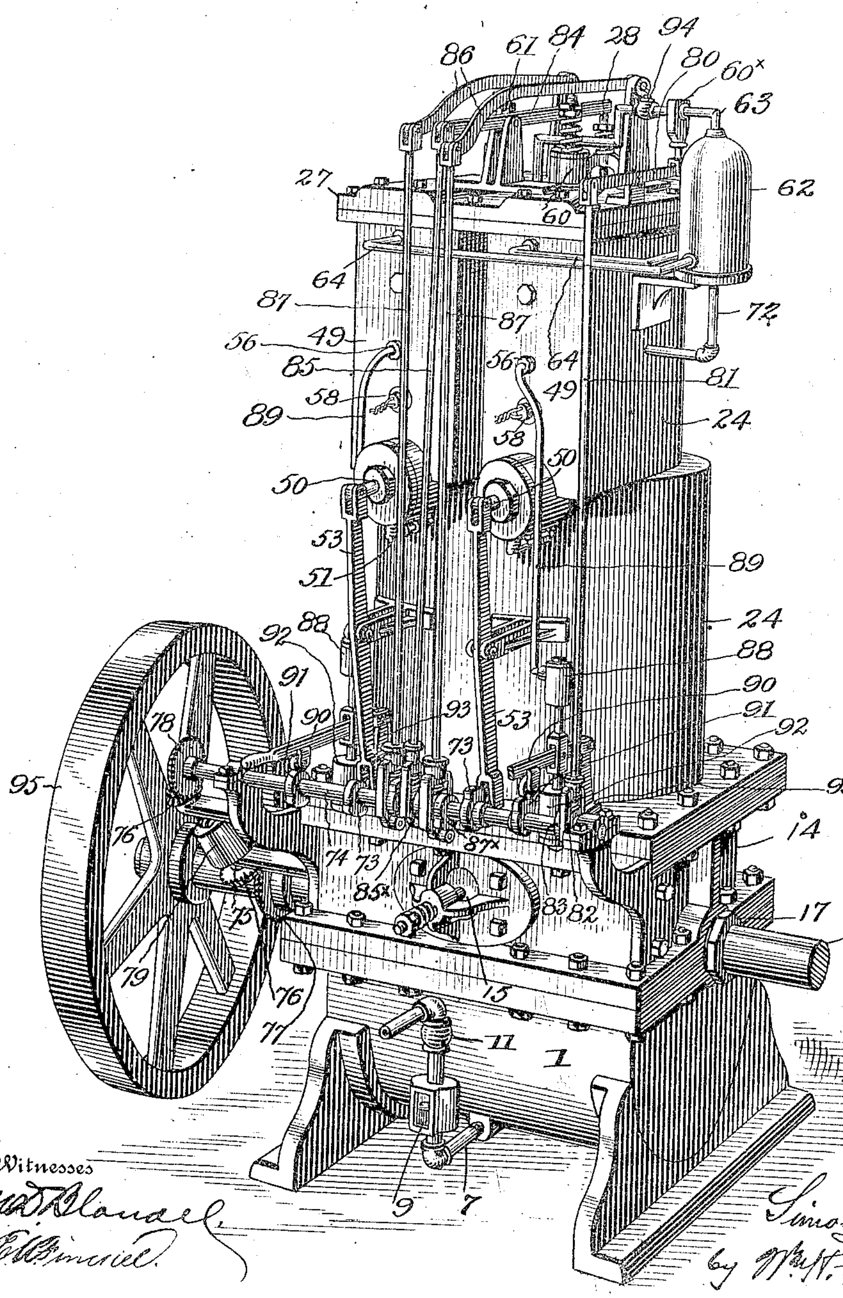
S. LAKE.
INTERNAL COMBUSTION ENGINE.
APPLICATION FILED DEC. 8, 1906.

970,063.

Patented Sept. 13, 1910.
5 SHEETS—SHEET 1.

Fig. 1.



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5 SHEETS—SHEET 2.

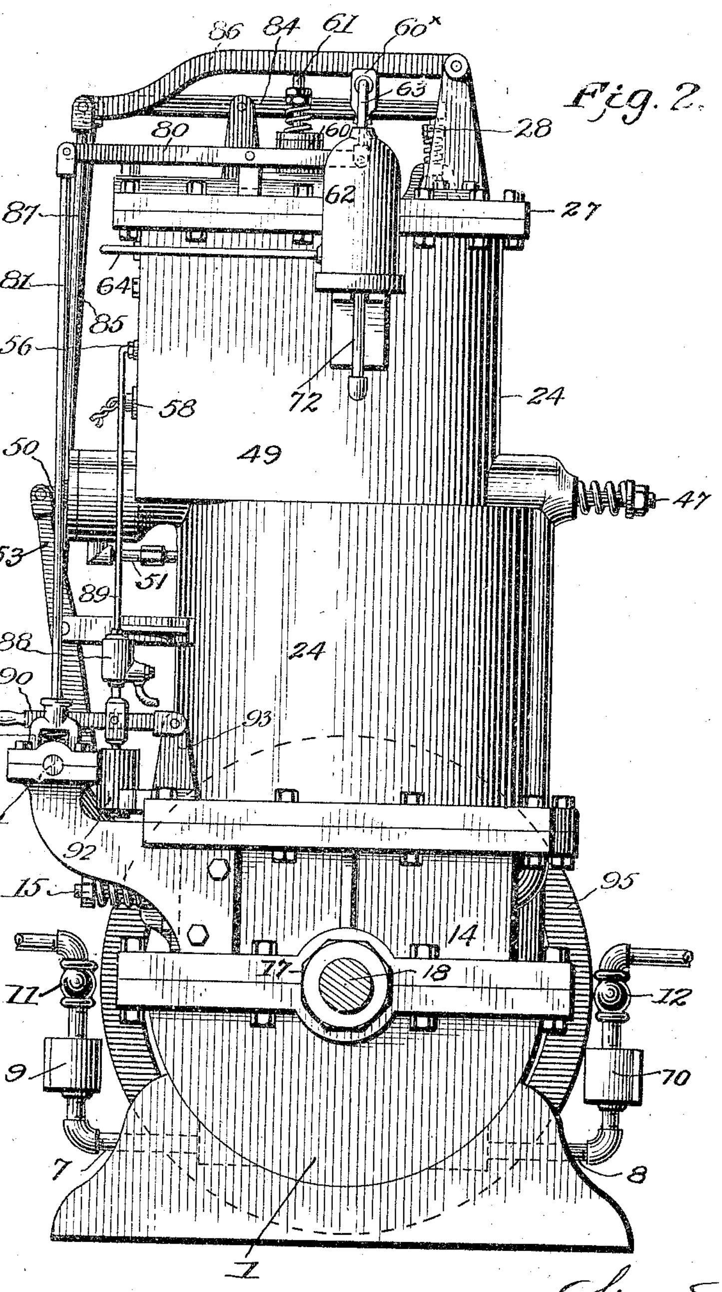

Fig. 2.

Witnesses

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5 SHEETS—SHEET 3.

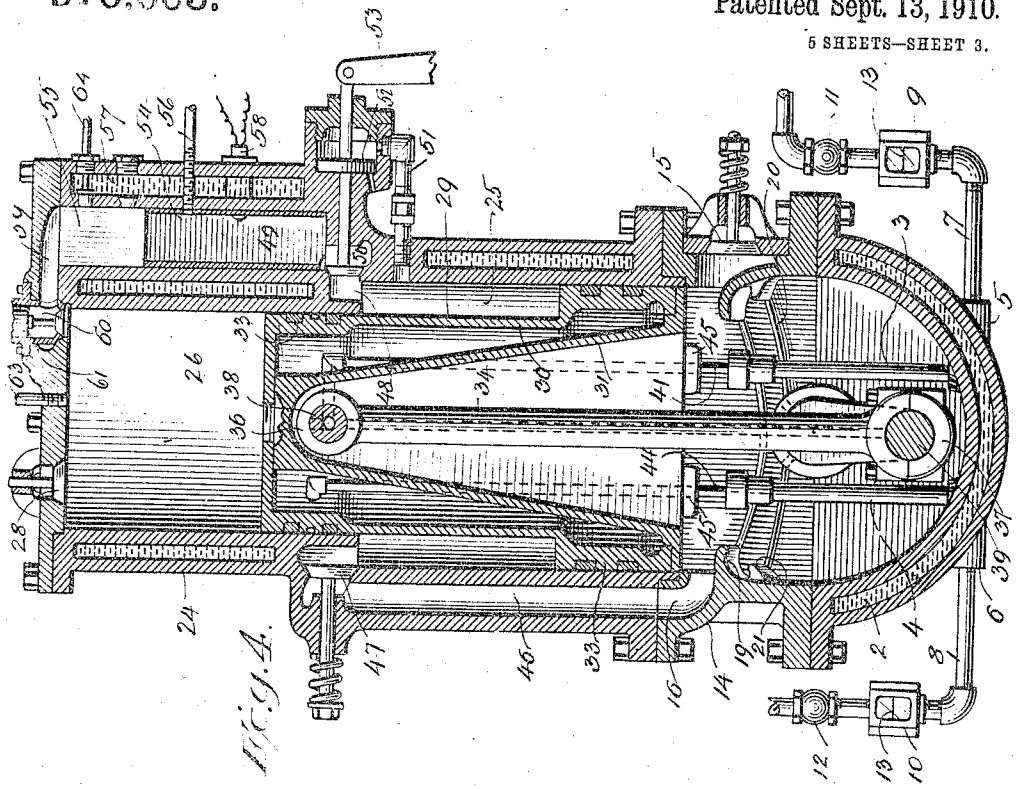

Fig. 4.

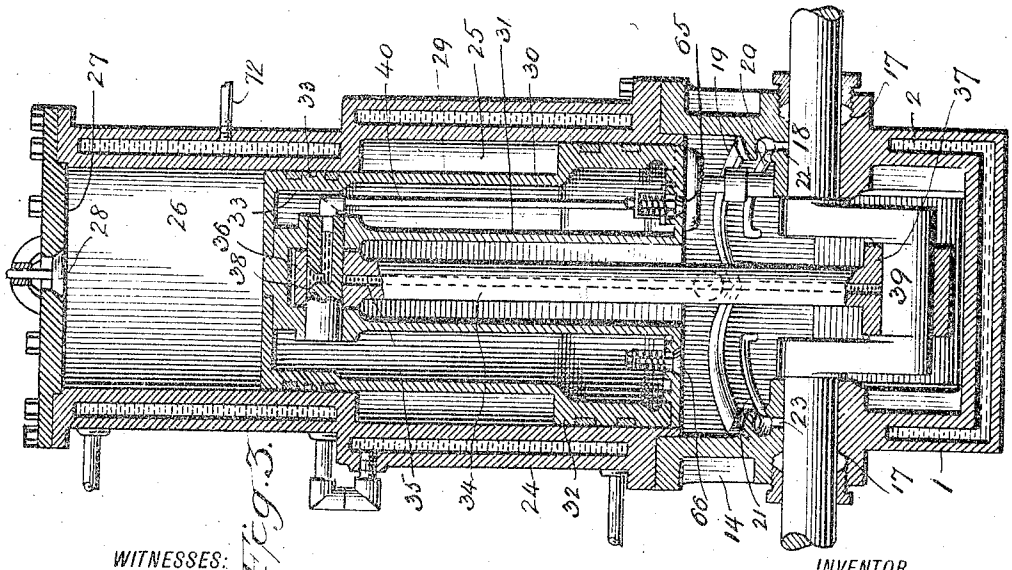

Fig. 3.

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5 SHEETS—SHEET 4.

Fig. 5.

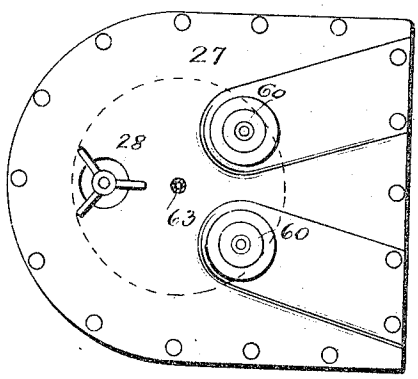


Fig. 6.

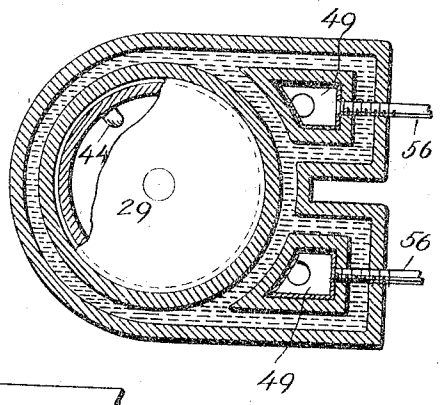


Fig. 7.

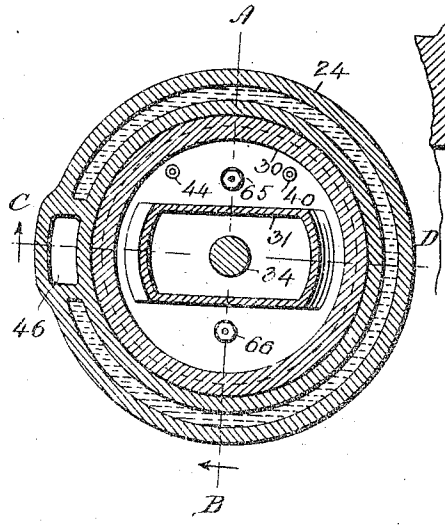
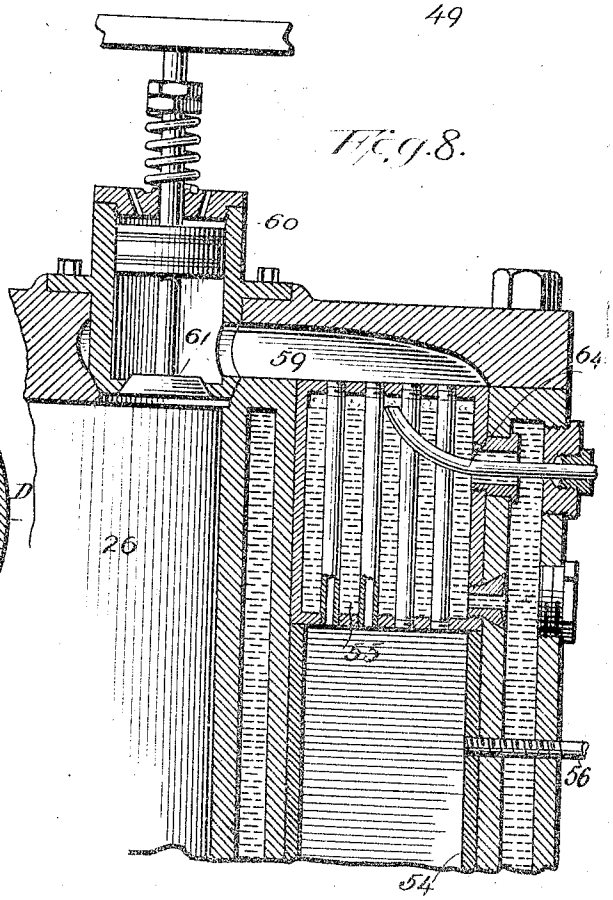


Fig. 8.



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INTERNAL COMBUSTION ENGINE.

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5 SHEETS—SHEET 5.

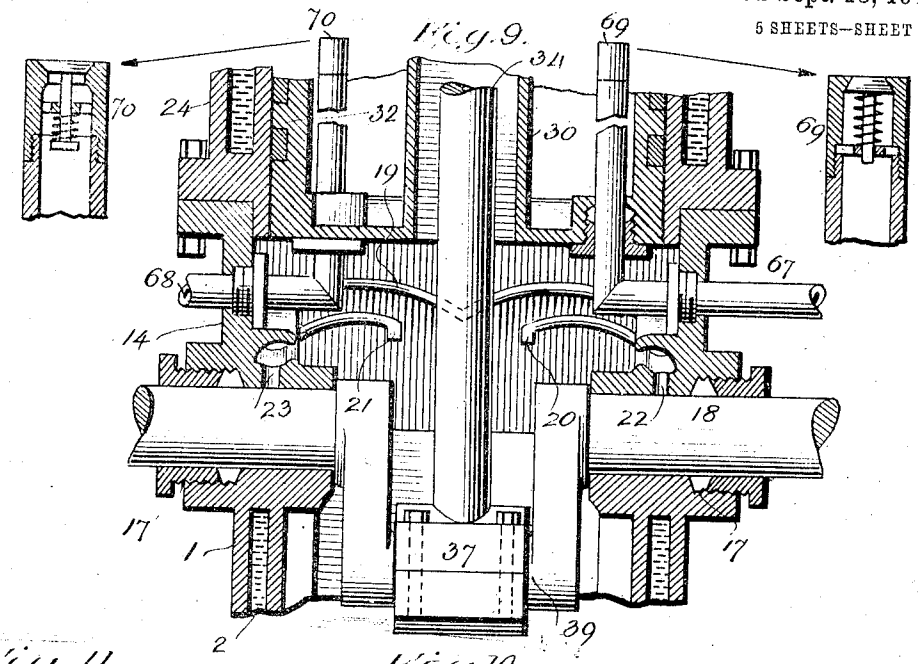
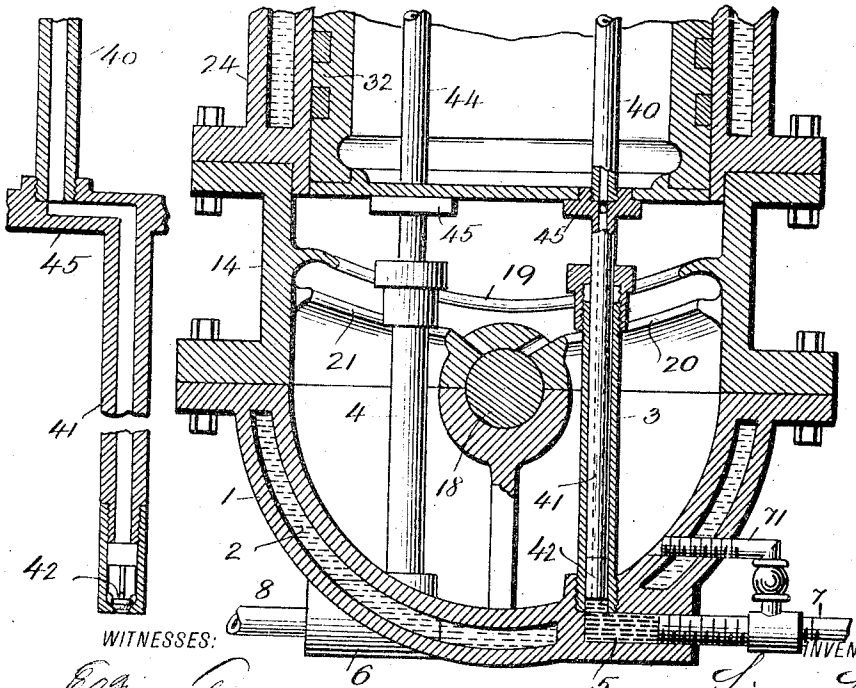


Fig. 9.

Fig. 11

Fig. 10.



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UNITED STATES PATENT OFFICE.

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INTERNAL-COMBUSTION ENGINE.

970,063. Specification of Letters Patent. **Patented Sept. 13, 1910.**

Application filed December 8, 1906. Serial No. 346,968.

To all whom it may concern:

Be it known that I, SIMON LAKE, a citizen of the United States, residing at Bridgeport, in the county of Fairfield and State of Connecticut, have invented a certain new and useful Improvement in Internal-Combustion Engines, of which the following is a full, clear, and exact description.

This invention is designed to provide a heat engine for use in an engine-room or space of restricted area and especially height, such as in marine vessels, automobiles, and the like, wherein a high heat is obtained by burning suitable fuel and this heat reduced by admixture with steam generated in the apparatus; and to provide for obtaining compression in alternate furnaces.

A main object of this invention is to provide a construction wherein a very high temperature is obtained, so that low grade fuel may be used and steam generated and admitted into the working end of the cylinder to reduce the temperature of the gases, which avoids injury to the valves and cylinder, and at the same time provides a working fluid at reduced temperature and of higher pressure than has heretofore been obtained.

These and other features germane thereto constitute the invention, as will now be described and then particularly pointed out and claimed.

In the accompanying drawings illustrating the invention, in the several figures of which like parts are similarly designated, Figure 1 is a perspective view. Fig. 2 is a side elevation. Fig. 3 is a vertical section, taken substantially in the plane of line A B, Fig. 7. Fig. 4 is a vertical section at right angles to Fig. 3 and taken substantially in the plane of line C D, Fig. 7. Fig. 5 is a top plan view. Fig. 6 is a horizontal cross-section through the working cylinder and furnaces, the top of the piston being partly broken away. Fig. 7 is a horizontal section through the compression cylinder and piston. Fig. 8 is a vertical section on a larger scale through the upper part of one of the furnaces. Fig. 9 is a vertical section of portions of a modification and showing at right and left, on a larger scale, the valves in the air-pipes. Fig. 10 is a vertical section, on a larger scale, showing details of the pumps. Fig. 11 is a longitudinal section of the pump plunger and connections.

The base 1 is of suitable construction, and adapted to the use and location of the engine, and it is preferably provided with a water-jacket 2 or other medium for keeping it relatively cool so as not to interfere with proper lubrication of the moving parts. This base has erected in it the cylinders of two oil pumps 3 and 4, and these cylinders are in communication with channels 5 and 6, Fig. 10, with which are connected the oil-supplying pipes 7 and 8 leading from suitable oil reservoirs. In each pipe is a sight-feed device 9 and 10, and above the latter a check-valve 11 and 12, respectively. The lines 13 in these sights indicate the oil level that should be maintained for the proper lubrication of the parts.

Above the base is erected a housing 14, secured to it in any suitable air-tight manner. This housing has an air-inlet valve 15 and an air-outlet passage 16. Between the housing and base are the bearings 17 for the main crank-shaft 18. In the housing is a ledge 19 dipping inwardly and toward the shaft bearings, and below this ledge are similar but shorter ledges 20 and 21, leading to oil-holes 22, 23, in the shaft bearings.

Mounted above and secured to the housing is the engine cylinder 24, having two chambers of different diameter, the larger chamber 25 constituting an air-compression chamber and the smaller 26 constituting the power-chamber or working cylinder proper. The cylinder 24 is water-jacketed or otherwise equipped with cooling agencies. The lower end of the larger chamber opens into the housing and base and its upper end into the working cylinder, and the top of the working-cylinder is closed by a head 27, having an exhaust valve 28 mechanically operated, as hereinafter explained.

Within the cylinder is the trunk-piston 29 having an outer shell 30 and an inner shell 31 connected air-tight at top and bottom. The piston has a compression head 32 to work in the compression chamber and a power head 33 to work in the working chamber or cylinder. The inner shell may be and is here shown as pyramidal to provide for the oscillation of the connecting-rod 34. This connecting-rod is hollow, that is to say, it is provided with a longitudinal

bore 35 which opens in the cross-heads 36 and 37, the former engaging the hollow wrist-pin 38 in the upper end of the piston and the latter engaging the crank wrist-pin 39 of the main shaft 18.

The wrist-pin 38 is connected by elbow pipe 40 with the hollow plunger 41 of the oil-pump 3. This plunger has in its bottom a check-valve 42 and hence as the piston descends the plunger goes with it and forces a supply of oil through the plunger and pipe to the interior of the wrist-pin 38 which overflows through opening 43 into the cross-head 36 and lubricates it and the wrist-pin and then runs down through the connecting-rod to the cross-head 37 and lubricates it and the crank wrist-pin. The reciprocation of the piston alternately charges and discharges the pump 3. The pump 4 has a similar hollow plunger with a check-valve therein, and its plunger is connected with a pipe 44 having an elbow connection with the piston head 33, so as to lubricate it and the lower piston head.

As shown in Fig. 11, the plungers are parts of or fixed to castings 45 on the lower head of the piston, and the communicating pipes are attached to the same feature. The oil falling into the base is swept up by the moving cross-head and thrown off onto the ledges 19, 20 and 21 and utilized to lubricate the shaft bearings.

The cylinder has a passage 46 connected with the passage 16 in the housing and opening into the interior of the cylinder, said opening being controlled by an automatic check-valve 47. Other passages 48 lead from the cylinder into the furnaces 49, of which there are two, as indicated in Figs. 5 and 6, and these passages are controlled by valves 50 which are power-actuated. For instance, the valves may be closed by air pressure taken from the compression chamber 25 through pipe 51 to act against the piston or diaphragm 52 on the stem of the valve 50 to normally close the said valve, while the opening movement is effected by the lever 53 or other valve-gear, one example being hereinafter fully explained.

The furnaces are substantially alike and include a highly refractory lining 54, a fire-flue boiler 55, a fuel inlet 56, a water-jacket 57 which in addition supplies water to the boiler 55, and a sparking device 58. The furnaces are supplied with outlet passages 59 opening into valve chambers 60 in which are valves 61, opening into the working cylinder, said valves being mechanically opened, as hereinafter described. As shown in Fig. 8, these valves are each provided with a piston of larger area than the valve itself, and exposed on its upper surface to atmospheric pressure. The valve is automatically seated.

The steam generated in the boiler is collected in the steam dome or chamber 62 which is connected by pipe 63 with the working cylinder. A mechanically operated valve $60^{\times}$, Figs. 1 and 2, may be employed for controlling the admission of steam. Steam is admitted into the dome through the pipe 64, which, as seen in Fig. 8, extends up into the steam space of the boiler. There is a pipe 64 for each boiler.

As already indicated, the trunk-piston is composed of two parts, between which is formed an air-tight space. To prevent the expansion of air within this space from doing injury to the parts, relief check-valves 65 and 66 are provided in the bottom of the piston. Or in the case of an engine of larger size, as shown in Fig. 9, there may be used the air pipes 67 and 68 passed through the housing and up into the piston in any suitable air-tight manner and terminating in check-valves 69 and 70, each of which is shown in detail at the sides of said Fig. 9. In either case, on the down stroke of the piston a quantity of air is admitted into the piston through the inlet check-valve and on the reverse stroke a quantity of air is discharged from the piston through the outlet check-valve; and in case of the use of the pipes, Fig. 9, the relative quantities will be substantially equal to the displacement of said pipes. Any other means may be employed for controlling the air within the piston.

Inasmuch as there will be some accumulation of oil within the base that is in condition to be used over again repeatedly, a branch pipe 71, Fig. 10, may be connected to said base and inlet oil pipe to effect a circulation of the oil. The pipe 72, or other suitable means connecting the steam-chamber 62 and water-jacket, may be used for caring for the water of condensation. Suitably arranged cams 73 on a cam-shaft 74 coöperate with levers 53 to open the air valves 50 at the proper time.

As shown in Fig. 1, the cam-shaft 74 is driven by a shaft 75 having gears 76, at each end which are in mesh with gears 77 and 78, carried by the main and cam-shafts, respectively. The shaft 75 is also provided with a suitable governor 79. The steam valve $60^{\times}$ has its stem connected with a lever 80 to which is also connected a rod 81, the lower end of which is provided with a yoke 82 which carries a roller that is engaged by a cam 83, mounted upon the cam-shaft 74. The exhaust valve 28 is operated by a lever 84 and a connecting rod 85, the lower end of which is provided with a reciprocating yoke that is engaged by a double cam $85^{\times}$ carried by cam-shaft 74. Levers 86, 86, for positively operating valves 61 are operated by connecting rods 87, 87, and their reciprocating yokes, by oppositely arranged cams $87^{\times}$ on cam-shaft 74.

88 designates fuel pumps to which are connected pipes 89 which extend to the fuel inlets 56 of the furnaces. The pumps are operated by levers 90 and cams 91, the fuel being forced into the furnaces by the action of springs arranged in the housings 92. The levers 90 are pivoted to brackets 93 carried by the flanges formed upon the lower end of the cylinder 24. The valves 50 are operated by the levers 53, suitably supported in brackets secured to the cylinder, and said levers are connected at their upper ends to the stems of the valves 50 and have their lower ends forked and provided with anti-friction rollers, which are respectively engaged by the oppositely arranged cams 73 carried by the cam-shaft 74.

94 designates a check-valve arranged in the pipe 63 extending from the steam dome 62 to the cylinder.

95 is any suitable fly-wheel.

In the operation of the engine, air is first drawn into the base on the up stroke of the piston, and on the down stroke the air so drawn in is forced through the passages 16 and 46 into the air-compressing chamber, and on the first stroke a very considerable quantity of air is forced in and this is an advantage, because at the next up stroke for effecting a compression of the air, that portion of the air that is forced into the furnace may receive a second compression. Fuel is admitted into the furnace, at any time from the commencement of the down stroke until the top of the next up stroke is reached, and ignited, some of the products of combustion passing up through the boiler and into the passage 59 and to the valve 61. Meanwhile, steam is being generated in the boiler, the products of combustion, however, remaining at a proper working temperature while confined within the furnace. When the valve 61 is opened (on the power stroke) the highly heated products of combustion contained within the furnace pass through the boiler to the cylinder, the temperature thereof being somewhat reduced by radiation to the boiler. A very great advantage is thus gained, since the temperature of the ignited gases is very high when ignited within a furnace provided with a highly refractory wall, and such temperature may be as high as two thousand five hundred (2500) or three thousand (3000) degrees, or perhaps higher and at a pressure of only a couple of hundred pounds per square inch, while the temperature of steam at five hundred (500) pounds pressure is only about four hundred and seventy (470) degrees. The temperature of the gas, therefore, is so high that it is injurious to the valves and cylinders and will not admit of their proper lubrication; but by utilizing this heat to produce steam and then combining both the steam and gas within the power cylinder, the evils of an excessively high temperature are avoided and perfect combustion at very high temperature is secured, and a working fluid of reduced temperature but high pressure obtained. As another result of this, lubrication may go on unimpeded. Upon the completion of the down stroke of the piston, the exhaust valve 28 is opened and maintained in such opened position a sufficient length of time to exhaust the cylinder of the products of combustion, and the valves 61 and 60ˣ closed to prevent the return of the products of combustion to the furnace and boiler.

The sparking devices 58 may be cut out of operation in any suitable manner, as by a usual switch in the sparking circuit, and the compression of the air in the furnaces relied upon to effect the explosion of the charge, and by the use of the compound compressing arrangement in connection with the furnaces, it is possible to compress the air in the furnaces sufficiently to cause the charge to explode and thus effect the operation of the engine without the use of the sparking devices.

As shown in Fig. 4, the parts are arranged to show the cycle of operation. The piston is shown at the bottom of the stroke and has compressed the air previously drawn into the crank chamber through the induction valve 15 into the intermediate compression space or cylinder 25, the air passing through port 46 and through valve 47.

It will be observed that the lower end of the piston is of larger area than the upper end, and that the space in the crank pit below the piston, when in its down position, has been reduced to barely sufficient size to permit the rotation of the crank which allows a considerable compression in the lower cylinder. In practice this may be as much as fifteen or twenty pounds per square inch and will give the advantage usual in two-stage compressors where a high compression is desirable. On the following up-stroke, the air passes through valve 50 which is positively opened by lever 53 controlled by cam 73 on cam shaft 74. The air is then compressed into a furnace chamber 49. On the completion of the up-stroke, the exhaust valve 28 is closed and valve 61 is opened which permits the escape of the products of combustion from furnace 49 to drive the piston on its next down stroke. At the moment of opening valve 61, the steam valve 60ˣ is also opened by its respective lever and cam.

The valves 50 are operated alternately so as to charge the two furnaces alternately. The valves leading from the furnaces to the cylinder are also operated alternately, the steam valve 60ˣ being operated to admit steam into the cylinder on each successive working stroke of the piston. With the two

furnaces in operation this permits the injection of the fuel at any desired point of the up-stroke of the piston. Very heavy oil may require the injection of the fuel at an early point of the up-stroke, which may be regulated by the adjustment of the cams.

What I claim is:—

1. An internal combustion engine, comprising a cylinder containing an air compressing chamber and a power chamber, a trunk piston having heads fitted to the respective chambers, an air-tight base upon which the cylinder is mounted, a power shaft within said base, a connecting rod connecting the shaft and piston, a passage connecting said compressing chamber and base, and means to admit air into the base to be compressed therefrom on the down-stroke of the piston into the air compressing chamber through said passage at intervals, the said piston adapted to compress the air in and discharge it from the compressing chamber on the up-stroke, combined with a furnace communicating with the compressing chamber and into which the highly compressed air is conducted from the compressing chamber before entering the power chamber, a fuel supply for said furnace and means for igniting the charge, and a passage connecting said furnace with the power chamber whereby the products of combustion are conducted into the power chamber.

2. An internal combustion engine, comprising a cylinder containing an air compressing chamber and a power chamber, a trunk piston having heads fitted to the respective chambers, an air-tight base upon which the cylinder is mounted communicating with the air compressing chamber, a power shaft within said base, a connecting rod connecting the shaft and piston, and means to admit air into the base to be compressed therefrom into the air compressing chamber at intervals, and means to discharge the air from the compressing chamber, combined with a furnace communicating with the compressing chamber and into which the air is discharged from the compressing chamber, a fuel supply for said furnace, and means for igniting the mixture of air and fuel, a steam boiler adjacent to said furnace and exposed to its heat, and means to admit the products of combustion and steam to the power chamber.

3. An internal combustion engine, comprising a cylinder containing an air compressing chamber and a power chamber, a trunk piston having heads fitted to the respective chambers, an air-tight base upon which the cylinder is mounted communicating with the air compressing chamber, a power shaft within said base, a connecting rod connecting the shaft and piston, and means to admit air into the base to be compressed therefrom into the air compressing chamber at intervals, combined with a furnace communicating with said compressing chamber and into which the air is discharged from the compressing chamber, a fuel supply for the furnace and means for igniting the mixture of air and fuel, a steam boiler adjacent to said furnace and exposed to its heat, passages to admit the products of combustion and steam to the power chamber, and valves for controlling the admission of air from the base into the compressing chamber and from the compressing chamber into the furnace, and valves for controlling the admission of steam and products of combustion into the power chamber.

4. An internal combustion engine, comprising a cylinder containing an air compressing chamber and a power chamber, a trunk piston having heads fitted to the respective chambers, an air-tight base upon which the cylinder is mounted, a passage connecting said base with the compressing chamber, a power shaft within said base, a connecting rod connecting the shaft and piston, and means to admit air into the base to be compressed therefrom on the down-stroke of the piston into the air compressing chamber at intervals, the said piston adapted to compress the air in and discharge it from the compressing chamber on the up-stroke, combined with a furnace communicating with the power chamber and into which the highly compressed air is discharged from the compressing chamber before entering the power chamber, a fuel supply for said furnace, and means to ignite the mixture of air and fuel in said furnace, and a valve to control the admission of the products of combustion into the power chamber from said furnace.

5. An internal combustion engine, comprising a base constituting a compression chamber, a cylinder having a compressing chamber adapted to communicate with said base, and a power chamber, a plurality of furnaces adjacent to said cylinder adapted to communicate with the said cylinder compressing chamber, means for admitting air to the base, a piston in said cylinder for compressing the air from the base into the cylinder compressing chamber on the down-stroke and from the cylinder compressing chamber into the furnaces alternately on the up-strokes, means for controlling the admission of the highly compressed air from the cylinder compressing chamber to the furnaces, means for admitting fuel to the furnaces, means for igniting the air and fuel in the furnaces, and means for alternately admitting the products of combustion from the furnaces to the power chamber of the cylinder.

6. An internal combustion engine, comprising a base constituting a compression

chamber, a cylinder having a compressing chamber adapted to communicate with said base, and a power chamber, a plurality of furnaces adjacent to the cylinder and adapted to communicate with the said cylinder compressing chamber, means for admitting air into the base, a piston in said cylinder for compressing the air from the base into the cylinder compressing chamber, means for controlling the admission of air from the cylinder compressing chamber to the furnaces, means for admitting fuel to the furnaces, and means for alternately igniting the mixture of air and fuel in the furnaces, a boiler arranged in each furnace, means for alternately admitting the products of combustion from the furnaces to the power chamber of the cylinder, and means for admitting steam from the boilers to the power chamber of the cylinder.

7. An internal combustion engine, comprising a cylinder having chambers of different diameters, a trunk piston having heads of different diameters fitted to the respective chambers and forming a power chamber and a compressing chamber, a power shaft, a connecting rod connecting the shaft and piston, a valve-controlled passage leading to the said compressing chamber to admit a fresh supply of air at intervals to the compressing chamber on the power stroke of the piston, a furnace communicating with and into which the air is discharged from said compressing chamber on the return stroke of the piston before entering the power chamber, a fuel supply for said furnace, a passage connecting said furnace and power chamber, and a valve for controlling the inlet to the power chamber.

8. An internal combustion engine, comprising a cylinder containing an air compressing chamber and a power chamber, a trunk piston having heads fitted to the respective chambers, a power shaft, a connecting rod connecting the shaft and piston, a valved passage to admit air into the compressing chamber at intervals to be discharged therefrom by said piston, combined with a furnace communicating with and into which the air is discharged from the compressing chamber and wherein it is ignited in the presence of fuel, a steam boiler adjacent to said furnace and exposed to its heat, passages establishing communication between the furnace and the power chamber and from the steam boiler to the power chamber, a valve for controlling the admission of air from the compressing chamber into the furnace, and valves for controlling the admission of steam and the products of combustion into the power chamber.

9. An internal combustion engine, comprising a cylinder containing a compressing chamber and a power chamber, a trunk piston having heads fitted to the respective chambers, a base, a power shaft mounted in the base, a connecting rod connecting the piston and shaft, means to admit air into the compressing chamber on the down stroke of the piston to be compressed therein on the up stroke of the piston, a furnace communicating with the compressing chamber and into which the air is conducted from the compressing chamber and mixed with fuel and highly compressed and exploded before entering the power chamber, means for controlling the passage of the air from the compressing chamber to the furnace, a valve-controlled passage connecting the furnace and the power chamber, means for operating the valve controlling the passage, and a fuel supply for said furnace.

In testimony whereof I have hereunto set my hand this 6th day of December A. D. 1906.

SIMON LAKE.

Witnesses:
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