United States Patent [19] **McAlister**

[11] **3,901,033**

[45] **Aug. 26, 1975**

[54] **VAPOR PRESSURIZED HYDROSTATIC DRIVE**

[76] Inventor: **Roy E. McAlister,** 5285 N. Red Rock Dr., Phoenix, Ariz. 85108

[22] Filed: **July 9, 1974**

[21] Appl. No.: **486,909**

Related U.S. Application Data

[62] Division of Ser. No. 229,764, Feb. 28, 1972, Pat. No. 3,830,065, which is a division of Ser. No. 58,934, July 28, 1970, Pat. No. 3,648,458.

[52] **U.S. Cl.** .... **60/516;** 60/655; 91/4 R

[51] **Int. Cl.** **F01k 23/02**

[58] **Field of Search** .... 91/4 R; 60/644, 655, 670, 60/698, 721, 325; 417/379

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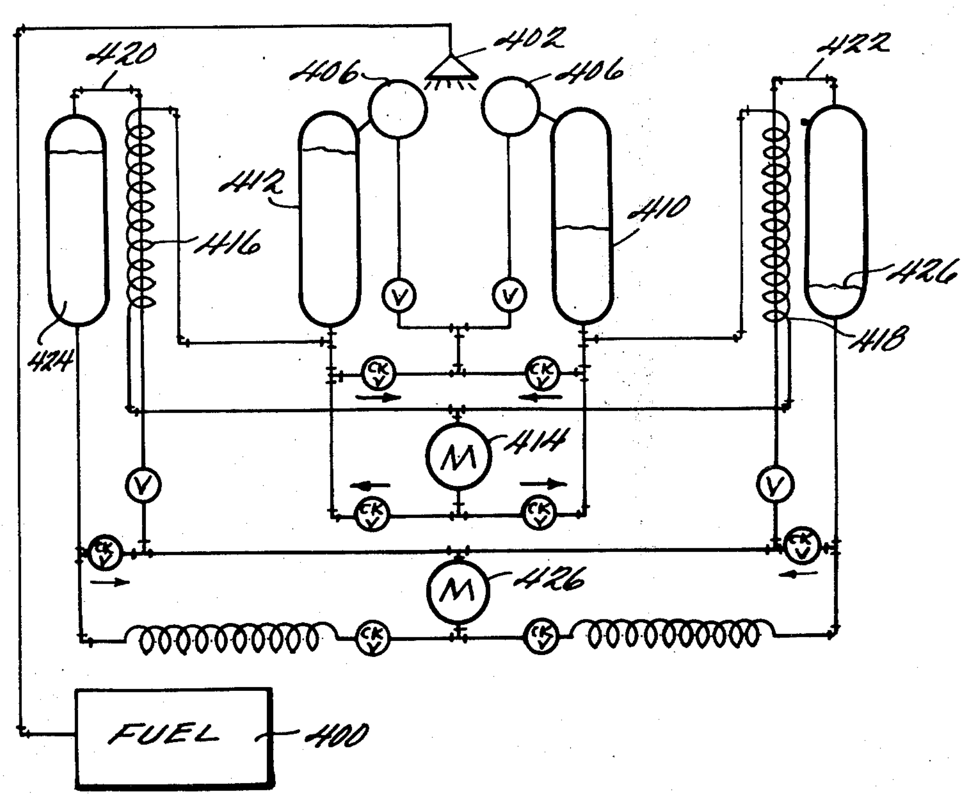
Primary Examiner—Martin P. Schwadron
Assistant Examiner—Allen M. Ostrager
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A hydrostatic drive system generally of the type wherein vapor is alternately directed into one of two reservoir tanks so that working fluid in that tank is forced out of the tank by pressure of the vapor and through a fluidic motor to generate a mechanical output before it returns to refill the other tank. When the first tank is substantially depleted, the vapor pressure is directed into the refilled tank so that fluid from that tank now flows through the moter to refill the first, now depleted, tank. In one embodiment, cyclic pressure generated by a vapor generator forces fluid cyclically through an AC fluid motor. In another embodiment, heat from the working fluid is employed to generate the vapor pressure and reduce the temperature of the working fluid passing through the motor. In a further embodiment, the fuel serves as the working fluid and the vapor from the refilling tank is combusted to provide heat to convert the fuel from its liquid to vapor state. In another embodiment, the combustion gases are combined with the vapor so that, when water is the working fluid, the water vapor in the combustion gases serves as make up working fluid. In a further embodiment, heat from working fluid on its way to the motor is transferred to other working fluid in a second system to drive a second motor. Further aspects of the invention are set forth below.

1 Claim, 18 Drawing Figures



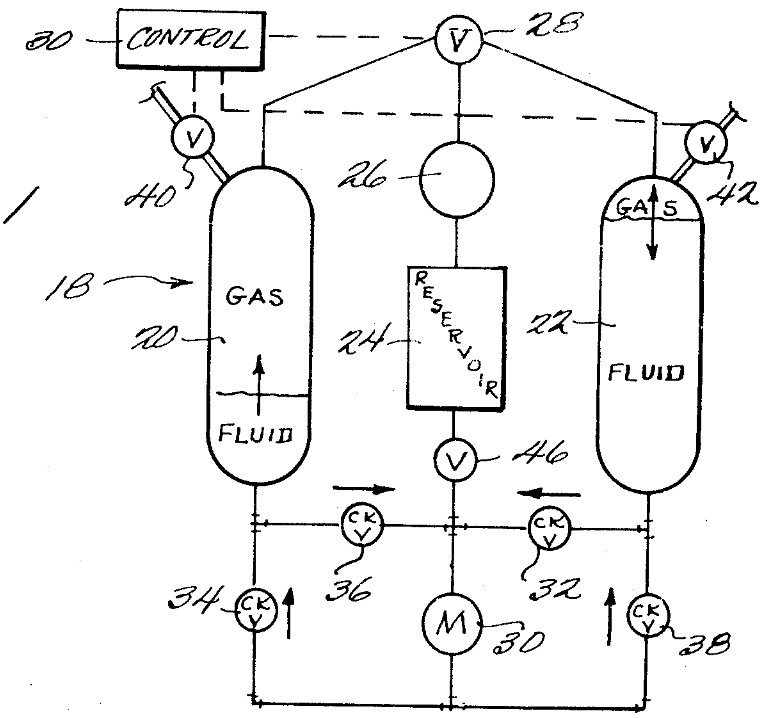

CONTROL
30
28
V
V
40
V
42
26
18
GAS
20
24
RESERVOIR
22
GAS
FLUID
FLUID
V
46
CK V
36
CK V
32
34
CK V
M
30
CK V
38

Fig. 1

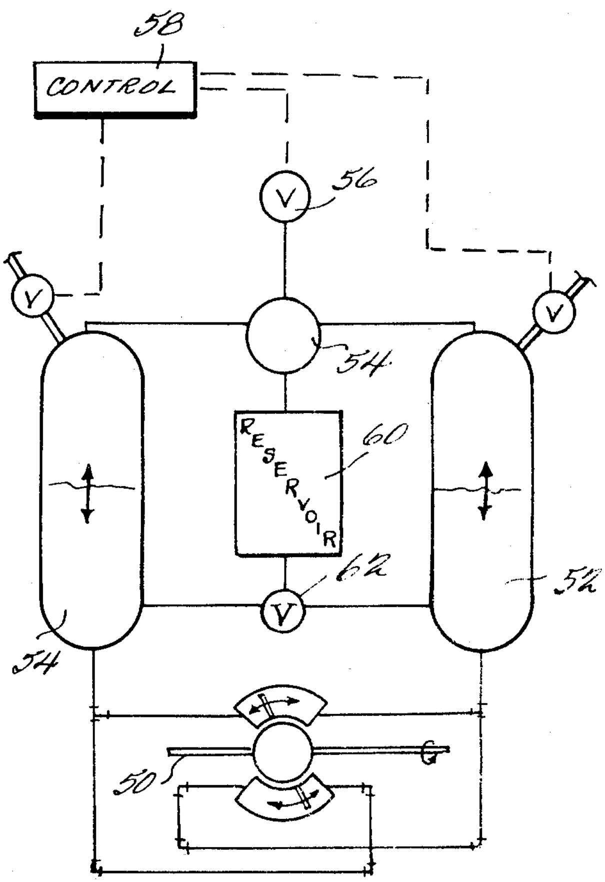
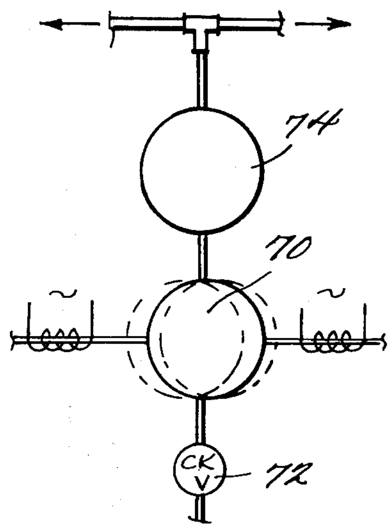

58
CONTROL
V
56
V
V
54
RESERVOIR
60
62
V
52
54
50

Fig. 2

Fig. 3


74
70
CK V
72

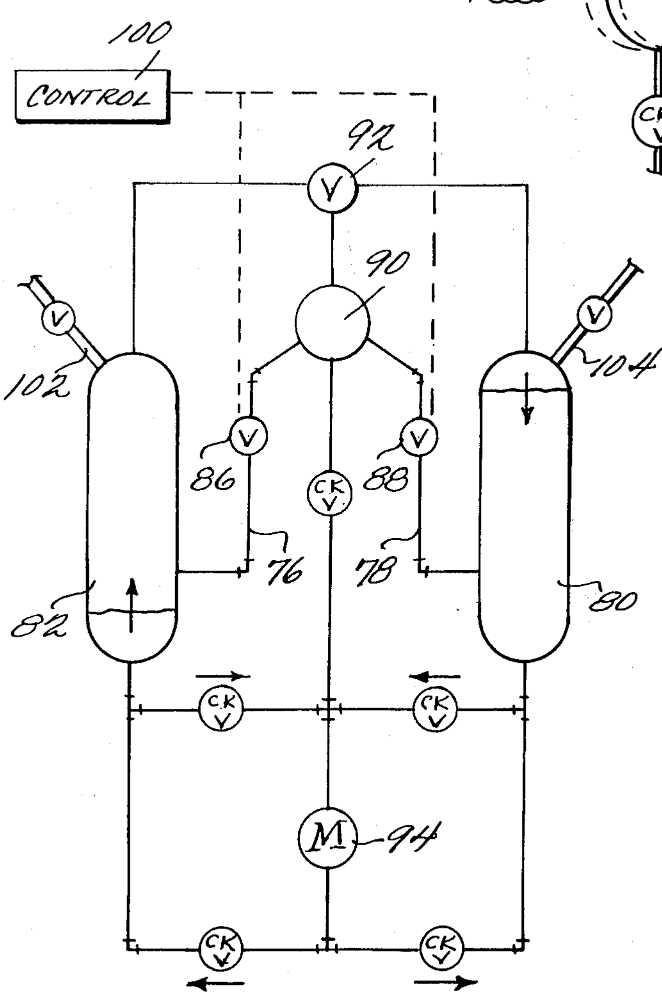

100
CONTROL
92
V
90
V
102
V
104
V
86
CK V
V
88
76
78
82
80
CK V
CK V
M
94
CK V
CK V

Fig. 4

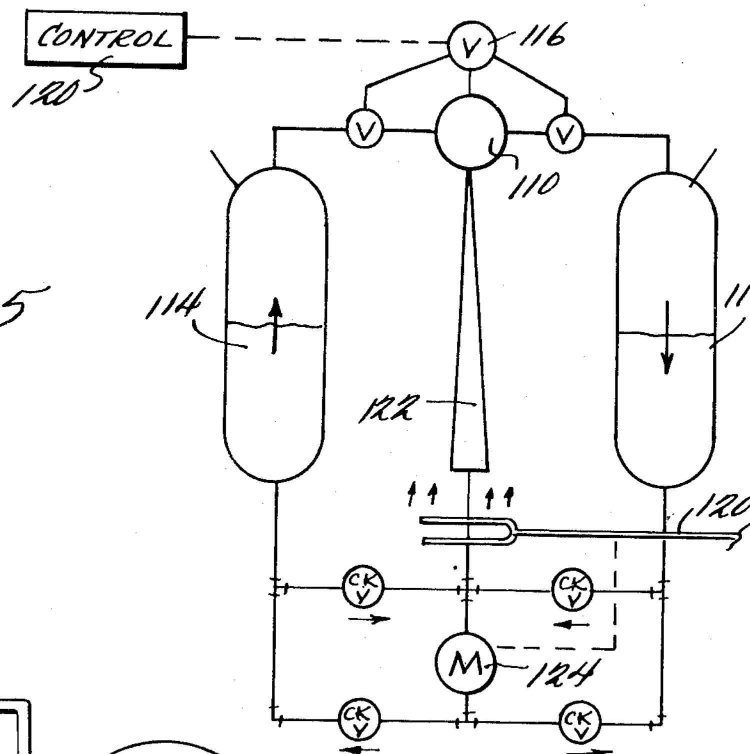

CONTROL
120
116
V
V
V
110
114
112
122
120
CK V
CK V
M
124
CK V
CK V

Fig. 5

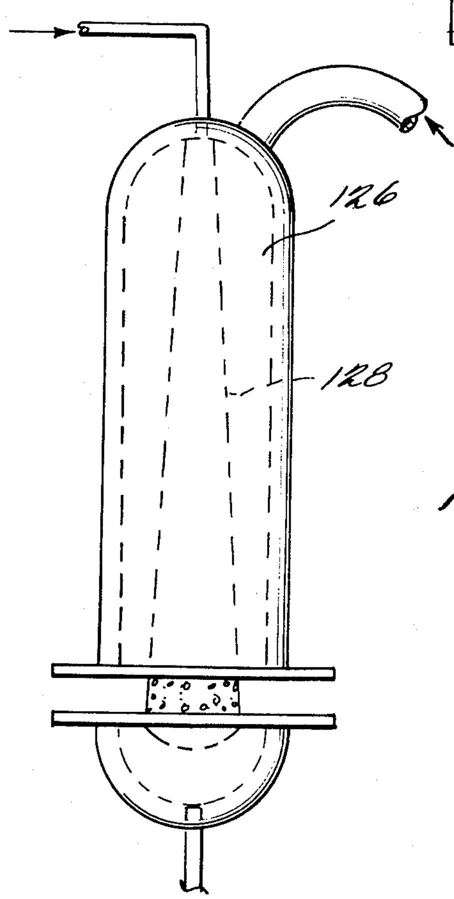

126
128

Fig. 6

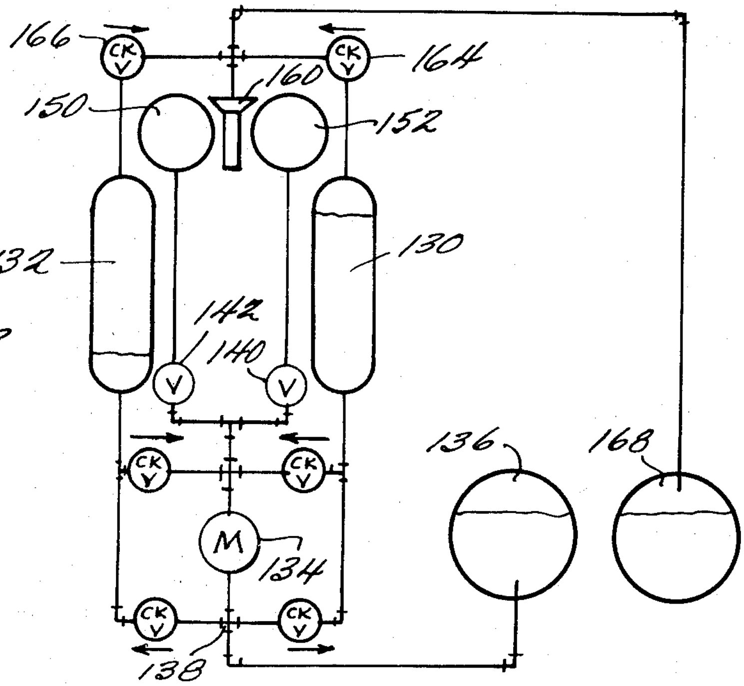

166
CK V
CK V
164
160
150
152
132
130
142
140
V
V
CK V
CK V
M
134
CK V
CK V
138
136
168

Fig. 7

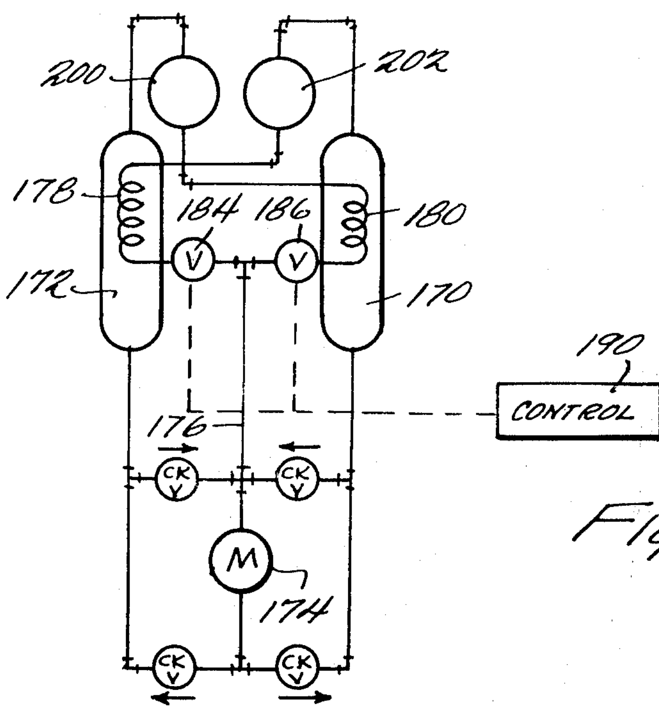

200
202
178
184
186
180
172
170
190
CONTROL
176
CK V
CK V
M
174
CK V
CK V

Fig. 8

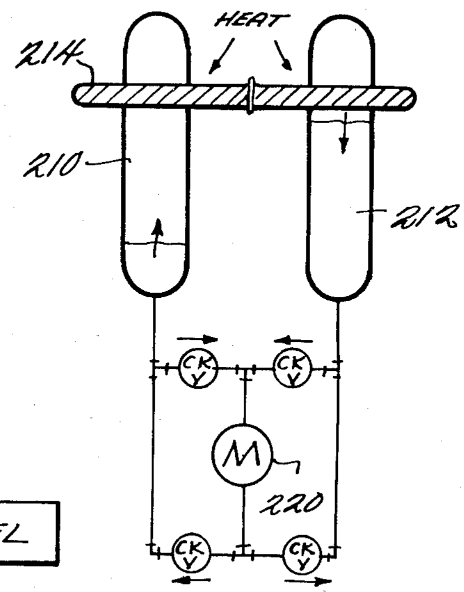

HEAT
214
210
212
CKV
M
220

Fig. 9

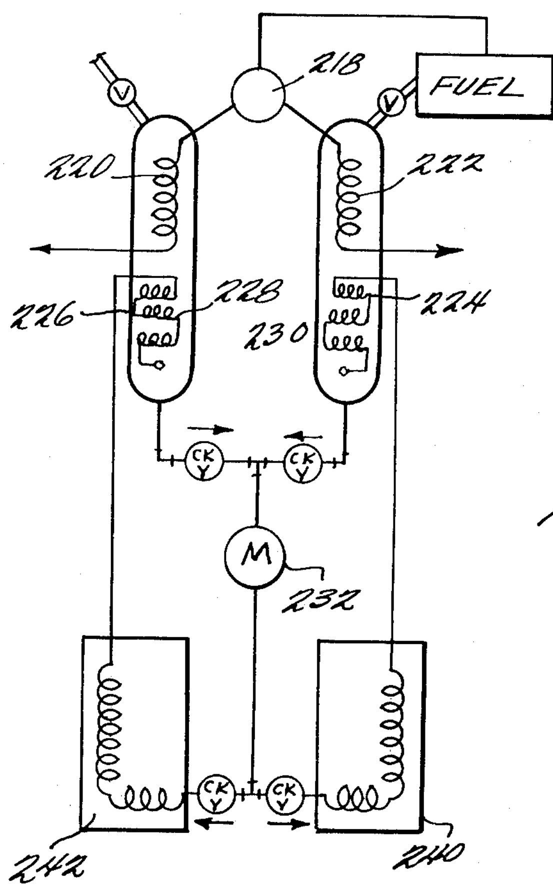

218
FUEL
V
220
222
226
228
224
230
CKV
M
232
242
240

Fig. 10

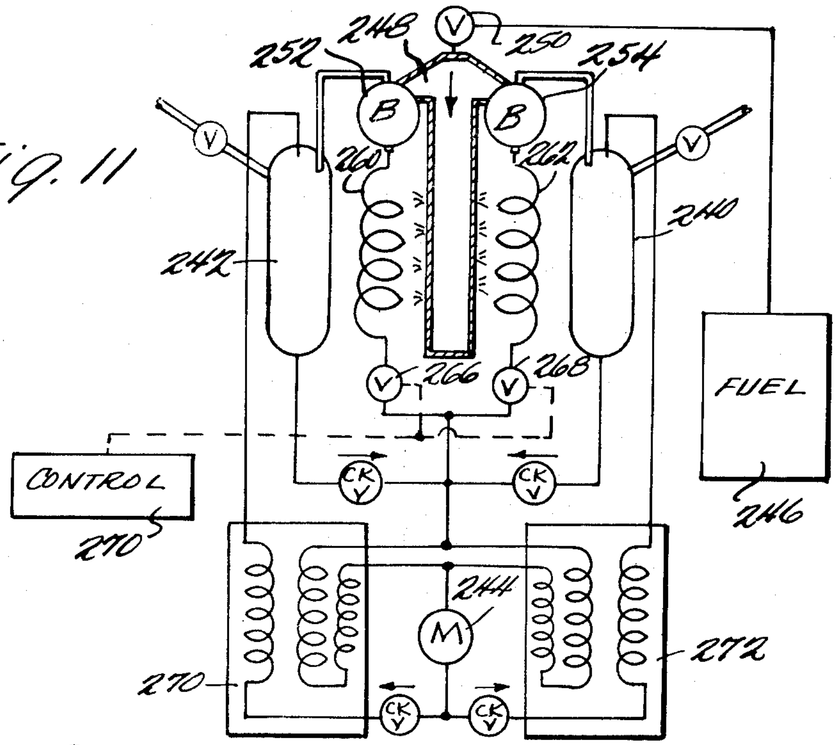

252
248
V
250
254
B
B
260
262
V
V
242
240
V
266
V
268
FUEL
CONTROL
CK V
CK V
270
246
244
M
272
270
CK V
CK V

Fig. 11

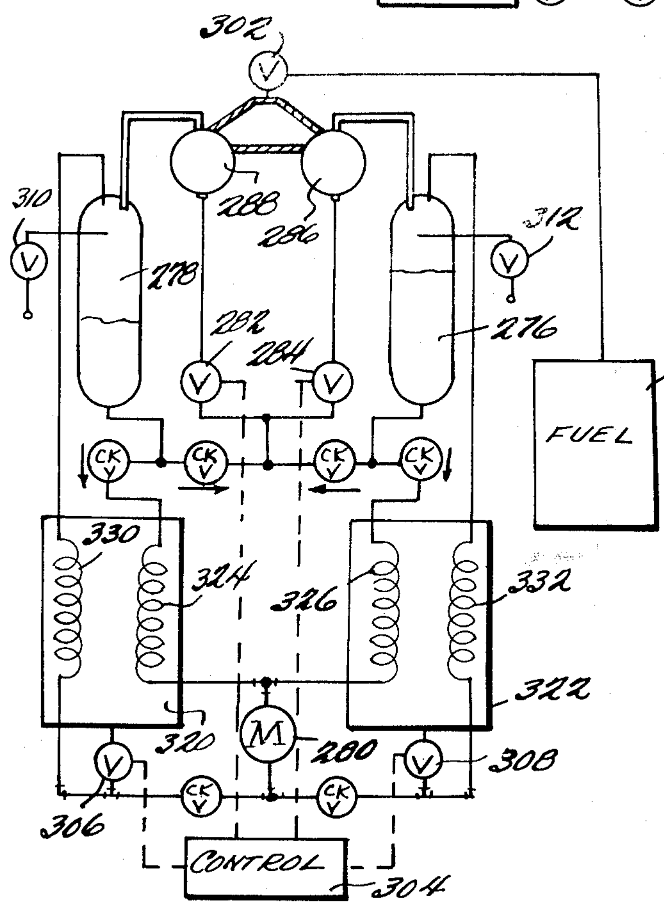

302
V
310
V
288
286
312
V
278
276
282
284
V
V
300
FUEL
CK V
CK V
CK V
CK V
330
324
326
332
322
320
M
280
V
V
308
CK V
CK V
306
CONTROL
304

Fig. 12

Fig. 13

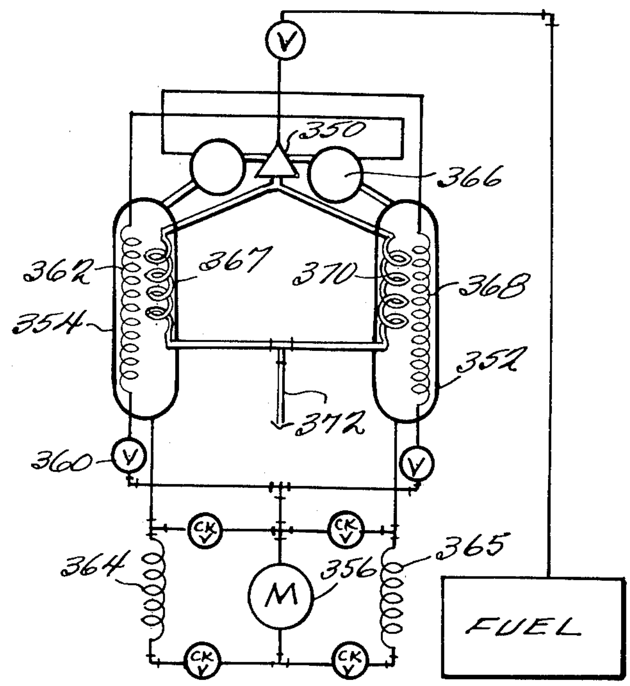
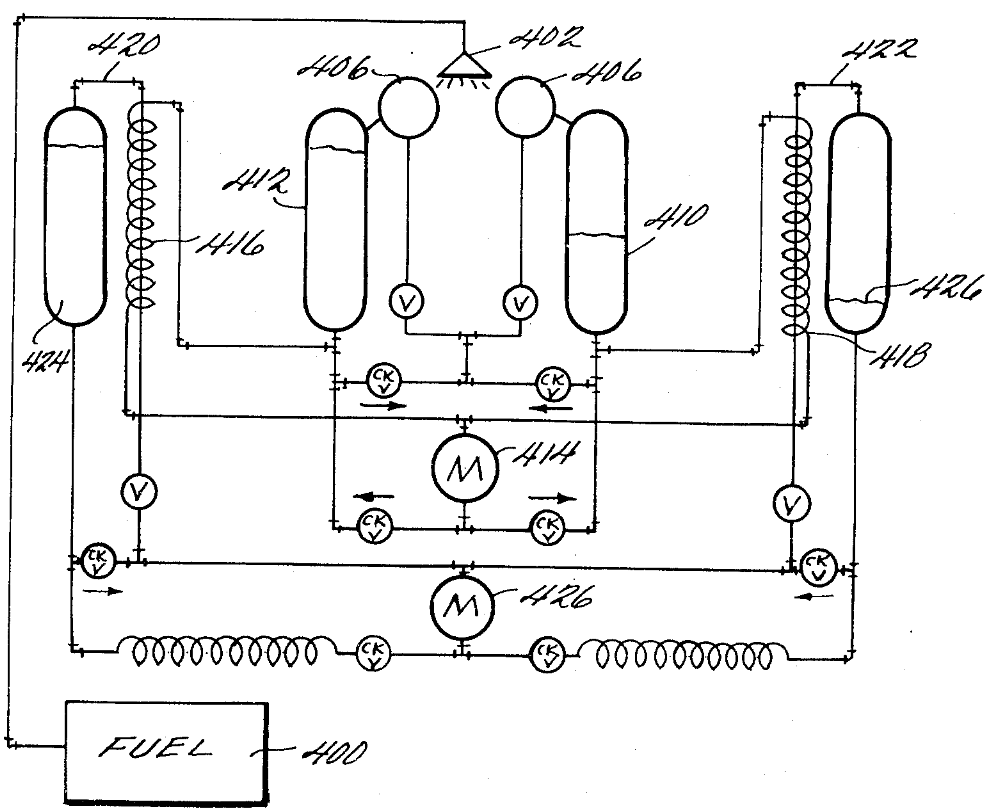

350
366
362
367
370
368
354
352
372
360
364
356
365
FUEL

Fig. 14


402
420
406
406
422
412
416
410
426
424
418
414
426
FUEL
400

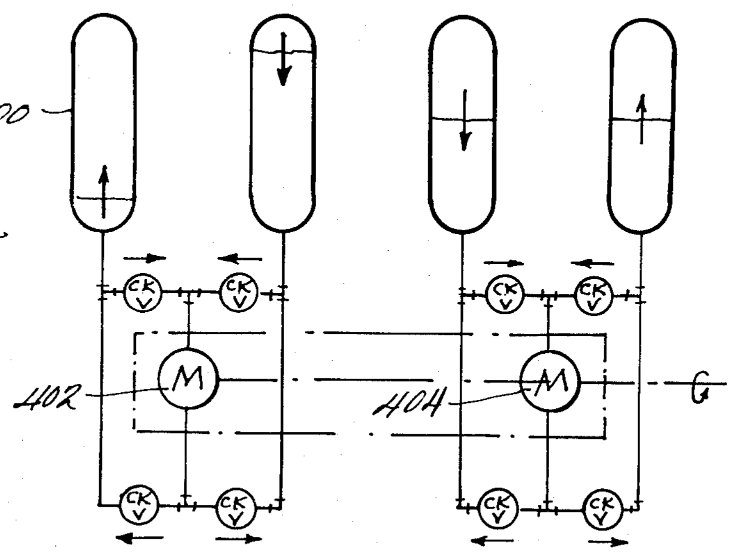


Fig. 15

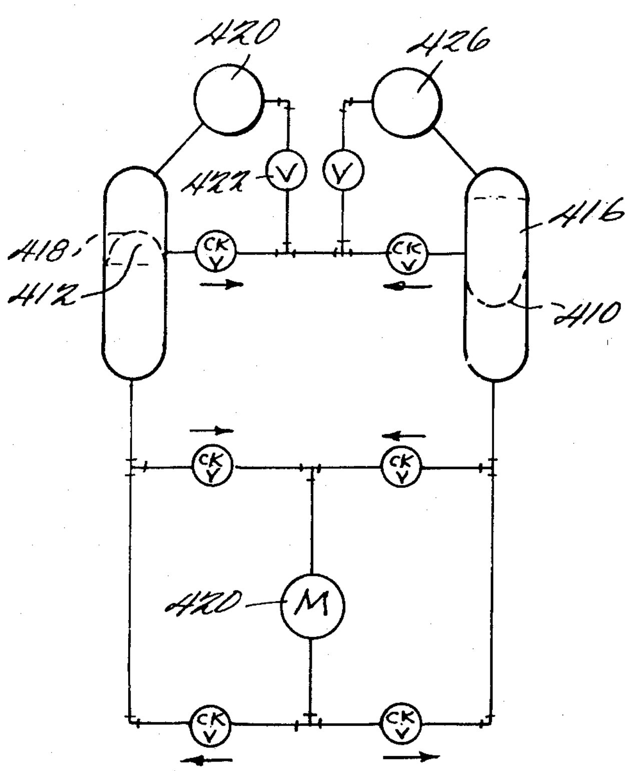


Fig. 16

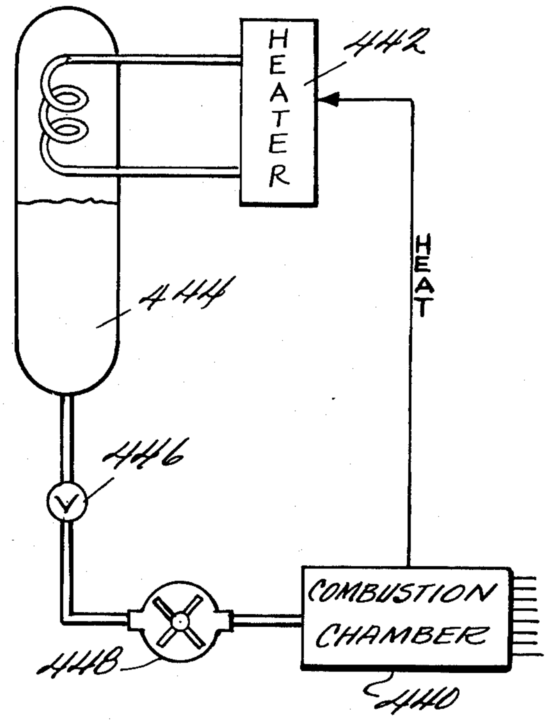

HEATER
442
444
446
448
COMBUSTION CHAMBER
440
HEAT

Fig. 18

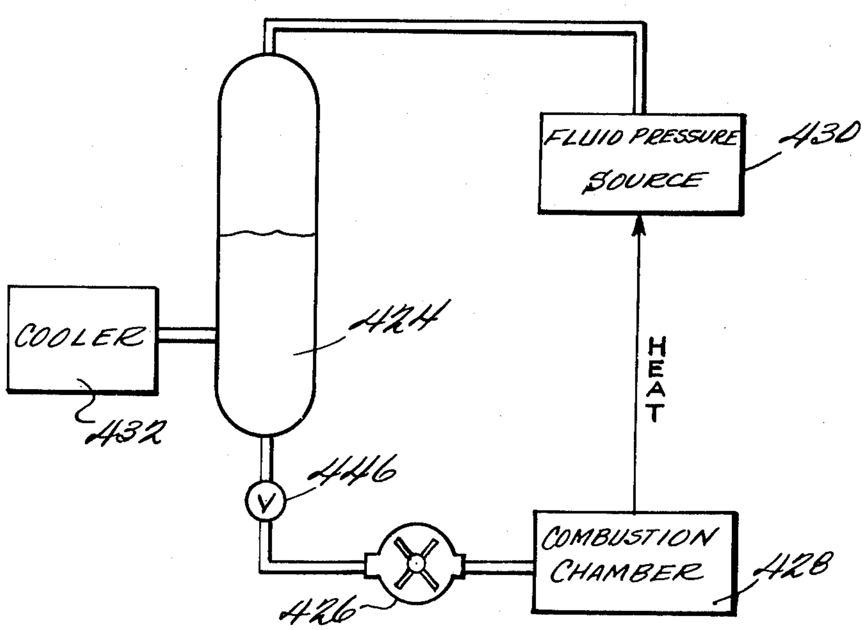

FLUID PRESSURE SOURCE
430
COOLER
432
424
HEAT
446
426
COMBUSTION CHAMBER
428

Fig. 17

VAPOR PRESSURIZED HYDROSTATIC DRIVE

This is a division of application Ser. No. 229,764, filed Feb. 28, 1972, now U.S. Pat. No. 3,830,065, which is a division of application Ser. No. 58,934, filed July 28, 1970, now U.S. Pat. No. 3,648,458.

BRIEF DESCRIPTION OF THE PRIOR ART AND SUMMARY OF THE INVENTION

The invention relation to a vapor pressurized hydrostatic drive for converting heat into mechanical motion.

Over the past few centuries, one of the continuing goals of technology has been the improvement of systems for converting energy in the form of heat into mechanical motion. The widely employed conventional steam engine and internal combustion engine are the products of this continued effort. Neither of these engines is, however, completely satisfactory. Both are complicated heavy machines whose efficiency in accomplishing the energy conversion is normally quite low. The internal combustion engine produces pollutants which are both dangerous and obnoxious.

One promising heat conversion apparatus which has been developed includes a tank containing a working fluid and a fluid motor operatively connected to the tank so that when heat is added to the system a pressure is generated on the fluid in the tank which forces it out the tank and through the motor, thus generating a mechanical output. A second tank can be added to the system so that the fluid after passage through the motor can refill that tank. When the second tank is full, pressure can be generated on the fluid in that tank to force fluid flow out of the second and through the motor to refill the first. Such systems are shown, for example, in Pike U.S. Pat. No. 228,555 and Parish U.S. Pat. No. 2,941, 608.

The present invention relates to a number of embodiments basically similar to such devices. In these embodiments, the basic engine is improved to increase its efficiency and make it more satisfactory for use as an energy conversion system.

Many other objects and purposes of the invention will become clear from the following detailed description of the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a first embodiment of the invention with a D.C. fluid motor,

FIG. 2 shows a further embodiment with an A.C. fluid motor,

FIG. 3 shows a device for injecting fluid as fine droplets into a steam generator,

FIG. 4 shows a further embodiment of the invention wherein the fluid to be varporized is drawn from the reservoir tank,

FIG. 5 shows a further embodiment of the invention in which a resonant coupled acoustic pump is employed to inject the fluid into a steam generator as fine droplets,

FIG. 6 shows a reservoir tank having a thin walled steam quench for preventing thermal shock to the reservoir walls,

FIG. 7 shows a further embodiment of the invention wherein the working fluid is a fuel which is combusted to provide heat,

FIG. 8 shows yet another embodiment of the invention in which fluid transmitted to the steam generator absorbs heat from the working fluid in the tank being refilled,

FIG. 9 shows a further embodiment of the invention in which a porous steam storage bed absorbs heat from the working fluid in the tank being refilled,

FIG. 10 shows another embodiment of the invention wherein a portion of the heat in the working fluid is recovered and employed to generate a mechanical output,

FIG. 11 shows another embodiment in which heat in the fluid on its way to the fluid motor is transmitted to fluid leaving the fluid motor on its way to refill one of the reservoir tanks,

FIG. 12 shows another embodiment of the invention wherein a portion of the working fluid is evaporated from the heat exchanger to cool the working fluid,

FIG. 13 shows another embodiment of the invention in which the working fluid which is vaporized absorbs heat from the working fluid in the tank being refilled,

FIG. 14 shows a further embodiment whereby heat in the working fluid on its way to the fluid motor is transferred to working fluid in a second system to cause vaporization of that second fluid and operation of a second fluid motor,

FIG. 15 shows an embodiment of the invention wherein two systems are connected together to a single shaft,

FIG. 16 shows an embodiment of the invention in which each reservoir includes fluids separated by an impermiable barrier which is able to move within the reservoir.

FIG. 17 shows another embodiment of the invention in which the heat generated by fuel being combusted is employed to generate vapor pressure to force the fuel through a fluid motor and into the combustion chamber,

FIG. 18 shows a modification of the embodiment of FIG. 17 in which the vapor pressure in the reservoir tank is generated by vaporizing a portion of the fuel in that tank.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to FIG. 1 which illustrates a hydrostatic drive system 18 suitable for use with a D.C. fluid motor. In this embodiment, as in many of the other embodiments of the invention, as discussed in detail below, vapor is alternatively directed into one of the two reservoir tanks 20 and 22 so that the working fluid in that tank is forced out of the tank by the pressure of the vapor, and through a conventional fluidic motor 38 to generate a mechanical output before it returns to refill the other tank. When the first tank is substantially depleted, the vapor pressure is directed into the refilled tank so that the fluid from that tank now flows again through motor 38 to refill the first, now depleted, tank.

In FIG. 1, a suitable reservoir 24 of a fluid such as water is connected to a conventional phase converter or boiler 26 which converts the fluid from a liquid to a vapor phase. This conversion may be accomplished by burning a suitable fuel such as a hydrocarbon adjacent boiler 26 so that the generated heat changes the phase of at least a portion of the fluid in boiler 26. Any other suitable arrangement for generating the vapor which is employed to impart motion to the working fluid can be employed. The vapor pressure output of boiler **26** is directed to either reservoir tank **20** or tank **22** via master valve **28** which may be a conventional solenoid valve or any other suitable type of conventional mechanism. As depicted schematically in FIG. **1**, valve **28** is operated by a suitable control apparatus **30**, which alternately causes valve **28** to direct the vapor pressure generated by boiler **26** to reservoir tanks **20** and **22**. Control **30** may be mechanically or otherwise linked to the fluid motor **38** so that the position of the valve **28** is responsive to the physical position of the rotating part of fluid motor **38**. Alternately, control **30** may include means for sensing the fluid level in tanks **20** and **22** and switching the tank which is being emptied whenever the fluid in a tank is detected below a certain predetermined level.

Assuming for the purposes of describing the operation of the embodiment of FIG. **1** that control **30** has shifted valve **28** to a position such that the vapor pressure generated by boiler **26** is transmitted into tank **22** as depicted, then that vapor pressure pushing the fluid in tank **22** causes working fluid to exit from the bottom of tank **22** and to flow through motor **38** via one way check vale **32**. Valve **32**, as well as the other check valves in this and the other embodiments set forth below, permit fluid flow in one direction but prevent it in the other. These valves may be of any suitable type and are well known in the art. After passage through motor **38**, the moving fluid passes through check valve **34** and enters tank **20**. The differential between the pressure of the fluid exiting from tank **22** and the fluid exiting from motor **38** prevents fluid from flowing back through check valves **36** and **38**. An exhaust valve **40**, which also is shown under the control of apparatus **30**, is vented to the atmosphere during this time so that the fluid can freely enter chamber **20**. Valve **42** at the same time is closed to prevent the loss of the vapor pressure generated by the flow of vapor into tank **22** via valve **28**.

The cyclic venting of tanks **20** and **22** to the atmosphere results in a gradual reduction in the quantity of working fluid in the system. Reservoir **24** provides some make-up fluid since some of the vapor directed into the tanks condenses therein and is thus added to the supply of working fluid. However, it may be desirable to provide some suitable arrangement for automatically or otherwise replenishing the working fluid from time to time.

When tank **22** has been depleted or substantially depleted, control mechanism **30** shifts the position of valve **28** so that the vapor pressure generated by boiler **26** is now directed into tank **20** and begins to force the fluid which has refilled it out of tank **20** and through fluid motor **38** via check valve **36**. At the same time, exhaust valve **40** is closed and valve **42** opened by apparatus **30** so that the fluid now flowing through motor **38** via check valve **36** returns to tank **32** via check valve **39**. Open valve **42** permits the vapor pressure in chamber **22** to escape to the atmosphere so that tank **22** can refill.

A portion of the fluid flowing out of one or the other of the tanks **20** or **22** also returns to reservoir **24** via valve **46** which may be controlled by apparatus **30** or may be manually or otherwise adjusted to provide a suitable flow of liquid into reservoir **24** for vaporization within boiler **26**. As mentioned above, while water is one suitable material which exists in the vapor and gaseous phase and can be suitably used in this arrangement, any other suitable fluid which can be satisfactorily converted from its liquid to its vapor phase can be employed.

Reference is now made to FIG. **2** which shows another embodiment of the invention of this application. In this arrangement, the fluid motor **50** is an A.C. hydrostatic motor which is capable of converting reciprocating motion into continuous shaft rotation, e.g. by means of a reciprocating or swash plate motor. Such A.C. motors are well known in the art, and no further discussion of them is necessary. This embodiment of the invention operates in the same fashion as the embodiment illustrated in FIG. **1** as discussed above with two tanks **52** and **54** alternately filled and emptied of the working fluid by means of vapor generated within boiler **54** and alternately directed to tanks **52** and **54** by master valve **56** which is under the control of a suitable control mechanism **58**. A reservoir **60** is provided in the system and a valve **62** connects reservoir **60** to the fluid in the two tanks for providing additional fluid for vaporization in boiler **54**. Boiler or vapor generator **54** produces cyclic pressure at N times the hydraulic motor **50** shaft rotation frequency, N being any suitable integer.

Reference is now made to FIG. **3** which depicts one suitable arrangement for injecting fluid into a boiler or simlar device, such as boiler **26** depicted in FIG. **1**, for conversion into a vapor phase such as steam. The fluid thus injected is preferably divided into droplets which are as small as possible to minimize the time required for vaporization. In the embodiment of FIG. **3**, fluid enters vessel **70** through a conventional inlet valve **72**. Vessel **70** is constructed or associated with piezo electric, magnetic restrictive, or solenoid driven material or structure so that the volume of vessel **70** is cyclically changed due to the harmonic residence of its elastic walls. Thus, the fluid which enters vessel **70** through inlet check valve **72** is cyclically injected into boiler **74** for conversion from a liquid to gaseous phase. This injection technique also finely divides the injected droplets. In fact, inlet valve **72** may not be required in operation because water is injected into the boiler steam generator **74** at such high rate to make back flow through the normally small orifices which will preferably be employed a negligible problem.

FIG. **4** illustrates another arrangement similar to that of FIG. **1** whereby the fluid which is converted into vapor is derived directly from the vessels themselves. In this arrangement, fluid lines **76** and **78** are connected to vessels **80** and **82** as shown. Valves **86** and **88** connect lines **76** and **78**, respectively, to a conventional boiler or other steam generator **90** which converts the received fluid from its liquid to its gaseous phase. Master valve **92** directs the fluid to tanks **80** and **82** alternately as in the embodiment of FIG. **1**, and the fluid forced from one tank by vapor pressure flows through actuator or fluid motor **94** and refills the other tank in the same manner as in FIG. **1**. Valves **86** and **88** are operated by control mechanism **100** which also controls master valve **92** so that fluid is drawn from the tank which is refilling to provide fluid to be vaporized to provide the pressure which imparts motion to the working fluid. As in the other embodiments, vapor pressure in the tank being refilled is vented to the atmosphere through valves **102** and **104**. Valves **86** and **88** are cyclically opened to cause flow into boiler **90**. The heat available from the walls of boiler **90** preferably converts the liquid to vapor. Preferably the period during which water flows into boiler **90** is related to the speed of sound in the vapor compared to its speed in the liquid and upon the geometrical proximities of valves and reservoirs.

FIG. **5** illustrates another embodiment of the invention similar to that of FIG. **1** in which a hydrostatic resonant coupled acoustic pump is employed to draw liquid from the drive system to be converted into vapor within boiler **110.** As in the arrangement of FIG. **1,** tanks **112** and **114** are alternately emptied and refilled with the working fluid by means of vapor pressure which is generated in boiler **110** and alternately directed into the respective tanks by master valve **116** which is controlled by a suitable control **120.**

Whenever additional working fluid, e.g. water, is required for boiler **110,** tuning fork **120** is set in motion by any suitable mechanism. For example, in this embodiment tuning fork **120** is shown connected to the hydrostatic motor **124** by some suitable linkage mechanism. The horn may also be driven by cams or strikers from the motor **124.** Horn **122** magnifies the acoustic excursion generated by fork **120** by the inverse ratio of the steam chamber inlet area to the base area so that water is pushed from the region of tuning fork **120** through horn **122** and injected into boiler **110** as fine droplets.

FIG. **6** illustrates one particular reservoir which is believed to be of particular use in conjunction with a system such as depicted in FIGS. **1–5** and in the other Figures discussed below. In this arrangement, the returning hot water enters tank **126** and is kept from the walls thereof by a thin-walled steam quench **128** which is provided with a number of holes which permit the returning hot water to exit therefrom. Quench **128** thus prevents the return water from thermally shocking the reservoir tank walls and also allows the heat stored in that wall to generate steam within the reservoir tank itself.

FIG. **7** illustrates yet another embodiment of the invention similarly to the basic D.C. hydrostatic drive system shown in FIG. **1.** In this arrangement, as in the others, fluid from two vessels **130** and **132** is alternately forced through a fluidic motor **134** via suitable check valves. However, this particular arrangement differs from those illustrated above in that the fuel which is burned to generate the heat which is converted to mechanical energy is also employed as the working fluid. The fuel, e.g. methane, is stored in a suitable reservoir **136** and added to the system at point **138** where the working fluid exists from fluidic motor **134.** The working fluid which is also the fuel then returns to the tank **130** or **132** which is being refilled through the associated check valve.

Part of the liquid which flows out of the tank **130** or **132** which is being depleted is also diverted through either valve **140** or **142,** which are both controlled by the control mechanism **134,** into either boiler **150** or **152,** respectively where heat is added to cause the fuel to change from a liquid to a gaseous state and expand into the associated tank so as to force the working fluid therein out its exit to drive fluid motor **138** and refill the other tank. The gas in the tank which is being refilled, for example, tank **130,** is also exhausted to a burner **160** via either valve **164** or **166.** An oxidant from a suitable reservoir **168** is also supplied to burner **160** for combusting the gaseous fuel. Thus the liquid fuel serves as the working fluid and the vapor which must be exhausted from the tank being refilled then combusted to provide a compact heat source. Floating head barriers may be disposed in each of the vessels **130** and **132** to increase heat transfer between the gas and fluid stages.

FIG. **8** illustrates yet another modification of the basic hydrostatic drive system set forth in FIG. **1.** In this arrangement, heat exchange from the vapor expanding within the reservoir tank to feed water on its way to the boiler or vapor generators provides a simple regenerative system. Tanks **170** and **172** are filled with a suitable working fluid as in the other embodiment, and this working fluid is alternately forced out of one of the tanks **170** and **172** through fluidic motor **174** to refill the other tank. Further, some of the fluid forced from tank **172** or **174** is diverted into line **176,** and from line **176,** the working fluid thus diverted flows through either coil **178** or **180** depending on which of the check valves **184** and **186** is open. Valves **184** and **186** are under the control of a suitable control apparatus **190** as shown so that the fluid is normally permitted to flow only through the coil **178** or **180** which is in the tank being refilled. The fluid passing through coil **178** or **180** absorbs heat from the working fluid in the surrounding tank and from the hot vapor in that tank as it is exhausted. Thus, the feed fluid enters either boiler **200** or **202** at an elevated temprature, which reduces the quantity of heat necessary to convert the fluid from a liquid to a vapor phase before injection into tank **170** or **172.**

FIG. **9** illustrates another embodiment of the invention which is regenerative in the sense that heat in the working fluid is employed, at least in part, to generate the vapor pressure which forces that fluid for one tank through the motor to refill the other tank. In this embodiment, two tanks **210** and **212** are designed to be filled to a maximum level which is just below the porous heat storage bed **214** with a fluid which will change from liquid to vapor phase at a suitable temperature. When heat is added to one side of storage bed **214,** for example, the side associated with tank **210,** the added heat causes a conversion of some of the fluid in vessel **210** from its liquid to its vapor phase resulting in a volume expansion which force part of the remaining fluid out the exit of vessel **210** and through a fluidic motor **220** to refill tank **210.** When tank **210** has been emptied to a desired level, the procedure is reversed and heat is added to the portion of the porous heat storage bed **214** associated with tank **212.** Next the working fluid in tank **212** is partially vaporized so that part of the remaining fluid is out the exit of tank **212** and through fluidic motor **220** into vessel **210.**

Meanwhile in the tank that is being refilled with working fluid, bed **214** is absorbing heat from the fluid entering that tank. This heat is retained in bed **214** until that tank has been refilled and additional heat can thereafter be added to cause partial vaporization of the fluid in that tank. Thus, the system is regenerative in the sense that a portion of the heat which is imparted to the working fluid and not initially used to generate mechanical output is thereafter removed from the fluid and reused to generate mechanical output.

FIG. **10** shows yet another embodiment of the invention in which heat is exchanged in the system in a manner similar to an Ericson cycle. In this arrangement, heat is generated, for example, by burning methane or some other suitable fuel in burner **218**, and then conducted into the vessel through coils **220** and **222**. Suitable valves may be provided for switching the flow of the exhaust gases and the heat to the respective tanks for cyclically emptying and refilling tanks **224** and **226**. The fluid re-enterting either of the tanks also passes through a coil **228** or **230** before being emptied into vessel **226** or **224**, respectively, so that the heat which exists in the fluid which is leaving the tank on its way through motor **232** is in part given back to the water which is returning to the vessel. Similarly, coils **242** and **244** are provided to at least partially cool the fluid exiting from motor **232**.

FIG. **11** shows yet another embodiment of the invention whereby the heat imparted to the working fluid which would be otherwise lost is in part saved and used to generate a mechanical output. In this embodiment, two tanks **240 242** are alternately filled and emptied with working fluid which passes through conventional fluid motor **244**. Fuel such as kerosene, natural gas, powered coal or LP gas from a suitable source **246** is combined with a suitable oxidant and combusted in a suitable burner **248** after passage through a valve **250** which may be manually or automatically adjusted to permit flow of a desired amount of fuel. Heat from the burner **248** is employed to convert the working fluid injected into boilers **252** and **254** into vapor, in which state it is directed into tanks **240** and **242**, respectively. Suitable valve means may be provided in boilers **252** and **254** if necessary or desirable.

A portion of the fluid exiting from the tank **240** and **242** being emptied is drawn through either coil **260** or **262** into boiler **252** or **254**, respectively. Valves **266** and **268** control the flow of fluid into coils **260** and **262** and these valves are controlled in turn by a suitable control apparatus **270** which insures that fluid will enter only that boiler which is supplying vapor to the tank which is being emptied. Thus, if fluid is to be forced out of tank **240** by the addition of vapor to the top thereof, then valve **268** will be open and valve **266** closed so that the fluid which passes valve **268** will pass through coil **262** and be injected by a suitable injector into boiler **254**. As the working fluid passes through coil **262**, heat is imparted to it by the burner **248** to preheat the fluid so that it arrives at the boiler at an elevated temperature, thus considerably increasing the amount of vapor that can be injected into the tanks **240** and **242** within any given period of time.

Further, water or other fluid existing from the tank being emptied passes through heat exchanger **270** or **272** before passage through fluid motor **244**. These heat exchangers reduce the temperature of the working fluid on its way to motor **244** and thereby decrease the possibility of damage to the fluid motor because of exposure to overheated fluid. The heat in the fluid which enters heat exchanger **272** from the tank **240** or **242** being emptied is in part transferred to the fluid which is leaving motor **244** and is being returned to the tank **240** or **242** which is being refilled so that this heat raises the temperature of the fluid in the tank being refilled.

Reference is now made to FIG. **12** which shows another embodiment of the engine whereby water derived as a by-product of hydrocarbon or other fuel combustion is employed as a make-up supply for the working fluid of the system and further as means of rejecting into the atmosphere heat which is not converted into useful mechanical output. This heat transfer management technique significantly simplifies the apparatus required for converting chemical potential energy into shaft work and increases the efficiency compared to Otto or Diesel cycle processes.

Hydrocarbon fuels yield carbon monoxide and water when burned to completion in oxygen or oxygen-bearing atmospheres. The amount of water produced compared to the amount of carbon monoxide produced depends upon the hydrogen to carbon ratio of the fuel being burned. In common liquid petroleum fuels, the amount of water produced is approximately equal to the amount of fuel burned. In liquefied petroleum gas fuels (butane, propane, methane, etc.) combustion products tend to an even greater extent to be water. Vaporization of water at a fixed pressure fixes the boil off temperature. At sea level the temperature for boil off is about 212°F. and, at lower atmospheric pressure, the boil off temperature is correspondingly lower. The embodiment of the invention as illustrated in FIG. **12** uses this by-product of hydrogenous fuel combustion as a make-up working fluid supply.

In this embodiment, as in the other embodiments, two reservoir tanks **276** and **278** are alternately discharged and refilled with working fluid which flows from one tank to the other through fluid motor **280**, thus, converting the pressure of the working fluid and the kinetic energy embodied in the flow of that fluid into useful output shaft power. The flow of the working fluid is also cyclically directed via valves **282** and **284** into the boilers **286** and **288** which provide the vapor pressure for forcing the working fluid cyclially from tanks **278** and **280**. Fuel from a suitable source **300** is directed via valve **302** into boilers **286** and **288**, respectively. Valve **302** may be under the control of a suitable mechanism such as control apparatus **304** which controls valve **282** and **284** as well as valves **306** and **308** in the same fashion as discussed above.

In contrast to the embodiment illustrated in FIG. **11**, the fuel derived from source **300** is combusted within boilers **286** or **288** which alternately may be any other type of combustion device suitable for combusting the fuel and directing the combined vapor and exhaust gases therefrom. The exhaust gases of combustion together with the water or other vapor produced from the working fluid are alternately passed into tanks **276** and **278** to force the fluid therein to flow out the exit and pass through the fluid motor **280**. In this fashion, the water vapor which is derived from the burning of the hydrocarbon fuel and thus added to the system at least in part replaces the vapor which is exhausted to the atmosphere by the alternate opening of valves **310** and **312** during alternate refilling of tanks **276** and **278**.

A portion of the fluid existing from motor **280** also passes through valves **306** and **308** which are under control of apparatus **304** and enter the evaporator radiator devices **320** and **322**. These devices are preferably provided with an open top or are otherwise accessible to the atmosphere so that the fluid that enters these devices evaporates to the atmosphere tanking with it heat imparted to the evaporating fluid by the working fluid which passes through coils **324** and **326** on its way to fluid motor **280**. Part of the heat imparted to the fluid in evaporators **320** and **322** is also transmitted to the fluid returning to tanks **276** and **278** via coils **330** and **332**. Thus, part of the heat of the working fluid in tanks

276 and 278 is employed to pre-heat the fluid returning to the tanks after passing through motor 280 and part is vented to the atmosphere so that the fluid which is passed through motor 280 is at a temperature which will not damage the motor.

As in the other embodiments, the working fluid in this embodiment may be water or may be more sophisticated solutions, e.g. mixtures of water and other compounds which might, for example, prevent freezing, increase lubricity, increase or decrease heat transfer, or aid or retard absorption and retention of combustion gases. Conversely, the working fluid may contain a less dense compound or particle which floats upon its surface, thus providing insulation between the combustion gases and working fluid during the period that the pressure is being transmitted in from the hot gases to the working fluid in the reservoir. Compounds added to the working fluid may be separated from vaporizable or combustible portions of the working fluid prior to admission to the generator-combustor sections such as boilers 286 and 288.

By utilization of common and inexpensive steels, ceramics, bearings, valves and other hardware, the embodiment of the invention illustrated in FIG. 12, as well as the embodiments of the other figures, maybe designed to operate at temperatures of, for example, 2000°F. and 6000 lbs. per square inch at the inlet of the tank receiving the vapor through 160°F. or lower by use of heat-dams, insulation, and other arrangements such as flow deflectors and surface coatings. Conversely, the upper portion of the reservoir walls may be maintained at temperatures exceeding 1200°F. if desired, thus allowing heat input and storage previous to steam generaton by conduction of heat into the fluid at the time during the filling of the reservoir tank that the fluid level reaches the high wall temperature level.

The basic versatility of the embodiment of FIG. 12 is further illustrated by the potential of using more than two fluid reservoirs. Manufacture of 100 horsepower modules consisting of two reservoirs and one motor actuator allows engine units of 200 HP, 400 HP, 600 HP, and 1000 HP, or more, to be assembled simply by joining the output shafts of each motor to a common output shaft. Such an output shaft would only have the minimum fabrication requirement of being attachable per the application function and would not involve the various sophistications characteristic of internal combustion engine crankshafts. Similarly multiple reservoir modules may be hydraulically connected to a single motor.

The vast variety of hydrostatic, hydraulic, and hydrodynamic actuators further exemplifies particuarly the versatility of the embodiment of FIG. 12 in various applications only being served today by complex mechanisms involving clutches, transmissions, angle drives, universal joints, and differentials. The probability of costly failure is inherently reduced in the embodiment. FIG. 12, as well as the other embodiments, compares favorably to conventional internal combustion reciprocating engines by the reduced number of working parts, the reduced metal to metal relative motion, and the reduced gyratory forces involved. The ability to achieve high horsepower to weight ratios at high efficiencies, particularly when materials selections typical to aircraft turbines are made, makes the engine shown in FIG. 12 preferable to turbines for propeller driven aircraft.

Reference is now made to FIG. 13 which shows another embodiment of the invention which is somewhat similar to the conventional Stirling cycle engine. The Stirling cycle distinguishes itself primarily as one employing regeneration techniques in which heat is transferred from the working fluid into a thermal reservoir as a working fluid begins its expansion. After mechanical output has been generated, the stored heat is re-added to the cooled working fluid as it is being reheated to the maximum temperature of the cycle.

The embodiment of the invention illustrated in FIG. 13 is similar in that it is regenerative, but this embodiment also employs advantageous aspects of both the liquid and gas phases in the process of converting heat into mechanical work. In the embodiment illustrated in FIG. 13, heat, for example, produced by combustion of hydrocarbon or other fuels, nuclear fission, or fusion is transferred into vapor phases of the working fluid at heat source 350 which may be, for example, a boiler such as in the other embodiments.

As in the other embodiments, heat from source 350 is employed to convert working fluid from a liquid to a gaseous phase and to direct the vapor pressure thus generated alternately into tanks 352 and 354 so that working fluid is forced out of one of the tanks and through fluidic motor 356 to refill the other tank. A portion of the working fluid which is forced out of each of the tanks is also employed to provide liquid for conversion to a gaseous phase. However, in this embodiment, fluid on its way to a vapor generator such as a boiler passes through a heating coil in the tank being refilled so as to absorb as much of the heat as possible from the fluid entering that tank and also to absorb as much heat as possible from and extended heat transfer surface which is mounted adjacent to the coil through which the fluid passes. For example, a portion of the fluid exiting from tank 352 passes through valve 360 and coil 362 which is mounted in tank 354 as shown. During the time that tank 354 is refilling, working fluid on its way to boiler 366 passes through tank 354 via coil 362. The fluid returning to tank 354 from motor 356 passes through negative heat rejection coil 364 and the fluid returning to tank 352 through negative heat rejection coil 365.

Further, an extended heat transfer surface comprising coil 367 within tank 354 is mounted adjacent coil 362. Coil 367 absorbs heat from the working fluid reentering tank 354 and also absorbs heat from the exhaust gases generated by source 350 which are exhausted to the atmosphere via coil 367 as well as coil 370. The heated fluid existing from coil 362 is injected into boiler 366 where it is converted into its vapor phase and that vapor then transmitted to tank 352 to force the working fluid therein out its exit and through motor 356. Coils 368 and 370 within tank 352 operate similarly when that tank is being refilled, and tank 354 is being emptied. As shown, coils 362 and 368, which each preferably comprise a hollow coil, are connected to an exhaust 372 so that, for example, the hot combustion gases are transmitted through coils 366 and 368 so that the heat of the combustion gases can, at least in part, be imparted to the working fluid which is to be vaporized and eventually employed to generate a mechanical output. Nuclear loop transfers, of course, would not need an exhaust but preferably employ a similar circuit to optimize the efficiency of energy conversion.

Reference is now made to FIG. 14 which shows yet another embodiment of the invention. In this arrangement, two or more working fluids are employed to permit extension of the thermal gradiant to higher and lower temperatures than allowed by a single working fluid. This arrangement offers considerable advantages from the standpoint of thermodynamics. In this embodiment, as in the embodiment of FIG. 11, fuel from a suitable source **400** is burned by a suitable burner **402** adjacent conventional boilers **406** and **408.** Vapor thus generated is alternately directed into reservoir tanks **410** and **412,** one of which is continually emptying and refilling the other through fluidic motor **414** and thus generating a continuous and useful mechanical shaft output.

However, fluid issuing from either of the tanks **410** or **412** passes through a heat exchanging coil **414** or **416** on its path through motor **414,** thus imparting heat to the fluid in lines **420** and **422** respectively which will normally contain working fluid having a different critical point than the working fluid in tanks **410** and **412.** The heat thus imparted causes the fluid in lines **420** and **422** to change from its liquid to its vapor phase and the resulting expansion of the working fluid causes the fluid in tanks **424** and **426** alternately to be forced through a second fluid motor **426** which may be in parallel with the first motor for combining the mechanical shaft output.

A number of combinations of working fluids can be employed in this arrangement. A few examples are mercury and water, mercury and potassium-sodium eutectic, water and freon, water and silicone fluids, freon and liquified gases and many others. A simple extension of the illustrated system permits the development of engines which use three or four or more working fluids.

Reference is now made to FIG. **15** which shows yet another embodiment of the invention in which two hydrostatic systems, each having two tanks are employed to operate a single shaft with two motors **402** and **404** connected in parallel. It should be apparent that any number of systems such as illustrated above can connected together to generate any desired power output.

FIG. **16** shows yet another embodiment of the invention wherein elastic diaphragms **410** and **412** are connected between two working fluids. The diaphragms separate each of the two tanks **416** and **418** into an upper and lower compartment. The fluid in the upper compartment, for example, the fluid in the upper part of tank **418** can be expanded for any suitable means, for example, by heating in boiler **420** with the result that the downward pressure exerted by elastic diaphragm **412** forces the fluid in the lower portion of tank **418** out of its exit and through hydrostatic motor **420** thus deriving a mechanical output. The fluid thus forced from tank **412** then refills the bottom portion of tank **410** which then forces the fluid out of the upper portion and thereof and into the upper portion of tank **418** via valve **422.** The process is then reversed with the fluid in the lower portion of tank **410** being forced out by the fluid expanded by boiler **426** and directed into the upper portion of tank **410.** Similarly pistons, bellows, and floating particles may be used to separate the fluids.

Reference is now made to FIG. **17** which shows a hydrostatic drive system employing only a single reservoir tank **424.** This embodiment which could be used, for example, in a rocket system for travel in outer space employs the heat generated by the fuel which is combusted to supply the rocket thrust to impart motion to the fuel which then serves as the working fluid for conventional hydrostatic or other similar motor **426.** The heat generated in combustion chamber **428** which is normally wasted is employed to convert the fuel fluid from a liquid to a gaseous state in pressure source **430** so that the pressure thus generated forces the fuel fluid in tank **424** out its exit and through motor **426** to be burned in combustion chamber **428.** A cooling arrangement **432** can be disposed adjacent the tank **424** for condensing some of the vapor added to tank **424** into a liquid which can then be used as the working fluid and combusted after passage through motor **426.**

FIG. **18** shows a modification of the embodiment of FIG. **7** whereby the heat generated by combusting the working fluid in a combustion chamber **440,** for example, to generate thurst to propel a rocket or other vehicle is employed by a heater **442** which has coils disposed about reservoir tank **444** which is filled with a suitable fuel fluid. The heat added to the fluid in tank **444** by heater **442** causes a portion of it to be converted into a vapor state and expand, thus forcing part of the working fluid in chamber **444** out past valve **446** and through fluid motor **448** to combustion chamber **440** where it is burned. Thus, the waste heat from the combustion is employed to generate the mechanical output which can be employed in the device for any purpose desired.

The above discussed embodiments of the invention can of course be satisfactorily employed in a number of applications. These include, but are not limited to:

a. Air heating and cooling,
b. Lawn mowers,
c. Motor generator units,
d. Garden Tractors,
e. Sump pumps,
f. Garbage Disposal and Compaction,
g. Irrigation pumps,
h. Electrical Power Generation
i. Compressor Stations
j Oil and Gas Drill Drilling and Pumping
k. Elevators and Lifts
l. Conveyors
m. Ore Crushers and Pulverizers
n. Grain Mills
o. Scrap Shredders and Compactors
p. Automobile
q. Rail Cars
r. Bus and Train
s. Truck and Tractors
t. Other Farm Equipment
u. Highway construction equipment
v. Pleasure and Commercial Boats
w. Aircraft

The following Table represents a few resultant engine horsepowers and weights based upon the use of fired boiler rated steels and conventional hydrostatic motors as derived from computer modeling studies.

TABLE

Engine Shown In	Maximum Continuous HP	No. of Reservoirs	Full Torque RPM Range	Total Engine Dry Weight
FIG. 12	5	2	100–2000 or 2000–20,000	30 lbs.
FIG. 12	15	4	100–2,000 or 2,000–20,000	72 lbs.
FIG. 13	50	4	100–2,000	128 lbs.
FIG. 13	100	4	100–2,000	182 lbs.
FIG. 11	300	2	100–2,000	287 lbs.
FIG. 11	600	4	100–2,000	665 lbs.

The use of titanium alloys, composites, and coatings will permit considerable improvement in the weight to power ratios of the Table. However, for most applications the Table ratios will be sufficient.

Many changes and modifications in the above discussed embodiments of the invention can of course be made without departing from the scope of the invention. Accordingly, that scope is intended to be limited only by the scope of the appended claims.

What is claimed is:

1. An energy conversion system comprising:

first means for containing a first working fluid,

second means for containing said first working fluid,

first motor means operatively communicating with said first working fluid in said first and second containing means for receiving said first working fluid so that said first working fluid flows into and out of at least a portion of said first motor means so as to generate a mechanical motion,

first means for transmitting said first working fluid from said first containing means to said first motor means,

second means for transmitting said first working fluid from said second containing means to said first motor means,

third means for transmitting said first working fluid from said motor means to said first containing means,

fourth means for transmitting said first working fluid from said motor means to said second containing means,

means for alternately supplying a given fluid in a vapor phase to said first containing means at a pressure such that said working fluid is forced from said first containing means, through said first transmitting means, into and out of said portion of said motor means through said third transmitting means and into said second containing means and to said second containing means at a pressure such that said first working fluid is forced from second means, through said second transmitting means, into and out of said portion of said motor means, through said fourth transmitting means and into said first means,

third means for containing a second working fluid different from the working fluid in said first and second containing means

fourth means for containing said second working fluid,

means for receiving said given fluid in a liquid phase and for heating said given fluid in said liquid phase to convert it to said given fluid in said vapor phase,

second motor means operatively communicating with said second working fluid in said third and fourth containing means for receiving said second working fluid so that said second working fluid flows into and out of at least a portion of said second motor means so as to generate a mechanical motion,

fifth means for transmitting said second working fluid from said third containing means to said second motor means,

sixth means for transmitting said second working fluid from said fourth containing means to said second motor means,

seventh means for tansmitting said second working fluid from said second motor means to said third containing means,

eighth means for transmitting said second working fluid from said second motor means to said fourth containing means,

first heat exchanger means associated with said first and said seventh transmitting means for transmitting heat from the fluid in said first transmitting means to the fluid in said seventh transmitting means, and

second heat exchanger means associated with said second and eighth transmitting means for transmitting heat from fluid in said second transmitting means to the fluid in said eighth transmitting means.

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