J. ERICSSON.

AIR ENGINE.

No. 13,348. PATENTED JULY 31, 1855.

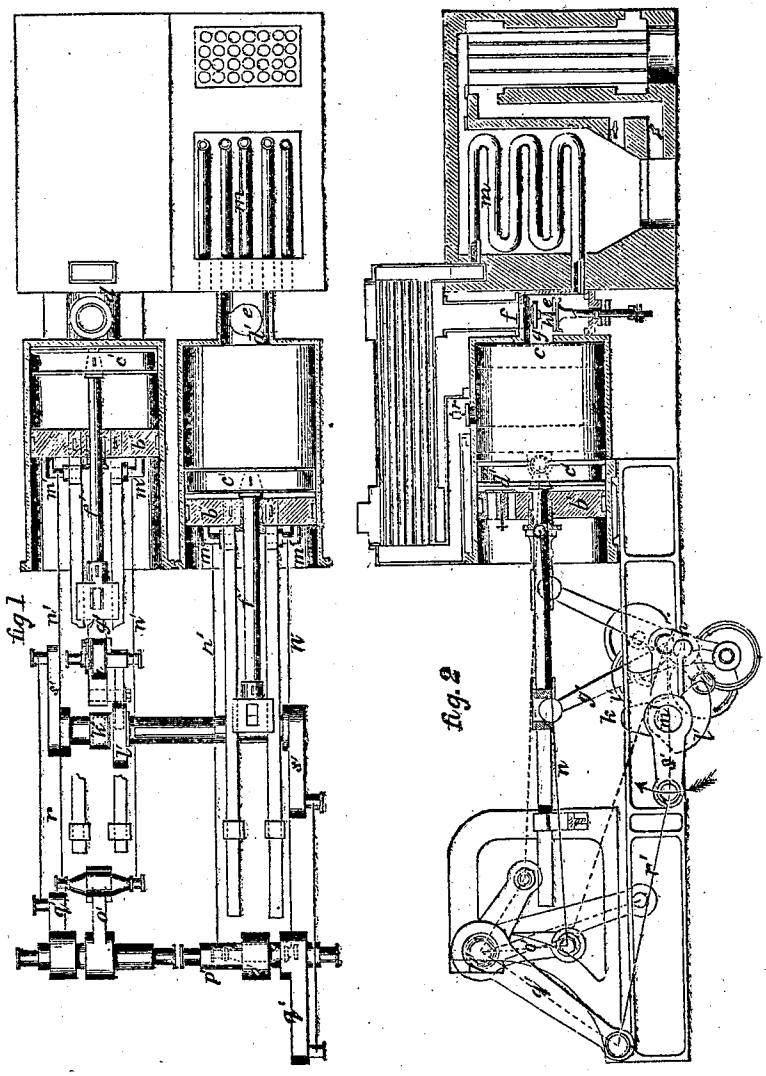

Fig. 1

Fig. 2

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JOHN ERICSSON, OF NEW YORK, N. Y.

IMPROVEMENT IN AIR-ENGINES.

Specification forming part of Letters Patent No. **13,348**, dated July 31, 1855.

To all whom it may concern:

Be it known that I, JOHN ERICSSON, of the city, county, and State of New York, have invented an Improved Air-Engine for Producing Motive Power by Heated Air, of which the following is a full, clear, and exact description, reference being had to the accompanying drawings, making part of this specification, in which—

Figure 1 is a plan, with the two cylinders, the pistons, and the air-heating apparatus in section; and Fig. 2 is a side elevation, with one of the cylinders, the piston, and the air-heating apparatus in section to exhibit the internal arrangement.

The application of the caloric in this engine is identical with that of the air-engine for which I obtained patents in England and other countries in the year 1833, descriptions and drawings of which have been published in several works, among which may be mentioned a work called "Dictionary of the Arts of Life and Civilization," by Sir Richard Philips, published in London, 1833. This work contains a correct delineation and description of my said air-engine.

The same letters indicate like parts in the two figures.

The heated air, after having performed its office in the working-cylinder of my present improved air-engine, may be made to circulate through a vessel containing a series of tubes, precisely as in my former engine referred to, and the current of heated air in passing through said vessel (called the "regenerator") may be met by a current of cold air circulating in an opposite direction through the series of tubes on its way to the working-cylinder, by which a transfer of caloric is effected between the two currents of air passing off from and entering the working-cylinder, precisely as in my said former engine, and the current of cold air on its way to the working-cylinder, after having been thus partially heated by the described process of transferring the caloric, is afterward made to pass through a series of tubes or other vessels exposed to the fire of a furnace, as in my said former engine, or in any other suitable manner; but although the means adopted for heating and for transferring the caloric from the escaping to the entering air is quite similar to that invented by me in the year 1833, yet the mechanism or engine which I have now invented for rendering the heating of the air, as described, subservient in producing motive power differs altogether from anything hitherto known. Before, however, describing my invention I deem it proper first to notice, in order that its nature may be correctly understood, that in all air-engines on what is called the "differential principle" (my improved air-engine for which I obtained patents in 1851, for instance) the motive energy depends solely on the difference of areas of the working and supply pistons. Experience has in the meantime demonstrated that in order to obtain a sufficient supply of air without resorting to a dangerously high temperature the supply-pump must be of such large capacity that the differential (active) area becomes too small. Unless, therefore, future experience should suggest some improvement, the power of such engines will always be found insufficient for practical purposes.

I will now proceed to describe the principal feature of my invention, which consists in charging the regenerator and heater, or either, with fresh compressed atmospheric air at each stroke of the engine without the employment of a supply-pump by the peculiar combined movements of two pistons within the working-cylinder, the introduction of fresh air and its transfer to the regenerator or heater in a compressed state being effected under a state of equilibrium of pressure, so that the supply-piston becomes entirely relieved from resistance during the process of charging the regenerator or heater, while at the same time one of these pistons performs the office of working-piston, exerting full force on the engine without suffering retardation by any unbalanced pressure against the supply-piston.

My said engine is single-acting, and I connect two of them by a crank-shaft, placing the two cranks at an angle of one hundred and eighty degrees, so that while the piston of one engine is being impelled by the tension of heated air the piston of the other shall be making its return-stroke, and vice versa, and as the two engines are identical in construction the description of one of them will answer for the two. The manner of connecting the two and the effects resulting therefrom will be subsequently described.

The cylinder *a* is open at one end and has a head, *b*, at the other, with a central aperture, *c*, leading to a valve-chest, *d*, with an induc-

tion-port, *e*, and an exhaust-port, *f*, fitted with valves *g* and *h*. The stem of the valve *g* passes through the hollow stem of the valve *h*, and these valves are to be operated by any known and suitable valve-gear giving the periods of movements such as will be presently described. The exhaust-port leads by a pipe, *i*, to a chamber, *j*, surrounding a series of small tubes, *k*, constituting what has been termed the "regenerator," so that the air passing from the cylinder to the escape-pipe *l* shall circulate around and among the series of tubes to impart its heat to the cold supply-air contained within the tubes, and the induction-port communicates with the tubes *m* of what is termed the "heater." The series of tubes *k*, constituting the regenerator, are suitably secured to a tube-sheet, *n*, at each end, and open into two chambers, *o* and *p*—the one, *o*, communicating by a pipe, *q*, with a port in the side of the cylinder, governed by a self-acting valve, *r*, opening outward, and the other, *p*, communicating with the heater-tubes *m*, which are to be suitably coiled or otherwise arranged to present a large extent of surface to the action of the heat evolved from the fire of a furnace, *s*, the series of tubes *m* being placed above the fire, so that the products of combustion in passing to the flue *t* shall circulate around and among them. The bottom plate of the flue *t* is a tube-sheet, to which are secured a series of flue-tubes, *u*, down which the products of combustion pass to a flue, *w*, below, leading to the chimney.

The flue-tubes *u* are inclosed in a chamber having an aperture, *v*, near the bottom, to receive a current of air from the atmosphere, and another aperture, *x*, near the top, through which the current of air passes after circulating around and among the flue-tubes by which it is heated, so that the products of combustion escape into the atmosphere at a very low temperature, for it will be observed that the two currents travel in opposite directions, the atmospheric current passing from the coldest toward the hottest ends of the flue-tubes gradually absorbing the heat from the products of combustion which are passing through the tubes in the opposite direction.

From the passage *x* the partially-heated air passes down a vertical flue or tube, *y*, having two apertures, *z* and *a'*, both governed by dampers or registers, one leading below the grate in the furnace to supply the fire when more heat is required, and the other above the fire to admit the air directly to the heater-tubes *m* when it becomes necessary to moderate the heat of the tubes. By this arrangement a great saving of fuel is effected and the attendant can control and regulate the heat of the heater-tubes with perfect ease.

To the cylinder are fitted two pistons, *b'* and *c'*. The one, *b'*, is nearest the open end of the cylinder and called the "working-piston," and is provided with a self-acting valve, *d'*, opening inward, and the other, *c'*, termed the "supply-piston," is placed between the working-piston and the head of the cylinder.

The rod *f'* of the supply-piston passes through a stuffing-box, *e'*, in the working-piston. This piston-rod embraces the end of an arm, *g'*, that vibrates on a fulcrum-pin, *h'*, and the arm carries two rollers, *i'* and *j'*—one on each side of the fulcrum-pin *h'*—which rollers, for the purpose of governing the motions of the supply-piston, are alternately acted upon by two cams, *k'* and *l'*, on the crank-shaft *m'*, the cam *k'* acting on the roller *i'* and the other, *l'*, on the roller *j'*.

In Fig. 1 the arm and the two cams are concealed on one of the engines, but represented on the other, and in Fig. 2 the arm and its rollers are represented in the two opposite extreme positions. The cam *k'* operates on the roller *i'* to carry the supply-piston inward toward the head of the cylinder, and the other cam, *l'*, controls or governs its motion in the opposite direction when impelled during a part of its movement by the heated air.

The working-piston is provided with two wrist-pins, *m' m'*—one on each side of the stuffing-box *e'*—which are taken hold of by two connecting-rods, *n' n'*, connected with a vibrating arm, *o'*, on a rock-shaft, *p'*, which is provided with another arm, *q'*, at the angle indicated on the drawings, and the arm *q'* is in turn connected by a rod, *r'*, with the crank *s'* on the crank-shaft *m'*, before named.

The required motions are to be imparted to the induction and eduction valves by suitable valve-gear taken from the crank-shaft, as before stated, and as the two single-acting engines are connected with one and the same crank-shaft, with the cranks on opposite sides, as the pistons of one are impelled by the heated air any power required to cause the pistons of the other engine to return will be derived from this source if the momentum of the moving parts be not sufficient for this purpose.

Having described the construction of one of the engines with its regenerator and heater, and stated that the two single acting engines are alike in every respect, as indicated by corresponding letters of reference, and having also described in what manner the two are connected, I will now describe the mode of operation, assuming that the furnaces of the heaters have been properly fired up.

By means of a hand air-pump applied to the chamber *p* at one end of the regenerator, or any other part of the regenerator or heater-tubes, I introduce a supply of atmospheric air at about the pressure of the atmosphere, and then the engine is in a condition to begin its operations. The cranks should be turned over or beyond the dead-point, as usual in steam-engines. Starting with the pistons of one engine in the position represented in Fig. 2, at the extremity of their outward stroke, as the crank *s'*, moving in the direction indicated by the arrow, is making that part of its circuit near the outer dead-point, and therefore imparting but little motion to the working-piston *b'*, the supply-piston *c'* is carried from the working-piston and toward the head of the cylinder with

a rapid motion by the action of the cam k' on the roller i' of the arm g', the cam rotating in the direction of the arrow, and its acting face being formed as represented, that the piston may be gradually started, rapidly accelerated, and near the end gradually arrested, and there retained in a state of rest as the extremity of the cam passes the roller. During this inward motion of the supply-piston the working-piston makes but a small portion of its inward stroke, and therefore the valve d' in the working-piston will be opened by the pressure of the atmosphere to permit cold air to enter and fill that part of the cylinder between the two pistons. So soon as the supply-piston stops the exhaust-port closes and the continued inward motion of the working-piston begins to compress the cold air thus supplied, which of course closes the self-acting valve d', through which the supply was admitted by atmospheric pressure. This supplied cold air continues to be compressed by the working-piston until the end of its inward stroke, and as the power for effecting this compression is derived for the time being from the other engine it is important to observe the condition of the connections.

At the time the supply-piston of one engine is started and the air is entering by atmospheric pressure, and when the arm o' on the rock-shaft p', with which the working-piston is connected by the rod n', is at its greatest leverage the corresponding arm of the rock-shaft of the opposite engine is at its shortest leverage; but as moved inward, and the supply-air, by reason of being gradually compressed, increases the resistance, the arm o' gradually shortens in leverage, and the same arm of the opposite engine gradually and in nearly the same ratio increases in leverage, on the principle of the bent lever, thus applying the power required to compress the supply-air to the best advantage. It should be borne in mind, however, that the power thus applied to compress the supply-air is not actually expended, but merely borrowed, for it is so much added to the elastic force of the air by which, when heated, the engine is impelled.

Just before the supply-piston begins the inward stroke just described, the eduction-valve g is opened, the induction-valve h having been previously closed, so that the charge of heated air by which the previous stroke of the engine was effected is permitted to escape freely into the atmosphere, so that the power required to move the supply-piston inward is very slight, the air escaping freely to the atmosphere on one side and entering by atmospheric pressure on the other through the valve d'; but as the heated air exhausts or escapes from the cylinder it passes around and among the series of small tubes k of the regenerator, thus imparting its heat through the metal of the tubes to the cold air contained inside of the tubes, which air is thus partially heated preparatory to being finally heated in passing through the heater-tubes. In this way much of the heat which would be otherwise wasted is saved. The supply of cold air having been introduced and compressed, the engine is prepared to be impelled by the expansive force of the heated air. The eduction-valve g having remained closed during the greater part of the inward motion of the working-piston, the induction-valve h' is now opened, which admits the heated air from the heater to the cylinder, by which the supply-piston is forced outward toward the working-piston. The form of the face of the cam l', as represented, is such as to cause the piston to be carried back with a rapid accelerated motion until it comes nearly in contact with the working-piston; and at first in this outward motion of the supply-piston the already-compressed supply-air between the two pistons is still further compressed, not by the power of the engine, but by the elastic force of the heated air, the supply-piston being, as it were, suspended between the heated air from the heater on one side and the cold air on the other, with the self-acting valve r (in the side of the cylinder) interposed between the two, for it must be remembered that as the heater and regenerator are in communication the air, which is a perfectly elastic fluid, will be under equal pressure in both, notwithstanding a portion is more highly heated than the other, and as the supply-air in the cylinder is simply separated from the air in the regenerator by the interposed valve r in the side of the cylinder the supply-piston will be moved outward by the heated air until the supply-air is compressed to an equal tension, and then the further motion of the supply-piston, effected by the cam l' as it approaches the working-piston, will transfer the supply-air from the cylinder to the regenerator through the valve r'. The only power expended by the engine in this transfer will be the small amount required to move the supply-piston between two equal pressures to give the slight preponderance to the one necessary to open the valve r, through which the transfer is made. The moment the supply-piston passes this valve and overtakes the working-piston the preponderance of pressure ceases and the valve closes by gravity. If desired, however, a positive motion properly regulated may be imparted to this valve by a suitable valve-gear. The operations just described for the final compression and transfer of the supply-air take place during the time that the working-piston is at rest, or nearly so. It is while the crank is passing the dead-point farthest from the arm q', connected by the rod r' with the crank, and as the crank and the connecting-rod have their centers of motion at the time of passing the dead-point on the same side of their points of connection, it follows that during the time the crank moves a given distance each side of the dead-point the piston will move through a distance comparatively much shorter than when the crank moves the same distance each side of the opposite dead-point, for in the one case the crank and the

connecting-rod simply represent the radii of two eccentric circles, while in the other they represent the radii of two opposite circles. By the time the supply-piston reaches its nearest proximity to the working-piston the latter has made but a very small part of its outward stroke.

At the time the supply-piston passes the valve *r* a film of compressed air remains between the two pistons to act as an elastic cushion. At this time the heated air then in the cylinder is cut off by the closing of the induction-valve *h*, and the working-piston is impelled outward by the expansive force of the heated air and the supply-piston by the cam-movement described.

The form of the cam *l'*, which acts on the roller *j'* to govern the outward stroke of the supply-piston, must be such, as represented, that the piston will move with a rapidly-accelerated motion until it approaches the working-piston, then gradually retarded, and from the point 1 to 2 its curvature must be such that its motion will be in unison with the motion imparted to the working-piston, by reason of its connection with the crank, modified by the interposition of the arms *o'* and *q'*, operating on the principle of the bent lever.

It has been shown that the alternating leverage of the arms *o'* of the two engines is such as to apply the power for compressing the supply-air to the best advantage, and it remains to show the connection between the two in furtherance of this economy. It will be seen that the arm *o'*, connected with the working-piston during the outward stroke, gradually increases in leverage as the heated air, by dilatation, gradually decreases in tension. Now the leverage of this arm gradually increases during the outward stroke of the working-piston of one engine as it gradually decreases in the other engine, where the working-piston is compressing the supply-air, and vice versa.

It has been stated that the power exerted on the working-piston to compress the supply-air was not an actual consumption, but a mere transfer of power. This will be apparent from the description of the entire operation, because the air thus compressed is transferred to the regenerator and from the regenerator to the heater, and thence to the cylinder, where it exerts on the piston the elastic force first impressed upon it by the piston, together with the tensive force which it has acquired by being heated, so that the compression which it received at first from the piston when working in one direction it returns to the piston when working in the opposite direction under the advantages due to the arrangement of the two engines, as above specified.

By the alternate strokes of each engine the required supply of cold air is introduced, compressed, and transferred from the cylinder to the regenerator, carried through the regenerator, thence through the heater, and from the heater back to the cylinder, and in this circuit it is gradually heated, first by the heat which it takes up from the escaping heated air, and then by the heat of the furnace, and as atmospheric air is a bad conductor of caloric, the heat will not be carried back by conduction from the heater to the regenerator, but after the heated air has exerted its elastic force in the cylinder in escaping it transfers its surplus heat to the supply-air on its passage through the regenerator. The object of the regenerator being, however, merely that of economizing fuel, it is evident that the supply-air may be passed directly from the cold end of the working-cylinder, by the action of the supply-piston, to a heater communicating with the other end of the working-cylinder.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. The method of supplying fresh air to the engine, compressing and transferring it to the regenerator and heater, or either, by the action of the supply and working pistons within the one cylinder, operating on the principle and in the manner substantially as herein described, whereby the air is admitted under atmospheric pressure as the supply-piston is moving from the working-piston as the previous charge of heated air is exhausting, so that the said supply-piston moves in equilibria, or nearly so, and by which, also, the supply-air is finally compressed and then transferred the regenerator and heater, or either, as the supply-piston moves between the supply-air and heated air during the period of the nearly stationary position of the working-piston.

2. In combination with the double-piston movement of each cylinder, the method of connecting the working-pistons of two single-acting engines to constitute a double-acting engine by means of two sets of vibrating arms attached to each other and vibrating on a common center connected with the two working-pistons, and with the two cranks on opposite sides of the axis of the crank-shaft, the two sets of arms operating on the principle of the bent lever, and the crank-shaft being so located relatively to the cylinders and the centers of vibration of the arms, substantially as described, that the working-piston shall be at the end of its inward stroke at the time the crank is passing the dead-point farthest from the point of connection of the connecting-rod with the vibrating arm, as described, by which the power of that working-piston which is being impelled by the heated air is applied to the best advantage to operate the other working-piston during its return-stroke, and by which, also, the working-piston remains nearly at rest during the time the supply-piston is making that part of its outward stroke during which the partially-compressed air is finally and fully compressed and transferred to the regenerator and heater, or either, as described.

J. ERICSSON.

Witnesses:
WM. H. BISHOP,
ANDREW DE LACY.