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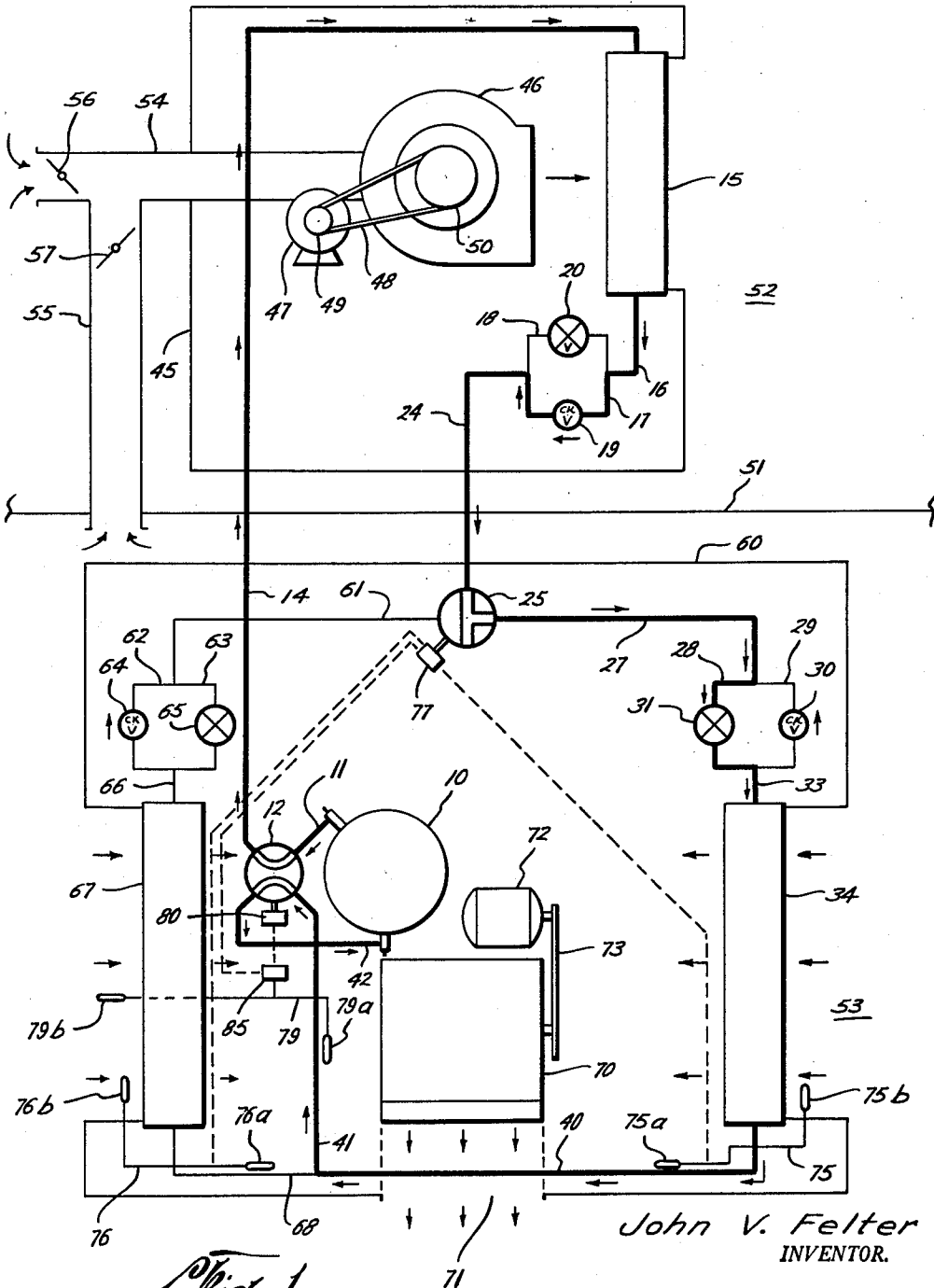
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3,060,698

HEAT PUMP AND METHOD OF OPERATION

Filed July 6, 1961

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

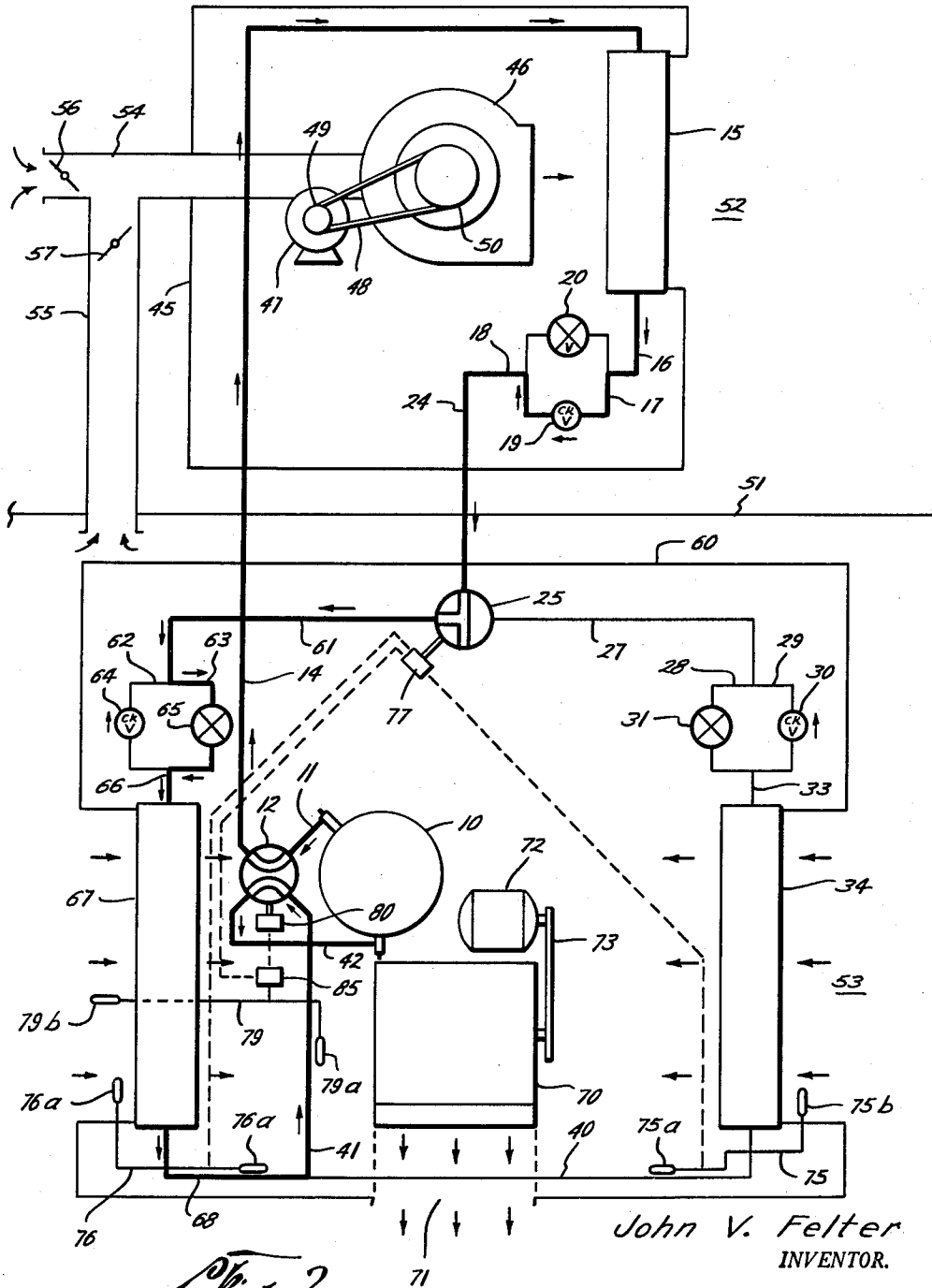


Fig. 2

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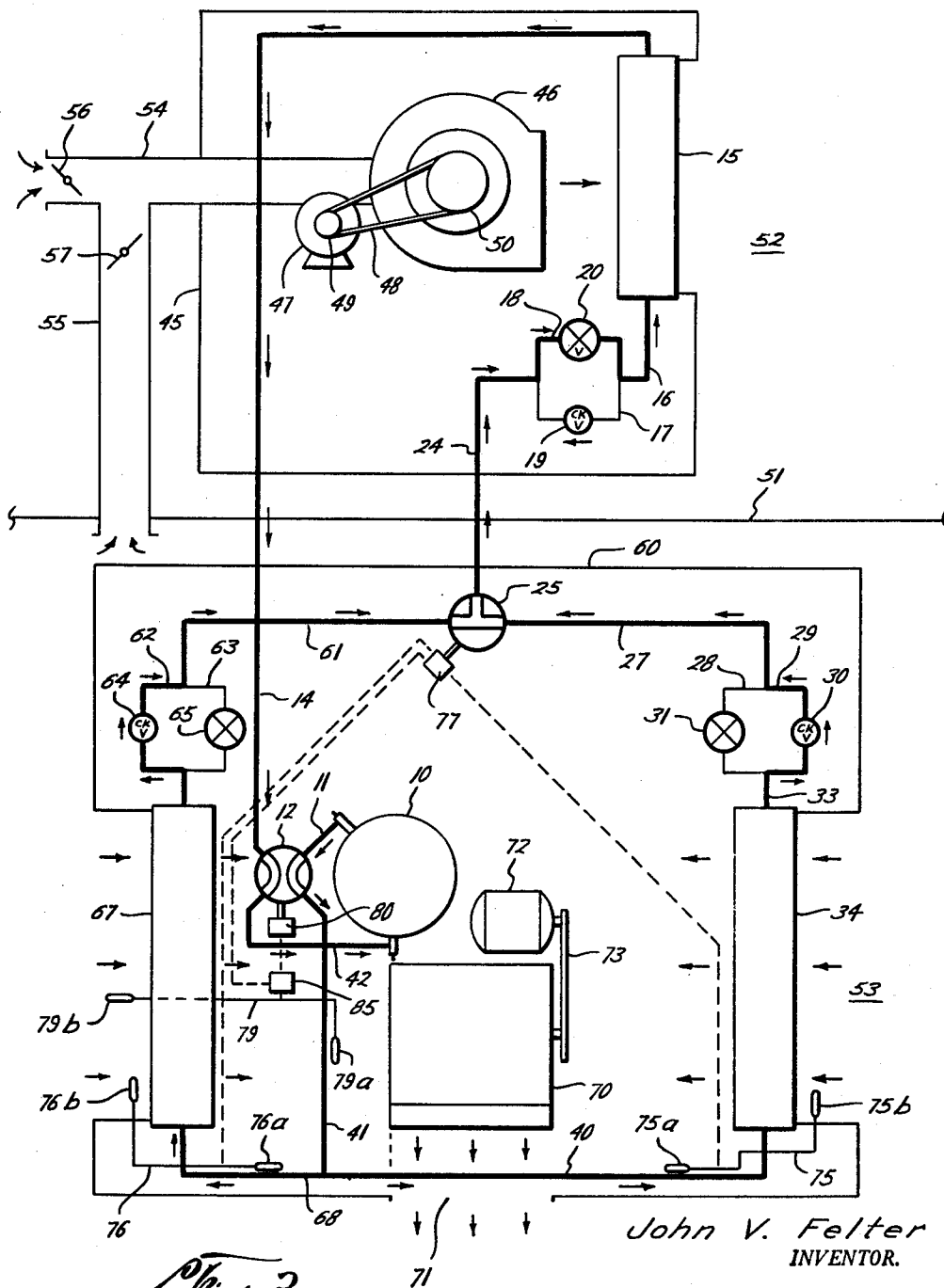
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HEAT PUMP AND METHOD OF OPERATION

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4 Sheets-Sheet 3



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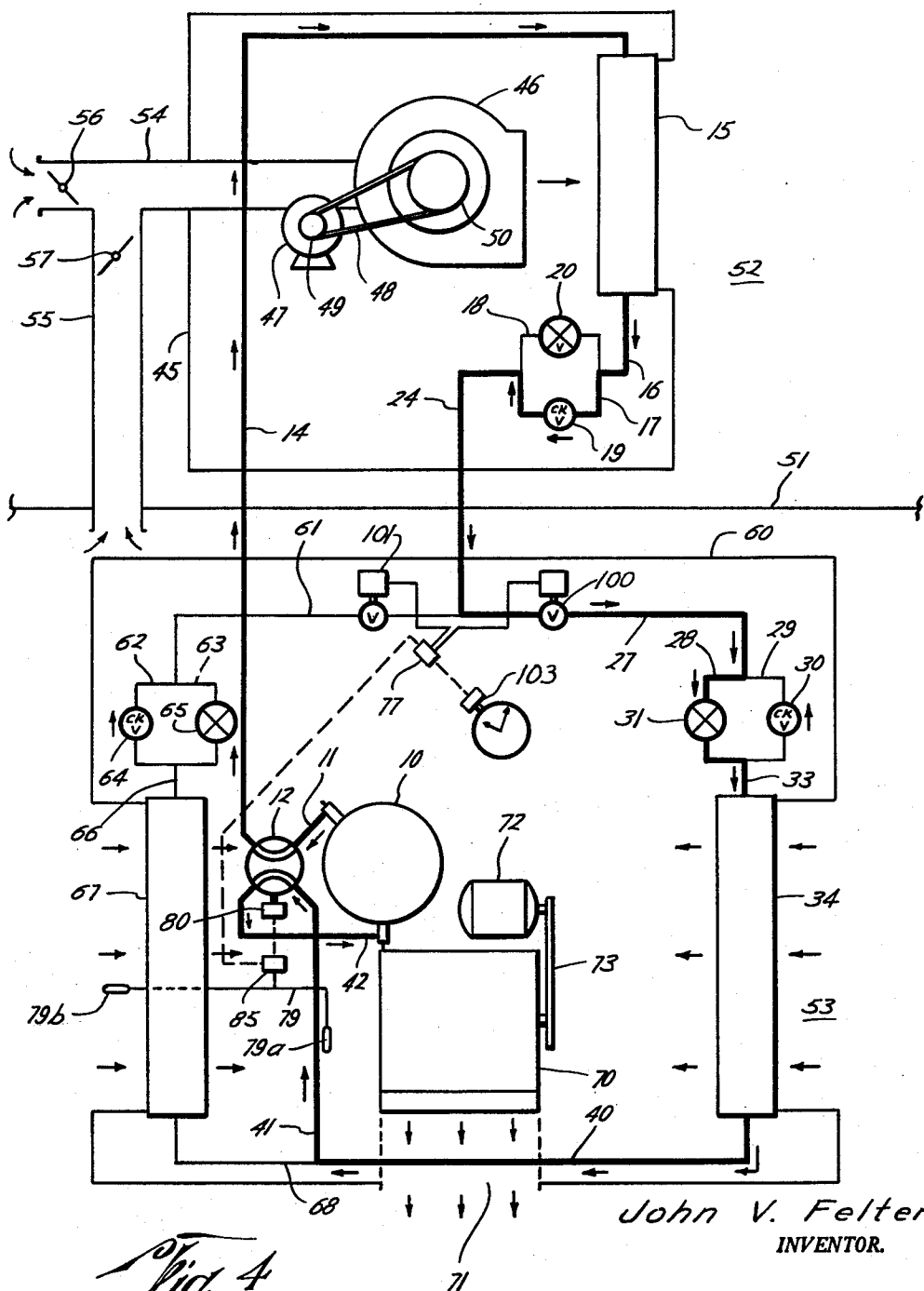
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4 Sheets-Sheet 4



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HEAT PUMP AND METHOD OF OPERATION

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3 Claims. (Cl. 62-160)

This invention pertains to heating and air conditioning apparatus and systems. More particularly, the invention pertains to heating and air conditioning employing the "heat pump" principle, wherein a single apparatus is used for both heating and air conditioning.

This application is a continuation-in-part of my copending application for United States Letters Patent, S.N. 850,553, filed November 3, 1959, now abandoned, and also entitled "Heat Pump and Method of Operation."

It is a principal object of the invention to provide a heating and air conditioning system of the heat pump type wherein, during the heating phase of operation, no reversal to the air conditioning phase of operation is ordinarily necessary in order to avoid "freezing up" of the apparatus.

Other objects of the invention are to provide heating and air conditioning apparatus and systems of the indicated type which are economical, which provide dependable continuous supplies of heated or cooled air or other transfer medium, which will operate equally effectively during both their heating and cooling phases of operation, and which include adequate control means so as to operate substantially automatically.

In conventional "heat pump" heating and air conditioning systems, it is universally encountered, during the heating phase of operation, that the means provided for transfer of heat to the circulating fluid is subject to "freezing up" to such a degree that frequent reversal of operation to the air conditioning phase is necessary to maintain the system in efficient operation. In such systems, in their heating phase of operations, a circulating fluid is compressed to cause it to be heated, and the heat therefrom is transferred, by some medium such as moving air, to the interior of a building. Expansion and cooling of the circulating fluid takes place at the exterior of the building where heat must be absorbed by the circulating fluid, usually from the atmosphere. During the cooling or air conditioning phase of operation, the heating phase is reversed, so that circulating fluid expansion and cooling takes place within the building and circulating fluid compression and heating takes place outside of the building. Change from heating to cooling phase of operation, and the opposite change from cooling to heating, involves in most cases only a reversal, in direction of flow through the system, of the circulating fluid. In conventional systems, during the heating phase of operation, it invariably has been found necessary to interpose brief periods of air conditioning operation in order to prevent "freezing up" of the outside coils where transfer of heat from the atmosphere to the circulating fluid occurs, in order to thaw the outside coils to maintain the system in operation.

The avoidance of reversing during heating to brief periods of air conditioning is a principal accomplishment of this invention.

Briefly, the system provided according to this invention includes an interior heat exchange apparatus to serve as a heat output means to the building interior during heating operation and to serve as an expansion zone to serve as a cold output means to the building interior during cooling operation; dual exterior heat exchange apparatus for causing heating of the circulating fluid during heating operation and for causing heat loss from the circulating fluid during air conditioning operation; and means for appropriately circulating the fluid

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to the above means. The dual exterior heat exchangers function alternately one at a time, one being in operation while the other is thawing, a novel arrangement for causing the thawing being provided. The provision of dual exterior heat exchangers is distinguished from customary systems wherein only one exterior heat exchange means is provided and thawing thereof is achieved by reversing the flow of the circulating medium to air conditioning operations, which latter reduces the overall efficiency of operation and interrupts the flow of heat to the building interior while it is taking place.

A further advantage of the invention is that it provides an optimum ratio of interior-exterior heat exchanger capacity or area for both the heating and cooling phases of operation. During the heating phase of operation, the optimum area or capacity ratios of the interior-exterior heat exchange means is 1:1. During the cooling, or air conditioning phase of operation, the exterior heat exchange means should be larger than the interior heat exchange means to insure dissipation of heat produced at the exterior heat exchange means. This invention provides the optimum 1:1 ratio during the heating phase of operation since, with the single interior exchanger and the dual exterior exchangers each of the same size, the interior exchanger and one exterior exchanger are in operation at any given time. During the cooling phase of operation, the dual exterior exchangers both operate continuously, to provide the desired larger exterior heat exchanger capacity. Thus, the invention provides for optimum use of the heat exchangers during both heating and cooling operation, and there is no wasted or lacking heat exchanger capacity at any time. In conventional systems, there is usually either a shortage of exterior heat exchange capacity during cooling operation, making the cooling operation inefficient, or there is a surplus of exterior heat exchange capacity during heating operation, making the heating operation inefficient, or there is an exterior heat exchange capacity of "average" size so that both heating and cooling operations are somewhat inefficient.

Other objects and advantages of the invention will appear from the following detailed description of a preferred embodiment thereof, reference being made to the accompanying drawings, of which:

FIGURES 1-3 are schematic representations of a preferred form of heating-air conditioning system and apparatus, showing respectively, the first and second heating, and the cooling, phases of operation thereof; and,

FIGURE 4 is a schematic representation of a modified form of apparatus according to the invention.

Referring now to the drawings, and first to FIGURE 1 showing one heating phase of operation, circulating fluid compressor 10 is indicated as delivering compressed fluid through conduit 11, or pipe, through one passage of dual valve 12 into conduit or pipe 14 and thence through interior heat exchange coil 15, or other suitable heat exchange device for transfer of heat to or from the circulating fluid. From coil 15, the fluid passes through pipes 16 to dual parallel pipes 17, 18. Pipe 17 includes a unidirectional check valve 19, permitting fluid flow only in the direction indicated by the arrow, and pipe 18 includes an expansion valve 20 which is any suitable flow-throttling valve for causing fluid pressure drop thereacross so that flowing fluid may be maintained in the liquid state at a higher pressure to one side and in the gaseous state at a lower pressure to the other side of the expansion valve, the direction of fluid flow being, of course, from high to low pressure.

Fluid passing through check valve 19 flows through pipe 24 to three-way valve 25 from which it is passed through pipe 27 to dual parallel pipe 28, 29. Flow through pipe 29 is prevented by check valve 30 therein

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which permits flow only in the opposite direction, so flow is entirely through pipe 28 containing expansion valve 31. Past the expansion valve, the fluid expands from liquid to vapor form in pipe 33 and coil 34, or other suitable heat exchange device, and is caused thereby to become cooled, the cooling produced being dissipated by flow of atmospheric air over the coil. Pipes 40, 41, the other flow passage of valve 12, and pipe 42 lead the fluid back to compressor 10 for recompression to commence another cycle.

The arrows shown on FIGURE 1 indicate circulating fluid flow corresponding to the description thereof above.

Completing the description of FIGURE 1, reference numeral 45 designates an enclosure, such as a box, in one wall of which is located the heat exchange coil 15. A blower 46 driven by electric motor 47 is located within enclosure 45. Belt 48 around sheaves 49, 50 on the motor and blower shafts, respectively, enables the motor to drive the blower, which may be of the centrifugal type indicated in the drawing, or of other suitable form. A building wall 51 separates the building interior 52 from the building exterior 53. A duct 54 leads from the building interior to blower 46, and a branch duct 55 leads from the building exterior. Flow through ducts 54, 55 may be controlled by dampers 56, 57 or other suitable means. Air to be heated is drawn through duct 54 and/or duct 55 by the blower 46 and delivered into enclosure 45 from whence it passes out over coil 15 in heated condition into building interior 52.

At the building exterior 53, an enclosure 60 has exchanger 34 disposed in a wall thereof. Pipe 24 enters enclosure 60 through a wall thereof, as indicated in the drawing, and compressor 10 and the described connections thereof and of exchanger 34 are disposed within the enclosure. Connecting from valve 25 is a pipe 61 leading to dual parallel pipes 62, 63 having check valve 64 and expansion valve 65, respectively, and in turn leading through pipe 66 into heat exchanger 67, preferably identical with exchanger 34. From exchanger 67, a pipe 68 leads to a connection with pipe 41, previously described. Exchanger 67 is disposed in a wall of enclosure 60, identically as exchanger 34, as is clearly shown in the drawings.

With continued reference to FIGURE 1, there is a blower or fan 70 within enclosure 60 opposite an enclosure outlet 71. An electric motor 72 drives blower 70 through belt 73, the belt passing over suitable sheaves (not shown) carried on the motor and blower shafts in conventional form.

It will be noted that exchanger 67, and its described connections, constitutes a system identical with and parallel to exchanger 34 and its described connections, and that the circulating fluid can be expanded through exchanger 67 instead of exchanger 34 by suitable movement of three-way valve 25, as will be explained more fully particularly in connection with FIGURE 2 of the drawings.

At exchanger or coil 34, there is a temperature sensitive device 75 having sensing or probe elements outside of enclosure 60 adjacent coil 34 and at pipe 40, device 75 being sensitive to the temperature differential between those points. At exchanger 67, there is an identical temperature sensitive device 76 for sensing the temperature differential between the outside of enclosure 60 adjacent exchanger 67 and fluid in pipe 68. Devices 75, 76 control valve 25 through an actuator 77. A third temperature sensitive device 79 is sensitive to the temperature differential between the exterior of enclosure 60 adjacent one of the exchangers 34, 67, shown in the drawings adjacent exchanger 67, and fluid in pipe 41. Device 79 controls valves 12, 25 through an actuator 80 associated therewith. The temperature sensitive devices 75, 76, 79 may be any suitable type of device known in the art for providing response to icing or freezing up of the two exterior heat exchangers, and the form shown is only exemplary. Devices for measuring only the temperatures at

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the fluid flow-way from the exchangers may be used. Or, alternatively, devices for measuring air flow through the exchangers may be employed. All of the above devices, in many forms, and others, will be suitable.

Exchangers or coils 34, 67 are adapted to permit flow of air therethrough in indirect heat exchange relation with fluid flowing through the exchanger. Thus, fluid flowing through either exchanger can either give up or take up heat from air drawn therethrough by blower 70, the air entering enclosure 60 through the exchangers and leaving enclosure 60 through outlet 71.

The apparatus shown in FIGURE 2 is the same as that of FIGURE 1. However, in FIGURE 2, three way valve 25 has been moved to a position such that the fluid flow therethrough is from pipe 24 to pipe 61 instead of from pipe 24 to pipe 27. Thus, in FIGURE 2, the circulating fluid is expanded at expansion valve 65 to pass through exchanger 67 before returning to compressor 10 through pipes 68, 41, valve 12, and pipe 42.

Referring now to both of FIGURES 1 and 2, FIGURE 1 shows one "heating" phase of operation and FIGURE 2 shows another "heating" phase of operation. In both FIGURES 1 and 2, a circulating fluid is compressed by compressor 10. The circulating fluid is a refrigerant material, for example, ammonia, Freon, or sulphur dioxide, which is vaporizable at low pressures and which can be liquified at somewhat higher pressures, latent heats of vaporization and condensation of the material giving the described cooling and heating effects. Many other refrigerants are known in the art which are suitable for use.

The compressed refrigerant, FIGURES 1 and 2, becomes hot as a result of compression thereof, and passes through exchanger coil 15 where air delivered by blower 46 takes up heat and passes into the building interior. This heat transfer causes cooling and liquifaction of the refrigerant in coil 15, so that the latent heat of condensation thereof becomes available at coil 15 for transfer to the air stream. From coil 15, the refrigerant passes through valve 25, and depending on the position of valve 25, through one of the expansion valves 31, 65 to reduce its pressure, whereupon the refrigerant expands and vaporizes in one of the exchanger coils 34, 67 to cause cooling due to the latent heat of vaporization of the refrigerant. After such vaporization, and after heat exchange with air passed over the exchanger to dissipate the cooling effect, the refrigerant is returned to the compressor 10 for recompression to commence another cycle through the apparatus.

Distinguishing the present invention from the ordinary heat pump system, the two exchanger coils 34, 67 are provided in lieu of the single such coil found in conventional systems. The temperature sensing devices 75, 76 each function to permit flow through the respective coil 34, or 67 until such time as the temperature differential measured by the device reaches a predetermined maximum temperature differential, indicating that the exchanger coil 34 or 67 has "frozen up" or become "iced," and that refrigerant flowing out of coil 34 is colder (at probe 75a of device 75 or at probe 76a of device 76) than the temperature at probe 75b or 76b by a greater extent than would exist were the coil 34 or 67 effectively causing warming of the refrigerant by transfer of heat thereto from the air stream passing over the coil. Each device 75, 76 operates in the identical manner, and only one coil can be receiving refrigerant flow from three way valve 25 at one time, so that under normal operating conditions first one, then the other, of the coils 34, 67 is in operation in repetitive alternating cycles between the two coils. Because severe cooling may be produced at points 75a, 76a during initiation of operation of either exchanger 34, 67, devices 75, 76 preferably include time delay means so that operation of each exchanger will not be cut off before the operation is established.

For example, say valve 25 is in the FIGURE 1 position and refrigerant is moving through coil 34. Heating at

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coil 15 and cooling at coil 34 continues until such time as the coil 34 develops a build up of ice or frost to a degree that insufficient air will pass therethrough to sufficiently warm the refrigerant passing through the coil. When this condition develops to a sufficient extent, device 75 will register an excessive temperature differential thereby causing actuator 77 to move valve 25 to the FIGURE 2 position thereof.

After valve 25 is in its FIGURE 2 position, heat is produced at coil 15 and cold at coil 67 until such time as coil 67 freezes up and a return to coil 34 is brought about by device 76 and actuator 77.

The coil 34 or 67 not receiving refrigerant is defrosted or de-iced while the other coil is working. It has been found that, almost regardless of the atmospheric temperature at the outside 53, the defrosting coil will be relieved of ice by the air moved thereover by blower 70, so that adequate defrosting will take place while the other coil is working. Contrary to previous concepts, whereby it was believed that a refrigerant reversal (as will be described in connection with FIGURE 3) was absolutely necessary to effect defrosting of an iced exterior coil, it has now been found that defrosting can be effected by air movement alone through provision of dual exterior coils. Even though the outside atmospheric temperature may be very low, and the humidity very high, it will be only a very rare occasion when defrosting of one coil will not take place in the time during which the other coil becomes iced. This is true partly because moisture will sublime and the defrosting coil will be defrosted and dried under all but the most severe atmospheric icing conditions.

The most severe icing conditions are when the coil temperature is well below the freezing point and the atmospheric temperature is just above the freezing point, say from about 34° F. to 45-50° F., and the atmospheric humidity is high. Under those conditions, the air carries substantial amounts of water vapor susceptible to condensation or contact with the cold exchanger coil, and the cold exchanger coil is in a cold condition which causes "sticking" and consequent buildup of the condensed frozen water. And the high humidity condition of the air will cause resistance to thawing of a frozen coil.

Referring now to FIGURE 3 of the drawings, there is shown the "reversed" phase of operation of the system which will not ordinarily be used, but which is provided to insure maintenance of continuous effective operation when operating conditions are severe and the outside atmosphere is most conducive to icing of the outside coils 34, 67. The reversed phase will come into play only when conditions are such that defrosting of the iced coil will not take place before the operating coil becomes iced. This condition is indicated and avoided by temperature differential sensitive device 79. When the temperature of refrigerant in pipe 41 at probe 79a of device 79 drops sufficiently below the temperature at probe 79b of device 79, indicating that the coil 34 or 67 which has last been put in operation by switch 25 is delivering refrigerant to pipe 41 at a lower than normal temperature, the coil not having been adequately defrosted, then device 79 acts to cause actuation of both valves 12 and 25 from their FIGURE 1 positions to their FIGURE 3 positions, or from their FIGURE 2 positions to their FIGURE 3 positions, depending on whether coil 34 or coil 67 was operating when the reversal was made.

In FIGURE 3, the system is "reversed" so that refrigerant is depressed at expansion valve 20 to vaporize and cool in coil 15, both outside coils then acting as heater coils to be defrosted rapidly. Device 79 incorporates a time delay switch 85 so that the reversed operation will continue only for a predetermined short period of time, one minute is usually sufficient. Reversed operation will never occur during normal operation unless the climatic conditions are unusually severe. Reversed operation will be necessary during severe conditions only after

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a number of heating cycles of coils 34, 67 according to the FIGURE 1 and 2 conditions.

Under certain conditions, it may be desirable to modify the apparatus as described so that when the operation is reversed, blower 70 is cut off. This may be achieved by linking the electrical controls of motor 72 with switch 85 so that the blower ceases operation whenever reversal occurs. Such modification might be necessary in cases where ice buildup within enclosure 60 occurs because of the cold temperature therein while the coils 34, 67 are warmed under reversed operation, the blower drawing water from the coils into the cold interior of enclosure 60.

FIGURE 3 operation is used during warm seasons for air conditioning of the building. Reversed operation will usually take place only rarely when the system is in use as a heating means.

Referring now to FIGURE 4 of the drawings, there is shown a modified form of the apparatus. FIGURE 4 shows the apparatus in use in one of the two heating phases of operation, similarly as FIGURE 1. The apparatus may be operated in all of the heating and cooling phases of operation of FIGURES 1-3 by appropriate manipulations or actions of the flow controls.

The apparatus shown in FIGURE 4 is identical with that of FIGURES 1-3 except for the three-way valve 25 and temperature sensing devices 75 and 76, which are replaced by other elements in the apparatus of FIGURE 4. Therefore, the descriptions of FIGURES 1-3 apply also to FIGURE 4 except as to those elements.

In FIGURE 4, instead of three-way valve 25, there are two normally-open solenoid-operated valves 100 and 101. Pipes 27 and 61 branch directly from pipe 24. Valve 100 is in pipe 27 and valve 101 is in pipe 61, so that each of the valves controls fluid flow through the respective pipe in which it is installed.

Actuator 77a is caused to operate either by temperature sensing device 79 and time delay 85, as earlier described in connection with FIGURES 1-3, or by a clock timer 103, or other suitable device operating on a timing basis. Instead of temperature sensing devices 75, 76 of FIGURES 1-3, the apparatus of FIGURE 4 employs timer 103 which at predetermined intervals switches circulated fluid flow from coil 34 to coil 67, and vice versa, cyclically. In this way, cooling and heating cycles of operation of coils 34, 67 are "reversed" on a time basis instead of in response to icing or freezing up of the coil then in use. It is preferred that timer 103 be of an adjustable type so that coil reversal timing may be adjusted to properly meet desired operational conditions, i.e. so that reversal will occur usually before severe freezing up of a coil occurs.

It is clear that the embodiment of FIGURE 4 will be subject to the same three cycles of operation exhibited in FIGURES 1-3, although only the cycle of FIGURE 1 is shown in the drawings.

The coils 34, 67 shown in both of the embodiments perform as "variable surface" evaporators. At different ambient temperatures, the coils will operate at different rates of heat exchange, either heat-gaining or heat-losing, and in accord therewith, at different rates of circulating liquid condensation or evaporation. More particularly, the coils 34 and 67, which normally operate in filled or flooded condition, unfill automatically to the proper degree under changed ambient temperature conditions to present a degree of filling or flooding to cause a proper effective surface area under any ambient temperature condition.

To explain further, and referring to FIGURE 3 of the drawings, the explanation applying equally to the FIGURE 4 apparatus when it is in the operating condition of FIGURE 3, when the outside summer ambient temperature is relatively lower, fluid evaporation in coils 34, 67 will take place at a relatively lower rate per unit of fluid-filled surface area and the coils will operate relatively fuller or more flooded. This gives a relatively

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higher extent of the coils filled with fluid to effectively receive heat exchanged from the outside air. On the other hand, when the outside summer ambient temperature is relatively higher, fluid evaporation in coils 34, 67 will take place at a relatively higher rate per unit of fluid-filled surface area and the coils will operate relatively less full or less flooded. This gives a relatively lower extent of the coils filled with fluid to effectively receive heat exchanged from the outside air. Therefore, the coils will act as balanced surface variable surface evaporators during the cooling cycle regardless of the outside ambient temperature.

Also, motor 72 may include a temperature sensitive device to cut off motor 72 when the outside ambient temperature is relatively very high. This control acts to reduce the high rates of fluid evaporation in the outside coils 34, 67 to reduce fluid input to compressor 10 and prevent it from becoming overloaded, as might otherwise tend to occur when the outside temperature is high.

While preferred embodiments of the invention system and apparatus have been described, many modifications thereof may be made by a person skilled in the art without departing from the spirit of the invention, and it is intended to protect by Letters Patent all forms of the invention falling within the scope of the following claims.

I claim:

1. Combination air conditioning and heating heat pump apparatus, comprising compressor means, interior heat exchange means for disposition within an enclosure, dual exterior heat exchange means for disposition exterior of said enclosure, four way valve means connected to receive compressed fluid flow from said compressor means, a flow connection between said four way valve means and said interior heat exchange means, a flow connection between said four way valve means and both of said exterior heat exchange means, said four way valve means being adapted to be moved to cause fluid flow either from said compressor means to said interior heat exchange means and from said exterior heat exchange means to said compressor means or to said compressor means from said interior heat exchange means and to both said exterior heat exchange means from said compressor means, three way valve means, a fluid flow connection between said interior heat exchange means and said three way valve means, a fluid flow connection between said three way valve means and one of said exterior heat exchange means, a fluid flow connection between said three way valve means and the other of said exterior heat exchange means, said three way valve means being adapted to be moved to permit fluid flow from said interior heat exchange means separately to either one of exterior heat exchange means and separately from both said exterior heat exchange means to said interior heat exchange means, said exterior heat exchange means-three way valve means flow connections each containing in parallel an expansion valve and a unidirectional check

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valve permitting fluid flow only from a said exterior heat exchange means to said three way valve means and not in the opposite direction so that fluid flow in the opposite direction must pass through said expansion valve, said interior heat exchange means-three way valve means flow connection containing in parallel an expansion valve and a unidirectional check valve permitting fluid flow only from said interior heat exchange means to said three way valve means and not in the opposite direction so that fluid flow in the opposite direction must pass through said expansion valve, a first air moving means for moving air over said interior heat exchange means to remove heat therefrom or give heat thereto depending on the relative temperatures, a second air moving means for moving air over both of said exterior heat exchange means to remove heat therefrom or give heat thereto depending on the relative temperatures, temperature sensitive means at each said exterior heat exchange means, an actuator for said three way valve means responsive to each said temperature sensitive means to move said three way valve means to permit fluid flow to the opposite of said exterior heat exchange means from said three way valve means when the exterior heat exchange means of the particular temperature sensitive means becomes iced to not permit normal air movement thereover, another temperature sensitive means at one of said exterior heat exchange means, an actuator for said four way valve means, said three way and four way valve actuators being responsive to said other temperature sensitive means to move said three way and four way valve means to permit fluid flow from said compressor to both said exterior heat exchange means when both said exterior heat exchange means become iced to provide heating and thawing thereof, and a supply of refrigerant fluid in said interior and exterior heat exchange means, said fluid flow connections and said three and four way valve means.

2. Combination of claim 1, said dual exterior heat exchange means each having variable effective surfaces to receive heat from the outside air to cause evaporation of fluid therein because of variable degree of fluid filling thereof responsive to outside air temperature.

3. Combination of claim 2, including means for shutting off said second air moving means in response to high outside air temperatures whereby the rate of delivery of said fluid to said compressor is reduced.

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