

[54] **THERMALLY POWERED DIAPHRAGM PUMP SYSTEM FOR HEAT TRANSFER**

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[52] U.S. Cl. **62/324, 62/116, 62/467, 62/498, 62/501, 62/510, 417/151**

[51] Int. Cl. **F25b 13/00**

[58] Field of Search..... **62/116, 467 P, 467 R, 467, 62/500, 498, 501, 510, 324**

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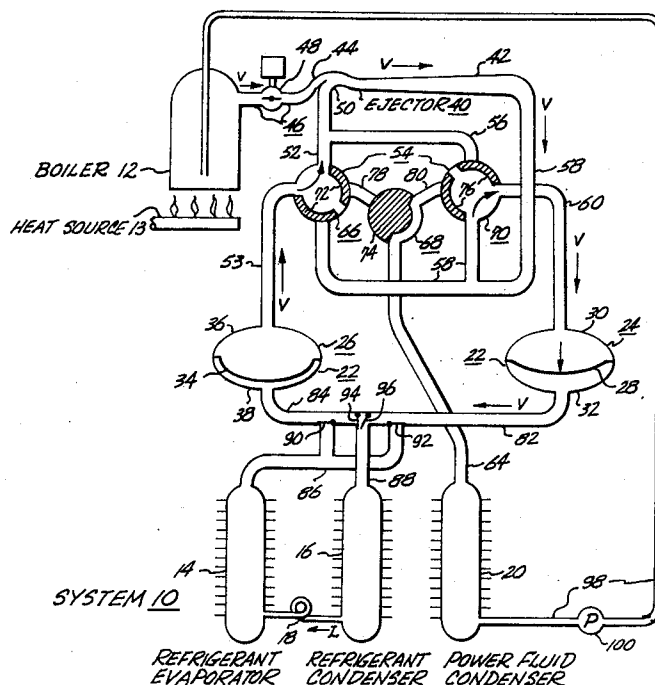
Primary Examiner—William J. Wye

Attorney—Kenneth W. Thomas

[57] **ABSTRACT**

A pneumatic diaphragm pump system shown embodied in a thermally powered refrigeration system with means for heat pumping with a high coefficient of performance while using any of several safe and non-toxic refrigerants. The pump system is driven by pressurized gaseous power fluid through a cycle in which in two embodiments an ejector salvages energy from the adiabatically expanding gaseous fluid in a compartment bounded by a pneumatic diaphragm. Means is provided for cyclic storing of energy and preheating any liquid returned to the gaseous fluid power source.

18 Claims, 18 Drawing Figures



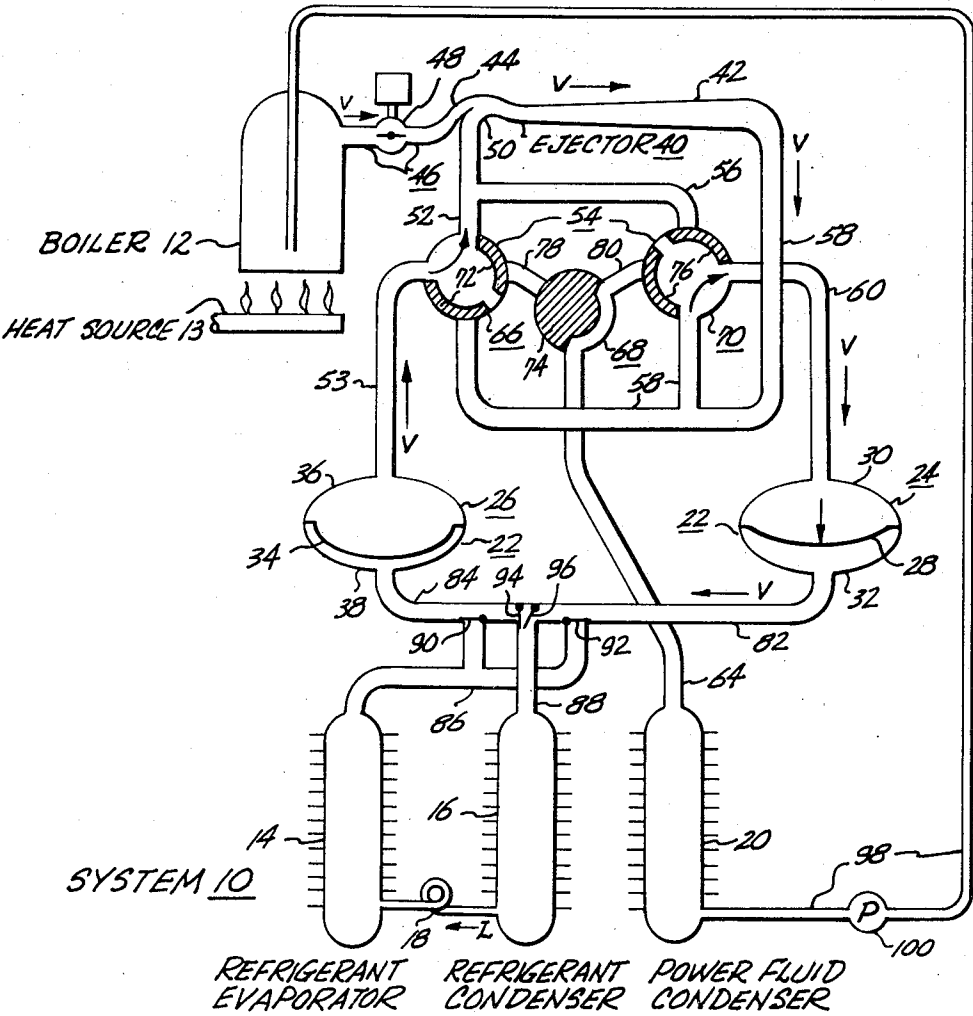


Fig. 1a.

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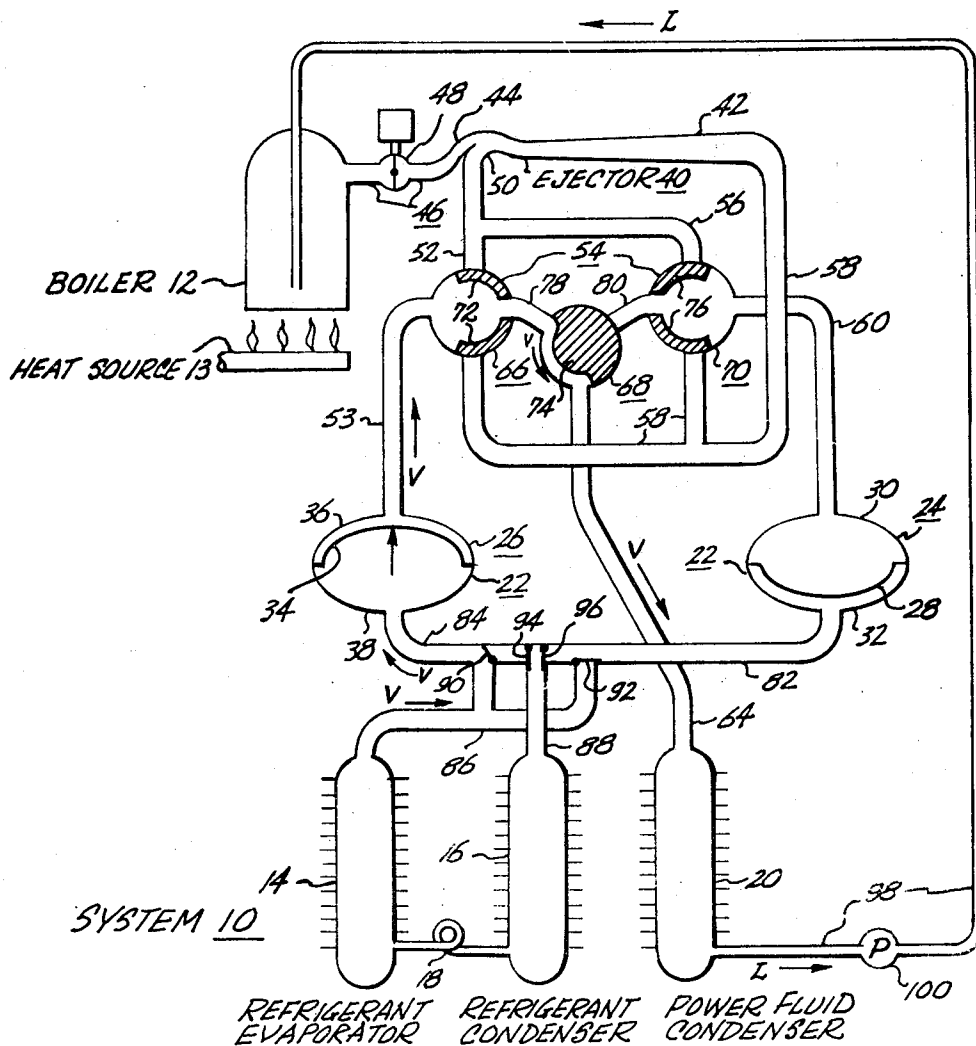


Fig. 1b.

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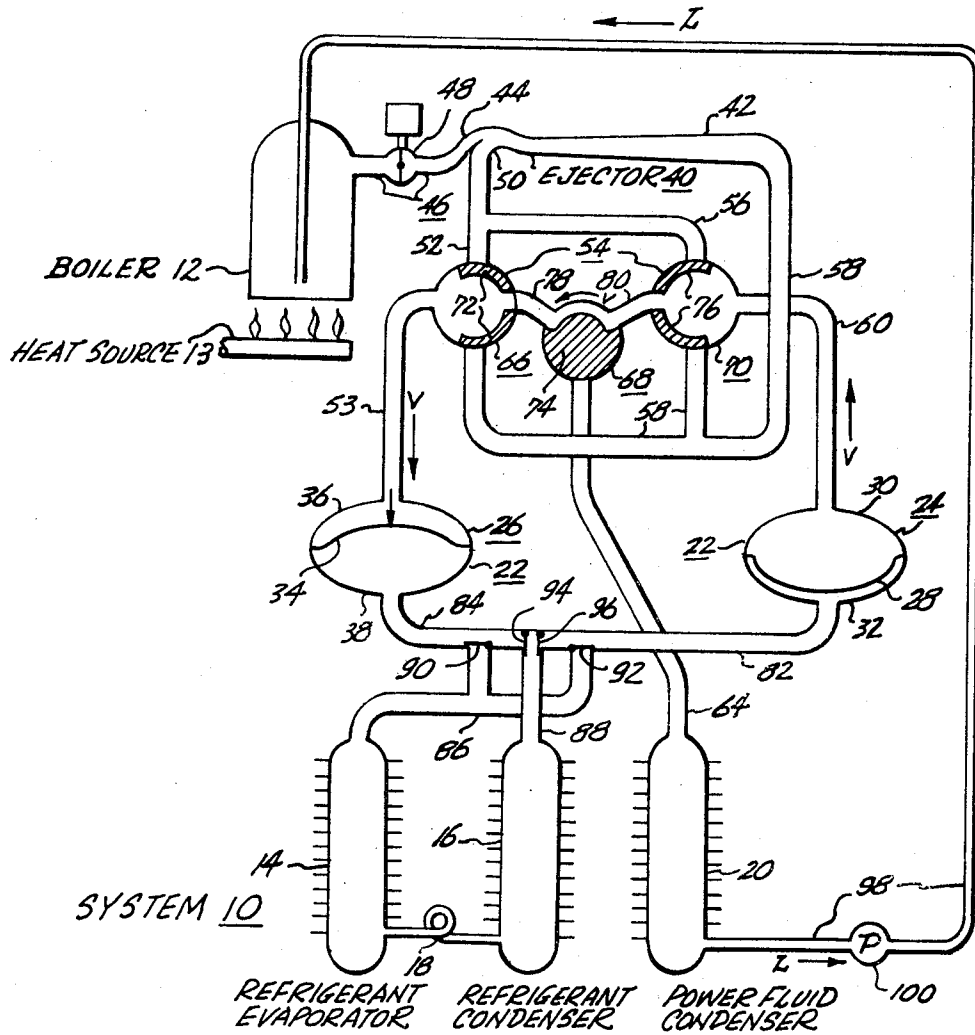


Fig. 1c.

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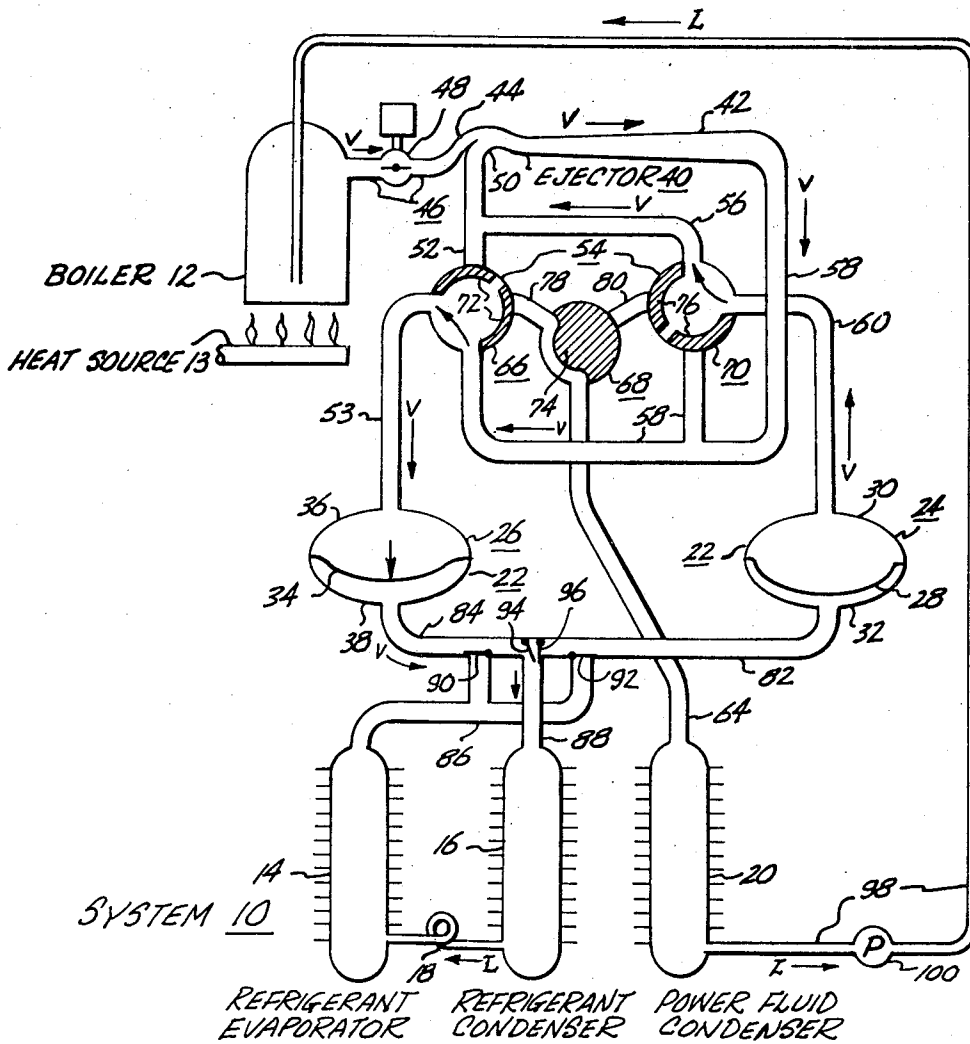


Fig. 1d.

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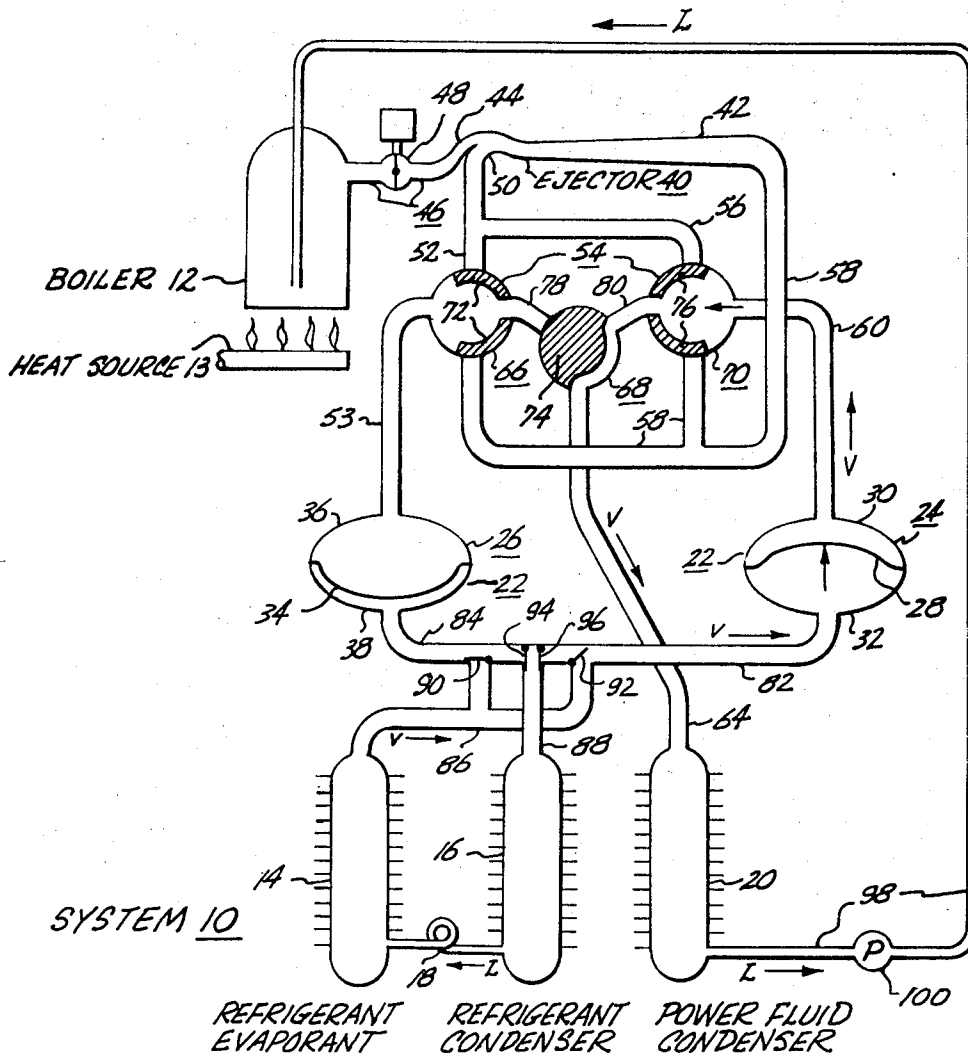


Fig. 1e.

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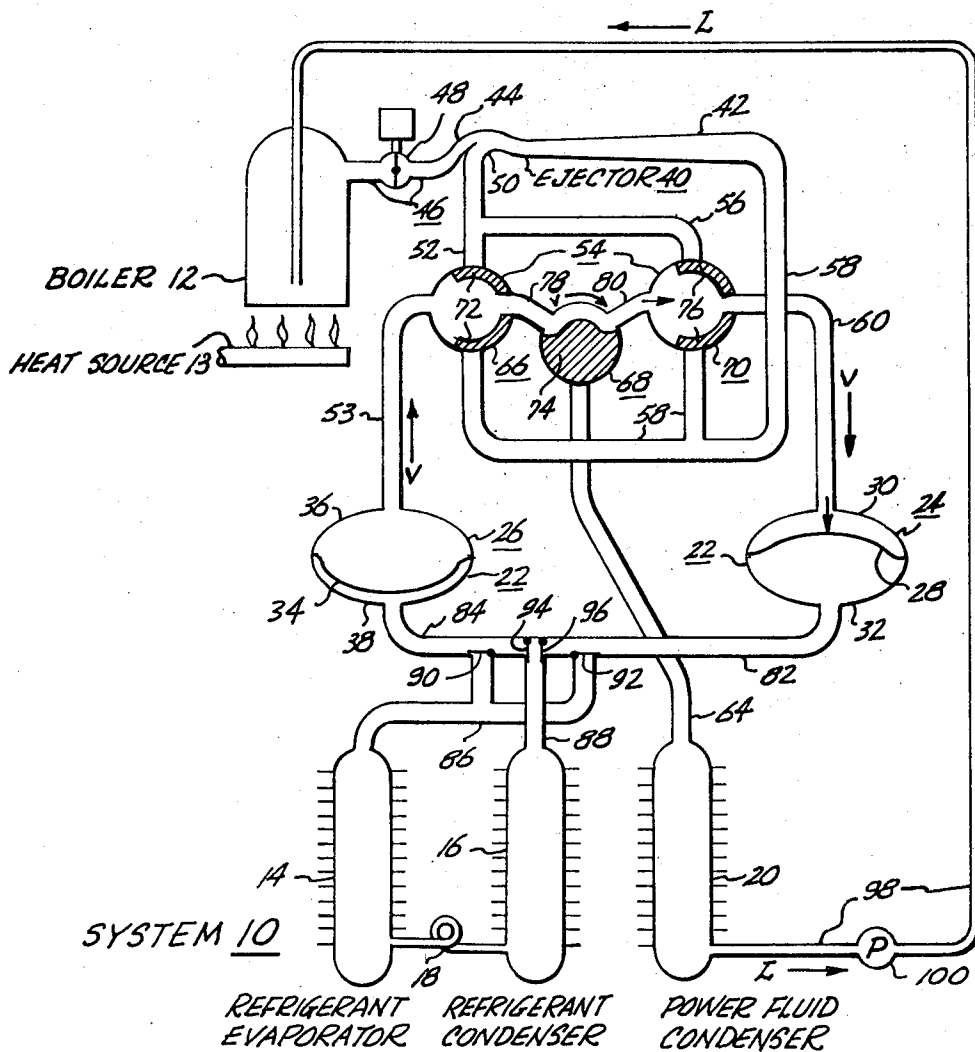
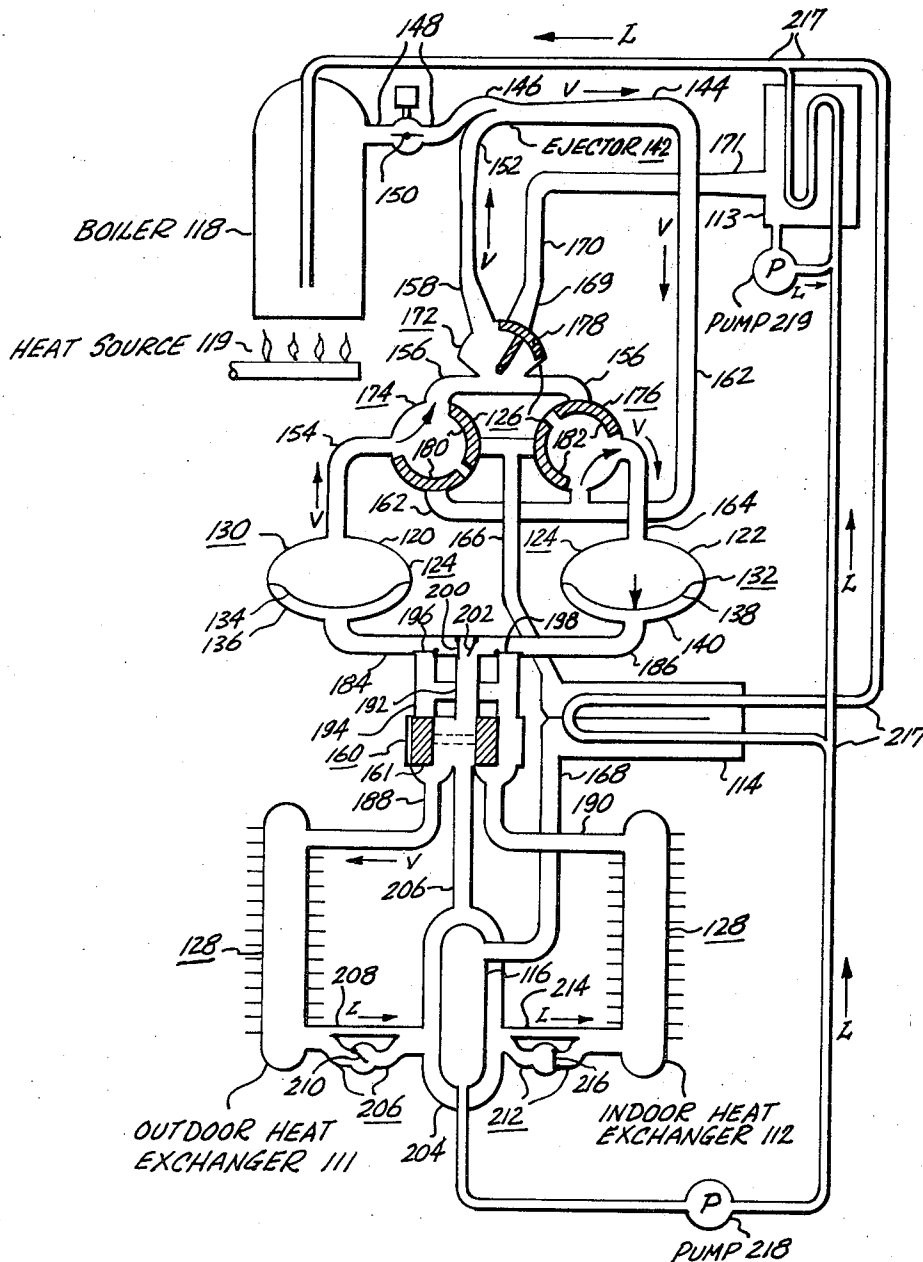


Fig. 1f.

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SYSTEM 110

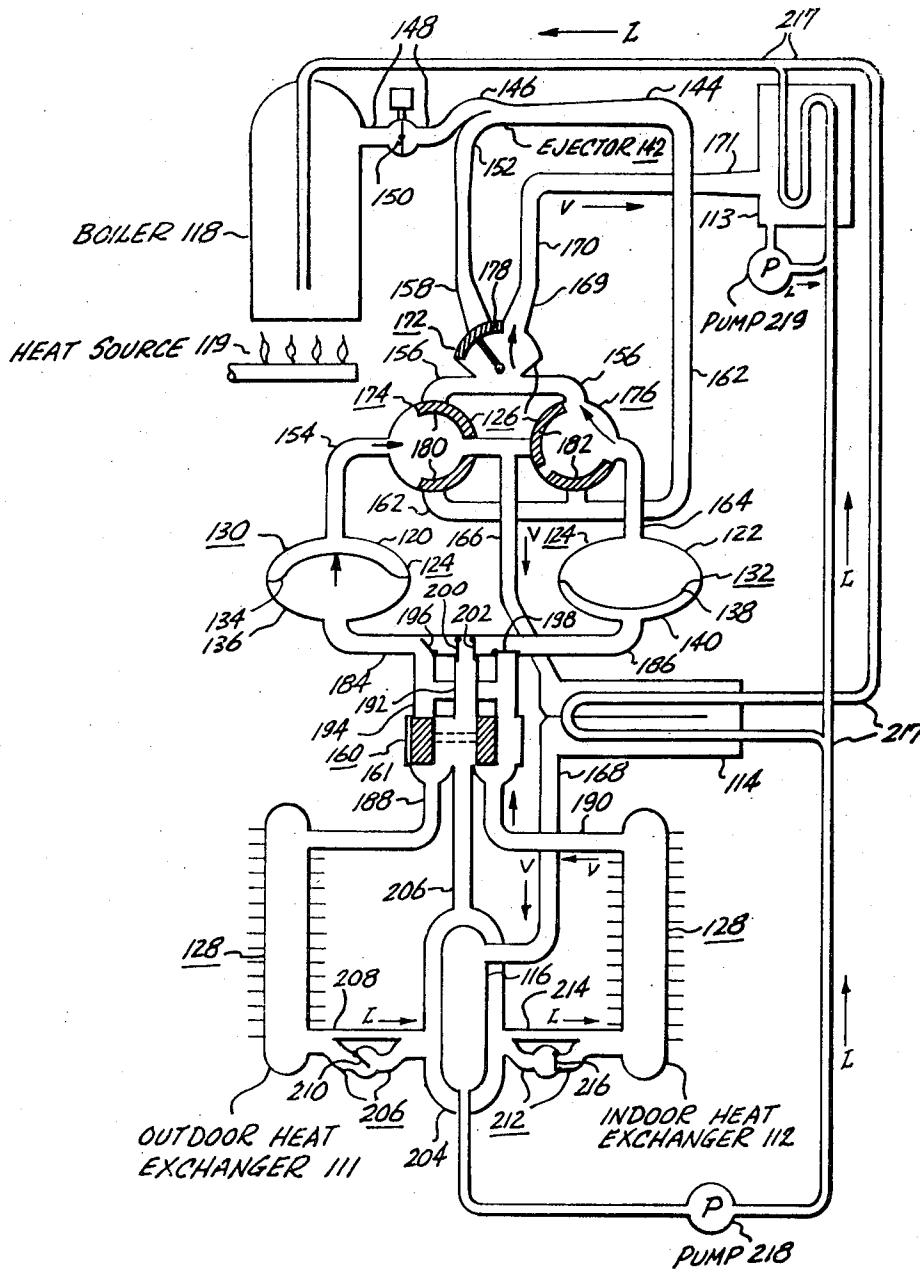
Fig. 2a.

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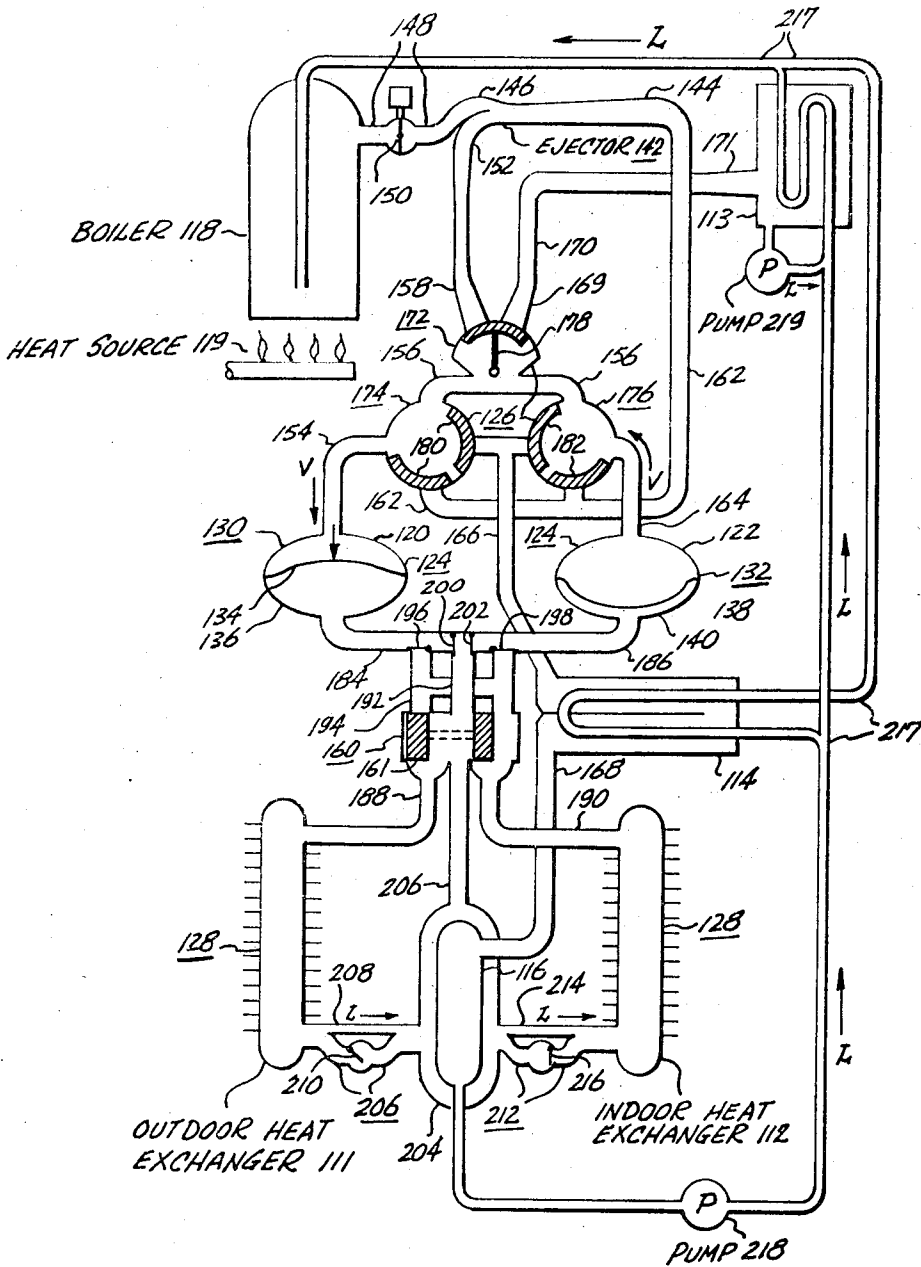


SYSTEM 110

Fig. 2b.

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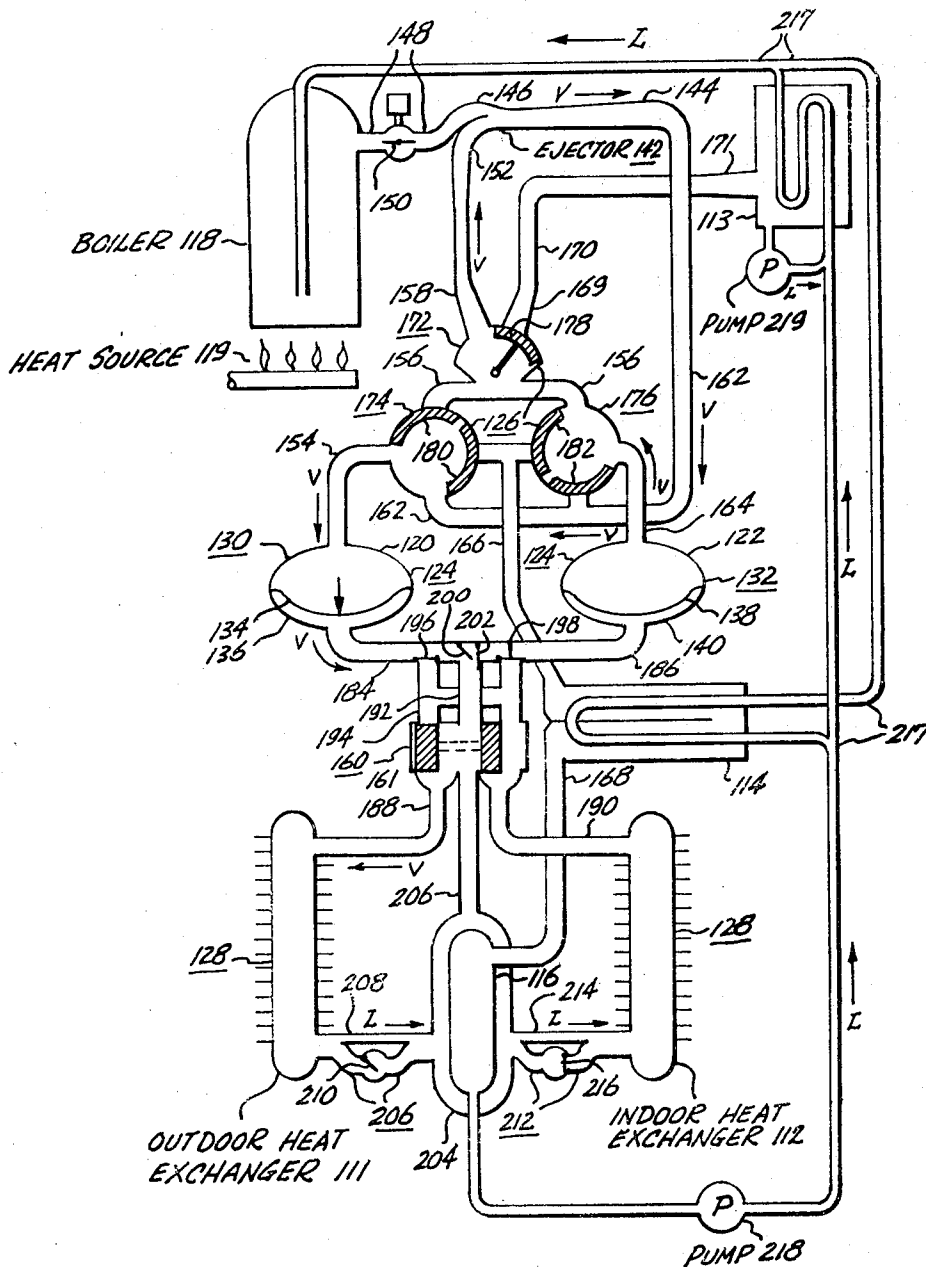
SYSTEM 110

Fig. 2c.

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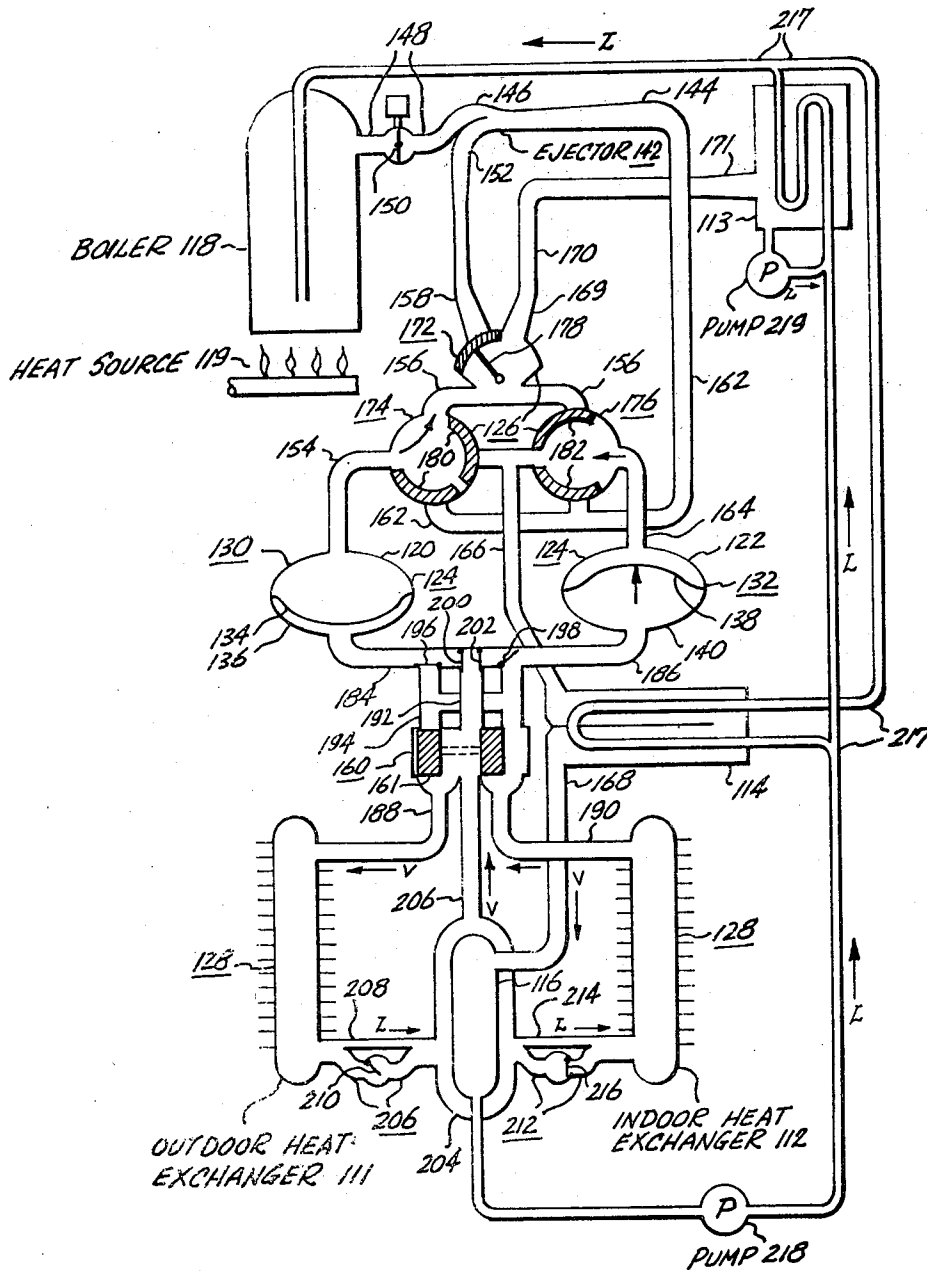
SYSTEM 110

Fig. 2d.

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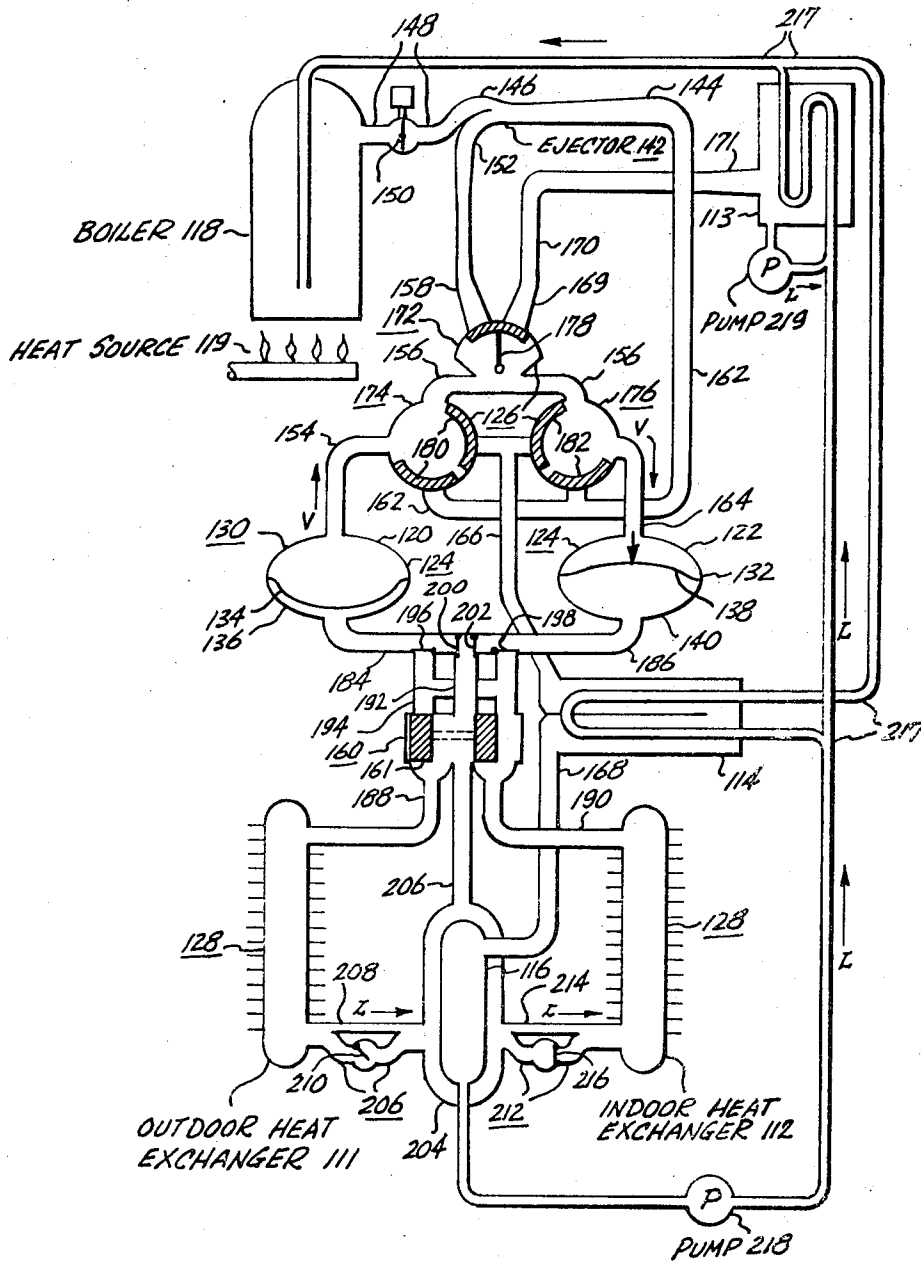


SYSTEM 110

Fig. 2e.

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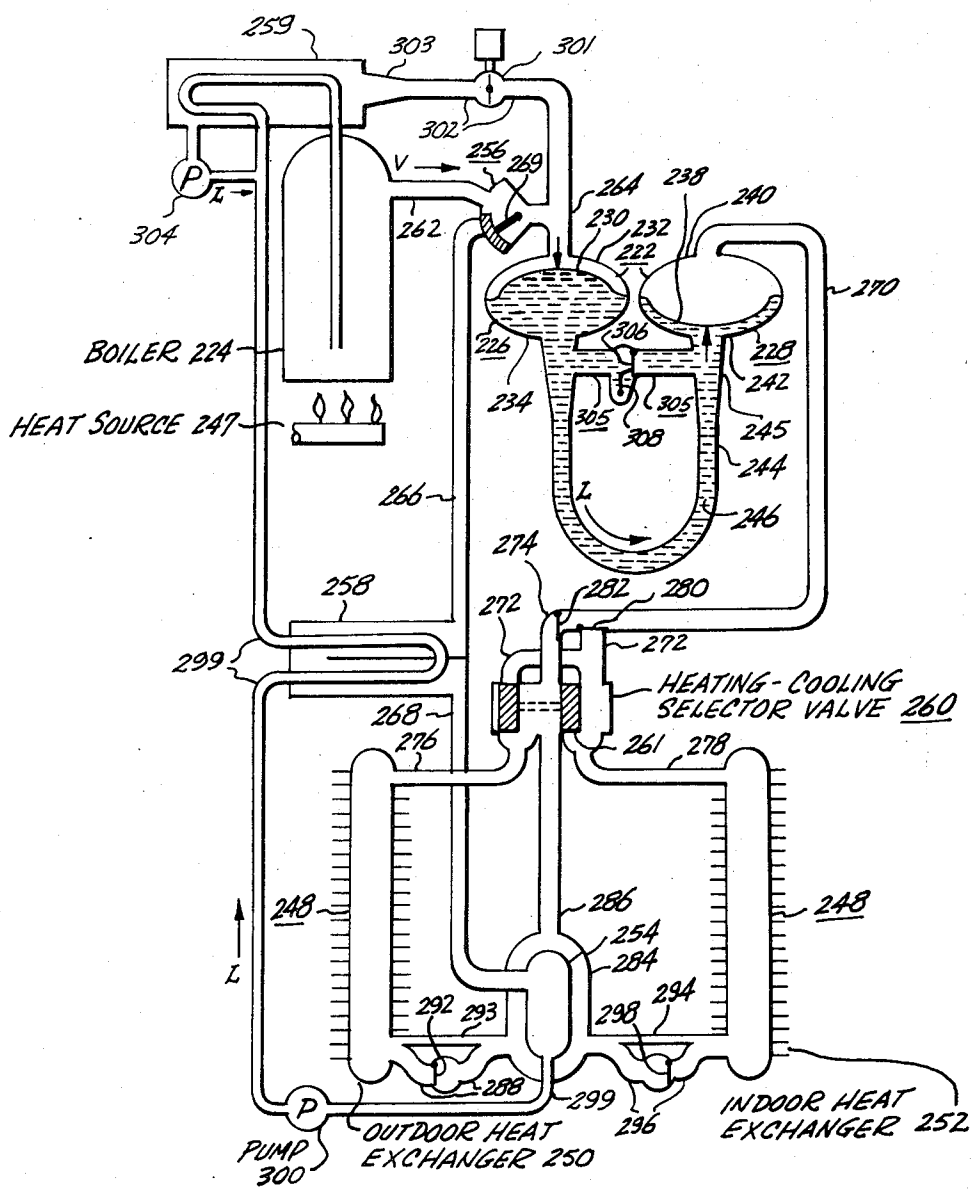


SYSTEM 110

Fig. 2f.

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SYSTEM 220

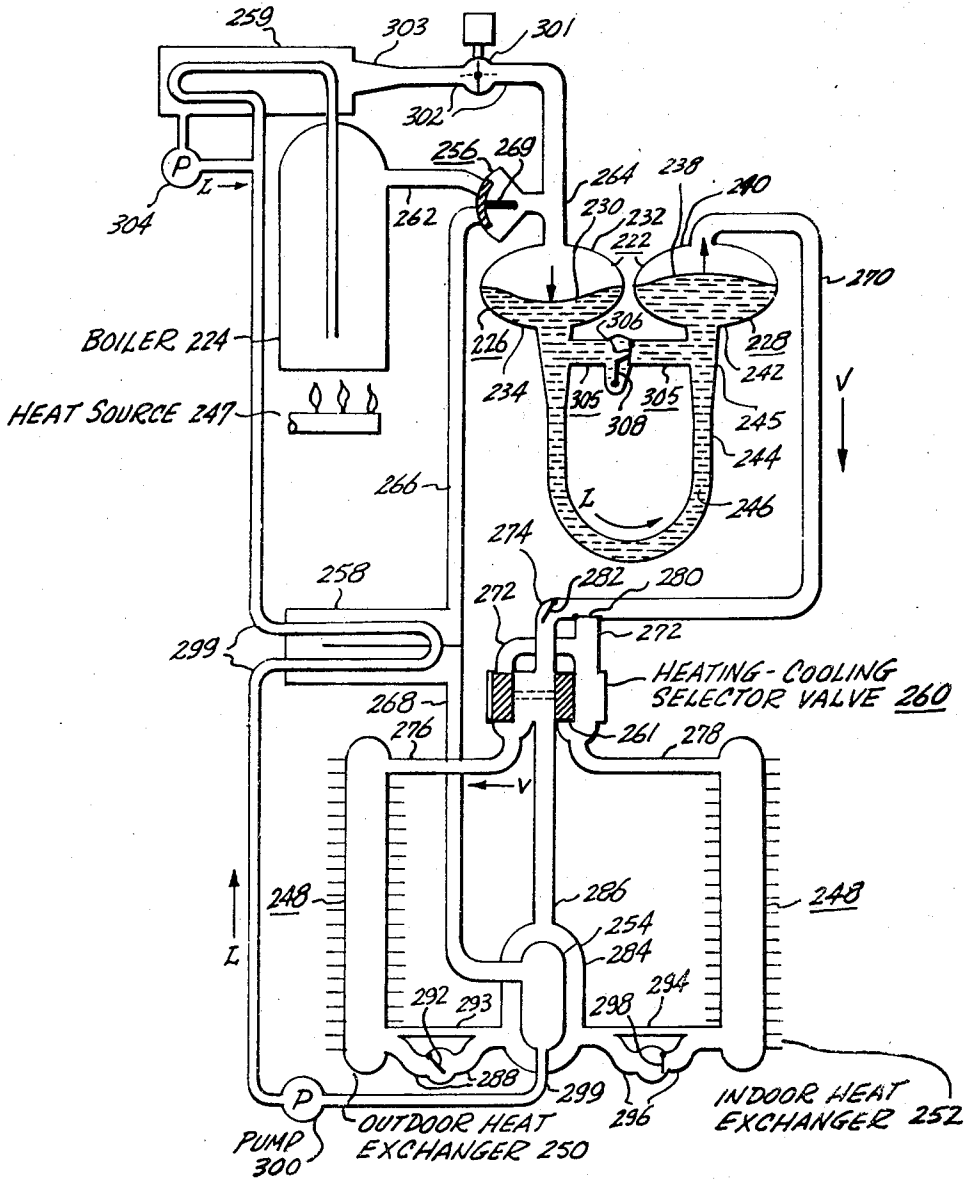
Fig. 3a.

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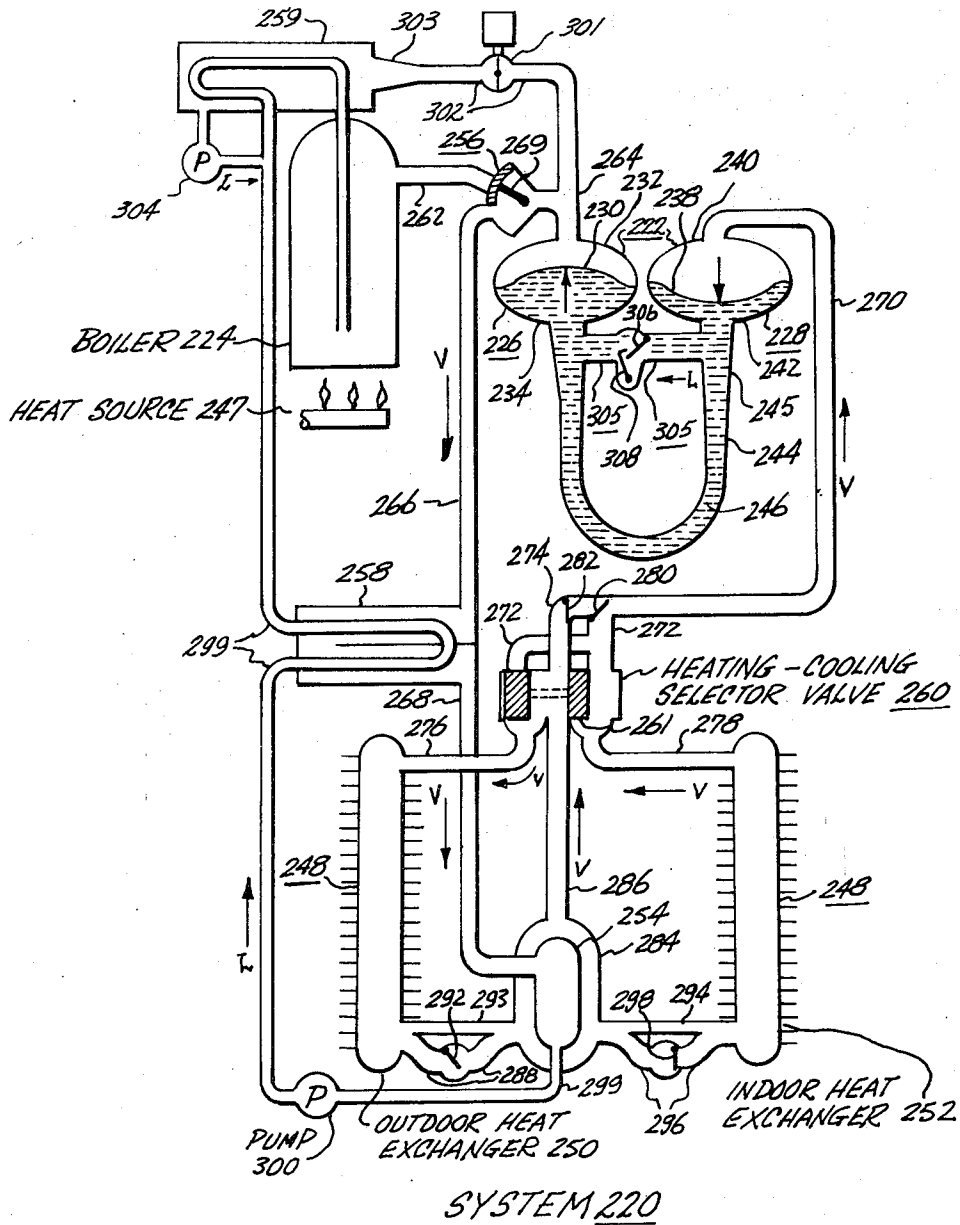
SYSTEM 220

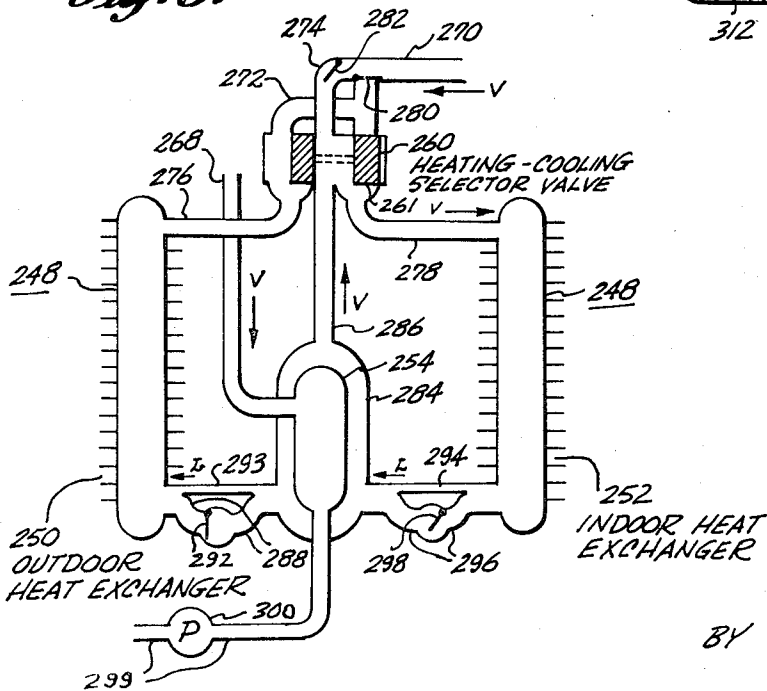
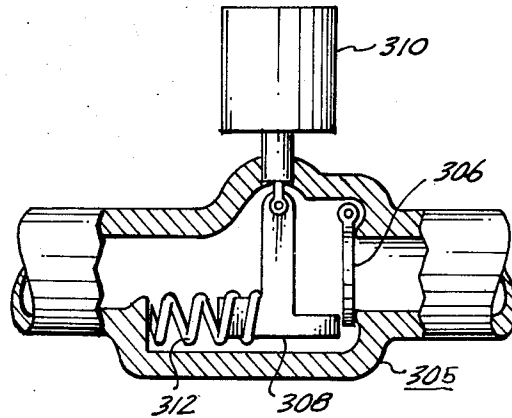
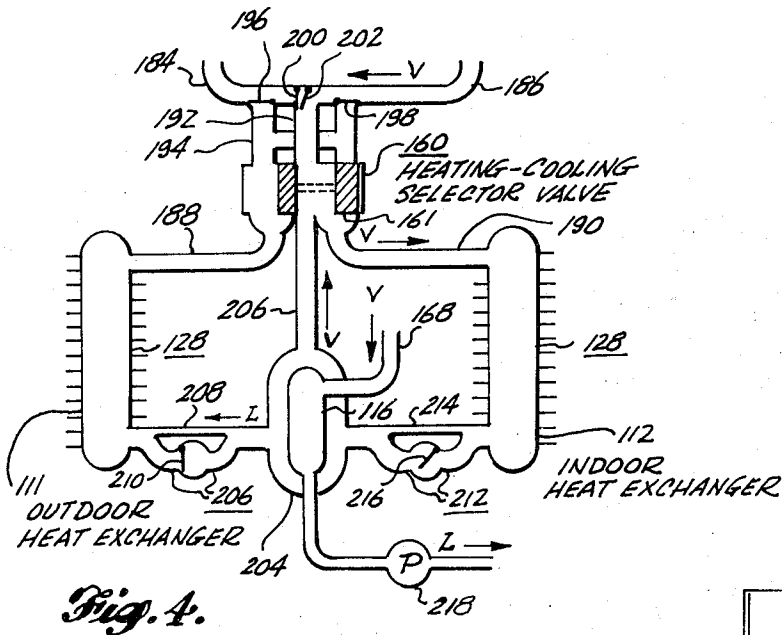
Fig. 3b.

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THERMALLY POWERED DIAPHRAGM PUMP SYSTEM FOR HEAT TRANSFER

This invention relates to a thermally powered diaphragm pump system as applied to a heat transfer system such as a refrigeration system or a heat pump.

In general, this invention is basically a gas or vapor driven heat transfer system that can efficiently pump gas or vapor, for example refrigerant vapor. This ability to pump a vapor is highly desirable in the case of a thermally powered air conditioning system, as the power fluid can then have a much higher boiling point and a much higher critical temperature point than that of the refrigerant fluid being pumped, but without the problems and limitations inherent in mixing the two fluids, such as take place in prior art absorption type air conditioning systems. In addition, a common linear ejector used alone as a vapor powered pump is mechanically inefficient, and is often unstable unless the pressure of the power vapor is accurately controlled as a function of the varying discharge or condenser pressure. A simple prior art diaphragm system used alone as a heat transfer system can maintain separation of gaseous power fluid of a higher boiling point power fluid and of a lower boiling point refrigerant fluid, but here again the mechanical efficiency is low because the energy of expansion of high pressure power vapor in the diaphragm compartment cavity cannot be recovered satisfactorily.

This invention incorporates a double diaphragm unit as a vapor powered pump which provides separation of the higher boiling point power vapor and the lower boiling point refrigerant vapor. In two embodiments of this invention an efficient and versatile ejector as described in U. S. Pat. No. 3,215,088 is associated with two diaphragm pump units in such a cycle that the ejector salvages power from adiabatically expanding power vapor in one diaphragm power vapor compartment to adiabatically compress refrigerant vapor in a diaphragm refrigerant vapor compartment. In a third embodiment of this invention momentum means is provided to assist adiabatic expansion of power vapor in a diaphragm power vapor compartment to help compress refrigerant vapor in a diaphragm refrigerant vapor compartment. In addition, there is means to salvage heat from power vapor to preheat power liquid being delivered to a boiler.

Therefore, an object of this invention is to provide an efficient and relatively inexpensive vapor pump system that can be driven by a wide variety of gaseous fluids.

Another object of this invention is to provide a heat transfer system and heat pump system that can operate directly from steam.

A further object of this invention is to provide an efficient diaphragm type pump system for air conditioning or heat pump systems in which there is a flexibility in choice of safe and nonflammable fluorocarbons to be used as the working substances in the system.

Still another object of this invention is to provide a thermally powered heat transfer system that can easily be reversed for heat pumping.

Another object of this invention is to provide a thermally powered heat transfer system in which the boiler temperature need not be excessively high so as to cause decomposition of the power fluid and corrosion within the boiler.

A further object of this invention is to provide an air conditioning or heat pump system in which the evaporator and/or condenser can be placed at some distance from the remaining power portion of the system.

Another object of this invention is to provide a thermally powered air conditioning or heat pump system without employing such components as rectifiers and analyzers that add considerable amounts of liquid to liquid heat exchange.

A still further object of this invention is to provide in a thermally powered heat transfer system means for separating the power fluid circuit from the refrigerant fluid circuit so that it becomes easily practical to maintain the proper and safe amount of power fluid in the boiler of the heat transfer system.

Still another object of this invention is to provide an air conditioning or heat pump system that is dependable and easy to service and that has quick response to cooling and heating demand.

A further object of this invention is to provide an air conditioning or heat pump system having convenient evaporator pressures and still have boiler pressures held within maximum values allowed by boiler codes.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawings in which:

FIGS. 1A through 1F are schematic diagrams of one embodiment of this invention in which the six time phases of operation for a complete cycle of operation are illustrated for a simple diaphragm pump type of refrigerating or air conditioning system in which an ejector cooperates with a pair of diaphragm pump units in which sequencing valve means is provided to produce the desired cycle of operation.

FIGS. 2a through 2f are schematic diagrams of another embodiment of this invention in which the six time phases of operation for a complete cycle of operation are illustrated for a diaphragm pump type of heat pump in which an ejector cooperates with a pair of diaphragm pump units and with sequencing valve means to produce the desired cycle of operation in which means is also provided for transferring heat from the expanded and exhausted power vapor to liquid power fluid being delivered to the boiler of the heat pump in order to preheat the liquid power fluid.

FIGS. 3a through 3c are schematic diagrams of still another embodiment of this invention in which the three time phases of operation for a complete cycle of operation are illustrated for a diaphragm pump type of heat pump in which the diaphragm pump means is provided with a liquid column of sufficient inertia to store energy during a portion of the cycle of operation.

FIG. 4 is a schematic diagram of a part of the heat pump shown in FIGS. 2a through 2f, which part includes the means for condensing and reevaporating the refrigerant fluid, the means for condensing the vaporized power fluid and the heating and cooling selector valve in which such valve is shown in this figure as set in the heating mode instead of in the cooling mode as is illustrated in FIGS. 2a through 2f.

FIG. 5 is a schematic diagram of a part of the heat pump shown in FIGS. 3a through 3c, which part includes the means for condensing and reevaporating the refrigerant fluid, the means for condensing the

vaporized power fluid and the heating and cooling valve in which such valve is shown in this figure as set in the heating mode instead of in the cooling mode as is illustrated in FIGS. 3a through 3c.

FIG. 6 is a partial section view detailing the unidirectional by-pass means of FIGS. 3a through 3c.

Referring to FIGS. 1a through 1f there is shown the six time phases of operation for one complete cycle of operation of a thermally powered refrigerating or air conditioning system 10 illustrating one embodiment of the teachings of this invention in which working substances such as dichlorodifluoromethane (R-12) for the refrigerant fluid and dichlorotetrafluoroethane (R-114) for the power fluid are utilized. In general, the power fluid should have sufficiently higher boiling point than the refrigerant fluid that the vapor pressure of the power fluid at the temperature within the power fluid condenser is somewhat less than the vapor pressure of the refrigerant fluid within the refrigerant evaporator. Under typical operating conditions the normal boiling point of the power fluid should be approximately 70° higher than the normal boiling point of the refrigerant fluid that is used as a working substance in the air conditioning system 10. However, other suitable working substances other than R-12 and R-114 could be utilized in the air conditioning system 10 provided the choice of working substances is made such that a satisfactory difference in boiling points is provided. Of course, a given boiling point for a given working substance can be achieved by mixing two liquids of unequal boiling points. For example, one can mix R-114 and trichloromonofluoromethane (R-11) to obtain a power fluid having a boiling point somewhat higher than that of R-114. One can choose water as the power fluid if a refrigerant of appropriate boiling point is selected such as trichlorotrifluoroethane (R-113). However, it is usually preferred to use fluorocarbons for both working substances as it is desirable that the vapor pressure of neither of the working substances multiplies too rapidly with increase in temperature.

In general, the air conditioning system 10 includes a boiler 12 for vaporizing power fluid disposed within the boiler 12; a heat source 13 for the boiler 12; an air finned refrigerant evaporator 14 for reevaporating liquid refrigerant fluid; an air finned refrigerant condenser 16 for condensing and liquefying refrigerant vapor; conduit means 18 for delivering refrigerant at a regulated rate from the refrigerant condenser 16 to the refrigerant evaporator 14; an air finned power fluid condenser 20 for condensing and liquefying power vapor; diaphragm pump means 22 responsive to the pressure energy of the vaporized power fluid from the boiler 12 and including two diaphragm pump units 24 and 26, the diaphragm pump unit 24 including a flexible diaphragm 28 separating the enclosure of the diaphragm pump unit 24 into a power vapor compartment 30 and a refrigerant vapor compartment 32 each of which compartments 30 and 32 is bounded by the diaphragm 28 and a portion of the enclosure of the diaphragm pump unit 24, and the diaphragm pump unit 26 including a flexible diaphragm 34 separating the enclosure of the diaphragm pump unit 26 into a power vapor compartment 36 and a refrigerant vapor compartment 38 each of which compartments 36 and 38 is bounded by the diaphragm 34 and a portion of the en-

closure of the diaphragm pump unit 26; a centrifugal type ejector 40, such as illustrated in U.S. Pat. No. 3,215,088, including a discharge 42, a primary inlet 44 for receiving vaporized power fluid from the boiler 12 through a conduit 46 which includes a solenoid controlled valve 48 which selectively permits or prevents a flow of vaporized power fluid from the boiler 12 to the primary inlet 44 of the ejector 40, and a secondary inlet 50 for receiving expanded vaporized power fluid from the power vapor compartment 36 of the diaphragm pump unit 26 through conduits 52 and 53; and sequencing valve means 54 for controlling the mode of operation of the diaphragm pump units 24 and 26. In practice, the internal volume of the enclosure of the diaphragm pump unit 24 should be substantially equal to the internal volume of the diaphragm pump unit 26. Therefore, the maximum internal volume of the power vapor compartment 36 is substantially equal to the maximum internal volume of the refrigerant vapor compartment 32 and the maximum internal volume of the power vapor compartment 30 is substantially equal to the maximum internal volume of the refrigerant vapor compartment 38.

The sequencing valve means 54 of FIGS. 1a through 1f is interconnected with the ejector 40 by means of the conduit 52, a conduit 56, conduit means 58, and with the diaphragm pump units 24 and 26 by means of conduits 53 and 60, and with the power fluid condenser 20 by means of a conduit 64. The sequencing valve means 54 includes three rotary type valves 66, 68 and 70, each of which has three operating positions. The rotary valves 66, 68 and 70 include rotors 72, 74 and 76 respectively, which are driven by a motor and cam combination (not shown) to position the particular rotors 72, 74 and 76 to form continuity between certain associated conduits including conduits 78 and 80 as will be explained more fully hereinafter. Whenever the solidly shown portions of the rotors 72, 74 or 76, or whenever any of the other solidly shown portions of any of the other rotors of any of the sequencing valve means hereinafter described, are shown covering the entrance or exit of a conduit it is to be understood that no power fluid can flow into or out of such covered entrance or exit of such conduit.

In order to interconnect the refrigerant vapor compartments 32 and 38 of the diaphragm pump units 24 and 26 respectively with the refrigerant evaporator 14 and with the refrigerant condenser 16, conduits 82, 84, 86 and 88 are provided. Intake check valves 90 and 92 are provided for permitting refrigerant vapor to flow from the conduit 86 to conduits 84 and 82 respectively, but for preventing refrigerant vapor flow in the reverse sense. On the other hand, exhaust check valves 94 and 96 permit flow of compressed refrigerant vapor respectively from conduits 84 and 82 to the conduit 88, but prevent flow of refrigerant vapor in the reverse sense.

For the purpose of delivering liquid power fluid to the boiler 12 a conduit means 98 including a pump 100 is provided. In particular, the pump 100 pumps condensed liquid power fluid from the power fluid condenser 20 through the conduit means 98 to the boiler 12.

The operation of the air conditioning system 10 of FIGS. 1a through 1f will now be described. As hereinbefore mentioned each complete cycle of operation has

six phases, each time phase of which is determined by the position of the sequencing valve means 54. The schematic diagrams in each of the FIGS. 1a through 1f illustrate respectively the positioning of the valve components and the direction of fluid flow for the particular time phase of operation being illustrated. It is to be noted that in each of the time phases of operation hereinafter described with reference to this embodiment and with reference to all subsequent embodiments, each diaphragm will have an associated arrow to indicate its direction of movement during the illustrated time phase; the absence of an arrow in any case indicates that the diaphragm is substantially not in motion during the illustrated time phase.

Referring to FIG. 1a, which illustrates the first of the six time phases of operation, the solenoid operated valve 48 is in the open position and the sequencing valve means 54 is so positioned as to permit the flow of vaporized power fluid from the boiler 12 through the conduit 46, the primary inlet 44 of the ejector 40, the discharge 42 of the ejector 40, the conduit means 58, the rotary valve 70 and the conduit 60 to fill the power vapor compartment 30 of the diaphragm pump unit 24 with vaporized power fluid at a pressure sufficient to overcome the pressure opposition of the diaphragm 28 as caused by the back pressure in the refrigerant condenser 16, to thereby effect a movement of the diaphragm 28 in a direction as shown by the arrow and expell refrigerant vapor from the refrigerant vapor compartment 32 and force such compressed refrigerant vapor through the conduit 82, the check valve 96 and the conduit 88 and into the refrigerant condenser 16 where heat of condensation of the refrigerant vapor is liberated and the refrigerant is condensed to a liquid. Liquefied refrigerant flows from the refrigerant condenser 16 to the refrigerant evaporator 14 in a restricted and controlled manner through the conduit means 18 during this time phase of operation and all subsequent time phases of operation. During this same time phase of operation as shown in FIG. 1a the secondary inlet 50 of the ejector 40 is connected through the conduit 52, the rotary valve 66, and the conduit 53 to the power vapor compartment 36 of the diaphragm pump unit 26 to permit substantially adiabatic expansion of the power vapor enclosed within the power vapor compartment 36 with resultant decrease in pressure therein and flow of the expanded power vapor from the power vapor compartment 36 through the conduit 53, the rotary valve 66, the conduit 52, the ejector 40, the conduit means 58, the rotary valve 70 and the conduit 60 into the power vapor compartment 30 of the diaphragm pump unit 24. This flow of expanded power vapor from the power vapor compartment 36 of the diaphragm pump unit 26, when the pressure within the power vapor compartment 36 is relatively lower than the pressure within the receiving power vapor compartment 30 of the diaphragm pump unit 24, and into the receiving power vapor compartment 30 is made possible by the pumping action of the ejector 40.

Referring to FIG. 1b there is illustrated the positioning of the various valve components and the fluid flow for the air conditioning system 10 for the second time phase of operation. During this time phase of operation the solenoid operated valve 48 is closed and the

sequencing valve means 54 is positioned to permit the flow of expanded vaporized power fluid from the power vapor compartment 36 of the diaphragm pump unit 26 through the conduit 53, the rotary valve 66, the conduit 78, the rotary valve 68 and the conduit 64 to the power fluid condenser 20 where the vaporized power fluid is condensed to a liquid. Since the pressure within the power vapor compartment 36 of the diaphragm pump unit 26 was decreased during the first time phase of operation, the amount of vaporized power fluid remaining in the power vapor compartment 36 is minimized, which in turn minimizes the amount of heat that must be rejected by the power fluid on condensing in the power fluid condenser 20. This in turn increases the coefficient of performance of the air conditioning system 10.

The positioning of the sequencing valve means 54 illustrated in FIG. 1b permits the pressure of the evaporated refrigerant vapor within the refrigerant evaporator 14 to force refrigerant vapor through the conduit 86, the check valve 90 and the conduit 84 to fill the refrigerant vapor compartment 38 of the diaphragm pump unit 26 with refrigerant vapor to thus effect a movement of the diaphragm 34 in the direction indicated by the arrow to thereby displace expanded power vapor within the power vapor compartment 36 through the conduit 53 and eventually into the power fluid condenser 20. The liquid condensed power fluid is continuously being pumped by the pump 100 during all of the time phases of operation from the power fluid condenser 20 through the conduit means 98 to the boiler 12.

Now referring to FIG. 1c there is illustrated the positioning of the various valve components and the fluid flow for the air conditioning system 10 for the third time phase of operation in which substantially adiabatic expansion of power vapor takes place in the power vapor compartment 30 of the diaphragm pump unit 24 and substantially adiabatic compression of refrigerant vapor takes place in the refrigerant vapor compartment 38 of the diaphragm pump unit 26. In the description of the various embodiments of this invention it is assumed that the diaphragm pump units such as the units 24 and 26 are sufficiently insulated from ambient heat sources that we can speak of substantially adiabatic expansion of vapor and of substantially adiabatic compression of vapor. It is also common in cases of adiabatic expansion that useful work is derived at the expense of heat stored in the adiabatically expanding vapor itself. This useful work shows up in substantially adiabatically compressing refrigerant vapor within another compartment. During this third time phase of operation the solenoid operated valve 48 is closed and the sequencing valve means 54 is set to permit substantially adiabatic expansion of the vaporized power fluid within the power vapor compartment 30 of the diaphragm pump unit 24 to cause a flow of vaporized power fluid through the conduit 60, the rotary valve 70, the conduit 80, the rotary valve 68, the conduit 78, the rotary valve 66 and the conduit 53 into the power vapor compartment 36 of the diaphragm pump unit 26 to deflect the diaphragm 34 in the direction indicated by the arrow and thus substantially adiabatically compress refrigerant vapor within the refrigerant vapor compartment 38 of the diaphragm pump unit 26.

Referring to FIG. 1d there is illustrated the positioning of the various valve components and the fluid flow for the air conditioning system 10 for the fourth time phase of operation. During the fourth time phase of operation the solenoid operated valve 48 is in the open position and the sequencing valve means 54 is set to permit the flow of vaporized power fluid from the boiler 12 through the conduit 46, the primary inlet 44 of the ejector 40, the discharge 42 of the ejector 40, the conduit means 58, the rotary valve 66 and the conduit 53 to fill the power vapor compartment 36 of the diaphragm pump unit 26 with vaporized power fluid at a pressure sufficient to overcome the pressure opposition of the diaphragm 34 as caused by the back pressure in the refrigerant condenser 16 to thereby effect a movement of the diaphragm 34 in a direction as indicated by the arrow and expell refrigerant vapor from the refrigerant vapor compartment 38 and force such compressed refrigerant vapor through the conduit 84, the check valve 94 and the conduit 88 and into the refrigerant condenser 16 where it is condensed to a liquid. During this same fourth time phase of operation the secondary inlet 50 of the ejector 40 is connected through the conduit 52, the conduit 56, the rotary valve 70 and the conduit 60 to the power vapor compartment 30 of the diaphragm pump unit 24 to permit substantially adiabatic expansion of the power vapor enclosed within the power vapor compartment 30 with resultant decrease in pressure therein and flow of the expanded power vapor from the power vapor compartment 30 through the conduit 60, the rotary valve 70, the conduit 56, the conduit 52 and the ejector 40 and thence finally into the power vapor compartment 36 of the diaphragm pump unit 26. This flow of expanded power vapor from the power vapor compartment 30 of the diaphragm pump unit 24, when the pressure within the power vapor compartment 30 is relatively lower than the pressure within the receiving power vapor compartment 36 of the diaphragm pump unit 26, and into the receiving power vapor compartment 36 is made possible by the pumping action of the ejector 40.

Referring to FIG. 1e there is illustrated the positioning of the various valve components and the fluid flow for the air conditioning system 10 for the fifth time phase of operation. During this time phase of operation the solenoid operated valve 48 is closed and the sequencing valve means 54 is set to permit the flow of expanded vaporized power fluid from the power vapor compartment 30 of the diaphragm pump unit 24 through the conduit 60, the rotary valve 70, the conduit 80, the rotary valve 68 and the conduit 64 to the power fluid condenser 20. Since the pressure within the power vapor compartment 30 of the diaphragm pump unit 24 was decreased during the fourth time phase of operation the amount of vaporized power fluid remaining in the power vapor compartment 30 is minimized which in turn minimizes the amount of heat that must be rejected in the power fluid condenser 20. This in turn increases the coefficient of performance of the air conditioning system 10. This positioning of the sequencing valve means 54 as shown in FIG. 1e permits the pressure of the evaporated refrigerant vapor within the refrigerant evaporator 14 to force refrigerant vapor through the conduit 86, the check valve 92 and the conduit 82 to fill the refrigerant vapor compartment 32

of the diaphragm pump unit 24 with refrigerant vapor to thus effect a movement of the diaphragm 28 in a direction as indicated by the arrow to thereby displace expanded power vapor within the power vapor compartment 30 through the conduit 60 and eventually into the power fluid condenser 20.

Referring to FIG. 1f there is illustrated the positioning of the various valve components and the fluid flow for the air conditioning system 10 for the sixth time phase of operation. During the sixth time phase of operation the solenoid operated valve 48 is closed and the sequencing valve means 54 is set to permit substantially adiabatic expansion of the vaporized power fluid within the power vapor compartment 36 of the diaphragm pump unit 26 to cause a flow of vaporized power fluid through the conduit 53, the rotary valve 66, the conduit 78, the rotary valve 68, the conduit 80, the rotary valve 70 and the conduit 60 into the power vapor compartment 30 of the diaphragm pump unit 24 to deflect the diaphragm 28 in a direction as indicated by the arrow and thus substantially adiabatically compress refrigerant vapor within the refrigerant vapor compartment 32 of the diaphragm pump unit 24.

Referring to FIGS. 2a through 2f there is shown the six time phases of operation to complete one cycle of operation for a thermally powered heat pump 110 illustrating another embodiment of the teachings of this invention in which working substances such as dichlorodifluoromethane (R-12) for the refrigerant fluid and dichlorotetrafluoroethane (R-114) for the power fluid are utilized. The main distinction between the apparatus illustrated in FIGS. 1a through 1f and the apparatus illustrated in FIGS. 2a through 2f is that the apparatus illustrated in FIGS. 2a through 2f is a heat pump 110 in the sense that an air finned outdoor heat exchanger 111 and an air finned indoor heat exchanger 112 can be reversed in function with respect to refrigerant condenser and refrigerant evaporator, whereas the apparatus illustrated in FIGS. 1a through 1f is an air conditioning system 10 which functions for cooling purposes only. In addition, in the apparatus shown in FIGS. 2a through 2f two heat exchangers 113 and 114 are provided for preheating the liquid power fluid being returned from a power fluid condenser 116 to a boiler 118. In the case of the heat exchanger 113 the liquid power fluid being returned to the boiler 118 is preheated by heat of condensation of that portion of initially expanded vaporized power fluid which the heat exchanger 113 receives from the power vapor compartments 120 and 122 of a diaphragm pump means 124 as controlled by a sequencing valve means 126. On the other hand, in the case of the heat exchanger 114 the liquid power fluid being returned to the boiler 118 is preheated by sensible heat from expanded vaporized power fluid alternately received from the power vapor compartments 120 and 122 of the diaphragm pump means 124 as controlled by the sequencing valve means 126.

In general, the heat pump 110 includes the boiler 118 for vaporizing power fluid disposed within the boiler 118; a heat source 119 for heating the boiler 118; means 128 including the air finned outdoor heat exchanger 111 and the air finned indoor heat exchanger 112 for condensing and for reevaporating refrigerant vapor received from the diaphragm pump

means 124; the power fluid condenser 116 for condensing and liquefying power vapor; the diaphragm pump means 124 which is responsive to the pressure energy of the vaporized power fluid received from the boiler 118 and which includes two diaphragm pump units 130 and 132, the diaphragm pump unit 130 including a flexible diaphragm 134 separating the enclosure of the diaphragm pump unit 130 into the power vapor compartment 120 and a refrigerant vapor compartment 136 each of the compartments 120 and 136 being bounded by the diaphragm 134 and a portion of the enclosure of the diaphragm pump unit 130, and the diaphragm pump unit 132 including a flexible diaphragm 138 separating the enclosure of the diaphragm pump unit 132 into the power vapor compartment 122 and a refrigerant vapor compartment 140 each of the compartments 122 and 140 being bounded by the diaphragm 138 and a portion of the enclosure of the diaphragm pump unit 132; a centrifugal type ejector 142, such as illustrated in U.S. Pat. No. 3,215,088, including a discharge 144, a primary inlet 146 for receiving vaporized power fluid from the boiler 118 through a conduit 148 which includes a solenoid controlled valve 150 which selectively permits or prevents the flow of vaporized power fluid from the boiler 118 to the primary inlet 146 of the ejector 142, and a secondary inlet 152 for receiving expanded vaporized power fluid from the power vapor compartment 120 of the diaphragm pump unit 130 through conduits 154, 156 and 158; the sequencing valve means 126 for controlling the mode of operation of the diaphragm pump units 130 and 132; the heat exchanger 113 and 114; and a heating and cooling selector valve 160 including a movable member 161 for effecting a flow of the compressed refrigerant vapor alternately from the refrigerant vapor compartments 136 and 140 of the diaphragm pump means 124 to the outdoor heat exchanger 111 when the movable member 161 of the heating and cooling selector valve 160 is set for the cooling mode of operation for the heat pump 110 and for effecting a flow of the compressed refrigerant vapor alternately from the refrigerant vapor compartments 136 and 140 to the indoor heat exchanger 112 when the movable member 161 of the heating and cooling selector valve 160 is set in the heating mode of operation for the heat pump 110. In practice, the internal volume of the enclosure of the diaphragm pump unit 130 should be substantially equal to the internal volume of the diaphragm pump unit 132. Therefore, the maximum internal volume of the power vapor compartment 120 is substantially equal to the maximum internal volume of the refrigerant vapor compartment 140 and the maximum internal volume of the power vapor compartment 122 is substantially equal to the maximum internal volume of the refrigerant vapor compartment 136.

The sequencing valve means 126 is interconnected with the ejector 142 by means of the conduit 158 and conduit means 162 and with the diaphragm pump units 130 and 132 by means of conduits 154 and 164 and with the power fluid condenser 116 by means of conduits 166 and 168. As shown, the heat exchanger 113 is interconnected with the sequencing valve means 126 by means of a conduit 170 having a diverging portion 171 for converting kinetic energy of the enclosed

power vapor to pressure energy. In the illustration of FIGS. 2a through 2f the sequencing valve means 126 includes rotary type valves 172, 174 and 176 each of which has three operating positions. The rotary valves 172, 174 and 176 each of which has three operating positions. The rotary valves 172, 174 and 176 have rotors 178, 180 and 182 respectively which are driven by a motor and cam combination (not shown) to position the particular rotors 178, 180 and 182 to form continuity between certain associated conduits as will be explained more fully hereinafter.

In order to interconnect the refrigerant vapor compartments 136 and 140 of the diaphragm pump units 130 and 132 respectively with the indoor heat exchanger 111 and with the outdoor heat exchanger 112, conduits 184, 186, 188, 190 and 192 and conduit means 194 are provided. Intake check valves 196 and 198 are provided for permitting refrigerant vapor to flow from conduit means 194 to conduits 184 and 186 respectively, but for preventing refrigerant vapor to flow in the reverse sense. On the other hand, exhaust check valves 200 and 202 permit flow of compressed refrigerant vapor respectively from conduits 184 and 186 to the conduit 192, but prevent flow of refrigerant vapor in the reverse sense.

The air finned outdoor heat exchanger 111 is constructed to function as either a refrigerant evaporator or a refrigerant condenser. In like manner, the air finned indoor heat exchanger 112 is constructed to function as either a refrigerant evaporator or as a refrigerant condenser. In order to dissipate heat from the power fluid condenser 116 to a selected region as will be explained more fully hereinafter, an ambient insulated heat exchanger 204 is disposed in heat exchanger relationship with the power fluid condenser 116 and is connected to the heating and cooling selector valve 160 by means of a conduit 206 so that refrigerant vapor from the ambient insulated heat exchanger 204 can be selectively delivered to either the outdoor heat exchanger 111 or to the indoor heat exchanger 112.

For the purpose of delivering liquid condensed refrigerant from the outdoor heat exchanger 111 to the ambient insulated heat exchanger 204 in an unrestricted manner, unidirectional conduit means 206 is provided with a check valve 210. This unidirectional conduit means 206 is in parallel with a metering restriction 208, the function of which will be explained hereinafter. In order to deliver refrigerant liquid at a controlled and metered rate from the ambient insulated heat exchanger 204 to the indoor heat exchanger 112 a metering restriction 214 is provided; there is no flow, when the heat pump 110 is functioning in the cooling mode, through the parallel unidirectional conduit means 212 which includes a check valve 216 which blocks unrestricted flow in this sense from the ambient insulated heat exchanger 204 to the indoor heat exchanger 112.

In order to deliver liquid power fluid to the boiler 118 conduit means 217 is provided. In particular, liquid condensed power fluid is pumped from the power fluid condenser 116 by a pump 218 and through the conduit means 217 to and through the heat exchangers 113 and 114 and from the heat exchangers 113 and 114 through the conduit means 217 to the boiler 118. A pump 219 is

provided for pumping that portion of power fluid that condenses in the heat exchanger 113 into the conduit means 217 to thus return this condensed liquid to the boiler 118.

The operation of the heat pump 110 of FIGS. 2a through 2f will now be described with the movable member 161 of the heating and cooling selector valve 160 set as shown in the cooling mode of operation for the heat pump 110. Each cycle of operation for the heat pump 110 has six time phases, each time phase of which is determined by the positions of the rotors 178, 180 and 182 of the separate rotary valves 172, 174 and 176 of the sequencing valve means 126. The schematic diagrams in each of the FIGS. 2a through 2f illustrate respectively the positioning of the component valves and the direction of fluid flow for the particular time phase of operation being illustrated.

Referring to FIG. 2a which illustrates the first of the six time phases of operation, the solenoid actuated valve 150 is in the open position and the sequencing valve means 126 is so positioned as to permit the flow of vaporized power fluid from the boiler 118 through the conduit 148, the primary inlet 146 of the ejector 142, the conduit means 162, the rotary valve 176 and the conduit 164 to fill the power vapor compartment 122 of the diaphragm pump unit 132 with vaporized power fluid at a pressure sufficient to overcome the pressure opposition of the diaphragm 138 as caused by the back pressure in the outdoor heat exchanger 111 which is now functioning as a refrigerant condenser. The power vapor entering the power vapor compartment 122 effects a movement of the diaphragm 138 in a direction as indicated by the arrow and further compresses and expells refrigerant vapor from the refrigerant vapor compartment 140 and forces such compressed refrigerant vapor through the conduit 186, the check valve 202, the conduit 192, the heating and cooling selector valve 160 and the conduit 188 and into the outdoor heat exchanger 111 where heat of condensation is liberated and the refrigerant vapor is condensed to a liquid. Liquefied refrigerant flows from the outdoor heat exchanger 111 to the ambient insulated heat exchanger 204 and to the indoor heat exchanger 112 as previously explained. During this same time phase of operation the secondary inlet 152 of the ejector 142 is connected through the conduit 158, the rotary valve 172, the conduit 156, the rotary valve 174 and the conduit 154 to the power vapor compartment 120 of the diaphragm pump unit 130 to effect substantially adiabatic expansion of the power vapor enclosed within the power vapor compartment 120 with a resultant decrease in pressure therein; and expanded power vapor flows from the power vapor compartment 120 through the conduit 154, the rotary valve 174, the conduit 156, the rotary valve 172, the conduit 158, the ejector 142, the conduit means 162, the rotary valve 176 and the conduit 164 into the power vapor compartment 122 of the diaphragm pump unit 132. This flow of expanded power vapor from the power vapor compartment 120 of the diaphragm pump unit 130, where the pressure within the power vapor compartment 120 is relatively lower than the pressure within the power vapor compartment 122, and into the power vapor compartment 122 of the diaphragm pump unit 132 is made possible by the pumping action of the ejector 142.

Referring to FIG. 2b there is illustrated the positioning of the various valve components and the direction of fluid flow for the heat pump 110 for the second time phase of operation. During this second time phase of operation the solenoid actuated valve 150 is closed and the sequencing valve means 126 is set to permit initial adiabatic expansion of the vaporized power fluid within the power vapor compartment 122 of the diaphragm pump unit 132 by allowing the flow of expanding vaporized power fluid through the conduit 164, the rotary valve 176, the conduit 156, the rotary valve 172 and the conduit 170 into the heat exchanger 113 where condensation of the power vapor liberates heat of condensation to provide heat to preheat liquid power fluid flowing to the boiler 118. During this same second time phase of operation the sequencing valve means 126 is set to permit the flow of expanded vaporized power fluid from the power vapor compartment 120 of the diaphragm pump unit 130 through the conduit 154, the rotary valve 174, the conduit 166, the heat exchanger 114 and the conduit 168 to the power fluid condenser 116 where the vaporized power fluid is condensed and in so doing gives up heat of condensation which is transferred to the liquid refrigerant within the ambient insulated heat exchanger 204; the heat thus liberated produces refrigerant vapor which flows through the conduit 206, the heating and cooling selector valve 160 and the conduit 188 and into the outdoor heat exchanger 111 where the heat originating from the condensing power fluid is liberated. The position of the sequencing valve means 126 as shown permits the pressure of the evaporated refrigerant within the indoor heat exchanger 112 to force refrigerant vapor through the conduit 190, the heating and cooling selector valve 160, the conduit means 194, the check valve 196 and the conduit 184 to fill the refrigerant vapor compartment 136 of the diaphragm pump unit 130 with refrigerant vapor to thus effect a movement of the diaphragm 134 in the direction shown by the arrow to thereby displace expanded power vapor within the power vapor compartment 120 through the conduit 154 and the heat exchanger 114 and eventually into the power fluid condenser 116.

Since the pressure within the power vapor compartment 120 of the diaphragm pump unit 130 was decreased during the first time phase of operation the amount of vaporized power fluid remaining in the power vapor compartment 120 is minimized which in turn minimizes the amount of heat that must be rejected in the power fluid condenser 116. This in turn increases the coefficient of performance of the heat pump 110. The vaporized power fluid within the power vapor compartments 120 and 122 originates within the heated boiler 118 and is therefore still hot while it leaves either of these compartments 120 and 122 and flows to the heat exchanger 114. Thus, sensible heat is recovered from this exhausted vaporized power fluid, which heat is exchanged to liquid power fluid within the conduit means 217 to preheat this power fluid returning to the boiler 118. The recovery of this sensible heat still further increases the coefficient of performance of the heat pump 110. The condensed power liquid during all the time phases of operation is continuously being pumped by the pump 218 from the power fluid condenser 116 through the conduit means 217 and the heat exchangers 113 and 114 to the boiler 118.

Now referring to FIG. 2c there is illustrated the positioning of the various valve components and the direction of the fluid flow for the heat pump 110 for the third time phase of operation in which substantially adiabatic expansion of power vapor takes place in the power vapor compartment 122 of the diaphragm pump unit 132, and substantially adiabatic compression of the refrigerant vapor takes place in the refrigerant vapor compartment 136 of the diaphragm pump unit 130. Specifically, during this third time phase of operation the solenoid actuated valve 150 is closed and the sequencing valve means 126 is set to prevent communication between the power vapor compartment 122 of the diaphragm pump unit 132 and the heat exchanger 113 and to prevent communication between either of the power vapor compartments 120 and 122 and the heat exchanger 114, and to permit substantially adiabatic expansion of the vaporized power fluid within the power vapor compartment 122 of the diaphragm pump unit 132 to cause a flow of vaporized power fluid through the conduit 164, the rotary valve 176, the conduit 156, the rotary valve 174 and the conduit 154 and into the power vapor compartment 120 of the diaphragm pump unit 130 to deflect the diaphragm 134 in a direction as indicated by the arrow and this substantially adiabatically compress the refrigerant vapor within the refrigerant vapor compartment 130 of the diaphragm pump unit 130.

Referring to FIG. 2d there is illustrated the positioning of the various valve components and the direction of fluid flow for the heat pump 110 for the fourth time phase of operation. During the fourth time phase of operation the solenoid operated valve 150 is in the open position and the sequencing valve means 126 is set to permit the flow of vaporized power fluid from the boiler 118 through the conduit 148, the primary inlet 146 of the ejector 142, the discharge 144 of the ejector 142, the conduit means 162, the rotary valve 174 and the conduit 154 to fill the power vapor compartment 120 of the diaphragm pump unit 130 with vaporized power fluid at a pressure sufficient to overcome the pressure opposition of the diaphragm 134 as caused by the back pressure in the outdoor heat exchanger 111, which is now functioning as a refrigerant condenser, to thereby effect a movement of the diaphragm 134 in a direction as indicated by the arrow and to expell refrigerant vapor from the refrigerant vapor compartment 136 and to force such compressed refrigerant vapor through the conduit 184, the conduit 192, the heating and cooling selector valve 160 and the conduit 188 and into the outdoor heat exchanger 111 where heat of condensation of the refrigerant vapor is liberated and the refrigerant is condensed to a liquid. Liquid refrigerant flows from the outdoor heat exchanger 111 to the ambient insulated heat exchanger 204 and to the indoor heat exchanger 112 as previously explained. During this same time phase of operation the secondary inlet 152 of the ejector 142 is connected through the conduit 158, the rotary valve 172, the conduit 156, the rotary valve 176 and the conduit 164 to the power vapor compartment 122 of the diaphragm pump unit 132 to permit substantially adiabatic expansion of the power vapor enclosed in the power vapor compartment 122 with resultant decrease of pressure therein; and to permit the flow of the expanded power vapor from the power vapor compartment 122 through

the conduit 164, the rotary valve 176, the conduit 156, the rotary valve 172, the conduit 158, the ejector 142, the conduit means 162, the rotary valve 174 and the conduit 154 and into the power vapor compartment 120 of the diaphragm pump unit 130. This flow of expanded power vapor from the power vapor compartment 122 of the diaphragm pump unit 132, where the pressure within the power vapor compartment 122 is relatively lower than the pressure within the receiving power vapor compartment 120 of the diaphragm pump unit 130, and into the power vapor compartment 120 is made possible by the pumping action of the ejector 142.

Referring to FIG. 2e there is illustrated the positioning of the various valve components and the direction of the fluid flow for the heat pump 110 for the fifth time phase of operation. During this fifth time phase of operation the solenoid actuated valve 150 is closed and the sequencing valve means 126 is set to permit initial adiabatic expansion of the vaporized power fluid within the power vapor compartment 120 of the diaphragm pump unit 130 and to allow the flow of expanding vaporized power fluid through the conduit 154, the rotary valve 174, the conduit 156, the rotary valve 172 and the conduit 170 and into the heat exchanger 113 where condensation of this power vapor takes place and the liberated heat of condensation preheats liquid power fluid flowing to the boiler 118 through the conduit means 217. During this same time phase of operation the sequencing valve means 126 is set to permit the flow of expanded vaporized power fluid from the power vapor compartment 122 of the diaphragm pump unit 132 through the conduit 164, the rotary valve 176, the conduit 166, the heat exchanger 114, and the conduit 168 to the power fluid condenser 116 where the vaporized power fluid is condensed to a liquid and the heat of condensation is transferred to liquid refrigerant within the ambient insulated heat exchanger 204 to in turn produce refrigerant vapor which flows through the conduit 206, the heating and cooling selector valve 160 and the conduit 188 and into the outdoor heat exchanger 111 where the heat originating from the condensing power fluid is liberated. Since the pressure within the power vapor compartment 122 of the diaphragm pump unit 132 was decreased during the fourth time phase of operation, the amount of vaporized power fluid remaining in the power vapor compartment 122 is minimized, which in turn minimizes the amount of heat that must be rejected in the power fluid condenser 116. This in turn increases the coefficient of performance of the heat pump 110. The positioning of the sequencing valve means 126 as shown in FIG. 2e permits the pressure of the evaporated refrigerant vapor within the indoor heat exchanger 112 to force refrigerant vapor through the conduit 190, the heating and cooling selector valve 160, the conduit means 194, the check valve 198 and the conduit 186 to fill the refrigerant vapor compartment 140 of the diaphragm pump unit 132 with refrigerant vapor which in turn causes a movement of the diaphragm 138 in a direction as indicated by the arrow which thereby displaces power vapor within the power vapor compartment 122 through the conduit 164 and eventually into the power fluid condenser 116.

Now referring to FIG. 2f there is illustrated the positioning of the various valve components and the direction of fluid flow for the heat pump 110 for the sixth time phase of operation in which substantially adiabatic expansion of the power vapor takes place in the power vapor compartment 120 of the diaphragm pump unit 130 and substantially adiabatic compression of refrigerant vapor takes place in the refrigerant vapor compartment 140 of the diaphragm pump unit 132. Specifically, during the sixth time phase of operation the solenoid actuated valve 150 is closed and the sequencing valve means 126 is set to prevent communication between the power fluid compartment 120 of the diaphragm pump unit 130 and the heat exchanger 113 and to prevent communication between either of the power vapor compartments 120 and 122 and the heat exchanger 114, and to permit substantially adiabatic expansion of the vaporized power fluid within the power vapor compartment 120 of the diaphragm pump unit 130 to cause a flow of vaporized power fluid through the conduit 154, the rotary valve 174, the conduit 156, the rotary valve 176, and the conduit 164 and into the power vapor compartment 122 of the diaphragm pump unit 132 to deflect the diaphragm 138 in the direction indicated by the arrow and thus substantially adiabatically compress refrigerant vapor within the refrigerant vapor compartment 140 of the diaphragm pump unit 132.

Referring to FIG. 4 the heat pump 110 is shown with the movable member 161 of the heating and cooling selector valve 160 set so that the heat pump 110 functions in the heating mode. For simplicity of the drawings only the heating and cooling selector valve 160 and the associated affected components and the conduits that are connected to the remainder of the heat pump 110 are shown. In other words, the structural portion of the heat pump 110 shown in FIG. 4 as well as the remaining structural portion of the heat pump 110 is identical to the heat pump 110 shown in FIGS. 2a through 2f.

In operation, with the heating and cooling selector valve 160 set with its movable member 161 as shown in FIG. 4 for the heating mode of operation, the indoor heat exchanger 112 functions as a refrigerant condenser for the heat pump 110 and the outdoor heat exchanger 111 functions as a refrigerant evaporator for the heat pump 110 so that heat can in effect be transferred from the outdoor heat exchanger 111 to the indoor heat exchanger 112. Thus, in operation with the heat pump 110 functioning in the heating mode, the operation of the heat pump 110 during all six time phases of operation is identical to the hereinbefore described operation for the heat pump 110 when functioning in the cooling mode except as to the flow of the refrigerant vapor to and from the means 128 for condensing and for reevaporating refrigerant vapor and the flow of liquid refrigerant between the indoor heat exchanger 112, the ambient insulated heat exchanger 204 and the outdoor heat exchanger 111. Specifically, when the heat pump 110 is set for the heating mode, refrigerant vapor flows during the first and fourth time phases of operation through the heating and cooling selector valve 160 and the conduit 190 to the indoor heat exchanger 112 for condensing, and the condensed liquid refrigerant flows unrestricted from the indoor

heat exchanger 112 through the check valve 216 into the ambient insulated heat exchanger 204 and it also flows in a restricted manner from the ambient insulated heat exchanger 204 through the metering restriction 208 to the outdoor heat exchanger 111. Then during the second and fifth time phases of operation evaporated refrigerant flows from the outdoor heat exchanger 111 through the conduit 188 and the heating and cooling selector valve 160 through the appropriate check valve as hereinbefore described with reference to the second and fifth cycle of operation of the heat pump 110 when it is functioning in the cooling mode. During the heating mode of operation for the heat pump 110 evaporated refrigerant flows from the ambient insulated heat exchanger 204 through the conduit 206, the heating and cooling selector valve 160 and the conduit 190 to the indoor heat exchanger 112 for condensing and liberating heat. The remainder of the operation of the heat pump 110 when functioning in the heating mode is substantially the same as the hereinbefore described operation for the heat pump 110 when functioning in the cooling mode.

Referring to FIGS. 3a through 3c there is shown the three time phases of operation which complete a cycle of operation for a thermally powered heat pump 220 illustrating another embodiment of the teachings of this invention in which working substances such as dichlorodifluoromethane (R-12) for the refrigerant and dichlorotetrafluoroethane (R-114) may be used for the power fluid.

In the heat pump 220 shown in FIGS. 3a through 3c diaphragm pump means 222 is responsive to the pressure energy of vaporized power fluid received from a boiler 224 which functions to vaporize the power fluid, and includes two diaphragm units 226 and 228. The diaphragm unit 226 includes a flexible diaphragm 230 which separates the enclosure of the diaphragm unit 226 into a power vapor compartment 232 disposed on the top side of the diaphragm 230 and a liquid filled compartment 234 disposed at the lower side of the diaphragm 230, the power vapor compartment being bounded by the diaphragm 230 and a portion of the enclosure of the diaphragm unit 226. On the other hand, the diaphragm unit 228 includes a flexible diaphragm 238 which separates the enclosure of the diaphragm unit 228 into a refrigerant vapor compartment 240 disposed above the diaphragm 238 and a liquid filled compartment 242 disposed below the diaphragm 238, the refrigerant vapor compartment 240 being bounded by the diaphragm 238 and a portion of the enclosure of the diaphragm unit 228. In practice, the maximum internal volume of the power vapor compartment should be substantially equal to the maximum internal volume of the refrigerant vapor compartment 240.

In order to provide inertia for the diaphragms 230 and 238 a venturi shaped conduit 244 with a diverging diffusor portion 245 encloses a liquid column 246 and is interconnected between the liquid filled compartment 234 of the diaphragm unit 226 and the liquid filled compartment 242 of the diaphragm unit 228 to thus interconnect the diaphragms 230 and 238 with a liquid having predetermined inertia that can be substantially reduced as will be explained more fully hereinafter. It is preferable that the liquid comprising the liquid column 246 and filling the compartments

234 and 242 be of relatively high boiling point, low thermal conductivity, and a low viscosity and relatively high density. The diverging portion 245 of the conduit 244 is provided for a true venturi effect by which the kinetic energy of liquid flowing in the directed sense from the liquid filled compartment 234 to the liquid filled compartment 242 is converted back into pressure energy in the liquid filled compartment 242.

In general, the heat pump 220 includes the boiler 224 for vaporizing the power fluid; a heat source 247 for heating the boiler 224; the diaphragm pump means 222; means 248 including an air finned outdoor heat exchanger 250 and an air finned indoor heat exchanger 252 for condensing and reevaporating refrigerant vapor received from the diaphragm pump means 222; a power fluid condenser 254 for condensing and liquefying power vapor; sequencing valve means 256 for controlling the mode of operation of the diaphragm units 226 and 228; heat exchangers 258 and 259 for preheating liquid power fluid being delivered to the boiler 224; and a heating and cooling selector valve 260 having a movable member 261 for effecting a flow of the compressed refrigerant vapor from the refrigerant vapor compartment 240 of the diaphragm unit 228 to the outdoor heat exchanger 250 when the movable member 261 of the heating and cooling selector valve 260 is set for the cooling mode of operation for the heat pump 220, and for effecting the flow of the compressed refrigerant vapor from the refrigerant vapor compartment 240 to the indoor heat exchanger 252 when the movable member 261 of the heating and cooling selector valve 260 is set in the heating mode of operation for the heat pump 220.

The sequencing valve means 256 is interconnected with the boiler 224 by means of a conduit 262 and with the power vapor compartment 232 of the diaphragm unit 226 by means of a conduit 264 and with the heat exchanger 258 by means of a conduit 266 and with the power fluid condenser 254 by means of a conduit 268 and the conduit 266. In the illustration of FIGS. 3a through 3c the sequencing valve means 256 includes a rotor 269 which is driven by a motor and cam combination (not shown) to form continuity between certain associated conduits as will be explained more fully hereinafter.

In order to interconnect the refrigerant vapor compartment 240 of the diaphragm unit 228 with the indoor heat exchanger 252 and with the outdoor heat exchanger 250 conduits 270, 272, 274, 276 and 278 are provided. Intake check valve 280 is provided for permitting refrigerant vapor flow from the conduit 272 to the conduit 270, but for preventing refrigerant flow in the reverse sense. On the other hand, exhaust check valve 282 permits flow of compressed refrigerant vapor from the conduit 270 to the conduit 274, but prevents flow of refrigerant vapor in the reverse sense.

The air finned outdoor heat exchanger 250 is constructed to function as either a refrigerant evaporator or as a refrigerant condenser. Also, the air finned indoor heat exchanger 252 is constructed to function either as a refrigerant evaporator or as a refrigerant condenser. In order to dissipate heat from the power fluid condenser 254 to a selected region as will be explained more fully hereinafter, an ambient insulated heat exchanger 284 is disposed in heat exchange rela-

tionship with the power fluid condenser 254 and is connected to the heating and cooling selector valve 260 by means of a conduit 286 is selectively deliver refrigerant vapor from the ambient insulated heat exchanger 284 to either the outdoor heat exchanger 250 or to the indoor heat exchanger 252 whenever the particular heat exchanger 250 or 252 is functioning as a condenser.

For the purpose of delivering condensed refrigerant from the outdoor heat exchanger 250 to the ambient insulated heat exchanger 284 in an unrestricted manner, unidirectional conduit means 288 is provided. The unidirectional conduit means 288 includes a check valve 292 for providing unrestricted flow of condensed refrigerant from the outdoor heat exchanger 250 to the ambient insulated heat exchanger 284 when the heat pump 220 is functioning in the cooling mode. This unidirectional conduit means 288 is in parallel with a metering restriction 293, the function of which will be described hereinafter. In order to deliver refrigerant liquid at a controlled and metered rate from the ambient insulated heat exchanger 284 to the indoor heat exchanger 252 a metering restriction 294 is provided. There is no flow, when the heat pump 220 is functioning in the cooling mode, through the parallel unidirectional conduit means 296 which includes a check valve 298 which blocks unrestricted flow in this sense from the ambient insulated heat exchanger 284 to the indoor heat exchanger 252.

In order to deliver liquid power fluid to the boiler 224 conduit means 299 is provided. In particular, liquid condensed power fluid is pumped from the power fluid condenser 254 by a pump 300 and through the conduit means 299 and through the heat exchangers 258 and 259 to the boiler 224. In the case of the heat exchanger 259 the liquid power fluid being returned to the boiler 224 is preheated by heat of condensation of that portion of initially expanded vaporized power fluid which the heat exchanger 259 receives from the power vapor compartment 232 of the diaphragm unit 226 as controlled by a solenoid operated valve 301. As shown, the condensing heat exchanger 259 is interconnected with the power vapor compartment 232 of the diaphragm unit 226 by means of the conduit 264 and a conduit 302 having a diverging portion 303 for converting kinetic energy of the enclosed power vapor to pressure energy. A pump 304 is provided for pumping that portion of power fluid that condenses in the heat exchanger 259 into the conduit means 299 to thus return this condensed liquid to the boiler 224. In the case of the heat exchanger 258 the liquid power fluid being returned to the boiler 224 is preheated by sensible heat from expanded and exhausted vaporized power fluid from the power vapor compartment 232 of the diaphragm unit 226 as controlled by the sequencing valve means 256. The action of the heat exchangers 258 and 259 in preheating the liquid power fluid being returned to the boiler 224 reduces the amount of heat that must be supplied by the heat source 247 to the boiler 224 thus increasing the coefficient of performance of the heat pump 220.

Again referring to the diaphragm pump means 222, the diaphragm pump means 222 also includes a unidirectional by-pass 305 for the liquid associated with the diaphragm pump means 222 so that during a particular time phase of operation, as will be explained

more fully hereinafter, the flow path is shortened for the liquid flowing from the liquid filled compartment 242 of the diaphragm unit 228 to the liquid filled compartment 234 of the diaphragm unit 226 thus reducing the inertia of such liquid flowing from the liquid filled compartment 242 to the liquid filled compartment 234.

As can more clearly be seen in FIG. 6 the unidirectional by-pass 305 includes a check valve 306 which is latched shut by a solenoid operated latch 308 which is shown in the latched closed position. Upon deenergization of a solenoid 310 the latch 308 drops down into the unlatched position in which it becomes disengaged from the check valve 306 so that the latter can freely open and allow liquid to flow freely in one direction. An override compression spring 312 cooperates with the latch 308 to allow the check valve 306 to open when sufficient liquid pressure is built up in the forward direction even though the latch 308 is in the latched closed position as shown in FIG. 6.

In as much as the liquid within the diaphragm pump means 222 is substantially incompressible the volume of liquid is substantially fixed and thus if the liquid in for instance the liquid filled compartment 234 of the diaphragm unit 226 moves a certain amount due to the motion of the diaphragm 230 the surface of the liquid in the liquid filled compartment 242 of the diaphragm unit 228 will move in accordance with the amount of movement of the diaphragm 230 whether or not there is a material diaphragm such as the diaphragm 238 on the surface of the liquid in the liquid filled compartment 242. Therefore, under certain conditions the diaphragm 238 may be omitted and the meniscus of the liquid in the liquid filled compartment 242 may function as the diaphragm 238. In such a case the diaphragm 230 in cooperation with the remainder of the diaphragm pump means 222 functions to separate the vaporized power fluid in the power vapor compartment 232 from the refrigerant vapor in the refrigerant vapor compartment 240. As shown in FIGS. 3a through 3c, the mean cross sectional area of the liquid column 246 is substantially less than the cross sectional area of the liquid at either the diaphragm 230 or the diaphragm 238, to thus reduce the mass of liquid required in the liquid column 246.

The operation of the heat pump 220 of FIGS. 3a through 3c will now be described with the heat pump 220 functioning in the cooling mode of operation. Each complete cycle of operation of the heat pump 220 has three time phases. The schematic diagrams of each of the FIGS. 3a through 3c illustrate respectively the positioning of the valve components and the direction of fluid flow for the particular time phase of operation being illustrated.

Referring to FIG. 3a, illustrating the first of the three time phases of operation, at the beginning of this first time phase of operation the diaphragm 230 is positioned in its uppermost position within the diaphragm unit 226 and the diaphragm 238 is positioned in its lowest position within the diaphragm unit 228 and the liquid of the diaphragm pump means 222 is at rest. The solenoid operated valve 301 is closed and the valve rotor 269 of the sequencing valve means 256 is so positioned as to close off the conduit 266 but permits the passage of vaporized power fluid from the boiler 224 through the conduit 262, the sequencing valve means

256 and the conduit 264 and into the power vapor compartment 232 of the diaphragm unit 226 to effect acceleration of the liquid column 246 from the liquid filled compartment 234 toward the liquid filled compartment 242 to thus move the diaphragm 230 and the diaphragm 238 in the directions shown by the arrows. During this time phase of operation and before the liquid column 246 has acquired its maximum velocity the inertia of the liquid column 246 offers sufficient opposition to the pressure of the vaporized power fluid flowing into the power vapor compartment 232 that the vaporized power fluid within the power vapor compartment 232 retains a large amount of potential energy by virtue of its pressure and volume that during the next time phase of operation substantially adiabatic expansion of the vaporized power fluid which entered the power vapor compartment 232 during the first time phase of operation will yield work sufficient to further increase the velocity and therefore the kinetic energy of the liquid column 246 so that substantially adiabatic compression of the refrigerant vapor within the refrigerant vapor compartment 240 can take place and the refrigerant vapor can be displaced from the refrigerant vapor compartment 240 during the second time phase of operation.

Referring to FIG. 3b there is illustrated the positioning of the various valve components and the fluid flow for the heat pump 220 for the second time phase of operation. During the second time phase of operation of the heat pump 220 the valve rotor 269 of the sequencing valve means 256 is positioned to prevent the flow of vaporized power fluid from the boiler 224 to the power vapor compartment 232 of the diaphragm unit 226 and also to prevent vaporized power fluid from passing from the power vapor compartment 232 to the power fluid condenser 254. During this time the check valve 306 of the unidirectional by-pass 305 is latched closed as shown in FIG. 6 by the action of the solenoid 310.

During the first portion of the second time phase of operation the solenoid operated valve 301 is open and the power vapor within the power fluid compartment 232 of the diaphragm unit 226 is allowed to expand substantially adiabatically and the initial adiabatic expansion of the power vapor within the power fluid compartment 232 causes a portion of the power vapor within the power fluid compartment 232 to flow unidirectionally from the power vapor compartment 232 through the conduits 264 and 302 into the condensing heat exchanger 259 where condensation of this portion of the power vapor liberates heat of condensation to provide heat to preheat liquid power fluid flowing to the boiler 224, and such initial adiabatic expansion of the power vapor within such compartment 232 also causes a transmittal of pressure energy to the liquid column 246. Such a flow of a portion of the power vapor to the condensing heat exchanger 259 permits the effective use of higher pressure and temperature within the boiler 224 which in turn increases the coefficient of performance of the heat pump 220. This increased pressure at higher temperature in the boiler 224 is brought about with only a slight increase in heat required from the heat source 247 per pound of power vapor produced. The additional energy caused by the amount of increase of pressure in the boiler 224

is used in the first time phase of operation to give greater acceleration to the liquid column 246 to thus require a lesser amount of energy to be applied during the second time phase of operation, through adiabatic expansion of a corresponding smaller amount of power vapor, to the liquid column 246 to thus permit dividing off a portion of the original power vapor that entered the power fluid compartment 232 during the first time phase of operation and letting the heat content of this portion of the power vapor to be returned during the second time phase of operation to the condensing heat exchanger 259 and thus to the boiler 224, which in turn reduces the heat required from the heat source 247. During the remaining portion of the second time phase of operation the solenoid operated valve 301 is closed and the remaining vaporized power fluid within the power vapor compartment 232 continues to expand substantially adiabatically to transmit its pressure energy to the liquid column 246 which in turn transmits pressure to the diaphragm 238 of the diaphragm unit 228 to thus substantially adiabatically compress refrigerant vapor within the refrigerant vapor compartment 240 of the diaphragm unit 228 and to finally expell such compressed refrigerant vapor from the refrigerant vapor compartment 240 through the conduit 270, the check valve 282, the conduit 274, the heating and cooling selector valve 260 and the conduit 276 and into the outdoor heat exchanger 250 to thereby condense and liquefy such compressed refrigerant vapor. During this remaining portion of this second time phase of operation the kinetic energy that was given to the liquid column 246 is converted back to pressure energy by action of the diverging diffuser 245 and is expended in expelling the aforementioned compressed refrigerant vapor. If any part of this kinetic energy remains after the diaphragm 238 reaches the upper restraining boundary of the refrigerant vapor compartment 240 of the diaphragm unit 228 the pressure suddenly increases within the liquid filled compartment 242 and this pressure energy is relieved by the opening of the spring biased check valve 306 and liquid is allowed to flow back to the compartment 234 through the unidirectional by-pass 305.

Liquefied refrigerant condensed in the outdoor heat exchanger 250 continuously flows from the outdoor heat exchanger 250 to the ambient insulated heat exchanger 284 and to the indoor heat exchanger 252 in a restricted manner as previously described.

Referring to FIG. 3c there is illustrated the positioning of the various valve components and the direction of fluid flow for the heat pump 220 for the third time phase of operation. During this third time phase of operation the solenoid operated latch 308 is allowed to drop by the action of the solenoid 310 into the unlatched position from the latched position as shown in FIG. 6 so that the check valve 306 is free to open and allow fluid to flow from the liquid filled compartment 242 of the diaphragm unit 228 through the unidirectional by-pass 305 to the liquid filled compartment 234 of the diaphragm unit 226 thus providing a liquid column having greatly reduced inertia.

During the third time phase of operation the solenoid operated valve 301 is closed and the rotor 269 of the sequencing valve means 256 is positioned to prevent the flow of vaporized power fluid from the boiler 224 to

the power vapor compartment 232 of the diaphragm unit 226, but to permit the flow of expanded vaporized power fluid from the power vapor compartment 232 of the diaphragm unit 226 through the conduit 264, the sequencing valve means 256, the conduit 266, the heat exchanger 258 and the conduit 268 and into the power fluid condenser 254 for condensing the expanded and expelled vaporized power fluid to a liquid. Such flow of expanded vaporized power fluid from the power vapor compartment 232 is due to the pressure of the evaporated refrigerant vapor flowing from the indoor heat exchanger 252 through the conduit 278, the heating and cooling selector valve 260, the conduit 272, the check valve 280 and the conduit 270 into the refrigerant vapor compartment 240 of the diaphragm unit 228, which flow displaces the diaphragm 238 in the direction indicated by the arrow and by means of the liquid interconnection with the diaphragm 230 of the diaphragm unit 226 the diaphragm 230 is moved in the direction indicated by the arrow to displace the aforementioned expanded vaporized power fluid from the power vapor compartment 232.

The power vapor that is condensed in the power fluid condenser 254 liberates heat of condensation which evaporates liquid refrigerant in the ambient insulated heat exchanger 284 and the resulting refrigerant vapor flows through the conduit 286, the heating and cooling selector valve 260 and the conduit 276 into the outdoor heat exchanger 250 where the evaporated refrigerant is condensed to liquid and the heat of condensation is liberated.

Condensed and liquefied power fluid is continuously pumped by the pump 300 from the power fluid condenser 254 through the conduit means 299 and through the heat exchangers 258 and 259 to the boiler 224.

Referring to FIG. 5 the heat pump 220 is shown with the movable member 261 of the heating and cooling selector valve 260 set so that the heat pump 220 functions in the heating mode. For simplicity of the drawings only the heating and cooling selector valve 260 with its movable member 261 and the associated conduits that connect it to the remainder of the heat pump 220 and the complete circuit of the refrigerant condensing and reevaporating means 248 are shown. In other words, the structural portion of the heat pump 220 shown in FIG. 5 as well as the remaining structural portion of the heat pump 220 not shown is identical to the heat pump shown in FIGS. 3a through 3c.

In operation, with the movable member 261 of the heating and cooling selector valve 260 set as shown in FIG. 5 for the heating mode of operation the indoor heat exchanger 252 functions as a refrigerant condenser for the heat pump 220 and the outdoor heat exchanger 250 functions as a refrigerant evaporator for the heat pump 220 so that heat can in effect be transferred from the outdoor heat exchanger 250 to the indoor heat exchanger 252. Thus, in operation with the heat pump 220 functioning in the heating mode, the operation of the heat pump 220 during all three time phases of operation is identical to the hereinbefore described operation for the heat pump 220 when functioning in the cooling mode except as to the flow of the refrigerant vapor to and from the means 248 for condensing and for reevaporating refrigerant vapor and the flow of liquid refrigerant between the indoor heat

exchanger 252, the ambient insulated heat exchanger 284 and the outdoor heat exchanger 250. Specifically, when the heat pump 220 is set in the heating mode refrigerant vapor flows during the second time phase of operation through the heating and cooling selector valve 260 and the conduit 278 to the indoor heat exchanger 252 for condensing and the condensed liquid refrigerant flows unrestricted from the indoor heat exchanger 252 through the check valve 298 into the ambient insulated heat exchanger 284 and flows in a restricted manner from the ambient insulated heat exchanger 284 through the metering restriction 293 to the outdoor heat exchanger 250. Then during the third time phase of operation evaporated refrigerant flows from the outdoor heat exchanger 250 through the conduit 276 and the heating and cooling selector valve 260 and through the check valve 280. During the heating mode of operation of the heat pump 220 evaporated refrigerant flows from the ambient insulated heat exchanger 284 through the conduit 286, the heating and cooling selector valve 260 and the conduit 278 to the indoor heat exchanger 252 to be condensed. The remainder of the operation of the heat pump 220 when functioning in the heating mode is substantially the same as hereinbefore described in the operation of the heat pump 220 when functioning in the cooling mode.

It is to be understood that in FIGS. 3a through 3c the diaphragm unit 228 could be replaced by two units (not shown) with the total internal volume equal to that of the diaphragm unit 228 as shown and with the such diaphragm units (not shown) being disposed substantially symmetrically on opposite sides of the diaphragm unit 226 so as to neutralize rotational reaction forces on the remainder of the heat pump as the liquid providing inertia within the system is accelerated during functioning of the heat pump. Of course in such a configuration for a heat pump (not shown) separate liquid columns (not shown) and separate unidirectional by-passes (not shown) would have to be provided to interconnect the smaller symmetrically disposed diaphragm units (not shown) with the centrally located diaphragm unit 226.

It is also to be understood that if water for instance were used as the power fluid for various embodiments shown herein, the condensed power fluid from for instance the condenser 254 of FIGS. 3a through 3c could be dumped, and a separate supply of water as power fluid could supply the boiler such as the boiler 224 of FIGS. 3a through 3c. It is further to be understood that there are many other sequencing valve concepts known in the art that could be used as the sequencing valve means in the systems 10, 110 and 220.

No heat exchanger has been employed in the various embodiments of this invention for heat exchange between liquid refrigerant flowing into the refrigerant evaporator and vaporized refrigerant leaving the evaporator as this technique is well known in the art of refrigeration. In practice such heat exchange technique would be expected to be used in connection with the embodiments shown and described herein.

It is also to be understood that the metering restrictions 208 and 214 of the heat pump 110 as illustrated in FIGS. 2a through 2f and the corresponding metering restrictions 293 and 294 of the heat pump 220 as illustrated in FIGS. 3a through 3c can be capillary tubes or

other evaporator liquid control devices known in the art such as thermal expansion valves.

It is to be understood that length of time involved in each of the time phases of the cycles for the various embodiments described herein depends largely on the fluid dynamics involved in the conduits of the various embodiments as determined by the various lengths and diameters of the conduits and the density of the fluids flowing therein. In general, the time length of each time phase of operation for the various embodiments described herein should be short enough to permit several complete cycles of operation per second.

Apparatus embodying the teachings of this invention has several advantages. For instance, there can be a wide choice of working substances for power fluid and for refrigerant fluid so that the thermally powered heat transfer system can be engineered to fit many special conditions. Another advantage of apparatus embodying the teachings of this invention is that such apparatus can readily function as an air to air heat transfer system. A further advantage of apparatus embodying the teachings of this invention is that such apparatus can be readily reversed so as to function as a heat pump. A still further advantage of apparatus embodying the teachings of this invention is that such apparatus has the possibility of a relatively high value of coefficient of performance. Other advantages of apparatus embodying the teachings of this invention is that such apparatus is simple, of low cost, can be readily designed for various capacity sizes, and can be easily serviced in the field.

I claim as my invention:

1. A thermally powered heat transfer system using as working substances a power fluid and a refrigerant fluid having a relatively lower boiling point than the power fluid and comprising the following connected components to form the heat transfer system: means for vaporizing the power fluid; means for condensing and for reevaporating the refrigerant fluid; diaphragm pump means having a power vapor compartment means and a refrigerant vapor compartment means and being responsive to the pressure energy of the vaporized power fluid; means for condensing the vaporized power fluid; means including sequencing valve means for controlling the mode of operation of said diaphragm pump means by permitting a flow of vaporized power fluid from said means for vaporizing the power fluid to the power vapor compartment means of said diaphragm pump means during a time phase of operation when said diaphragm pump means is offering sufficient pressure opposition to the vaporized power fluid flowing into the power vapor compartment means of said diaphragm pump means that at another time phase of operation as determined by said sequencing valve means substantially adiabatic expansion of such vaporized power fluid in such power vapor compartment means will yield work sufficient to substantially adiabatically compress refrigerant vapor in the refrigerant vapor compartment means of said diaphragm pump means, and by permitting during still another time phase of operation a flow of expanded vaporized power fluid from the power vapor compartment means of said diaphragm pump means to said means for condensing the vaporized power fluid, such flow of expanded vaporized power fluid being due to

the pressure of evaporated refrigerant vapor flowing from said means for condensing and for reevaporating the refrigerant fluid to the refrigerant vapor compartment means of said diaphragm pump means; means for delivering the substantially adiabatically compressed refrigerant vapor from the refrigerant vapor compartment means of said diaphragm pump means to said means for condensing and for reevaporating the refrigerant fluid; and means for delivering liquid power fluid to said means for vaporizing the power fluid.

2. The heat transfer system of claim 1 in which the maximum internal volume of the power vapor compartment means of said diaphragm pump means is substantially equal to the maximum internal volume of the refrigerant vapor compartment means of said diaphragm pump means.

3. The heat transfer system of claim 1 in which at least the refrigerant fluid is a fluorocarbon.

4. The heat transfer system of claim 1 in which said means for condensing and for reevaporating the refrigerant fluid includes an outdoor heat exchanger which is constructed to function as either a refrigerant evaporator or as a refrigerant condenser, and an indoor heat exchanger which is constructed to function as either a refrigerant condenser or as a refrigerant evaporator; an ambient insulated heat exchanger disposed in heat exchange relationship with said means for condensing the vaporized power fluid; a heating and cooling selector valve for effecting a flow of the compressed refrigerant vapor from the refrigerant vapor compartment means of said diaphragm pump means to said outdoor heat exchanger when said heating and cooling selector valve is set for the cooling mode of operation for the heat transfer system, and for effecting a flow of the compressed refrigerant vapor from the refrigerant vapor compartment means of said diaphragm pump means to said indoor heat exchanger when said heating and cooling selector valve is set for the heating mode of operation for the heat transfer system; means for delivering condensed refrigerant from said outdoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the cooling mode of operation for the heat transfer system; means for delivering condensed refrigerant from said indoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the heating mode of operation for the heat transfer system; and means for selectively delivering refrigerant vapor from said ambient insulated heat exchanger to either said outdoor heat exchanger or to said indoor heat exchanger when the particular said outdoor heat exchanger or said indoor heat exchanger is functioning as a condenser.

5. The heat transfer system of claim 1 in which said diaphragm pump means includes a pair of diaphragm units in which the power vapor compartment means is associated with one of said diaphragm units and the refrigerant vapor compartment means is associated with the other of said diaphragm units.

6. The heat transfer system of claim 5 in which means is provided for interconnecting said pair of diaphragm units with a confined column of liquid having inertia and velocity during at least a portion of the cycle of operation of the heat transfer system.

7. A thermally powered heat transfer system using as working substances a power fluid and a refrigerant fluid having a relatively lower boiling point than the power fluid and comprising the following connected to form the heat transfer system: means for vaporizing the power fluid; means for condensing and for reevaporating the refrigerant fluid; diaphragm pump means responsive to the pressure energy of the vaporized power fluid and including at least two diaphragm units, one of said two diaphragm units having a diaphragm, a power vapor compartment disposed on one side of the diaphragm and a liquid filled compartment disposed on the opposite side of the diaphragm, and the other of said two diaphragm units having a diaphragm, a refrigerant vapor compartment disposed on one side of such latter diaphragm and a liquid filled compartment disposed on the opposite side of such latter diaphragm, and conduit means enclosing a liquid column and being interconnected between the two liquid filled compartments associated with said two diaphragm units to thus interconnect said diaphragms with liquid having a predetermined inertia; means for condensing the vaporized power fluid; means including sequencing valve means for controlling the mode of operation of said diaphragm pump means by permitting during a time phase of operation a flow of vaporized power fluid from said means for vaporizing the power fluid to the power vapor compartment of said diaphragm pump means to effect an acceleration of said liquid column from the liquid filled compartment associated with said one of said two diaphragm units toward the liquid filled compartment associated with said other of said two diaphragm units, and by preventing during the next time phase of operation the flow of vaporized power fluid to the power vapor compartment of said diaphragm pump means during which latter time phase of operation the vaporized power fluid within the power vapor compartment of said diaphragm pump means expands substantially adiabatically to thus substantially compress refrigerant vapor in the refrigerant vapor compartment of said diaphragm pump means and expell such compressed refrigerant vapor into said means for condensing and for reevaporating the refrigerant fluid, and by permitting during still another time phase of operation a flow of expanded vaporized power fluid from the power vapor compartment of said diaphragm pump means to said means for condensing the vaporized power fluid, such flow of expanded vaporized power fluid being due to the pressure of evaporated refrigerant vapor flowing from said means for condensing and for reevaporating the refrigerant fluid to the refrigerant vapor compartment of said diaphragm pump means; and means for delivering liquid power fluid to said means for vaporizing the power fluid.

8. The heat transfer system of claim 7 in which said diaphragm pump means includes a unidirectional bypass for the liquid associated with said diaphragm pump means so that during said still another time phase of operation the flow path for the liquid flowing from the liquid filled compartment associated with the refrigerant vapor compartment to the liquid filled compartment associated with the power vapor compartment is shortened thus reducing the inertia of such flowing liquid.

9. The heat transfer system of claim 7 in which the meniscus of the liquid in the liquid filled compartment associated with the refrigerant vapor compartment functions as the diaphragm separating such liquid filled compartment from such refrigerant vapor compartment.

10. The heat transfer system of claim 7 in which said means for condensing and for reevaporating the refrigerant fluid includes an outdoor heat exchanger which is constructed to function as either a refrigerant evaporator or as a refrigerant condenser and an indoor heat exchanger which is constructed to function as either a refrigerant condenser or as a refrigerant evaporator; an ambient insulated heat exchanger disposed in heat exchange relationship with said means for condensing the vaporized power fluid; a heating and cooling selector valve for effecting a flow of the expelled compressed refrigerant vapor from the refrigerant vapor compartment of said diaphragm pump means to said outdoor heat exchanger when said heating and cooling selector valve is set in the cooling mode of operation for the heat transfer system and for effecting a flow of the expelled compressed refrigerant vapor from the refrigerant vapor compartment of said diaphragm pump means to said indoor heat exchanger when said heating and cooling selector valve is set for the heating mode of operation for the heat transfer system; means for delivering condensed refrigerant from said outdoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the cooling mode of operation for the heat transfer system; means for delivering condensed refrigerant from said indoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the heating mode of operation for the heat transfer system; and means for selectively delivering refrigerant vapor from said ambient insulated heat exchanger to either said outdoor heat exchanger or to said indoor heat exchanger when the particular said outdoor heat exchanger or said indoor heat exchanger is functioning as a condenser.

11. The heat transfer system of claim 7 in which said means for delivering liquid power fluid to said means for vaporizing the power fluid includes a condensing heat exchanger for preheating such liquid power fluid by means of power vapor received from said power vapor compartment during the first portion of said next time phase of operation in which initial substantially adiabatic expansion of the power vapor within said power vapor compartment takes place.

12. A thermally powered heat transfer system using as working substances a power fluid and a refrigerant fluid having a relatively lower boiling point than the power fluid and comprising the following connected to form the heat transfer system: means for vaporizing the power fluid; means for condensing and for reevaporating the refrigerant fluid; diaphragm pump means responsive to the pressure energy of the vaporized power fluid and including at least two diaphragm pump units each of said two diaphragm pump units having a diaphragm, a power vapor compartment on one side of the diaphragm and a refrigerant vapor compartment on the opposite side of the diaphragm; means for condensing the vaporized power fluid; an ejector for receiving vaporized power fluid from said means for

vaporizing the power fluid; means including sequencing valve means for controlling the mode of operation of said diaphragm pump means by permitting during a time phase of operation a flow of vaporized power fluid from said means for vaporizing the power fluid and through said ejector to fill the power vapor compartment of one of said two diaphragm pump units with vaporized power fluid to overcome the pressure opposition of the diaphragm of said one of said two diaphragm pump units as caused by the back pressure in a condensing portion of said means for condensing and for reevaporating the refrigerant fluid to thereby expell refrigerant vapor from the refrigerant vapor compartment of said one of said two diaphragm pump units into said means for condensing and for reevaporating the refrigerant fluid, and by permitting during another time phase of operation substantially adiabatic expansion of such vaporized power fluid in the power vapor compartment of said one of said two diaphragm pump units to substantially adiabatically compress refrigerant vapor in the refrigerant vapor compartment of the other of said two diaphragm pump units, and by permitting during still another time phase of operation a flow of expanded vaporized power fluid from the power vapor compartment of said one of said two diaphragm pump units to said means for condensing the vaporized power fluid, such flow of expanded vaporized power fluid being due to the pressure of evaporated refrigerant vapor flowing from said means for condensing and reevaporating the refrigerant fluid to thus fill the refrigerant vapor compartment of said one of said two diaphragm pump units; and means for delivering liquid power fluid to said means for vaporizing the power fluid.

13. The heat transfer system of claim 12 in which means is provided for heat exchanging the expanded vaporized power fluid flowing from the power vapor compartment of said one of said two diaphragm pump units to said means for condensing the vaporized power fluid with at least a portion of the liquid power fluid being delivered to said means for vaporizing the power fluid to thereby preheat such liquid power fluid by cooling the expanded vaporized power fluid before delivery to said means for condensing the vaporized power fluid.

14. The heat transfer system of claim 12 in which said means for condensing and for reevaporating the refrigerant fluid includes an outdoor heat exchanger which is constructed to function as either a refrigerant evaporator or as a refrigerant condenser, and an indoor heat exchanger which is constructed to function as either a refrigerant condenser or as a refrigerant evaporator; an ambient insulated heat exchanger disposed in heat exchange relationship with said means for condensing the vaporized power fluid; a heating and cooling selector valve for effecting a flow of the expelled refrigerant vapor from the refrigerant vapor compartment of said one of said two diaphragm pump units to said outdoor heat exchanger when said heating and cooling selector valve is set for the cooling mode of operation for the heat transfer system, and for effecting a flow of the expelled refrigerant vapor from the refrigerant vapor compartment of said one of said two diaphragm pump units to said indoor heat exchanger when said heating and cooling selector valve is set for

the heating mode of operation for the heat transfer system; means for delivering condensed refrigerant from said outdoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the cooling mode of operation for the heat transfer system; means for delivering condensed refrigerant from said indoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the heating mode of operation for the heat transfer system; and means for selectively delivering refrigerant vapor from said ambient insulated heat exchanger to either said outdoor heat exchanger or to said indoor heat exchanger when the particular said outdoor heat exchanger or said indoor heat exchanger is functioning as a condenser.

15. A thermally powered heat transfer system using as working substances a power fluid and a refrigerant fluid having a relatively lower boiling point than the power fluid and comprising the following connected to form the heat transfer system; means for vaporizing the power fluid; means for condensing and for reevaporating the refrigerant fluid; diaphragm pump means responsive to the pressure energy of the vaporized power fluid and including at least two diaphragm pump units each of which diaphragm pump units having a diaphragm, a power vapor compartment on one side of the diaphragm and a refrigerant vapor compartment on the opposite side of the diaphragm; means for condensing the vaporized power fluid; an ejector including a discharge, a secondary inlet and a primary inlet for receiving vaporized power fluid from said means for vaporizing the power fluid; means including sequencing valve means interconnected with said two diaphragm pump units and with the discharge and with the secondary inlet of said ejector for controlling the mode of operation of said diaphragm pump means by permitting during a time phase of operation a flow of vaporized power fluid from said means for vaporizing the power fluid and through the primary inlet and discharge of said ejector to fill the power vapor compartment of one of said two diaphragm pump units with vaporized power fluid to overcome the pressure opposition of the diaphragm of said one of said two diaphragm pump units as caused by the back pressure in a condensing portion of said means for condensing and for reevaporating the refrigerant fluid, to thereby expell refrigerant vapor from the refrigerant vapor compartment of said one of said two diaphragm pump units into said means for condensing and for reevaporating the refrigerant fluid, and by permitting during the same time phase of operation a flow of power vapor from the power vapor compartment of the other of said two diaphragm pump units to the secondary inlet of said ejector, and by permitting during another time phase of operation substantially adiabatic expansion of such vaporized power fluid in the power vapor compartment of said one of said two diaphragm pump units to substantially adiabatically compress refrigerant vapor in the refrigerant vapor compartment of said other of said two diaphragm pump units, and by permitting during still another time phase of operation a flow of expanded vaporized power fluid from the power vapor compartment of said one of said two diaphragm pump units to said means for condensing the vaporized power fluid,

such flow of expanded vaporized power fluid being due to the pressure of evaporated refrigerant vapor flowing from said means for condensing and reevaporating the refrigerant fluid to thus fill the refrigerant vapor compartment of said one of said two diaphragm pump units; and means for delivering liquid power fluid to said means for vaporizing the power fluid.

16. The heat transfer system of claim 15 in which means is provided for heat exchanging the expanded vaporized power fluid flowing from the power vapor compartment of said one of said two diaphragm pump units to said means for condensing the vaporized power fluid with at least a portion of the liquid power fluid being delivered to said means for vaporizing the power fluid to thereby preheat such liquid power fluid by cooling the expanded vaporized power fluid before delivery to said means for condensing the vaporized power fluid.

17. The heat transfer system of claim 15 in which said means for condensing and for reevaporating the refrigerant fluid includes an outdoor heat exchanger which is constructed to function as either a refrigerant evaporator or as a refrigerant condenser and an indoor heat exchanger which is constructed to function as either a refrigerant condenser or as a refrigerant evaporator; an ambient insulated heat exchanger disposed in heat exchange relationship with said means for condensing the vaporized power fluid; a heating and cooling selector valve for effecting a flow of the expelled refrigerant vapor from the refrigerant vapor compartment of said one of said two diaphragm pump units to said outdoor heat exchanger when said heating and cooling selector valve is set for the cooling mode of operation for the heat transfer system and for effecting a flow of the expelled refrigerant vapor from the refrigerant vapor compartment of said one of said two diaphragm pump units into said indoor heat exchanger when said heating and cooling selector valve is set for the heating mode of operation for the heat transfer system; means for delivering condensed refrigerant from said outdoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the cooling mode of operation for the heat transfer system; means for delivering condensed refrigerant from said indoor heat exchanger to said ambient insulated heat exchanger when said heating and cooling selector valve is set in the heating mode of operation for the heat transfer system; and means for selectively delivering refrigerant vapor from said ambient insulated heat exchanger to either said outdoor heat exchanger or to said indoor heat exchanger when the particular said outdoor heat exchanger or said indoor heat exchanger is functioning as a condenser.

18. The heat transfer system of claim 15 in which said means for delivering liquid power fluid to said means for vaporizing the power fluid includes a condensing heat exchanger for preheating such liquid power fluid by means of power vapor received through said sequencing valve means from the power vapor compartment of said other of said two diaphragm pump units during still another time phase of operation in which initial adiabatic expansion of the power vapor within the power vapor compartment of said other of said two diaphragm pump units takes place.

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