E. E. CAMPBELL & G. W. HEALD.

HOT AIR ENGINE.

APPLICATION FILED SEPT. 2, 1913. RENEWED OCT. 28, 1916.

1,277,849.

Patented Sept. 3, 1918.

5 SHEETS—SHEET 1.

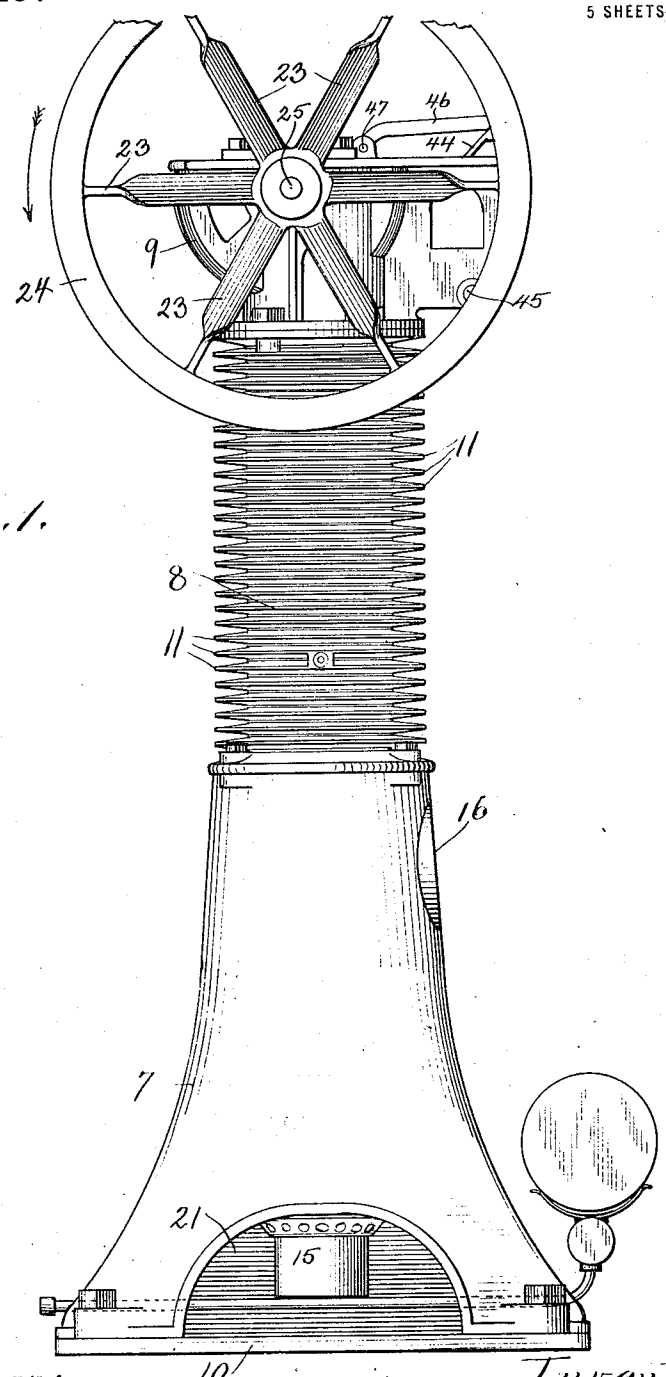


Fig. 1.

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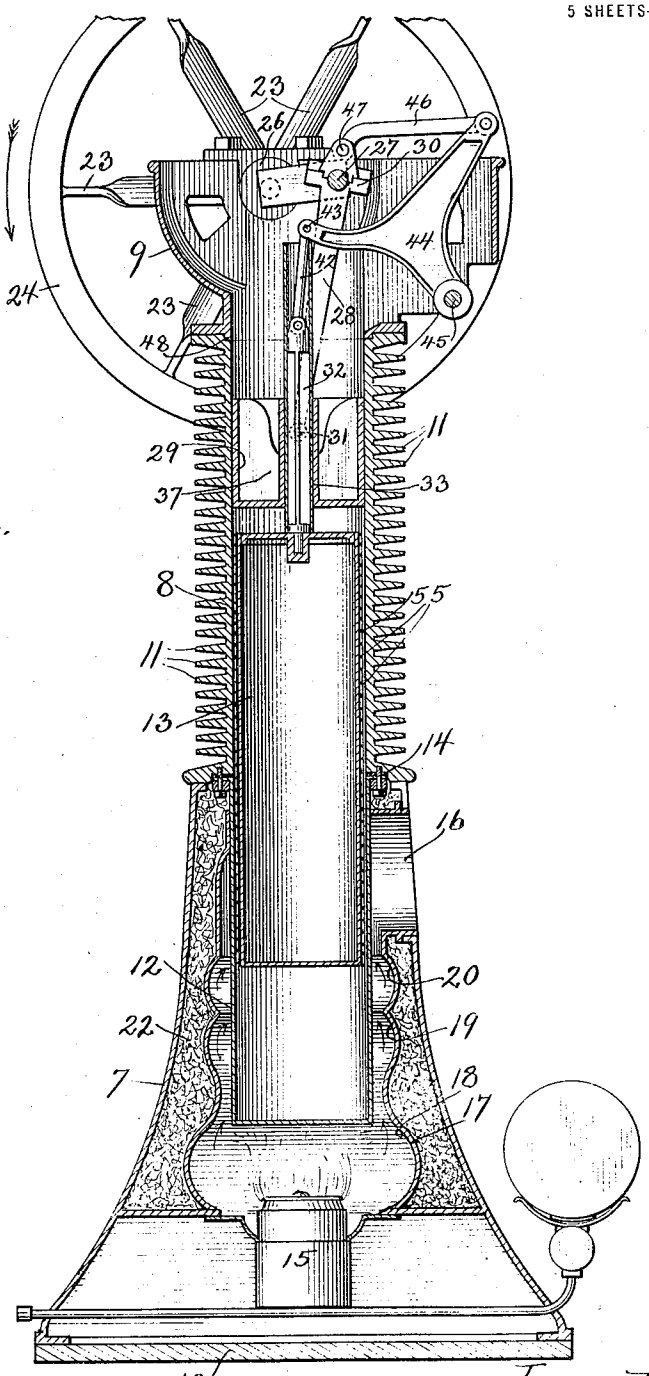


Fig. 2.

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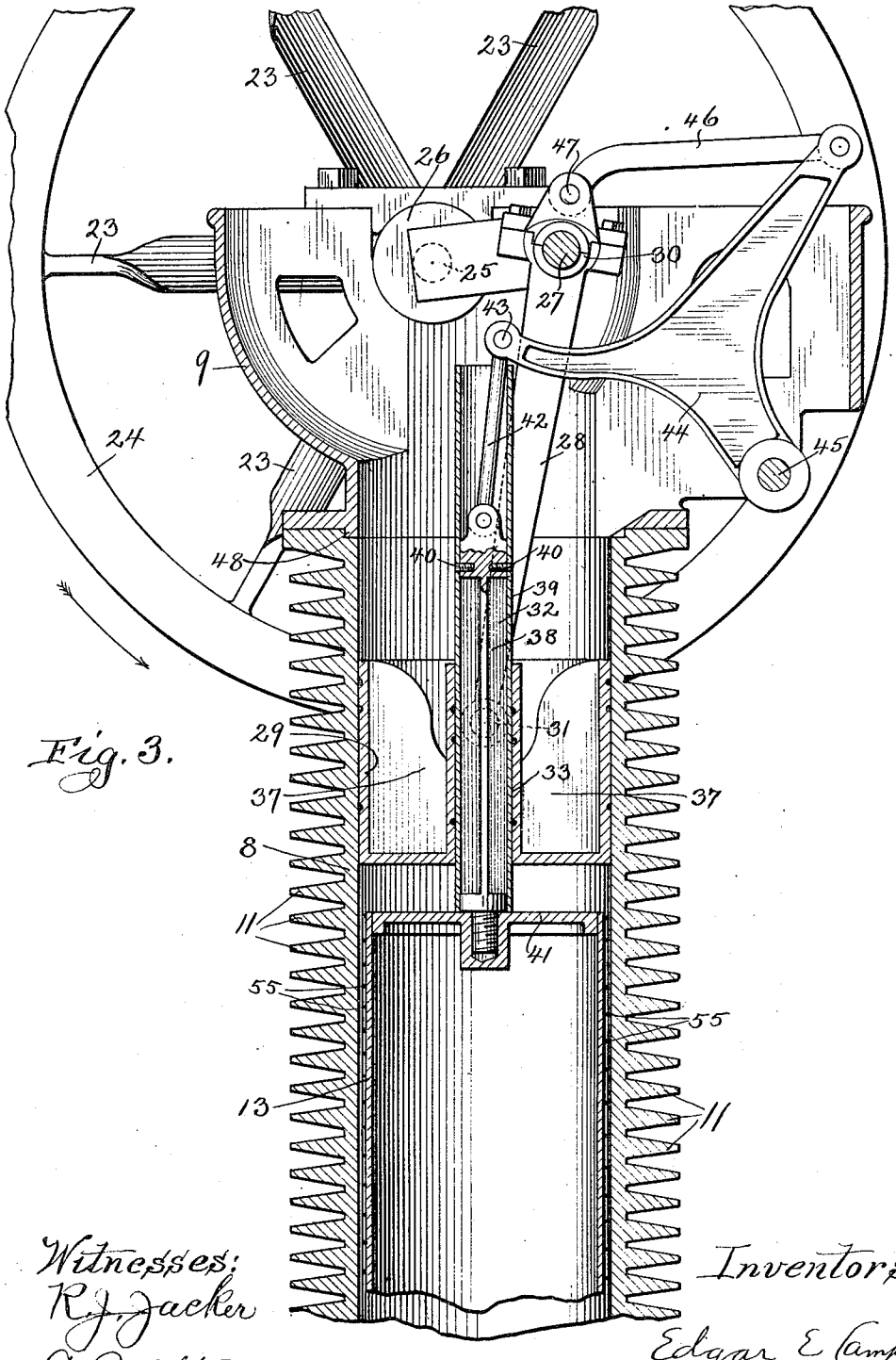


Fig. 3.

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5 SHEETS—SHEET 4.

Fig. 4.

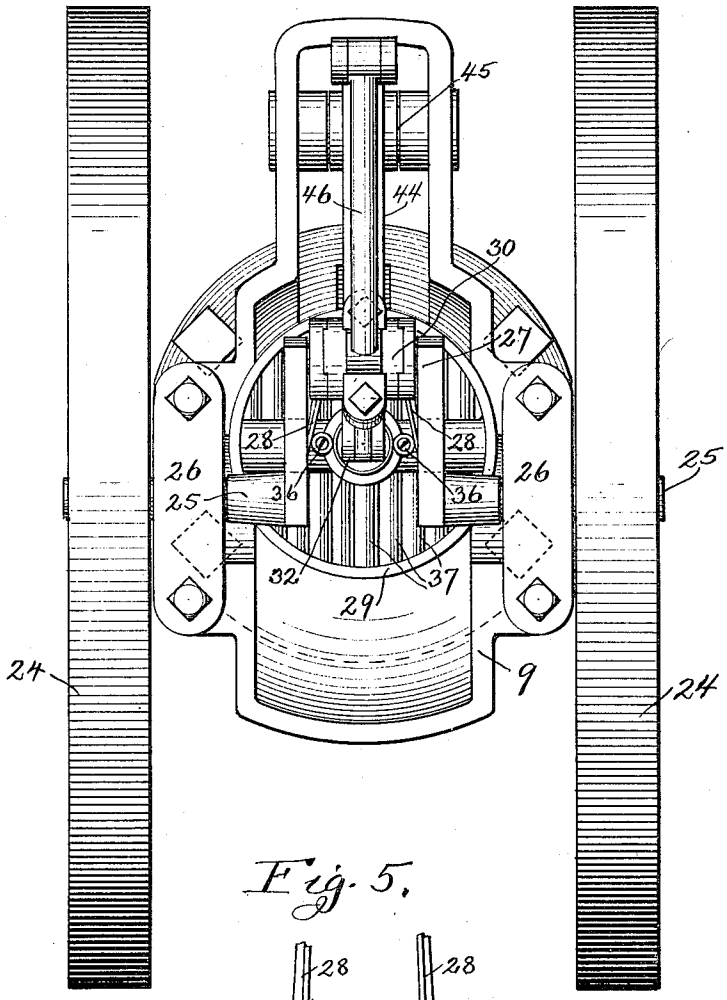
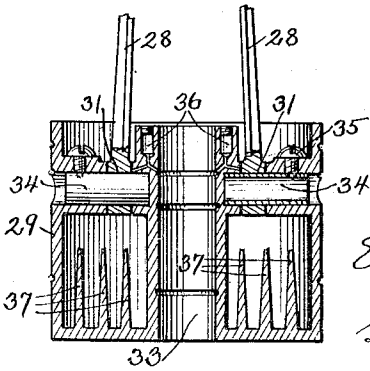


Fig. 5.



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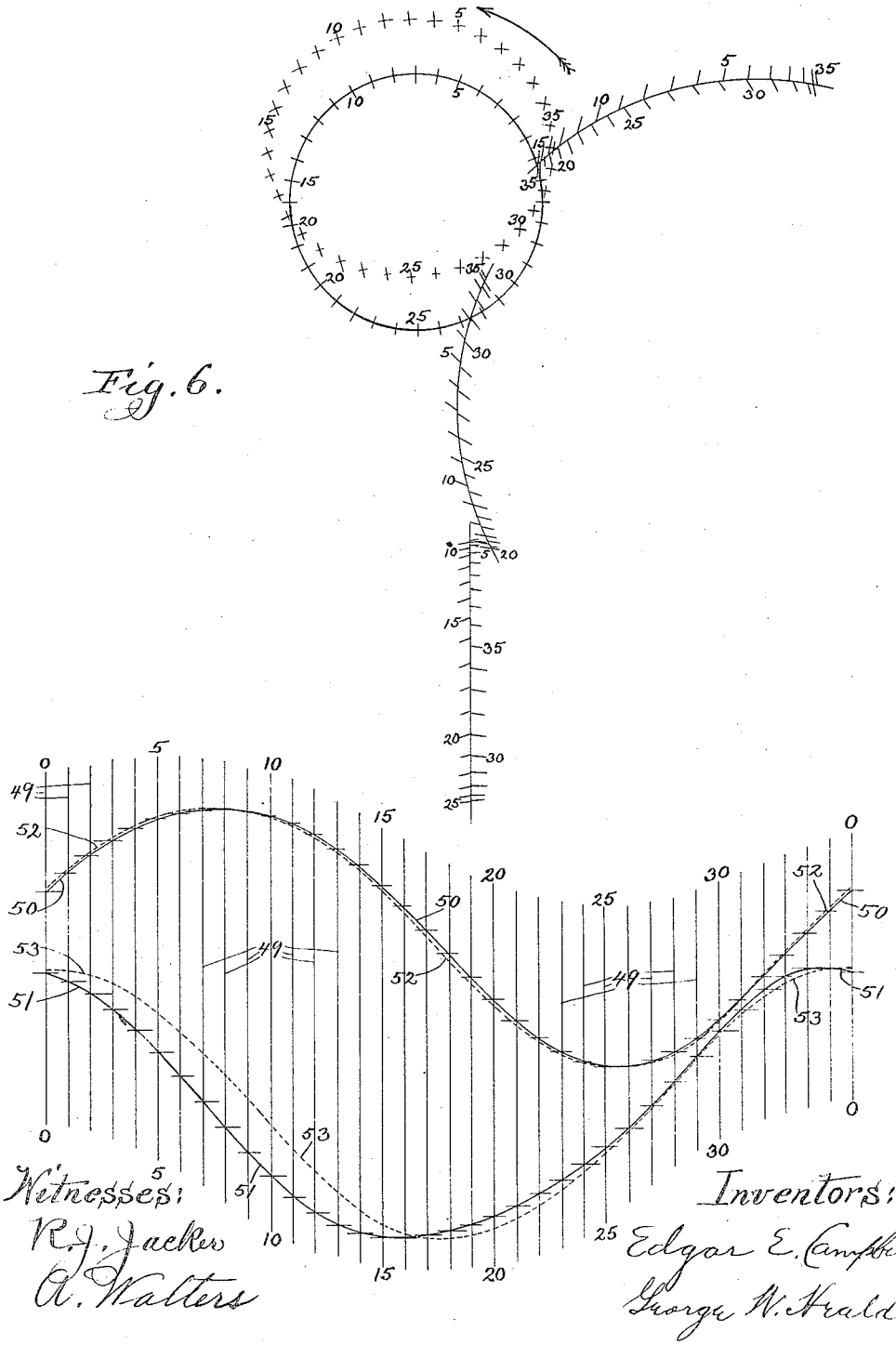
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5 SHEETS—SHEET 5.

Fig. 6.



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UNITED STATES PATENT OFFICE.

EDGAR E. CAMPBELL AND GEORGE W. HEALD, OF CHICAGO, ILLINOIS, ASSIGNORS, BY MESNE ASSIGNMENTS, TO GENERAL UTILITY POWER COMPANY, OF CHICAGO, ILLINOIS, A CORPORATION OF SOUTH DAKOTA.

HOT-AIR ENGINE.

1,277,849. Specification of Letters Patent. Patented Sept. 3, 1918.

Application filed September 2, 1913, Serial No. 787,804. Renewed October 28, 1916. Serial No. 128,343.

To all whom it may concern:

Be it known that we, EDGAR E. CAMPBELL and GEORGE W. HEALD, citizens of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented a new and useful Hot-Air Engine, of which the following is a specification.

Our invention relates to hot air engines of the closed cycle type in which a power piston and a displacer piston move vertically in the same cylinder, and the objects of our improvements are first, to provide an improved hot air deflecting and insulating flue; second, to extend the radiating surface of the cylinder nearer to the heating surface; third, to improve the removal of heat from the cylinder by providing fly wheels with specially shaped arms; fourth, to apply the offset or off-center crank shaft to this type of engine; fifth, to improve the relative motions of the two pistons to increase the compression, vacuum and cushion effect; sixth, to locate all moving parts between the fly wheels; seventh, to have the plane of motion of the mechanism driving the displacer piston located in approximately the same vertical plane as the center line of the cylinder; eighth, to arrange all the operating parts to swing on fixed pivots so that the parts cannot work loose, be misassembled or have any spring or lost motion; ninth, to provide a one-piece crank case containing all the fixed bearings and affording protection from moving parts and surplus oil; tenth, to provide an improved method of lubrication; eleventh, to make a built-up piston rod for the displacer piston; twelfth, to increase the condenser effect of the displacer piston by attaching a coil of fine wire to its outer surface and other features to become apparent from the description to follow.

We are aware that hot air engines have been made embodying the general features of this one, *i. e.*, a power piston and a displacer piston to move vertically in the same cylinder and we do not claim such a construction broadly. Hot air engines heretofore have not been a commercial success for general power purpose because of the expensive construction; the liability to get out of order; the complications met with in the assembling; the inability to make easy repairs, the slow and unsteady motion and the general inefficiency of the engine. These features which render the engine a commercial failure are entirely eliminated in constructing an engine in accordance with our invention which embodies elements which reduce the cost of manufacture to a minimum practically eliminate all liability of getting out of order from long and continued use; make the assembling of the engine in all its parts so simple that an inexperienced person cannot fail to properly assemble it and make the several parts of the engine as integral pieces so that any part can be duplicated and assembled in case of needed repairs and which all combined coöperate together to produce a practical, efficient and commercial engine.

To describe our invention so that others versed in the art to which it pertains can make and use the same we have illustrated it on the accompanying five sheets of drawings forming a part of this specification in which:—

Figure 1 is a side elevation of an engine embodying our invention; Fig. 2, is a central vertical section of the same partly in elevation; Fig. 3, is a similar view enlarged and partly broken away; Fig. 4, is a plan view of Fig. 1, enlarged with the base omitted; Fig. 5, is a detail sectional view showing the construction of the power piston and means of lubricating the same and Fig. 6, is a diagrammatical view showing the relative positions of the two pistons during a cycle of operations.

Similar reference characters refer to similar parts throughout the several views.

The engine frame comprises the base 7, the cylinder 8 and the crank case 9, which are rigidly fastened together by bolts. The engine is preferably mounted on a sub-base 10 of asbestos or other suitable material which acts as a combined heat insulator and deadening cushion. The cylinder 8 is provided with the cooling ribs 11 and the sub-cylinder 12 extending down into the hollow portion of the base 7 and secured to the lower end of cylinder 8 by bolts to register therewith and form a continuation of the same and within which the displacer piston 13 moves. A gasket 14 of asbestos or other suitable non-heat-conducting material is interposed between the lower end of cylinder 8 and the

upper end of sub-cylinder 12 to prevent heat being conducted from one to the other. The upper end of the cylinder 8 is open and the lower end of the sub-cylinder 12 is closed. In operation the cylinder 8 is air cooled and the sub-cylinder 12 is kept constantly hot by a flame or otherwise. In the drawings Fig. 2, the sub-cylinder 12 is shown as being heated by a flame emitted from a suitable burner 15. The burner 15 is directly below the sub-cylinder 12 and the heat from same passes upward against the bottom of the sub-cylinder 12 thence spreading passes upward on all sides of said sub-cylinder and finally passes out to the atmosphere through the discharge opening 16 provided in and near the upper end of the base 7. To increase the amount of heat directed against the sub-cylinder 12 we provide a cylindrical heat deflector 17 larger than and concentric with the sub-cylinder 12 and provided with the annular deflecting surfaces 18, 19 and 20. A sufficient quantity of air is admitted to the burner 15 through the opening 21 provided in the lower part of the base 7 to feed the flame. The space between the deflector 17 and the walls of the base 7 is preferably filled with some non-heat-conducting material 22.

The cylinder 8 is cooled by a constant current of air being blown over the same by means of the fan shaped spokes 23 of the fly wheels 24.

The fly wheels 24 are rigidly mounted on either end of the crank shaft 25, journaled in suitable bearings 26 of the crank case 9. The crank 27 is made integral with the crank shaft 25 so that there is no possibility of the crank and shaft becoming disarranged or disconnected. The crank shaft 25 is not located centrally over the cylinder 8 but is set some distance to the left thereof as viewed in Figs. 1, 2 and 3 and the crank 27 is connected by means of the connecting rods 28 to the power piston 29 fitted to move in the cylinder 8. The piston 29 is made to fit snugly in the cylinder 8 and its movement is such that it never passes out of the cylinder 8. As clearly shown in Figs. 4 and 5 there are two connecting rods 28 which have their upper ends joined by means of the bearing box 30 and have their lower ends pivotally connected at 31 to the lower piston 29, which lower ends also straddle the piston rod 32 carrying on its lower end the displacer piston 13 and mounted to slide in the bore 33 provided therefor in the power piston 29. As seen in Fig. 5, the lower ends of the connecting rods 28 at 31 are pivotally mounted on the tubular pins 34 held against longitudinal movement in suitable sockets provided therefor in the power piston 29 by the set screws 35 or other suitable means. The bearings at 31 and the bore 33 are kept lubricated by means of oil from the cups 36 gravitating through small ducts to said points. The inner walls of the power piston 29 are provided with the air cooling ribs 37 preferably arranged in parallel vertical planes.

The piston rod 32 is made light, strong and of simple construction, and to this end comprises the inner bar 38 made cross shaped in cross section and the outer tube 39 which is of a size to fit snugly over the bar 38 and into the bore 33. The tube 39 is secured to the bar 38 by means of the screws 40, and the lower end of the bar 38 is screwed into the head 41 of the displacer piston 13. The upper end of the bar 38 is operatively connected by means of the connecting rod 42 at 43 to one free arm of the bell crank lever 44 pivotally mounted on the shaft 45 journaled in suitable bearings in the crank case 9. The other free arm of the bell crank lever 44 is operatively connected by means of the connecting rod 46 to the pin 47 mounted in an extension on the bearing box 30. The parts are so arranged and connected that the movements of the two pistons will be substantially as follows: The displacer piston 13 will move down from its upper position to its lower position while the power piston 29 is in its upper position, and the displacer piston 13 will move up from its lower position to its upper position while the power piston 29 is in its lower position.

While the first impression would give the idea that the ideal movements of these pistons would be to have the displacer piston 13 make its complete downward travel while the power piston 29 is substantially at rest in its uppermost position, and have the displacer piston 13 make its complete upward travel while the power piston 29 is substantially at rest in its lowermost position, this fact is not true; but the ideal movements of these pistons, *i. e.*, the movements which will result in the engine giving the best possible efficiency is, to have the displacer piston 13 make its downward and upward travel as rapidly as possible with relation to the movement of the power piston 29 and still provide for a cushioning effect for the power piston 29 at the end of each stroke, and it is such ideal movements of the pistons which is accomplished by an engine constructed in accordance with our invention.

It will be noted that the tube 39 of piston rod 32 extends materially above the upper end of the bar 38. This is done to enable building the engine more compact. The crank case 9 it will be noted is an integral piece and carries both the bearings for the crank shaft 25 and the bell-crank lever shaft 45 neither of which shafts have any operating parts secured or keyed thereto, thus eliminating all possibility of any working

parts slipping or getting out of order. The crank case 9 can thus be accurately machined and trued up so that no fitting or setting is necessary when the engine is assembled. The lower surface of the crank case 9 is provided with the annular shoulder or offset 48 which fits into a companion depression formed in the top of the cylinder 8.

It will also be noted that the extreme right hand position of the upper free arm of the bell crank lever as viewed in Figs. 2 and 3, is within the circumferential bounds or limits of the fly wheels; this particular construction eliminates all danger of any person accidentally coming into contact with a moving part of the engine, as well as affording a construction which is compact and can easily have its operating parts inclosed by a protecting cover.

The pin 47 is located a short distance from the crank 27 and on that side thereof which is directly opposite to the power piston 29, which because the pin 47 is mounted in a part rigid with the connecting rod 28, will cause the pin 47 to travel a greater distance from right to left above the crank shaft 25 and from left to right below the crank shaft 25 than the crank 27 itself, as viewed in Fig. 3; and this longer travel from side to side of the pin 47 will cause the displacer piston 13 to travel down and up with greater speed than if the pin 47 were placed otherwise. It will be understood that the displacer piston 13 is slightly smaller in diameter than the bores of the cylinder 8 and the sub-cylinder 12 and that a cylindrical port or passageway is formed between the piston 13 and the inner walls of cylinder 8 and sub-cylinder 12 to form a means of communication between the space above the displacer piston 13 and the space below the displacer piston 13.

The action of the engine in operation is as follows starting from the position shown in Fig. 3:

The fly wheels rotate to the left as indicated by the arrow; the crank 27 and piston 29 move upward being forced up by the expanding air in the cylinder; just before the piston 29 reaches its uppermost position the piston 13 is moving downward most rapidly and transfers the air from the sub-cylinder 12 (below piston 13) to the cylinder 8 (above piston 13); then the air is cooled and contracts and draws the piston 29 down and of course also pulls the crank 27 downward; just before the piston 29 reaches its lowermost position the piston 13 starts to ascend and when the piston 29 is in its lowermost position the piston 13 is moving upward most rapidly and transfers the air from the cylinder 8 (above piston 13) to the sub-cylinder 12 (below piston 13); then the air is heated and expands and forces the piston 29 and of course also the crank 27 upward and so on continuing the same cycle of movements.

The parts are so constructed and arranged that when the piston 29 is in its uppermost position the piston 13 is traveling at its greatest speed downward creating a vacuum between the two pistons and pulling the piston 29 downward; the position of the pin 47 above the crank 27 increases the downward speed of the piston 13; and furthermore a cushion is formed for the piston 29 at the end of each stroke; *i. e.*, at the end of its upward movement by a vacuum being formed and at the end of its downward movement by compression.

The advantage gained by having the crank shaft 25 off-set to one side of the center line of the cylinder, besides the ordinary one of having more effective thrust on the crank 27 during the power stroke is, that in the down stroke there is practically no side pressure because the piston 29 is actually pulled downward by force of vacuum instead of being forced downward by the crank 27; furthermore the working stroke continues during a longer time and the return stroke is accomplished in a shorter time.

The actual relative position of the two pistons 29 and 13 can be clearly traced throughout a complete cycle by means of the diagrammatical view shown in Fig. 6. The vertical lines 49 indicate time in the travel of the pistons; the lines 50 and 51 indicate the positions of the pistons 29 and 13 respectively at the different times. The dotted lines 52 and 53 adjacent the lines 50 and 51 indicate the positions of the pistons in an engine whose crank shaft is located centrally above the cylinder and the displacer piston is operated through connections made direct with the crank instead of a point being removed slightly from the crank.

Starting at the 0 line it will be noted that the upper or power piston 29 is moving rapidly upward while the lower or displacer piston 13 is just starting to move downward. Passing along to line 5 it will be noted that the upper piston 29 is about at its uppermost position while the lower piston 13 is moving rapidly downward. As the upper piston 29 approaches its uppermost position it is desirable to check its momentum and thus prevent retarding the action of the crank 27, and this is accomplished to a nicety by the rapid downward movement of the lower piston 13 at the time just above referred to—line 5. This rapid downward movement of the lower piston 13 tends to create a vacuum between the two pistons on account of the sudden cooling of the air and pulls downward on the upper piston 29, thus checking its upward momentum. While passing

from the 0 line to line 5 it is well to note the dotted lines 52 and 53 which represent the upper and lower pistons of an engine as heretofore constructed, and note that the upper piston moves less rapidly toward its uppermost position and that the lower piston moves considerably less rapidly downward and the latter also starts on its downward movement at a later time *i. e.* when the upper piston is nearer to its uppermost position. Passing along to line 10 it will be noted that the upper piston 29 is just starting to move down from its uppermost position while the lower piston 13 is still moving rapidly downward. Thus the air is transferred to the cool end of the cylinder, contracts, and tends to form a vacuum and pulls the upper piston 29 downward. It will be noted that the dotted line 52 indicates that the upper piston of former engines does not move downwardly as rapidly as our present engine and that the dotted line 53 between the lines 5 and 10 indicate that the lower piston of former engine does not move downwardly as rapidly as that of our engine.

Passing along to line 15 of the diagram it will be noted that the upper piston 29 is moving down rapidly and the lower piston 13 is just about at its lowermost position. It should be noted that the dotted line 53 indicates that the lower piston of former engines did or does not reach its lowermost position until some time later. At line 20 it will be noted that the upper piston 29 is still moving rapidly downward and that the lower piston 13 is moving upward; thus the air in the cylinder is being transferred from the cool end to the hot end, expands, and forms just sufficient compression within the cylinder to retard or counteract the downward momentum of the upper piston 29 when it nears its lowermost position, which cushioning effect is very desirable and prevents any retarding action on the crank 27. It will be noted that at line 20 the dotted line 53 indicates that the lower piston of former engines does not move upward nearly as rapidly and therefore does not give the best results. Passing along to time-line 25 it will be noted that the upper piston 29 is substantially at its lowermost position and the lower piston 13 is moving rapidly upward thus transferring the air from the cool end of the cylinder to the hot end thereof, the air, expanding becomes compressed and forces the upper piston 29 upward and exerts the power stroke on crank 27. At time-line 30 both upper and lower pistons 29 and 13 are moving rapidly upward and are at the point where they are nearest together, from whence they move to the starting point, time-line 0. An intake check valve 54 is provided in the cylinder 8 through which atmospheric air is drawn into the cylinder automatically when the vacuum becomes too great within the cylinder or to take up the deficiency due to piston leakage.

This lower or displacer piston 13 is in effect a condenser, since it takes up the heat of the air while the air is moving upward in the cylinder and then gives out some heat to the air while the air is moving downward in the cylinder. To increase the efficiency of said piston 13 as a condenser we provide a coil of wire 55 on the exterior of said piston 13.

Having thus fully described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. In a device of the class described, a vertically disposed cylinder, means for heating the lower end of said cylinder, means for cooling the upper end of said cylinder, a power piston provided with a central bore fitted to move in the upper part of said cylinder, a displacer piston arranged to move freely in said cylinder below the power piston, a piston rod connected to the displacer piston extending through and fitted to slide in the bore of the power piston, a crank shaft above and off-set to one side of the center line of the cylinder, a connecting rod to connect the crank shaft with the power piston provided with an extension above the pivotal connection with the crank shaft, a bell crank lever pivotally mounted on the upper end of the cylinder, a link connecting one arm of the bell crank lever to the extension on the power piston connecting rod and a second link connecting the remaining arm of the bell crank lever to the displacer piston rod whereby the displacer piston is given the desired movement with relation to the power piston.

2. In a device of the class described, a vertically disposed cylinder, means for heating the lower end of said cylinder, means for cooling the upper end of said cylinder, a power piston and a displacer piston arranged to move in said cylinder, a crank shaft above said cylinder off-set to one side of the center line thereof, a connecting rod to connect the power piston with the crank shaft provided with an extension above the crank shaft, a piston rod connected to said displacer piston and means comprising a bell crank lever for operatively connecting said displacer piston rod with said power piston connecting rod extension above the crank shaft whereby the displacer piston is given the desired movement relative to the power piston.

3. In a device of the class described, a vertically disposed cylinder, means for heating the lower end of said cylinder, means for cooling the upper end of said cylinder, a power piston arranged to move in said cylinder, a displacer piston arranged to move in said cylinder below the power piston, a

crank shaft mounted above the cylinder, a connecting rod connecting said power piston to said crank shaft provided with an extension above the crank shaft, a bell crank lever pivotally mounted on the upper end of the cylinder, a connecting rod connecting said displacer piston to one free arm of the bell crank lever and a connecting rod connecting the other free arm of the bell crank lever to the extension on the power piston connecting rod above the crank shaft whereby the displacer piston is given the desired movement relative to the power piston.

4. In a device of the class described, a power piston, a displacer piston, a crank shaft, a connecting rod connecting said crank shaft to said power piston, an extension on said connecting rod on the opposite side of the crank shaft from the power piston, a bell crank lever, a link connecting one arm of the bell crank lever with the extension on the power piston connecting rod and a second link connecting the remaining arm of the bell crank lever with the displacer piston rod.

5. In a device of the class described, a vertically disposed cylinder, a crank shaft mounted in suitable bearings on the upper end of said cylinder, a crank in the center of said shaft, a fly wheel rigidly mounted on each extremity of said shaft, a connecting rod operatively connecting said crank to the power piston and provided with an extension above the crank, a bell crank lever pivotally mounted on the upper end of said cylinder, a link connecting one free arm of the bell crank lever to said extension on the connecting rod, and a second link connecting the other free end of the bell crank lever to the displacer piston whereby the latter is given the desired movement relative to the power piston.

6. In a device of the class described, a cylinder, a power piston in said cylinder, a displacer piston in said cylinder, a shaft, a crank on said shaft, a connecting rod forming operative connection between the crank and the power piston, suitable mechanism operatively connecting said connecting rod with the displacer piston comprising a bell crank lever and two links, said parts being so arranged and constructed that the center line of force exerted between the crank and the power piston will be in the same plane with the center line of force exerted between the said bell crank lever and two links and the displacer piston.

7. In a device of the class described, a vertically disposed cylinder, suitable uprights on opposite sides of the cylinder, a shaft mounted in suitable bearings in said uprights, a crank on the shaft between said bearings, a power piston to move in said cylinder, a displacer piston to move in said cylinder, a piston rod connected to said displacer piston and piercing the power piston, connecting rods on either side of said piston rod connecting the crank to the power piston and provided with extensions above the crank, a bell crank lever in the same vertical plane with the centers of the two pistons pivotally mounted on the upper end of said cylinder, a link connecting one free end of said bell crank lever with the extensions on said connecting rods above the crank and a second link connecting the other free arm of the bell crank lever with said displacer piston rod.

8. In a device of the class described, a cylinder, a power piston in said cylinder, a displacer piston in said cylinder, a crank shaft, bearings on the upper end of the cylinder in which the shaft is journaled, a bell crank lever pivotally mounted on the upper end of the cylinder, a connecting rod connecting the crank to the power piston, a link connecting one free arm of the bell crank lever to the crank, a link connecting the other free arm of the bell crank lever to the displacer piston, and a case secured to the upper end of the cylinder entirely inclosing said crank, connecting rod, links and bell crank lever whereby the working parts are protected against coming in contact therewith.

9. In a device of the class described, a vertically disposed cylinder, a power piston to move in said cylinder, a displacer piston to move in said cylinder below the power piston, means for cooling the upper end of said cylinder and means for heating the lower end of said cylinder comprising a burner and a cylindrical heat deflector encircling the lower end of the cylinder and having a plurality of annular curved deflecting surfaces.

10. In a device of the class described, a suitable cylinder, a displacer piston slightly smaller than the bore of the cylinder to move longitudinally in said cylinder and a coil, or a series of rings, of wire on the exterior surface of said displacer piston to increase the condenser effect of the same.

In testimony whereof we have signed our names to this specification, in presence of two subscribing witnesses this 21st day of August, 1913, at Chicago, Illinois.

EDGAR E. CAMPBELL.
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Witnesses:
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