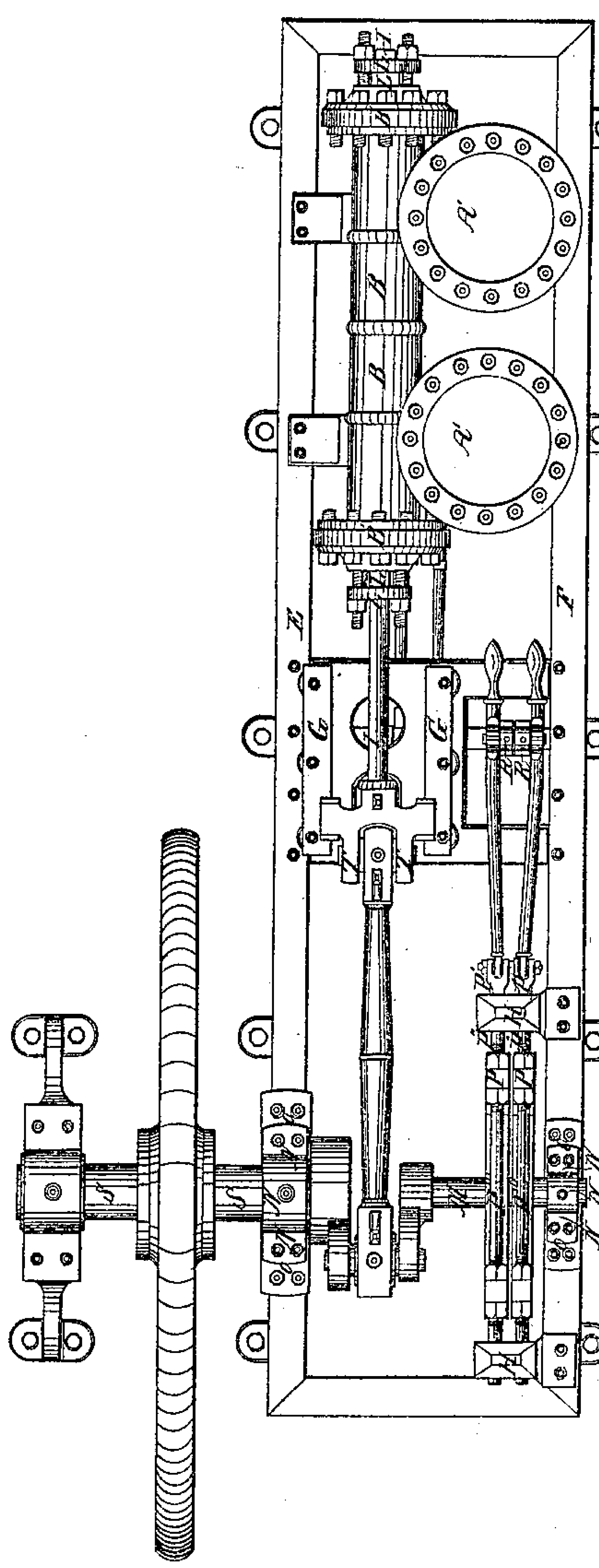
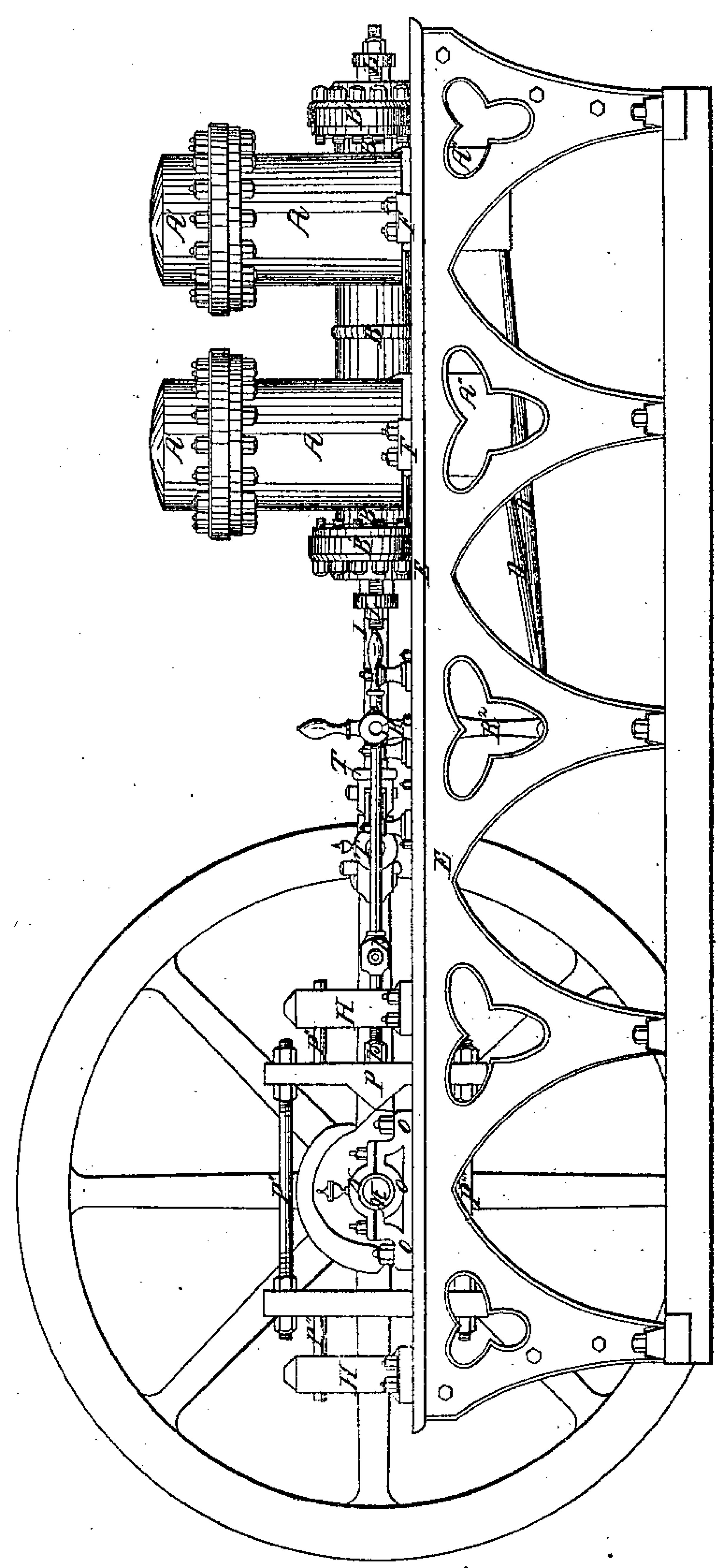
3 Sheets—Sheet 1.

A. S. LYMAN.

AIR ENGINE.

No. 10,576. Patented Feb. 28, 1854.





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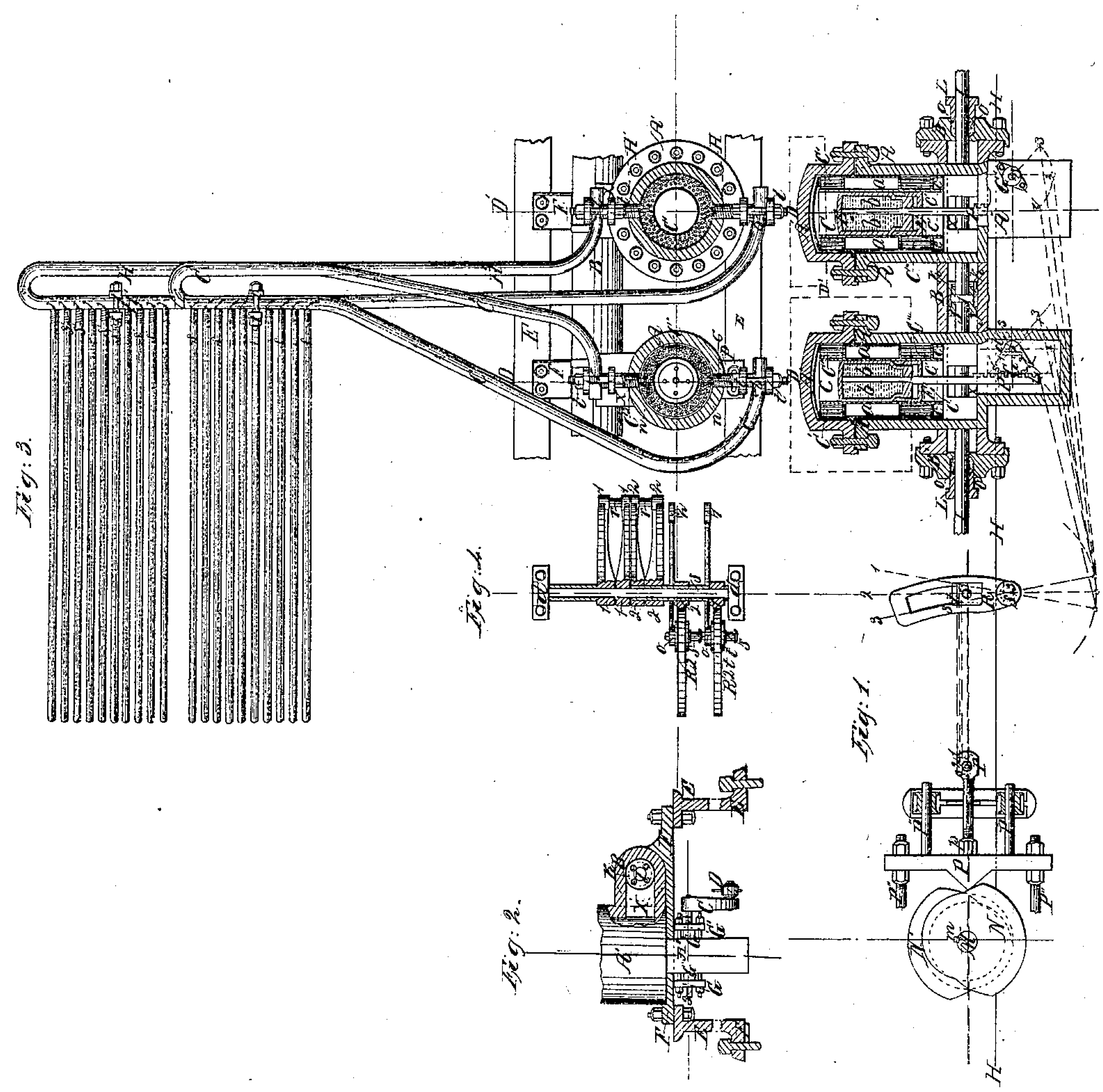

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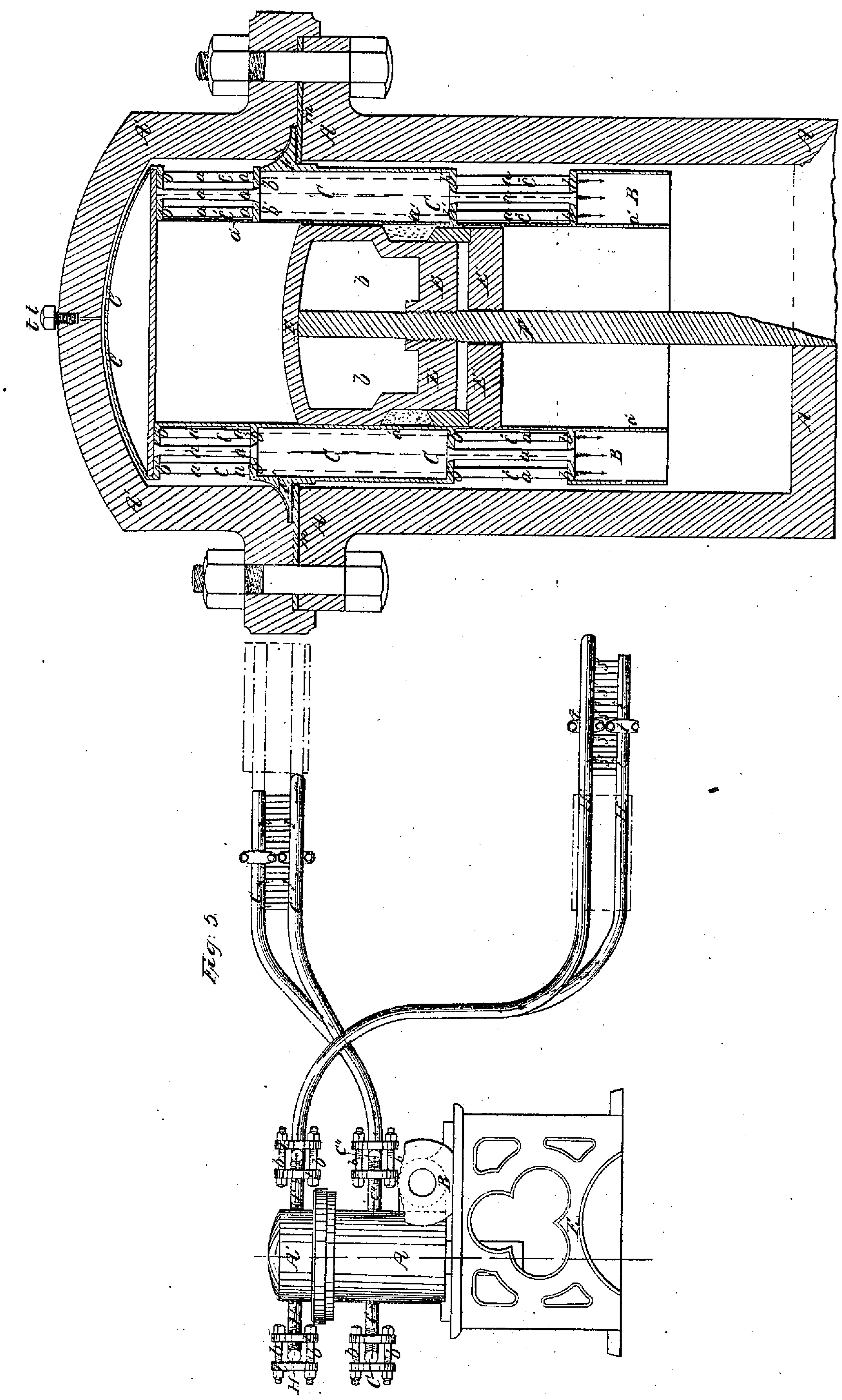

UNITED STATES PATENT OFFICE.

A. S. LYMAN, OF NEW YORK, N. Y.

AIR-ENGINE.

Specification of Letters Patent No. 10,576, dated February 28, 1854.

To all whom it may concern:

Be it known that I, A. S. Lyman, of the city, county, and State of New York, have invented new and useful improvements in engines for generating power by means of the expansive force derived from heated air and gases, also by means of the expansive force of liquid carbonic acid and other expansible liquids; and I do hereby declare that the following is a full, clear, and exact description of the principles of my invention and of the construction and operation of the same, reference being had to the accompanying drawings, making a part of this specification.

In order that the nature and extent of my improvements may be readily understood, I will begin by stating wherein my engine resembles Sterling's air engine and wherein it differs from that and from all others in use. It resembles Sterling's engine in the fact that two strong vertical, and nearly air tight cylinders, called generating cylinders, are connected, one with each end of a working cylinder, in which a piston moves in the usual manner. Each of these generating cylinders contains a generating plunger, which moves up and down, for the purpose of displacing the air. When this plunger is at one end of the generating cylinder the air is at the other, and as one end of this cylinder is kept at a high temperature and the other cold, as is practicable, when the air is brought to the hot end it has its temperature and pressure increased; when it is brought to the cold end its heat and pressure are diminished. While moving from one end of the generating cylinder to the other, it passes through a multitude of narrow passages, called the heat repository or heat restorer, (the regenerator of Ericsson,) where it leaves a part of its heat when on its way to the refrigerator, and takes it up again when returning toward the heater. These generating plungers are made to move in opposite directions. When one is up, the other is down. It follows that when the pressure in one vessel is increased that in the other is diminished. The plungers are moved nearly at the same relative time with the valves of a steam engine, and the piston is thus caused to move alternately from one end of the working cylinder to the other. There were, however, several serious defects in Sterling's engine, which prevented its general introduction, and these defects are common to all other high pressure air engines with which I am acquainted.

A great obstacle to the success of Sterling's or other air engines has been their liability to leak when a high pressure has been attempted. This difficulty has been so great as to render it not only impracticable to attempt the use of air under a very great pressure, but utterly impossible to use carbonic acid in a liquid state, which expands and contracts by given changes of temperature three or four times as much as air, and for other reasons is believed to be more economical. But in my improved apparatus so long as there is a proper supply nothing but water or oil can, in any case, leak out, or escape, from any joint, or through the pores of iron or metal. Even when charged with liquid carbonic acid, under one hundred atmospheres pressure, the acid would not tend to leak through its case any more than the same amount of water would under the pressure of one atmosphere only.

Another obstacle to the success of air engines, which is often said to be insurmountable, is the burning out of the heating surface. But in this apparatus, the heat is applied through the medium of water, or other suitable liquid, and it is not possible to overheat so as to burn the metal.

Another difficulty in the way of the success of air engines has resulted from the nature of the fluid used in them. While steam is a lubricator, hot air generates friction, and rapidly destroys the cylinder and packing. To avoid this destruction and waste of power, more particularly the leaks caused by it, some have used the air from the cold end of the generating cylinder, but this has always been done at the expense of a large amount of fuel wasted. In case the air was so heated as to double its tension, it would require twice as much fuel when the working cylinder was supplied from the cold end as when supplied from the hot end of the generating cylinder. In my improved engine, the whole working cylinder is filled with water, and the generating cylinders also, except their upper ends, which are occupied by the hot air chambers, the heat repositories, and the generating plungers, and the hot air chamber is enlarged, as the piston recedes from it, so that all the air is kept hot, and the piston is in effect driven with hot air, although the working cylinder is full of cold water. Again, it is a very common remark with authors on steam and the Steam Engine (E. G. Renwick, page 251) that "the maximum performance of the low pressure engine takes place when the velocity of the piston is from 250 to 280 feet per minute, because the whole tension of the steam acts as a pressure on the piston only; when that is at rest and with every increase of velocity, the pressure must be diminished." The above remark is probably correct, as applied to the ordinary steam engine, or to any of the forms of air engines that have been made public, for it is a common and a very serious defect with all of them that they pass the steam or air through contracted pipes between the boiler or generator and the working cylinder. These passages being only from $\frac{1}{10}$ to $\frac{1}{30}$ the area of the cylinder, the air or steam must pass through them from 10 to 30 times as rapidly as the piston of the engine moves. That is, when the piston of the engine travels 250 or 280 feet per minute the steam or air must move from 2500 to 8000 feet per minute in its passage to the working cylinder.

My fourth improvement consists in combining the generating cylinders with the opposite ends of the working cylinder direct, and dispensing with these contracted pipes, by making the passages as large as the working cylinder in area, so that the piston may be driven as fast as the motive power moves, without the loss of power from the above mentioned cause.

A fifth source of loss has resulted from the application of the heat to the lower end of the generating cylinder, while, at the same time, the attempt has been made to keep the upper end of this cylinder cold by the application of cold water upon it. But air being heated its specific gravity is lessened, and it rises, and currents are formed of hot air rising from the lower or heated end through the heat restorer into the cold part, while currents of cold air flow downward. The heater and cooler thus each tend to neutralize the effect of the other. In my improved engine, I apply the heat in the upper part of the generating cylinder and the cooling fluid in the lower part, so that while the heated air rises, and the cold air falls, it does not tend to destroy the effect of the heat restorer, but rather to render it more perfect.

A sixth source of loss has arisen from the fact that the heat restorer, as commonly made, has been very defective. Composed principally of metal, it has conducted the heat from the hot to the cold side. When made of sheets of metal separated by non-conducting substances, it did not allow free passage for the air. In my improved engine, I use glass tubes and rods, from the size of a hair upward, standing vertical and parallel, the air passing through them lengthwise, the upper end being hot and the lower end cold. As glass is a very bad conductor, the heat is not so much conducted downward by it, and fuel is thus saved that was wasted by the other plans, while at the same time the air, liquid carbonic acid, or other fluid passes more freely through this heat restorer than through those ordinarily in use.

Plate 1, is a horizontal plan of my improved engine. Plate 2, is a side view. Plate 3, shows the sections. Plate 4, is a vertical section on a larger scale, showing more clearly the internal arrangement.

Plate 3.—Figure 1, represents a vertical longitudinal section, through the principal parts. Fig. 2, is an end view of some parts with a section of others. Fig. 3, is a horizontal section through one cylinder, at D, D, (Fig. 1), and through the other at D′, D′; also a horizontal plan of one of the series of heating tubes and one of the series of cooling tubes. Fig. 4, is a section through the rocking shafts and their appendages. Fig. 5, is an end view.

Similar letters of reference indicate corresponding parts in each of the several figures.

A, A, A, A, the generating cylinders; B, working cylinder; J, the working piston in this cylinder; E, E, the generating plungers moved up and down in the generating cylinders by F, F, the plunger rods, with their lower ends toothed to correspond with, and receive the teeth of G, the toothed segments which, by their partial revolutions, raise and depress the generating plungers.

Plate 4.—*a′*, *a′*, *a′*, *a′*, *a′*, *a′*, represents the internal cylinder in which the generating plungers, E, E, move. *b*, *b*, *b*, *b*, &c., is a flange extending out from this internal cylinder, a distance equal to about one fourth of its diameter.

C′, C′, represent the internal heater, consisting of small tubes, which connect the upper two flanges in the same manner as the tube sheets of the locomotive boiler are connected by the boiler tubes. These tubes are surrounded by hot water. C″, C″, the refrigerator, consisting of small tubes connecting the lower flanges in the same manner and surrounded by cold water; *c*, *c*, *c*, *c*, a cap attached to the outer edges of the upper flanges by an air tight joint.

n, *n*, represent the short cylinder connecting the middle flanges at their outer edges, and together with these flanges and the inner cylinder forming a chamber which has no openings, except by the heating tubes, C′, C′, and the cooling tubes, C″, C″; *a*, *a*, the heat repository, or heat restorer, (called by Ericsson the regenerator). This consists of a great number of glass rods and tubes, from the size of a hair upward, standing vertical and prevented from falling into the tubes by a few sheets of wire gauze, upon which the glass tubes and rods rest. Glass being a very bad conductor of heat, the tubes and rods may be short, and although their upper ends may remain at a high temperature, their lower ends will not be heated by conduction. The air also passes much more freely through the direct passages of this regenerator than through the same distance of wire gauze. B, B, a short cylinder extending down from the lower flange, and forming with it and the inner cylinder the cold air chamber; F′, F′, a flange extending out a short distance from the cylinder, inclosing the heat repositories, for the purpose of supporting the heat repositories, the heating tubes, (C′), and the cooling tubes, (C′′), which are all connected together. This flange rests upon the outer case, or generating cylinder, (A, A). There are also small openings through this flange vertically, for the purpose of allowing the free passage of the water, or other liquid, up and down between the external strong iron cylinder, for sustaining the pressure, and the internal thin copper cylinder for containing the air. *m*, *m*, rings of bad conducting material, introduced between the flanges of the upper and lower or the hot and cold parts of the outer case. The case is divided at that point, and separated by bad conducting material, for the purpose of preventing waste of fuel, that would otherwise occur. *t*, *t*, small screw plugs for the purpose of letting out the air from the narrow space between the strong outer case and the internal copper cylinders and tubes, containing the air.

Fig. 2: X, is the passage between the generating cylinder and the working cylinder. The area of this passage is as large as that of the working cylinder. I, is the piston rod.

Figs. 1 and 4: R, is the square link arm, with a sliding box, *t*, in the link, through the center of which the pin S, is fixed, serving as the connecting pin for the connecting rod from the cam frame, P, to P′. P′′, P′′, are the guides to the cam frame, moving in the brass boxes which are shown in a section, with a plan of a part of the cam frame. N, is a cam on the shaft, M. N′, is the other cam in its relative position to the cam, N, to produce a proper movement of the generating plungers, (*b*), (*b*).

Fig. 2: A, is the box in which the toothed segment, C, Fig. 1, is worked. S, is the shaft, and C, the arm, by means of which this segment is worked. G′, G′, are caps to the shifting boxes, in which the shaft, S, of the toothed segment rolls.

Figs. 3 and 5: H—S′, S′, S′, H′, are the hot water circulating tubes, the direction of the currents represented by the arrows. C, S′, S′, S′, C^2 are the cold water circulating tubes. The furnace under the hot water tubes and the box containing the reservoir of cold water surrounding the refrigerating tubes are not shown.

Fig. 4: S′, is the small rocking shaft to which the link arm, R, 1, and the rocking arms, R′′, 1, and R′′, 1, are attached. S′′, is a shaft which turns around the surface of the shaft, S, and to which are keyed, the link arm, R, 2, and the rocker arms, R′, 2, R′, 2. *d*, *d*, are boxes in which the inner shaft moves. O, 2, and O, 1, are lifting rods attached to the block, *t*, Fig. 1, which pass and move vertically through holes bored through both shafts, in line with the center of the link blocks, and of their respective rocker arm connecting pins, *r*, *r*. The lower ends of the lifting rods, marked, 2 and 1, are slotted in a link which is at right angles and in the same plane with the vertical links, R, 1, and R, 2. A pin attached to the end of a lifting arm, works in these small limbs, 2 and 1, by which the generating plungers are given a full or part of a stroke.

It will be perceived that the form of the cam is such that the generating plunger will be brought from the lowest to the highest point of its movement in the shortest practicable space; and consequently the air in that cylinder will be cooled in the shortest practical time. It will also be seen that the form of the cam is such that the generating plunger will be brough down about two thirds of its stroke in this case in the shortest practicable time, when it will move slowly, so that the hot air chamber shall be enlarged only as fast as the working piston recedes from it and the air shall not expand down through the cooler. By thus gradually enlarging the hot air chamber, during the entire stroke of the piston, it is evident, that a great saving of fuel may be effected.

Directions for charging the engine.—Tubes leading from a common reservoir (not shown) connect with the lower part of each of the generating cylinders through self-acting valves. That separate reservoir is charged to any desired pressure, and the air permitted to escape freely into both of the generating cylinders through these valves. They are consequently uniformly charged with the same pressure when the air is of the same temperature in each, if the engine is in operation. If it is desired to charge with air to a pressure of 600 lbs. per inch, we first charge the whole working and generating cylinders with a pressure of 200 lbs. We then force in water until the whole apparatus is about two-thirds full. This water is easily pumped in under a pressure of 500 or 800 lbs, and it compresses nearly all the air up under the internal copper cylinder. Loosen the small screw plug at the top of the outer case until the air contained between the internal copper cylinder and the outer case has all escaped by it. When the water begins to escape from the plug, it is tightened. Small plugs are also loosened at the highest point of the circulating tubes of the refrigerator and the air permitted to escape. We have here three cylinders surrounding the air or other driving power. 1st. The thin copper cylinder. This cylinder is open only at the bottom, and the air, from its less specific gravity, remains in it. 2d. The cylinder of water surrounding this copper cylinder and completely lining the outer case. 3d. The strong outer case. Now it is plain that nothing but water can leak from the outer case, for nothing but water comes in contact with it inside, so long as there is sufficient in the engine to prevent the air or other driving fluid from expanding, so as to more than fill the inner copper cylinder, and the pressure on the outside of the thin copper cylinder and tubes being equal to the pressure within them the air or liquid carbonic acid will not tend to leak through this inner cylinder or tubes, even if under a pressure of a hundred atmospheres, any more than if under a pressure of only one atmosphere. We have here, also, a very extensive heating surface. The hot water from the furnace coil circulates freely around the tubes, C′, around the upper part of the generating plunger case, as well as over the inner cap, between it and the outer iron case. On being heated, this water, and that in the coil, expands, and a small quantity passes down through the holes in the flange F, Plate 4, supporting the internal copper cylinder tubes, etc., and forcing the cold water, before it compresses the air or other driving power, still higher up under the inner cylinder.

The operation is as follows: When the engine is started by moving the starting bar, so as to bring the generating plunger nearest to the working piston downward, then the air which is in the cooling tubes, C″, and in the space, (*c*), below them will rush up through the heat restorer and through the heating tubes, C, and occupy the space above the plunger, *b*, *b*. The space in the cooling tubes, C″, and below them first occupied by the air is now filled with the cold water displaced by the generating plunger in its downward movement. The air in passing through the upper part of the heat restorer and the heating tubes, C′, is heated, and consequently expanded. The same movement of the starting bar that brings one generating plunger down and heats the air raises the other generating plunger and forces the air above it, down through the heating tubes, C′, the heat repository, *a*, where it leaves most of its heat, into the cooling tubes, C″, and the chamber, (C), below. This air is consequently cooled and condensed. The air being thus suddenly expanded in the space back of the piston and condensed in front of it, the piston is forced to the other end of the cylinder, when, by the movement of the cams, the position of the generating plunger is reversed and the pressure transferred to the other side of the piston, and thus the reciprocating motion is produced.

What I claim as new, and desire to secure by Letters Patent, is:—

1. The mode of preventing the waste of the compressed air, liquid carbonic acid, or other driving power, by interposing between it and the outer cylinder of the engine, a reservoir of water, or other suitable liquid, substantially in the manner described.

2. I claim the mode of applying the heat to the generating power, through the agency of water, or other liquid, in the manner substantially as specified; thus avoiding the possibility of burning and scaling the metal, and also greatly increasing the extent of heating surface.

3. I claim the mode of preventing the loss of power, otherwise caused by the expansion of the air, liquid carbonic acid, or other driving power, in passing through the repository and refrigerator, and being cooled and condensed before the working piston has completed its stroke, in the manner described—that is, by moving the generating plunger downward, as the working piston recedes from it; thus enlarging the heating chamber as fast as the air or other fluid expands.

4. I claim the combination of the generating cylinders, with the opposite ends of the working cylinder direct; thus dispensing with contracted passages and pipes, and causing the piston to move as rapidly as the working fluid moves.

5. I claim the construction of the heat repositories, and restorers, of small glass tubes, or glass rods, arranged substantially as described, for the purposes specified.

6. I claim the combination of the heater, the repository, and the cooler, substantially as described, the heater being above the repository, and the cooler below it, so that as the heat rises, it does not tend to destroy the effect of the repository, but rather renders it more perfect.

7. I claim the partial isolation or separation, of the upper part of the outer case, containing the heating liquid, from the lower part containing the cooling liquid, by the introduction of bad conducting material between them.

8. I claim the combination of the external heater, with the internal heater, and the combination of the external refrigerator, with the internal refrigerator, substantially as specified, for the purposes set forth.

A. S. LYMAN.

Witnesses:
D. H. MEGIE,
TIMOTHY D. JACKSON.