J. R. NAPIER & W. J. M. RANKINE.

AIR ENGINE.

No. 11,696. Patented Sept. 19, 1854.

Fig: 1

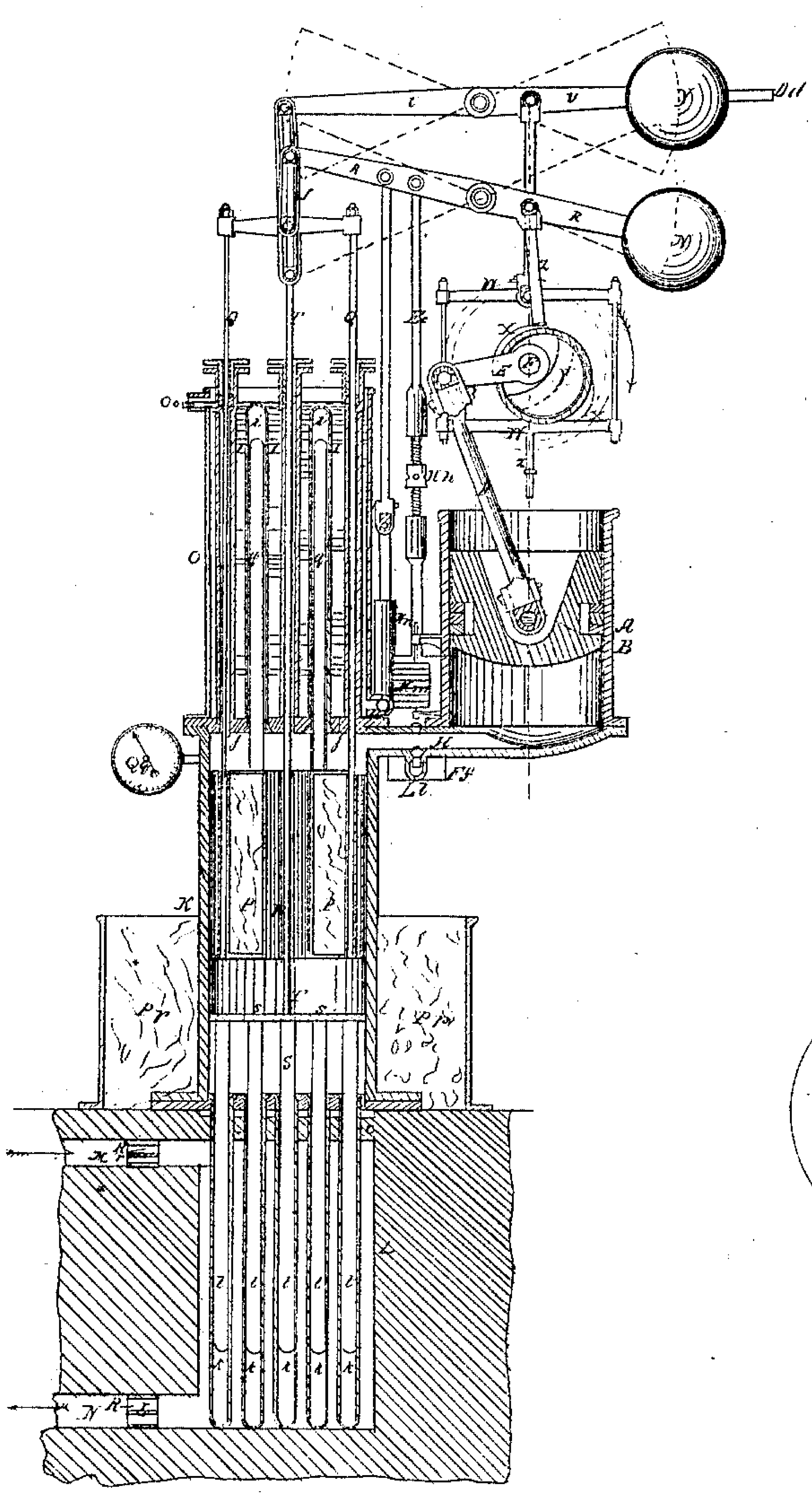


Fig: 2

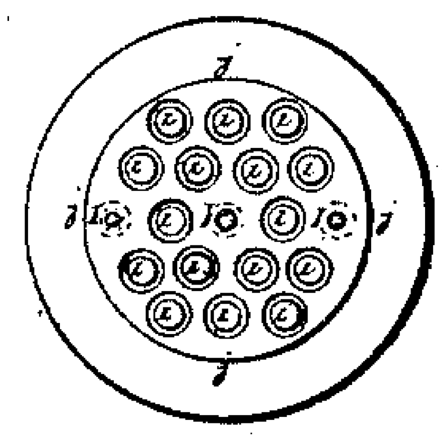


Fig: 4

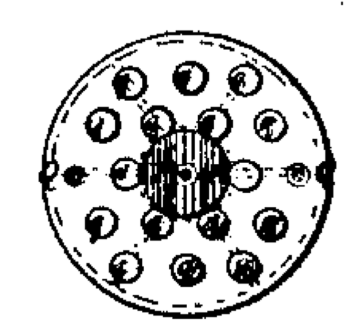


Fig: 3

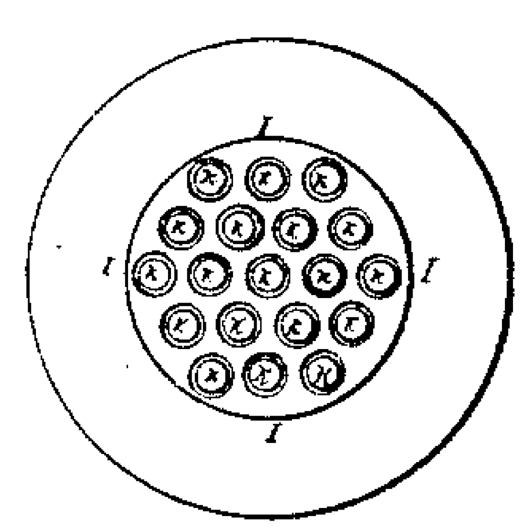
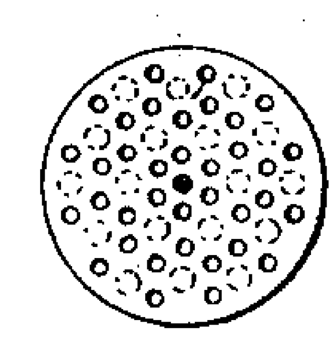


Fig: 5.



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UNITED STATES PATENT OFFICE.

JAMES R. NAPIER, OF GLASGOW, AND WILLIAM J. M. RANKINE, OF GOVAN, SCOTLAND.

IMPROVEMENT IN AIR-ENGINES.

Specification forming part of Letters Patent No. **11,696**, dated September 19, 1854.

To all whom it may concern:

Be it known that we, JAMES ROBERT NAPIER, mechanical-engineer and iron-ship builder, of Lancefield House, Glasgow, in the county of Lanark and United Kingdom of Great Britain and Ireland, and WILLIAM JOHN MACQUORN RANKINE, civil engineer, formerly of Rosebank House, in the parish of Rutherglen and county aforesaid, now of Moss Farm Cottage, in the parish of Govan and county of Renfrew, in the said Kingdom, subjects of the Queen of Great Britain, have invented or discovered new and useful Improvements in Engines for Developing Mechanical Power by the Action of Heat on Air and other Elastic Fluids; and we, the said JAMES ROBERT NAPIER and WILLIAM JOHN MACQUORN RANKINE, do hereby declare the nature of our said invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statements—that is to say:

The engines which this invention is calculated to improve are those which develop mechanical power applicable to the moving of any kind of machinery by successively heating, dilating, cooling, and condensing a portion or portions of air or any other elastic fluid in such a manner that the dilatation takes place at a higher temperature and the condensation at a lower temperature, and which are known by the names of "air-engines" and "caloric engines."

The engine which we will now describe for the purpose of showing the nature of the improvements proposed by us, and which is represented in the annexed drawings, forming part of this specification, consists partly of parts and combinations of parts which have been heretofore used and partly of parts and combinations of parts which we claim as our invention for the improvement of such engines, and which we shall hereinafter specify and claim in detail.

The arrangement of the different portions of the engine shown in the drawings is one of many practicable arrangements which we select as being well adapted to display all the essential parts of the engine at one view. It is obvious that the essential parts of the engine being properly connected with each other may be arranged in any other way which may be found best suited to the situation in which it is to be used and the work which it is to perform. The frame-work by which the working parts of the engine are to be supported is omitted from the drawings, because it involves nothing new or peculiar and would interfere with the distinct representation of the working parts.

Figure 1 represents a vertical section of the engine. Figs. 2, 3, 4, and 5 are plans of detached portions to be afterward more particularly specified.

In Fig. 1, A is a vertical section of a cylinder containing a piston B, which is connected by means of a connecting-rod D with a crank E and gives motion to a shaft F, which may be used to drive any machinery and on which is a fly-wheel. (Not shown in the drawings.) Besides the mode here shown of connecting the piston with the crank, any of the other modes used in steam-engines and air-engines might be employed.

H is a passage connecting the cylinder with a strong air-tight receiver K, the body or central part of which is cylindrical, and is shown in section in Fig. 1. The uppermost part of this receiver consists of a number of tubes of brass or other suitable metal open at the bottom, where they are strongly fixed in a plate *j*. These tubes are to be surrounded by water circulating in a tank O. Their arrangement is shown in the plan, Fig. 2. Three of these tubes (marked I) are provided with stuffing-boxes at the top, being intended for the passage of rods to be afterward described. The remainder (marked *i*) are closed at the top, and it is intended that the air or other gas should be cooled in them.

The lowest part of the receiver K consists of a number of tubes of brass or other suitable metal (marked *k*) arranged in the manner shown in the plan, Fig. 3, closed at the bottom and open at the top, where they are strongly fixed in a plate *i*. It is intended that the air or other gas should receive heat through them by conduction from the flame of a furnace circulating in a flue L around and between the tubes. The plate L is protected from the action of the flame by a fire-clay shield *o*.

M is a flue conducting the flame from a furnace; N, a flue which conducts the products of combustion to the chimney.

P is a plunger, of sheet iron or other metal, divided into compartments so as to be at once light and strong, as shown in the plan, Fig. 4. Some of these compartments are to be air-tight and to be filled with brick-dust, fire-clay, or some other substance which conducts heat slowly; but one or more compartments are to extend through the plunger, so as to form a passage for air or gas, and are to be filled with a series of layers of wire-gauze or thin perforated metal plates, strips, or wires, or of some substance capable of conducting heat rapidly, and so formed and arranged as to expose a large surface for the communication of heat to and from the air which may pass through. One such passage occupied as described is represented by *p* in the section and plan.

The plunger P is to be made to fit the body of the receiver K as closely as is consistent with its moving up and down with as little friction as may be against the sides of the receiver. It is to be suspended by one or more rods from levers (marked R) which move on a pivot *r* and have a counterpoise at V′. In the engine shown in the drawings there are two such rods for this plunger, (marked Q.) They work through stuffing-boxes at the top of two of the tubes I and are attached to a cross-bar, which is hung from the levers R by a pair of links J, and is so formed as to allow a third rod T to pass freely through it for a purpose to be afterward stated. Another of the tubes I is traversed by this rod. The tubes *i*, two of which only are shown in section, are occupied by cylindrical rod-shaped metal plungers *q*, which, being arranged as shown in the plan, Fig. 4, are fixed to the top of the plunger P, forming part of it and moving along with it and fitting the tubes *i* loosely, so as to leave a passage for air or gas all round each tube about an eighth of an inch wide.

The rod T, suspended from the beam U, works through a stuffing-box at the top of one of the tubes I, and, descending through that tube, traverses also the center of the plunger P by a passage wide enough to let it work without friction, and is attached to the heat-screen S. This heat-screen consists of a circular plate *s*, of iron, brass, or other suitable metal, pierced with holes fitting the cylindrical part of the receiver K, but not so tight as to produce friction, and of a series of rod-shaped plungers *t*, of brass, copper, or other suitable metal, fixed to this plate and moving with it and capable of filling the tubes *k*, except a passage of about an eighth of an inch all round each tube. This heat-screen is shown in plan in Fig. 5, where the holes in the plate *s* are indicated by small full circles, the rod-shaped plungers *t* by dotted circles, and the rod T by which the heat-screen is suspended, by a dark spot.

The object of the heat-screen is to regulate the transmission of heat from the flame in the chamber L to the air or other gas in the lower part of the receiver K, so that it shall take place wholly or chiefly during the expansion of this air or other gas, which is the period most favorable for the development of mechanical power, and shall be wholly or almost wholly cut off at other times when the heat would be wasted or would impede the action of the engine. The rods *q* and *t* may be made hollow for the sake of lightness, but the hollows should be air-tight.

The form of the heat-screen shown in the drawings is a result of the tubular form of the bottom of the receiver with which it is made to correspond. Should the bottom of the receiver be made of any other shape, the heat-screen must be made to fit it. In like manner the top of the plunger P is to be made to fit the top of the receiver. The beam U, from which the heat-screen hangs by the rod T, moves on the axis *u*.

V is a counterpoise to balance wholly or partially the weight of the heat-screen. In stationary engines a preponderance may be allowed to the heat-screen sufficient to make it descend to the bottom of the receiver from the top of its stroke with rapidity, but not with violence. In marine and locomotive engines the balance of weight should be exact and the descent of the heat-screen should be produced by means of a spring or some other suitable mechanical contrivance.

X is a cam for moving the beam U; W, the frame on which the cam acts; *x*, a small guide-rod for this frame, and *w* a rod by which it is suspended from the beam U.

The cam X is so formed that while the air is being compressed or being cooled the heat-screen S remains quiescent at the bottom of the receiver K, and while the air is expanding and receiving heat the heat-screen rises and falls. Other mechanical contrivances might be used to produce the same motion of the heat-screen.

D *d* is a handle for raising the heat-screen by hand.

Y is an eccentric-wheel for working the plunger P. By means of the rod Z it gives a reciprocating motion to the levers R.

E *e* is a rod for working a forcing-pump F *f*, by which air or the other gas employed is to be compressed into the receiver and cylinder, both to obtain a sufficient pressure and to supply the loss by leakage.

H *h* is an adjusting-screw by which the rod E *e* can be lengthened or shortened, so as to increase or diminish or altogether to stop the supply of compressed air or gas forced into the engine at each stroke of the pump.

L *l* is a valve opening upward leading from the compressing-pump into the receiver and cylinder.

M *m* is a safety-valve.

N *n* is a forcing-pump, which supplies a stream of cold water to the tank O, which gradually rising among the tubes contained in that tank escapes finally by the waste-pipe O *o*, which should be conducted to some convenient outlet. In locomotive and marine engines the tanks should be subdivided by their perforated partitions to check agitation of the water. Another mode of cooling the tubes is to sprinkle them with water from a number of jets.

Q *q* is a pressure-gage. It should be capable of indicating pressures up to two hundred pounds on the square inch.

P *p* is an outer casing for the lower part of the cylindrical body of the receiver K, filled with brick-dust, engine-ashes, or some other slow conductor of heat.

R *r* are dampers for the flues. In the engine shown in the drawings the receivers are vertical; but it is obvious that they might be placed horizontally, the plungers and heat-screens being supported on rollers and the motion of the heat-screens toward the hot sides of the receivers being produced by springs or other mechanical contrivances.

Having thus described the parts of the engine and their connection with each other, we shall now describe how it is to work. During the working of the engine the following is the succession of changes undergone by the air in the receiver K: During the downstroke of the piston the heat-screen lies at the bottom of the receiver. The plunger P descends and the air, with the exception of a trifling quantity, passes through the passage *p* and gives out a large portion of its sensible heat to the wires, strips, or sheets of metal or other conducting-bodies contained in that passage. The remainder of the excess of the heat of the air above that of the water in the tank O is abstracted by the surface of the tubes *i* and rods *q*. The downstroke of the piston causes this air to be compressed. This compression produces heat, which is also abstracted by these rods and tubes. This heat were it not so abstracted would increase the elasticity of the air and oppose the motion of the piston. During the upstroke the plunger P rises, the air descends through the passage *p* and recovers the greater part of the sensible heat formerly lost from the wires or metal sheets or strips or other conducting substances, the heat-screen S is raised and dropped, and the air by circulating over its rods *t* and through the hot tubes *k* acquires the remainder of the sensible heat necessary to elevate its temperature and also the latent heat necessary to expand it. This completes the cycle of operations. The effect of these operations is of a similar nature to that which takes place in all engines driven by the action of heat on an elastic substance—viz., that the substance is alternately expanded at a higher temperature and contracted at a lower, so that the power developed by the expansion is greater than the power consumed by the contraction, and a surplus of power remains to drive machinery.

When the engine begins to work, should the cylinder and receivers be filled with air or other gas at a pressure not sufficiently great to perform the required work, the engine must be disconnected from the machinery it is intended to drive, and the pump-rods E *e* being adjusted by the screw H *h*, so that the piston of the pump shall nearly touch the bottom of the barrel at each stroke, the whole surplus power of the engine will be employed for some minutes in filling the receiver and the cylinder with compressed air. When the gage indicates that the required pressure has been attained, the engine may be connected with the machinery to be driven and the pump-rod E *e* shortened by means of the screw H *h*, so as to supply enough of air only to make up for leakage, which condition will be indicated by the pressure-gage.

The engine shown in the drawings is a single-acting engine, being the most simple form, steadiness of motion being obtained by means of the inertia of a fly-wheel and by properly adjusting the weight of the piston B. The steadiness of motion may be increased, as in the case of steam-engines, by using a double-acting engine having a receiver connected with each end of the cylinder, or by using two or more engines to drive the same shaft, their motion being so adjusted as to produce the nearest possible approach to uniformity of action on the shaft.

It is evident that many of the details may be varied without departing from the peculiar character of our invention as herein described.

Having thus described the nature of our invention, we would have it understood that we make no claim to any of the mechanical parts separately; but

We claim as the improvements which constitute the peculiarity of the engine—

1. The invention and adaptation of what we have called a "heat-screen," the form of which may be varied, and the means of giving motion thereto may also be varied, the said heat-screen being separate and distinct from the plunger which drives the air or other gas from the hot to the cold end of the receiver, and vice versa, and being adapted to the following purposes: first, to screen the principal portions of the air or other gas from the communication of heat from the furnace or source of heat at those times when that heat would impede the motion of the engine—that is to say, when the air or other gas is being passed toward the cold end of the receiver to be cooled, when it is not being expanded, and when it is being compressed; second, to receive and store up in its own material at such times the heat communicated from the furnace; third, to permit and accelerate the communication of heat to the air

or other gas at the time when it is most effective in developing mechanical power—that is to say, when the air or other gas is being expanded.

2. The adaptation of tubular receivers for the purpose of heating and cooling the air or other gas in the manner described in this specification—that is to say, by the aid of rod-shaped heat-screens or plungers nearly filling the tubes and serving by being moved out and in, whether by the mechanism shown in the drawings or by any other suitable mechanism, to admit and expel the air or other gas and promote its circulation over the heated or cooled surface.

3. We do not, however, claim the invention of tubes as a means of increasing heat-conducting surface, but simply the adaptation of tubes to engines worked by the action of heat on air or other gas by the aid of the rod-shaped heat-screens or plungers before described.

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