

[54] **CONTROL SYSTEM FOR AIR-CONDITIONING EQUIPMENT**

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62/325, 62/118, 62/122, 62/185, 62/201
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[58] Field of Search62/98, 99, 159, 325, 118, 122,
62/185, 201

[56] **References Cited****UNITED STATES PATENTS**

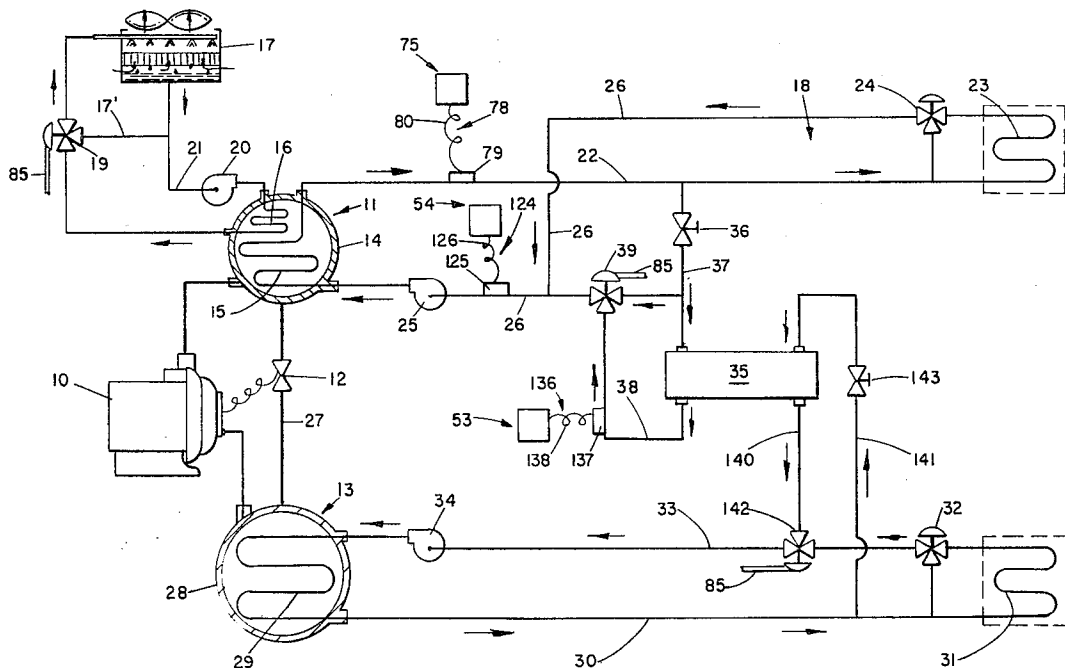
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[57] **ABSTRACT**

A control system for air-conditioning equipment including a refrigeration machine of the kind wherein heat rejected in the condenser is employed to satisfy a demand for heat within a plurality of areas in an enclosure wherein said refrigeration machine has a normal operating characteristic such that the temperature of a relatively warm heat exchange medium passing from the condenser to the areas requiring heating varies inversely in a predetermined relationship to the temperature of the air outside the enclosure. The temperature of said heat exchange medium is selectively increased and decreased respectively upwardly and downwardly a predetermined amount from said normal operating characteristic when said areas are respectively substantially occupied and unoccupied. Excess heat produced when the areas are substantially occupied is stored until required to satisfy the heating requirement in areas in the enclosure when said areas are substantially unoccupied. After sufficient heat is stored, the temperature of said heat exchange medium is decreased until it reaches its predetermined normal operating point related to outdoor temperature.

8 Claims, 4 Drawing Figures



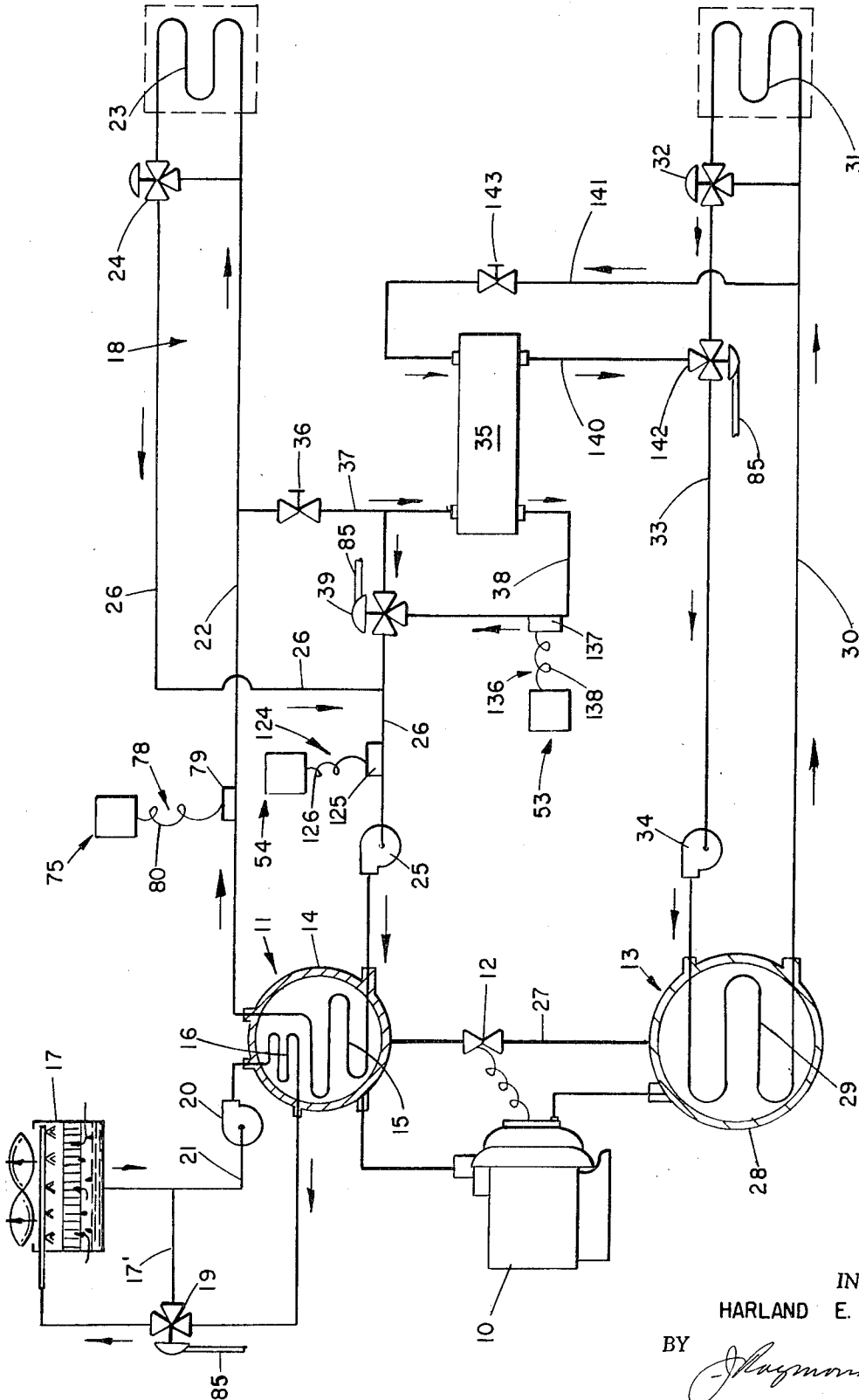


FIG. 1

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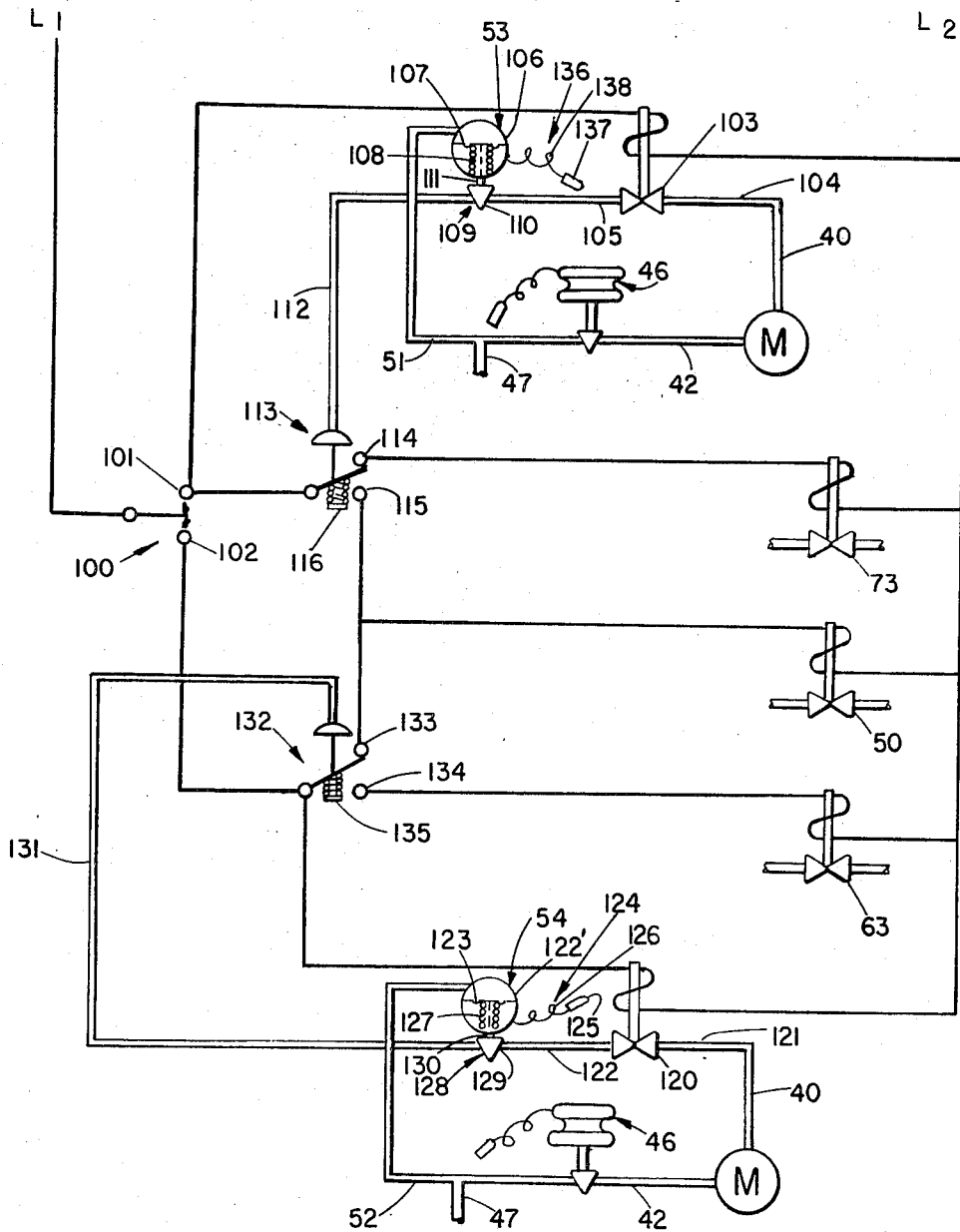


FIG. 2

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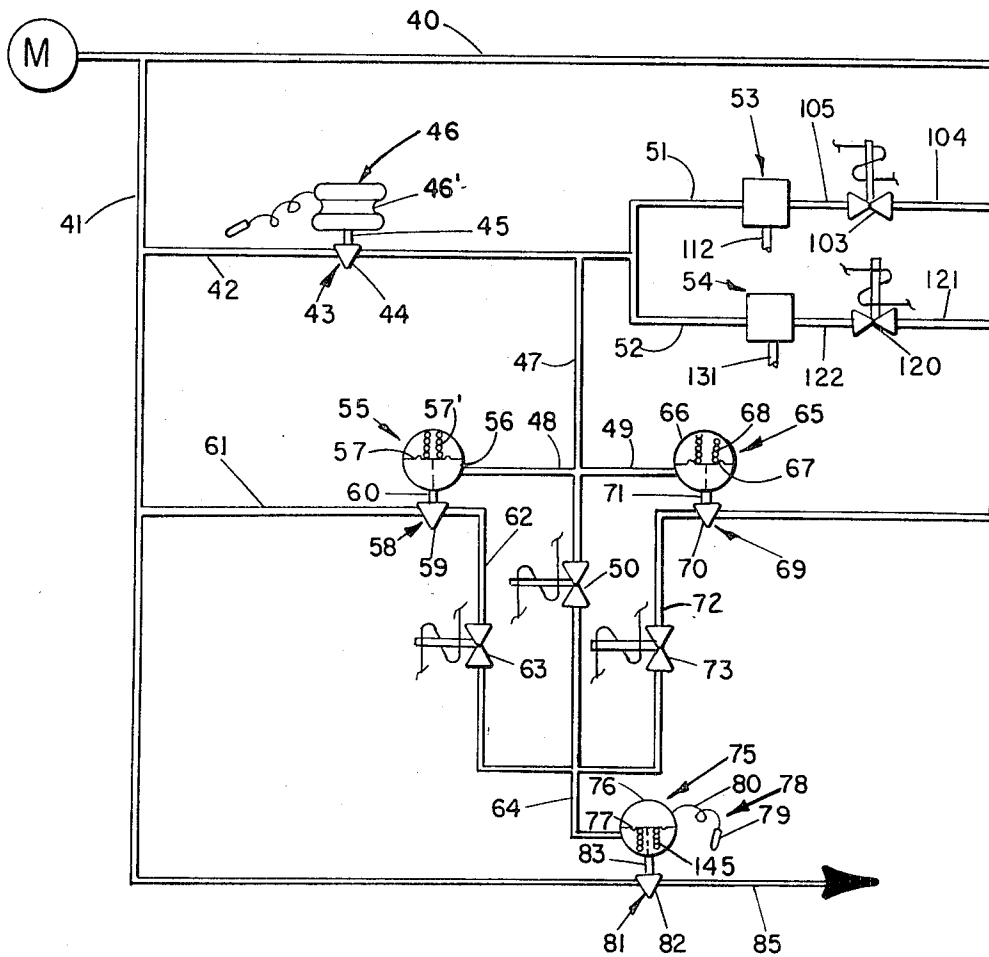


FIG. 3

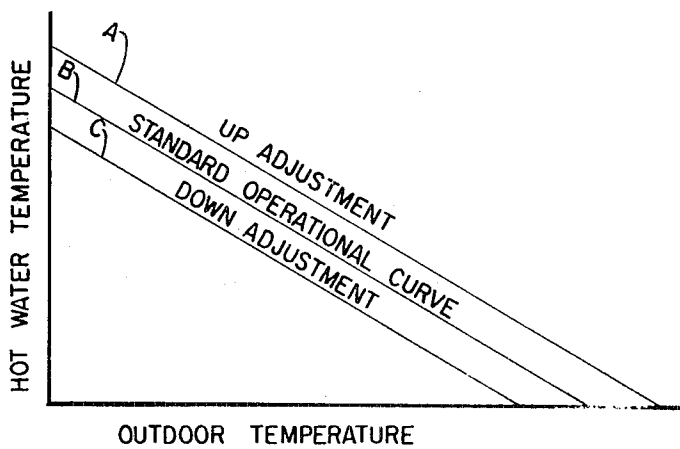


FIG. 4

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CONTROL SYSTEM FOR AIR-CONDITIONING EQUIPMENT

BACKGROUND OF THE INVENTION

This invention relates primarily to an air-conditioning system for use where it is desired to satisfy simultaneously heating and cooling loads in an enclosure composed of individual rooms such as offices in commercial buildings. More particularly, this invention relates to such systems wherein heat rejected from one portion of the system is employed to, at a minimum, partially satisfy a demand for heat in another portion of the system.

The modern office building is generally divided into what is referred to as interior zone offices or areas and perimeter zone offices or areas. The interior areas generally require cooling throughout the entire year when the area is occupied. The perimeter areas require either heating or cooling, depending upon the temperature of the air outside the building. There is generally an excessive amount of heat produced in the interior areas from the lights, machines, and people therein, which must be rejected during the cooling of such areas. To reduce operating costs and to obtain "free" heating, it is desirable to transmit the excess heat rejected from the interior areas during the cooling thereof to the perimeter areas when such areas require heating.

To obtain this desirable "free" heating of perimeter areas in an enclosure such as an office building when such areas require heat, the air-conditioning system serving the enclosure generally includes apparatus known in the art as a heat pump. Briefly, the heat pump extracts heat delivered from a source by a heat exchange medium employed in a standard refrigeration circuit and transmits the extracted heat via a second relatively warm heat exchange medium to the areas requiring same.

To increase the efficiency of such refrigeration machines, heat storage means have been included in air-conditioning systems of the type herein described. Such heat storage means normally comprise a water tank to which the relatively warm heat exchange medium is delivered during times when more heat is available from the interior zone areas than is required by the perimeter zone areas. When the excess heat is no longer available to heat the perimeter zone areas, such as when the interior zone areas are unoccupied and the lights and machines therein are inoperative, the stored warm heat exchange medium may be employed to warm those areas requiring heating. Such systems wherein heat storage means are employed are generally known as heat conservation applications.

Normally, control means are utilized in such applications to sense the temperature outside of the enclosure and to control the heat exchange medium being used to heat those areas requiring same in a manner such that there is a predetermined relationship between the temperature of the heat exchange medium and the temperature of the outdoor air. It has become the practice to adjust the control so that the temperature of the heat exchange medium is increased above its normal predetermined operating point to its maximum designed operating temperature when the internal areas are occupied and have excessive heat to reject, to warm the heat exchange medium used in the heat storage tank to obtain maximum heat conservation.

Particularly in mild weather this practice has proved to be inefficient, since the heat storage means is warmed to a higher temperature than required to heat the areas requiring same when the internal areas are unoccupied. The increased artificial load on the refrigeration machine thus produced substantially increases the power required to operate the machinery, thereby increasing operating costs. This inefficient use of the machinery has in some cases negated any benefits provided by the system.

The object of this invention is a novel method of controlling refrigeration machines employed in air-conditioning systems of the type herein described that alleviate the problems hereinabove discussed.

SUMMARY OF THE INVENTION

This invention relates to a control system for air-conditioning equipment including a refrigeration machine of the kind wherein heat rejected in the condenser is employed to satisfy a demand for heat within a plurality of areas in an enclosure, wherein said refrigeration machine has a normal operating characteristic such that the temperature of a relatively warm heat exchange medium passing from the condenser to the areas requiring heating varies inversely in a predetermined relationship to the temperature of the air outside the enclosure. To overcome the problems hereinabove discussed, the temperature of said heat exchange medium is increased upwardly a predetermined amount from said normal operating characteristic, said amount being less than the maximum design operating point, when the interior zone areas are occupied and excess heat therein is being rejected. The additional heat thus available is utilized to raise the temperature of the heat storage means as is desired. When the heat storage means has its temperature raised upwardly the desired amount, means become operable to reduce the temperature of the heat exchange medium to its normal operating point related to the temperature of the outside air.

When there is no longer excess heat to be rejected from the interior zone areas, such as when they are unoccupied, the heat available from the heat storage means is employed to heat those areas requiring heating. Operation of the compressor of the refrigeration machine is interrupted to increase the efficiency of the machine during this period. To increase the period of time in which the compressor is inoperative, the design operating temperature of the heat exchange medium is reduced a predetermined amount.

When the temperature of the heat exchange medium is reduced so sufficient heat is not available therefrom to maintain the temperatures within the areas at the desired point, the operating temperature of the heat exchange medium is increased to its normal design point. The compressor is then restarted and the refrigeration machine functions as a heat pump with the heat storage means serving as the source of heat to heat the areas in the enclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 of the drawings schematically shows an air-conditioning system including a refrigeration machine embodying the novel control system;

FIG. 2 of the drawings schematically shows a portion of the control system;

FIG. 3 schematically shows a further portion of the control system; and

FIG. 4 graphically illustrates the operating characteristics of the refrigeration machine shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, there are shown schematic views of the refrigeration machinery of the air-conditioning system herein disclosed and of the controls therefor. In referring to the drawings, like numerals shall refer to like parts.

Referring now in particular to FIG. 1, there is schematically shown refrigeration machinery operable to provide heating and cooling to a plurality of areas in an enclosure when such is required, or to provide solely cooling or solely heating to such areas.

The refrigeration machinery includes a compressor 10, shown as a centrifugal compressor, a condenser 11, expansion means 12, shown as a thermostatic expansion valve, and an evaporator or chiller 13, connected together by suitable piping to form a refrigerant circuit. It should be understood that other compressors, such as a reciprocating compressor, may be utilized in lieu of the centrifugal type shown.

The condenser of the refrigerant circuit is of a type known to those skilled in the art as a "double bundle" condenser. The condenser includes a shell or housing 14 enclosing two separate heat exchange circuits, one connected to a conven-

tional cooling tower 17 and the other connected to the enclosure hot water heating loop 18. Although a condenser having a single heat exchange circuit therein may be employed, utilization of the "double bundle" type eliminates contaminating the hot water circuit with a concentration of dirt and minerals usually found in cooling tower water. Further, the most effective and least expensive water treatment method for individual circuits may be employed.

The heat exchange media flowing through the two circuits in the condenser are in heat exchange relation with the gaseous refrigerant supplied thereto by the compressor. The heat exchange medium flowing through circuit 15, preferably water, extracts heat from the gaseous refrigerant. The water flowing through second circuit 16 leaves the condenser and flows to a three-way valve 19, the operation thereof to be more fully explained hereinafter. When the valve is in one position, the water is directed to a conventional cooling tower 17 of the type familiar to those skilled in the art. Heat is extracted from the water in the cooling tower and the water returns via conduit 21 to the condenser, via pump 20. When it is not necessary to operate the cooling tower, the water from condenser 11 is directed via valve 19 through line 17' to bypass cooling tower 17. Valve 19 may be modulated to pass a portion of the water to the cooling tower and to bypass the remaining portion around same to regulate the temperature of the water for a reason to be more fully explained hereinafter.

When heating is required in the areas being served by the machinery, the water having been heated in heat exchange circuit 15 of condenser 11 flows via conduit 22 to heating coils 23 located in each of the areas requiring heating. The water passes through the coils in heat transfer relation with air from the area being blown thereover by means such as a fan (not shown). The water is cooled and the air is thus heated as desired. Three-way valve 24 is used to regulate the amount of water flowing through the heat exchange coils or bypassing same. The water is returned to condenser 11 via conduit 26 and pump 25.

The refrigerant of the system having been condensed in condenser 11 flows to chiller 13 via conduit 27 and passes therein in heat exchange relation with a heat exchange medium, preferably water, flowing through heat transfer coils 29 located in shell 28 of the chiller. The refrigerant extracts heat from the water and is evaporated thereby. The cold water produced in chiller 13 is transmitted via conduit 30 to heat exchange coils 31 located in the areas requiring cooling, the cold water cooling the air of the area passing over the coils in heat transfer relation with the water. Three-way valve 32 regulates the amount of cold water passing through the coils or bypassing same. The cold water returns to chiller 11 via conduit 33 and pump 34.

The heating and cooling system herein disclosed may be utilized in applications wherein certain areas in the enclosure will require cooling at all times, such as the interior zone rooms of an office building; and other areas in the enclosure, such as perimeter zone rooms, will require either cooling or heating, depending upon the temperature of the air outside the enclosure.

When the enclosure is occupied, machines, lights, and people will provide a relatively constant heat load in the interior areas. When heating is required in the perimeter zone due to ambient temperatures being relatively low so that there is a flow of heat from the enclosure to the outside, it is highly desirable to transfer the heat from the interior areas to the exterior areas, thus reducing operating costs.

The interior areas are cooled and the heat extracted therefrom is rejected to the refrigerant of the system in evaporator 13. The rejected heat is transmitted via the compressor to the condenser where the heat is extracted from the refrigerant and transmitted by a heat exchange medium to the heat exchange coils in those areas requiring heating. Such machines are generally referred to as heat pumps.

To increase the efficiency of such refrigeration machines, heat storage means have been included in air-conditioning

systems of the type herein disclosed. Such heat storage means generally comprise an insulated water tank to which the relatively warm heat exchange medium is delivered during times when more heat is available from the interior zones than is required to heat the perimeter zone areas. When the excess heat is no longer available to heat the exterior zone areas, such as when the interior zone areas are unoccupied and the lights and machines therein are inoperative, the stored warm heat exchange medium may be employed to warm those areas requiring heating. Such systems are generally known as heat conservation applications.

Heat storage means 35 is included in the system to store excess heat rejected from the interior areas, the operation thereof to be more fully explained hereinafter.

During times when heating is being provided to the areas and excess heat is available, to increase the temperature of heat storage means to a desired level, a portion of the warm water flowing to the heating coils is directed to heat storage means 35 via valve 36 disposed in conduit 37. To maintain the level of heat exchange medium in heat storage means 35, an equal amount of water is withdrawn from storage means 35 via conduit 38 and three-way valve 39. The manner of control of valves 36 and 39 shall be explained more fully hereinafter.

When heat storage means 35 is serving as the source of heat to provide heating to those areas requiring same and the compressor is operative, the port of valve 39 communicating conduit 38 with conduit 26 is closed. Valve 36 is also closed. Storage means 35 at such times is in communication with cold water supply and return conduits 30 and 33 via conduits 140 and 141 having valves 142 and 143 respectively disposed therein, to regulate flow therefrom. Heat storage means 35 functions as the source of heat to vaporize the refrigerant in the chiller. The refrigerant is then condensed in condenser 11, thereby warming the water being supplied to the areas requiring heating. The manner in which valves 142 and 143 are controlled shall be explained more fully hereinafter.

Referring now to FIG. 4, there is shown a graphical representation of the operating characteristics of the refrigeration machinery heretofore described. Particularly, line B labeled "Standard Operating Curve" represents the normal operating characteristic of the refrigeration machinery wherein the temperature of the hot water flowing to the heat exchange coils in those areas requiring heating is regulated in a predetermined manner in accordance with the temperature of the outside air, such that the hot water temperature varies inversely to the outdoor air temperature. For example, when outdoor temperature is at 75°, the hot water temperature is supplied at 75°. If the outdoor temperature were to drop to 65°, it would be necessary for the hot water temperature to be increased to, for example, 85° to maintain the desired warmth in those areas being served.

To obtain the heat conservation heretofore described, the operating characteristic of the refrigeration machine is increased upwardly a predetermined amount, when there is excess heat available from the interior areas, such as when the areas are occupied, to raise the temperature of the water in the heat storage means as desired. Thus, the refrigeration machinery then operates along line A, labeled "Up Adjustment." When the temperature of the heat storage means has been raised to the desired level, the operating characteristic of the machinery is reset to standard, as represented by curve B labeled "Standard Operating Curve."

To increase the efficiency of operation of the machinery, operation of the compressor is interrupted when heating is required and the temperature of the heat storage means is of a sufficient magnitude to provide the required heating. At such times, the areas are unoccupied and do not have any excess heat to reject. To prolong the period during which the compressor need not be operated, the heating requirements, as related to ambient temperature, are changed so that the air-conditioning equipment is operating along line C of FIG. 4, labeled "Down Adjustment."

When the temperature of the heat storage means has been reduced so that it can no longer maintain the temperature indicated along line C, the compressor is restarted. The operating characteristic for the refrigeration machinery is then increased upwardly to line B of FIG. 4. The refrigeration machinery then functions as a heat pump with the heat storage means serving as the source of heat.

The control system serving as the subject of this invention is utilized with refrigeration machinery of the kind described hereinabove. Particularly, the novel control system will permit the refrigeration machinery to operate in an efficient manner to obtain the desired results heretofore described.

Referring now to FIGS. 2 and 3, there is schematically shown the novel control system. Referring in particular to FIG. 3, there is represented a portion of the electropneumatic control system. The pneumatic controls are operated from a source of pressurized air, the source being indicated by the figure labeled M. The air is transmitted from the source of supply via main supply lines 40 and 41. Branch conduit 42, connected to main supply line 41, transmits a portion of the main supply air to controls to be hereinafter described.

Disposed in branch conduit 42 is valve assembly 43, including valve element 44 and rod 45. Valve assembly 43 is connected to temperature responsive control 46 including bellows 46', the operation thereof being controlled in response to the temperature of the air outside the enclosure. As the temperature of the air outside the enclosure increases, bellows 46' expands, closing valve assembly 43 to bleed a lesser amount of air to the "downstream" side of valve element 44.

Connected to the "downstream" portion of conduit 42 are a plurality of control elements, operable to receive the control signal transmitted through branch 42 in response to the temperature of the air outside the enclosure. A first supply branch 47 operates to transmit the control signal to either a second supply branch 48, a third supply branch 49, or to a normally closed, electrically operated solenoid valve 50, disposed in supply branch 47. The manner in which the control signal is directed shall be explained hereinafter.

Additionally, connected to branch conduit 42 are fourth and fifth supply branches 51 and 52. Supply branches 51 and 52 transmit the control signal regulated by temperature responsive control 46 to either temperature sensing element 53 or temperature sensing element 54 for a reason to be described hereinafter.

Associated with supply branch 48 is control element 55. Control element 55 includes a shell 56 enclosing a diaphragm 57, which separates the shell into upper and lower compartments. Branch 48 is connected to control element 55 to deliver the control signal from conduit 42 to the lower compartment. The control signal produces a force which operates on the lower surface of diaphragm 57, pushing the diaphragm upwardly as viewed in FIG. 3. A spring 57' of a predetermined characteristic is disposed in the upper compartment to deliver a force in opposition to the force produced by the control air pressure. Connected to diaphragm 57 is valve assembly 58, including valve element 59 and rod 60. Valve assembly 58 is disposed in branch conduit 61, connected to main supply line 41, the valve assembly controlling the pressure of the air passing from conduit 61 to conduit 62 communicating therewith "downstream" of valve assembly 58. The valve assembly is designed to pass less air from conduit 61 to conduit 62 upon a decrease in the control signal to element 55, which is indicative of an increase in ambient temperature. The manner in which control element 55 operates shall be described hereinafter.

Disposed in conduit 62 is normally closed solenoid actuated valve 63. The energization thereof operates to transmit the control signal regulated by control element 55 to conduit 64.

Disposed in branch 49 is control element 65. Control element 65 includes an outer shell 66 enclosing a diaphragm 67, which separates the shell into upper and lower compartments. Branch 49 transmits the control signal to the lower compartment so the force produced by the control signal operates on

the lower surface of diaphragm 67. Disposed in the upper compartment of control element 65 is spring 68, which provides a force in opposition to the force produced by the control air supplied to the lower compartment. Connected to diaphragm 67 is valve assembly 69, including valve element 70 and rod 71. Valve assembly 69 operates to regulate the flow of control air through supply line 40 to branch conduit 72 in communication therewith. The assembly 69 is designed to pass less air from supply line 40 to conduit 72 upon a decrease in the control signal to element 65, which is indicative of an increase in ambient temperature.

Disposed in branch conduit 72 is normally closed solenoid valve 73, the energization thereof operating to transmit the control signal regulated by control element 65 to conduit 64.

Connected to conduit 64 is temperature responsive control 75 including an outer shell 76 enclosing a diaphragm 77, which separates the shell into upper and lower compartments. Conduit 64 is connected to control element 75 to supply the control signal therefrom to the lower compartment in shell 76, the control signal thereby producing a force to act on the lower surface of diaphragm 77. A spring 145 having predetermined characteristics is disposed in the lower compartment to provide a predetermined force to operate on the lower surface of the diaphragm. The upper compartment of control element 75 includes a thermal responsive substance. Associated with the thermal substance is temperature sensing means 78, including bulb 79 and capillary tube 80. Bulb 79 senses the temperature of the hot water flowing in conduit 22 shown in FIG. 1. The capillary tube provides communication between the bulb 79 and the thermal responsive substance in control element 75. As the temperature of the hot water flowing in conduit 22 increases, the thermal substance in the upper compartment expands, thereby increasing the force on the upper surface of diaphragm 77.

Connected to diaphragm 77 is valve assembly 81, including valve element 82 and rod 83. The valve assembly regulates the flow of air passing from line 41 to conduit 85 in communication therewith for a reason to be explained hereinafter.

The control signal flowing in conduit 85 is transmitted to a plurality of pneumatically operated valves, 19, 39, and 142, shown in FIG. 1, thereby controlling the operation thereof.

Referring now to FIG. 2, there is shown a second portion of the control system for the refrigeration machinery hereinbefore described.

A source of power represented by L_1 and L_2 operates the electrically operated elements to be described hereinafter. Connected to the source of power is a switch 100 having a first operating position 101 and a second operating position 102. Switch 100 may be controlled manually or may be controlled automatically by means such as a time clock, so that the switch is in its first operating position when the areas in the enclosure are substantially occupied and is in its second operating position when the areas in the enclosure are substantially unoccupied. When switch 100 is in its first operating position, the refrigeration machinery will be operable to transmit any excess heat available from interior zones to those areas requiring heating such as exterior zones and is additionally operable to elevate the temperature of the heat storage means 35 to a desired temperature. When switch 100 is in its second operating position, the heat storage means heretofore described will be serving as the source of heat, with the compressor either operative or inoperative depending upon the temperature of the heat storage means.

Connected in series with first position 101 of switch 100 is normally closed solenoid actuated valve 103. Valve 103 is disposed in conduit 104 and operates to control flow of air from a source of supply represented by M to conduit 105 in communication with conduit 104.

As previously noted, conduit 42 is connected to the source of supply M via supply line 41. Temperature responsive control 46, disposed in conduit 42, is operable to regulate the flow of air from conduit 42 to branch 51 in communication therewith.

Disposed in branch 51 is temperature sensing element 53. Element 53 includes shell 106, enclosing a diaphragm 107, which separates the shell into upper and lower compartments. Branch 51 is connected to shell 106 to transmit the control signal flowing therethrough to the upper compartment, the force produced by the control signal operating on the upper surface of diaphragm 107. Spring 108 having predetermined characteristics provides a force acting on the lower surface of the diaphragm. The lower compartment includes a thermal responsive substance. Associated with the thermal substance is temperature sensing means 136, including bulb 137 and capillary tube 138. Bulb 137 senses the temperature of the hot water leaving storage means 35 via conduit 38, shown in FIG. 1. Capillary tube 138 provides communication between the bulb and the thermal responsive substance in temperature sensing element 53. An increase in temperature of the hot water flowing from storage means 35 expands the thermal substance thereby providing an increased force on the lower surface of the diaphragm.

Associated with diaphragm 107 and operated thereby is valve assembly 109 comprising valve element 110 and rod 111. Valve assembly 109 regulates the passage of air from conduit 105 to conduit 112 in communication therewith. Conduit 112 terminates at pressure responsive reset control switch 113 having a first operating position 114 and a second operating position 115. Spring 116 maintains reset control switch 113 in its first operating position. When a predetermined pressure is transmitted via conduit 112 to switch 113, the reset control switch is moved to its second operating position 115. When switch 113 is in its first operating position 114, normally closed solenoid valve 73 is energized. When switch 113 is in its second operating position 115, valve 73 is closed and normally closed solenoid actuated valve 50 is energized.

Connected in series with second operating position 102 of switch 100 is normally closed solenoid valve 120. Valve 120 controls the flow of supply air from the source of supply M through conduit 121 to conduit 122 in communication therewith. As previously noted, also connected to the source of supply is conduit 42 having temperature responsive control 46 disposed therein, control 46 being operable to regulate the flow of air from conduit 42 to branch 52 in communication therewith. For purposes of clarity, conduit 42 and control 46 have been shown twice in FIG. 2. However, it is apparent from looking at FIG. 3, only a single conduit 42 and a single control 46 need be employed in the invention. Branch 52 transmits the control signal regulated by control 46 to temperature sensing element 54.

Element 54 includes a shell 122' having diaphragm 123 disposed therein, separating the shell into upper and lower compartments. Conduit 52 transmits the control signal to the upper compartment of shell 122'. The force produced by the signal acts upon the upper surface of the diaphragm. A heat responsive substance is included in the lower compartment. The heat responsive substance is controlled by temperature sensing means 124 including temperature sensing bulb 125 and capillary tube 126, operable to communicate bulb 125 with the heat responsive substance in the lower compartment. Bulb 125 senses the temperature of the heat exchange medium flowing through conduit 26, shown in FIG. 1. The heat responsive substance in the lower compartment expands as the temperature of the heat exchange medium flowing in conduit 26 increases. The force produced by the expansion of the heat responsive substance acts upon the lower surface of diaphragm 123. Additionally, spring 127 disposed in the lower compartment of shell 122' provides a second force to act on the lower surface of diaphragm 123.

Connected to diaphragm 123 is valve assembly 128 including valve element 129 and rod 130. Valve assembly 128 operates to regulate the flow of air passing from conduit 122 to conduit 131 in communication therewith. The control signal supplied via conduit 131 is transmitted to pressure responsive reset control switch 132, having a first operating position 133 and a second operating position 134. When the

control signal transmitted via conduit 131 is below a predetermined amount, spring 135 places reset control switch 132 in its first operating position, thereby energizing normally closed valve 50. When the pressure of the control signal transmitted via conduit 131 exceeds a predetermined amount, switch 132 is placed in its second operating position 134, thereby energizing valve 63.

OPERATION

Cooling

The operation of the air-conditioning apparatus including the refrigeration machinery and the controls therefor hereinabove described may be best understood by describing the operation thereof during various conditions.

Initially, the refrigeration machinery will be described as operating during times when only cooling is required in all the areas within the enclosure.

When outdoor temperature controller 46 senses that the ambient temperature without the enclosure is above a predetermined temperature, for example 75°, the refrigeration machinery will be operable on a standard refrigeration cycle. Referring particularly to FIG. 1 of the drawings, compressor 10 discharges gaseous refrigerant to condenser 11, the refrigerant being condensed by passing in heat transfer relation with heat exchange medium flowing through heat exchange circuit 16. The second heat exchange circuit 15 of condenser 11 is inoperative during cooling cycle operation. The condensing heat exchange medium leaves condenser 11 and flows to cooling tower 17 through three-way valve 19. Valve 19 is regulated at this time so that full flow of condensing water is directed to the cooling tower. The heat extracted from the gaseous refrigerant is rejected in the cooling tower. The heat exchange medium then returns to the condenser via pump 20 disposed in conduit 21.

The condensed refrigerant flows through expansion valve 12 via conduit 27, to chiller 13 where the refrigerant extracts heat from a heat exchange medium flowing through heat exchange coil 29 disposed in chiller 13. The medium, after having passed in heat transfer relation with the refrigerant, is transmitted via conduit 30 to heat exchange coils 31, located in the areas requiring cooling. Three-way valve 32, controlling the flow of the cold water through coil 31 or the flow of water bypassing same, is modulated by means not shown to obtain the desired temperature in the area.

The heat exchange medium is returned to the evaporator via conduit 33 and pump 34. It should be noted that the port of valve 142 communicating conduit 140 to conduit 33 is closed. Additionally, valve 143 disposed in conduit 141 is closed at such times.

Heat storage means 35, coils 23, pump 25, and heating loop 18 are inoperative when cooling only is required in all areas being served by the refrigeration machinery.

SIMULTANEOUS COOLING AND HEATING REQUIREMENTS

Interior Areas Occupied

When the temperature of the air outside the enclosure falls below a predetermined temperature, for example 75°, the perimeter zone areas in the enclosure will require heating, whereas the interior zone areas when occupied will require cooling. To provide simultaneous heating and cooling, pumps 25 and 34 are both started.

Temperature responsive control 46, note FIG. 2, senses ambient temperature and operates to transmit a signal related thereto; the magnitude of the signal being relatively smaller when the ambient temperature is of a higher magnitude and the magnitude of the control signal being relatively larger when the ambient temperature is of a lesser magnitude. The control signal regulated by controller 46 is transmitted via conduit 51 to the upper compartment of temperature sensing element 53.

As noted hereinabove, the interior zone areas are occupied; therefore, switch 100 is in its first operating position 101 whereby normally closed solenoid valve 103 is energized, thus communicating conduit 104 with conduit 105. Under these circumstances valve 120 remains closed so that temperature sensing element 54 is unaffected.

Temperature sensing means 136, located on conduit 38, is operable to expand the temperature responsive substance in the lower compartment of temperature sensing element 53, the degree of expansion depending upon the temperature of the hot water flowing from storage means 35 through conduits 38 and 26; the warmer the water, the greater will be the expansion of the temperature responsive substance. The force produced by the expansion of the temperature responsive substance acting in conjunction with the force produced by the spring operates on the lower surface of diaphragm 107. Valve assembly 109, connected to diaphragm 107 will be opened to pass a greater amount of control signal from conduit 105 to conduit 112 in communication therewith as the pressure acting on the lower surface of the diaphragm increases. The force produced by the control signal transmitted via conduit 51 operates on the top surface of the diaphragm to prevent the diaphragm from opening the valve assembly until a predetermined pressure in the lower compartment is reached.

Assume the predetermined pressure has not been reached, therefore the valve assembly is closed, preventing communication between conduits 105 and 112. Pressure responsive switch 113 therefore is in its first operating position 114 and normally closed solenoid valve 73 is energized to its open position.

Referring now to FIG. 3, the control signal transmitted via conduit 42 is additionally directed to supply branch 47, which communicates with third supply branch 49 having control element 65 associated therewith. As previously noted, the magnitude of the control signal flowing through branch 49 is related to the temperature of the outside air. The control signal is transmitted to the lower compartment of control element 65 and provides a force operable on the lower surface of diaphragm 67. Valve assembly 69, operated by diaphragm 67, is actuated to bleed a greater or lesser amount of air from line 40 to conduit 72. For example, a large magnitude control signal to element 65 will produce a large magnitude control signal in conduit 72. As previously noted, solenoid valve 73 has been opened, thereby passing the control signal from conduit 72 to conduit 64.

Associated with conduit 64 is temperature responsive control 75. The control signal is directed to the lower compartment of control 75 and provides a force operable on the lower surface of diaphragm 77 disposed therein. Additionally, spring 145 provides a second force to assist the force provided by the control signal. Temperature sensing means 78 senses the temperature of the hot water flowing through conduit 22. Capillary tube 80 transmits the temperature as sensed by bulb 79 to the temperature responsive substance disposed in the upper compartment of control 75, the substance being expanded as the temperature of the hot water increases. The expanding substance provides a force on the top surface of diaphragm 77 in opposition to the force produced on the lower surface thereof. Depending upon the magnitude of the two forces, valve assembly 81 will be actuated to bleed a greater or lesser amount of control air from line 41 to conduit 85 in communication therewith. It is apparent that a control signal of smaller magnitude will be transmitted via conduit 85 when the temperature of the air outside the enclosure is relatively high, for example 70°.

The control air flowing through conduit 85 is directed to three-way valves 19 and 39. The control air transmitted to valve 19 operates to bypass a greater or lesser amount of heat exchange medium flowing to cooling tower 17 from the second heat exchange circuit 16 in condenser 11. A control signal of relatively high magnitude will actuate valve 19 to bypass a substantial portion of the medium about the cooling tower 17. Conversely, when the control signal is of a relatively small magnitude, a substantial portion of the heat exchange

medium is directed to the cooling tower 17 to reject heat therein. Until the temperature of the heat exchange medium flowing through conduit 22 is increased to a predetermined point related to the temperature of the outside air, thus decreasing the control signal in conduit 85, a greater amount of heat exchange medium will be bypassed through conduit 17' around cooling tower 17 as in the case explained above.

As noted hereinabove, it is desirable to store excess heat available from the interior zone areas when they are occupied for future use. To obtain this desirable end, valve 36 disposed in conduit 37 is opened to permit a portion of the hot heat exchange medium passing through conduit 22 to flow to heat storage means 35. Valve 36 may be opened manually or by automatic means not shown such as employing a solenoid valve as valve 36. To compensate for the heat exchange medium flowing into storage means 35, three-way valve 39 is actuated to communicate conduit 38 with conduit 26, by the control signal transmitted via conduit 85.

Referring now to FIG. 4, assume the outdoor temperature is at 65°. The normal operating characteristic of the hot water flowing to the heat exchange coils 23 in those areas requiring heating, as related to this temperature, is 85°. However, the magnitude of the control signal directed to control 75 is such that the operating characteristic of the refrigeration machinery is increased upward to line A so that the temperature of the hot water is required to be 95° to satisfy the heating demands thereon.

When the temperature sensing means 136, operable to sense the temperature of the hot water flowing through conduit 38, senses that the temperature thereof has reached the predetermined point as determined by the operating characteristic of line A, for example 95°, the thermal responsive substance in the lower compartment of control 53 is expanded to raise diaphragm 107, thereby opening valve assembly 109 to pass a greater amount of control air from conduit 105 to conduit 112. The increased control signal actuates pressure responsive reset control switch 113 so that the switch is placed in its second operating position, thereby deenergizing valve 73 and energizing solenoid valve 50.

As shown in FIG. 3, when valve 73 is closed the control signal transmitted via conduit 72 is interrupted. In lieu thereof, the opening of valve 50 communicates conduit 64 with branch 47. The control signal thus passing to control element 75 is of a lesser magnitude when compared to the one having passed from conduit 72. The decrease in force acting on the lower surface of diaphragm 77, caused by the decreasing magnitude of the control signal, operates to close valve assembly 81 thereby passing a lesser amount of control air from line 41 to conduit 85.

The decrease in hot water temperature thus produced is such that the operating characteristic of the refrigeration machinery is returned to its normal point as represented by line B, as related to the temperature of the air outside the enclosure.

When the temperature of heat storage means 35 has been brought to its predetermined point, valve 36 is closed either manually or automatically and the port of valve 39 communicating conduit 38 with conduit 26 is also closed. Thereafter, valve 19 is modulated so that the heat rejected to the heat exchange medium flowing through circuit 16 is withdrawn therefrom in cooling tower 17 to maintain the temperature of the hot water to the heating coils at its desired level as related to the outside air.

The hot water flowing through conduit 22 is transmitted to the heat exchange coil 23 located in the areas requiring heating. Valve 24 is modulated by means not shown to maintain the desired temperature in the rooms.

The cooling cycle operation during such times is the same as previously described.

SIMULTANEOUS COOLING AND HEATING REQUIREMENTS

Interior Areas Unoccupied

Assume now that the interior areas in the enclosure are unoccupied and therefore there is no longer excess heat available therefrom to provide heating for the perimeter areas when they require heating. Switch 100 is therefore placed in its second operating position 102 as by a timer or any other conventional means. At such times heat storage means 35 is employed as the source of heat for such areas. To increase the efficiency of operation of the refrigeration machinery, the compressor 10 is stopped when the temperature of the heat storage means is of a sufficient magnitude to provide the necessary heating without the compressor having to function as a heat pump. The compressor may be stopped manually or by automatic means not shown. To further increase the efficiency of the refrigeration machinery, by maintaining the compressor inoperable for a greater duration of time, the operating characteristic of the refrigeration machinery is decreased below the normal point as related to the temperature outside the enclosure, the operating temperature during such times being determined by line C.

For example, and again referring to FIG. 4, assume that the outdoor temperature is at 65° when the enclosures are unoccupied. As noted hereinabove at such temperature the normal operating point for the hot water supplied to the areas requiring heating is 85°.

However, as will become more apparent hereinafter, the operating characteristic is decreased a predetermined amount, for example to 75°, so that the heat storage means may serve as the source of heat with the compressor inoperable for a greater period of time.

When the temperature of the heat storage means falls below the point on line C, the compressor is restarted either automatically or manually and the heat storage means 35 then serves as a source of heat for the refrigeration machinery, then functioning as a standard heat pump.

Again referring to FIGS. 1, 2, and 3, the manner in which the above-described operation is obtained will be hereinafter described. When switch 100 is in second operating position 102, normally closed solenoid valve 120 is opened, thereby communicating conduit 121 with conduit 122. A control signal regulated by control 46 is transmitted to the upper compartment of temperature sensing element 54. The manner in which the magnitude of the control signal transmitted to the upper compartment of element 54 is regulated by control 46 has been heretofore explained.

The control signal is supplied to temperature sensing element 54, providing a force operable on the upper surface of diaphragm 123 disposed therein. Acting in opposition to this force is a force produced by the expansion of the thermal responsive substance disposed in the lower compartment, expansion thereof being related to the temperature of the heat exchange medium flowing through conduit 26 as sensed by temperature sensing element 124. Spring 127 provides a second force to assist the force produced by the thermal responsive substance.

At the outset of the unoccupied period of operation the temperature of the hot water flowing through conduit 26 is sufficiently high to expand the substance in the lower compartment of element 54 so that the diaphragm actuated thereby is raised to bleed a greater amount of control air from conduit 122 to conduit 131 in communication therewith. This control signal is transmitted via conduit 131 to pressure responsive reset control switch 132. The control signal operates to place the switch in its second operating position 134, thereby energizing solenoid valve 63.

The control signal regulated by control 46 is also transmitted, via branch 47, to branch 48 in communication therewith. Associated with branch 48 is control element 55, operable to regulate a control signal transmitted from branch

conduit 61 to branch conduit 62. The higher the temperature of the air outside the enclosure, the smaller will be the magnitude of the control signal transmitted to control element 55 via branch 48. When the control signal is of relatively high magnitude the control element is actuated so the valve assembly associated with diaphragm 57 bleeds a greater amount of the control air from conduit 61 to conduit 62. When the temperature of the air outside the enclosure is relatively low, the control signal transmitted via conduit 62 will be of a greater magnitude.

The opening of solenoid valve 63 permits the control air to flow from conduit 62 to conduit 64 and then to temperature responsive control 75, associated with conduit 64. The control signal transmitted via conduit 64 operates to actuate control 75 in a manner heretofore explained. Since the control signal is of a relatively small magnitude when the ambient temperature is at the example of 65°, valve assembly 81 is actuated to bleed a relatively small amount of control air from line 41 to conduit 85, thereby requiring the temperature of the hot water flowing to the areas being served be at a relatively low temperature. The required temperature for the hot water is decreased from its normal operating point, as represented by line B downward to the point as represented by line C of FIG. 4. It should be noted that the control signal regulated by element 55 is of a lesser magnitude when compared to the control signal from element 65, assuming the temperature outside the enclosure has remained constant.

So long as the heat storage means is of a sufficiently high temperature, to maintain the hot water flowing to heating coils 23 at the point required, the compressor 10 of the system is inoperable and pump 34, operable to circulate the cold water to heat exchange coils 31, is also inoperable.

When the compressor has been stopped and switch 100 has been placed in its second operating position, valve 36 is opened. The control signal transmitted via conduit 85 operates to modulate valve 39 to withdraw the necessary water from the heat storage means to maintain the temperature of the hot water at its desired operating point.

Now assume the temperature of the hot water has fallen below its operating point on line C. The temperature sensing means 124 associated with conduit 26 will sense the decrease in temperature. The thermal responsive substance in temperature sensing element 54, operated by temperature sensing means 124 will contract, thereby reducing the force operating on the lower surface of diaphragm 123. Valve assembly 128 will thereby be actuated to decrease the control air flowing from conduit 131 to pressure actuated reset control switch 132. The decrease in pressure on reset switch 132 will cause the switch to move from its second operating position 134 to its first operating position 133, thereby deenergizing valve 63 and energizing valve 50.

With valve 63 deenergized the control signal from control element 55 is interrupted. Opening of the solenoid valve 50 communicates conduit 64 with conduit 47. The control signal flowing to temperature sensing element 75 is regulated by control 46, this signal being related to the temperature of the air outside the enclosure. The control signal from control 46, transmitted to temperature responsive control 75, is of a greater magnitude as compared to the control signal regulated by element 55 for the same outside temperature. The increased magnitude of the control signal thereby operates to return the operating characteristic of the refrigeration machinery from line C to line B.

The compressor is restarted. The refrigeration machinery is operated as a heat pump with heat storage means 35 serving as the heat source. Valve 36 is closed. In addition, the control signal to valve 39 is interrupted by means not shown, such as a manually operated or automatically operated valve; the port of valve 39 communicating conduit 38 with conduit 26 is thereby closed. With the compressor operative and the heat storage means operating as the heat source, valve 143 is opened. The control signal transmitted via conduit 85 is directed to valve 142 which is modulated thereby. The heat

exchange medium from the heat storage means 35 is now directed through conduit 33, via pump 34, to heat exchange coil 29 in evaporator 13. The heat exchange medium rejects heat to the refrigerant of the system, vaporizing same. The gaseous refrigerant thus produced is pumped via compressor 10 to condenser 11. The gaseous refrigerant is condensed by rejecting heat to the heat exchange medium flowing through heat exchange circuit 15. The heat exchange medium from circuit 15 is then transmitted via conduit 22 to the heat exchange coils 23 located in the areas requiring heating.

The control system herein described is operable to provide for a more efficient operation of the type of refrigeration machinery herein disclosed.

While I have described and illustrated a preferred embodiment of my invention it will be understood that the invention is not so limited since it may be otherwise embodied within the scope of the following claims.

I claim:

1. In combination with a refrigeration machine operable to provide heat transfer media for use in an air-conditioning system serving a plurality of areas in an enclosure, each of said areas having heat transfer means located therein to permit the heat transfer media to be passed therethrough in heat transfer relation with the air in the area, said system including at least two fluid flow circuits for the circulation of heat transfer media, said machine including a compressor; a condenser for rejecting the heat of compression to at least the first fluid flow circuit; an evaporator through which chilled water flows in the second circuit; and expansion means, said air-conditioning system having a normal operating characteristic such that the temperature of the relatively warm heat exchange medium exiting from the condenser varies inversely in a predetermined relationship to the temperature of the air outside the enclosure, a control system for operating said refrigeration equipment comprising:

- A. means for sensing the temperature of the air outside the enclosure and for transmitting a first signal related thereto;
- B. means for receiving the first signal and for transmitting a second signal related to said first signal; said second signal being of a first magnitude when the areas in the enclosure are substantially occupied and being of a second magnitude when the areas in the enclosure are substantially unoccupied;
- C. means for receiving said second signal including means operable to sense the temperature of the relatively warm heat exchange medium flowing to said heat transfer means in said areas, said second signal receiving means being operable to maintain the relatively warm heat exchange medium exciting from the condenser of the system at a temperature related to said second signal, said second signal receiving means being additionally operable to increase the temperature of said relatively warm heat exchange medium a predetermined amount from said normal operating characteristic when said areas are substantially occupied and being operable to decrease the temperature of said relatively warm heat exchange medium from said normal operating characteristic when said areas are substantially unoccupied;
- D. heat storage means;
- E. means for supplying heat to said heat storage means via said relatively warm heat exchange medium when the areas of the enclosure are substantially occupied; and
- F. means operable to transfer the heat from said heat storage means to said areas in the enclosure when said areas are substantially unoccupied.

2. The combination in accordance with claim 1 further including means operable to decrease the temperature of said relatively warm heat exchange medium a predetermined amount to said normal operating characteristic when said temperature of said heat storage means has reached a predetermined point and said areas are substantially occupied.

3. The combination in accordance with claim 2 further including means for discharging excess heat from the system when the temperature of said heat storage means has reached a predetermined point and said temperature of said relatively warm medium has been decreased to its normal operating point.

4. The combination in accordance with claim 3 further including means separable to increase the temperature of said relatively warm heat exchange medium a predetermined amount to said normal operating characteristic when said temperature of said heat storage means has reached a predetermined point and said areas are substantially unoccupied.

5. The combination in accordance with claim 1 further including means operable to increase the temperature of said relatively warm heat exchange medium a predetermined amount to said normal operating characteristic when said temperature of said heat storage means has reached a predetermined point and said areas are substantially unoccupied.

6. A method of controlling the operation of a refrigeration machine of the kind wherein heat rejected in the condenser is employed to satisfy a demand for heat within a plurality of areas in an enclosure, said refrigeration machine having a normal operating characteristic such that the temperature of a relatively warm heat exchange medium passing from the condenser varies inversely in a predetermined relationship to the temperature of the air outside the enclosure, comprising the steps of:

- A. sensing the temperature of the air outside the enclosure;
- B. transmitting a first signal related to the outside temperature;
- C. receiving the first signal;
- D. transmitting a second signal related to said first signal, said second signal being of a first magnitude when the areas in the enclosure are substantially occupied and being of a second magnitude when the areas in the enclosure are substantially unoccupied;
- E. receiving said second signal;
- F. controlling the temperature of the relatively warm heat exchange medium flowing to said heat transfer coils in said areas, depending upon the magnitude of said second signal;
- G. selectively increasing and decreasing the temperature of said relatively warm heat exchange medium a predetermined amount from said normal operating characteristic when said areas are respectively substantially occupied and unoccupied;
- H. storing excess heat available from the refrigeration machine when the areas in the enclosure are substantially occupied; and
- I. transferring the stored heat to the areas in the enclosure when said areas are substantially unoccupied.

7. A method of controlling the operation of an air-conditioning system including refrigeration machinery of the kind wherein heat rejected in the condenser is employed to satisfy a demand for heat within one or more areas in an enclosure, said air-conditioning system including heat storage means, said refrigeration machinery having a normal operating characteristic such that the temperature of a relatively warm heat exchange medium passing from the condenser and employed for heating purposes varies inversely in a predetermined relationship to the temperature of the air outside the enclosure, comprising the steps of:

- A. sensing the temperature of the air outside the enclosure;
- B. operating the refrigeration machinery to provide the heat exchange medium to be employed for heating purposes at a temperature a predetermined amount greater than the temperature indicated by the normal operating characteristic of the machinery when the heat available to the machinery exceeds that necessary to satisfy the heating demands;
- C. raising the temperature of the heat storage means to a predetermined point when the heat exchange medium is being supplied at the greater temperature;

D. lowering the temperature of the heat exchange medium being supplied to its normal level as related to the temperature of the air outside the enclosure when the temperature of the heat storage means has been raised to the predetermined point;

E. interrupting the operation of the refrigeration machinery in the absence of the excess heat; and

F. circulating the heat exchange medium employed for heating at a temperature a predetermined amount below the temperature indicated by the normal operating 10 characteristic of the refrigeration machinery while the

machinery is inoperative, the heat storage means being employed to maintain the desired temperature.

8. The method in accordance with claim 7 further including the step of:

A. restarting the refrigeration machinery when the heat storage means is unable to maintain the desired temperature, the refrigeration machinery being operable as a heat pump, the heat storage means being employed as the source of heat for the heat pump.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,636,721 Dated January 25, 1972

Inventor(s) HARLAND E. REX

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 14, line 8, Claim 4, "separable" should read
--operable--

Signed and sealed this 15th day of August 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents