J. W. MORRIS.

HEAT ENGINE.

APPLICATION FILED MAR. 5, 1908. RENEWED MAY 26, 1917.

1,253,413.

Patented Jan. 15, 1918.

3 SHEETS—SHEET 1.

Fig. 1

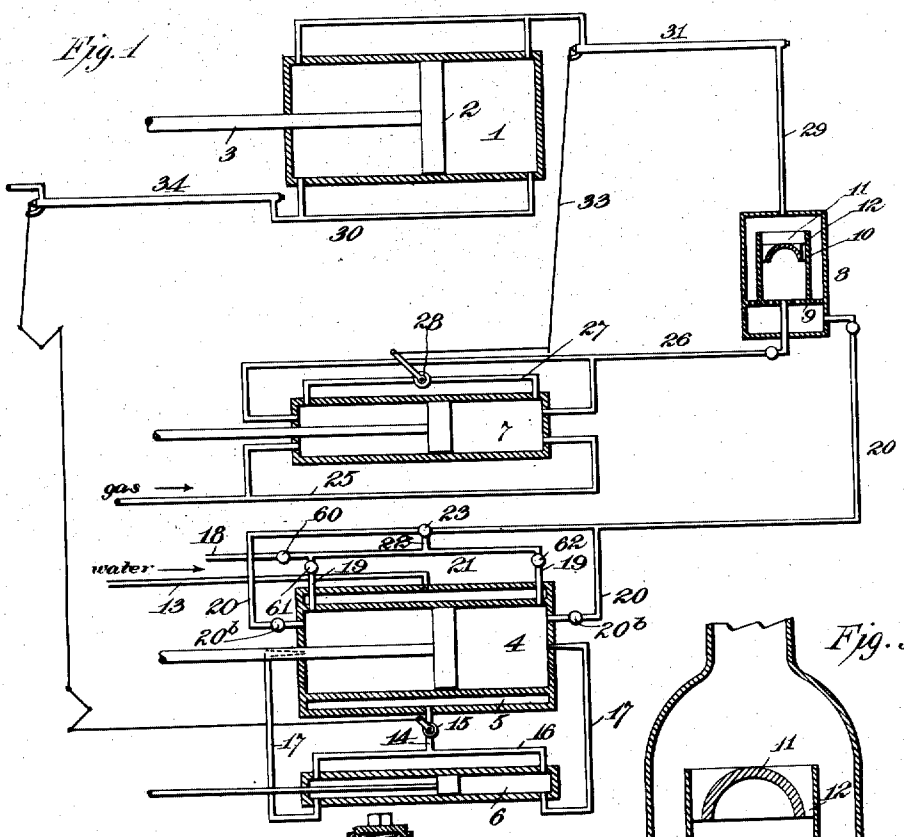


Fig. 2

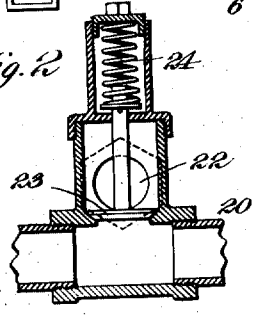


Fig. 3

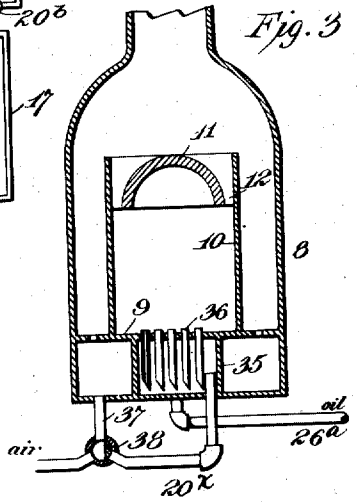
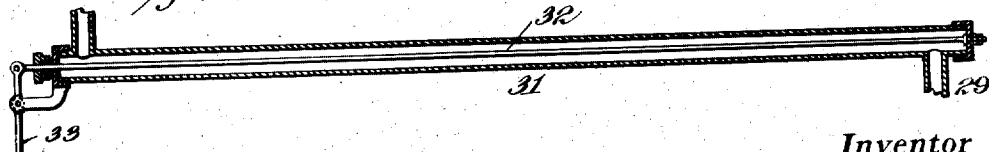


Fig. 4



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3 SHEETS—SHEET 2.

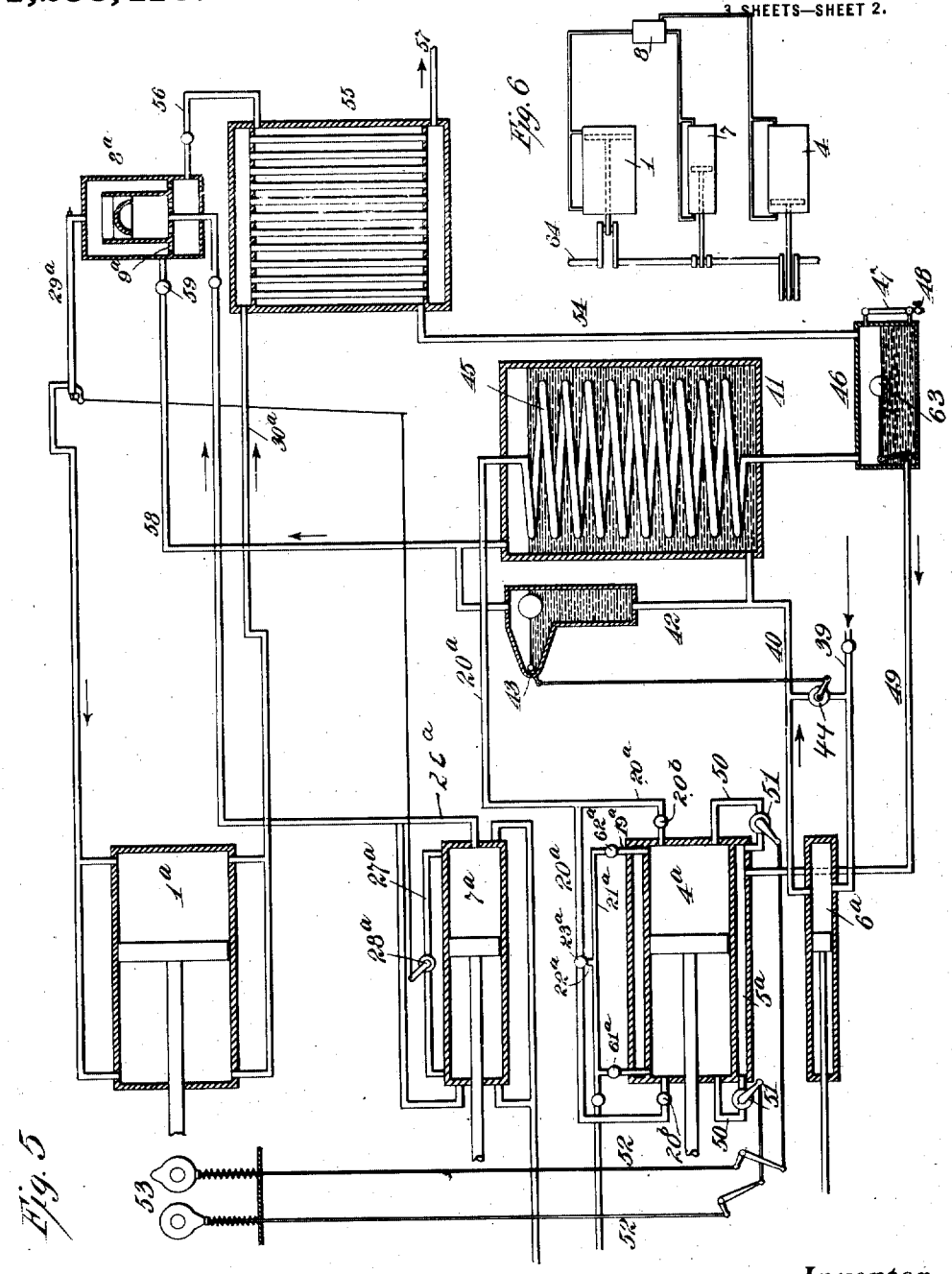


Fig. 5

Fig. 6

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3 SHEETS—SHEET 3.

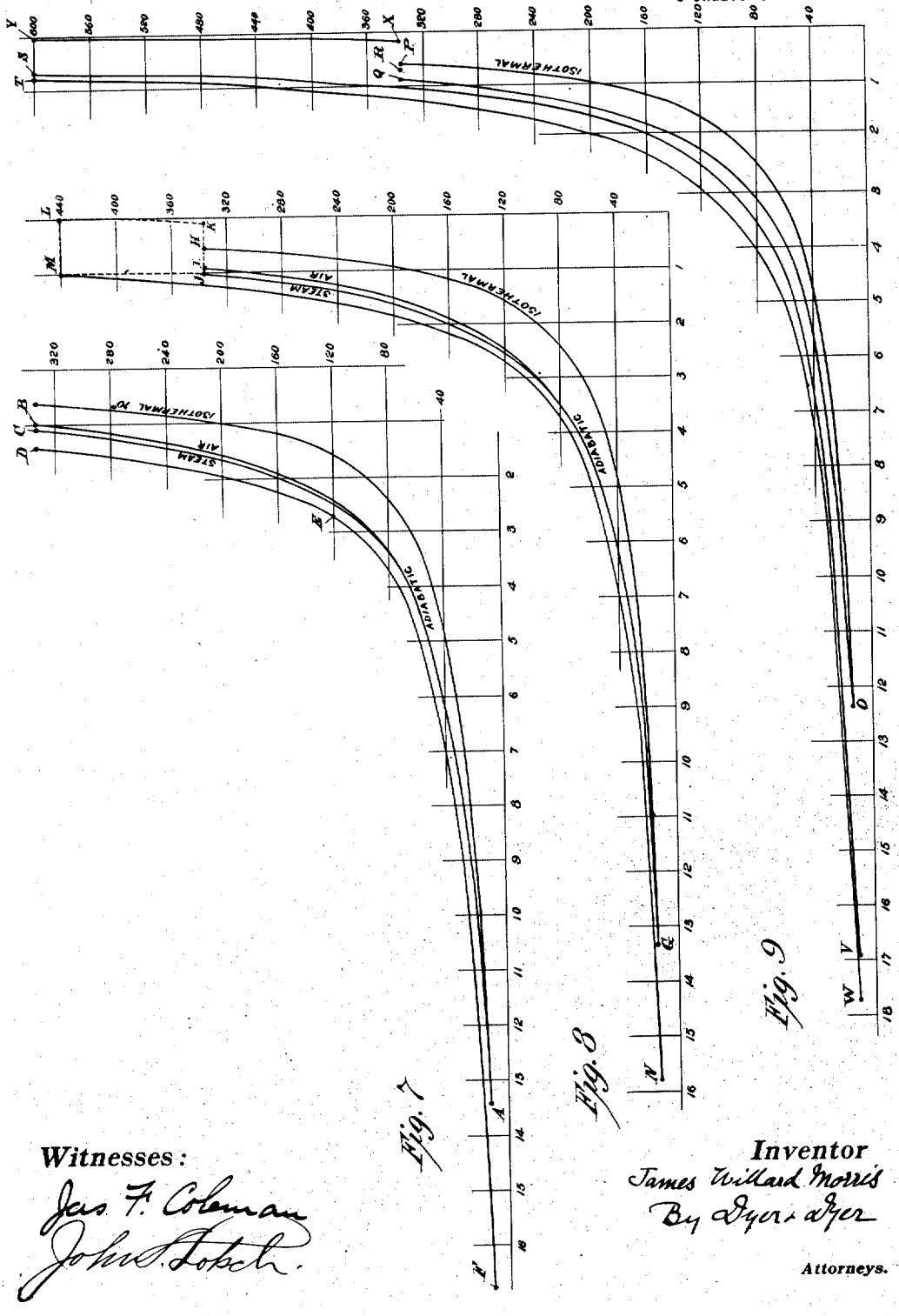


Fig. 7

Fig. 8

Fig. 9

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UNITED STATES PATENT OFFICE.

JAMES WILLARD MORRIS, OF NEW YORK, N. Y., ASSIGNOR TO THE SINPAR COMPANY, A CORPORATION OF NEW YORK.

HEAT-ENGINE.

1,253,413. Specification of Letters Patent. Patented Jan. 15, 1918.

Application filed March 5, 1908, Serial No. 419,313. Renewed May 26, 1917. Serial No. 171,304.

To all whom it may concern:

Be it known that I, JAMES WILLARD MORRIS, a citizen of the United States, and a resident of the borough of Manhattan, city, county, and State of New York, have invented a new and useful Heat-Engine, of which the following is a specification.

This invention relates to an improvement in heat engines or machines for obtaining power from heat.

The object of my invention is to provide an engine to work with great economy and at the same time will possess the desirable flexibility and have a continuous torque to a degree equal if not greater than that of the steam engine. Further objects are to produce an engine which will be cheap to construct, of small bulk and weight commensurate with the power obtained, which may be started when cold in the minimum length of time, and which may be run with heavy and light loads with great economy. These and further objects will appear in the following specification and accompanying drawings, considered together or separately.

I attain these objects by the mechanism illustrated in the accompanying drawings, in which—

Figure 1 is a diagrammatic view of the parts of an engine embodying my invention.

Fig. 2 is a detail of a pressure valve used in connection with the air compressor.

Fig. 3 is a sectional view of a modified form of furnace for burning liquid fuel.

Fig. 4 is a detail of the thermostatic regulator used in connection with the engine.

Fig. 5 is a diagrammatic view of a modified form of my invention.

Fig. 6 is a diagrammatic view of the power cylinder, fuel cylinder, air cylinder and furnace showing the arrangement of the cranks; and

Figs. 7, 8 and 9 are drawings showing the volumes and pressures of the fluid in their passage through the apparatus.

In all of the views like parts are designated by the same reference characters.

I will first describe one form of apparatus by means of which my invention may be carried out.

1 represents a power cylinder, in which a piston 2 works, the power being taken off through a piston rod 3. The air pump 4 contains a double-acting piston and the usual valves. The air pump cylinder 4 is provided with a water jacket 5. The water pump cylinder 6 has a double-acting piston within it. The fuel pump cylinder 7 is provided with a double-acting piston. The structure illustrated in Fig. 1 is adapted to use gas as fuel. The furnace 8 comprises a drum or cylinder having a perforated diaphragm 9 near its bottom and a smaller cylinder 10 containing an arch 11 of fire brick or other material, this arch having one or more perforations 12. The diaphragm 9 is perforated, certain of the perforations leading into the cylinder 10, and others leading outside of the cylinder in the space between the cylinder 10 and the outer casing of the furnace. The space below the diaphragm constitutes a chamber.

The pipe connections are as follows: Water is admitted into the water jacket 5 through the pipe 13. From the water jacket it passes through a pipe 14, containing a valve 15, to a double pipe 16, leading into the water cylinder 6. From this cylinder the water is forced, its direction being controlled by the usual valves (not shown) through the pipes 17—17, into the air pump cylinder 4.

Air is drawn into the air pump cylinder through the pipe 18 and the branch pipes 19—19. These pipes are provided with check valves 60, 61 and 62. The inlet valves for the cylinder can be used for this purpose. The air is ejected through the pipe 20, which communicates with the furnace 8 below the diaphragm 9. A by-pass pipe 22 connects the pipe 20 to the pipe 21, the by-pass and the pipe 20 being connected together through a spring loaded valve 23. The details of this valve are shown in Fig. 2. This valve is kept seated by means of a spring 24, such spring being adjusted to permit the valve to rise and be lifted off of its seat and be opened, after a certain amount of pressure accumulates in the pipe 20, permitting the air from the pipe 20 to enter the pipes 21 and 19 When the valve

23 is open, the air will be idly circulated through the pipes 19, 21 and 22, escape backward being prevented by means of the check valve 60. The air compressor will wholly or partially cease to compress air when the capacity of the spring loaded valve 23 is reached. The fuel gas enters the pipe 25, and from thence is drawn into the fuel pump cylinder 7. The gas from the pump is delivered into a pipe 26, which pipe passes into the furnace through the diaphragm 9 into the cylinder 10. A by-pass pipe 27 connects the two ends of the cylinder; a valve 28 is provided in this by-pass, such valve being controlled by a thermostatic device, which will be described. The upper portion of the furnace communicates through a pipe 29 with the valve chest of the power cylinder 1, the exhaust from the cylinder being through a pipe 30. The pistons in the cylinders 4, 6 and 7 are adapted to be operated by any suitable mechanism; for instance, they may be connected to the shaft 64 which is rotated by means of suitable connections by means of the piston 3 (see Fig. 6).

The operation of so much of my invention is as follows: Assuming the engine to be running, and air is compressed within the cylinder 4 to a certain pressure, for instance, 160 pounds absolute to the square inch, the temperature would be increased from ambient temperature (say 70° F.) to about 642° F. A part of the heat, due to compression, is taken up by the water in the water jacket 5. The rest of the heat will remain in the compressed air. The pump cylinder 6 will force a certain quantity of water from the water jacket and without loss of its heat into the compressed air contained within the cylinder through the pipes 17—17. The amount of water injected will be in quantities sufficient only to be converted into steam at that pressure; there is injected about .045 of a pound of water per pound of air. The temperature will be that of steam at 160 pounds pressure per square inch absolute, or about 363° F. This mixture of heated compressed air and steam will be forced through the pipe 20 into the furnace 8. The gas will be forced through the pump 7 into the cylinder 10, in the furnace 8, and will be ignited there and will burn. A portion of the compressed air and steam entering the furnace through the pipe 20 will pass through the diaphragm 9 and through the perforations therein into the cylinder 10, in amount sufficient for the purpose of securing combustion. The excess of air will pass through the other perforations in the diaphragm outside of the cylinder 10 and will be heated therein and afterward further heated by admixture with the products of combustion. The size and number of the perforations in the diaphragm 9 is proportioned so that only a little more than sufficient air enters the cylinder 10 to secure combustion which keeps the arch 11 sufficiently hot to insure combustion, the greater proportion of air passing outside the cylinder 10. The amount of air is sufficient to reduce the temperature of the mixture to a degree that the cylinder will withstand, or, in other words, the amount of fuel burned will be sufficient to raise the temperature of the total products to a definite practical temperature, say 650° F. The mixture of superheated steam, oxygen, nitrogen and carbon dioxid, produced by the combustion, will pass through the pipe 29 and into the valve chest of the engine. Useful work will be done by this mixture and the discharged products of the engine will escape through the pipe 30.

The engine should be properly proportioned so that the exhaust from it will be practically at the temperature of condensing steam, 212° at atmospheric pressure. The best results will be secured by lagging the cylinder 1. The cylinder may be compounded in the usual manner, and if desired, a turbine or other form of heat engine may be employed in place of the cylinder diagrammatically illustrated.

It will be apparent that all of the heat imparted to the water by compression in the compressing cylinder 4 will be utilized, part of it in heating the water in the jacket, and the utilization of such water in the form of steam. It is, therefore, apparent that no heat is lost in compressing the air, for on the falling of temperature by expansion, the steam would be condensed and give back its heat to the air. Part of the heat of the furnace, however, can be recovered from the exhaust, and for that reason I have devised an arrangement illustrated in Fig. 5, to accomplish it. Before describing that apparatus I will first describe certain devices which may be attached to the mechanism illustrated in Fig. 1.

For the purpose of automatically governing the quantity of gas admitted to the furnace, it is but necessary to connect with the pipe 29 a suitable thermostat or thermostatic device to operate the valve 28. Such a device is shown in Fig. 4, in which 31 is a pipe, which may be a portion of the pipe 29, and 32 is a rod lying within that pipe. The pipe and rod had best be made of materials of different coefficients of expansion, for instance, the pipe 31 may be made of steel and the rod 32 of brass; one end of the rod is anchored to the pipe, the other end passes through a stuffing box and is connected to a lever 33, which in turn is connected to the valve 28. Expansion or contraction of the rod 32 and tube moves the

lever 33 and closes or opens the valve 28, thus permitting the fuel to pass through the by-pass from one end to the other of the piston without being forced through the pipe 26. When the temperature in the pipe decreases below a certain limit set, the valve 28 will be partially closed.

A similar thermostatic device 34, which is located in the exhaust pipe 30 is connected by a system of linkage to the valve 15. When the exhaust products of combustion are above 212°, which will indicate that there is too much water being injected into the air compressor, so that all the steam made is not condensed, the valve 15 will partially close; where the exhaust products are too cold, this valve will open, and the quantity of water injected into the compressed air will be more.

Fig. 3 illustrates a section of the furnace used in connection with liquid fuel. This liquid fuel is introduced through the pipe 26^a, the air, as before, being injected through a pipe 20^x. The space below the diaphragm 9 is divided into two chambers by means of a cylindrical partition 35. A number of tubes 36 are located inside the partition 35 the upper side of these tubes extend above the partition 9, the lower ends down close to the bottom of the furnace. These lower ends are beveled at an angle, as shown. The pipe 20^x extends up into the space inside of the cylindrical partition 35, some distance above the lower ends of the pipes 36. A by-pass 37 connects the tube 20^x with the inside of the furnace below the diaphragm 9 and outside of the partition 35. A 3-way valve 38 is connected at the joint between the pipe 20^x and the by-pass 37. This 3-way valve controls the passage of air into the space inside or outside of the cylindrical partition 35. Liquid fuel is admitted inside of the cylindrical partition 35, and is forced by the pressure of the air through the pipe 20^x, which acts on the surface of the liquid fuel and causes it to pass through the pipes 36. The liquid fuel is forced through the pipes 36 and is thoroughly atomized by such passage; it is ignited within the cylinder 10 and burns the air mixed with the oil, securing complete combustion. The additional compressed air and steam will pass through the by-pass 37 into the space outside of the cylinder 10 in the manner described in the foregoing embodiment of my invention.

In the modification shown in Fig. 5, I provide means whereby a part of the loss of heat escaping in the exhaust through the power cylinder 1 at the temperature of saturated steam is avoided. I secure this by first cooling the compressed air and thereby making additional steam; the air is thereby enabled to take up heat from the exhaust.

In the structure illustrated in Fig. 5, the power cylinder 1 and its appurtenances are the same as that described in Fig. 1. The air compressing cylinder 4^a, the water cylinder 6^a, and the fuel compressing cylinder 7^a, are the same as before, and the connections from the latter to the furnace are the same. The connections from the water-jacket to the water pump of the air compressing cylinder are somewhat different.

Referring to Fig. 5, there is illustrated a structure in which the water enters the water pump cylinder 6^a through a pipe 39 from a suitable source of supply. From the pump it passes through a pipe 40 to a closed tank 41. Connected with the pipe 40 is a water leg 42, containing a float valve 43. This valve is connected by a link to the valve 44 in the pipes 39 and 40, for controlling the supply of water to the tank 41. The float valve will keep the water within the tank at a constant level, as will be apparent. The pipes 20^a—20^a, the same as the pipes 20—22, in Fig. 1, are connected to a coil 45, immersed within the water in the tank 41. The outlet of this coil communicates with a trap 46. This trap is provided with a glass gage 47 and a draw-off cock 48. From the bottom of the trap a pipe 49 connects with the water jacket 5^a of the cylinder 4^a; a float valve 63, of the type that closes by the float dropping, is provided for the entrance to the tube 49. From the water jacket pipes 50—50 communicate with the interior of the cylinder 4^a. Each pipe 50 is provided with a valve 51, which by means of a system of rods and bell cranks 52 connects with cams 53, which are mounted upon a shaft which rotates in time with the shaft to which the piston rod and the piston lying within the cylinder 4^a is connected. These valves 51—51 are adapted to be opened, each one during the stroke of the piston within the cylinder 4^a, preferably at the last part of the stroke.

In the trap 46 a pipe 54 enters the interior of a heat exchanger 55. This heat exchanger, as illustrated, comprises a shell with a quantity of tubes within it. The air contained in the pipe 54 passes around these tubes, and by means of a pipe 56 enters the furnace 8^a. Communication from the furnace 8^a is by means of a pipe 29^a to the power cylinder 1^a. The exhaust from the power cylinder 1^a is through the pipe 30^a, through the tubes in the heat exchanger 55, and out through an exhaust pipe 57. A valve 28^a, with a by-pass 27^a, is provided, such valve being actuated by means of a thermostat, as described in connection with Fig. 1. A steam pipe 58 communicates with the upper part of the closed tank 41 and connects with the furnace 8^a above the diaphragm 9^a; a check valve 59 is placed within

this pipe for the purpose of preventing the passage of fuel in the other direction. The operation of this embodiment of my invention is as follows:

Assuming the engine to be in operation, and the air, water and fuel pumps moving in time with the piston, the operation will be as follows.

Cold water is drawn through the pipe 39 and forced through the pipe 40 and into the closed tank 41 in degrees required by the height of the water in that tank, as automatically controlled by means of the float valve 43. A certain quantity of cold water lies within the trap 46. The air is compressed in the cylinder 4^a and forced through the pipes 20^a—20^a through the coil 45. The heated compressed air is cooled in the coil 45, and the water, mixed with such air in the manner as will be described, is cooled in that coil, the cooled water accumulating in the trap 46. The pressure of air upon the surface of the water in the trap will force this cold water from the trap into the water jacket 5^a; the same pressure will force it through the pipes 50—50, and when the valves 51—51 are opened, the water will be injected in proper quantities into the compressed air in the cylinder 4. The water, therefore, contained in the trap 46, will be continually circulated through the air compressing pump and coil 45. As this water will increase in volume rather than diminish, owing to the presence of moisture in the air which is being compressed, the level may be observed through the glass 47 and the surplus thrown off from time to time by means of the cock 48. The compressed dry cold air which reaches the trap 46 will pass through the pipe 54 into the heat exchanger 55, where it will be heated by the discharged products from the cylinder 1^a which pass through the other portion of the exchanger, thus condensing the remainder of the steam in the exhaust. This water, so recovered from the exhaust, may be cooled, so as to keep up the supply of water, if desirable, as for instance, in a vehicle. The dry compressed air will now be heated to temperature of the exhaust and will enter the furnace 8^a, where it will be heated in conjunction with the combustion produced by means of the fuel entering the furnace through the pipe 26^a.

The cooling of the air and water in the coil 45 will transmit its heat to the water contained in the tank 41, and the upper part of that water will boil, the steam thereby produced will pass out through the pipe 58, into the furnace 8^a, and will mix with the other products of combustion. In this case, the water in circulation will be heated to the temperature of steam at the working pressure, but no steam will be made in the compressor. If the amount of water circulated is too large, owing to the fact that the trap 46 is too full, the temperature of the water at the top of the tank 41 will not rise to the point of ebullition at the pressure therein, consequently no steam will be made and no heat will be carried off by steam from the tank 41. Consequently no cold water will be pumped into the tank 41, and the temperature at the bottom of the tank 41 will correspondingly rise, and the water reaching the trap 46 will correspondingly rise in temperature and flow through the pipe 49 at a higher temperature, entering the jacket 5^a, where it will also rise in temperature. The consequence of this action will be that at this time steam will be made in the tank 41, because the air and water will reach the top of the coil 46 at a temperature sufficient to make steam in the tank 41, but when this pipe 49 becomes warm by letting some of the hot water escape from the trap 46, the amount of water circulating will be diminished to the required amount, thus restoring the system to equilibrium. The discharge of superheated steam, oxygen, nitrogen and carbon dioxid will pass through the pipe 29^a into the cylinder 1^a, and will do the necessary work. As already described, the discharged products will pass through the pipe 20^a through the heat exchanger 55, and transfer its heat to the cold and dry compressed air which enters said heat exchanger through the pipe 54.

By means of the structure thus described, it is apparent that the heat produced in compressing the air is all utilized, first, by transferring it to the water, heating the water in the tank 41, and utilizing the steam thus produced directly in the furnace through the pipe 58. The cold air will now take up the heat from the discharge of the working cylinder through the heat exchanger 55, and hence by properly proportioning the parts it is possible that the discharge through the pipes 57—57 will be much below the temperature of saturated steam at atmospheric pressure.

For the purpose of illustrating the principle of my invention by concrete examples, I show in Fig. 7 a diagram illustrating the volumes and temperatures of fluids passing through an engine of the type illustrated in Fig. 1, and in which the furnace is of relatively large size, that is, a size greater than the power cylinder, so that heat is received at constant pressure, and the pressure accumulates in such furnace independently of the movements of the piston in the power cylinder and in the air compressing cylinder. As an example of the operation of an engine working upon this principle, refer-

ence being had to Fig. 7, the following will appear:

In Figs. 7, 8 and 9, the ordinates represent volumes and the abscissæ represent the pressures absolute.

1 pound air compressed to 336 pounds per square inch absolute from A to B, cooled during compression with water enough to be all evaporated. An isothermal curve is shown for comparison.

Temperature of air at the end of compression is 428°, which is equal to temperature of steam at 336 pounds per square inch.

Heat developed by compression (428—70°)×.2735 (specific heat of air at constant pressure)=85 B. T. U.+72 B. T. U. in water and steam to C=157 B. T. U. total.

Heat in power cylinder when air and steam are heated to 650°=to D=229 B. T. U.

229—157=72 B. T. U. to be supplied by furnace.

Heat rejected at end of expansion at F (208°—70°)×.2375=32.8 B. T. U.+9.7 B. T. U. in water at 208°=42.5. Steam begins to condense at E.

72 (furnished)—42.5 (rejected)=29.5 B. T. U. converted into power.

$$\frac{100\times 29.5}{72}=41\%$$ theoretical efficiency.

In order to get a greater efficiency with a smaller power cylinder, I can proportion the parts shown in Fig. 1 so as to have the furnace of much smaller size than in the preceding example. In this construction it is necessary that the cranks of the power and air compressing cylinders be properly correlated. Fig. 6 illustrates such an arrangement in which the pistons in the cylinders 1 and 4 work simultaneously. The piston in the cylinder 7, which supplies fuel to the furnace 8, is arranged 90° behind the pistons in the other cylinders; hence with this structure the air is compressed and forced into the furnace at the proper time to be led from the furnace into the working cylinder 1. The fuel from the cylinder 7 will be forced into the furnace also at the proper time.

As a concrete example of the operation of such a structure, reference is called to Fig. 8, which shows a curve of pressures and volumes similar to the curve shown in Fig. 7. In this figure the isothermal line G, H, is shown for comparison.

Assuming that 1 pound of air is compressed to 336 pounds per square inch from G to I, .07 pounds water supplied begins to make steam at 90 pounds, all evaporated to the point J. The temperatures of air and steam are the same as the first example. From K to L the curve represents the power of the compression of the gas required to follow up the rise in pressure due to the increment of heat. The point K, indicating volume of gas, would be about 1/13th of the distance from the ordinate of line of zero volume. By supplying heat enough to heat the mixture to 700° the pressure will be raised to 438 pounds, shown by the rectangle JKLM.

Heat in power cylinder at end of gas supply=242 B. T. U.

Heat from compression as before, 157+2 for gas=159.

242—159=83 B. T .U. supplied from furnace.

Heat rejected at end of expansion at N at 172°=24.2 B. T. U. in air and 7.1 in water at 172° (counted from initial temperature 70°)=31.2 B. T. U.

Heat supplied from furnace less heat rejected=83—31.2=52 converted.

$$\frac{52\times 100}{83}=62\%$$ efficiency.

It is apparent that this structure is more efficient than the preceding as well as having a smaller cylinder.

For the purpose of illustrating a concrete example of the operation of the structure shown in Fig. 5, recourse should be had to Fig. 9, which shows a curve of volumes and temperatures of the fluids in their passage through such a structure. In this illustration the air is cooled and heated by the exhaust from the power cylinder and then heated to 700° at constant volume. The isothermal line O, P, is indicated for comparison. Air is compressed with sufficient moisture to not generate steam but to just reach temperature of saturated steam at 336 pounds=428°. In this way compression follows the line O, Q, which will be seen to be lower than the curve A, C, in Fig. 7. The air on reaching the point Q is cooled to the isothermal at P, then is heated to 212°, which expands its volume to R. The air is now heated to 700° at constant volume, which raises its pressure to 600 pounds, or to the point S. Steam from cooler is admitted and superheated to the same temperature which gives us the volume S, T. Steam and air now expand adiabatically. During the expansion the superheated steam is always warmer than air and gives its heat to it. At 160 pounds the steam has reached saturation point and thereafter is continuously condensed. On the start there will be .1342 pounds steam to 1 pound air. At the end of expansion there will be only .0303 pounds left. The air will be at the temperature of steam of air pressure, or 212°, expanding in volume to the point V. The steam will have a further volume to the point W.

Heat in cylinder (above 70°) required to heat 1 pound of air from 70° to 700°=630×.2372=149.7 B. T. U. and heat required to heat .1342 pounds of water from 70° to 428°, evaporate it, and superheat the steam to 700°=176.5.

Total heat in cylinder is 149.7+176.5	326.2	B. T. U.
Supplied by compression	160.	B. T. U.
To be furnished	166.2	
Heat taken up from exhaust (217—70)×.2372	33.7	
Heat to be supplied by furnace	132.5	
Total heat in exhaust = heat rejected (33.7, amount in air on leaving cylinder, + 19.4 = heat in liquid at same temperature, + 29.7 = heat in vapor at same temperature,— 33.7 = heat given up by exhaust)	49.1	
Heat converted into power	83.4	

$$\frac{83.4\times100}{132.5}=63\%\text{ efficiency.}$$

It is thus apparent that there is slightly better efficiency than in the second example and much greater power proportional to the size of cylinders.

The engine, whether it is a reciprocating engine, a rotary engine or a turbine, may be reversed in the usual manner by the usual mechanism ordinarily applied for that purpose. Applied to a reciprocating engine, the structure shown in Fig. 6 is useful, as by placing the crank which actuates the piston of the fuel cylinder 7 at about 90° behind the crank of the power piston 1, the engine when reversed will then have the same lead of the crank of the power piston over the crank of the fuel piston as it has when running ahead.

The engine made in accordance with this invention may be governed by any form of governor, which may vary the cut-off in connection with a reciprocating engine or will throttle or vary the number of nozzles that are in use in a turbine, or in any other well understood manner. When governing the engine, the amount of fluid which passes through the working cylinder is reduced, and the temperature naturally rises; this, however, will be taken care of by the thermostatic device 31, which will control the amount of fuel passing through the valve 28, as has already been described.

In accordance with the provisions of the patent statutes, I have described the principle of my invention, together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is merely illustrative and that the invention can be carried out in other ways.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A heat-engine embodying therein a power cylinder, an air compressor, means delivering water to said compressor in such quantities as to insure its being converted into steam therein, a furnace divided into compartments communicating with each other only at the top and bottom, fuel feeding means, and means whereby a charge of air and steam is conveyed from said compressor and heated and expanded while being passed about one of said compartments of said furnace, and thereafter, and before delivery to said power cylinder, mixed with the products of combustion from said other compartment to reduce the temperature of the mixture so that substantially all of the steam will be condensed during the expansion of the mixture in the power cylinder.

2. A heat-engine embodying therein a power cylinder, an air compressor, means delivering water to said compressor in such quantities as to insure its being converted into steam therein, a furnace divided into compartments communicating with each other only at the top and bottom, fuel feeding means, means whereby a charge of air and steam is conveyed from said compressor and heated and expanded while being passed about one of said compartments of said furnace, and thereafter, and before delivery to said power cylinder, mixed with the products of combustion from said other compartment to reduce the temperature of the mixture so that substantially all of the steam will be condensed during the expansion of the mixture in the power cylinder, and automatically acting means actuated through temperature variations of the charge passing from said furnace to said power cylinder whereby the supply of fuel for said furnace is controlled to regulate the temperature of the charge delivered to said power cylinder.

3. A heat-engine embodying therein a power cylinder, an air compressor, means delivering water to said compressor in such quantities as to insure its being converted into steam therein, a furnace divided into compartments communicating with each other only at the top and bottom, fuel feeding means, means whereby a charge of air and steam is conveyed from said compressor and heated and expanded while being passed about one of said compartments of said furnace, and thereafter, and before delivery to

said power cylinder, mixed with the products of combustion from said other compartment to reduce the temperature of the mixture so that substantially all of the steam will be condensed during the expansion of the mixture in the power cylinder, and automatically acting means actuated through temperature variations of the exhaust from said power cylinder, for regulating the quantity of water delivered to said air compressor.

4. A heat engine which comprises means for compressing air, means for introducing water into the air during compression and thereby producing steam, means for cooling the compressed air and for transferring the heat from such compressed air and steam to water, utilizing the heat thereby transferred, and heating and expanding the air.

5. A heat engine having a power cylinder, an air compressing cylinder and a fuel cylinder, the said cylinders being connected to one shaft, the power crank and the air compressor crank being substantially 180 degrees apart, the cranks for the fuel cylinder and the power cylinder being at substantially right angles.

6. A power engine which comprises an air compressing cylinder, means for introducing water into such cylinder, a coil connected to the cylinder, a closed tank surrounding the coil, a trap connected to the outlet of the coil and connections between the trap and the compressing cylinder, whereby a closed circulation is secured.

7. A power engine which comprises an air compressing cylinder, means for introducing water into such cylinder, a coil connected to the cylinder, a closed tank surrounding the coil, a trap connected to the outlet of the coil, connections between the trap and the compressing cylinder whereby a closed circulation is secured, a heat exchanger, connections between the trap and heat exchanger, a furnace, connections between the furnace and the heat exchanger, connections between the tank and furnace, a power cylinder, connections between the furnace and the power cylinder, and connections between the power cylinder and the heat exchanger.

8. A power engine which comprises an air compressing cylinder, means for introducing water into such cylinder, a coil connected to the cylinder, a closed tank surrounding the coil, a trap connected to the outlet of the coil, connections between the trap and the compressing cylinder whereby a closed circulation is secured, a heat exchanger, connections between the trap and heat exchanger, a furnace, connections between the furnace and the heat exchanger, connections between the tank and the furnace, a power cylinder, connections between the furnace and the power cylinder, connections between the power cylinder and the heat exchanger, a fuel pump and valve for controlling the discharge from such pump and a thermostatic device interposed between the furnace and the power cylinder and connected to the valve, for controlling the amount of fuel given to the furnace in relation to the temperature of the discharged products of combustion.

9. A heat engine which comprises an air compressing cylinder, means for introducing water into such cylinder, a coil connected with the cylinder, a closed tank surrounding the coil, the said tank forming a cooling means for the coil, connections between the coil and cylinder, a combustion chamber, and connections between the tank and the combustion chamber.

10. A heat engine comprising an air compressing cylinder, means for introducing water into such cylinder, an air coil connected to the cylinder, the introduction of the air being at the top of the coil, a closed tank surrounding the coil, means for admitting cold water at the bottom of the tank, and means for drawing off steam at the top of the tank.

11. A heat engine which includes an air compressing device and a furnace, the said furnace comprising a portion in which combustion occurs, an arch within this portion, connections between this portion and the air compressing device, for introducing a small quantity of air necessary to produce combustion, and an additional connection between the air compressing device and the portion of furnace in which combustion does not occur whereby the arch is kept sufficiently hot to insure ignition.

12. A heat engine which includes a compressor, a furnace and a power cylinder, all connected in series, means for cooling the compressor by a formation of steam and means for condensing substantially all of the steam in the power cylinder.

This specification signed and witnessed this second day of March, 1908.

JAMES WILLARD MORRIS.

Witnesses:

LEONARD H. DYER,

JOHN L. LOTSCH.