

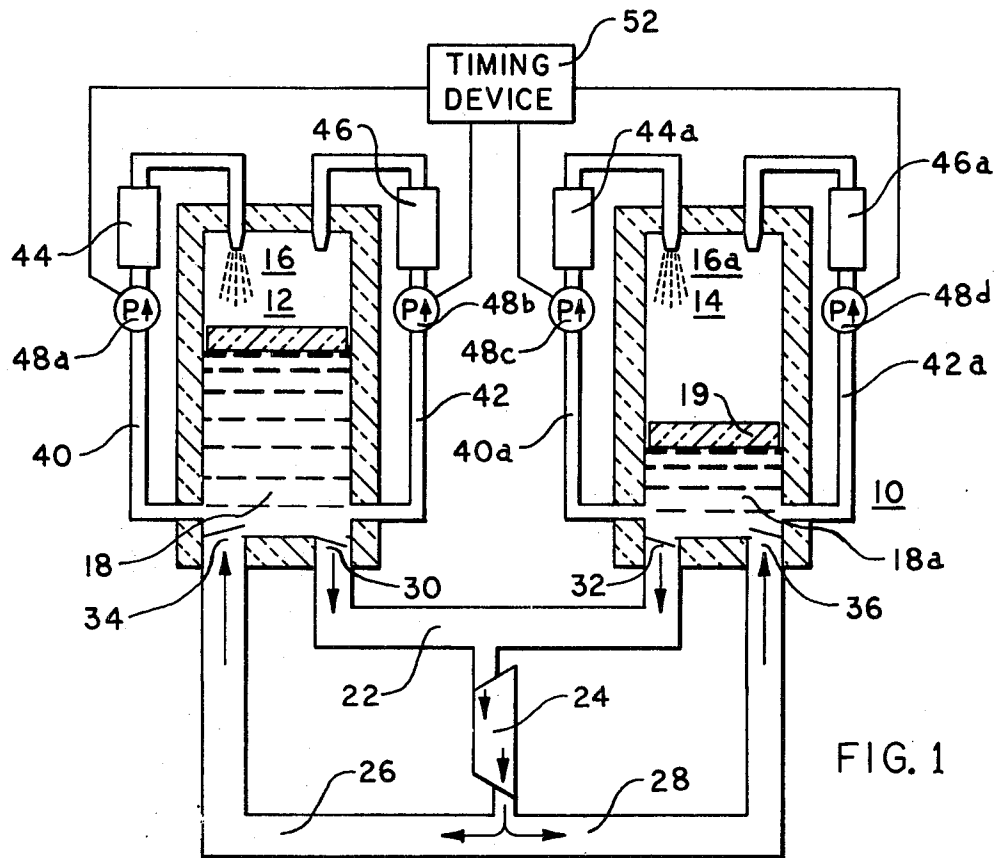


FIG. 1

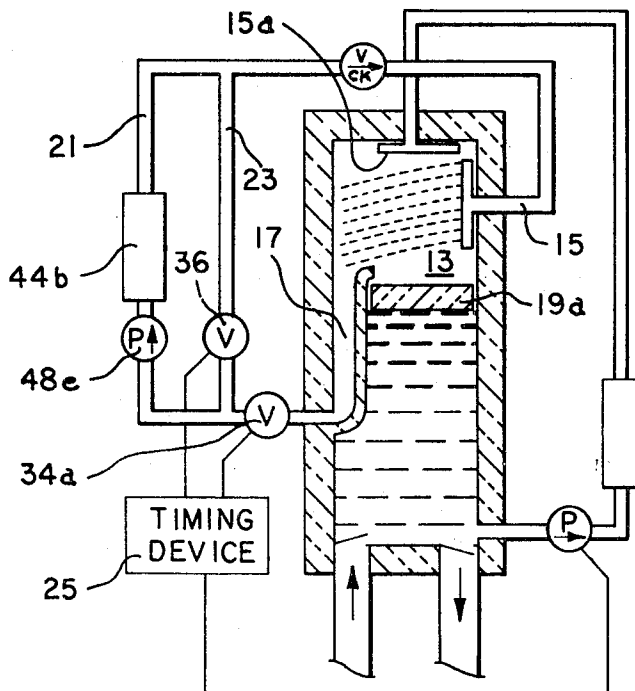


FIG. 1a

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3,608,311

ENGINE

Filed April 17, 1970

3 Sheets-Sheet 2

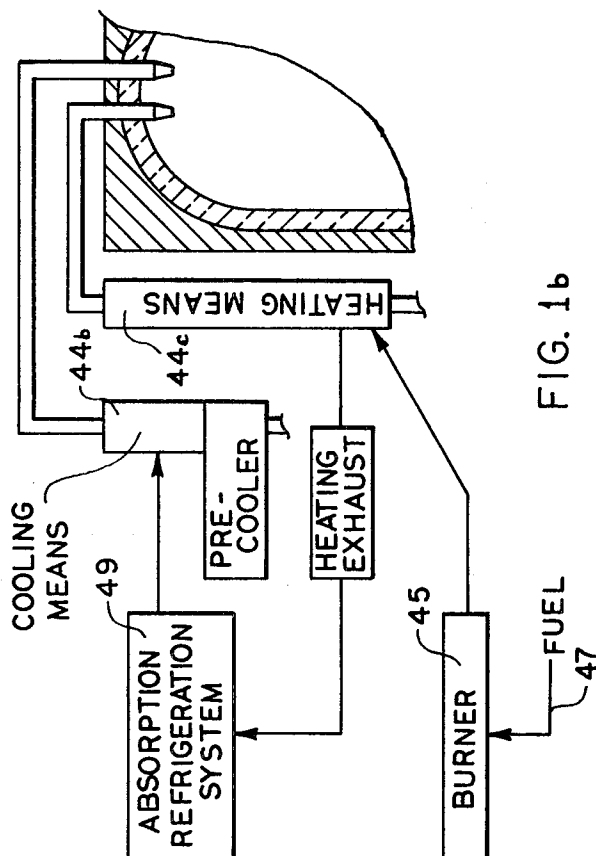


FIG. 1b

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3 Sheets-Sheet 3

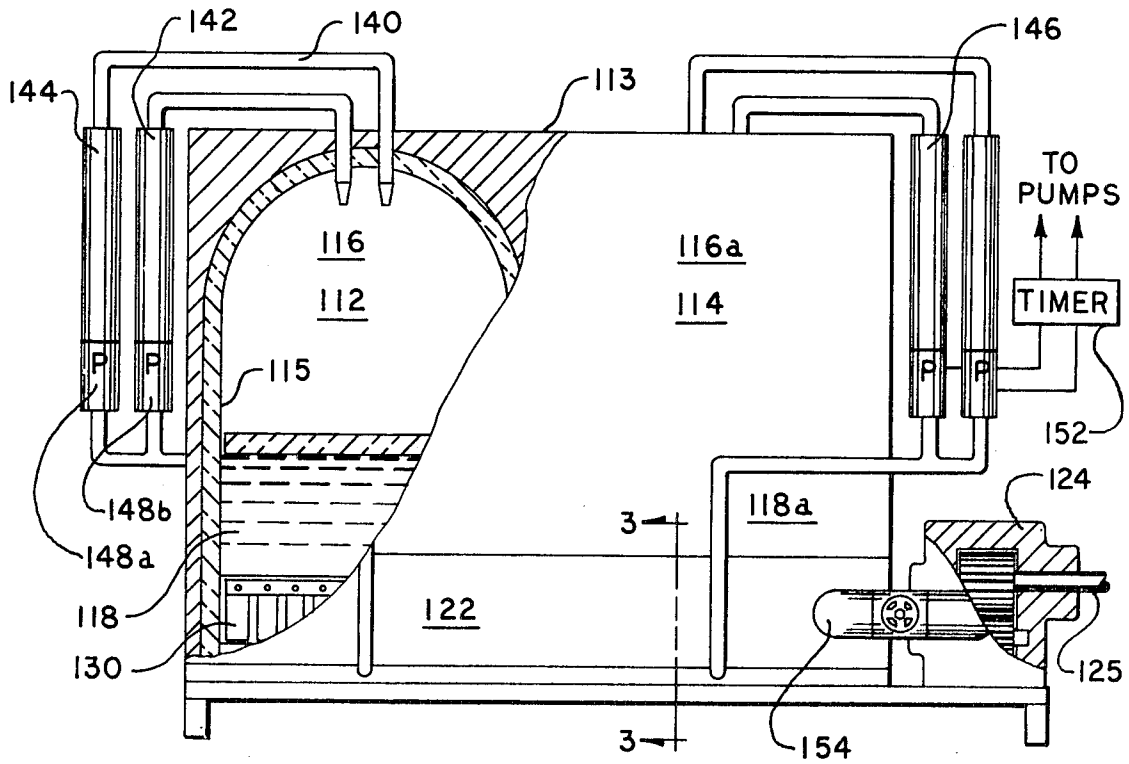


FIG. 2

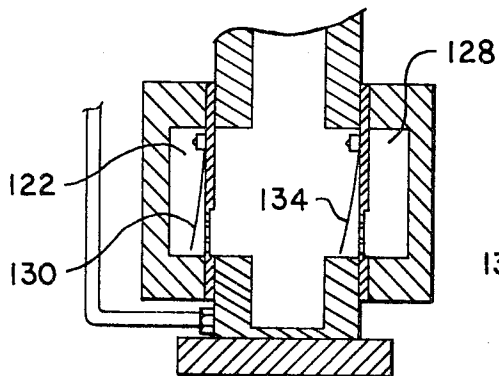


FIG. 3

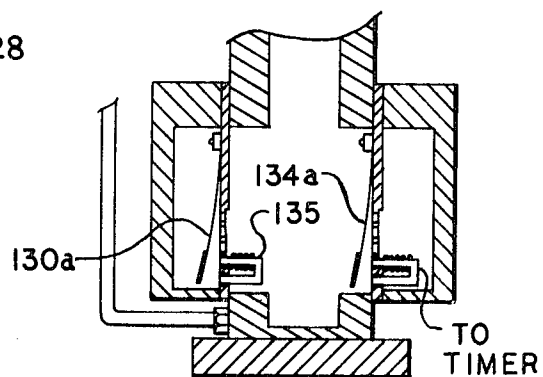


FIG. 4

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3,608,311
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Int. Cl. F01d 15/08; F04b 17/00
U.S. Cl. 60—108 14 Claims

ABSTRACT OF THE DISCLOSURE

In a heat engine where heat is applied to a working fluid contained in a chamber to expand the fluid, removing the heat source while allowing the fluid to expand further, applying cooling while compressing the working fluid and removing the cooling while further compressing the fluid, said fluid during said expansion being applied to utilization means to perform work, the improvement therein comprising: having at least two chambers which contain a liquid and a gas section; hot and cold lines connecting the liquid sections to the gas sections, including pumping means, heating and cooling means in the respective lines; forward and return flow passages communicating between said liquid sections across one-way valves which allow flow into the forward flow passage and out of the return flow passage, and a work area in series between the forward and return passages; and, timer means coupled to said hot and cold lines to sequentially allow hot and cool liquid to flow from liquid to gas sections to cause gas expansion and compression resulting in a flow of liquid out of at least one chamber into said forward passage and/or out of said return passage into at least one chamber across said work area.

BACKGROUND OF THE INVENTION

The present invention relates to a differential heat engine and more particularly to a closed cycle heat engine which has controllable rate and duration of the heat input and rejection processes with few moving parts.

BRIEF DESCRIPTION OF THE PRIOR ART

The fundamental concept of a heat engine is based upon the so-called "Carnot cycle" named after Nicolas Leonard Sadi Carnot. Carnot's work in the early nineteenth century was continued by Diesel and indeed, Diesel's early versions of his now famous diesel engine was based upon the teachings of Sadi Carnot. It is significant that heretofore, although "Carnot cycle" engines were known, they exist only in textbooks and as scientific curiosities (C. Osborn Mackey et al., Engineering Thermodynamics, John Wiley & Sons, page 255) without any application in practice as industrial machines. The present invention concerns an industrial machine based on the teachings of Sadi Carnot and avoiding the pitfalls which befell Diesel, Stirling and others.

A heat engine converts heat into work by adding heat to a working fluid, usually a gas, so that the fluid expands and exerts pressure on a piston or on turbine blades. Although steam and air are the most common working fluids, in theory any gas can serve as the medium for this kind of energy conversion. The efficiency of the process, according to Carnot, does not depend on the choice of medium, but obviously some gases have more convenient properties than others.

The usual Carnot cycle engine described in textbooks is a one-cycle engine with a piston. In an ideal Carnot

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cycle engine, at the start of the cycle, a large heat reservoir is in contact with the cylinder head, and heat flowing from it into the working fluid causes the fluid to expand isothermally, that is, without an increase in temperature. Next, the heat source is removed and the cylinder head is insulated, the working fluid continues to expand with the expansion being adiabatic, that is, without the flow of heat to or from the fluid. The temperature of the fluid therefore drops. Then the piston must be driven back, compressing the fluid before it. During this compression the cylinder head is placed in contact with a cooler heat reservoir so that as the compression process occurs, heat flows from the fluid to the cold body such that the temperature of the fluid remains constant and the compression is isothermal. Finally, the cold body is replaced by insulation and the piston is returned to the starting position by adiabatic compression. The energy generated by the piston's work raises the temperature of the working fluid to its original level, thereby completing the cycle.

It is significant that the previous workers in the field, e.g., Brayton, Otto, Diesel, were not able to successfully construct a practical engine which operated on the Carnot cycle even though serious attempts were made to do so. In particular, the requirement of isothermal expansion has not been possible to meet in engines where air is the working fluid and its oxygen is used for combustion within the cylinder. Also, when combustion occurs in the cylinder, the combustion products must be removed and fresh air brought in. Therefore, in an internal combustion engine, the system must be an open one.

Attempts have been made by other workers in the field to eliminate the troublesome piston. Typical of these attempts is the one described in the T. Y. Korsgren, Sr., U.S. Pat. No. 3,183,662. However, in this patent, mechanically coupled fluid displacers are used which limit the cycle to that defined by Stirling. Also, the working cycle of the engine is closely coupled to the hot and cold cycle which hinders the usefulness of the engine in practice.

The present invention, on the contrary, relates to a Carnot cycle closed loop system. It uses a heat transfer process which has a controllable duration and heat transfer rate in and out of the expansion chamber. This allows the tailoring of the cycle to meet isothermal or other requirements.

Furthermore, although the components shown and described herein appear in a compact configuration, the various component sections can be separated, elongated, and extended so as to occupy almost any type of space provided.

This makes the engine particularly suitable for use where packaging is important, e.g., as a boat or airplane engine.

SUMMARY OF THE INVENTION

Generally speaking, the present invention provides for an engine preferably having at least two insulated chambers. Although these are shown one alongside the other in the drawing, they can be widely separated. Each chamber contains a gas and a liquid. The expansion and contraction of the gas in these chambers force the liquid to pass in and out through one-way valves connected to exit and return lines. These valves may be simple passive spring loaded check valves, or in some cases, they may be positive acting externally controlled valves. On ex-

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pansion, fluid passes out of one chamber through a work flow chamber, which extracts work from the fluid and passes into the second chamber causing compression of its gas. Some of the liquid is also pumped separately from the liquid sections through two lines, one which is heated and the other cooled. During this heating and cooling, a phase change may or may not occur, e.g., it may form a gas upon heating. Heat is transferred to or from the gas at will by sequentially pumping hot or cold fluid to the gas section of the chamber. The amount, duration and timing of the heat transfer is controlled by a distributor timer connected to the hot and cold lines. The fluid pumped into the gas section flows down to the liquid section to close its cycle.

It is also possible to operate with only one chamber and a reservoir, instead of the second chamber.

The invention, as well as the objects and advantages thereof will be more apparent from the following detailed description, when taken in connection with the accompanying drawing in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional flow diagram of a simplified form of the engine contemplated herein;

FIG. 1a is a cross-sectional flow diagram showing a modified version of the arrangement depicted in FIG. 1;

FIG. 1b also presents a cross-sectional flow diagram with another modification of the version shown in FIG. 1;

FIG. 2 shows a cross-sectional view of an industrial version of the engine contemplated herein;

FIG. 3 is a cross-sectional view along lines 3—3 of FIG. 2; and,

FIG. 4 shows a modified version of the arrangement shown in FIG. 3.

DETAILED DESCRIPTION

Shown in FIG. 1 is a differential heat engine 10, having a first insulated expansion chamber 12 and a second insulated expansion chamber 14. Each chamber is outwardly in the form of an elongated narrow rectangle and is divided generally into a gas section 16, 16a and a liquid section 18, 18a. Advantageously, a layer of solid insulation 19 can be disposed to float over the liquid between the two sections. Connected to the output side or bottom of each chamber is a Y-connection 22 leading to a work flow chamber 24, wherein is located an output motor. From the work flow chamber 24 are first and second return lines 26, 28 to the first and second oil expansion chambers 12, 14. Each arm of the Y-connection 22 has an out-going check valve 30, 32. Each return line 26, 28 likewise has an in-feeding check valve 34, 36, i.e., these are inflow valves. Each expansion chamber has a hot injection line 40, 40a and a cold injection line 42, 42a going from the liquid section to the gas section in each chamber. These lines respectively pass through heating means 44, 44a and cooling means 46, 46a. There is also a pump 48a, 48b, 48c, 48d in each line. Each line is connected to a timer 52, which can alternately act on a hot injection line and a cold injection line in each chamber.

SIMPLE OPERATING SEQUENCE

The engine operates as follows:

The hot line for one chamber and the cold line for the other chamber are acted on by the distributor timer. Liquid is pumped by the respective pumps and ejected out of nozzles from the hot and cold lines. As the hot liquid is injected into the chamber by the nozzle, it is broken up into many fine particles which together present a large surface area to the gas. The gas expands pressing down on the liquid. Other means of creating small droplets may also be used. The liquid flows through the one-way valve into one leg of the Y-connection into the work flow chamber. The work flow chamber has a turbine arrangement with an output shaft. As the liquid flows through the chamber, it causes the shaft to turn. The liquid then

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goes into the return paths. During this time, the cold liquid also is injected into the other chamber, removing heat and contracting the gas. During this second portion, i.e., the adiabatic portion of the compression cycle, the inertia of the liquid in the chamber assists in the gas compression. Thus, liquid flows up the return path leading to the other chamber past the one-way valve and into the chamber. On the next cycle, the cold line of the first chamber and the hot line of the other chamber are acted upon. This time the liquid flow is down the other leg of the Y-connection, but again passes through the work flow chamber in the same direction continuing the rotation of the turbine. It is to be observed that the pumps do not pump the liquid across the turbine, but merely pump liquid from the bottom of the liquid section to the top of the gas section and the pressure of the gas is changed by the fact that a mist or droplets of hot or cold liquid hits the gas. Thus, the pumps do not see the turbine counter force. As for the turbine, all that the turbine sees is the liquid passing through the work flow chamber going from the Y-connection to the return lines.

HOT LIQUID AND WASTE HEAT RECOVERY

In the operating sequence just described, the hot liquid supplied into the chamber by the nozzle should be metered, since if excessive liquid is thrown into the chamber, the heat produced by this excessive liquid is just wasted. Thus, only enough hot liquid for optimum operation is thrown into the chamber and no more. The simplicity of operation and efficiency may be greatly enhanced by recovering the hot liquid and also recovering the waste heat. The hot liquid recovery is shown in FIG. 1a, where only one of the insulated chambers is shown. In the chamber 13 is a hot liquid nozzle 15 having a multitude of small vertical apertures for spraying the liquid horizontally across the chamber. Opposite to hot liquid spray nozzle 15, is a hot liquid recovery vessel 17 disposed below the level of the spray nozzles to recover the hot droplets sprayed across the chamber. Floating in the chamber 15 is a loose fitting block of insulation 19a, which will permit cold liquid to pass through to the lower chamber, and yet act as a thermal barrier to help maintain the isothermal and adiabatic portions of the cycle. Disposed at the top of the chamber is a cold liquid nozzle 15a which will spray cold liquid downwards. Below this cold liquid spray nozzle is the block of insulation 19a. The cold liquid spray is not recovered, but on the contrary, is sprayed downwards towards the main body of liquid. From the bottom of the hot liquid recovery vessel 17, to the spray nozzle, is a feed forward line 21 having a pump 48e, a heating means 44b and a parallel by-pass line 23. The recovery vessel 17 and the by-pass line 23 have one-way valves 34a, 36a, which are active valves operated by a timing device 25. The by-pass line is necessary to provide a continuous oil flow during the cold cycle of the chamber 13, and thus, reduce the acceleration required during the start and stop portion of the injection cycles. The waste heat recovery is shown in FIG. 1b. The heating means 44c is heated by a burner 45 having a fuel input section 47. The heat flows from the burner 45 to the heating means 44c and from there to an absorbent refrigeration system 49 and then is finally exhausted. The absorbent refrigeration system 49 is coupled to the cooling means 46b. The cold liquid from the bottom of the chamber passes through a pre-cooler, then to cooling means and is injected into the chamber from the top of the chamber and sprayed downwards vertically, as described. The hot liquid is recovered from the bottom of the recovery vessel, passes across the feed forward line to the spray nozzle, and is sprayed across the chamber horizontally.

WORKING EMBODIMENT

The theoretical device just described illustrates the principles of operation of the invention herein contemplated.

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plated. A more practical engine based on these theoretical principles is shown in FIGS. 2 to 4. Thus, there are the two chambers 112 and 114 made from an elongated, narrow, rectangular frame 113. The chambers 112 and 114 are defined by an insulated wall 115 within the frame. Each chamber has an upper gas section 116, 116a and a lower liquid section 118, 118a. Instead of the Y-connection shown in FIG. 1, there is a straight forward passage 122 defined in the base of the frame. This forward passage 122 runs alongside both chambers on one side of the frame. Separating the forward passage from the chambers are reed valves 130. These reed valves are one-way valves allowing liquid to go out of the chambers into the forward passage, but not from the forward passage into the chambers. At one end of the engine is the work flow chamber 124, having a turbine and an output shaft 125. Along the other side of the frame is a return passage 128, similar to the forward passage, also connected to the work flow chamber 124, and again, this return passage is separated from the chambers by reed valves 134. As best shown in FIG. 3, these reed valves 134 permit one-way flow into the chambers. Each chamber has a hot and a cool flow line 140, 142. Each line has a pump 148a, 148b and the hot flow lines have a heater 144, while the cool flow lines have a cooling coil 146. Each chamber has a suitable liquid, such as silicon fluoride oil, in the liquid section and a suitable gas, such as argon gas, in the gas section. The working embodiment just described works just like the theoretical machine previously described. There is a distributor timer 152, shown greatly magnified in the drawing. This can either be a mechanical cam or solid state electronic timer. The timer acts on one hot and one cold line simultaneously spraying hot and cold liquid in the respective chambers. The gas accordingly expands in the one chamber and contracts in the other, forcing liquid out of the chamber into the forward passage and bringing liquid into the other chamber from the return passage across the work flow chamber. Preferably, the feed to the work flow chamber is across auxiliary lines 154, which can properly guide the fluid flow across the chamber. If necessary, a whirling impeller can be used in the gas section to enhance the breaking up of the injected fluid. However, a good spray nozzle, such as a sonic spray nozzle, may be mounted in the outlet part of the lines into the gas chamber which sprays droplets of oil into the chamber in which case no whirling impeller is needed.

As shown in FIG. 2a, the efficiency of the engine can be enhanced by providing a simulated flywheel effect. This is accomplished by using active valves with enabling means, e.g., solenoid actuated electro-magnetic valves. Thus, valves 130a and 134a are opened and closed by means of a solenoid 135 connected to the timer 152.

It is to be observed, therefore, that the present invention provides for an engine having at least two chambers 12, 14; 112, 114, each chamber having a gas and a liquid section 16, 18; 116, 118. Hot and cold pump lines which include appropriate pumps, and heating and cooling means, e.g., 40, 42; 140, 142 are disposed to pump liquid from the liquid section to the gas section, either of the same chamber, or of another chamber. Connected to each liquid section across one-way valves outwards and inwards is a forward passage and a return passage 22, 122; 28, 128 with a work flow chamber 124 inbetween. A distributor timer 52, 152 is connected to each pump line to sequentially pump liquid across a hot or cold line from the liquid section to the gas section of the chambers, the expansion and contraction of gas in these chambers forcing oil to pass out through the forward passage across the work flow chamber and back to another chamber through the return line.

Should the pumps for one chamber fail to function, the engine will still operate, however with reduced efficiency. In other words, the second chamber acts as a reservoir.

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For the purpose of giving those skilled in the art a better understanding of the invention, the following technical data is provided:

TABLE

5 Volume of expansion chambers—200 cu. in. (total for two)
Compression ratio—3.1
Speed—1,200 cycles/min.
Hot oil temperature—600° F.
Gas—argon; Oil—Silicon fluoride

10 Initial gas pressure, p.s.i. (cold)	Hot oil injected stroke, lbs.	Input B.t.u. to heater, B.t.u./hr.	Output H.P.
0.....	.00002	636	.09
100.....	.00021	6, 614	.9
1,000.....	.0021	67, 416	7.7
0.....	.00040	15, 060	1.12
100.....	.0048	146, 534	11.52
15 ,000.....	.035	1.07×10 ⁶	72.0
.....	.0021	65, 889	2.070
100.....	.021	633, 456	19.16
1,000.....	.0933	2.8×10 ⁶	92.4

According to the present inventive concept, hot oil mist (or other suitable material) is injected at a controlled rate to obtain essentially isothermal, i.e., constant temperature expansion. The hot gas continues to expand approximately adiabatically, i.e., no heat in or out, in a insulated chamber. Then, cold oil mist is injected at a controlled rate to obtain isothermal compression. The gas is then compressed adiabatically. The advantages of this arrangement are several. Oil mist is used for heat transfer. Thus, there is a large surface area of a rapid heat transfer without loss of working volume. Also, the arrangement allows remote location of heat exchange units, i.e., the heating and cooling units. This also means external combustion, rather than internal combustion. In order to obtain isothermal expansion and compression, there is a controlled heat rate input. Furthermore, other appropriate working curves for the system can be defined and controlled. The oil piston allows the use of fluid mist for the heat transfer without complicated oil recovery methods and also allows the use of insulated expansion chambers. There is no mechanical sliding surface internal to the engine. The production cost for the engine is greatly reduced with a greatly increased reliability and operating life of the engine. No rigid mechanical power transmission system is required. The oil output can be readily controlled and simple hydraulic feed lines can be placed where needed. Furthermore, the system lends itself to a low cost, reliable, silent, hermetically sealed engine that can operate on any heat source. This allows external combustion and fuels, in the case of a boat, truck, or automobile, which can greatly reduce undesirable pollution.

What is claimed is:

1. An engine comprising:

- (a) at least two chambers, each chamber containing a gas and a liquid section;
- (b) hot and cold lines going from a liquid section to a gas section, including heating and cooling means in the respective lines;
- (c) forward and return flow passages communicating between said liquid sections across one-way valves which allow flow into the forward flow passage and out of the return flow passage, and a work area in series between the forward and return passages; and,
- (d) timer means coupled to said hot and cold lines to sequentially allow hot and cool liquid to flow from liquid to gas sections to cause gas heating and cooling resulting in a flow of liquid out of at least one chamber into said forward passage and/or out of said return passage into at least one chamber across said work area.

2. An engine comprising:

- (a) first and second chambers, each chamber having an upper gas section and a lower liquid section;
- (b) a forward flow passage connected to each chamber across one-way valves allowing flow into the passage and a return flow passage connected to each

chamber across one-way valves allowing flow into the chambers, and a work chamber therebetween in a series of said passages;

- (c) hot and cool lines from the liquid to the gas section in each chamber, including pump means for each line, heating means heating the hot lines and cooling means cooling the cool lines; and,

- (d) timer means for alternately allowing flow in the hot line in one chamber and the cool line in the other, and in the cool line in the one chamber and the hot line in the other, whereby the pumping of hot liquid to the gas section causes the gas therein to expand, whereas the pumping of cool liquid to the gas section causes it to contract, the pressure of the gas on the liquid in each chamber alternately forcing the liquid across the work area.

3. An engine as claimed in claim 2, including a hot liquid recovery vessel defined in at least one of said chambers, hot liquid spray means connected to said hot line to spray hot liquid across at least said one chamber into said recovery vessel, said hot line being a forward feed line from said recovery vessel including a one-way input valve on the input side, a pump and a heating means and on output side in series with said spray means, a by-pass line and valve between said input and output sides, and timer means operatively connected to said valves to cyclically circulate said liquid to said spray means.

4. An engine as claimed in claim 3, including an absorption refrigeration system operably coupled to said heating means, said cooling means being operably connected to said absorption refrigeration means, said absorption refrigeration means serving to at least partially cool said cooling means with the exhaust heat from said heating means.

5. An engine as claimed in claim 2, including enabling means operably connected to said valves actuated by said timer means.

6. An engine comprising:

- (a) a pumping chamber having a liquid and a gas section defined therein;
- (b) hot and cold lines from the liquid section to the gas section including heating and cooling means in the respective lines;
- (c) a reservoir;
- (d) forward and return flow passages communicating between said liquid section and said reservoir across one-way valves which allow flow into the forward flow passage and out of the return flow passage;
- (e) a work area in series between the forward flow passage and the return flow passage; and
- (f) timer means, coupled to said hot and cold lines to sequentially allow hot and cool liquid to flow from said gas section to cause heating and cooling resulting in a flow of liquid between said chambers and reservoir across said work area.

7. An engine comprising:

- (a) pumping chamber having a gas and a liquid section and a reservoir chamber;
- (b) a forward flow passage connected to each chamber across one-way valves allowing flow into the passage and a return flow passage connected to each chamber across one-way valves allowing flow into the chambers and work area therebetween, in series with said chambers;
- (c) hot and cool lines from the liquid to the gas section in said pumping chamber, including pump means for each line, heating means and cooling means respectively operatively connected to hot and cool lines; and,

- (d) timer means for alternately acting on the hot and cool lines.

8. In a heat engine where heat is applied to a working fluid contained in a chamber to expand the fluid, removing the heat source while allowing the fluid to expand further, applying cooling while compressing the working fluid and removing the cooling while further compressing the fluid, said fluid during said expansion being applied to utilization means to perform work, the improvement therein comprising:

- (a) there being at least two chambers, at least one of said two chambers containing a liquid and a gas section;

- (b) hot and cold lines connecting a liquid section to a gas section, including pumping means, heating and cooling means in the respective lines, and means for enhancing the liquid to gas contact within at least said one chamber;

- (c) forward and return flow passages communicating between said liquid sections across one-way valves which allow flow into the forward flow passage and out of the return flow passage, and a work area in series between the forward and return passages; and,

- (d) timer means coupled to said hot and cold lines to sequentially allow hot and cool liquid to flow from liquid to gas sections to cause gas expansion and compression resulting in a flow of liquid out of at least one chamber into said forward passage and/or out of said return passage into at least one chamber across said work area.

9. An engine as claimed in claim 8, wherein said engine has two substantially similar chambers, each chamber having its own hot and cold lines.

10. An engine as claimed in claim 8, said valves having active means to open and close the valves, said active means being connected and operated by said timer means.

11. An engine as claimed in claim 8, each of said chambers including a hot liquid recovery vessel defined therein, so disposed that said hot liquid will cross said chamber, expand the gas therein and enter said hot liquid recovery vessel for recirculation in said hot line of said chamber.

12. An engine as claimed in claim 8, including burner means to heat said heating means, said heating means including an exhaust side, an absorption refrigeration system coupled to said heating means exhaust side, said absorption refrigeration system being coupled to said cooling means and at least partially cooling said cooling means.

13. An engine as claimed in claim 8, wherein said means for enhancing are spray means.

14. An engine as claimed in claim 8, wherein said means for enhancing are multiple stream forming means.

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U.S. Cl. X.R.

60—1, 24; 417—379