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2,350,408

DIRECT EXPANSION AIR CONDITIONING CONTROL SYSTEM

Filed May 28, 1941

2 Sheets-Sheet 1

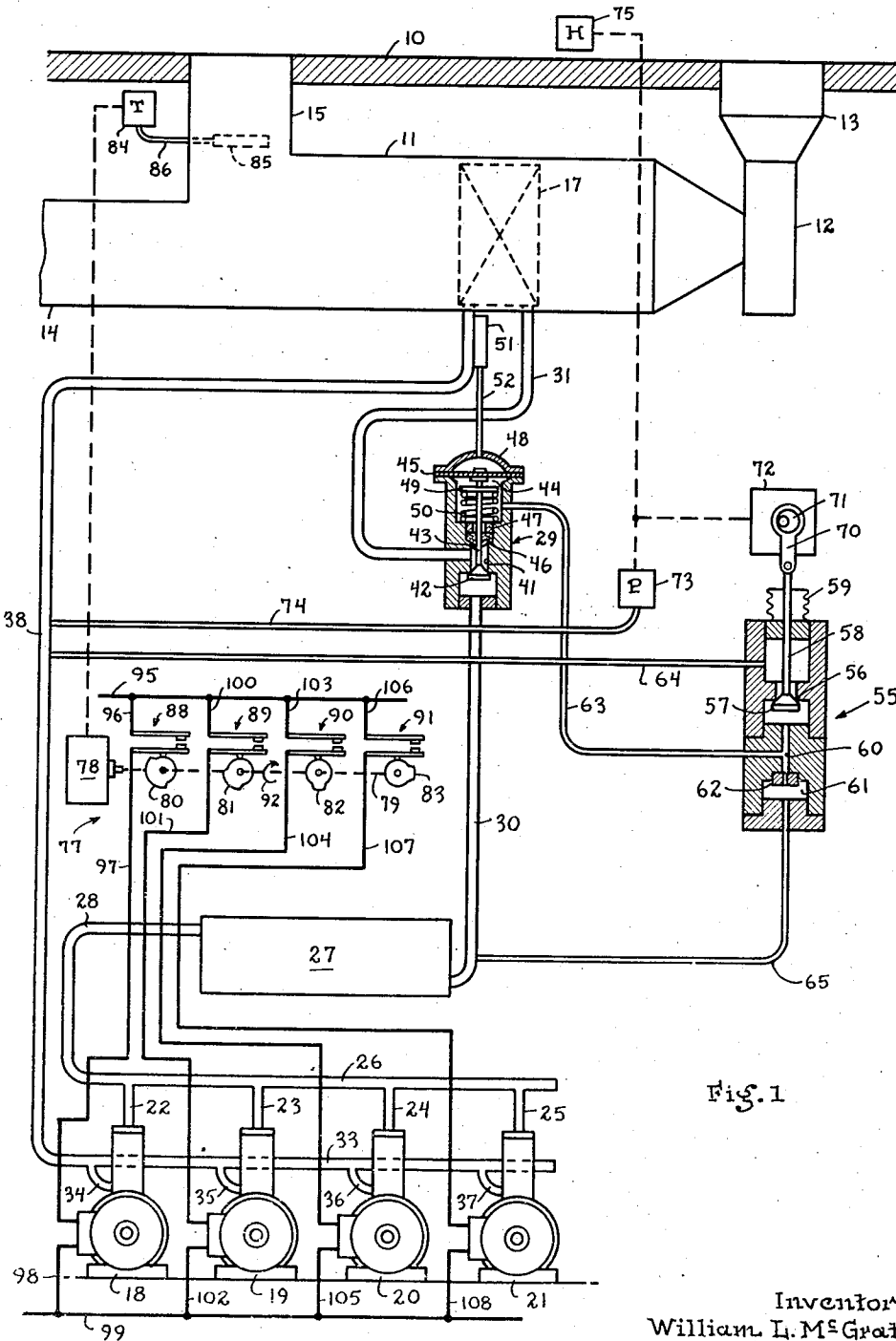


Fig. 1

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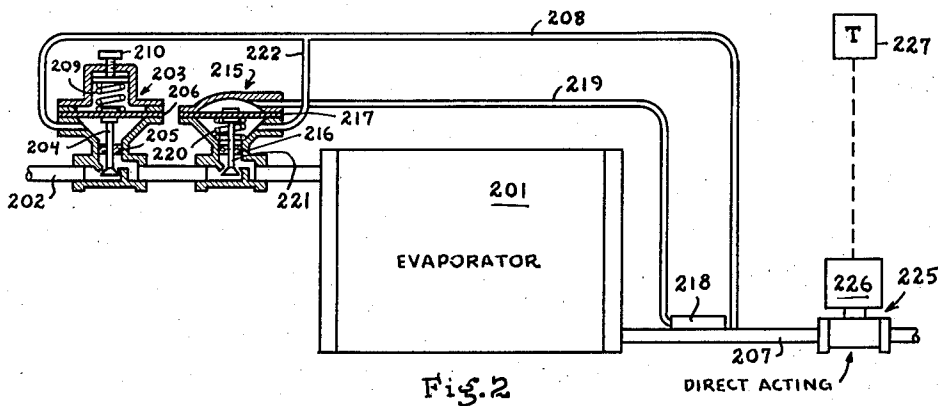
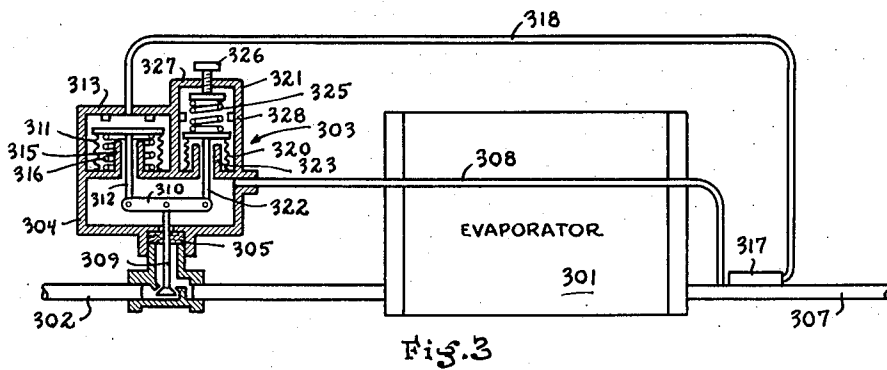
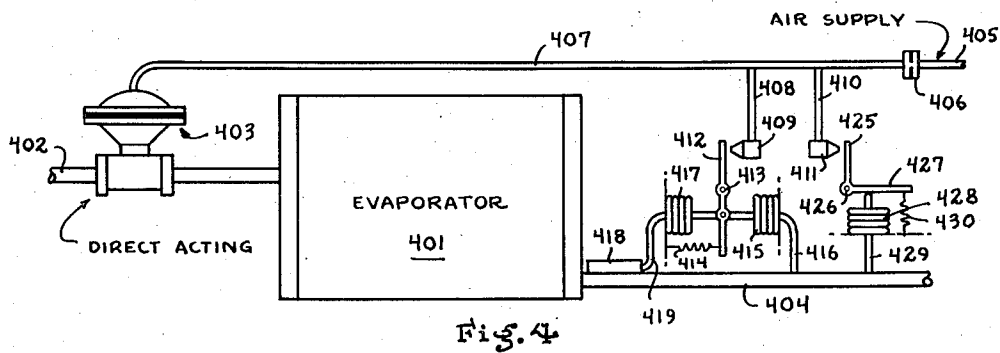
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DIRECT EXPANSION AIR CONDITIONING CONTROL SYSTEM

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

2,350,408

DIRECT EXPANSION AIR CONDITIONING  
CONTROL SYSTEM

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22 Claims. (Cl. 62--6)

This invention relates to control of direct expansion refrigerating apparatus, particularly that used in air conditioning work, that is, where the air to be treated is passed over the evaporator of the refrigerating apparatus.

Direct expansion type refrigerating apparatus is commonly used in air conditioning systems for cooling and de-humidifying air. Various control arrangements have heretofore been used to control such systems in attempting to maintain desired temperature and/or humidity conditions. The desideratum to be fulfilled is that of controlling the amount of refrigeration produced while maintaining proper operating conditions in the evaporator as respects the relative portions of the evaporator containing unevaporated refrigerant and dry gas and at the same time controlling the evaporator temperature so as to maintain the proper dehumidifying effect. The primary object of my invention is to fulfill the said desideratum in an improved and more efficacious manner.

In the types of systems in question the amount of refrigeration produced is frequently varied by providing a plurality of compressors feeding a common evaporator. In the past it has been proposed to control the evaporator temperature by controlling the amount of refrigeration effected, that is, by controlling the operation of the compressors in response to evaporator pressure. However, to thus control the compressors in sequence in response to evaporator pressure the pressure controller must have a relatively wide differential to prevent short cycling of the compressors from one step of operation to another and when the controller has such a wide differential undesirable variations in suction pressure, that is, evaporator pressure, takes place. According to my invention, I control the evaporator pressure by controlling the admission of refrigerant through the expansion valve and this may be smoothly and uniformly done.

Specifically an object of my invention is to provide a control arrangement for direct expansion type refrigerating apparatus used for conditioning air wherein the amount of refrigerant circulated through the evaporator is varied and admission of refrigerant to the evaporator is controlled by a superheat type expansion valve having means whereby the valve is adjustable by evaporator pressure to maintain the evaporator pressure within limits necessary for proper dehumidification.

Another object is to control the amount of re-

frigerant circulated through the evaporator and to simultaneously control the pressure by one valve, and the superheat at the evaporator outlet by another valve.

5 Another object of my invention is to control the amount of refrigerant circulated in response to temperature requirements and to adjust the pressure maintained by the valve in response to humidity requirements.

10 Other objects of my invention and its numerous advantages will become apparent as the following specification is read in the light of the accompanying drawings, in which,

15 Figure 1 represents diagrammatically an air conditioning system employing direct expansion refrigerating apparatus having one form of my invention embodied therein,

Figure 2 diagrammatically represents a portion of the complete system shown in Figure 1 and illustrating a modified form of my invention,

20 Figure 3 illustrates a portion of the complete system incorporating another modified form of my invention, and

25 Figure 4 illustrates a portion of the complete system embodying still another form of my invention.

Referring to the drawings, numeral 10 represents the floor of a room or other space to be conditioned. The air to be conditioned is circulated through a duct 11 which is connected to the inlet of a fan 12 which may be driven by a motor or other suitable means. The fan discharges through a duct 13 into the room the air of which is to be treated. The duct 11 has a portion 14 through which outdoor air, that is, fresh air is admitted, and the duct 11 has a branch portion 15 communicating with the room or other space through which air from the room or space is returned to the duct 11 to be recirculated. All fresh air, or all return air, may be used, or a mixture thereof may be automatically controlled in any of the usual manners.

45 Disposed in the duct 11 where the mixture of return and outdoor air may be passed over it is a coil or evaporator 17 forming part of a direct expansion refrigerating apparatus. The refrigerating apparatus includes four compressors 18, 19, 20 and 21. The compressors have discharge conduits 22, 23, 24 and 25 respectively, which are connected to a common discharge header 26. The header 26 is connected to a condenser 27 by means of a pipe 28 and the condenser 27 is connected to an expansion valve 29 by means of a pipe 30. The outlet of the expansion valve 29

is connected to the evaporator 17 by means of a pipe 31. The suction side of the four compressors are connected to a common suction header 33 by means of pipes 34, 35, 36 and 37 respectively. The outlet of the evaporator 17 is connected to the suction header 33 by means of a pipe 38. From the foregoing it is apparent that the compressors 18, 19, 20 and 21 are connected in parallel to the evaporator 17 of the refrigerating apparatus.

The expansion valve 29 is of a type which maintains a predetermined degree of superheat at the outlet of the evaporator. This particular expansion valve is disclosed in detail in an application of Alwin B. Newton, Serial No. 286,594, filed July 26, 1939. The valve 29 has a body having a longitudinal throat 41 therein forming a seat for a valve head 42. Numeral 43 designates a valve stem which extends upwardly into a chamber 44 in the upper part of the body of the valve, the valve stem being connected to a flexible diaphragm 45. The upper part of the throat 41 is slightly enlarged and in the enlarged portion is disposed packing material 46 around the valve stem 43 to prevent leakage around the valve stem, the packing being held in place by a ring 47. The diaphragm 45 is secured between a flange at the upper part of the body of the valve 29 and a corresponding flange on a dome shaped cap member 48 which may be secured to the body of the valve in any suitable manner. Attached to the valve stem 43 is a disc 49 and disposed between this disc and the bottom of the chamber 44 is a coil spring 50 which normally urges the valve into closed position. The space within the cap member 48 is connected to a thermal bulb 51 by means of a capillary tube 52, the thermal bulb 51 being disposed adjacent the pipe 38 which connects the evaporator with the suction side of the various compressors. The bulb 51 is charged with a vaporizable liquid which vaporizes and produces a pressure in the bulb 51, tube 52, and within the cap 48, the pressure depending upon the temperature of the refrigerant in the pipe 38 adjacent to the evaporator 17.

Means are provided to form an equalizer connection between the chamber 44 of the valve 29 and the suction pipe 38. The purpose of the equalizer connection as well known in the art, is to render the diaphragm 45 responsive to pressure at the outlet of the evaporator. Numeral 55 designates a valve disposed in the equalizer connection, the purpose of which is to vary the effect of evaporator outlet pressure on the diaphragm 45. The valve 55 has an internal partition having an opening extending therethrough which forms a seat 56 for a valve head 57. Numeral 58 designates a valve stem connected to the head 57 and extending externally of the valve through a sealing bellows 59, one end of which is attached to the body of the valve 55 and the other end of which is attached to the stem 58. The lower portion of valve 55 has a vertical channel 60 therein which communicates with the valve chamber and with a chamber 61 at the lower part of the valve body. At the lower end of channel 60 is an orifice member 62 having an orifice providing communication between chamber 61 and channel 60. The equalizer connection above referred to comprises a pipe 63 connecting the chamber 44 with the channel 60, and a pipe 64 providing communication between the chamber in the upper part of the valve body, that is, on the discharge side of the valve 55 and the suction pipe 38. Communication is therefore pro-

vided between the chamber 44 and the suction pipe 38 through the valve 55. The chamber 61 is connected to the pipe 30 by a pipe 65. High pressure refrigerant may be bled into the equalizer connection through the pipe 65, the orifice 62 and the channel 60. When the valve 55 is fully closed this high pressure refrigerant flows through the pipe 63 into the chamber 44 and maintains the valve 29 fully closed. When the valve 55 is open, refrigerant which is bled into the channel 60 and into the chamber 44 through the pipe 63 may be bled off to the suction pipe 38 through the valve 55 and the pipe 64. The pressure in the chamber 44 and pipe 63 then of course depends upon the rate at which refrigerant is bled through the valve 55.

The stem 58 of valve 55 is connected to a crank 70 which is engaged upon an eccentric 71 driven by the proportioning motor 72. The proportioning motor is controlled by a pressure controller 73 which is connected to the suction pipe 38 by means of a pipe 74 and by a compensating humidity responsive controller 75. The proportioning motor 72 and the controllers 73 and 75 by which it is controlled correspond to similar controllers disclosed in detail in the patent to Haines, No. 2,173,331, it being understood of course that the controller 73 comprises a potentiometer type of controller operated in response to suction pressure, and the controller 75 comprises a potentiometer type of controller operated in response to variations in humidity in the space wherein the air is being treated. The connections between the controllers 73 and 75 and the proportioning motor 72 are substantially the same as those shown in the Haines patent. The controller 73 corresponds to the controller 21 of Haines and the controller 75, which acts as a compensator, corresponds to the controller 31 of Haines. The operation of motor 72 in response to its controllers is the same as that described in the Haines patent. The proportioning motor 72 rotates the eccentric 71 in one direction or the other and when the eccentric is thus rotated, the crank 70 is moved substantially in a vertical direction either upwardly or downwardly so as to thereby move the valve stem 58 in a manner to move the valve head 57 towards closed position or away from closed position.

The compressors 18, 19, 20 and 21 are controlled by a step controller 77 which comprises a reversible motor 78 which drives a shaft 79 upon which are mounted cams 80, 81, 82 and 83. The motor 78 is controlled by a temperature responsive controller 84 which comprises a potentiometer type controller operated responsively to temperature in the return air duct 15, the controller including a thermal bulb 85 disposed in the air stream and connected to the controller by means of a capillary tube 86. The details of the controller 84 and motor 78 are the same as those of the Haines patent referred to above.

Each of the cams 80, 81, 82 and 83 has a dwell, the dwells being angularly spaced about the shaft 79 and the dwells being operable to actuate a movable blade of switches 88, 89, 90 and 91 respectively. Upon a temperature rise affecting the controller 84, the motor 78 rotates the shaft 79 in the direction indicated by arrow 92 and the cams sequentially close their respective switches, the switch 88 closing first and the other switches closing afterwards upon a progressive increase in temperature. On the other hand, upon a fall in temperature affecting the controller 84 the switches 88, 89, 90 and 91 are

opened in sequence in the reverse order. The switches 88, 89, 90 and 91 control the compressors 18, 19, 20 and 21 respectively, as will presently appear.

With the parts in the positions shown, the temperature and humidity conditions in the space are satisfactory. All of the switches 88, 89, 90 and 91 are open and all the compressors are inactive. The valve 29 is in fully closed position and the valve 55 is also in fully closed position.

Considering the operation of the system as a whole, it is to be understood that the controller 84 may have an operating range of from 74° F. to 80° F. for example. That is, upon a rise in temperature of the return air from 74° F. to 80° F., the controller 84 will operate motor 78 an amount sufficient to close all of the switches 88, 89, 90 and 91. In other words, when the return air temperature rises from 74° F. to 80° F. all four of the compressors will be energized as will presently appear.

The function of the valve 29 is normally to maintain a predetermined degree of superheat at the outlet of the evaporator. In operation, the coil 17 cools as well as dehumidifies the air which passes thereover. At times, particularly when only one or two compressors, for example, are in operation the evaporator pressure may tend to rise to such a high value that the temperature of the evaporator would not be low enough to provide for the proper amount of dehumidification of the air. To prevent the temperature of the evaporator from thus rising to a higher than desired value, I have provided the controller 73 in connection with the valve 55. The function of the controller 73 as will presently appear, is to maintain the evaporator pressure at substantially a predetermined value.

If in a system of the type disclosed, "Freon 12" is the refrigerant used in the refrigerating apparatus, proper dehumidification will be obtained if the evaporator pressure does not rise above 45 pounds. Thus the controller 73 may be set so as to prevent the evaporator pressure from rising above 45 pounds when it would otherwise tend to do so. The controller 73 has an operating differential which may be relatively narrow as respects its total differential or range. Its operating differential may be two pounds for example, that is, the controller 73 will control the valve 55 so as to move it between fully opened and fully closed position when the pressure affecting controller 73 deviates through an amount of two pounds. For example, with the parts in the position shown, the valve 55 is fully closed and the pressure in the suction pipe 38 and thus the pressure affecting the controller 73 is about 45 pounds. When the pressure affecting controller 73 is reduced to 45 pounds, the valve 55 will begin to open and will be fully opened when the pressure has fallen to 43 pounds.

The humidity controller 75 may have a fairly narrow differential and normally will tend to maintain the humidity at a desired value of 50%. Should the humidity rise above the desired value, the controller 73 will be reset to maintain a lower suction pressure and conversely if the humidity falls below the desired value, the controller 73 will be reset to maintain a higher suction pressure.

With the parts in the position shown, should the temperature in the return air duct 15 rise above 74°, the motor 78 will be operated to cause

closure of switch 88 and energization of compressor 18 through the following circuit: from line conductor 95 through wire 96, switch 88, wire 97, the motor of compressor 18, and wire 98 to line conductor 99, the line conductors 95 and 99 being connected to any suitable source of power not shown. When the compressor 18 is started, the pressure in evaporator 17 and suction pipe 38 will be reduced. As soon as the pressure in suction line 38 has been reduced into the operating range of controller 73, that is, to 45 pounds, for example, the controller 73 will operate motor 72 in a manner to crack the valve 55 open. When valve 55 is thus opened refrigerant will be permitted to bleed from chamber 44 underneath diaphragm 45 through pipe 63, channel 60 and through valve 55 and pipe 64 to the suction pipe 38. This will permit valve 29 to open, the amount of opening of course depending upon the pressures on opposite sides of diaphragm 45, the pressure above the diaphragm depending upon the temperature at the outlet of the evaporator affecting thermal bulb 51 and the pressure below the diaphragm in chamber 44 depending upon the amount of opening of valve 55 and the pressure in the suction pipe 38. The valve 29 will now admit refrigerant to the evaporator and a relatively large number of degrees of superheat will be maintained at the outlet of the evaporator, perhaps 30° F. or 40° F. Upon a further rise in temperature in the return air duct 15 affecting the controller 84 the motor 78 will be operated to cause cam 81 to close switch 89 energizing compressor 19 through the following circuit: from line wire 95 through a wire 100, switch 89, wire 101, the motor of compressor 19, and wire 102 to line conductor 99. When compressor 19 starts there will be a greater suction taken on evaporator 17 tending to reduce the pressure therein. The controller 73 will respond to the increased suction in the suction pipe 38 and the reduction in pressure will cause the controller to operate motor 72 in a direction to move valve 55 to a wider open position. This will permit bleeding of refrigerant from the chamber 44 at a greater rate and valve 29 will move toward a wider open position, that is, permitting a lower number of degrees of superheat to be maintained at the outlet of evaporator 17. In other words, the amount of effective surface of evaporator 17 will be increased when compressor 19 is started but the controller 73 will maintain the pressure in the evaporator at substantially the same value. It is to be understood that if the equalizer connections were connected directly to the suction pipe 38 without the valve 55 and controller 73 being provided, with compressors 18 and 19 operating or only compressor 18 operating, the valve 29 would operate normally to maintain the usual number of degrees of superheat at the outlet of the evaporator 17 which would be perhaps 10°. Under these circumstances the pressure in the evaporator would very likely be considerably above 45 pounds which with the type of refrigerant "F12," above referred to, would be too high for proper dehumidification of the air. It is to be seen therefore that the controller 73 and valve 55 operate to prevent the evaporator pressure from rising above desired values when only one or two compressors are operating.

If the temperature in the return air duct 15 affecting controller 84 continues to rise the motor 78 will be operated sufficiently to cause cam 82 to close switch 90 energizing compressor 20 by

means of the following circuit: from line conductor 95 to wire 103, switch 90, wire 104, the motor of compressor 20 and wire 105 to line conductor 99. When compressor 20 is started, there will be a further increased suction effect in suction pipe 38 which will be sensed by the controller 73. The increased suction effect produced by starting of compressor 20 will be sufficient to cause controller 73 to move to the limit of its operating differential, that is, to cause the valve 55 to move to fully open position. If so, the chamber 44 underneath diaphragm 45 will now be in unrestricted communication with the suction pipe 38, and the valve 55 will have no effect upon the number of degrees of superheat maintained at the outlet of the evaporator by the valve 29. That is, the starting of compressor 20 may now reduce the evaporator pressure below 43 pounds, controller 73 having no further control effect on the system. The valve 29 will now operate normally to maintain 10° superheat, for example, at the outlet of the evaporator which is the number of degrees of superheat usually maintained by superheat type of expansion valves. It is to be seen therefore that the effect of controller 73 is to increase the number of degrees of superheat maintained at the outlet of the evaporator and to thereby prevent the pressure in the evaporator from rising above a given value, controller 73 normally maintaining the evaporator pressure substantially constant.

Upon a further rise in temperature affecting the controller 84 the motor 78 will be operated to cause cam 79 to close switch 91 energizing compressor 21 by means of a circuit as follows: from line conductor 95 to wire 106, switch 91, wire 107, the motor of compressor 21 and wire 108 to line conductor 99. Starting of compressor 21 will produce an increased suction effect in suction pipe 38 tending to further reduce the pressure in evaporator 17. The valve 29 will continue to maintain 10° of superheat at the outlet of the evaporator. By reason of all four compressors now being in operation the maximum amount of refrigeration will be taking place in evaporator 17 and the pressure will be at a relatively low value.

The temperature in the return air duct 15 and affecting controller 84 should now begin to fall, and as it falls below 80° the switches 88, 89, 90 and 91 will be sequentially opened, the switch 91 opening first. When switch 91 opens compressor 21 will be stopped and the amount of refrigerant circulated through evaporator 17 will of course be reduced. Due to stopping of compressor 21, the evaporator pressure will rise but it will not rise sufficiently to cause controller 73 to move into its operating range and there will be no change in the amount of superheat maintained at the outlet of evaporator 17. As the temperature affecting controller 84 continues to fall switch 90 will be opened next stopping compressor 20. When compressor 20 stops, the reduction of suction effect in pipe 38 will be sufficient to cause controller 73 to move into its operating range, that is, the pressure in pipe 38 will rise above 43 pounds causing controller 73 to again effectively control motor 72 and valve 55. When controller 73 thus moves into its operating range, the valve 55 will be moved towards closed position tending to restrict the bleed from chamber 44 through valve 55 and to the suction pipe 38. Due to the restriction, that is, the reduced rate of bleed, the pressure within chamber 44 will be slightly increased tending to move valve

29 towards closed position, thus restricting or throttling the admission of refrigerant to evaporator 17. In other words, a higher number of degrees of superheat than normal will now be maintained at the outlet of evaporator 17. By thus throttling the admission of refrigerant to the evaporator and increasing the amount of superheat maintained at the outlet the pressure therein is prevented from rising above the setting of controller 73. As the temperature affecting controller 84 continues to decrease, the switch 89 will next be opened causing the compressor 19 to stop. Upon stopping of compressor 19 there will be a further reduced suction effect in suction pipe 38 which will be sensed by controller 73, that is, there will be a rise of pressure in pipe 38 and controller 73 will respond moving valve 55 further towards closed position. This will further restrict the bleed from chamber 44 and the resulting increased pressure therein will tend to cause valve 29 to move further in a throttling direction causing the number of degrees of superheat maintained at the outlet of the evaporator to be further increased. Thus again by throttling the flow of refrigerant to the evaporator and increasing the amount of superheat maintained at the outlet, the pressure therein is prevented from rising above the setting of controller 73.

When the temperature in the return air duct has fallen to the desired value of 74°, motor 78 will be operated to cause cam 80 to open switch 88 and the last compressor, that is, compressor 18 will be stopped. When compressor 18 is stopped, there will be no further suction effect in pipe 38 and the evaporator pressure and the pressure in pipe 38 will rise and the rise in pressure will cause controller 73 to move to the limit of its operating range causing valve 55 to move to a fully closed position. Refrigerant will not now be permitted to bleed from chamber 44 and high pressure refrigerant from pipe 65 will be communicated through restricted orifice 62, channel 60 and pipe 63 into chamber 44, and the resulting pressure therein will maintain valve 29 in fully closed position.

From the foregoing, it is to be seen that when only one or two compressors are operating, so that with the usual type of control the evaporator pressure would be relatively high, too high for proper dehumidification of the air, the control arrangement of my invention provides for limiting the pressure in the evaporator so that it does not rise above a value at which proper dehumidification will be obtained, the arrangement normally maintaining the evaporator pressure constant. After the valve 55 has been fully opened, as is apparent, it has no further effect upon the number of degrees of superheat maintained at the outlet of the evaporator by valve 29. Further reduction in evaporator pressure is then of course dependent upon the relationship between the total compressor capacity and the capacity of evaporator 17. It is to be understood that the operating differential of controller 73 might be so related to the compressors and evaporator used that the controller 73 would effectively control the pressure in evaporator 17 during the time that any or all compressors are operating.

As pointed out above, the controller 73 has a relatively wide total differential which may be 40 pounds pressure, for example. At any time when one or more compressors are operating if the relative humidity in the space being served

should rise above the desired value of 50% relative humidity, the compensating controller 75 will act to reset the control point of controller 73. That is, if the humidity rises above 50%, for example, the control point of controller 73 will be lowered to a value below 45 pounds, for example, the control point of controller 73 might be reduced to 39 pounds. The operating differential of controller 73 would remain the same, that is, two pounds, for example, and it would now move the valve 55 between fully closed and fully opened positions when the pressure affecting controller 73 changed between 40 pounds and 38 pounds, for example. Under these circumstances, the controller 73 would operate in a similar manner to that described above to maintain the evaporator pressure between 38 and 40 pounds, that is, the evaporator pressure would not be permitted to rise above 40 pounds. The lower evaporator pressure and corresponding evaporator temperature would cause increased dehumidification which would cause the humidity to return to the proper value of 50%.

On the other hand, if the relative humidity should fall below the desired value of 50%, the control point of controller 73 will be moved in the opposite direction, that is, raised, and the controller 73 will operate to maintain a higher evaporator pressure, that is, it will prevent the evaporator pressure from rising above a higher predetermined value.

My invention may be carried out in various other manners somewhat different than that of Fig. 1. In Fig. 2 of the drawings, I have shown an arrangement wherein the pressure in the evaporator is controlled by means of a separate valve responsive to evaporator pressure. In Fig. 2, numeral 201 represents an evaporator of the direct expansion type. If desired, this evaporator may be used in a system the same as the one disclosed in detail in Fig. 1 including a plurality of compressors sequentially controlled in response to temperature requirements. In Fig. 2, numeral 202 represents a liquid refrigerant line through which refrigerant is supplied from a source of supply. Interposed in the line 202 is a first valve 203 which is of a conventional type arranged to respond to pressure so as to maintain the pressure beyond the valve at a constant value. The valve has a stem 204 which passes through packing material 205 to prevent the leakage of refrigerant past the stem into the upper part of the valve body. The valve stem is connected to a flexible diaphragm 206 which forms a chamber underneath the diaphragm and this chamber is connected to the discharge pipe 207 of the evaporator by a tube 208. The pressure underneath the diaphragm urges the valve in closing direction against the force of a coil spring 209 which may be adjusted by means of an adjusting knob 210. The valve 203 is normally open, and when the pressure communicated through the tube 208 rises to a predetermined value determined by the setting of knob 210, the diaphragm 206 moves the valve toward closed position sufficiently to maintain the pressure at the said predetermined value.

Interposed in the liquid line 202 beyond the valve 203 is a second valve 215 which is of the conventional type adapted to maintain a predetermined degree of superheat at the outlet of the evaporator. The valve has a stem 216 which is connected to a diaphragm 217 forming part

of a pressure chamber above the diaphragm. This chamber is connected to a thermal bulb 218 by means of a tube 219, the thermal bulb 218 being disposed in heat exchange relationship with the discharge pipe 207 of the evaporator. The bulb 218 is filled with an expansible liquid which vaporizes and develops a pressure above the diaphragm 217 depending upon the temperature affecting the bulb. The diaphragm 217 is normally urged upwardly by a coil spring 220 this spring thus urging the valve in closing direction. The valve stem passes through packing material 221 to prevent leakage of refrigerant past the valve stem and the chamber underneath the diaphragm 217 is connected to the tube 208 by a tube 222 so that pressure from the discharge pipe 207 of the evaporator is communicated to a chamber underneath the diaphragm. The pressures on opposite sides of the diaphragm 217 normally maintain the valve 215 in a balanced position dependently upon the amount of superheat existing in the discharge pipe 207. In other words, if the number of degrees of superheat increases, the pressure above the diaphragm tends to preponderate over that below the diaphragm and the valve is moved slightly in opening direction until rebalance is brought about.

Disposed in the discharge pipe 207 is a motorized valve 225 driven by an electric motor 226 which is controlled by a thermostat 227 responsive to the temperature of medium cooled by the evaporator. The thermostat 227 and valve 225 may be of the type disclosed in detail in the patent of D. G. Taylor, No. 2,028,110. Upon a rise in temperature the thermostat 227 opens the valve 225 to permit a greater amount of refrigerant to be circulated through the evaporator, and upon a fall in temperature the thermostat 227 causes the valve 225 to be moved toward closed position to reduce the amount of refrigerant circulated through the evaporator.

In normal operation the valve 225 controls the amount of refrigerant circulated through the evaporator and the valve 203 controls the admission of refrigerant to the evaporator to maintain a predetermined pressure in the evaporator. As pointed out above, the valve 203 operates to maintain a predetermined pressure on the downstream side of the valve, that is, in the evaporator. In other words, the thermostat 227 controls the refrigerative capacity, that is the amount of refrigerant which is circulated while the valve 203 maintains the pressure in the evaporator constant. The valve 215 is normally in a relatively wide open position, but in the event that liquid refrigerant tends to pass over into the discharge pipe 207 of the evaporator, the temperature affecting bulb 218 will be so reduced that the reduction in pressure above diaphragm 217 will permit spring 220 in conjunction with the pressure underneath the diaphragm to move valve 215 towards closed position so as to reduce the rate of admission of refrigerant to the evaporator so as to prevent liquid from passing into the discharge pipe. Thus, the system operates to vary the amount of refrigerant circulated while its pressure is maintained constant, the valve 215 acting to prevent liquid from passing into the suction line.

Figure 3 shows a different form of my invention wherein a single valve is used in the liquid line, this valve being operative in response both to the amount of superheat in the discharge pipe

of the evaporator and also to pressure in the evaporator. The arrangement of Fig. 3 may be used with the multiple compressor arrangement of Fig. 1 or the suction line valve of Fig. 2 may be used, or both. Numeral 301 represents the evaporator in Fig. 3 and numeral 302 designates the liquid line. The valve 303 of Fig. 3 comprises a housing 304 into which the valve stem extends through a packing 305. The lower portion of the housing 304 is in communication with the discharge pipe 307 of the evaporator by a tube 308. The valve stem 309 is connected to a floating lever 310, the left end of which is connected to an expansible and contractible bellows 311 by a stem 312. The bellows 311 is disposed in a portion 313 of housing 304 forming a bellows chamber, the stem 312 passing through an annular member 315 forming a stop limiting contraction of the bellows 311. The bellows is normally urged into an expanded position by a coil spring 316 inside of the bellows. The chamber outside the bellows is connected to a thermal bulb 317 by means of a tube 318, the bulb 317 being disposed in heat exchange relation with the discharge pipe 307 of the evaporator.

The right end of lever 310 is connected to an expansible and contractible bellows 320 disposed within a portion 321 of housing 304 forming a chamber for the bellows. The stem 322 passes through an annular member 323 forming a stop limiting contraction of the bellows 320. Numeral 325 designates a coil spring which normally urges the bellows 320 into compressed position, the spring 325 being adjustable by means of a manual knob 326 outside of the housing 304. Numerals 327 and 328 designate stops within the portion 321 of housing 304 which limit the expansion of bellows 320. The bulb 317 is filled with expansible liquid which vaporizes and thus the pressure exterior of the bellows 311 depends upon the temperature in the discharge pipe 307.

In operation, the valve 303 is normally adjusted primarily by the bellows 320 responsive only to pressure in the pipe 307. Upon an increase in pressure the bellows 320 tends to expand moving the right end of lever 310 and the valve upwardly toward closed position. Thus, the valve will normally be positioned dependently upon the pressure in the evaporator and the pressure will be maintained at a value depending upon the adjustment of spring 325.

The bellows 311 will normally assume a balanced position dependently upon the pressure within the bellows and the pressure on the outside of the bellows communicated through tube 318 from the bulb 317. As in the previous embodiment, if liquid refrigerant should tend to pass into the discharge pipe 307, the temperature within bulb 317 and consequently the pressure around the outside of bellows 311 will be so reduced that the bellows will be expanded by means of the spring 316 acting in conjunction with the pressure within the bellows to move the left end of lever 310 and the valve upwardly towards closed position. This movement of the valve will reduce the admission of refrigerant to the evaporator sufficiently to prevent any liquid from being carried over into the discharge pipe 307.

In Fig. 4, I have shown an arrangement similar to that of the previous figures but wherein the valve is operated by pneumatic control devices. In Fig. 4, the evaporator is designated by the numeral 401 and the liquid line is designated by the numeral 402. Disposed in the liquid line

is an air pressure operated control valve 403 of the well known direct acting type which has a pressure chamber including an expansible wall which acts to close the valve upon an increase in pressure in the pressure chamber. Numeral 404 designates the discharge pipe of the evaporator. Numeral 405 designates a supply pipe from a source of air pressure such as is conventionally used in pneumatic control systems, the supply of air pressure usually being at fifteen pounds. Numeral 406 designates a fixed restriction through which the air must pass before being communicated to the control device. The restriction 406 is connected to the expansible chamber of the valve 403 by a tube 407. Numeral 408 designates a first branch pipe communicating with pipe 407, the branch pipe having a fitting at its end, 409, with a bleed orifice thereon. Numeral 410 designates a second branch pipe communicating with pipe 407 having a fitting 411 with a bleed orifice therein. Associated with the orifice in the fitting 409 is a flapper 412 arranged to control the rate of bleed from the orifice. The flapper 412 is pivoted at 413 and it is normally biased in a clockwise direction by a coil spring 414. An expansible bellows 415 is connected to the flapper member 412 so as to urge it toward the fitting 409 when the bellows expands, the bellows 415 being connected to the discharge pipe 404 by a tube 416. A second expansible bellows 417 is connected to the flapper member 412 so as to oppose the bellows 415 and to urge the flapper away from the fitting 409 when the bellows 417 expands. The bellows 417 is connected to a thermal bulb 418 disposed in heat exchange relation with the discharge pipe 404 by a tube 419. The bellows 417 expands and contracts in accordance with the temperature in the discharge pipe 404. From the foregoing, it is to be seen that the operating means for the flapper 412 respond to the amount of superheat in the discharge pipe 404 inasmuch as the pressure in the said pipe acting through bellows 415 opposes the temperature of the discharge pipe acting through the bellows 417.

Numeral 425 designates a flapper disposed adjacent the orifice in fitting 411, flapper 425 being pivoted at 426 and having an arm 427 which is normally in engagement with an operating stem connected to an expansible and contractible bellows 428. The bellows 428 is connected to the discharge pipe 404 by a tube 429. The flapper 425 is normally urged away from the fitting 411 by a coil spring 430 connected to the arm 427. Upon an increase in pressure the bellows 428 expands moving the flapper 425 toward fitting 411, and upon a decrease in pressure in bellows 428 the flapper 425 is moved away from the fitting 411.

The size of the orifices in fittings 409 and 411 is such that the rate of bleed through each of these orifices is less than through the restriction 406. Thus if the orifice in either of the fittings 409 or 411 is completely obstructed, the pressure will build up in pipe 407 to a value sufficiently high to completely close the valve 403. In normal operation the superheat in the discharge pipe 404 is great enough so that the pressure in bellows 417 preponderates over the pressure in bellows 415 and the flapper 412 is held in a position away from fitting 409 so as not to obstruct the bleed of air therefrom. The bellows 428 normally controls the rate of bleed through fitting 411 so as to control the pressure acting on the valve 403 to cause a predetermined evaporator

pressure to be maintained. Thus, when bellows 428 expands in response to an increase in pressure, flapper 425 is moved toward fitting 411 and thus the rate of bleed is decreased and the pressure in pipe 407 affecting the valve is increased. Thus, upon the increase in pressure the valve 403 is moved towards closed position to reduce the pressure in the evaporator. Upon a decrease in pressure within bellows 428, the pressure in pipe 407 is similarly decreased, and valve 403 moves in opening direction to increase the evaporator pressure. That is, the evaporator pressure is normally maintained at a constant value in response to the bellows 428. In the event that liquid refrigerant should tend to pass into the discharge pipe 404, the temperature affecting bellows 414 will be reduced and the corresponding pressure in bellows 415 will preponderate over the pressure in bellows 417. The flapper 412 will be moved towards the fitting 409 to reduce the rate of bleed therefrom. Correspondingly, the pressure in pipe 417 affecting valve 403 will be increased so as to move the valve 403 towards closed position to reduce the rate of admission of refrigerant to the evaporator and thereby prevent liquid from passing over into the discharge pipe 404.

From the foregoing, those skilled in the art will readily appreciate that I have provided a very unique control arrangement for refrigerating apparatus wherein the evaporator pressure is maintained constant and also liquid refrigerant is prevented from passing into the suction line of the evaporator. The amount of refrigerant circulated through the evaporator may be varied to meet load demands while the pressure is kept at a desired value and the evaporator is operated under efficient conditions.

The embodiments of my invention which I have disclosed are representative of its previous forms. Various modifications and changes may be made by those skilled in the art and it is to be understood that my invention is to be limited not by my disclosure but only in accordance with the claims appended hereto.

I claim as my invention:

1. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator, means comprising a plurality of compressors whereby the amount of refrigeration produced by the apparatus may be varied, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means responsive to a condition of the air being treated for controlling said compressors to control the amount of refrigeration produced by the refrigerating apparatus, and means including a valve controlling the supply of refrigerant to the evaporator, said last means being responsive to evaporator pressure and arranged to control the admission of refrigerant to the evaporator in a manner to maintain the evaporator pressure substantially constant while the amount of refrigeration produced by the refrigerating apparatus is varied.

2. In an air conditioning system, in combination, refrigerating apparatus including an evaporator and a variable capacity source of refrigerant supply connected to the evaporator, means responsive to a condition of air being treated for controlling the capacity of the source of refrigerant supply, and means including a valve controlling the supply of refrigerant to the evaporator, said last means being responsive to evaporator pressure and arranged to control the admission

of refrigerant to the evaporator to maintain a constant evaporator pressure when the capacity of the source of supply is varied.

3. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator, means whereby the amount of refrigeration produced by the apparatus may be varied, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means responsive to a condition of the air being treated for controlling the amount of refrigeration produced by the refrigerating apparatus, means including a valve of the type responsive to superheat at the outlet of the evaporator controlling the admission of refrigerant to the evaporator, and means responsive to evaporator pressure for additionally controlling the position of said valve in accordance with variations in evaporator pressure for maintaining said pressure at a value at which it is capable of dehumidifying the air passing over said evaporator.

4. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator, means whereby the amount of refrigeration produced by the apparatus may be varied, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means responsive to a condition of the air being treated for controlling the amount of refrigeration produced by the refrigerating apparatus, means including a valve controlling the supply of refrigerant to the evaporator, said last means being responsive to evaporator pressure and arranged to control the admission of refrigerant to the evaporator in a manner to maintain the evaporator pressure substantially constant while the amount of refrigeration produced by the refrigerating apparatus is varied, and humidity responsive means associated with said last-named means operable to vary the evaporator pressure maintained and correspondingly the evaporator temperature in order to preserve proper humidity conditions.

5. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator and a variable capacity source of refrigerant supply connected to the evaporator, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means responsive to a condition of the air being treated for controlling the capacity of the source of refrigerant supply, means including a valve controlling the supply of refrigerant to the evaporator, said last means being responsive to evaporator pressure and arranged to control the admission of refrigerant to the evaporator to prevent the evaporator pressure from rising above a predetermined value when the capacity of the source of supply is reduced, and humidity responsive means associated with said last-named means and operable to vary the evaporator pressure maintained and correspondingly the evaporator temperature in order to preserve proper humidity conditions.

6. In a refrigerating system, in combination, a compressor, a condenser, and an evaporator, a valve of the superheat responsive type controlling the admission of refrigerant to the evaporator, means for varying the amount of refrigerant circulated through the evaporator tending to cause the evaporator pressure to vary, and means associated with said valve for adjusting the valve for normally maintaining the evaporator pressure

constant while the amount of refrigerant circulated through the evaporator is varied.

7. In a refrigerating system, in combination, a compressor, a condenser and an evaporator, valve means of the superheat responsive type controlling the admission of refrigerant to the evaporator, means for varying the amount of refrigerant circulated through the evaporator tending to cause the evaporator pressure to vary, said valve means including an expansible chamber, means providing communication between said chamber and the outlet of the evaporator, the pressure in said chamber affecting the valve means to govern the number of degrees of superheat maintained at the evaporator outlet, valve means controlling said means of communication and means responsive to evaporator pressure controlling said last valve means whereby said first valve means is controlled in a manner to normally maintain a substantially constant evaporator pressure while the amount of refrigerant circulated through the evaporator is varied.

8. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means whereby the amount of refrigeration produced by the apparatus may be varied, means responsive to load requirements controlling said last means, means including a valve of the type responsive to superheat at the outlet of the evaporator controlling the admission of refrigerant to the evaporator, and means responsive to evaporator pressure for additionally controlling the position of said valve for maintaining said evaporator pressure substantially constant while the amount of refrigeration produced by the refrigerating apparatus is varied.

9. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator, means comprising a plurality of compressors whereby the amount of refrigeration produced by the apparatus may be varied, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means responsive to the temperature of the treated air whereby said compressors are started and stopped in sequence depending on the temperature of the air, and means including a valve controlling the supply of refrigerant to the evaporator, said last means being responsive to evaporator pressure and arranged to control the admission of refrigerant to the evaporator in a manner to maintain the evaporator pressure substantially constant while the amount of refrigeration produced by the refrigerating apparatus is varied.

10. In an air conditioning system, in combination, a direct expansion type refrigerating apparatus including an evaporator, means comprising a plurality of compressors whereby the amount of refrigeration produced by the apparatus may be varied, means for passing air to be conditioned over the evaporator whereby the air is cooled and dehumidified, means responsive to the temperature of the treated air whereby said compressors are started and stopped in sequence depending on the temperature of the air, and means including a valve controlling the supply of refrigerant to the evaporator, said last means being responsive to evaporator pressure and arranged to control the admission of refrigerant to the evaporator in a manner to maintain the evaporator pressure substantially constant while

the amount of refrigeration produced by the refrigerating apparatus is varied, said valve means having a pressure chamber connected to the evaporator outlet and a controlling valve interposed in the connection between the said pressure chamber and evaporator outlet for varying the pressure in said chamber.

11. In a refrigerating system, in combination, a compressor, a condenser and an evaporator, valve means of the superheat responsive type controlling the admission of refrigerant to the evaporator, means for varying the amount of refrigerant circulated through the evaporator tending to cause the evaporator pressure to vary, said valve means including an expansible chamber, means providing communication between said chamber and the outlet of the evaporator, the pressure in said chamber affecting the valve means to govern the number of degrees of superheat maintained at the evaporator outlet, valve means controlling said means of communication, means responsive to evaporator pressure controlling said last valve means whereby said first valve means is controlled in a manner to maintain a substantially constant evaporator pressure, and means responsive to the humidity of the treated air cooperating with said evaporator pressure responsive means for varying the pressure maintained in the evaporator so as to preserve proper humidity conditions.

12. In an air conditioning system, in combination, direct expansion refrigerating apparatus including an evaporator, means for passing air over the evaporator for cooling and dehumidifying the air, a plurality of compressors connected to said evaporator for circulating refrigerant therethrough, means responsive to the temperature of the treated air controlling the compressors whereby the compressors are started and stopped depending on the air temperature, means comprising an expansion valve controlling the admission of refrigerant to the evaporator, said valve means embodying mechanism to maintain the evaporator pressure at a substantially constant value when the number of compressors in operation is varied, said mechanism comprising a pressure chamber and means providing communication between said chamber and the outlet of the evaporator, the pressure in said chamber governing the amount of opening of the expansion valve, a control valve interposed in said means providing communication, and means responsive to evaporator pressure controlling said control valve to maintain a substantially constant evaporator pressure.

13. In an air conditioning system, in combination, direct expansion refrigerating apparatus including an evaporator, means for passing air over the evaporator for cooling and dehumidifying the air, a plurality of compressors connected to said evaporator for circulating refrigerant therethrough, means responsive to the temperature of the treated air controlling the compressors whereby the compressors are started and stopped depending on the air temperature, means comprising an expansion valve controlling the admission of refrigerant to the evaporator, said valve means embodying mechanism to maintain the evaporator pressure at a substantially constant value when the number of compressors in operation is varied, said mechanism comprising a pressure chamber and means providing communication between said chamber and the outlet of the evaporator, the pressure in said chamber governing the amount of opening of the expansion

sion valve, a control valve interposed in said means providing communication, means responsive to evaporator pressure controlling said control valve to maintain a substantially constant evaporator pressure, and means responsive to humidity of the treated air associated with said pressure responsive means for varying the evaporator pressure maintained to preserve proper humidity conditions.

14. In a refrigerating system, in combination, means comprising a source of refrigerant supply, an evaporator, means controlling the supply of refrigerant to the evaporator comprising a valve, said valve including mechanical means responsive to pressure in the evaporator and to temperature at the outlet of the evaporator for adjusting the valve in accordance with the amount of superheat at the evaporator outlet, and mechanical means responsive to evaporator pressure for adjusting the valve to maintain a constant evaporator pressure.

15. In a refrigerating system, in combination, means comprising a source of refrigerant, an evaporator, means controlling the flow of refrigerant to the evaporator comprising a valve, said valve including a bodily movable lever member for actuating the valve, means responsive to evaporator pressure and to temperature at the outlet of the evaporator for actuating said member whereby the valve is adjusted to control the amount of superheat at the outlet of the evaporator, and another means responsive to evaporator pressure for actuating said member whereby said valve is adjusted in a manner to control the evaporator pressure.

16. In a refrigerating system, in combination, means forming a source of refrigerant, an evaporator connected to said source, means comprising a valve controlling the flow of refrigerant to the evaporator, said valve being of the type adapted to control the amount of superheat at the outlet of the evaporator, a second valve controlling the flow of refrigerant through the evaporator, said valve having means whereby it is responsive to evaporator pressure so as to control the evaporator pressure to maintain it constant, and means for varying the amount of refrigerant circulated through the evaporator while the pressure is maintained at a constant value.

17. In a refrigerating system, in combination, means forming a source of refrigerant, an evaporator connected to said source, means comprising a valve controlling the flow of refrigerant to the evaporator, said valve being of the type adapted to control the amount of superheat at the outlet of the evaporator, a second valve controlling the flow of refrigerant through the evaporator, said valve having means whereby it is responsive to evaporator pressure so as to control the evaporator pressure to maintain it constant, and means for varying the amount of refrigerant circulated through the evaporator while the pressure is maintained at a constant value, said last means comprising another valve responsive to a condition of medium being treated by the system.

18. In a refrigerating system, in combination,

means forming a source of refrigerant, an evaporator, means for circulating refrigerant through the evaporator, means for varying the amount of refrigerant circulated so as to tend to cause the evaporator pressure to vary, means responsive to a condition of air being treated controlling said last means, means for maintaining a constant evaporator pressure while the amount of refrigerant circulated is varied, and means responsive to superheat at the evaporator outlet for preventing liquid refrigerant from passing out of the evaporator.

19. In an air conditioning system, in combination, an evaporator, means passing air to be cooled and dehumidified over said evaporator, means for supplying said evaporator with liquid refrigerant, means controlling the amount of refrigerant delivered to the evaporator in accordance with the temperature of the conditioned air, a constant superheat expansion valve in control of said evaporator tending to maintain a relatively high pressure in said evaporator when the temperature of said conditioned air is relatively low, and means maintaining said pressure relatively low for purposes of dehumidification of the air passing over said evaporator.

20. In an air conditioning system, in combination, an evaporator, means passing air to be cooled and dehumidified over said evaporator, means for supplying said evaporator with liquid refrigerant, means controlling the amount of refrigerant delivered to the evaporator in accordance with the temperature of the conditioned air, a constant superheat expansion valve in control of said evaporator tending to maintain a relatively high pressure in said evaporator when the temperature of said conditioned air is relatively low, means maintaining said pressure relatively low for purposes of dehumidification of the air passing over said evaporator, and means responsive to the humidity of the conditioned air for varying the evaporator pressure which said maintaining means tends to maintain.

21. In an air conditioning system, in combination, a source of liquid refrigerant, an evaporator for said refrigerant for cooling a fluid medium, means for causing a flow of refrigerant from said source to said evaporator, a first valve for varying said flow in accordance with the temperature of said medium, a second valve in control of said flow of refrigerant, and means responsive to evaporator pressure in control of said second valve for maintaining said pressure constant.

22. In an air conditioning system, in combination, a source of liquid refrigerant, an evaporator for said refrigerant for cooling a fluid medium, means for causing a flow of refrigerant from said source to said evaporator, a first valve for varying said flow in accordance with the temperature of said medium, a second valve in control of said flow of refrigerant, means responsive to evaporator pressure in control of said second valve for maintaining said pressure constant, and means including a third valve for maintaining a constant degree of superheat at the outlet of said evaporator.

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