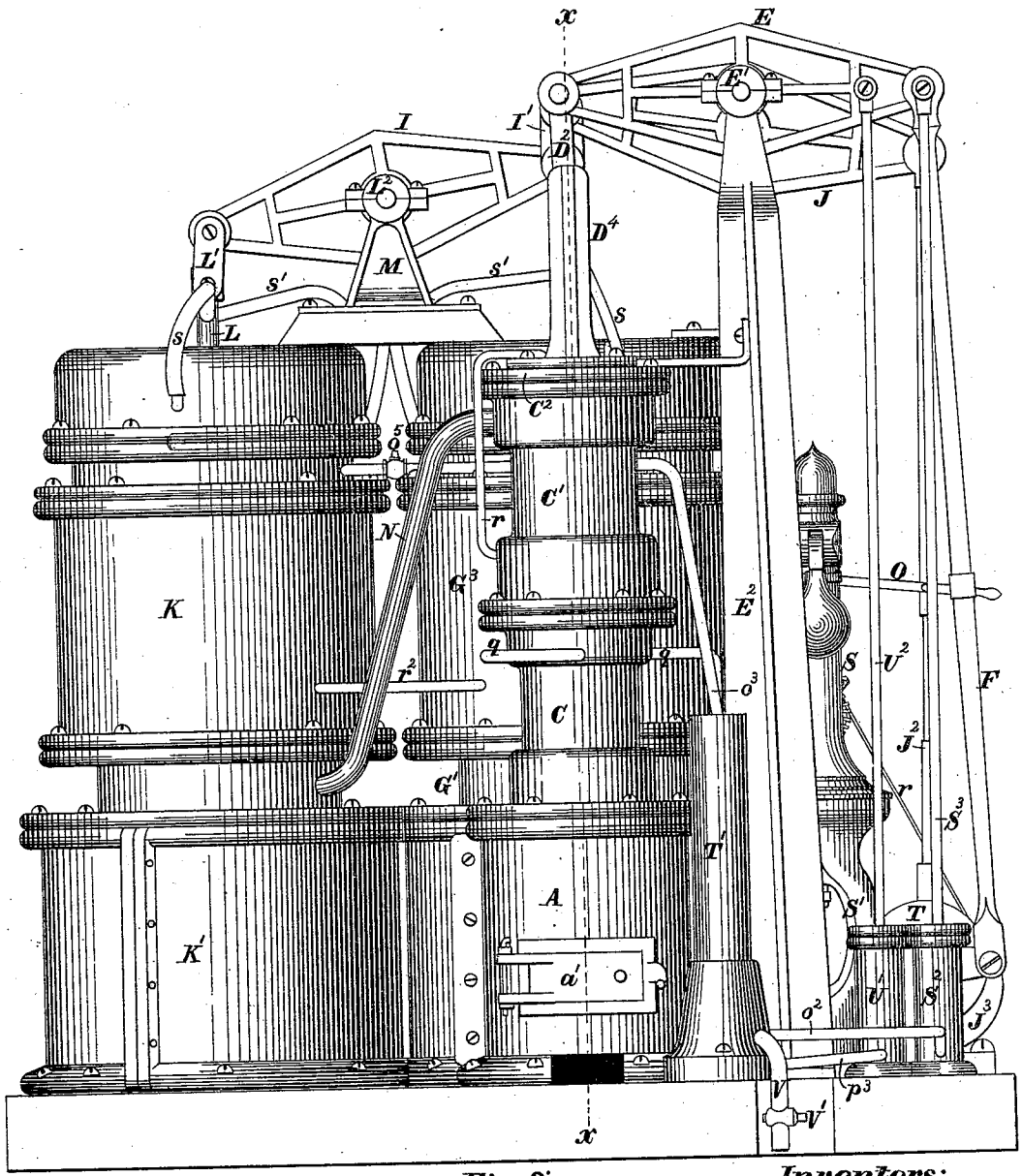

Fig. 2.

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4 Sheets—Sheet 3

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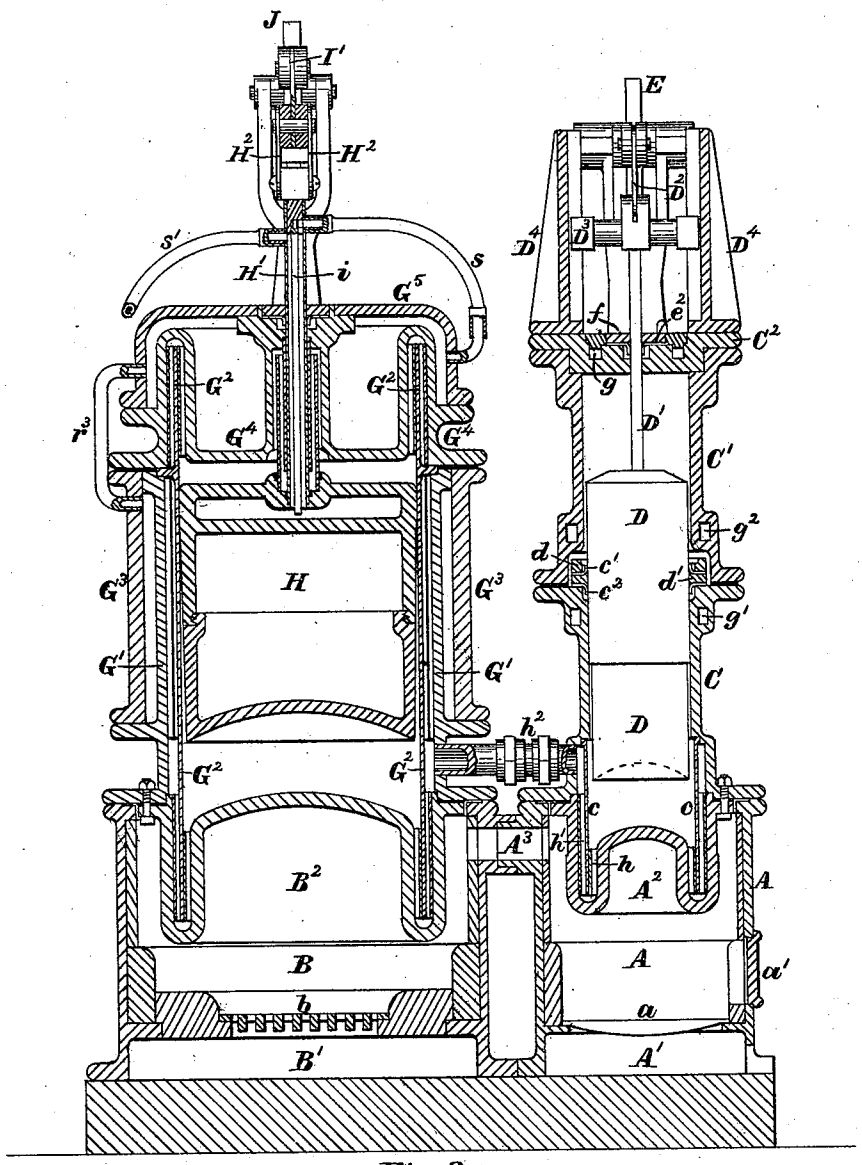

Fig. 3.

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4 Sheets—Sheet 4

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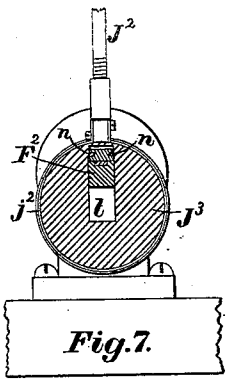

Fig.7.

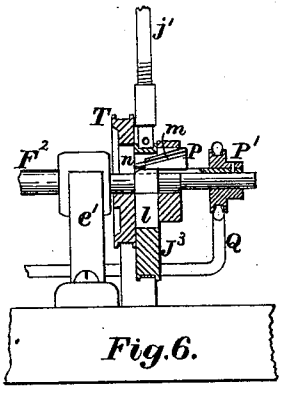

Fig.6.

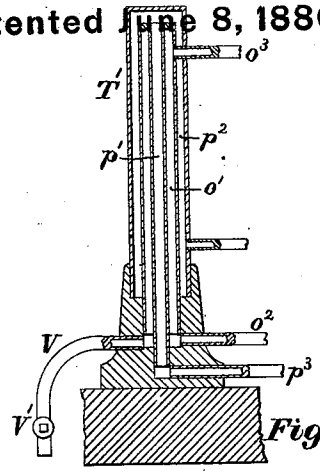

Fig.5.

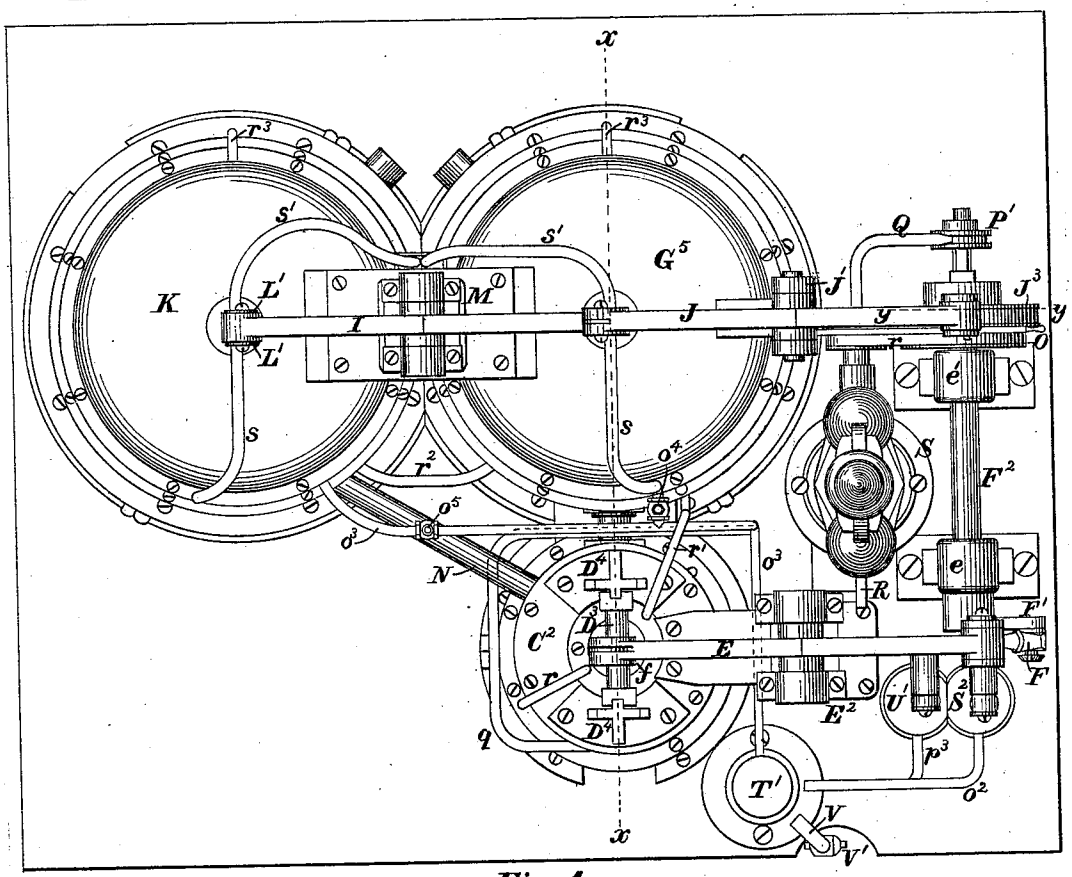

Fig.4.

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UNITED STATES PATENT OFFICE.

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AIR-ENGINE.

SPECIFICATION forming part of Letters Patent No. 228,713, dated June 8, 1880.

Application filed May 1, 1879.

To all whom it may concern:

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

Our invention relates to that class of air-engines which are operated by alternately heating and cooling the same body of air, and to that particular kind of such engines in which a working-cylinder is used in combination with one or more reverser-cylinders, each provided with a reciprocating piston adapted to displace the air alternately from either end of said cylinder and force it to the opposite end; and it consists, first, in the combination of two reverser-cylinders, a double-acting working-cylinder provided with a long piston, and a furnace or other means of applying heat to each of said cylinders.

It further consists in the use, in combination with a double-acting working-cylinder operated by hot air applied to both ends of the working-piston, of a chamber in the cylinder-head, through which the piston-rod passes, and in close proximity to the packing of the piston-rod, through which water or other cooling material is made to circulate as a means of preventing the heat from destroying the packing.

It further consists in the combination, with a working-cylinder provided with a long piston actuated by hot air applied to both ends thereof, of a packing for said piston, located at or near the center of the length of said cylinder.

It further consists in the combination, with a working-cylinder provided with a piston actuated by hot air applied to each end thereof, and a packing for said piston, located at or near the center of the length of said cylinder, of an annular chamber above and below said packing, through which water or other cooling liquid is made to circulate as a means of keeping the packing cool.

It further consists in the combination, with a double-acting working-cylinder and one or more reverser-cylinders, each composed of a heater, a refrigerator, and a regenerator, of one or more pipes or passages leading from said reverser-cylinder at a point between the heater and regenerator to either end of the working-cylinder.

It further consists in the combination, with a working-cylinder and one or more reverser-cylinders, of an air-pump adapted to force air into said cylinders under pressure, and a cooler located between said pump and the reverser-cylinder, and through which water or other cooling liquid freely circulates in contact with the pipe through which the air passes on its way from said pump to the cylinders.

It further consists in the use of a cooler for reducing the temperature of the air before it enters the cylinders of the engine, composed of three pipes, arranged one within the other in such a manner as to form an outer and an inner water-space and an annular air-space between them, with suitable inlet and outlet pipes communicating with both the water and air spaces, as will be described.

It further consists in the combination, with a working-cylinder and one or more reverser-cylinders, of mechanism for varying the power of the engine at will by increasing or diminishing the stroke of the reverser-piston.

It further consists in the combination, with the piston of a reverser-cylinder and the crank-shaft operated by the piston of the working-cylinder, of an adjustable eccentric mounted on said shaft and connected by its rod and a lever or beam to the reverser-piston and a wedge connected therewith and with a regulator, and adapted to be moved endwise by said regulator in either direction parallel with the axis of the shaft, thereby causing the eccentric to be moved radially upon said shaft to vary the throw of the eccentric, and thereby change the stroke of the reverser-piston.

It further consists in the combination, with the piston of a reverser-cylinder of an air-engine, of an eccentric-rod made in two parts, adapted to slide one within or upon the other, a lever connected with one portion thereof, as a means of operating the reverser-piston by hand to start the engine, and a locking device adapted to securely couple the two parts of said rod together.

Figure 1 of the drawings is a front elevation of an engine embodying our improvements. Fig. 2 is a side elevation. Fig. 3 is a vertical section on line *x x* on Figs. 2 and 4. Fig. 4 is

a plan. Fig. 5 is a central vertical section of the tubular air-cooler. Fig. 6 is a longitudinal vertical section through the eccentric and its appendages, and Fig. 7 is a transverse section of the same on line *y y* on Figs. 1 and 4.

A is the furnace of the working-cylinder, provided with a grate, *a*, fire-door *a'*, ash-pit A', and heater A^2, and connected by the flue A^3 with the furnace B, also provided with a grate, *b*, a fire-door, *b'*, ash-pit B', and heater B^2, all constructed substantially the same as described in detail in another application of even date herewith.

C and C' are the two sections of the working-cylinder, provided with the cylindrical deflector *c*, packing-rings *c'* and c^2, secured by the metal rings *d* and *d'*, and firmly secured together and to the furnace A by suitable bolts, with a packing of asbestus or copper-wire gauze embedded in red lead, and having its upper end closed by the head C^2, as shown in Fig. 3.

D is the working-piston, made long, and connected by the piston-rod D' and link D^2 to one end of the beam E, mounted by central trunnions E' in bearings in the column E^2, the opposite end of said beam being connected by the rod F to the crank F', secured to one end of the shaft F^2, mounted in bearings *e* and *e'*, said piston-rod being guided in its movements by the cross-head D^3 and the slides D^4.

The piston-rod D' is packed, where it passes through the cylinder-head C^2, by means of a leather-cupped packing, e^2, firmly held in place by the disk *f*, bolted firmly to the cylinder-head, and clamping said packing-ring between it and the cylinder-head, as shown.

An annular chamber, *g*, is formed in the cylinder-head C^2, surrounding the piston-rod and in close proximity to the packing-ring, through which water or other cooling liquid is made to circulate to prevent the packing from being injured by the great heat of the air contained in the space between said head and the piston D.

Similar annular chambers *g'* and g^2 are formed above and below the piston packing-rings *c'* and c^2, through which water or other liquid is made to circulate to keep said packing-rings cool.

The space beneath the working-piston D is connected by the annular passages *h* and *h'* and the pipe h^2 to the reverser-cylinder, composed of the heater B^2, regenerator-casing G', deflector or inner cylinder, G^2, outer casing, G^3, refrigerator G^4, and bonnet or outer cap, G^5, all constructed, arranged, and secured together with suitably-packed joints, substantially in the same manner as described in the application before cited.

The space between the lower portions of the deflectors *c* and G^2 and the outer and inner walls of the heaters A^2 and B^2, between the upper portion of the deflector G^2 and the outer and inner walls of the refrigerator G^4, and between the central portion of the deflector or inner cylinder, G^2, and the regenerator-casing G', are filled with corrugated plates of metal, as described in the before-cited application of even date herewith.

H is the reverser-piston, provided with a hollow piston-rod, H', having therein an inner pipe, *i*, as shown, said piston-rod being connected by the links H^2 to one end of the beam I, and by the link I' to one end of the beam J, mounted by central journals in bearings formed in the upper end of the bifurcated stand J', and connected at its other end with the upper end of the eccentric-rod J^2, as shown.

K is a second reverser-cylinder, and K' its furnace, constructed in all respects like the reverser-cylinder and its furnace hereinbefore described, and provided with a reverser-piston and the hollow piston-rod L, also constructed as heretofore described, said piston-rod L being connected by the links L' to the beam I at the end opposite where the piston-rod H' is connected thereto, said beam being mounted by central journals, L^2, in bearings formed in the stand M, supported by the two reversing-cylinders, as shown.

The heated end of the reverser-cylinder K is connected by the pipe N with the chamber above the working-piston in substantially the same manner that the other reverser-cylinder is connected by the pipe h^2 to the chamber beneath said working-cylinder.

The eccentric-rod J^2 is made in two parts, *j* and *j'*, the upper part, *j*, being weighted or made heavy to partially balance the piston H of the reverser, and its lower end is made tubular to receive the upper end of the portion *j'*, the lower end of which is connected by the strap j^2 to the eccentric J^3, the two parts *j* and *j'* of the rod J^2 being firmly secured together, so as to act as one rod, by the spring-actuated locking-pin *k*, as shown in Fig. 1.

O is a lever, fulcrumed at *k'* and connected to the lower end of the portion *j* of the rod J^2, by means of which, acting through the beam J, the reverser-piston H may be moved by hand for starting the engine.

The eccentric J^3 is provided with an oblong slot, *l*, which fits closely upon two opposite sides to a square portion of the shaft F^2 in such a manner that the eccentric may be moved radially upon said shaft to increase or diminish its throw.

P is a wedge fitted to and adapted to slide in a longitudinal groove formed in the shaft F^2, and having formed in opposite sides thereof inclined grooves *m m*, which engage with correspondingly-inclined inwardly-projecting lips *n n*, attached to or forming a part of the eccentric, as shown. The wedge P is firmly secured to the grooved disk P', with the groove of which the shipper-fork Q engages, said shipper being connected to one arm of the elbow-lever R, pivoted at *o*, and having its other arm connected to the vertically-sliding rod *p* of the governor S, supported upon the stand S', and having motion imparted thereto by the belt *r*, leading from the pulley T on the shaft F^2 to the pulley U of the regulator.

T is a stand-pipe or cooler, composed of three pipes arranged one within the other, as shown in Fig. 5, to form an annular air-space, o', an inner water-space, p', and an outer water-space, p^2.

S^2 is an air-pump, the plunger S^3 of which is operated from the beam E, and by its reciprocation forces air through the pipe o^2, air-space o' in the cooler T′, and through the pipe o^3 to the interior of each of the reverser-cylinders. The object of this pump is twofold—namely, first to pump up the pressure in the cylinders to the desired standard, and, second, to supply any loss that may be occasioned by leakages, and thus maintain the pressure at the desired standard after it has once been attained, the air being prevented from returning from said reverser-cylinders by the check-valves o^4 and o^5.

U′ is a water-pump, the piston U^2 of which is operated by the beam E, and acts to force water through the pipe p^3 and water-spaces p' and p^2 in the cooler T′, thence through q to the annular chamber g', after traversing which it passes through pipe q' to the annular chamber g^2, and thence through pipe r, chamber g in the cylinder-head C^2 of the working-cylinder, and through pipe r' to the annular chamber surrounding the regenerator of the contiguous reverser-cylinder, then through the pipe r^2 into the chamber surrounding the regenerator of the other reverser-cylinder, and then passing in two currents through the pipe r^3 to the water-chambers surrounding the refrigerators, from there through the pipes s, a portion of which, at least, are made of flexible material, to one of the passages in each of the piston-rods H and L, through which it reaches the chambers in the upper ends of the reverser-pistons, from which it is discharged through the central passages of said piston-rods and the flexible pipes s' into the open air.

V is a pipe set in the lower end of the cooler T, and provided with the cock V′, for the purpose of facilitating the withdrawal of the water of condensation from the air-space within said cooler.

What we claim as new, and desire to secure by Letters Patent of the United States, is—

1. The combination of two reverser-cylinders and a double-acting working-cylinder provided with a long piston with a furnace or other means of applying heat to each of said cylinders, substantially as described.

2. In a double-acting working-cylinder operated by hot air upon each side of the piston, a water-space in close proximity to the packing of the piston-rod, substantially as and for the purposes described.

3. In combination with a double-acting working-cylinder of a hot-air engine provided with a long piston, a packing for said piston, located at or near the center of the length of said cylinder, substantially as and for the purposes described.

4. In combination with a double-acting working-cylinder provided with a piston actuated by hot air applied to each end thereof, a packing for said piston, located at or near the center of the length of said cylinder, and an annular water-space upon each side of said packing, substantially as and for the purposes described.

5. In combination with a double-acting working-cylinder provided with a long piston and two reverser-cylinders, a pipe or passage leading from the hot end of one of said reverser-cylinders to the lower end of the working-cylinder, and a pipe or passage leading from the hot end of the other reverser-cylinder to the upper end of the working-cylinder, substantially as and for the purposes described.

6. In combination with a working-cylinder and one or more reverser-cylinders, an air-pump adapted to force air into said cylinders under pressure, and a cooler located between said pump and the reverser-cylinder, through which water freely circulates around the pipe or pipes through which the air passes on its way to said cylinder, substantially as described.

7. A cooler composed of three pipes, arranged one within the other, as set forth, to form an outer and an inner water-space and an air-space between them, substantially as described.

8. In combination with one or more working-cylinders and one or more reverser-cylinders, mechanism for varying the stroke of the reverser piston or pistons, as a means of regulating the power of the engine, substantially as described.

9. In combination with the piston of a reverser-cylinder and the crank-shaft operated by the working-piston, an adjustable eccentric mounted on said shaft, and connected by its rod and a suitable lever or beam to the reverser-piston and a wedge connected therewith and with a regulator, and adapted to be moved by said regulator in either direction parallel with the axis of the shaft, and thereby cause the eccentric to be moved radially upon said shaft to increase or diminish its throw, substantially as described.

10. In combination with the piston of a reverser-cylinder of an air-engine, an eccentric-rod made in two parts, adapted to slide one within or upon the other, a lever connected with one portion thereof, as a means of operating the reverser-piston by hand, and a locking device adapted to securely couple the two parts together, substantially as and for the purposes described.

Executed at Boston, Massachusetts, this 28th day of April, A. D. 1879.

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