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AIR CONDITIONING SYSTEM

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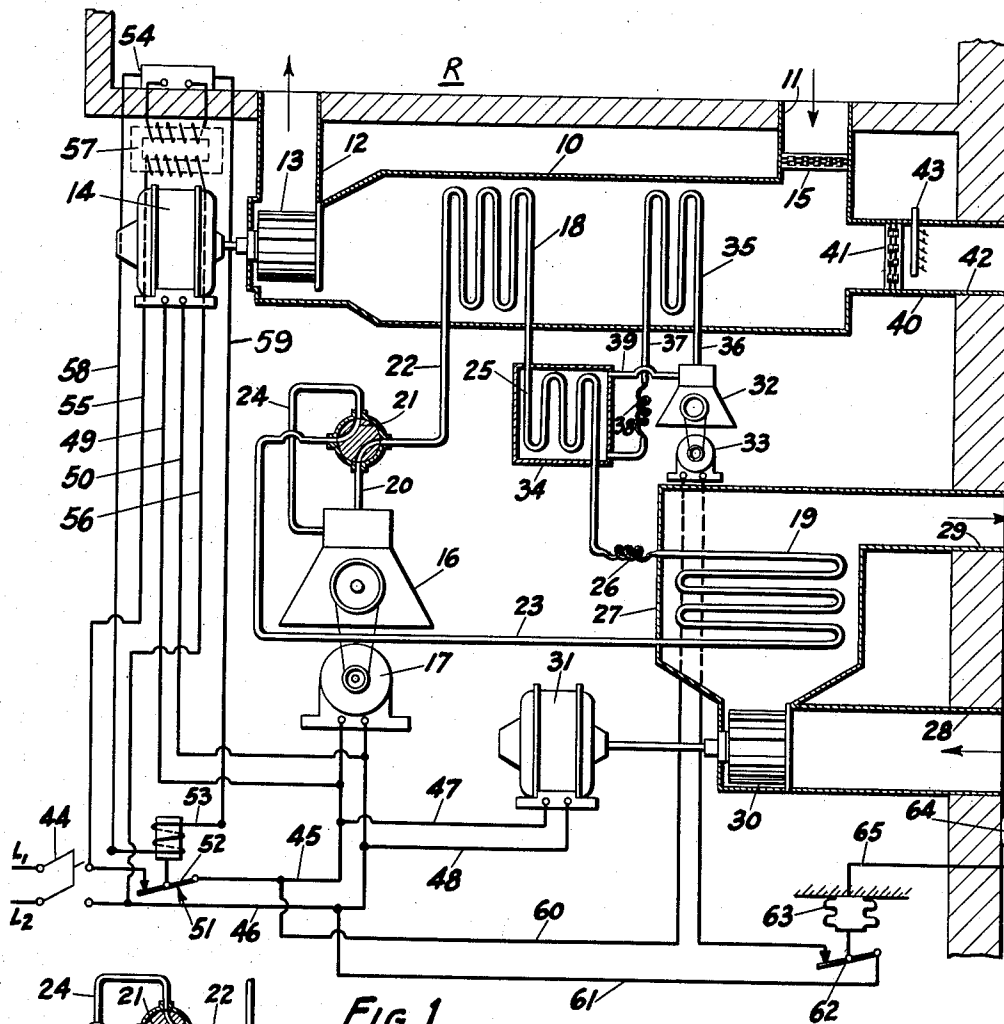


FIG. 1

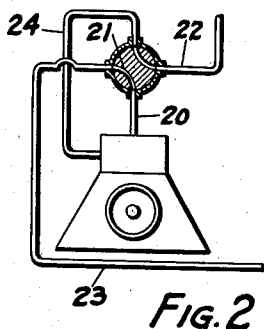


FIG. 2

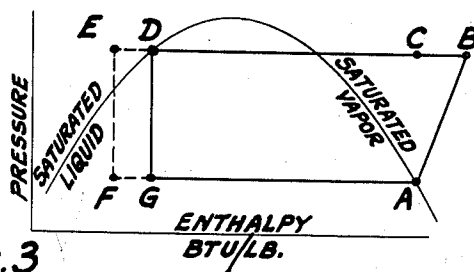


FIG. 3

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AIR CONDITIONING SYSTEM

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10 Claims. (Cl. 62—160)

This invention relates to reversible refrigerating apparatus more commonly known as heat pumps.

It is well known, of course, that refrigerating apparatus can be reversed and utilized for heating an enclosure rather than for cooling an enclosure. Operated in this manner, heat is picked up from outside air or water by evaporating low temperature refrigerant which is then compressed to a sufficiently high pressure and corresponding temperature by the refrigerating compressor to give up its heat to the air within the enclosure, the refrigerant becoming condensed thereby. Since in the great majority of instances there is not sufficient amounts of water practically available, outside air must be utilized as the heat source.

There are many factors limiting the use of outside air as a heat source, however. The primary one is the fact that as the outside air temperature drops, the capacity of the apparatus drops at the very time when heating requirements are increasing. This drop is caused by two factors: one, as the outside air temperature drops, the temperature differentials at which the compressor must operate correspondingly increase, since the upper or condensing temperature must remain fairly constant and at an elevated temperature. The volumetric efficiency of the compressor thereby decreases, since it is a well established fact that the efficiency of a compressor varies inversely as the pressure differential at which it must operate, corresponding to the temperature differential, increases. Two, as the outside air temperature drops, the evaporator of the refrigerating apparatus must operate at a correspondingly lower temperature and corresponding pressure to remove heat from the outside air, thereby decreasing the density of the refrigerant gas circulated. It will be appreciated, of course, that with a compressor of a fixed volumetric displacement, as the density of the refrigerant decreases, the total weight of refrigerant circulated decreases with a corresponding decrease in capacity. The capacity, of course, is directly dependent on the pounds of refrigerant circulated through the apparatus.

For the above reasons, heat pumps, although performing satisfactorily in moderate climates, are not in general use in those climates having sustained cold periods below 30° F. unless, as pointed out above, there is sufficient water available as a heat source.

With the continual expansion of air conditioning there has been a considerable research effort expended in trying to increase the capacity of the heat pump at low outside air temperatures. It can be easily understood that great economies could be effected if the same apparatus that was used to cool an enclosure in the summer could be efficiently used to heat the enclosure in the winter.

It is an object of this invention to provide a heat pump system utilizing a primary refrigerating apparatus including an outdoor heat-exchanger for absorbing heat from the outside air and an indoor heat-exchanger in heat-exchange relation with the room air to be heated and, in addition thereto, a secondary refrigerating apparatus including, an evaporator utilizing hot liquid refrigerant in the primary refrigerating apparatus as a heat source, and a condenser in heat-exchange relation with the room air to be heated.

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The secondary refrigerating apparatus serves to cool the refrigerant liquid in the primary system from a condensing temperature in the order of 105° F. to a temperature in the order of 40° F. The fact that the evaporator temperature of the secondary refrigerating apparatus is considerably higher than the temperature in the outdoor heat-exchanger of the primary refrigerating apparatus, which for winter operations acts as an evaporator at temperatures ranging down to 0° F., results in a high co-efficient of performance for this secondary apparatus which reflects on the overall co-efficient of performance of the entire system in a beneficial way. The outside air cooling capacity of the primary system is increased by reason of the fact that each pound of refrigerant circulated to the outdoor heat-exchanger contains fewer B.t.u.'s, having been cooled by the secondary refrigerating apparatus, and therefore can pick up more B.t.u.'s in evaporation. These extra B.t.u.'s are transferred to the secondary apparatus and are then discharged into the air to be heated by the condenser of the secondary refrigerating apparatus.

It is a further object of the invention to provide a heat pump system as above set out and wherein actuating means are provided for the secondary apparatus responsive to a predetermined low outside air temperature. In operation the primary refrigerating apparatus, which cools air during summer operation, may be reversed as soon as there is a need for heating in the enclosure. This apparatus generally will be able to supply sufficient heat down to some predetermined low temperature, say 30° F. As the outside temperature reaches the predetermined low point, a control will actuate a switch putting the secondary apparatus in operation to provide the additional heating required.

A still further object of the invention is to provide an air conditioning system including a primary refrigerating apparatus having an indoor heat-exchanger in heat-exchange relation with the air to be heated and an outdoor heat-exchanger in heat-exchange relation with the outside air and including a secondary refrigerating apparatus comprising a condenser in heat-exchange relation with the air to be heated and an evaporator in heat-exchange relation with liquid refrigerant flowing between the indoor and outdoor heat-exchangers of the primary apparatus; and means for directing the refrigerant in a first path through said heat-exchangers when cooling is desired and in a reversed path when heating is desired and further including means responsive to a predetermined low outdoor temperature for actuating the secondary apparatus.

The invention consists of the novel constructions, arrangements and devices to be hereinafter described and claimed for carrying out the above-stated objects and such other objects as will appear from the following description of preferred embodiments of the invention described with reference to the accompanying drawings, in which: Fig. 1 is a schematic representation of an air conditioning system embodying the invention, including a refrigerant reversing valve in its heating position; Fig. 2 is a partial view showing the reversing valve in its cooling position; and Fig. 3 is a pressure-enthalpy diagram illustrating the principles involved.

In accordance with the invention, means are provided for conditioning the air in an enclosure R. A duct 10 communicates with the enclosure to be conditioned by way of an inlet 11 and an outlet 12. A fan 13 driven by a motor 14 is positioned to withdraw air from the enclosure via inlet 11 and thence through duct 10, discharging

Fig. 1 is a schematic representation of an air conditioning system embodying the invention, including a refrigerant reversing valve in its heating position;

Fig. 2 is a partial view showing the reversing valve in its cooling position; and

Fig. 3 is a pressure-enthalpy diagram illustrating the principles involved.

In accordance with the invention, means are provided for conditioning the air in an enclosure R. A duct 10 communicates with the enclosure to be conditioned by way of an inlet 11 and an outlet 12. A fan 13 driven by a motor 14 is positioned to withdraw air from the enclosure via inlet 11 and thence through duct 10, discharging

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ing it through outlet 12 back into the enclosure. A filter 15 is positioned in inlet 11 for removing filterable impurities from the circulating air.

A primary refrigerating apparatus is provided for conditioning the air passing through duct 10. The primary refrigerating apparatus includes a compressor 16 driven by a motor 17, an indoor heat-exchanger 18 located in duct 10, and an outdoor heat-exchanger 19. When referring to an "indoor" heat-exchanger, I mean only that the heat-exchanger is in heat-exchange relation with the air to be heated or cooled. When referring to the "outdoor" heat-exchanger, I mean only that the heat-exchanger is in heat-exchange relation with outside air. It will be appreciated that the terms "indoor" and "outdoor" refer solely to the function of the heat-exchangers rather than to their physical location. A hot gas line 20 connects the discharge of compressor 16 with a three-way valve 21. From three-way valve 21, refrigerant lines 22 and 23 are provided, line 22 leading to the indoor heat-exchanger and line 23 to the outdoor heat-exchanger. A suction line 24 communicates valve 21 back to the inlet of the compressor. Heat-exchangers 18 and 19 are interconnected by a liquid line 25 having a restrictor or capillary tube 26 therein.

A duct 27 is provided with an inlet 28 and an outlet 29 communicating with the outside air space. Outdoor heat-exchanger 19 is located within duct 27, and a fan 30 driven by a motor 31 is provided and positioned to circulate outside air thereover.

A secondary refrigerating apparatus is provided and comprises a compressor 32 driven by a motor 33 and includes an evaporator 34, and a condenser 35 located in duct 10. Evaporator 34 is in heat-exchange relation with the liquid line 25 which interconnects indoor heat-exchanger 18 with outdoor heat-exchanger 19. A hot gas line 36 connects the discharge of compressor 32 with condenser 35. The condenser communicates with the evaporator through liquid line 37 having a restrictor or capillary tube 38 therein. A suction line 39 connects the evaporator to the inlet of the compressor 32 to complete the circuit.

A duct 40 having a filter 41 therein, connects the duct 10 with the outside air space by way of an inlet 42 should it be desired to bring in a certain amount of outside air to mix with the circulating room air passing through duct 10. A damper 43 is provided for regulating the flow of outside air.

Power for operating the apparatus is supplied through a master switch 44. With switch 44 closed, electrical current is supplied to lines 45 and 46 which are connected directly to motor 17. Lines 47 and 48 are appropriately connected across lines 45 and 46 and are directly connected to motor 31. Lines 49 and 50 are also connected across lines 45 and 46 and are connected to motor 14. A thermostatically controlled solenoid switch 51, comprising a switch blade 52 and solenoid 53, is provided in line 45 and is connected to a conventional heating-cooling thermostat 54 which controls the operation of the switch 51. Leads 55 and 56 are connected directly across lines 45 and 46 and lead to a transformer 57 for reducing the voltage to thermostat 54. Leads 58 and 59 join the thermostat with solenoid 53 for energizing the same.

A pair of leads 60 and 61 are connected across lines 45 and 46 and connected to the secondary compressor motor 33. In order that motor 33 be not actuated when switch 44 is first closed, line 61 has a thermostatically controlled switch 62 therein connected to a bellows 63 operatively connected to a thermostatic control bulb 64 by way of a capillary 65. Control bulb 64 is so set that upon a predetermined low outside air temperature in the order of about 30° F., bellows 63 will contract, closing switch 62 thereby actuating the motor 33 of compressor 32 placing the secondary refrigerating apparatus into operation.

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When cooling of the enclosure R is desired, valve 21 is rotated 90° in a clockwise direction to its position as shown in Fig. 2. Thermostat 54 functions to open switch 51 on a drop in temperature in the conditioned space, shutting down the primary refrigerating apparatus. On a rise in temperature when cooling is, therefore, indicated, thermostat 54 acts to energize solenoid 53 to actuate switch blade 52 to its upper, closed position to actuate the primary refrigerating apparatus. With switch blade 52 closed under the influence of thermostat 54, an electrical circuit is completed to electric motor 17 through lines 45 and 46. Since leads 49 and 50 connected to motor 14 are connected directly across lines 45 and 46, motor 14 is actuated at this time. Similarly, motor 31 is actuated since leads 47 and 48 connected thereto are directly connected across lines 45 and 46. Primary refrigerant gas compressed in compressor 16 then flows via hot gas line 20, valve 21 and line 23 into the outdoor heat-exchanger 19 where it gives up its heat to the outside air and is condensed. The high pressure liquid then flows through capillary 26 and has its pressure and corresponding temperature reduced thereby. The now low pressure, cold liquid then flows via liquid line 25 into indoor heat-exchanger 18 picking up heat from the room air flowing thereover. As the refrigerant vaporizes in heat-exchanger 18, the vapor or gas flows via refrigerant line 22, through valve 21 and suction line 24 back to the inlet of compressor 16 to complete the cycle. The secondary refrigerating apparatus is, of course, not operative during the cooling cycle.

In operation, when heating is desired, valve 21 is set as shown. On the heating cycle thermostat 54 functions reversely to its operation on the cooling cycle. As the temperature in the enclosure drops below the desired temperature, thermostat 52 closes switch 51 allowing current to flow to the motors operating the primary refrigerating apparatus and fans 13 and 30 (the same circuits are set up as on the cooling cycle). Upon a rise in temperature in the conditioned space above the predetermined level, thermostat 54 will open switch 51 and thereby discontinue the current supply to motors 14, 17 and 31. With switch 51 closed, hot, primary, compressed refrigerant gas exits compressor 16 by way of hot gas line 20 flowing through valve 21 and thence into refrigerant line 22 leading to the indoor heat-exchanger 18. The hot refrigerant gas is liquefied by room air flowing through the duct 10 and over heat-exchanger 18 and gives up its heat of condensation to the said air. Hot liquid refrigerant leaves indoor heat-exchanger 18 by way of liquid line 25. In flowing through capillary 26, the pressure and corresponding temperature of the refrigerant liquid en route to the outdoor heat-exchanger 19 is reduced so that it will be at a temperature sufficiently low to pick up heat from the cold outside air flowing over the heat-exchanger under the influence of fan 30. In its passage through the heat-exchanger 19, the liquid refrigerant is vaporized and this vapor or gas flows through refrigerant line 23, valve 21 and suction line 24 back to the inlet of compressor 16 to complete the cycle.

When additional capacity is called for, switch 62 is closed under the influence of bulb 64 and the secondary refrigerating apparatus is activated by current flow through line 45, lead 60 to motor 33 and thence through lead 61 (with switch 62 closed) and back to line 46 to complete the circuit. Cold secondary liquid refrigerant in the evaporator 34 removes heat from the hot primary refrigerant liquid flowing through liquid line 25 en route from heat-exchanger 18 to heat-exchanger 19. This serves both to sub-cool the primary refrigerant liquid and to vaporize the secondary refrigerant liquid in evaporator 34. The secondary refrigerant vapor or gas then flows by way of suction line 39 into the inlet of compressor 32. It is compressed therein to a high pressure and corresponding high temperature and the high temperature gas then flows by way of hot gas line

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36 to condenser 35 where the gas is condensed by the room air flowing thereover, giving up its heat of condensation to the room air. The secondary refrigerant, now liquid, then flows via liquid line 37 through capillary 38 wherein its pressure and temperature are correspondingly reduced as it passes therethrough. The cold low pressure liquid then flows back into the evaporator 34 in heat-exchange relation with the hot primary refrigerant liquid therein to complete the circuit.

Fig. 3 is a pressure-enthalpy diagram illustrating the thermal cycle of my heat pump system. The normal heat pump system cycle would be as follows: starting at "A" the refrigerant gas is compressed in compressor 16 to point "B" increasing both its pressure and its total heat content. The increase in total heat content due to compression is the amount $B-C$ B.t.u.'s per pound. The refrigerant is condensed to a liquid at point "D" in indoor heat-exchanger 18 at a constant pressure. The total amount of heat given up in the indoor heat-exchanger to the fluid flowing thereover is, therefore, the amount $B-D$ B.t.u.'s per pound. In passing through capillary 26, the refrigerant is then throttled down to a considerably lower pressure to point "G" and at a constant enthalpy. The refrigerant evaporates in outdoor heat-exchanger 19 to point "A" picking up $A-G$ B.t.u.'s per pound.

What I have done then is sub-cooled the primary refrigerant liquid from "D" to point "E" in evaporator 34. The B.t.u.'s per pound picked up in the secondary refrigerating apparatus would then be $D-E$. This heat, plus the heat of compression of the secondary compressor, is then given up to the air flowing over condenser 35. The primary refrigerant is then expanded from "E" to "F" and in evaporating in outdoor heat-exchanger 19, picks up the extra B.t.u.'s per pound $G-F$ which is equivalent to $D-E$, the amount picked up by the secondary apparatus.

I wish it to be understood that my invention is not to be limited to the specific constructions and arrangements shown and described, except only insofar as the claims may be so limited, as it will be apparent to those skilled in the art that changes may be made without departing from the principles of the invention.

What is claimed is:

1. A heating system comprising a primary refrigerating apparatus, including a compressor, an indoor heat-exchanger in heat-exchange relation with a fluid to be heated, and an outdoor heat-exchanger in heat-exchange relation with outside air, all connected in a closed refrigerating circuit; means for directing a refrigerant fluid from said compressor via said circuit to said indoor heat-exchanger thence to said outdoor heat-exchanger and back to said compressor; and a secondary refrigerating apparatus, including an evaporator for removing heat from refrigerant fluid en route from said indoor heat-exchanger to said outdoor heat-exchanger, a condenser for rejecting said heat into the fluid to be heated, and means for actuating said secondary refrigerating apparatus independently of said primary refrigerating apparatus.

2. An air conditioning system comprising a primary refrigerating apparatus, including a compressor, an indoor heat-exchanger, an outdoor heat-exchanger and refrigerant flow connections therebetween; means for directing refrigerant fluid from said compressor to said outdoor heat-exchanger, thence to said indoor heat-exchanger and back to said compressor when cooling is desired; means for directing said refrigerant fluid in a reverse path when heating is desired whereby the functions of said heat-exchangers are reversed; means for flowing a fluid to be conditioned in a path including said indoor heat-exchanger; means for flowing outside air over said outdoor heat-exchanger; and a secondary refrigerating apparatus, including a condenser placed in

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said conditioned fluid path and an evaporator in heat-exchange relation with liquid refrigerant flowing between said indoor and outdoor heat-exchangers.

3. The system as set out in claim 2, wherein the evaporator of said secondary refrigerating apparatus is in heat-exchange relation with that portion of the refrigerant flow connections between the indoor and outdoor heat-exchangers.

4. The system as set out in claim 2; and actuating means for said secondary refrigerating apparatus responsive to a predetermined low outside air temperature.

5. A heating system comprising a primary refrigerating apparatus including a compressor, an indoor heat-exchanger in heat-exchange relation with air to be heated, an outdoor heat-exchanger in heat-exchange relation with outside air, and refrigerant flow connections therebetween; a secondary refrigerating apparatus including a condenser in heat-exchange relation with the air to be heated and an evaporator in heat-exchange relation with the refrigerant flow connections between the indoor and outdoor heat-exchangers; and actuating means for said secondary refrigerating apparatus responsive to a predetermined low outside air temperature.

6. An air conditioning system comprising a primary refrigerating apparatus including a compressor, an indoor heat-exchanger, an outdoor heat-exchanger and refrigerant flow connections therebetween; means for directing refrigerant fluid in a path from said compressor to said outdoor heat-exchanger, thence to said indoor heat-exchanger and back to the compressor when cooling is desired; means for directing said refrigerant fluid in a reverse path when heating is desired whereby the functions of said heat-exchangers are reversed; means for flowing a fluid to be conditioned in a path including said indoor heat-exchanger; means for flowing outside air over said outdoor heat-exchanger; a secondary refrigerating apparatus for removing heat from hot refrigerant liquid flowing from said indoor heat-exchanger to said outdoor heat-exchanger when the system is heating and including a condenser placed in said conditioned fluid path; and means for actuating said secondary refrigerating apparatus responsive to a predetermined low outside air temperature.

7. A heat pump system comprising a first refrigerating apparatus including an outdoor heat-exchanger for absorbing heat from outside air and an indoor heat-exchanger in heat-exchange relation with a fluid to be heated and supplied to an enclosure; a second refrigerating apparatus including, an evaporator utilizing hot refrigerant in said first apparatus as a heat source and a condenser in heat-exchange relation with the fluid to be heated; a first thermal responsive means for controlling operation of said first and second apparatus; and a second thermal responsive means for further controlling the operation of said second apparatus.

8. The system of claim 7 wherein said first thermal means is responsive to the temperature within the enclosure to be heated, and said second thermal means is responsive to outside air temperature.

9. A heat pump system comprising a first refrigerating apparatus including an outdoor heat-exchanger for absorbing heat from outside air and an indoor heat-exchanger in heat-exchange relation with a fluid to be heated; and a second refrigerating apparatus including an evaporator utilizing hot refrigerant in said first apparatus as a heat source, a condenser in heat-exchange relation with the fluid to be heated, and actuating means for said second refrigerating apparatus responsive to a predetermined low outside air temperature.

10. A heat pump system comprising a first refrigerating apparatus including an outdoor heat-exchanger for absorbing heat from outside air, an indoor heat-exchanger in heat-exchange relation with a fluid to be

heated and a flow connection for the liquid refrigerant en route from said indoor heat-exchanger to said outdoor heat-exchanger; and a second refrigerating apparatus including a condenser in heat-exchange relation with the fluid to be heated and an evaporator positioned in heat-exchange relationship with said flow connection for utilizing hot refrigerant in said first apparatus as a heat source.

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References Cited in the file of this patent

UNITED STATES PATENTS

2,221,688	Gibson	Nov. 12, 1940
2,242,588	McGrath	May 20, 1941
2,434,221	Newton	Jan. 6, 1948

FOREIGN PATENTS

494,996	Great Britain	Nov. 4, 1938
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