No. 880,744. PATENTED MAR. 3, 1908.

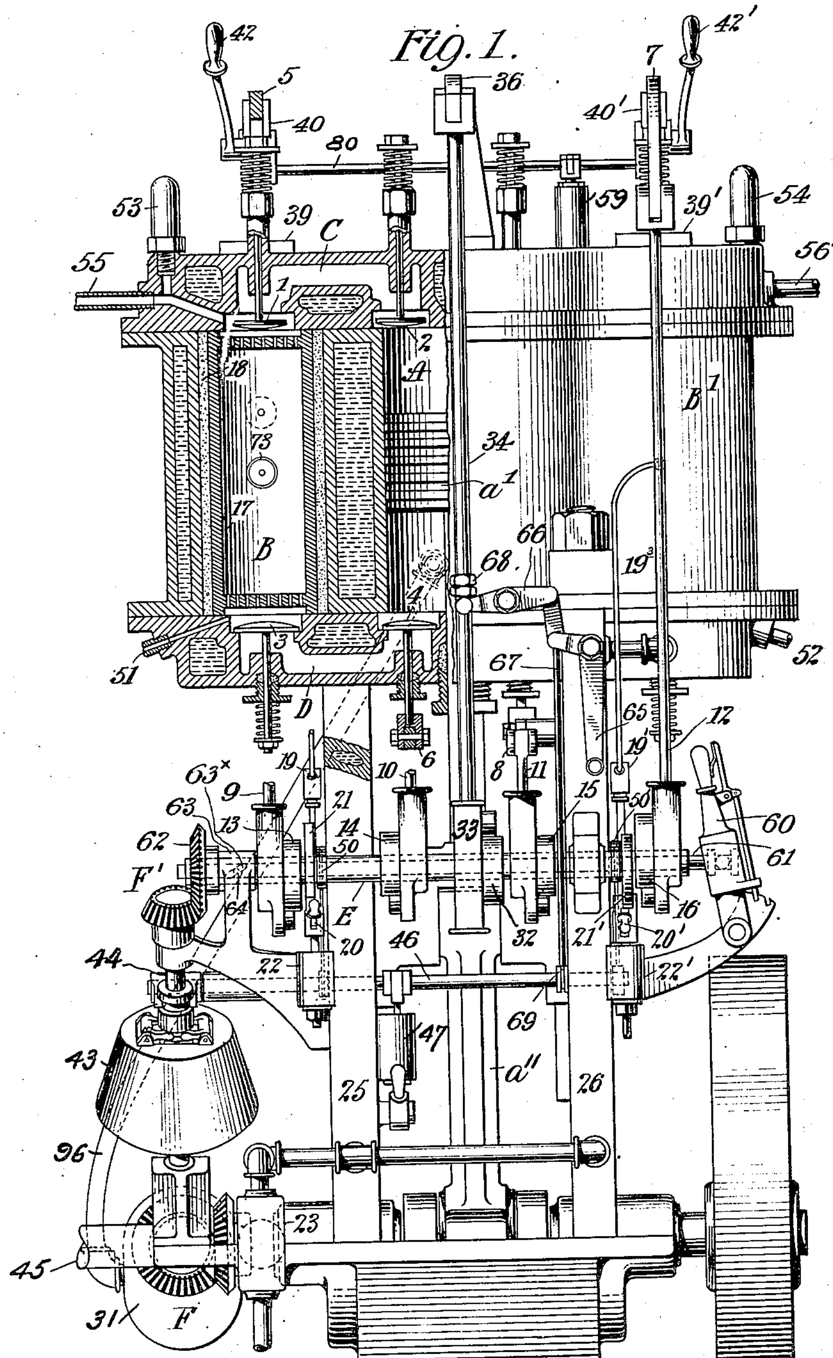
S. LAKE.

HEAT ENGINE.

APPLICATION FILED FEB. 10, 1906.

10 SHEETS—SHEET 1.

Fig. 1.



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10 SHEETS—SHEET 2.

Fig. 2.

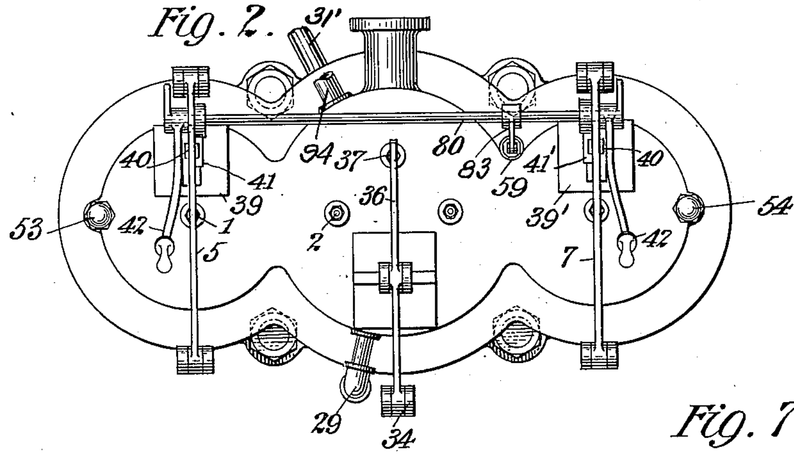


Fig. 6.

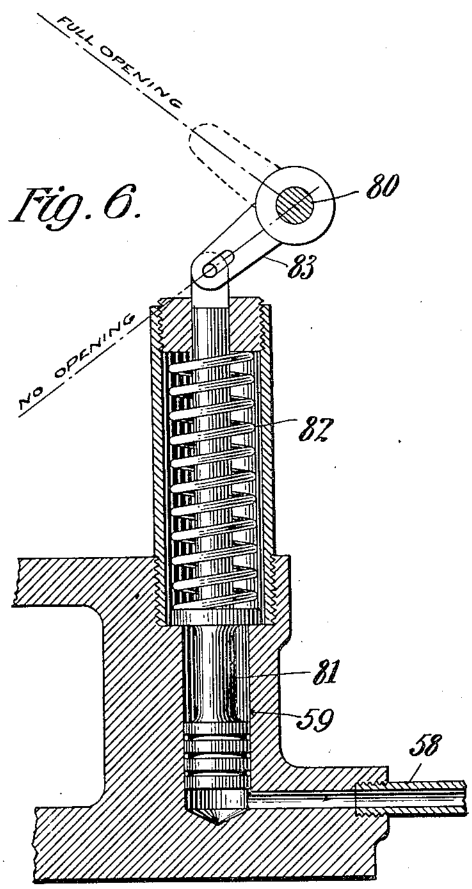
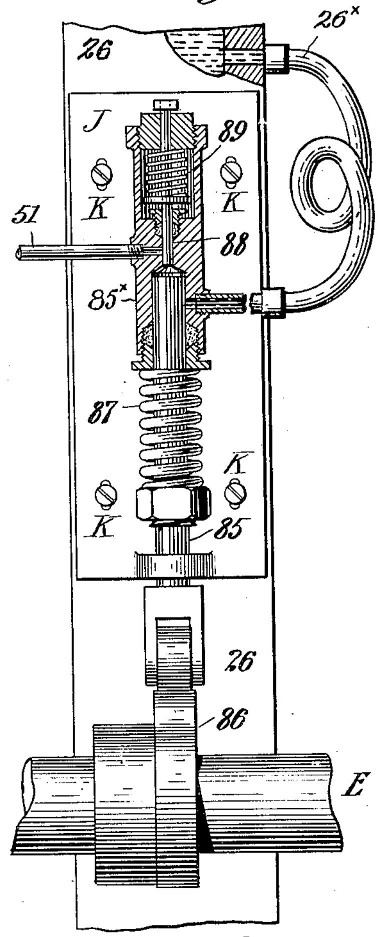


Fig. 7.



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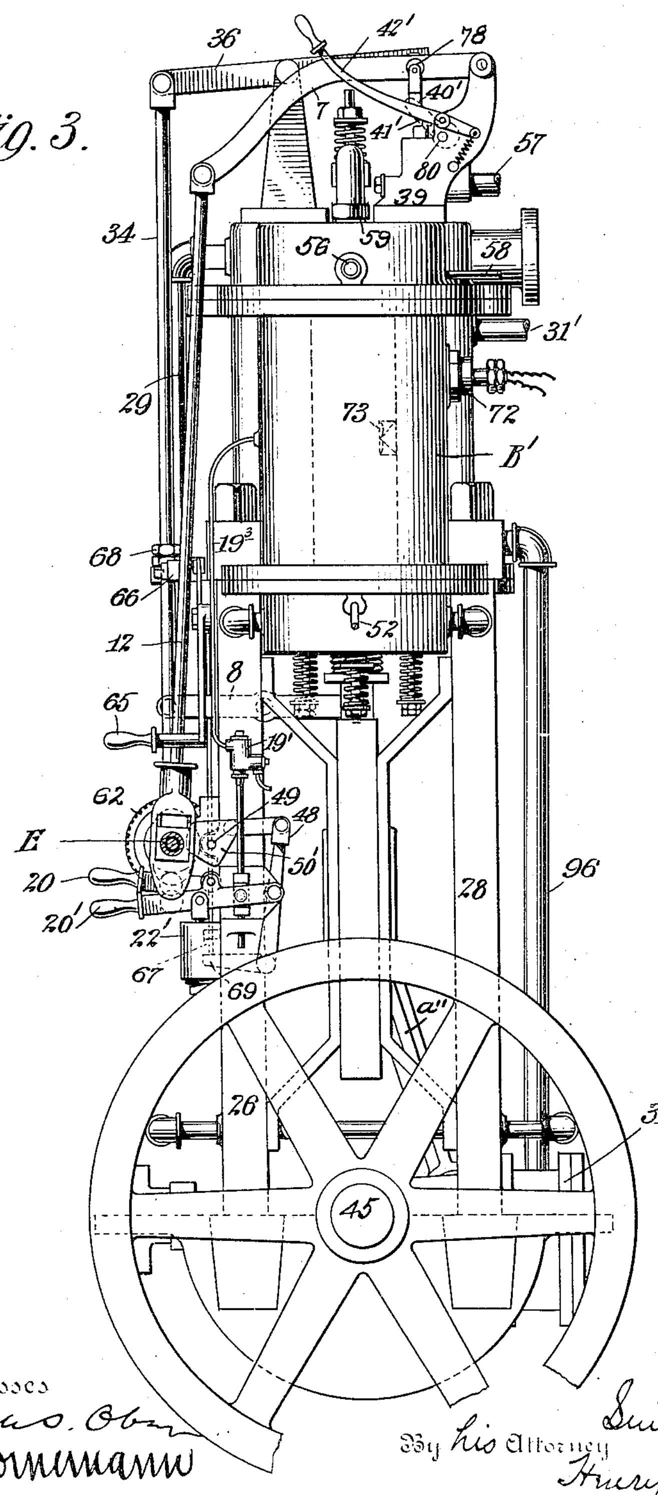
10 SHEETS—SHEET 3.

Fig. 3.



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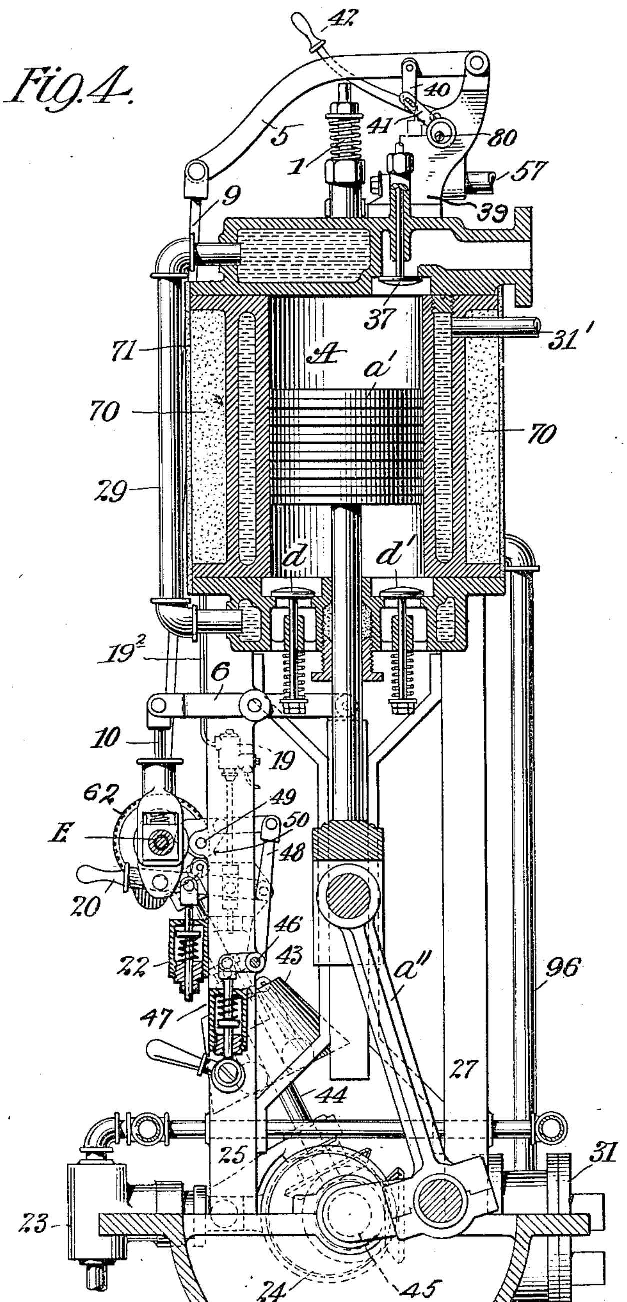
10 SHEETS—SHEET 4.

Fig. 4.



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10 SHEETS—SHEET 5.

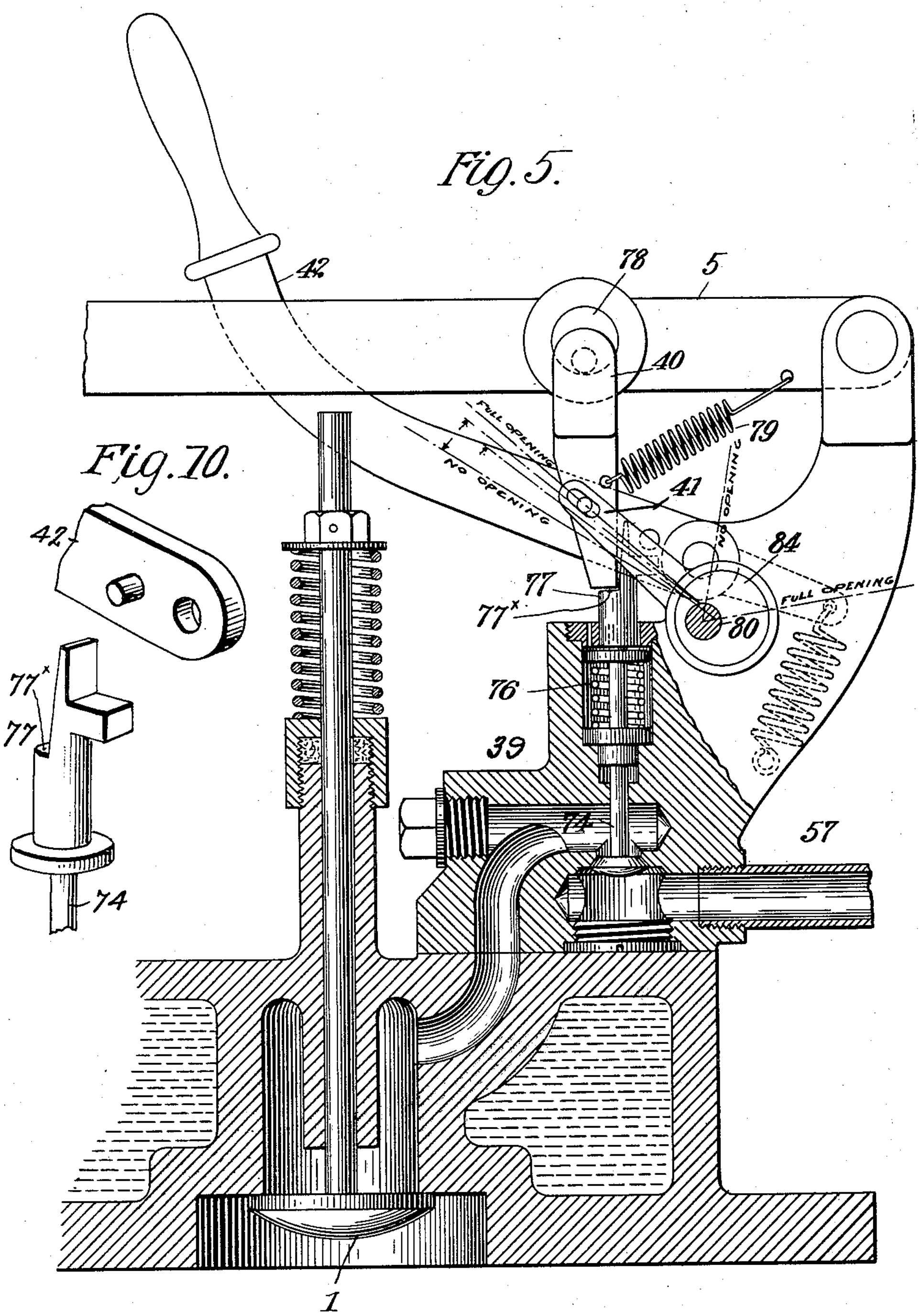

Fig. 5.

Fig. 10.

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10 SHEETS—SHEET 6.

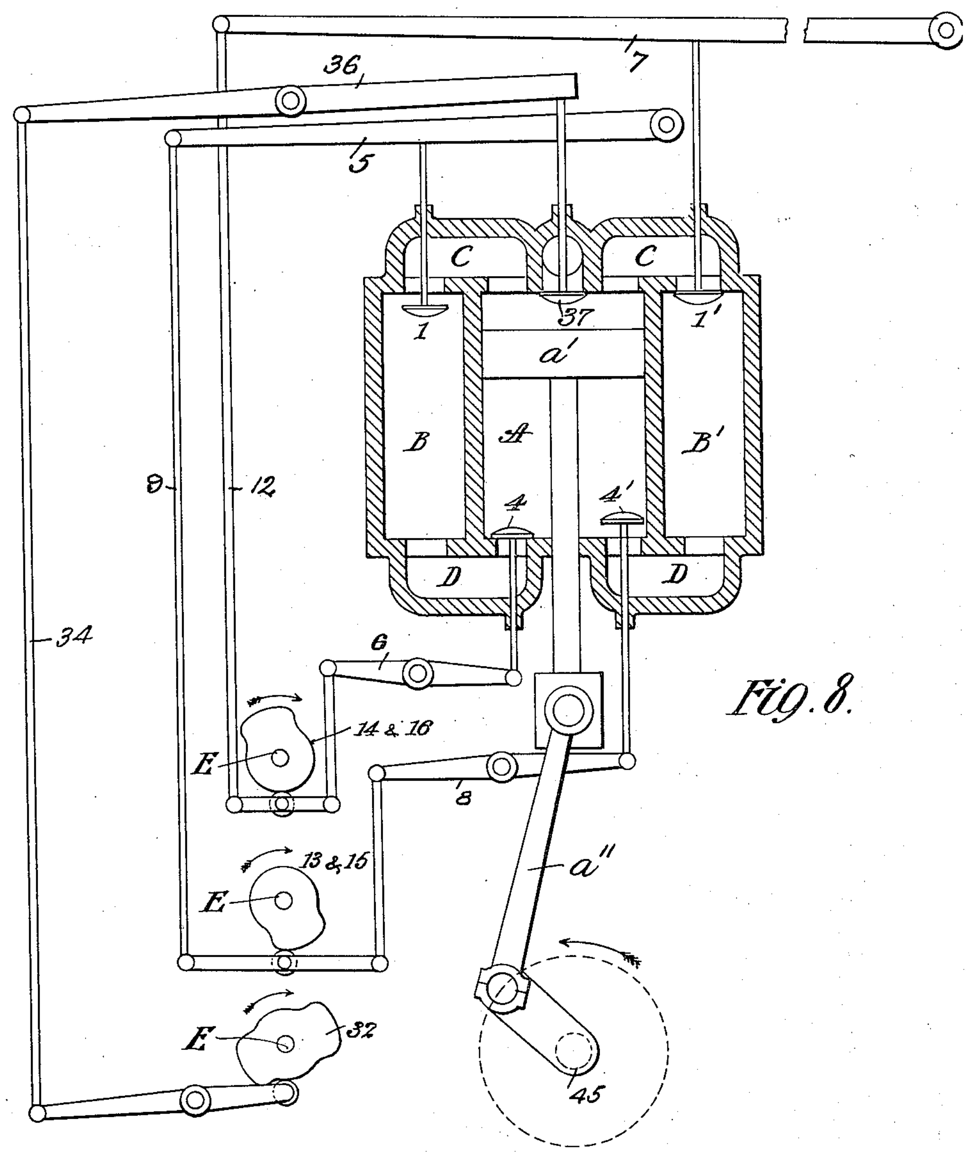

Fig. 8.

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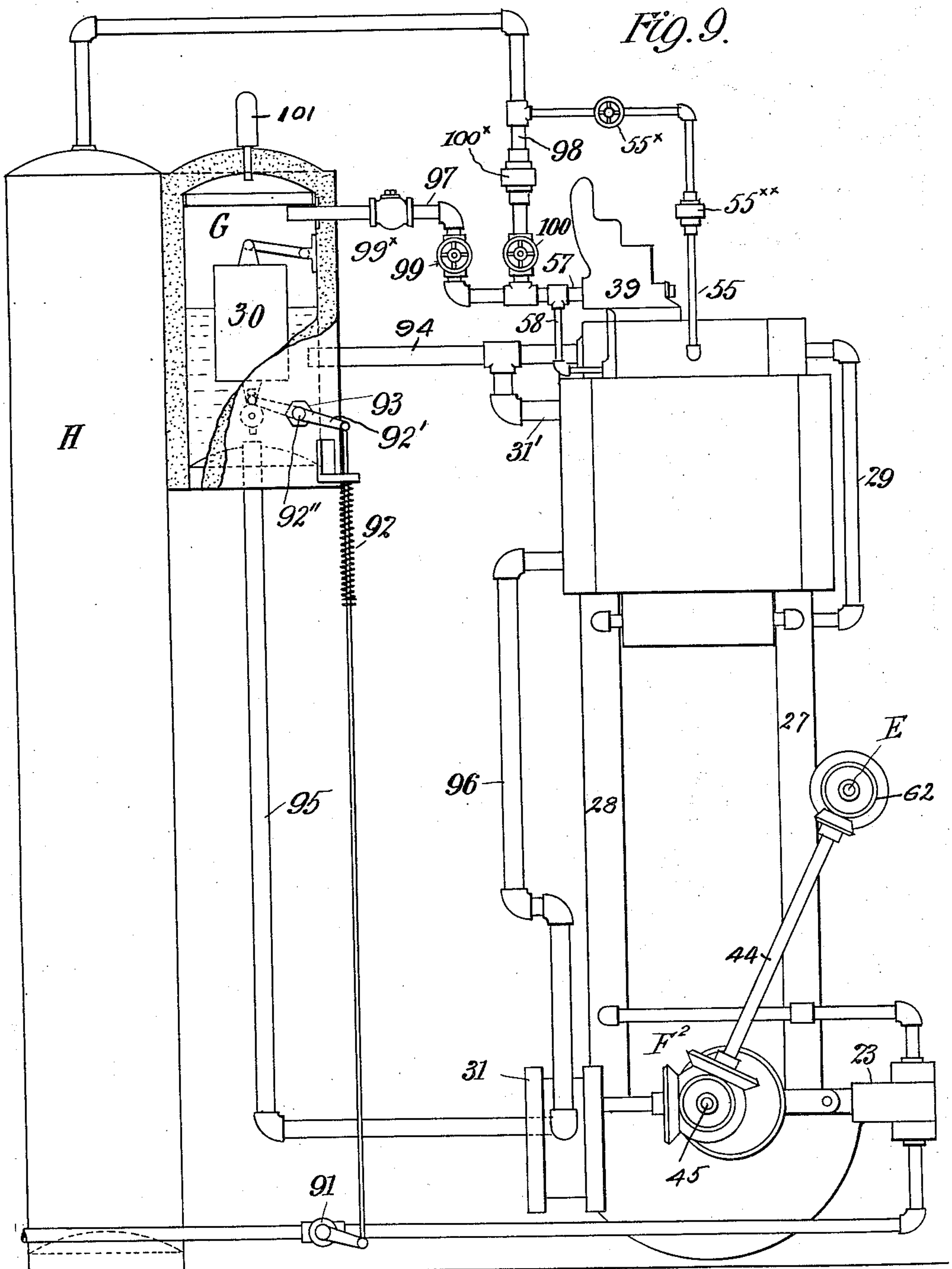
10 SHEETS—SHEET 7.

Fig. 9.



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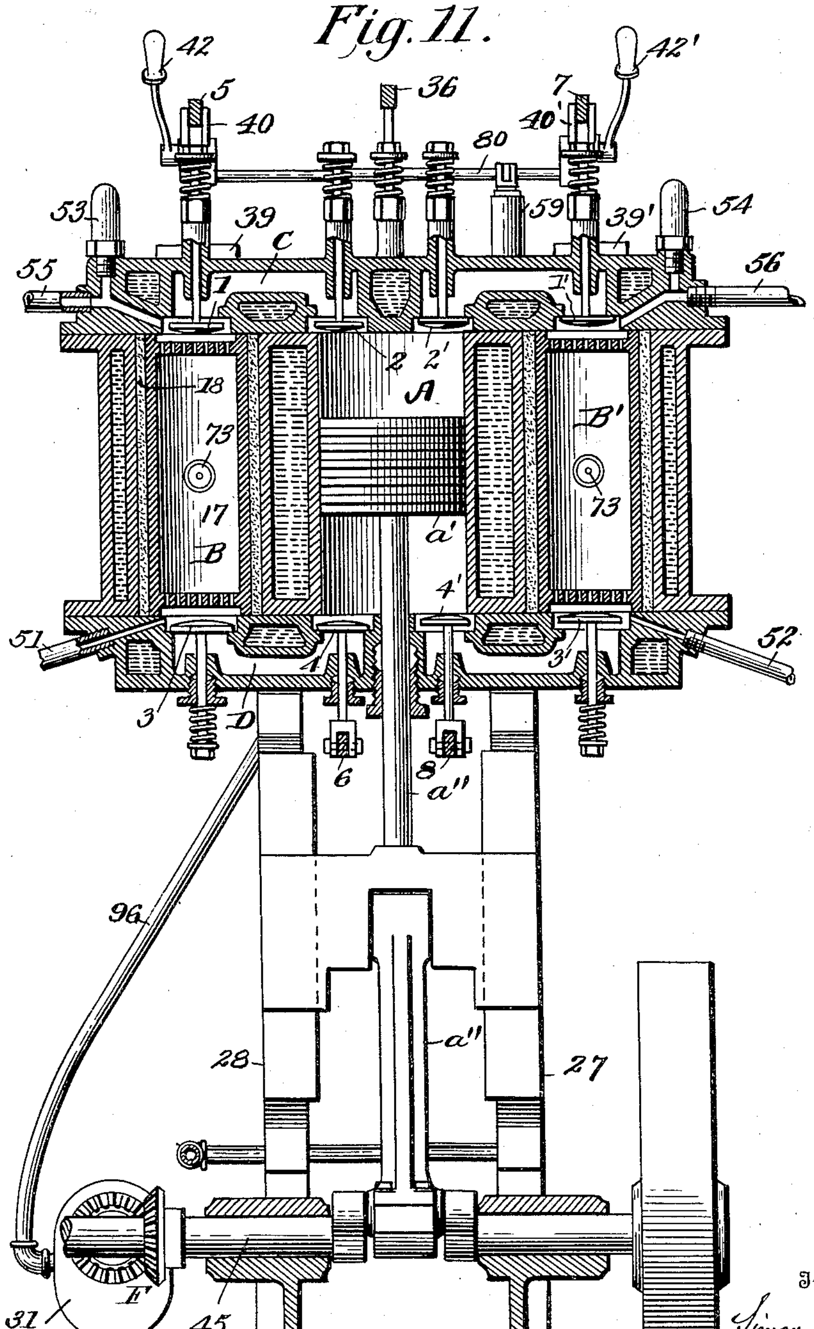
APPLICATION FILED FEB. 10, 1906.

10 SHEETS—SHEET 8.

Fig. 11.



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10 SHEETS—SHEET 9.

Fig. 12.

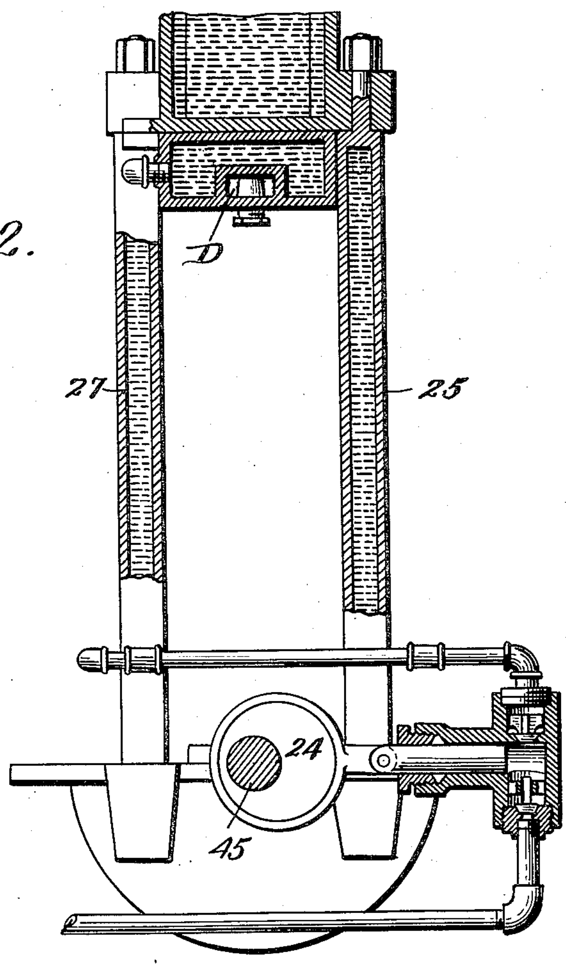
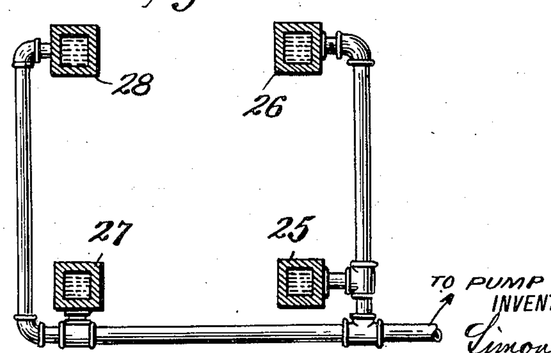


Fig. 13.



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10 SHEETS—SHEET 10.

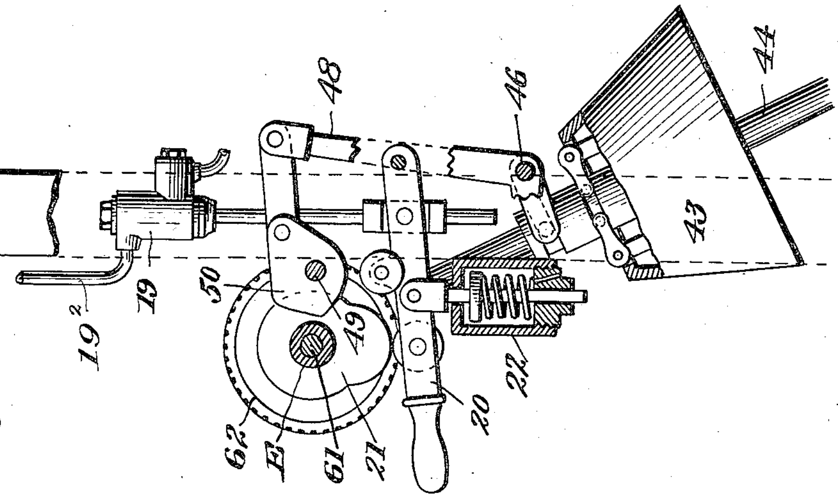

Fig. 15.

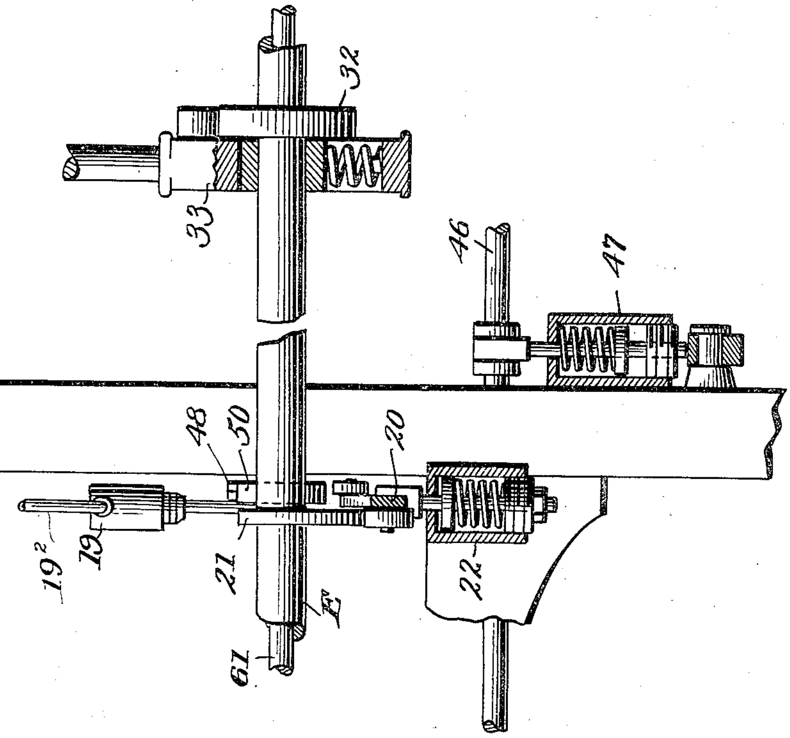

Fig. 14.

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UNITED STATES PATENT OFFICE.

SIMON LAKE, OF BERLIN, GERMANY.

HEAT-ENGINE.

No. 880,744. **Specification of Letters Patent.** **Patented March 3, 1908.**

Application filed February 10, 1906. Serial No. 300,520.

To all whom it may concern:

Be it known that I, SIMON LAKE, a citizen of the United States, temporarily residing at 23 Friedrich Wilhelmstrasse, Berlin, Germany, have invented certain new and useful Improvements in Heat-Engines, of which the following is a specification, reference being had therein to the accompanying drawings.

One object of this invention is to produce an internal combustion engine similar in operation to a steam engine, in that it gives a constant pressure in its cylinder for a portion of the power stroke, rather than an explosion, and also in that its power supply may be cut off, and the products of combustion and the heat generated by the initial compression utilized expansively and in the most economical manner, and also in its capacity of being readily reversed as to its direction of rotation, thereby adapting it to purposes of ship propulsion, hoisting engines and the like.

Another object of the invention is to convert into effective work the heat which is lost in internal combustion engines of usual construction, due to the water circulation necessary to keep the valves and pistons in a condition in which they will work.

Another object of the invention is to provide a construction whereby practically complete combustion of all cheap, low-grade fuel, as well as the better grades of fuels may be effected, such low-grade fuels having been difficult to burn perfectly in some prior engines, because of the inability to use sufficiently high temperatures.

Another object of the invention is to give additional horse power and economy over engines of usual construction, without varying the cylinder volume and number of revolutions.

A further object of the invention is generally to increase the efficiency and reliability of internal combustion engines in certain principles and details of construction.

Having thus stated the general objects of the invention, I will proceed now to describe in detail a construction whereby these objects may be attained and then will particularly point out and distinctly claim the parts, improvements or combinations which I claim as my invention.

In the accompanying drawings, illustrating the invention, in the several figures of which like parts are similarly designated, Figure 1 is a side elevation of the engine, showing one of the combustion chambers or furnaces and half of the cylinder in vertical section. Fig. 2 is a top plan view of the engine cylinder and furnaces, showing the relative positions of the controlling valves. Fig. 3 is a side view of the engine. Fig. 4 is a vertical section taken through the center of the cylinder and showing the positions of the exhaust valve and air inlet valve. Fig. 5 is a vertical section, on a larger scale, through the head and over one of the furnaces and showing the means of controlling the steam inlet valve. Fig. 6 is a longitudinal section, on a larger scale, of the steam cut-off-controlling cylinder and attachments. Fig. 7 is an elevation and partial section of the furnace cooling and cleaning device for special fuel, sometimes hereinafter referred to as the scavenging device. Fig. 8 is a diagram showing the operation of the valves. Fig. 9 is a diagram showing the engine connected up with a steam and water supply-regulating reservoir. Fig. 10 is a perspective view of parts of the controlling mechanism for the steam valve shown in Fig. 5. Fig. 11 is a vertical section taken substantially through the center of the cylinder and furnaces, with some of the valve mechanism in elevation. Fig. 12 is a partial longitudinal section showing the force pump, the water columns, the lower head and the water jackets. Fig. 13 is a horizontal section through the water columns. Fig. 14 is a sectional elevation, on a larger scale, showing part of the fuel-supplying arrangement. Fig. 15 is an end elevation, partly in section, of parts of the fuel-supplying arrangement.

In the selected illustrations of the invention, A is a cylinder, fitted with a usual piston, a' and connecting rod a''. Joined to this cylinder are two combustion chambers B B', which I prefer to call furnaces. These furnaces communicate with the cylinder A both at the top and bottom, by valve-fitted passages C and D. The upper passage C admits the contents of the furnace to the cylinder above the piston, and the lower passage D admits to the furnaces air which had been previously drawn into the cylinder below the piston, through valves d d' (see Fig. 4), upon the up-stroke of the piston. Inwardly opening valves 1 and 2 and 1' and 2' control communication between the passage C and the two furnaces and the cylinder respectively, and similar valves 3 and 4 and 3' and 4' control communication between the lower passage D and the two furnaces and the cylinder respectively.

As shown in Fig. 8 valves 1 and 4 are controlled by the levers 5 and 6, and the corresponding valves of the other furnace are controlled by levers 7 and 8 respectively, and these levers are operated by the connecting rods 9, 10, 11, 12 and their reciprocating yokes by cams 13, 14, 15, 16 on the cam-shaft E, and this same shaft is driven at half the speed of the main shaft (45) by bevel gears F and F′, in any customary manner.

The furnaces may be provided with refractory linings 17, which may also be insulated by asbestos or other suitable substance 18, to prevent the heat from being too rapidly absorbed by the water contained in the surrounding water-jacket.

The fuel pumps 19 19′ are connected by pipes 19^2 and 19^3 with the respective furnaces, and the pumps are operated by levers 20 and 20′ and cams 21 and 21′, the fuel being forced into the furnaces by the action of a spring in the housings 22 and 22′. This spring is of sufficient power to inject the fuel at the maximum pressure at which the engine is designed to operate. The fuel pumps are of well known construction, and may be fed from a reservoir (not shown) located at any convenient place, and they inject the fuel through the pipe, as shown, directly into the furnace and with considerable force, depending on the power of the spring.

A force pump 23 (see details Fig. 12) is provided and operated by the eccentric 24. This pump discharges into the bottom of the hollow columns 25, 26, 27 and 28, whence the water passes into the lower cylinder and furnace head, then up through pipe 29 to the upper cylinder head and from there into a steam and water reservoir G which has a regulator 30, Fig. 9, for automatically controlling the supply of water, as hereinafter described. Connected with this reservoir G at its lower end, is a pipe (95) leading the water to a circulating pump 31 operated from the main shaft 45 by bevel-gears F^2, from which pump the water is forced around the cylinder and furnace walls and finally back again to the reservoir through pipe 31′ shown broken off in Figs. 3 and 4. The exhaust is controlled by the double cam 32, yoke 33 and connecting rod 34 and lever 36. This cam is set so as to open valve 37 on each up-stroke of the piston. Steam-admission valves are shown at 39 and 39′, with automatic cut-off detents 40 and 40′, stroke-regulating links 41 and 41′ and starting levers 42 and 42′. The operation of the steam-admission valves will be better understood by referring to the enlarged details in Figs. 5 and 10 and the subsequent description.

43 is a governor, which may be of the usual centrifugal type, mounted on the gear shaft 44, which is connected by the bevel-gears F F′ with the main crank-shaft 45 and the half-speed shaft E and therefore connects shafts 45 and E. The governor controls the amount of fuel fed by the pumps, through the medium of shaft 46, an adjusting spring contained in housing 47, arm 48, stud 49 and cams 50 and 50′.

51 and 52 show small pipes broken off which lead into the furnace chambers. These pipes are for the purpose of injecting a small quantity of steam or water which acts as a scavenger to clean the furnace and slightly reduce its temperature, which might be desirable with certain kinds of fuel. As this will not be necessary with many of the fuels I have not shown the scavenger attached to the assembled drawings but show it as an auxiliary attachment in Fig. 7, to be described.

53 and 54 are relief valves.

55 and 56, Figs. 1 and 11, are pipes fitted with stop-valves and leading to the air reservoir H, Fig. 9. In Fig. 9 the pipe 55 and its stop-valve $55^{\times}$ are shown, and it is sufficient to say that pipe 56 and its stop-valve not shown, are similarly arranged on the other side.

57 is the steam inlet pipe, shown broken off in Figs. 3, 4 and 5 and in full in Fig. 9. 58, Figs. 6 and 9, is a small steam pipe leading from pipe 57 to the steam cut-off-controlling cylinder 59.

60 is the engine-reversing lever, of well known construction, connected with a rod 61, extending through the hollow cam-shaft E to the bevel-wheel 62 of the bevel-gears F′. This bevel-gear 62 is carried in the bearing 63 by an extension of its hub, shown by dotted lines Fig. 1. This hub contains a helical slot $63^{\times}$ through which is fitted a pin 64 extending into the shifting-rod 61. This rod is connected with the cam-shaft E in such way as to permit of its being moved endwise only in its relation to the cam-shaft. It will, therefore, be seen that the position of the bevel-gear 62 in its relation to the cam-shaft is controlled by the location of pin 64 in the helical slot.

65 is a hand-lever, connected with a rocking-arm 66, one end of which carries a rod 67 and the other contacts with a stop-collar 68 on the exhaust valve operating rod 34 to open said valve. At the same time rod 67 engages a toe 69 on the shaft 46 cutting off the fuel-supply when desired.

The cylinder is jacketed by asbestos or other non-conducting material 70 and covered with a casing 71, as shown in Fig. 4.

72 is a sparking plug; one for each furnace.

73 is a raised seating on the walls of each furnace (Figs. 1 and 3) arranged opposite the respective fuel pipes 19^2 and 19^3 for spraying the fuel as it is injected under pressure.

This spraying device is so formed, for example, as a cone, as to distribute the injected fuel to all parts of the furnace.

Referring to Fig. 5, 74 is the steam-valve, held to its seat by spring 76 and the steam pressure as well. The valve-stem is screwed into head 77, which head is provided with a seat 77$^{\times}$ for detent 40. This detent engages with the seat 77$^{\times}$ at the end of the lift of lever 5, and its movement is regulated by the eccentric 78 situated in the lever. Spring 79 pulls the detent into engagement, while the tripping-link 41 forces it off its seat upon the down stroke, depending on the position of the tripping-link, which is varied by revolving the eccentric-shaft 80.

Connected to the eccentric-shaft 80 is the automatic cut-off, comprising the cylinder 59 and a piston 81 which is held in its normal position as shown in Fig. 6 by spring 82. When steam is admitted below the piston, it tends to compress spring 82 and through the lever 83 revolves shaft 80 and eccentric 84 and thus changes the position of link 41 and consequently the point of trip or cut-off of the steam-valve.

Referring to Fig. 7, the scavenger pump is shown arranged upon a base plate J mounted on column 26. The supply pipe 26$^{\times}$ connects with the water under pressure in the circulating system, while discharge pipe 51 leads into the furnace at its lower end. This pump consists of a plunger 85 working in a cylinder 85$^{\times}$ and operated by the cam 86 mounted on the cam-shaft E. The plunger is shown at its top stroke under the lift of the cam, and its reverse movement is effected by the spring 87. When the plunger in its down-stroke has passed the opening of the supply pipe 26$^{\times}$, the water under pressure fills the space above the plunger, and on the next succeeding up-stroke the plunger first cuts off the water supply and then forces the trapped water into pipe 51 after lifting the piston valve 88. This piston valve is held down by the spring 89 with sufficient force to prevent its being lifted by the pressure of the water alone. The stroke of the pump may be adjusted by moving its base plate J up or down the column, which is permitted by the slotted openings and screws K for securing the plate in place.

Referring to Fig. 8, which is a diagrammatic view showing the sequence of the valve motions, the engine is supposed to be running from right to left, and is on the down-stroke, the cylinder being fed from furnace B, valve 1 being held open by the cam 13, and valve 4′ held open by cam 15. Cams 14 and 16 are free, but will lift valves 1′ and 4 on the next down-stroke, while the double cam 32 will lift the exhaust valve 37 on every up-stroke. On revolving the cam-shaft a quarter-turn, the opposite faces of the cams become the lifting faces, and give the proper lead to cause the engine to run in the reverse direction.

Fig. 9 shows the engine connected up with a steam and water regulator G, also with an air reservoir H. This view shows the arrangement of piping for the water, steam and air supply. The water enters through the supply pipe and is regulated as to quantity by valve 91, which is controlled by the operation of the regulator 30. This regulator consists of a cylinder which acts as a "float" when balanced by the spring 92, which operates on a lever 92′ connected to a shaft 92″ extended out through the side of reservoir G through stuffing-box 93. This so-called float is sufficiently strong to resist collapse by the working pressure of the water contained within the reservoir. If the water falls below its working level, the float compresses the spring 92 and opens wider the supply valve 91. When the water rises, the spring is released and the valve closes, shutting off the supply. Thus the pump can only receive sufficient water to maintain the constant level, which amount depends, of course, on the amount of steam used. The water passes from the pump 23 to the hollow columns 25, 26, 27, 28, thereby keeping them and the mechanism mounted thereon cool, then from the columns to the lower cylinder head, from the lower cylinder head through pipe 29 to the upper head, from the upper head through pipe 94 to the reservoir, from the reservoir through pipe 95 to circulating pump 31, from there through pipe 96 around the furnace and cylinder walls to pipe 31′, and from there to the reservoir again. The steam is fed to the steam-chest through pipe 97, which pipe is fitted with throttle-valve 99 and check-valve 99$^{\times}$. Pipes 55 and 56 are for passing the compressed air from the furnaces to the air reservoir H. This reservoir connects with the steam-chest through a supply pipe 98, having a throttle-valve 100 and a check-valve 100$^{\times}$, whereby flow is into the steam-chest but not reversely. These pipes 55 and 56 are not only fitted with throttle-valves as described, but also with check-valves, as 55$^{\times\times}$, which will admit air from the furnace to the reservoir, but not in the reverse order. This arrangement allows one furnace to be cut out as a power generator and the engine run as an air compressor on every alternate revolution; that is, the air delivered from one down-stroke is forced into the furnace and when the fuel is injected the latter is there ignited, and the air from the next down-stroke would then be forced into the reservoir through the other furnace; but as no fuel is admitted and the valve is open to the reservoir, it enters the reservoir, the valve leading to the cylinder being disconnected. The reservoir is in this manner charged so as to be available for starting the engine again when the steam pressure has fallen, as will be later described.

101 is a safety valve, in the regulator G.

The adjustment for starting the engine is as follows: The half-speed cam-shaft runs in the opposite direction to the main shaft. For purpose of illustration, assuming that the crank is on the top center, and it is desired to run the engine from right to left in the direction of the arrow on Fig. 8: The exhaust valve cam 32 is loosened on its shaft and revolved by hand in the same direction in which the engine is to run, just so a contact is made on the exhaust-valve-stem, but not with sufficient force to unseat said valve, and the cam is then secured. All valves are closed at this point. The cams controlling the levers 5 and 8 are now revolved by hand on the cam-shaft in the opposite direction to which the engine is to run until a contact is made on their respective valve-stems. If the engine is to use steam in connection with the products of combustion or heated air from the furnaces, the detent 40 is also adjusted by means of the eccentric 78 in lever 5, so as to engage the stem of valve 74 in the steam-chest, or it will probably be better practice to slightly unseat this steam valve, so as to give a slight lead to the same sufficient to permit the steam pressure to assist in opening the valve 1 and to also form a steam cushion for the piston on the top of its upstroke. The engine is now turned by hand, the steam valve 74 and the induction valve 1 are opened, and the exhaust valve 37 remains closed. The cam controlling the exhaust valve travels away from its contact with the cam wheel in the yoke, so that were there any pressure either in the furnace or steam pipe the contents would pass into the cylinder by opening the check-valve 2 and thereby force the piston on its down-stroke. The air which had previously been drawn into the cylinder below the piston is at the same time being forced into furnace B′ through its valve 4′ which is controlled by lever 8, this valve being identical in construction to valve 4 as shown in the sectional view. Valves 3 and 3′ are simply check-valves. This combination of one positively-operated valve and one check-valve results in a better control of the contents of the furnaces, since the operation is in large part automatic.

During the down-stroke just described, the cam 21 had been set so as to effect a supply of fuel into the cylinder of the fuel pump and to compress the spring which will inject the fuel into the furnace at a point desired, depending on the position at which this cam is set to permit the spring to act. The conditions are now as follows: The piston is on the down-stroke, the main shaft has made a half revolution, the half-speed shaft has made a quarter revolution, and as all the cams controlling valves 1 and 4 can only hold the valves open during a quarter revolution, they are also closed again. The fuel pump is charged, and the furnace B′ is also charged with compressed air; lever 36 has again formed contact with the stem of valve 37; the up-stroke is now started by continuing the revolution, and immediately the exhaust valve 37 is opened, permitting the escape of the contents above the piston, and fresh air comes in below the piston through the check valves d d'. At any desired time during the up-stroke, the fuel may be injected into the furnace B′. It will be observed that all valves, except the exhaust, are closed on this up-stroke. On the completion of the up-stroke, the exhaust valve closes, the main shaft has now made a complete revolution, the cam-shaft a half revolution, and furnace B is charged with a mixture of air and fuel under pressure. Cams controlling valves 1′ and 4 are now properly adjusted by hand as previously described, and the pump for forcing the fuel into furnace B is adjusted, the pump being given a few strokes by hand to first fill the pipe between the pump and furnace, and the engine is ready to start on the ignition of the contents of furnace B′, which may be accomplished by means of an electric spark or any of the well-known methods in use for this purpose; it being only necessary to set the crank a little over the center in the direction it is to run and then ignite the mixture. The piston is then forced down on its second stroke, at the same time charging furnace B with air and fuel, which is in turn ignited or exploded as desired. It will, therefore, be seen that every down-stroke is a power stroke, and that the furnaces are charged on each alternate stroke. After a few revolutions, the temperature of the furnaces becomes sufficiently high to immediately ignite the fuel on its introduction, so that no other sparking or igniting means are longer required, and the engine will continue to run so long as air and fuel are admitted. In a few minutes steam is generated by the heat of the walls of the cylinders and furnace, and when the steam pressure rises sufficiently, it is turned onto the steam-chest and is permitted to enter the cylinder along with the products of combustion from the furnace, the quantity of steam used depending on the quantity of fuel used, and the point of cut off.

The cut off is automatically controlled in the following manner: For purposes of illustration, assume that the engine is designed for a maximum working pressure of five hundred pounds per square inch, which is the maximum pressure that can be raised in the furnace by the ignition of the maximum quantity of oil delivered by the pump and the maximum volume of air. Also assume that the point of steam cut off will be approximately one-eighth of the stroke at full pressure, the spring on the steam cut-off cylinder is adjusted against a pressure of five hundred pounds so it will stand at a position to throw off the detent 40 by means of the tripping link 41. When the piston has reached one-eighth of its stroke, from the arrangement of the valve mechanism already described it will be seen that as the steam pressure increases, the point of cut off is made later, and as the pressure goes down the point of cut off is made earlier. The admission of steam will, therefore, take place as follows, reference being had to the Figs. 1 and 5: On the arrival of the piston at the top of the stroke, the steam valve is opened slightly in advance of the valve 1, the steam filling the passage C, and if the steam pressure is in excess of the pressure of the gases in the furnace, it will also open valve 1, or will assist in opening said valve. The steam and hot gases now join and are thoroughly mixed. The temperature of the steam on its introduction at five hundred pounds pressure is approximately 467 degrees, while the temperature of the gases may be as much as 3000 degrees or more. The result of this mixing is that the steam cuts down the temperature of the gases, but at the same time its own temperature is raised so that it is further expanded and it is converted into a permanent gas which will continue to expand down to atmospheric pressure. It will be seen also that it is steam against gas, and that one will equalize the other and maintain the pressure down to the point of cut off. If the gas pressure is the greater, on opening valve 1 steam will not enter until the pressure has fallen equal to the steam pressure. If the steam pressure is greater then gas will not enter until the steam pressure falls to equal the gas pressure, or until the point of steam cut off is reached. It will also be seen, that this combination makes the engine either a gas engine or steam engine as required or a combination of both. On starting up the day's work, it would be a gas engine, but as soon as steam is generated, it is a combination of both. During the latter part of the run, the fuel may be cut off and the engine run as a steam engine, until the latent heat contained in the water of circulation is utilized.

To reverse the engine, the steam and fuel are shut off and the exhaust-valve opened. The engine will now stop very quickly, owing to the compression of the air below the piston, and the discharge through the open exhaust. When the engine slows down sufficiently, the reversing lever 60 is thrown to reverse the cams, the steam throttle is opened and the exhaust-valve and fuel pump are put into operation and the next stroke becomes a power stroke in the reverse direction; or if the engine comes to a stop, the exhaust-valve will be held open and the engine will probably stop near the top of the stroke owing to the compression below the piston; then the lever 65 is thrown to reverse the cams and set the engine just over the center in the direction it is to run, and steam is admitted and the engine will start in the proper direction. If the engine has been shut down long enough for the steam pressure to go down, air is admitted to the steam-chest from the air reservoir H, which will give the first few revolutions necessary to heat up the furnace to a point which will ignite the fuel, providing the initial compression is a high one; otherwise it will be necessary to ignite the first few charges.

The scavenger pump is used where very high temperatures are required to give perfect combustion and to cool and clean the furnace of the burned products. The charge of water is admitted near the completion of the down-stroke, and when the pressure in the furnace has been very much reduced, the water immediately flashes into superheated steam and enters the furnace through the numerous small holes in the bottom of the same, forcing the burned gases out ahead of it.

A very small percentage of the products of combustion remaining in the cylinder cuts down efficiency enormously. This is shown by the difference in horse-power per pound of fuel used in what is generally known as the two and four cycle engines. The best two-cycle engines will consume nearly fifty per cent. more fuel per horse-power than the four-cycle engines, owing to the fact that the four-cycle engine gets clear of more of its products of combustion, which, to use a common phrase among gas engineers, "poisons the mixture." With the introduction of this scavenger charge near the end of the stroke, practically all of the burned gases are cleared out on every alternate stroke, instead of every fourth stroke as in the four-cycle engines.

To adapt this engine for running with gas instead of liquid fuel, it is only necessary to change the fuel pump for one of larger size adapted to handle a sufficient volume of gas preferably under pressure, which is injected in a manner similar to that already described. I have not considered it necessary to illustrate a device for this purpose here, as several plans would readily suggest themselves to any experienced manufacturer of gas engines.

It is evident from the foregoing that this engine is not restricted in operation as to any particular point for injecting the fuel or steam. The injection of the fuel may be made simply by shifting the pump cam from any point, beginning with the up-stroke of the piston after the air has been introduced into the furnace until the piston is well on its down-stroke. The fuel is injected immediately after the beginning of the up-stroke so that the ignited fuel may be permitted to remain sufficiently long to become thoroughly consumed by the intense heat of the furnace. This might be the best practice for heavy low-grade refractory oils, while for the lighter oils, such as kerosene, benzin or naphtha, a later admission might be found preferable. When the engine is running without the introduction of steam or water it may be found more advantageous to delay the admission of the fuel until the piston has reached the limits of its up-stroke or has started on its down-stroke. Therefore, the invention is not limited to the exact method of either construction or operation as herein described.

What I claim is:—

1. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, upper and lower heads covering the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves arranged in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder and the expulsion of air from the cylinder to the combustion chambers on opposite sides of the piston, respectively, means to positively actuate said valves, an exhaust port and valve therefor arranged on the pressure side of the piston, and means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed.

2. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, upper and lower heads covering the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves arranged in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder and the expulsion of air from the cylinder to the combustion chambers on opposite sides of the piston, respectively, means to positively actuate said valves, an exhaust port and valve therefor arranged on the pressure side of the piston, and means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, combined with fuel reservoirs and valved connections between said reservoirs and said combustion chambers.

3. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, upper and lower heads covering the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves arranged in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder and the expulsion of air from the cylinder to the combustion chambers on opposite sides of the piston, respectively, means to positively actuate said valves, an exhaust port and valve therefor arranged on the pressure side of the piston, and means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, combined with fuel reservoirs, and connections between the reservoirs and combustion chambers, whereby the contents of the reservoirs are admitted into the combustion chambers at each alternate stroke of the piston.

4. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, upper and lower heads covering the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves arranged in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder upon one side of the piston and the expulsion of air from the cylinder upon the opposite side of the piston to the combustion chambers, means to positively actuate said valves, an exhaust port and valve therefor arranged in said cylinder on the pressure side of the piston, means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, and fuel inlets for said combustion chambers, combined with fuel reservoirs, valved connections between said reservoirs and the combustion chambers, and means for injecting the fuel from said reservoirs into said combustion chambers under pressure.

5. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, heads covering the ends of the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves arranged in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder upon one side of the piston and the expulsion of air from the cylinder upon the opposite side of the piston to the combustion chambers, means to positively actuate said valves, an exhaust port and valve therefor arranged in said cylinder on the pressure side of the piston, means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, independent liquid fuel, steam and air inlets for said combustion chambers, and means for injecting the liquid fuel, steam and air into said combustion chambers under pressure to thoroughly mix the same therein before ignition.

6. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, a water-jacket surrounding said combustion chambers,

heads covering the ends of the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder upon one side of the piston and the expulsion of air from the cylinder upon the opposite side of the piston to the combustion chambers, means to positively actuate said valves, an exhaust port and valve therefor arranged in the cylinder on the pressure side of the piston, means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, liquid fuel and air supplies for said combustion chambers, and a water-supply for said water-jacket, combined with a reservoir, circulating pipes connecting said reservoir with the water-jacket, means for maintaining circulation of water between said reservoir and water-jacket, a water-supply regulator for maintaining the level of the water in said reservoir below the top thereof to form a steam-space, and a valved connection between said steam-space and the combustion chambers for supplying steam to said combustion chambers under pressure.

7. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, a water-jacket surrounding said combustion chambers, heads covering the ends of the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder upon one side of the piston, and the expulsion of air from the cylinder upon the opposite side of the piston to the combustion chambers, means to positively actuate said valves, an exhaust port and valve therefor arranged in the cylinder on the pressure side of the piston, means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, independent liquid fuel and steam inlets for said combustion chambers, and a water supply for said water-jacket, combined with a reservoir, circulating pipes connecting said reservoir with the water-jacket, means for maintaining circulation of water between said reservoir and water-jacket, a water-supply regulator for maintaining the level of the water in said reservoir below the top thereof to form a steam-space, a valved connection between said steam-space and the combustion chambers for supplying steam to said combustion chambers under pressure, means for supplying liquid fuel to said combustion chambers under pressure, and a compressed air reservoir and connections between said compressed air reservoir and said combustion chambers for supplying air to said combustion chambers under pressure, and means for igniting the mixed charge of liquid fuel, air and steam in said combustion chambers upon each alternate stroke of the piston.

8. A heat engine, having a cylinder, a reciprocating piston therein, combustion chambers adjacent to the cylinder, a water-jacket surrounding said combustion chambers, heads covering the ends of the cylinder and combustion chambers and having passage-ways connecting the cylinder and combustion chambers, valves in said passage-ways to control the supply of pressure from the combustion chambers to the cylinder upon one side of the piston, and the expulsion of air from the cylinder upon the opposite side of the piston to the combustion chambers, means to positively actuate said valves, an exhaust port and valve therefor arranged in the cylinder on the pressure side of the piston, means to positively open said exhaust valve on each up-stroke of the piston when the pressure inlet valves are closed, independent liquid fuel and steam inlets for said combustion chambers, and a water supply for said water-jacket, combined with a reservoir, circulating pipes connecting said reservoir with the water-jacket, means for maintaining circulation of water between said reservoir and water-jacket, a water-supply regulator for maintaining the level of the water in said reservoir below the top thereof to form a steam-space, a valved connection between said steam-space and the combustion chambers for supplying steam to said combustion chambers under pressure, means for supplying liquid fuel to said combustion chambers under pressure, and a compressed air reservoir and connections between said compressed air reservoir and said combustion chambers for supplying air to said combustion chambers under pressure, means for igniting the mixed charge of liquid fuel, air, and steam in said combustion chambers upon each alternate stroke of the piston, and a branch connection between said water-supply and the combustion chambers including a pump for forcibly injecting water into the combustion chambers for scavenging said chambers.

9. A heat engine, comprising a cylinder, a reciprocating piston therein, combustion chambers adjacent to said cylinder, a water-jacket surrounding said cylinder and combustion chambers, means for circulating water through said water-jacket to convert it into high pressure steam, and means for conveying said steam to said combustion chambers, including a positively actuated valve and means to automatically regulate the lift of said valve in accordance with the steam pressure, to thereby regulate the pressure of the steam and to proportion the mixture of steam and gases in the combustion chambers.

10. A heat engine, comprising a cylinder, a

reciprocating piston therein, combustion chambers adjacent to said cylinder, a water-jacket surrounding said cylinder and combustion chambers, means for circulating water through said water-jacket to convert it into high pressure steam, and means for conveying said steam to said combustion chambers, including a positively actuated valve, a tripping link for operating said valve, a lever connected to said link for disengaging it from said valve at a predetermined time of cut-off, a shifting fulcrum for said lever for varying the time of cut-off, a piston for shifting said fulcrum operated by steam pressure in one direction and a spring in the other direction, and means for adjusting the pressure of said spring to regulate the movement of the piston.

11. In a heat engine of the character described, comprising a cylinder, a reciprocating piston therein, combustion chambers arranged alongside of the said cylinder, a water-supply surrounding the cylinder and combustion chambers, a scavenger pump connected with said water-supply and with said combustion chambers, and means to actuate said pump to force a charge of water into the combustion chambers near the end of the power stroke of the piston.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

SIMON LAKE.

Witnesses:
WOLDEMAR HAUPT,
HENRY HASPER.