FIG. 1

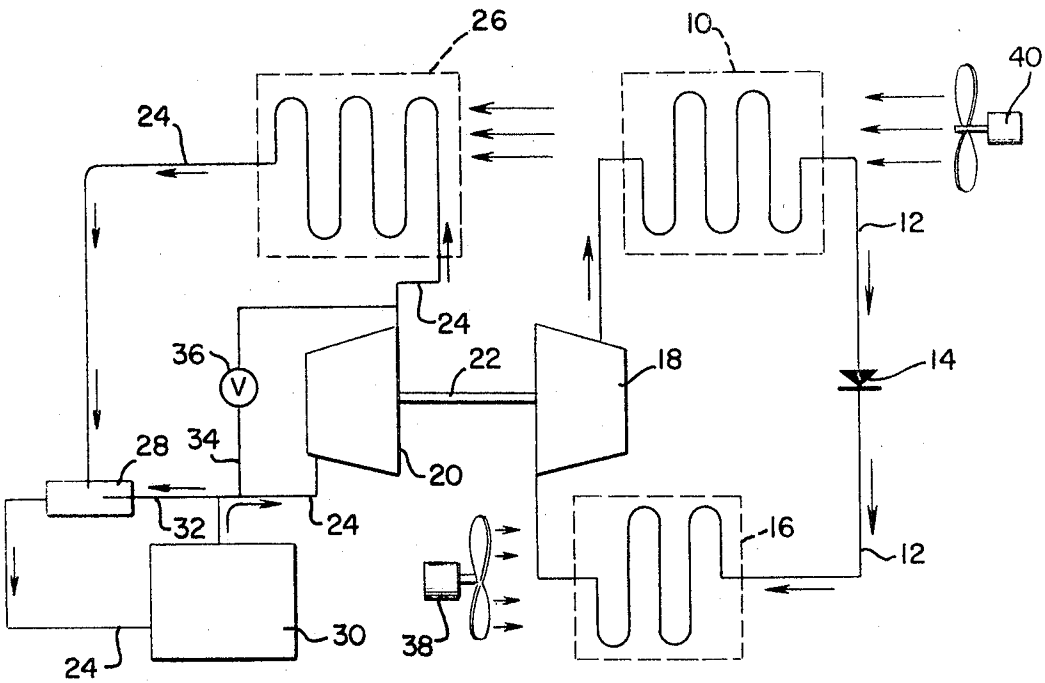

FIG. 4

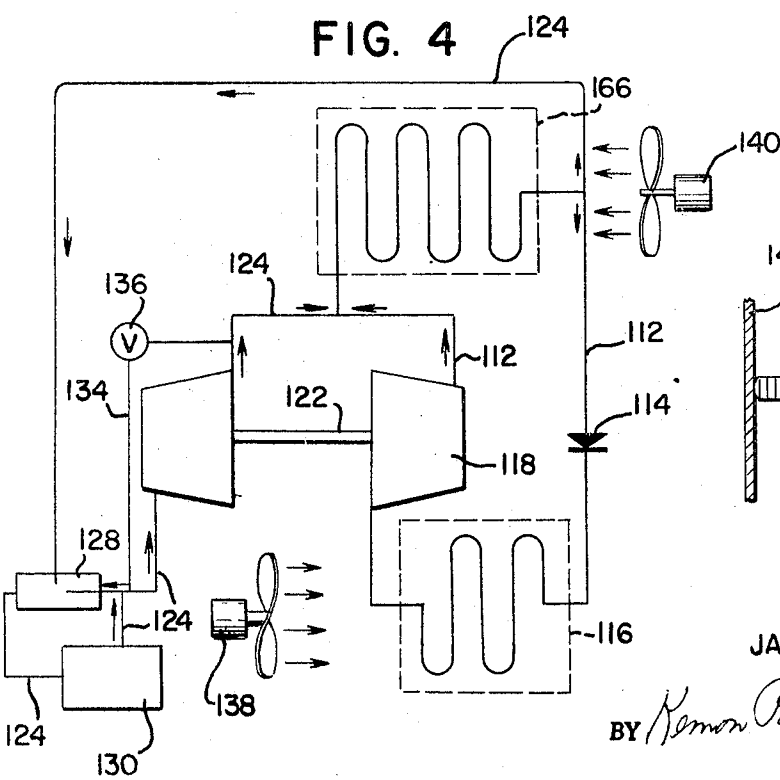

FIG. 5

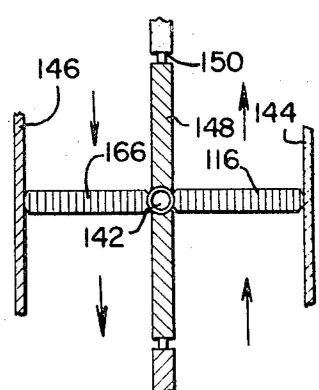

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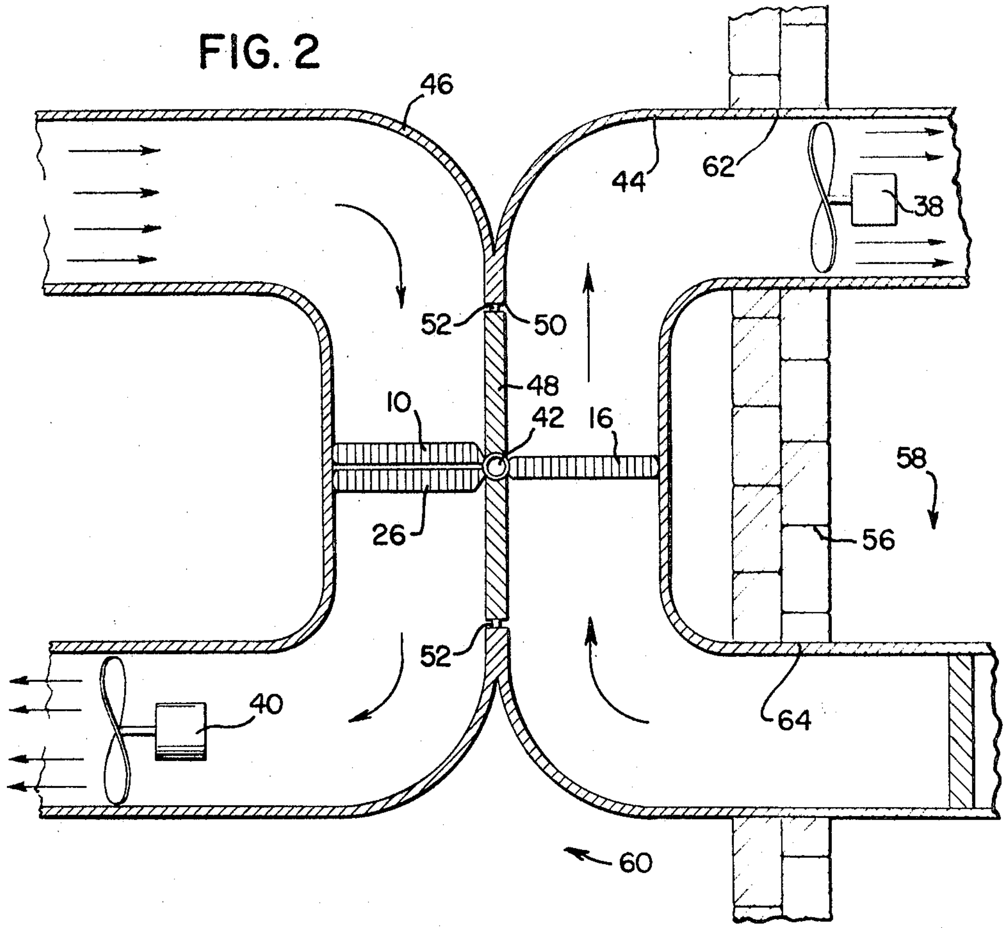
FIG. 2



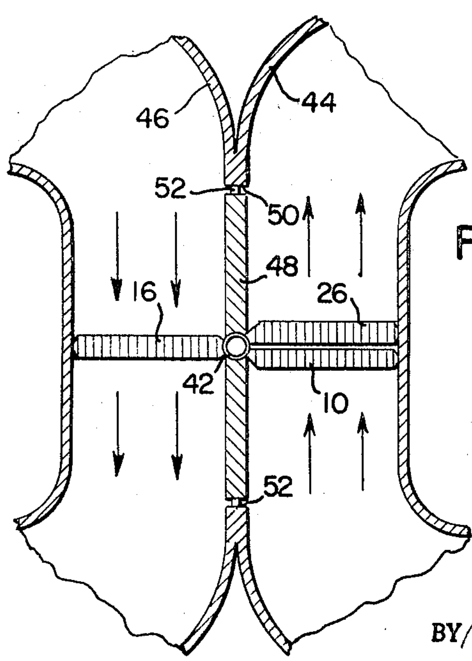


FIG. 3

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3,519,066
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3,519,066
HEAT PUMP

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Int. Cl. F25d *9/00*
U.S. Cl. 165—29 7 Claims

ABSTRACT OF THE DISCLOSURE

A heat pump having a closed cycle refrigeration system including a condenser, evaporator and compressor and a vaporized fluid power system for driving the compressor including a boiler and condenser. The condensers are arranged in such a manner that heat is transferred to the ambient when the apparatus is utilized to cool a conditioned zone and heat is transferred to the conditioned zone when the apparatus is utilized to heat a conditioned zone. The evaporator simultaneously removes heat from the conditioned zone during cooling thereof and removes heat from the ambient during heating of the conditioned zone. A fluid bypass system is provided to supply heat directly from the boiler to the condenser of the vaporized fluid power system during extreme, low ambient temperature conditions when the conditioned zone is being heated.

BACKGROUND OF THE INVENTION

Heat pump apparatus are in wide use for heating and cooling buildings in the art. Prior art heat pumps generally include a refrigeration system having a condenser exposed to ambient and an evaporator exposed to the zone to be conditioned to provide cooling for the zone. Means, generally including flow control valves, are provided to transfer the evaporation portion of the process to the ambient and the condenser portion of the process to the condition zone to provide heating for the zone. Due to the relatively limited heat output capability of the refrigeration system condenser, prior art heat pumps have found application primarily in moderate climates or have necessitated the use of additional or supplementary heating apparatus in conjunction therewith.

SUMMARY OF THE INVENTION

This invention relates generally to devices for transferring heat energy from a low temperature locality to a high temperature locality and more specifically to a heat pump for accomplishing such transfer by mechanical means involving the compression and expansion of a fluid by mechanical refrigeration. The invention relates more particularly to such an apparatus as applied to heating or cooling a building by transferring heat from or to the ambient air.

This invention provides a novel heat pump apparatus which avoids the disadvantages of the prior art by furnishing a vaporized fluid power system including a condenser for powering a closed cycle refrigeration system whereby the condensers of the vaporized fluid power system and of the refrigeration system are utilized to selectively transfer heat to the ambient or to the conditioned zone while the evaporator of the refrigeration system is utilized to extract heat from the ambient or the conditioned zone.

The invention also provides a novel evaporator-condenser structure which may be quickly manipulated to switch from the function of extraction of heat from, to the transfer of heat to the conditioned zone.

The invention further provides novel means for bypassing the power unit of the vaporized fluid power system for circulating heat energy directly to the condenser

thereof to increase the heat output of the apparatus during heating of the condition zone at low ambient temperatures.

In the preferred embodiment, the invention comprises a refrigeration system comprising a condenser, expansion means, evaporator and compressor, the compressor being driven by a vaporized fluid power system comprising a rotary boiler, turbine and condenser. The condensers and evaporator are rotatably mounted in opposed relationship so that the evaporator may be mechanically moved from communication with the conditioned zone to communication with the ambient while the condensers are simultaneously moved from communication with the ambient to communication with the conditioned zone, thereby providing means to switch from transfer of heat from, to transfer of heat to the conditioned zone. A bypass is provided to communicate fluid from the boiler of the vaporized fluid power system, around the turbine, directly to the condenser thereof to increase the heat output of the vaporized fluid power system when required for heating the conditioned zone.

These and other objects of the invention will become better understood to those skilled in the art by reference to the following detailed description when viewed in light of the accompanying drawings wherein like numerals throughout the figures thereof indicate like components and wherein:

FIG. 1 is a schematic view of a heat pump apparatus in accordance with the invention;

FIG. 2 is a fragmentary plan view, in section, of the evaporator-condenser structure of the invention of FIG. 1 disposed in ducting and configured to transfer heat from the conditioned zone;

FIG. 3 is a view similar to FIG. 2 showing the evaporator with the condenser structure of the invention disposed in such a manner to transfer heat to the conditioned zone;

FIG. 4 is a schematic view similar to FIG. 1 showing another embodiment of the invention; and

FIG. 5 is a fragmentary plan view similar to FIG. 3 showing the evaporator-condenser structure of the embodiment of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, the heat pump comprises a refrigeration apparatus including a a condenser **10** communicating in series through a conduit **12** with an expansion valve **14**, evaporator **16** and a compressor **18**. Power for the compressor **18** is derived from a vaporized fluid power system comprising a turbine **20**, connected to the compressor **18** through a shaft **22**, and communicating in series through a conduit **24** with a condenser **26**, an injector **28** and a boiler **30**. The injector **28** is powered by a branch conduit **32**, communicating with the conduit **24** at the portion thereof supplying fluid to the turbine **20**, and serves to increase the pressure of the fluid circulating from the condenser **26** to the boiler **30** in a manner well known in the art.

A bypass conduit **34**, including a valve **36**, communicates with the conduit **24** on either side of the turbine **20** to provide a means to selectively bypass the turbine. Air circulating means such as fans **38** and **40** are disposed to induce air flow over the evaporator **16** and the condensers **10** and **26** respectively.

The aforedescribed components may be of any type commonly known in the art. Although illustrated schematically as an axial flow rotary turbine-compressor, for example, the compressor may take the form of a radial flow turbine and/or compressor or reciprocatory motor-compressor structure if so desired.

In the disclosed embodiment, it is contemplated that fluid in the refrigeration system will comprise one of the suitable conventional refrigerants such, for example, as ammonia or one of the fluorocarbons, while the fluid in the vaporized fluid power system will preferably comprise a halogenated hydrocarbon suitable for the purpose such, for example, as Freon 114 (dichlorotetrafluoroethane $CClF_2CClF_2$) or Freon-318 (octafluorocyclobutane C_4F_8). A vaporized fluid power system particularly suitable for this purpose is disclosed in Pat. No. 3,315,466, issued Apr. 25, 1967. In the event that such a fluid power system with a rotary turbine-compressor structure is utilized to transmit power between the vaporized fluid power system and the refrigeration system, segregation of the fluids and lubrication of the turbine-compressor may be accomplished with the bearing and seal system disclosed in Pat. No. 3,258,199, issued June 28, 1966.

In utilizing fluids such as the above-mentioned Freons as working fluids in the vaporized fluid power system, cavitation problems are encountered in transmitting the fluid from the condenser to the boiler. It is contemplated that such problems, if encountered, can be overcome by subcooling the fluid supplied to the injector **28** by means of a structure such as the subcooling column **16** disclosed in the aforementioned Pat. No. 3,315,466.

Although the boiler **30** may be of any of the types common in the art, for the purposes of compactness and efficiency as well as for particular adaptability for use with fluorocarbons, it is preferred that a boiler structure such as the rotary vapor generator disclosed in U.S. Pat. No. 3,260,050, issued July 12, 1966, be utilized. If such a boiler is used, as disclosed in that patent, a major portion of the pumping work necessary for circulating fluid through the vaporized fluid power system can be accomplished in the rotary boiler and the work required from the injector can thereby be reduced or eliminated. For this reason, it is possible that the injector **28** may be, in some cases, eliminated from the system by proper design.

Referring now to FIG. 2 of the drawings, the evaporator **16** and the condensers **10** and **26** are shown mounted in opposed substantially coplanar relationship to one another on a rotatable member **42**, disposed between a conditioned zone duct **44** and an ambient duct **46**. The fans **38** and **40** are mounted in the ducts **44** and **46** respectively to circulate air as shown by the arrows through the ducts. A movable panel **48** is disposed in an opening **50**, formed between the ducts **44** and **46** and is mounted for rotation on the rotatable member **42** in perpendicular relationship to the condensers **10** and **26** and the evaporator **16**. A suitable elastic seal **52** is provided between the panel **48** and the opening **50** to block communication between the ducts **44** and **46** when the panel **48** is aligned therewith as illustrated.

A wall **56** segregates a conditioned zone, indicated generally at **58**, from an ambient area, indicated generally at **60**. The duct **44** penetrates the wall **56** through openings **62** and **64** to provide communication with the conditioned zone **58**.

In operation, with the apparatus in the configuration illustrated in FIGS. 1 and 2 and the valve **36** (FIG. 1) closed, the conditioned zone **58** is cooled by energization of the boiler **30** and the fans **38** and **40**. Upon energization of the boiler, as more particularly described in aforementioned Pat. No. 3,260,050, the vaporized fluid power system operates generally in accordance with that disclosed in aforementioned Pat. No. 3,315,466 with the substitution of the injector **28** for the main pump **20** and elimination of the recuperator **10** thereof. Heated, high pressure fluid is delivered through the conduit **24** to the turbine **20**, thereby driving the compressor **18** through the shaft **22**. Turbine exhaust fluid is directed through the conduit **24** to the condenser **26** whereby heat is removed therefrom by passage of air therethrough by means of the fan **40** and the duct **46**. Fluid is returned to the boiler **30** through the conduit **24** by means of the influence of the injector **28** deriving energy for increasing the feed pressure to the boiler from a portion of high energy fluid diverted thereto through the branch conduit **32** as described above.

Fluid, compressed in the compressor **18**, is circulated through the condenser **10** for removal of heat therefrom by air flow directed thereover by means of the fan **40** and the duct **46**. The cooled high pressure fluid is then transmitted through the conduit **12** to the expansion valve **14** for expansion and cooling thereof in a conventional manner. The expanded, cooled fluid is then transmitted through the evaporator **16** for a transfer of heat thereto from conditioned zone air directed thereover by means of the fan **38** and the duct **44** in a manner well known in the refrigeration art. The expanded, warmed refrigeration fluid is then returned to the compressor **18** for recycling thereof in a closed cycle.

It should be noted at this point that the arrangement of the condensers **10** and **26** relative to the direction of air flow through the duct **46** is particularly efficient since the Coefficient of Performance of a Carnot cycle is a function of the difference between the temperature of heat in and the temperature of heat rejected divided by the temperature of heat in as in the following relationship:

$$COP_{\text{Carnot}}=\frac{T_1-T_2}{T_1}$$

while the Coefficient of Performance of a refrigerator is a function of the temperature of heat in, divided by the difference between the temperature of heat rejected and the temperature of heat in as in the following relationship:

$$COP_{\text{Refrig.}}=\frac{T_3}{T_2-T_3}$$

The overall Coefficient of Performance is then as follows:

$$COP_{\text{Total}}=\frac{T_1-T_2}{T_1}\times\frac{T_3}{T_2-T_3}$$

When the heat rejector or condenser structures are placed in series, either the hot body of heat or the cold body of heat can be rejected at the higher temperature. Presuming the following:

T_1=temperature of heat supplied.

T_{2a}=temperature of heat rejected from the power condenser **26**.

T_{2b}=temperature of heat rejected from the refrigerator condenser **10**.

T_3=temperature of heat supplied to refrigerator.

The overall Coefficient of Performance of the heat pump then is as follows:

$$COP_{\text{Total}}=\frac{T_1-T_{2a}}{T_1}\times\frac{T_3}{T_{2b}-T_3}$$

For example, by first placing the refrigerator condenser **10** upstream to receive the coolest supply of airflow and assuming the following values (absolute):

$T_1=1010.$
$T_{2a}=595.$
$T_{2b}=585.$
$T_3=505.$

For these parameters, the Coefficient of Performance is calculated as follows:

$$COP=\frac{425}{1010}\times\frac{505}{80}=2.59$$

By reversing the condensers and placing the power condenser **26** upstream of the refrigeration condenser **10** with the above same assumptions, the parameters are:

$T_1=1010.$
$T_{2a}=585.$
$T_{2b}=595.$
$T_3=505.$

The Coefficient of Performance then is as follows:

$$COP=\frac{425}{1010}\times\frac{505}{90}=2.36$$

or an increase in Coefficient of Performance of .23 by proper arrangement of the condensers, as illustrated.

Referring now to FIG. 3 of the drawings, the evaporator-condenser of FIG. 2 is shown rotated 180° to place the condensers **10** and **26** in the conditioned zone duct **44** and the evaporator **16** in the ambient duct **46**. The panel **48** once more aligns with the ducts **44** and **46** to provide segregation of airflow therebetween.

Since fluid connection from the condensers **10** and **26** and the evaporator **16** with the remainder of the system must be accomplished through six conduits as described above, it is preferable, in order to avoid multiple seal problems, to design the connections in such a manner that communication is provided while allowing 180° rotation of the structure. Such communication may be accomplished by providing tubes formed as helical springs twistable through 180° or communicating tubes of sufficient length to permit a 180° twist without yielding the tube material. It has been found that such can be accomplished with steel tubes of the following characteristics, for example:

$E_s=12\times10^6$ p.s.i.
$S_s=20,000$ p.s.i.
$d=.625$ inch.
Straight length=58.9 in.

It should be noted at this point, that since the condenser side of the structure would normally have a higher resistance to airflow than the evaporator side, it is advisable to make provision for increasing the airflow through the condenser side of the structure. This could be accomplished by providing a two-speed arrangement on the fans **38** and **40** so that the fans may be switched from a higher airflow when the condenser section is disposed in a particular duct to a lower airflow when the evaporator side is disposed therein. Another alternative would be to mount a supplementary fan on the condenser structure to automatically compensate for the additional flow resistance therethrough.

With the apparatus structured in accordance with the configuration shown in FIG. 3, heat is supplied to the conditioned zone by means of rejection from the condensers **10** and **26** disposed in the duct **44** while heat is extracted from air circulated through the duct **46** by the evaporator **16**. Heat supplied in this manner is suitable for moderate cold weather conditions and temperature may be controlled at a desired level by regulating the amount of heat supplied to either or both of the condensers **10** or **26**. In moderate weather conditions, the compressor supplies some heat to the condenser **10** while whatever additional heat is required may be extracted from the condenser **26**.

In very cold weather conditions, the compressor **18** will normally not supply sufficient heat through the condenser **10** to enable the heat derived from the turbine through the condenser **26** to suitably augment the heat output. Under these conditions, it is more efficient to remove the compressor from the line and direct heat generated by the boiler **30** directly to the condenser **26**. This is accomplished by opening the valve **36** and bypassing the turbine **20** to channel the heated fluid for the boiler **30** directly through the conduit **34** to the condenser **26**, thereby channeling all of the heat from the boiler **30** to the airflow directly.

Referring now to FIG. 4 of the drawings, another embodiment in accordance with the invention is illustrated. Since fluorocarbons such as the above-mentioned Freons are equally suitable for use as refrigerants, the heat pump can utilize a single fluid system. This is accomplished by joining the exhaust from the turbine and the discharge

from the compressor and directing the flow to a common condenser. In such a system, illustrated in FIG. 4 components thereof corresponding to like components of the preceding figures are indicated by like numerals of the next higher order. In this figure the exhaust from the turbine **120** is manifolded into a combined condenser **166** through the conduit **124** with the exhaust or discharge from the compressor **118** fed through the conduit **112**. The condensate from the condenser **166** is divided subsequent to condensation in the conduit **124**, for return to the boiler **130**, and the conduit **112**, for channeling through the expansion valve **114**. The operation of the remainder of the system is identical to that described for the embodiment of FIG. 1.

In FIG. 5, the evaporator-condenser structure is shown disposed in the ambient duct **146** and conditioned zone duct **144** and operates in a manner identical to that described for the embodiment of FIGS. 2 and 3 for switching from cooling, as illustrated, to heating of the conditioned zone.

In the single fluid system disclosed in FIGS. 4 and 5, it is possible to substitute an injection or jet type compression apparatus for the rotary turbine-compressor illustrated. The principles of operation of such an apparatus are well known in the steam power plant art and are illustrated by the injector **28** utilized in the embodiment of FIG. 1. In such a device, the high energy, high temperature fluid from the boiler **130** would be injected through the conduit **124** into the low energy fluid in the conduit **112** after passage thereof through the evaporator **116**, thereby raising the pressure and energy level of the fluid entering the condenser **166**. After cooling in the condenser **166**, the high energy fluid would then be divided as described above, a portion thereof returning to the boiler **130** while the remainder thereof is expanded through the expansion valve **114** for reentry into the evaporator **116**.

What has been set forth above is intended as exemplary of teachings in accordance with the invention to enable those skilled in the art in the practice thereof. It should therefore, be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is new and therefore intended to be protected by Letters Patent of the United States is:

1. A heat pump for transferring energy between a conditioned zone and an ambient zone comprising:
- a closed cycle refrigeration apparatus including in series compressor means, first condenser heat exchange means and evaporator heat exchange means;
- a vaporized fluid power apparatus including in series vapor generator means, second condenser heat exchange means and means transferring energy from the output of said vapor generator means to said compressor means; and
- flow control means to communicate the heat product of said condenser heat exchange means to one of said zones and the heat intake of said evaporator heat exchange means to the other of said zones including a single rotor means so positioned to selectively reverse communication of said heat exchange means with said zones.

2. A heat pump in accordance with claim **1** wherein said first and second condenser heat exchange means comprise a single condenser structure and wherein the fluid in said refrigeration and power apparatus is manifolded upstream and divided downstream of said condenser structure.

3. A heat pump in accordance with claim **1** wherein said means transferring energy from the output of said vapor generator means comprises a rotary turbine-compressor unit.

4. A heat pump in accordance with claim **1** wherein said vaporized fluid power apparatus further includes means including a valve for bypassing said means transferring energy from the output of said vapor generator means to thereby selectively direct fluid from said vapor generator means directly to said condenser means.

5. A heat pump in accordance with claim **1** where said flow control means further comprises means to transmit air from said zones through said heat exchange means and wherein said second condenser heat exchange means is disposed in series on the downstream side of said first condenser heat exchange means with respect to the airflow therethrough.

6. A heat pump in accordance with claim **5** wherein said flow control means further comprises parallel, adjacent ducts, each of said ducts being in communication with one of said zones, said evaporator heat exchange means being mounted in substantially coplanar adjacent relation to said condenser heat exchange means on a rotatable axis disposed between said ducts, said ducts having openings in the common wall thereof encompassing said rotatable axis and accommodating said heat exchange means for rotation therein, and a panel coextensive with said openings and mounted substantially normal to said heat exchange means on said rotatable axis to segregate flow through said ducts when said heat exchange means are substantially normal thereto.

7. A heat pump in accordance with claim **1** wherein said vapor generator comprises: an enclosure for containing a vaporizable fluid therein, a vapor exhaust standpipe disposed in said enclosure, means to control fluid com-

munication between said enclosure and said standpipe, means to heat said enclosure to provide vaporization of the fluid therein, a rotating support in said enclosure coaxially disposed intermediate the ends of said standpipe, a vapor dome mounted on said rotating support to enclose the upper end of said standpipe, a fluid heat exchange and transmitting tube assembly disposed on said rotating support, means to transmit vapor from said assembly to said vapor dome for storage therein, a preheater tube assembly fixedly mounted around the walls of said enclosure adjacent said rotating support and fluid assembly, means to supply liquid to said preheater tube assembly for preheating therein and means to transmit preheated liquid therefrom to the fluid assembly disposed on said rotating support, and means to control the quantity of liquid and heat supplied to said generator.

References Cited

UNITED STATES PATENTS

3,153,442	10/1964	Silvern	165—50
2,984,087	5/1961	Folsom	62—325

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U.S. Cl. X.R.

62—402, 498; 165—50