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AIR CONDITIONING APPARATUS

Filed Sept. 3, 1936

2 Sheets-Sheet 1

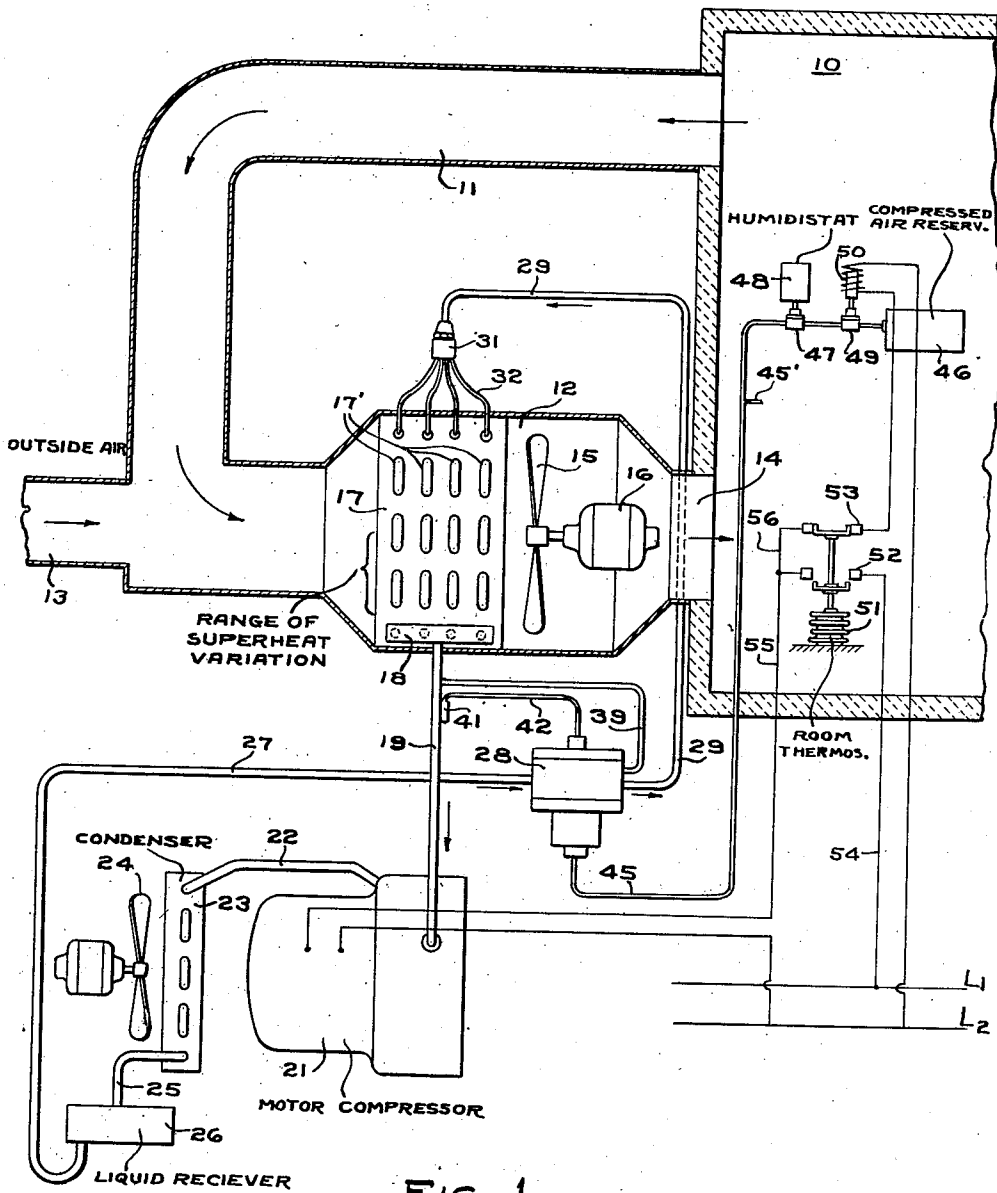


FIG. 1.

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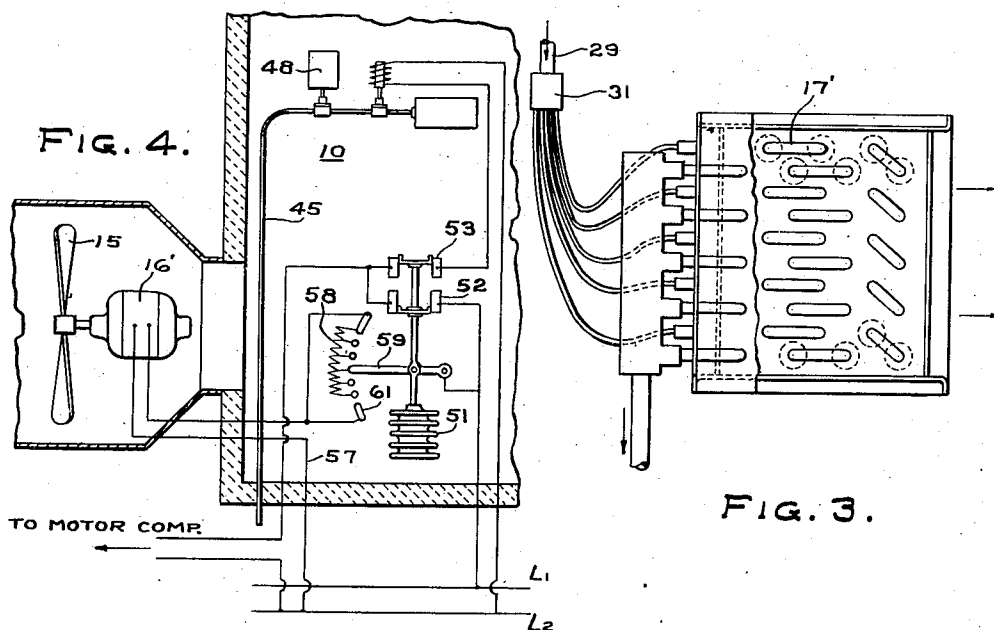
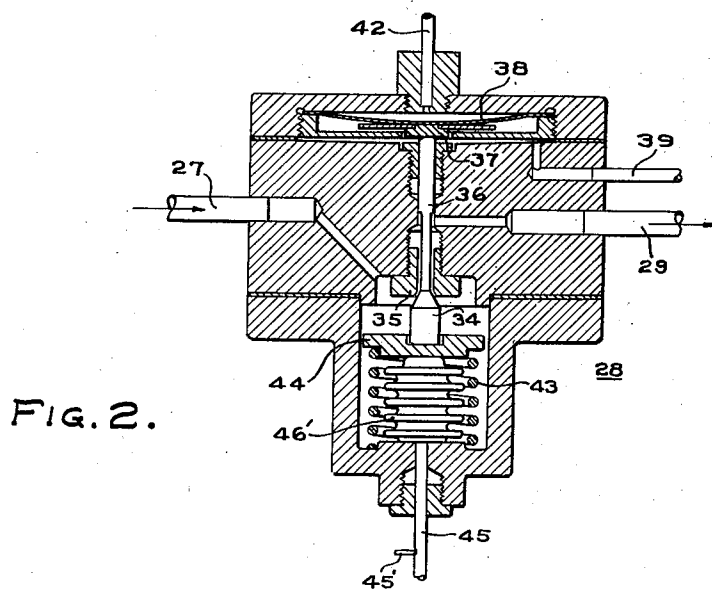
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2,236,191

AIR CONDITIONING APPARATUS

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2 Claims. (Cl. 62—6)

My invention relates to air conditioning apparatus, more particularly to apparatus for cooling and dehumidifying air for an enclosure, and it has for an object to provide improved apparatus.

Another object is to provide apparatus of relatively simple form whereby the humidity of the air in the enclosure, as well as the temperature thereof, may be maintained within desired limits.

A particular object is to provide air cooling apparatus comprising a compressor, in which the full capacity of the compressor is utilized whenever it is in operation and in which the portion of the cooling effect utilized to effect dehumidification may be increased when the demand for dehumidification is increased.

In the preferred form of my invention, I provide an evaporator of the dry type having a thermostatic expansion valve for controlling the admission of refrigerant to the evaporator. The setting of the thermostatic expansion valve is adjusted for a higher degree of superheat in response to increase in the humidity of the air in the conditioned enclosure. The effect of this adjustment is to decrease the portion of the evaporator containing liquid refrigerant and to lower the refrigerant temperature in said portion. Thus, the air passing over the portion of the evaporator containing liquid refrigerant is cooled to a lower temperature and the portion of the cooling effect applied to dehumidification is increased.

The dry bulb temperature of the air in the enclosure may be controlled by starting and stopping the operation of the air cooling apparatus. In this way, the decrease in removal of sensible heat occasioned by the increased amount of dehumidification is compensated by prolonging the period of operation.

An alternative embodiment of the invention further comprises means for increasing the rate of air circulation over the evaporator and into the enclosure in response to increase in the temperature of the enclosure.

The above recited and other objects are effected by my invention as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application in which:

Fig. 1 is a diagrammatic view of air conditioning apparatus embodying my invention;

Fig. 2 is a sectional view of the thermostatic expansion valve;

Fig. 3 is an end elevation of a modified form of evaporator that may be employed; and,

Fig. 4 is a partial diagrammatic view of a modification in which the rate of air circulation is varied in response to temperature in the enclosure.

Referring to the drawings in detail, I show an enclosure 10 to which cooled and dehumidified air is to be delivered. Air from the enclosure is conveyed through a duct 11 to an air conditioning chamber 12 and outdoor air is conveyed thereto through a duct 13. From the chamber 12, the air is delivered to the enclosure 10 through an inlet 14. The circulation is effected in any suitable manner, as by means of a fan 15 disposed in the chamber 12 and driven by a motor 16.

Within the chamber 12, there is provided an evaporator 17 for cooling and dehumidifying the air. In the illustrated embodiment, the evaporator 17 is of the type known as a dry evaporator and it has four coils 17', each coil comprising a plurality of horizontal tubes disposed in a common vertical plane and connected at their ends for flow of refrigerant from the uppermost tube successively to the lowermost tube. In accordance with common practice, these tubes are provided with fins to increase the air cooling surfaces.

The lowermost tubes of the four coils are connected to a suction header 18, from which the vaporized refrigerant is conveyed to the inlet of the compressor of a motor compressor unit 21 by means of a suction conduit 19 which provides unrestricted communication therebetween. From the latter, the compressed refrigerant is conveyed through a conduit 22 to a condenser 23. It is to be understood that any suitable form of condenser may be employed, the air cooled condenser 23 over which air is circulated by means of a fan 24 being shown merely by way of example. From the condenser, the liquid refrigerant flows through a conduit 25 to a liquid receiver 26 and then through a conduit 27 to a thermostatic expansion valve 28.

The valve 28 regulates the flow of refrigerant and effects a portion of the expansion thereof. The refrigerant is then conveyed through a conduit 29 to a fitting 31, from which it is distributed to the several coils 17' through flow-resistance tubes 32, sometimes known as capillary tubes. The tubes 32 are dimensioned to effect distribution of refrigerant in desired proportions among the several coils. In the present case, these tubes should be designed to supply successively smaller quantities to the several coils, the capacity of the several coils being successively smaller due to the successively lower tempera-

ture of the air passing over the coils in series.

The thermostatic expansion valve 28, shown in detail in Fig. 2 is of conventional design except that it is provided with suitable means for adjusting the setting thereof, which is accomplished in the present case in accordance with the humidity in the enclosure 10. The valve proper comprises a movable valve element 34 cooperating with a valve seat 35. The valve element 34 is formed on the end of a stem 36 that abuts against a disc 37 carried by a diaphragm 38. On its lower side, the diaphragm 38 is subjected to the pressure of the refrigerant leaving the evaporator, this pressure being conveyed thereto in the present case by means of a tube 39 connected to the suction conduit 19. The upper side of the diaphragm 38 is subjected to a pressure that varies as a function of the temperature of the refrigerant leaving the evaporator. This pressure is provided by a fluid contained in a thermostatic bulb 41, disposed in contact with the conduit 19 or otherwise in heat exchange relation with the discharged refrigerant, and it is communicated to the upper side of the diaphragm by means of a tube 42. The difference between these pressures is a measure of the superheat of the discharged refrigerant, and it acts downwardly on the diaphragm 38 to bias the valve element 34 in opening direction against the force of a compression spring 43, the latter biasing the valve 34 upwardly in closing direction through a spring nut or washer 44.

The thermostatic expansion valve operates in conventional manner to control the flow of refrigerant to the evaporators so as to maintain the degree of superheat of the discharged refrigerant substantially constant, as follows: Upon increase in the degree of superheat, the increased pressure differential acting on the diaphragm 38 moves the valve element 34 in valve opening direction in opposition to the spring 43 and the flow of refrigerant is increased until the degree of superheat is reduced to the desired value. Upon decrease in the degree of superheat, the decreased pressure differential on the diaphragm 38 permits the spring 43 to move the valve element 34 in closing direction. The flow of refrigerant is then restricted to the amount that can be superheated to the desired value.

By increasing the upward bias on the valve element 34, the valve is adjusted to maintain a higher degree of superheat, since the flow of refrigerant is restricted until the increased pressure difference corresponding to greater superheat balances the increased bias. In the present embodiment, such increased bias is applied by air pressure transmitted through a tube 45 to a bellows 46', by means of which it is applied upwardly against the spring nut 44 to bias the valve element 34 in valve closing direction. Air under pressure is supplied to the tube 45 from a reservoir 46, and the flow thereof is regulated by means of a valve 47 actuated by a humidistat 48. The tube 45 is provided with a restricted leakoff 45'. The humidistat 48 is disposed at any suitable point at which it is subjected to the air in the enclosure 10 and is shown as disposed within the enclosure. The humidistat and the valve 47 are constructed and arranged so that the valve is opened to increase the air pressure in the tube 45 in response to increase in humidity in the enclosure 10 and vice versa.

A valve 49 is adapted to shut off the flow of air from the reservoir 46 to the tube 45. The

valve 49 is controlled by a solenoid 50, the valve being opened upon energization and closed upon deenergization.

A room thermostat 51 is responsive to the dry bulb temperature of the air in the enclosure 10 and is shown as disposed within the enclosure. The thermostat 51 is adapted to actuate two sets of contacts, shown at 52 and 53. The contacts 52 are adapted to be closed upon increase in temperature in the enclosure 10 above the temperature which it is desired to maintain therein, for example, 75° F. The contacts 53 are adapted to be opened when the temperature in the enclosure 10 rises to some higher value, for example, 80° F., at which time it is desired to effect the maximum possible temperature reduction of the air in the enclosure, giving secondary consideration to dehumidification. As conductor 54 extends from the line conductor L₁ to the contacts 52. From the contacts 52 a circuit 55 extends through the motor of the motor compressor 21 and thence to the line conductor L₂. A circuit 56 extends from the contacts 52, through the contacts 53 and the solenoid 50 to the line conductor L₂.

Operation

The refrigerating system operates in the usual manner of such apparatus: Refrigerant compressed by the compressor is liquefied in the condenser 23. It passes through the thermostatic expansion valve 28 which regulates the flow thereof as described above and effects the major portion of the expansion thereof. It is then distributed to the several coils 27' by the tubes 32, which effect the remainder of the expansion. The refrigerant enters the coils at the top thereof and flows through the successive tubes to the discharge header 18 from which the vaporized refrigerant is returned to the compressor.

As the refrigerant flows through the coils, the liquid portion thereof is gradually vaporized. As the outlet end is approached, vaporization is completed, so that the portion of the evaporator adjacent the outlet ends of the coils contains only vaporized refrigerant being superheated. The refrigerating capacity of the portion of the evaporator containing liquid refrigerant is much greater than that of the superheat portion or portion containing vapor being superheated.

Assume now that the temperature of the air in the enclosure is above the desired value, while the humidity is as low as desired. The thermostatic expansion valve is adjusted for minimum superheat, for example, 10° F., a value commonly used. The superheat portion of the evaporator is, accordingly, at a minimum, while the portion containing liquid refrigerant is at a maximum. Under these conditions the maximum amount of sensible heat is removed from the air stream passing over the evaporator, due to the fact that the maximum portion thereof is effectively cooled. The degree of cooling of the air will ordinarily effect some dehumidification except at times at very low humidity. Such operation effects temperature reduction of the air in the enclosure at a maximum rate.

Referring to the detail operation, the thermostat 51 responds to increase above a predetermined temperature, for example, 75° F., by closing the contacts 52, so that a circuit is closed from the line conductor L₁, through the conductor 54, the contacts 52, the circuit 55 and the motor, to the line conductor L₂ to energize the motor and effect operation of the refrigerating apparatus. The contacts 52 also close a circuit from the line

conductor L₁, through the conductor 54, the contacts 52, the circuit 56, including the previously closed contacts 53 and the solenoid 50, to the line conductor L₂. This circuit energizes the solenoid 50 to open the valve 49. The humidistat 48, however, in response to the low humidity in the enclosure 10 closes the valve 47 to provide zero air pressure in the tube 45 and the bellows 46'. Accordingly, the thermostatic expansion valve 28 is adjusted for minimum superheat.

Next assume that the temperature in the enclosure is somewhat above the desired value, so that cooling thereof is required, and that the humidity has risen to such an extent that it is desired to utilize the greater portion of the cooling effect provided by the refrigerating apparatus to effect dehumidification of the air. In this case, operation of the refrigerating apparatus is effected in the same manner as described above. However, the thermostatic expansion valve 28 is adjusted for a higher degree of superheat, so that the portion of the evaporator containing only vapor is increased. Accordingly, a greater portion of the air is only slightly cooled. The portion of the evaporator containing liquid refrigerant is correspondingly decreased, resulting in decreased pressure and temperature of refrigerant therein. The air passing over the liquid containing portions is cooled to a lower temperature, so that a greater degree of dehumidification is effected. Thus, the major portion of the available cooling effect of the refrigerating apparatus is applied to a smaller portion of the air but such smaller portion is cooled more intensively so that a greater amount of dehumidification thereof is effected.

Referring to the detail operation, the humidistat 48 responds to the higher humidity by opening the valve 47. A restricted flow of air under pressure from the reservoir 46 is admitted into the tube 45 providing a pressure therein which is a function of the humidity of the air in the enclosure, the pressure increasing upon increase in humidity and vice versa. The pressure is communicated from the tube 45 to the bellows 46', in which it is applied to the valve element 34 to bias the same in valve closing direction, the effect of which is to adjust the setting of the expansion valve to a higher degree of superheat as already described.

Upon decrease in humidity in the enclosure 10, the humidistat 48 moves the valve 47 in closing direction to decrease the air pressure in the tube 45. The decreased pressure thus transmitted to the bellows 46' permits a lower pressure difference on the diaphragm 38 to balance the combined force of the spring 43 and the air pressure, so that the expansion valve 28 is adjusted to effect a lower degree of superheat. Less dehumidification is then effected and a greater portion of the cooling effect is applied to sensible heat cooling.

When the pressure of the refrigerant in the evaporator is reduced, by adjusting the valve 28 to a higher degree of superheat as described, the capacity of the refrigerating apparatus, that is, the total quantity of the heat which it is adapted to remove from the air, is reduced. Ordinarily, this means only that it will take a longer period of operation to bring the temperature in the enclosure down to the desired value at which operation is terminated. However, on extremely hot days it may be desirable, notwithstanding the high humidity, to utilize the maximum possible capacity of the refrigerating apparatus to effect reduction in temperature of the air, obtaining such dehumidification as accompanies cooling

under such circumstances. For this purpose, the contacts 53 are provided, and they are adapted to open the circuit 56, in response to increase above a higher temperature, for example, 80° F. The solenoid 50 is thereby deenergized whereupon the valve 49 shuts off the flow of air to the tube 45 and reduces the pressure therein to zero. The expansion valve 28 is then adjusted to maintain minimum degree of superheat, which means that the maximum portion of the evaporator coil contains liquid refrigerant. Accordingly, the evaporator operates at higher suction pressure, and a greater amount of heat is abstracted from the air.

The invention may be applied to any suitable form of evaporator, for example, it may be applied to the evaporator shown in Figure 3. In this case, the coils 17' are arranged in parallel with respect to the flow of air, the tubes of each coil being arranged in two adjacent rows parallel to the flow of air. The refrigerant flows first through the tube of one row on the side of the evaporator from which the air enters, then through successive tubes toward the side from which air leaves, and then reversely through the tubes in the adjacent row back to the side from which the air enters. The action of this evaporator is substantially the same as that of Figure 1, the portion of each coil containing liquid refrigerant being reduced to effect a lower temperature thereof in response to increase in demand for dehumidification.

The embodiment shown in Fig. 4 is the same as that shown in Fig. 1, except that the temperature of the air in the enclosure 10 is controlled at least in part by varying the speed of the fan 15. The latter is driven by a variable speed motor 16' connected in a circuit 57. A rheostat 58 is connected in the circuit 57 and includes a contact arm 59 actuated by the room thermostat 51 in such manner as to decrease the resistance in response to increase in temperature. There is also provided a contact 61 adapted to be engaged by the contact arm 59 to short circuit the resistance 58 when the thermostat 51 opens the contacts 52.

In the operation of this embodiment, the contacts 52 are closed by the thermostat 51 in response to increase in temperature above the desired value as in the first embodiment. Whenever the contacts 52 are closed to effect cooling, the rheostat 58 is effective to vary the speed of the motor 16' and the fan 15. Upon increase in temperature, the resistance is reduced and the speed increased, so that the rate of air circulation over the evaporator is increased. The increased air velocity increases the rate of heat transfer from the air to the evaporator, so that the evaporator is capable of effecting increased extraction of heat. The air is not cooled to as low a temperature as at lower air velocity, so that the air is dehumidified to a less extent per unit of volume, but, due to the increased amount of air delivered to the enclosure per unit of time, the rate of dehumidification is not decreased very greatly. Upon decrease in temperature in the enclosure, the thermostat 51 actuates the rheostat 58 to increase the resistance and decrease the speed of the motor and the fan. The air is then circulated over the evaporator and delivered to the enclosure 10 at reduced velocity, thereby effecting a lesser amount of sensible heat cooling.

When the temperature in the enclosure has been reduced to the desired value, the thermostat 51 opens the contacts 52 as in the first embodiment, and it also moves the contact arm 59 into engagement with the contact 61, thereby short

circuiting the rheostat 58. Full line voltage is applied to the motor 16' so that maximum rate of air circulation is effected when the refrigerating apparatus is shut down.

- 5 The humidity of the air in the enclosure is controlled in the same manner as in the first embodiment.

I contemplate the provision of suitable means for effecting adjustment of each and every part of the above-described apparatus for which there may be any occasion for adjustment. Such adjustments include the temperature at which the contacts 52 engage, the temperature at which the contacts 53 disengage, the air pressure in tube 45 in relation to the humidity, the initial compression of the spring 43, and the speed variation of the fan. Inasmuch as such adjustments can be readily made by one skilled in the art, they are not described in detail.

- 20 The invention is not to be limited to the specific apparatus described above. It contemplates, broadly, any expansion valve adapted to effect at least a part of the expansion or pressure reduction of the refrigerant and to determine the portion of the evaporator that receives liquid refrigerant.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In apparatus for air conditioning an enclosure, the combination of an evaporator, means for conveying air over said evaporator into the enclosure, a compressor having its inlet in unrestricted communication with the evaporator so that the pressure in the evaporator is variable dependent upon operating conditions of the apparatus,

a condenser connected to the compressor and providing liquid refrigerant for the evaporator, a valve connected between the condenser and the evaporator for controlling the flow of liquid refrigerant from the former to the latter, means responsive to the pressure of refrigerant in the evaporator and to the temperature of the vaporized refrigerant leaving the evaporator for actuating said valve to control the superheat of said leaving refrigerant, and means responsive to a humidity condition of air for imposing a variable fluid pressure upon said last-mentioned means and for varying said fluid pressure gradually to adjust said last-mentioned means for a greater degree of superheat upon increase in humidity and for a lesser degree of superheat upon decrease in humidity.

2. In apparatus for air conditioning an enclosure, the combination of an evaporator, means for conveying air over said evaporator and into the enclosure, means for supplying liquid refrigerant to said evaporator and for removing vaporized refrigerant therefrom, a valve for regulating the flow of refrigerant to said evaporator, pressure-responsive means for controlling said valve, means for imposing upon said pressure-responsive means in valve-closing direction a fluid pressure which is substantially the pressure of the refrigerant in the evaporator, means for imposing on said pressure-responsive means in valve-opening direction a fluid pressure varying as a function of the temperature of the vaporized refrigerant leaving said evaporator, the last two mentioned means cooperating to control the superheat of said vaporized refrigerant, and means for imposing upon said pressure-responsive means a third fluid pressure and varying the same gradually in response to a humidity condition of air in such a manner as to provide a greater degree of superheat upon increase in humidity and a lower degree of superheat upon decrease in humidity.

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