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UNIDIRECTIONAL HEAT PUMP SYSTEM

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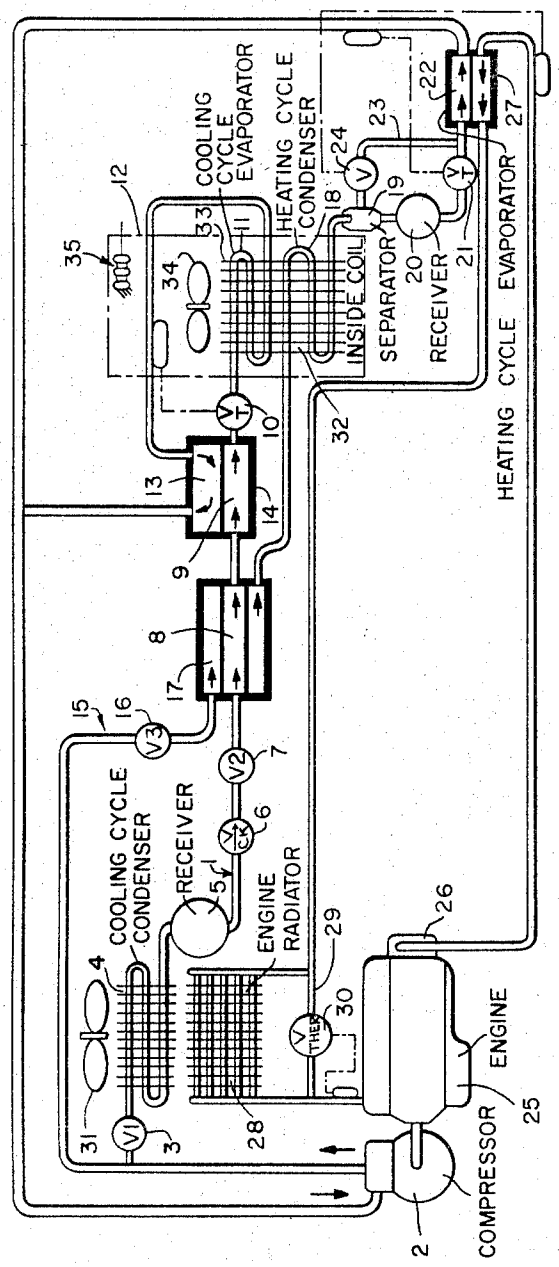


FIG. 1

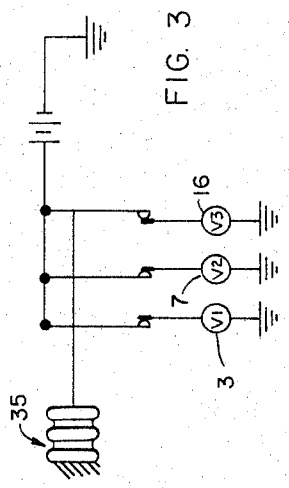


FIG. 3

OPERATING MODE	V1	V2	V3
COOLING	OPEN	OPEN	CLOSED
COMPENSATING	OPEN	OPEN	OPEN
HEATING	CLOSED	CLOSED	OPEN

FIG. 2

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UNIDIRECTIONAL HEAT PUMP SYSTEM

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ABSTRACT OF THE DISCLOSURE

A heat pump system having a heating circuit and a cooling circuit which contemplates only one direction of refrigerant flow in said circuits, a common compressor for said circuits and means for transferring the refrigerant from one circuit to the other. The disclosure also includes an internal combustion engine drive for the aforementioned system with specific means for utilizing the engine heat to vaporize the refrigerant in the heating circuit and special provision for controlling the refrigerant flow in the heating circuit in response to engine cooling fluid temperature.

Background of the invention

Many engine driven heat pumps using a vapor-compression refrigeration cycle have been devised for heating and cooling a conditioned space. Most of these systems, however, operate to reverse the refrigerant flow during one cycle of operation or the other. Such systems generally employ a complicated and somewhat unreliable reversing valve. Further, such systems present a problem in returning to the compressor lubricating oil which has become entrained with the refrigerant. An evaporator or condenser which may be designed for good oil return for one direction of refrigerant flow is generally of inferior design for returning oil to the compressor under the opposite direction of refrigerant flow.

Systems which utilize an atmospheric air heated evaporator for the heating cycle often experience too low a suction pressure for adequate capacity.

Further, reverse cycle systems which utilize the engine as a source of heat generally find it difficult and complicated to utilize the engine as a heat sink.

Summary of the invention

It is generally an object of the instant invention to provide a system which obviates the above indicated problems. The instant invention contemplates a heat pump refrigerant system employing a first refrigerant circuit for cooling and a second refrigerant circuit for heating and a compressor means common to each of said circuits. Means for transferring refrigerant charge from one circuit to the other as required is provided.

The instant invention further contemplates a control system for directing refrigerant to one or the other or both of the refrigerant circuits for heating, cooling or compensating operation as the temperature of the space being conditioned may dictate. This invention employs refrigerant circuits that make it unnecessary to reverse the flow of refrigerant within the system thereby eliminating reversing valve means and attendant problems of oil return. Further, this invention includes a means for utilizing engine heat for evaporating refrigerant on the heating cycle thereby eliminating problems of low suction pressure normally associated with atmospheric air heated evaporators.

This invention involves a refrigeration system comprising: a refrigerant compressor; a first refrigerant condenser; a second refrigerant condenser; a first refrigerant evaporator; a second refrigerant evaporator; a first refrigerant circuit serially connecting said compressor, said first condenser, and said first evaporator in a closed refrigerant loop; a second refrigerant circuit serially connecting said compressor, said second condenser, and said second evaporator in closed refrigerant loop; a portion of said first and second circuits at said compressor being common to each other; a refrigerant receiver disposed in said first circuit downstream of said first condenser and upstream of said first evaporator; a heat exchange means disposed in said second circuit upstream of said second condenser and downstream of said common portion of said circuit for exchanging heat from said second circuit to said receiver.

This invention is directed to a refrigeration system comprising: a refrigerant compressor; a first refrigerant condenser; a second refrigerant condenser; a first refrigerant evaporator; a second refrigerant evaporator; a first refrigerant circuit serially connecting said compressor, said first condenser, and said first evaporator in a closed refrigerant loop; a second refrigerant circuit serially connecting said compressor, said second condenser, and said second evaporator in closed refrigerant loop; a portion of said first and second circuits at said compressor being common to each other; a conditioned space disposed in heat exchange relation with said first evaporator and said second condenser; a continuously operating internal combustion engine drivingly connected to said compressor; and control means for directing refrigerant gas from the compressor through said first circuit for cooling said conditioned space, for directing refrigerant gas from said compressor through said second circuit for heating said conditioned space, and for directing refrigerant gas from said compressor simultaneously through both of said first and second circuits for providing a minimum heat exchange with said conditioned space.

This invention further involves a refrigeration system comprising: a refrigerant compressor; a first refrigerant condenser; a second refrigerant condenser; a first refrigerant evaporator; a second refrigerant evaporator; a first refrigerant circuit serially connecting said compressor, said first condenser, and said first evaporator in a closed refrigerant loop; a second refrigerant circuit serially connecting said compressor, said second condenser, and said second evaporator in closed refrigerant loop; a portion of said first and second circuits at said compressor being common to each other; an internal combustion engine drivingly connected to said compressor; means for cooling said engine with a cooling fluid; means for heat exchanging said cooling fluid with said second evaporator.

Other objects and advantages will become apparent as this specification proceeds to describe the invention in detail with reference to the accompanying drawings in which:

FIGURE 1 is a flow diagram of a refrigeration system incorporating aspects of the instant invention;

FIGURE 2 is a table showing the modes of operating the system shown in FIGURE 1; and

FIGURE 3 is a temperature control circuit for the system shown in FIGURE 1.

Now referring to FIGURE 1, it will be seen that the refrigeration system has a first refrigeration circuit **1** comprising a refrigerant compressor **2**, a first solenoid operated normally closed shut-off valve **3**, an air cooled refrigerant condenser **4**, a first refrigerant receiver **5**, a one-way check valve **6** arranged for flow from the receiver, a second solenoid operated normally closed shut-off valve **7**, a second receiver **8** adapted to be heated by refrigerant in a second refrigerant circuit yet to be described, the first portion **9** of a suction line heat exchanger **14**, a throttling means such as thermostatically

controlled expansion valve 10, an air heated evaporator 11 disposed in heat exchange relation with a space 12 to be temperature conditioned, and the second portion 13 of heat exchanger 14 respectively serially connected in a closed refrigerant loop. The refrigeration system further has a second refrigerant circuit 15 comprising compressor 2, solenoid operated normally closed shut-off valve 16, heat exchanger 17 adapted to heat receiver 8, an air cooled condenser 18 disposed in heat exchange relation with space 12, a liquid-gas separator 19, a refrigerant liquid receiver 20, a throttling means such as thermostatically controlled expansion valve 21, and a water heated evaporator 22 respectively serially connected in a closed refrigerant loop. Second refrigerant circuit 15 further includes a conduit 23 bypassing receiver 20 and expansion valve 21 for conducting gas from separator 19 to a point in the second refrigerant circuit downstream of expansion valve 21 and upstream of evaporator 22 which includes a thermostatically controlled valve 24 arranged to open upon sensing a temperature below a predetermined temperature. It will be noted that those portions of said first and second circuits immediately upstream and downstream of compressor 2 are common to each other.

Compressor 2 is driven continuously by internal combustion engine 25. Engine 25 is provided with a water cooling system including a water circulator pump 26, a heat exchanger 27 adapted to heat evaporator 22 and an air cooled engine radiator 28 respectively connected in series with the water jacket of engine 25. The cooling water circuit further has a bypass conduit 29 shunting radiator 28 provided with a water temperature responsive valve 30 for controlling the temperature of the water returning to the engine. Valve 24 is arranged to be responsive to the temperature of the water in that portion of the water cooling circuit downstream of pump 26 and upstream of heat exchanger 27.

The refrigeration system further has a fan 31 for passing atmospheric cooling air sequentially over condenser 4 and radiator 28. Evaporator 11 and condenser 18 are constructed as separate circuits in a single fin-and-tube heat exchanger 32 having common fins 33 embracing both circuits. Fan 34 is arranged to pass air from the conditioned space over heat exchanger 32 for conditioning the air in space 12. A control thermostat 35 arranged in heat exchange relation with space 12 operates the valves 3, 7 and 16 in accordance with the operating modes shown in the chart of FIGURE 2. The control circuit for this purpose is shown in FIGURE 3.

Operation

Assume engine 25, fan 31 and fan 34 are operating and space 12 is excessively warm. The bellows of temperature controller 35 is in a position energizing solenoid valves 3 and 7 to their open position and de-energizing solenoid valve 16 to its closed position. No refrigerant flows in refrigerant circuit 15 as valve 16 is closed. Compressor 2 delivers refrigerant gas under high pressure via valve 3 to condenser 4. The refrigerant is cooled and caused to condense in condenser 4 by the cooling air from fan 31. Condensed refrigerant passes to receiver 5 through check valve 6, open solenoid valve 7, receiver 8 to the first portion 9 of suction line heat exchanger 14 where the liquid refrigerant is further cooled by heat exchange with suction gas. The subcooled liquid refrigerant is throttled to a lower pressure by passage through expansion valve 10. The refrigerant at greatly reduced pressure is caused to evaporate in evaporator 11 by heat absorbed from the air of the condition-space circulated over evaporator 11 by fan 34. The vaporized refrigerant passes to the suction side of the compressor via the second portion 13 of the suction line heat exchanger 14. During this cooling cycle of operation, receiver 8 is substantially full of liquid refrigerant. Also the engine 25 is cooled by cooling water which passes from pump 26, through exchanger 27, and radiator 28 from whence it is returned to the engine. Bypass 29 and thermostatic valve 30 control the temperature of this return water. The system operating in this manner will cause the temperature in conditioned space 12 to be lowered until thermostatic control 35 indicates that no further substantial cooling is needed by energizing valve 16 thus causing valve 16 to open. Valves 3 and 7 remain energized and open.

A portion of the compressed refrigerant from compressor 2 continues to pass through the first refrigerant circuit in the manner just described. However, since valve 16 is now open, a portion of the compressed refrigerant from compressor 2 passes through valve 16, heat exchanger 17, to condenser 18. The hot refrigerant gas is then cooled and condensed by heat rejected to the conditioned space via the air directed over condenser 18 by fan 34. Also some heat is conducted directly to evaporator 11 via fins 33. The condensed refrigerant then passes through separator 19, receiver 20 to expansion valve 21 where the pressure is reduced upon the refrigerant entering evaporator 22. The liquid refrigerant at reduced pressure in evaporator 22 is vaporized by heat from the engine cooling water in heat exchanger 27. The thus vaporized refrigerant is returned from evaporator 22 to compressor 2. Since evaporator 11 tends to cool while condenser 18 tends to heat the conditioned space, the net exchange of heat between the conditioned space and heat exchanger 32 is little or nothing. If desired, the system components may be designed to achieve small net cooling or heating by exchanger 32 under this compensating cycle of operation.

Should the conditioned space drop in temperature sufficiently to require heating, temperature controller 35 will further move to a position de-energizing and opening solenoid valves 3 and 7 thus terminating flow through the first refrigerant circuit. Valve 16 remains energized and open and the second refrigerant circuit continues to operate in a manner similar to that just described. However, now all the compressed refrigerant gas from compressor 2 is directed through valve 16, etc. This gas passing through heat exchanger 17 causes some refrigerant in receiver 8 to vaporize whereupon the refrigerant in receiver 8 is driven through evaporator 11 into the suction side of the compressor and ultimately into the second refrigerant circuit. Thus a large portion of the refrigerant used in the first refrigerant circuit for the cooling cycle is utilized in the second refrigerant circuit during the heating cycle thereby minimizing the amount of refrigerant required in the system.

Should the internal combustion engine 25 be first started when heating of space 12 is required, the cooling water in heat exchanger 27 will not at first have sufficiently high temperature to vaporize the refrigerant liquid in evaporator 22. To assist in starting the refrigerant flow through the second refrigerant circuit, valve 24 is opened in response to low cooling water temperature. This permits the refrigerant gas at separator 19 to temporarily bypass receiver 20 and expansion valve 21 thereby permitting an unrestricted flow of refrigerant gas back to the compressor. Separator 19 permits substantially only gas to travel this route so that no slugging will occur in the compressor. After the normal engine temperatures are reached, valve 24 is closed and all refrigerant passing through the second refrigerant circuit 15 must pass through expansion valve 21 as during normal operation under compensating or heating modes of operation.

Having thus described in detail the preferred embodiment of our invention, we contemplate that many changes may be made without departing from the scope or spirit of our invention and we accordingly desire to be limited only by the claims.

We claim:

1. A refrigeration system comprising: a refrigerant compressor; means for driving said compressor; a first refrigerant condenser; a second refrigerant condenser; a

first refrigerant evaporator; a second refrigerant evaporator; a first refrigerant throttling means; a second refrigerant throttling means; a first refrigerant circuit serially connecting said compressor, said first condenser, said first refrigerant throttling means, and said first evaporator respectively in a closed refrigerant loop; a second refrigerant circuit serially connecting said compressor, said second condenser, said second refrigerant throttling means, and said second evaporator respectively in a closed refrigerant loop; a portion of said first and second circuits at said compressor being common to each other; a refrigerant receiver disposed in said first circuit downstream of said first condenser and upstream of said first evaporator; a heat exchange means disposed in said second circuit upstream of said second condenser and downstream of said common portion of said circuit for exchanging heat from said second circuit to said receiver.

2. The apparatus as defined by claim **1** including valve means disposed in said first circuit downstream of said first condenser and upstream of said receiver for preventing reverse flow in said first circuit when said receiver is heated by said heat exchange means.

3. The apparatus as defined by claim **1** including a conditioned space disposed in heat exchange relation with said first evaporator and said second condenser; a first valve means disposed in said first circuit upstream of said first condenser and downstream of the common portion of said circuits; a second valve means disposed in said first circuit upstream of said receiver and downstream of said first condenser; a third valve means in said second circuit upstream of said heat exchange means and downstream of the common portion of said circuits; and control means for opening said first and second valve means and closing said third valve means for cooling said conditioned space, for closing said first and second valve means and opening said third valve means for heating said conditioned space, and for opening said first, second and third valve means for providing minimum heat exchange with said conditioned space.

4. A refrigeration system comprising: a refrigerant compressor; a first refrigerant condenser; a second refrigerant condenser; a first refrigerant throttling means; a second refrigerant throttling means; a first refrigerant evaporator; a second refrigerant evaporator; a first refrigerant circuit serially connecting said compressor, said first condenser, said first refrigerant throttling means, and said first evaporator respectively in a closed refrigerant loop; a second refrigerant circuit serially connecting said compressor, said second condenser, said second refrigerant throttling means, and said second evaporator respectively in a closed refrigerant loop; a portion of said first and second circuits at said compressor being common to each other; a conditioned space disposed in heat exchange relation with said first evaporator and said second condenser; a continuously operable internal combustion engine drivingly connected to said compressor; and control means for directing refrigerant gas from the compressor through said first circuit for cooling said conditioned space, for directing refrigerant gas from said compressor through said second circuit for heating said conditioned space, and for directing refrigerant gas from said compressor simultaneously through both of said first and second circuits for providing a minimum heat exchange with said conditioned space.

5. A refrigeration system comprising: a refrigerant compressor; a first refrigerant condenser; a second refrigerant condenser; a first refrigerant throttling means; a second refrigerant throttling means; a first refrigerant evaporator; a second refrigerant evaporator; a first refrigerant circuit serially connecting said compressor, said first condenser, said first refrigerant throttling means, and said first evaporator respectively in a closed refrigerant loop; a second refrigerant circuit serially connecting said compressor, said second condenser, said second refrigerant throttling means, and said second evaporator respectively in a closed refrigerant loop; a portion of said first and second circuits at said compressor being common to each other; an internal combustion engine drivingly connected to said compressor; means for cooling said engine with a cooling fluid; and means for heat exchanging said cooling fluid with said second evaporator.

6. The apparatus as defined by claim **5** including a gas-liquid separator disposed in said second circuit downstream of said second condenser and upstream of said second evaporator; refrigerant throttling means disposed in said second circuit downstream of said separator and upstream of said second evaporator; a bypass conduit connected to said separator for conducting gas therefrom to a point in said second circuit downstream of said throttling means on the upstream side of said second evaporator; and automatic valve means in said bypass conduit responsive to the temperature of said engine cooling fluid.

7. The apparatus as defined by claim **5** wherein said first evaporator and said second condenser are first and second circuits respectively of a heat exchanger having fins common to both the circuits of the heat exchanger and disposed in heat exchange relation with a conditioned space.

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