

Aug. 11, 1942.

H. L. STEINFELD

2,292,486

AIR CONDITIONING SYSTEM

Filed Feb. 7, 1938

5 Sheets-Sheet 1

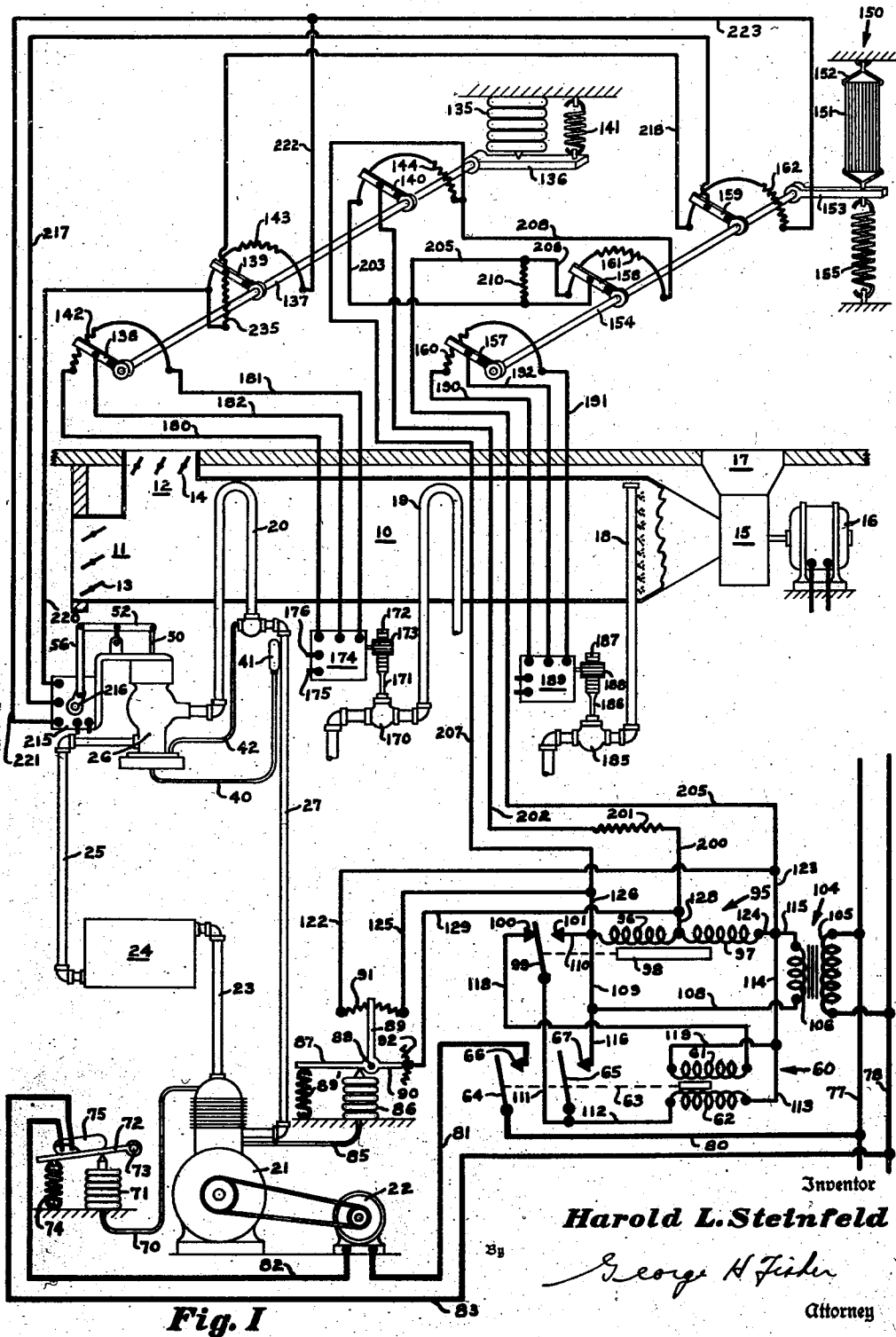


Fig. 1

Inventor
Harold L. Steinfeld

George H. Fisher

Attorney

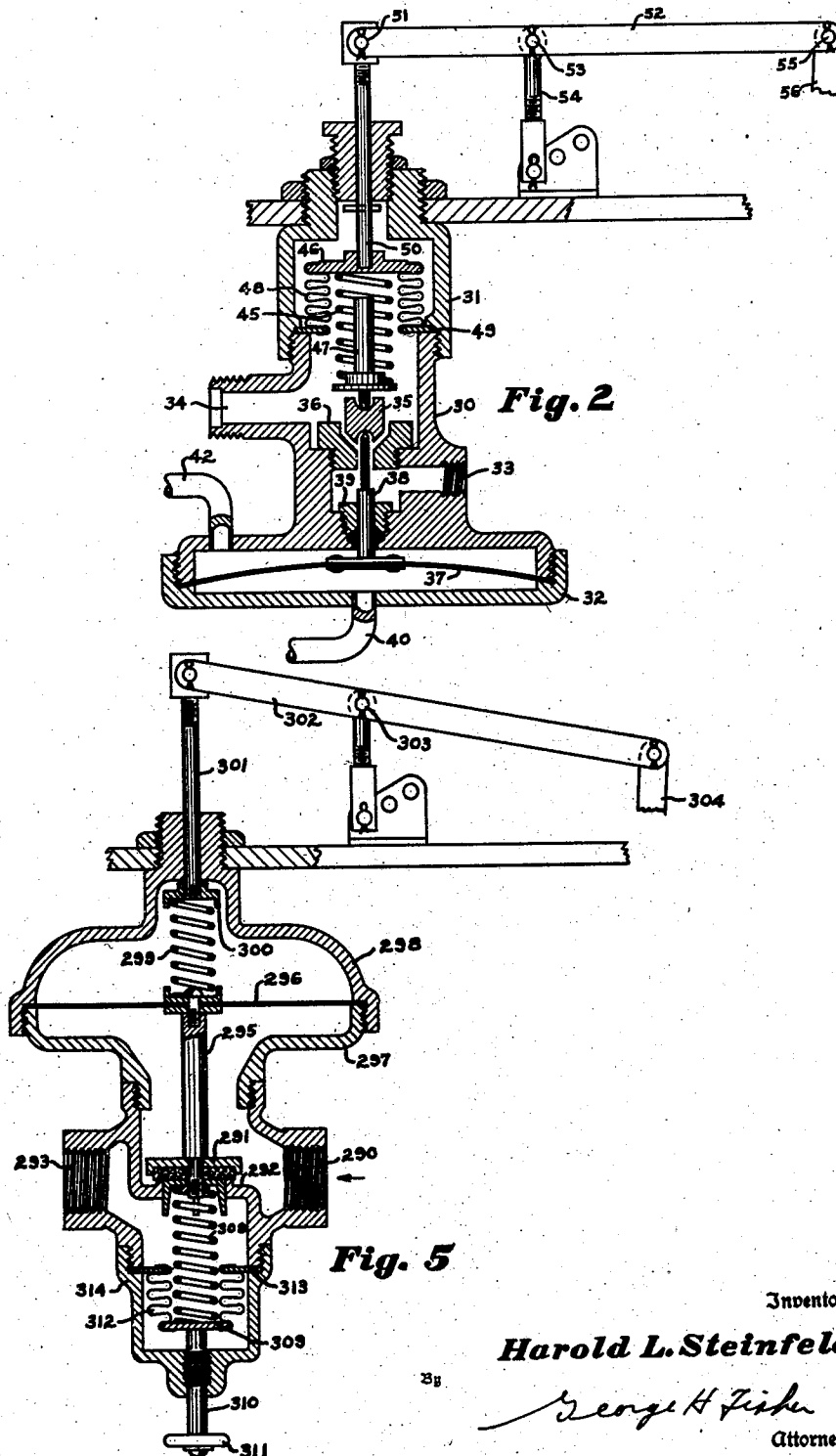
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5 Sheets-Sheet 2



Inventor

Harold L. Steinfeld

George H. Fisher

Attorney

Aug. 11, 1942.

H. L. STEINFELD

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AIR CONDITIONING SYSTEM

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5 Sheets-Sheet 3

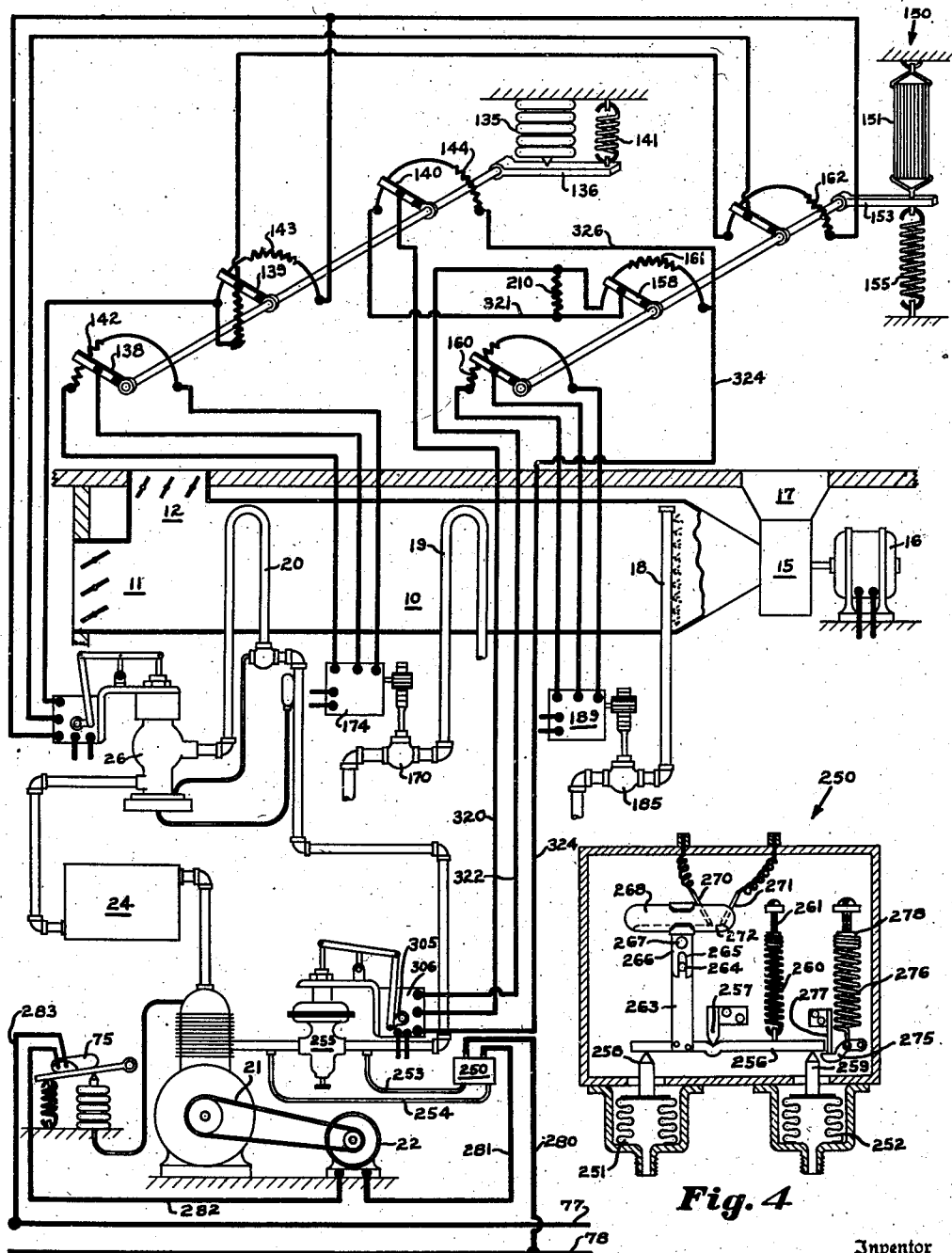


Fig. 3

Fig. 4

Inventor

Harold L. Steinfeld

By

George H. Fisher

Attorney

Aug. 11, 1942.

H. L. STEINFELD
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5 Sheets-Sheet 4

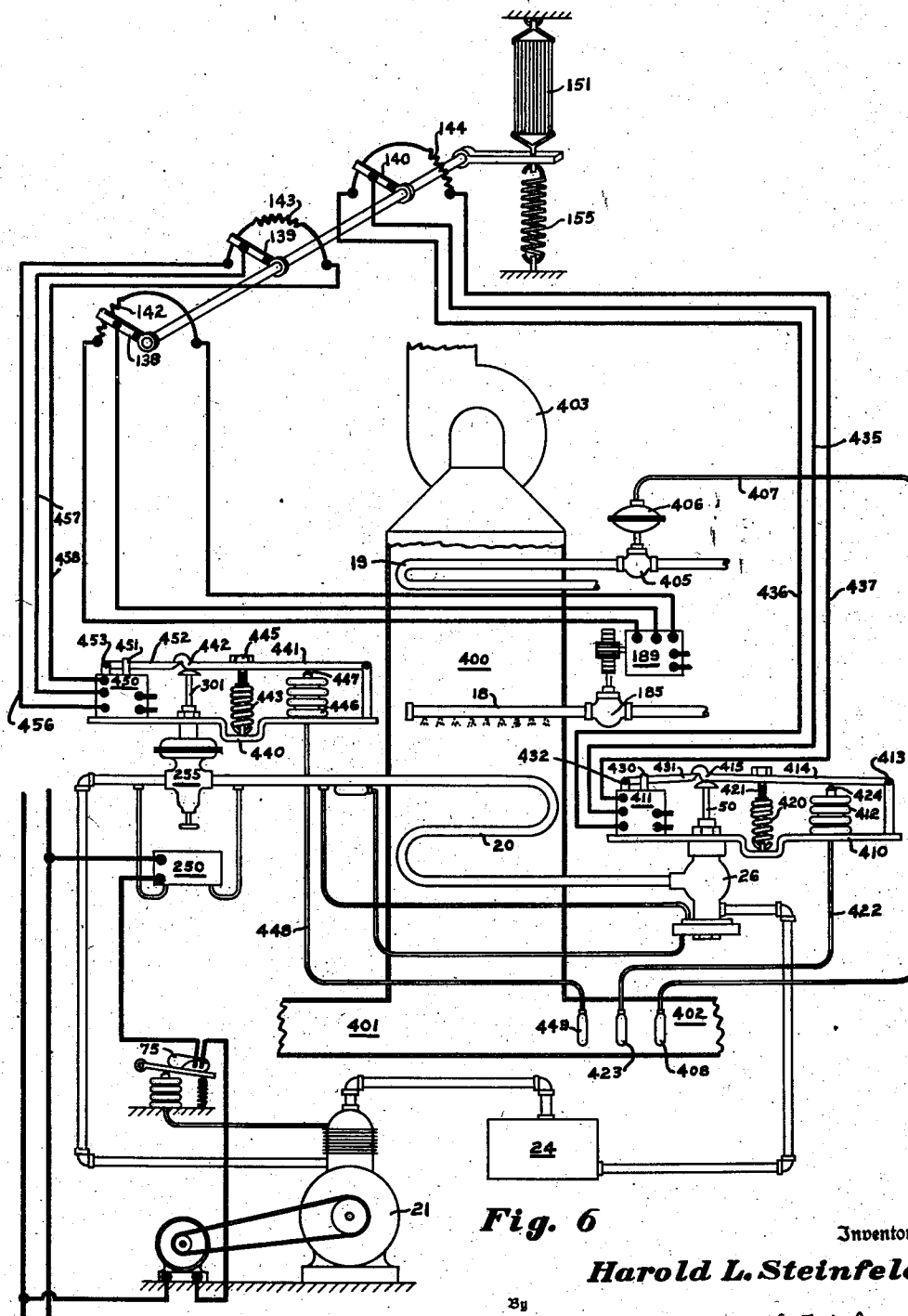


Fig. 6

Inventor

Harold L. Steinfeld

By

George H. Fisher

Attorney

Aug. 11, 1942.

H. L. STEINFELD

2,292,486

AIR CONDITIONING SYSTEM

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5 Sheets-Sheet 5

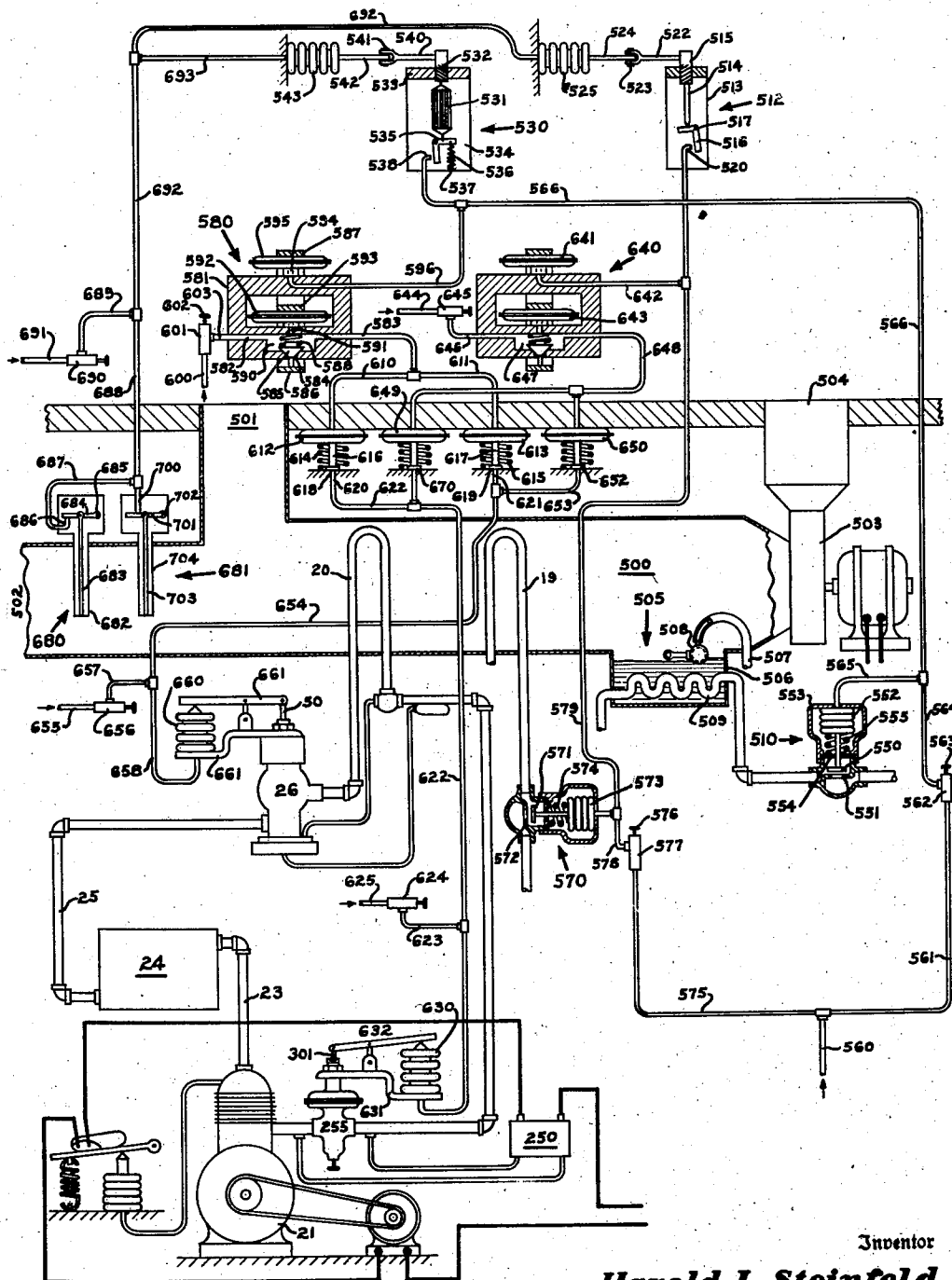


Fig. 7

Inventor
Harold L. Steinfeld

George H. Fisher
Attorney

UNITED STATES PATENT OFFICE

2,292,486

AIR CONDITIONING SYSTEM

Harold L. Steinfeld, East Orange, N. J., assignor
to Minneapolis-Honeywell Regulator Company,
Minneapolis, Minn., a corporation of Delaware

Application February 7, 1938, Serial No. 189,073

23 Claims. (Cl. 257-3)

This invention relates to an air conditioning system and more particularly to a system of the type wherein the air within a space is heated, cooled, humidified or dehumidified according to requirements of said space.

One of the objects of my invention is the provision of an improved control system for an air conditioning system of the above described type.

Another object of my invention is the provision of improved control means for a refrigeration system.

More specifically, it is an object of my invention to provide a refrigeration system wherein the temperature of the evaporator is controlled in accordance with the humidity of the space being conditioned, and the effective area of the evaporator is controlled in accordance with the temperature of the space being cooled, with improved control means for controlling the temperature and effective area of the evaporator.

Another object is the provision of a novel control means for controlling the operation of a thermostatic expansion valve used in a refrigeration system.

Another object is the provision of a novel control means for controlling the operation of the compressor of a refrigeration system.

Other objects will become apparent upon a study of the specification, claims and appended drawings wherein like reference characters represent like parts in the various views, and in which

Figure 1 is a schematic view of one form of an air conditioning system embodying my invention;

Figure 2 is a cross sectional view of the thermostatic expansion valve illustrated in Figure 1;

Figure 3 is a schematic view of a modification of the system illustrated in Figure 1;

Figure 4 is a cross sectional view of the differential pressure controller illustrated in Figure 3;

Figure 5 is a cross sectional view of the back pressure controller illustrated in Figure 3;

Figure 6 is a schematic view of another form of air conditioning system embodying my invention; and

Figure 7 is a schematic view of the air conditioning system embodying my invention utilizing pneumatic controls.

In accordance with my invention, a year around air conditioning system is illustrated wherein provision is made for heating, cooling, humidifying and dehumidifying according to the requirements of the space being conditioned.

Heat and humidity are supplied to the space when the temperature and the humidity in the space are below predetermined values. An evaporator of a refrigeration system is provided for cooling or dehumidifying the air to the space being conditioned when the requirements of the space are such as to require cooling or dehumidifying. The same temperature controller that controls the operation of the heating means controls the superheat at the evaporator outlet to vary the same in accordance with the temperature of the space so that the effective cooling area of the coil is varied according to the amount of cooling required and the temperature of the cooling coil is controlled by the same controller that controls the operation of the humidifying means. The temperature controller also controls the temperature of the coil if the temperature in the space attains an excessively high value and the humidity controller controls the effective cooling area of the coil if the humidity in the space attains a predetermined value. In other words, the temperature controller normally controls the effective cooling area of the evaporator coil but the humidity controller acts as a limit control when the humidity becomes excessive to control the effective area irrespective of the temperature controller, and the humidity controller normally controls the temperature of the evaporator coil but the temperature controller acts as a limit control to also control the temperature of the coil irrespective of the humidity controller when the temperature in the space attains an excessive value.

Referring more particularly to Figure 1, an air conditioning chamber is represented generally by the reference character 10, this chamber being provided with a fresh air inlet 11 and a return air inlet 12, the inlets 11 and 12 being controlled by dampers 13 and 14 which may be manually or automatically controlled in any suitable manner. A fan 15 driven by a motor 16 draws air through the chamber 10 and discharges it through an outlet 17 into the space being conditioned. Mounted within the chamber 10 is a spray 18 for supplying humidity to the space being conditioned, a heating coil 19, and an evaporator coil 20 of a refrigeration system.

This refrigeration system may include a compressor 21 driven by means of a motor 22, a pipe 23 leading from the high pressure side of the compressor to a condenser 24. A pipe 25 connects the outlet of the condenser to an expansion valve 26 through which the condensed refrigerant is expanded and then flows into the

evaporator 20 wherein the expanded refrigerant picks up heat from the air surrounding the coil and becomes evaporated and then flows through a pipe 27 back to the inlet of the compressor.

The details of the expansion valve are illustrated in Figure 2 and this valve may include a casing made up of sections 30, 31, and 32. The section 30 includes an inlet 33 and an outlet 34, communication between the inlet and outlet being controlled by a valve comprising a valve member 35 and a valve seat 36. The operating means for the valve member 35 includes a diaphragm 37 which may be clamped between the casing sections 30 and 32 as indicated in the drawing, diaphragm 37 being provided with a plunger 38 which extends into the casing section 30 through a packed joint 39. A capillary tube 40 connects the space beneath the diaphragm 37 with a bulb 41 illustrated in Figure 1, this bulb and tube being filled with a volatile fluid and the bulb being mounted in intimate contact with the evaporator outlet so that the pressure beneath the diaphragm corresponds to the temperature of the refrigerant leaving the evaporator. The space above the diaphragm 37 is connected by means of a small pipe 42 to the evaporator outlet so that pressure in the space above the diaphragm corresponds to the pressure of the refrigerant leaving the evaporator. The valve is normally biased toward closed position by means of a spring 45 acting between a plate 46 and a plunger 47 which bears against the top of valve element 35. A sealing bellows 48 is connected to the plate 46 and to an annular plate 49 which may be clamped between the casing sections 30 and 31 or may be otherwise suitably connected to the casing section 30 to prevent the leakage of refrigerant from the casing section 30. Provision is made for adjusting the position of the plate 46 and this includes a push rod 50 bearing against the top of the plate 46 and being seated within a recess therein, the upper end of this rod being pivotally connected at 51 to one end of a lever 52 in turn pivoted at 53 to an adjustable fulcrum 54. The opposite end of lever 52 is connected at 55 to an arm 56 operatively connected to a motor whereby the position of the plate 46 may be suitably adjusted in response to the conditions existing in the space as will be hereinafter set forth.

The position of the valve element 35 depends upon the force exerted by the spring 45, the pressure existing at the evaporator outlet and the temperature existing at the evaporator outlet and it is therefore apparent that the valve responds to the superheat at the evaporator outlet, the amount of superheat required to open the valve being dependent upon the force exerted by the spring 45, or in other words, upon the adjustment of lever 52. However, if plate 46 is moved downwardly sufficiently, it will engage plunger 47 and positively hold the valve closed, irrespective of the superheat existing at the evaporator outlet.

The operation of the compressor 21 is controlled by a relay generally designated by the reference character 60, this relay comprising coils 61 and 62, an armature 63, switch arms 64 and 65 operated by the armature 63 and contacts 66 and 67 cooperating with the switch arms 64 and 65. Upon energization of the relay coil 62 the arms 64 and 65 are moved by the armature 63 into engagement with the contacts 66 and 67 and the compressor 21 is placed into operation. Upon deenergization of coil 62, which

is caused, as will be later described, by the energization of coil 61, arms 64 and 65 are moved out of engagement with contacts 66 and 67 into the positions illustrated.

The outlet of the compressor is connected by a tube 70 to a bellows 71 which operates an arm 72 pivoted at 73 and held against the top of a bellows by means of spring 74. A mercury switch 75 is carried by the lever 72 and when the pressure at the compressor outlet reaches an excessive value the pressure within the bellows 71 causes expansion of this bellows to tilt lever 72 and switch 75 to a circuit opening position as will be readily apparent. Lines 77 and 78 connected to a suitable source of power (not shown) are provided for supplying power to the compressor motor 22. It will now be apparent that upon energization of relay coil 62, the compressor motor 22 will be energized by means of the following circuit: from the line 77 through conductor 80, arm 64, contact 66, conductor 81 through the motor 22, conductor 82, mercury switch 75 and conductor 83 to the line 78. The compressor will continue to run until coil 62 becomes deenergized or the circuit through the switch 75 is broken by reason of an excessive pressure on the high pressure side of the compressor.

Communicating with the suction side of the compressor by means of a tube 85 is a bellows 86 which operates a lever 87 pivoted at 88 and biased against the top of the bellows by means of a spring 89'. Lever 87 includes arms 89 and 90 which are arranged to sweep over resistance 91 and center tapped resistance 92 in response to variations in suction pressure at the compressor. As the suction pressure drops, arm 89 moves to the left and arm 90 moves upwardly, and as the suction pressure rises, the arms move in the reverse directions.

The energization of relay coils 61 and 62 is controlled by means of a relay 95 which includes opposed balanced coils 96 and 97, an armature 98 connected to an arm 99 cooperating with contacts 100 and 101. Energization of coil 97 to a greater extent than coil 96 causes movement of armature 98 to the right whereupon arm 99 moves into engagement with contact 101. When the coils are equally energized, the armature 98 and arm 99 move to a mid-position, and upon energization of coil 96 to a greater extent than coil 97, the armature moves to the left, moving arm 99 into engagement with contact 100. Power may be supplied to the relays 60 and 95 by means of a transformer 104 including a primary 105 connected to the lines 77 and 78, and a low tension secondary 106. When the relay coil 97 becomes more highly energized than the relay coil 96 to move the switch arm 99 into engagement with the contact 101, the coil 62 of relay 60 becomes energized through the following circuit: from one side of the transformer secondary 106 through conductors 108, 109, 110, contact 101, arm 99, conductors 111, 112, coil 62 and conductors 113, 114, and 115 to the other side of secondary 106. As previously stated the energization of relay coil 62 causes engagement of the switch arms 64 and 65 with their respective contacts, the engagement of arm 64 with contact 66 causing operation of the compressor motor 22. The engagement of arm 65 with contact 67 closes a holding or maintaining circuit for the relay coil 62, which circuit is independent of the engagement of arm 99 with the contact 101, this circuit

being as follows: from the transformer secondary 106 through conductors 108, 116, contact 67, arm 65, conductor 112, relay coil 62, conductors 113, 114, 115 to the other side of the secondary 106. The relay coil 62 will therefore remain energized until the arm 99 of relay 95 is moved into engagement with contact 100 which will take place when the relay coil 96 of relay 95 becomes more highly energized than coil 97. When this happens, the relay coil 61 of relay 60 becomes energized through the following circuit: from the transformer secondary 106 through conductors 108, 116, contact 67, arm 65, conductor 111, arm 99, contact 100, conductor 118, relay coil 61 and conductors 119, 114, and 115 to the other side of the secondary. Coil 61 opposes the effect of the relay coil 62 so that the armature 63 is not attracted by the relay coils and the arms 64 and 65 move out of engagement with the contacts 66 and 67 whereupon the maintaining circuit for the coil 62 is interrupted and the circuit through the coil 61 is likewise interrupted since this circuit includes the maintaining arm 65 and contact 67.

It will accordingly be seen that the operation of the compressor is controlled by the relay 95. This relay is controlled by the potentiometer comprising resistance 91 and arm 89, which is in turn operated by the pressure at the suction side of the compressor, as follows: the resistance 91 is connected to the extremities of the relay coils 96 and 97, the left end of resistance 91 being connected by the conductors 122, 123, and 124 to the end of coil 97 and the right end of resistance 91 being connected by conductors 125 and 126 to the end of coil 96. The arm 89 is connected to the junction of the coils 96 and 97 by means of conductors 128, 129, the center tapped resistance 92 and the slider 90. It will therefore be seen that the resistance 91 and the arm 89 are connected in parallel with the coils 96 and 97 and that the energization of these coils will depend upon the position of arm 89 with respect to the resistance 91 and will therefore depend upon the pressure existing at the suction side of the compressor. Movement of the arm 89 to the left of the resistance 91 increases the flow of current through the coil 96 whereas movement of the arm 89 to the right increases the flow of current through the coil 97. It will therefore be apparent that as the suction pressure decreases and the arm 89 moves to the left, that the coil 96 will become more highly energized than the coil 97, causing movement of armature 98 and arm 99 to the position which causes the energization of relay coil 61 and deenergization of relay coil 62 stopping the operation of the compressor. With the compressor at rest the pressure on the suction side of the compressor will gradually increase until the arm 89 has moved sufficiently far to the right over resistance 91 to cause the coil 97 to be more highly energized than coil 96 which in turn causes the energization of relay coil 62 of relay 60 and therefore the operation of the compressor. It will therefore be seen that the operation of the compressor is controlled by the suction pressure to maintain the suction pressure within desired limits.

Mounted within the space being conditioned is a temperature responsive device consisting of a bellows 135 containing a volatile fluid and acting against an arm 133 connected to a shaft 137 carrying contact arms 138, 139, and 140 suitably insulated therefrom. Arm 136 is held against the bellows 135 by means of a spring 141. Arms 138, 139, and 140 are arranged to travel over resistances 142, 143, and 144, respectively, these resistances being so arranged that they are engaged sequentially by the respective arms. In other words, upon a progressive increase in temperature arm 138 moves across resistance 142 and after it reaches the end of said resistance the arm 139 starts moving across resistance 143 and subsequently the arm 140 starts to move across resistance 144 after the arm 139 has left resistance 143. Upon a decrease in temperature the reverse operation takes place.

Also mounted in the space to be conditioned is a humidity responsive device 150 which may be of any suitable construction but is illustrated as comprising a plurality of hygroscopic elements such as hairs fixed at their upper ends to a support 152 and connected at their lower ends to an arm 153 fixedly mounted on a shaft 154. Arm 153 is biased downwardly by means of a spring 155 and tends to cause the elongation of the hygroscopic elements 151 as the humidity within the space increases. Shaft 154 carries arms 157, 158, and 159 arranged to sweep across resistances 160, 161, and 162 which are arranged with respect to the arms in the same way as the resistances in the temperature responsive control device. In response to a rise in temperature the arms of the temperature responsive device move clockwise and likewise in response to an increase in humidity, the arms of the humidity responsive device move clockwise, the arms moving in the reverse direction in response to a decrease in temperature or humidity in the space being conditioned.

The arm 138 of the temperature controller controls the operation of the heating coil 19. The flow of a heating medium such as steam through this coil is controlled by a valve 170 which valve may include a valve stem 171 to which is connected a rack 172 operated by a pinion 173 of a motor 174. Leads 175 and 176 supply power to the motor from a suitable power source. This motor is of the proportioning type and may be of the form shown in the patent to D. G. Taylor 2,028,110 issued January 14, 1936. Such a motor includes opposed relay coils such as the relay coils 96 and 97, the energization of one coil causing rotation of the motor in one direction and the energization of the other coil causing rotation of the motor in the opposite direction. Resistance 142 is connected by means of conductors 180 and 181 to the extremities of these coils and the arm 138 is connected by means of a conductor 182 to the junction of the relay coils, the extremities of the coils also being connected to the leads 175 and 176. It will therefore be apparent that the movement of arm 138 over the resistance 142 will control the energization of the relay coils and cause the motor to rotate in one direction or the other. As illustrated in the Taylor patent aforementioned the motor also includes a balancing potentiometer which is operated when the motor rotates, this balancing potentiometer being connected to the relay coils in parallel with the potentiometer 142 and operated in a direction to offset the effect of potentiometer 142 so that the motor will rotate in one direction or the other an amount corresponding to the movement of arm 138 over the resistance 142 whereupon the effect of this resistance is counter-acted by the balancing potentiometer and the motor will come to rest. The valve 170 is thus operated by the temperature controller to open or close the valve in ac-

cordance with temperature in the space, or in other words, in accordance with the position of arm 138 with respect to the resistance 142. When the temperature in the space reaches such a value that the arm 138 is at the upper extremity of resistance 142 the valve will be fully closed and no heat will be supplied to the coil 19. When the arm 138 is at the lower extremity of resistance 142 the valve will be in wide open position and the coil 19 will be operated at maximum capacity.

Arm 157 operated by the humidity responsive device controls the operation of the spray 18 for supplying humidity to the air being conditioned. The spray 18 is controlled by a valve 185 which valve may include a valve stem 186 connected at its upper end to a rack 187 which is operated by a pinion 188 driven by a motor 189, said motor being similar in construction to the motor 174. Conductors 190 and 191 connect the extremities of resistance 160 to the extremities of the relay coils of said motor, the junction of these coils being connected by means of the conductor 192 to the arm 157. This motor will operate the valve to supply a maximum amount of moisture to the air when the humidity is at a minimum value and the arm 157 is at the lower extremity of resistance 160. When the humidity attains a high enough value so that arm 157 is at the upper end of resistance 160 the motor is rotated to a position wherein the valve 185 is fully closed and no moisture is being supplied by the spray 18 to the air being conditioned.

The relay 95 controlling the operation of the compressor which relay is controlled by the controller 89, as previously set forth, is also controlled by the arm 158 of the humidity controller so that when the humidity in the space reaches a high enough value so that the arm 158 starts to move across resistance 161, this arm and resistance exert a controlling function over the relay 95. The arm 158 is connected to the junction of the coils 96 and 97 of the relay 95 by means of the conductor 128, conductor 200, a resistance element 201, a conductor 202, the arm 140 of the temperature controller and the conductor 203. The end of relay coil 97 is connected by means of conductors 124, 123, 205, and 206 to the left end of the resistance 161 and the relay coil 96 is connected by means of conductors 126, 207, and 208 to the right end of the resistance 161. It is therefore seen that the potentiometer 161 is connected to the relay coils in parallel with the potentiometer 91, the arm of the potentiometer 161 being connected to the junction of the coils through the arm 140 of the potentiometer 144. By reason of the provision of the resistance 201 in the circuit to the arm 158 of potentiometer 161 the effect of this potentiometer is less than the effect of potentiometer 91 on the relay 95. In other words, movement of arm 158 from the left end to the right end of resistance 161 will be balanced by the movement of arm 89 over resistance 91 through a relatively short distance. With the arm 158 in the position illustrated it will be noted that the coil 96 of the relay 95 is energized more highly than the coil 97 as far as this potentiometer is concerned since the only resistance in the circuit through the coil 96 is the resistance 201. As the humidity within the space starts to increase and the arm 158 starts to move over the resistance 161 the resistance in series with the coil 96 increases whereas the resistance in series with the coil 97 decreases until the coil 97 becomes the more highly energized coil and arma-

ture 98 moves to the right starting the compressor as heretofore explained. The operation of the compressor forces refrigerant through the expansion valve 26 and the evaporator 20, this flow being controlled by the valve 26 and the compressor will continue to operate until the arm 89 has moved to the left of resistance 91 a sufficient amount to cause coil 96 of relay 95 to be more highly energized than coil 97 whereupon the compressor will come to rest. As stated before it takes a relatively small movement of the arm 89 of resistance 91 to counter-act the effect of a large movement of arm 158 over the resistance 161 and the control range of the arm 89 on the resistance 91 depends upon the position of arm 158 with respect to the resistance 161. As the arm 158 moves farther to the right over resistance 161 indicating a higher humidity in the space being conditioned the control range of the potentiometer 91 is shifted to the left so that lower suction pressures will be maintained by the compressor and therefore a lower coil temperature at the evaporator 20 will be maintained thus increasing the dehumidifying effect of the coil 20 since this effect is dependent primarily upon the coil temperature. The provision of resistance 92 in series with the arm 89 and the junction of the relay coils 96 and 97 insures that the control range of the potentiometer 91 will always be the same length regardless of whether the control range is at the center of the resistance or at either end thereof.

It will be noted that the right end of resistance 144 is connected to the right end of resistance 161 by means of conductor 208 and these ends of resistances are connected by means of conductors 207 and 126 to the left end of the relay coil 96. The arm 140 which cooperates with resistance 144 is connected by means of the wire 202, resistance 201, and conductor 200 to the junction of the relay coils 96 and 97. Since the controller 140 is intended to act only as a limit controller and to have no control function whatever over the relay 95 unless the temperature reaches such a high value that arm 140 moves over the resistance 144, a resistance 210 is connected between the conductor 203 which connects to the left of resistance 144 and to the conductor 205 which connects to the extremity of coil 97. This resistance 210 is of the same resistance value as resistance 144 so that the resistance 144 has no effect whatever upon the relay 95 when the arm 140 is positioned as shown at the extreme left end of resistance 144. Should the temperature in the space reach such a high value that the arm 140 starts moving across resistance 144, this controller will increase the energization of coil 97 and decrease the energization of coil 96 and move the control range of the controller 89 further to the left whereupon a lower suction pressure will be maintained by the compressor and a lower coil temperature will be maintained at the evaporator 20. The controller 140 will therefore control the compressor to maintain lower suction pressures whenever the temperature in the space reaches a sufficiently high value even if the humidity is so low that the arm 158 is at the left of resistance 161, the controller 140 acting as a limit control.

It will therefore be seen that the temperature maintained at the evaporator 20 is controlled primarily by the humidity responsive device, the temperature responsive device under normal conditions having no effect on the temperature being maintained by the coil but under extremely high temperature conditions this temperature respon-

sive device will exert its effect on the coil temperature to lower the same.

Referring now to the expansion valve 26, the tension of the spring 45 is controlled by the motor 215 to which the arm 216 is connected and by means of the link 56 connected to the lever 52 whereby the tension of the spring is varied in accordance with the position of arm 216. Rotation of arm 216 in a clockwise direction causes the rod 50 to be moved upwardly and thus the force exerted by the spring 45 on the valve 35 is decreased so that a lesser degree of superheat at the evaporator outlet is required to open the valve. As the superheat maintained at the evaporator outlet decreases, the effective cooling area of the coil 20 increases. Accordingly, the effective cooling area is increased as the arm 216 of motor 215 moves in a clockwise direction and the effective cooling area is decreased as this arm moves in a counter-clockwise direction. Should the arm move far enough in this direction, plate 46 will engage plunger 47 and positively hold the valve closed.

The motor 215 may be of the same type as motor 174 and includes opposed relay coils similar to the coils 96 and 97. The junction of these coils is connected by means of a conductor 217, the arm 159 of the humidity controller, conductor 218 to the arm 139 of the temperature responsive device. The end of one of the coils is connected by means of a conductor 220 to the left end of resistance 143 and the end of the other relay coil is connected by means of a conductor 221 and conductor 222 to the right end of resistance 143. When the humidity is not excessively high so that arm 159 has not started to move over resistance 162, the motor 215 will be controlled directly by the controller 139 and the degree of rotation of arm 216 will be in direct proportion to the extent of movement of arm 139 over resistance 143. Thus as the temperature in the space starts to rise and the arm 139 moves to a certain point on resistance 143, the motor 215 will operate until the effect of the potentiometer 143 is counter-balanced by the effect of the balancing potentiometer within the motor 215, the arm 216 coming to rest in a new position, having moved clockwise from that illustrated, thus decreasing the tension of spring 45 within the expansion valve 26 and thus increasing the effective cooling surface of the coil 20. In other words the tension of the spring 45 of the expansion valve is adjusted in direct accordance with the position of the arm 139 of the temperature responsive controller. It is therefore seen that the main control over the effective cooling area of the evaporator is by the temperature responsive device to increase the effective cooling area as the temperature increases and vice versa.

The resistance 162 of the humidity responsive device acts as a limit control and causes the operation of motor 215 in a direction to move arm 216 clockwise if the humidity in the space reaches an excessively high value so that arm 159 moves over resistance 162 regardless of the temperature being maintained within the space. Resistance 162 is connected to the resistance 143 and the motor 215 in the same manner as resistance 144 is connected to the relay 95. Conductors 222 and 223 connect the right portions of the resistances 143 and 162, the arm 159 of the controller 162 being connected directly to the junction of the relay coils as aforesaid. In order that the resistance 162 will have no effect on the motor when the arm 159 is at the left end of the resistance, a resistance 235 having a resistance 75

value equal to that of the resistance 162 is connected between the conductors 217 and 220, resistance 162 being connected between the conductors 217 and 221 when the arm 159 is off the resistance 162.

Under normal conditions therefore the control of the effective cooling area of evaporator 20 is by means of the temperature responsive device, the humidity responsive device having no effect whatever unless the humidity in the space reaches an excessive value whereupon the arm 159 is caused to move over the resistance 162 and cause the operation of motor 215 to relieve the tension of the spring within the expansion valve and increase the effective cooling area of the evaporator.

In the system of Figure 1, whenever the humidity within the space is below a desired value the valve 185 will be controlled by the humidity responsive device 150 to supply moisture to the space being conditioned. When the humidity rises to a high enough value, valve 185 will be moved to closed position and prevent the supply of moisture to the air. If the humidity should rise above a desired value, whereupon the arm 158 starts to move across the resistance 161, the suction pressure maintained by the compressor will be lowered and the compressor will operate to maintain the temperature at the evaporator 20 progressively lower as the humidity in the space increases. The heating coil 19 is operated by the temperature controller 135 to supply heat to the space in accordance with the temperature therein, the valve 170 being closed when the temperature reaches a desired value, preventing the supply of heating medium to the coil 19. If the temperature increases above the desired value, the arm 139 will start to move over the resistance 143 and adjust the spring within the expansion valve 26 to increase the effective cooling area of the evaporator 20. In the normal operation of the system therefore the temperature controller controls the heating coil 19 and the effective area of the evaporator 20 whereas the humidity controller controls the spray 18 and the temperature of the evaporator 20. Should the humidity increase to an excessive amount while the temperature in the space is at or below the desired value, the humidity controller will, in addition to controlling the temperature of the evaporator 20, also control the effective cooling area thereof. On the other hand if the humidity is at or below the desired value and the temperature should reach an excessively high value the temperature controller will lower the temperature of the evaporator as well as increasing the effective cooling area thereof. Thus by means of a single humidity responsive device and a single temperature responsive device the temperature and humidity of a space being conditioned is very effectively controlled during both the heating and cooling seasons.

Referring now to Figure 3, an air conditioning chamber having heating, humidifying, and cooling coils arranged in the same manner as in Figure 1 is illustrated. The heating coil 19 and humidifying spray 18 may be controlled in exactly the same manner as in Figure 1 and further description thereof is unnecessary. Likewise the effective cooling area of the evaporator 20 is controlled primarily by the temperature in the space but may also be increased if the humidity in the space reaches an excessive value, the means for controlling this effective area being identical to that of Figure 1. The means for controlling the

temperature of the coil are however different from that shown in Figure 1.

The operation of the compressor is controlled in this figure by a differential pressure controller indicated generally by the reference character 250 and illustrated in detail in Figure 4. This controller comprises a pair of bellows 251 and 252 closed at their upper ends and connected by means of pipes 253 and 254, respectively, to the high and low pressure sides of a back pressure valve 255. A lever 256 pivoted by means of a knife edge pivot 257 has its ends in engagement with plungers 258 and 259 connected to the upper ends of the bellows 251 and 252. A spring 260 is connected to the right of pivot 257, to the lever 256, the upper end of this spring being connected to an adjusting screw 261 whereby the tension of this spring may be varied. This spring biases the lever 256 to rotate about the pivot 257 in a counter-clockwise direction. Extending upwardly from the lever 256 and rigidly secured thereto to the left of pivot 257 is an arm 263 carrying a pin 264 which is received in a slot 265 of an arm 266 pivoted at 267, the arm 266 carrying a mercury switch 268. As the pressure differential within the bellows 251 and 252 increases the lever 256 is caused to move about the pivot 257 in a clockwise direction moving the pin 264 to the right and causing movement of arm 266 about the pivot 267 in a direction to tilt the mercury switch 268 to the left. Mercury switch 268 includes contacts 270 and 271 and a mercury element 272 and it will be readily apparent that as the pressure differential between the bellows reaches a high enough value the mercury switch will be tilted to a position wherein a circuit through contacts 270 and 271 by the mercury element 272 will be interrupted.

Mounted in the path of downward movement of the right end of lever 256 is a pivoted arm 275 held by means of a spring 276 against a stop 277. The upper end of spring 276 is connected to an adjusting screw 278 whereby the tension of the spring may be readily adjusted. The force exerted by the spring 276 is added to the force exerted by the spring 260 and as the pressure differential between the bellows 251 and 252 starts to increase the right end of arm 256 will move downward rather rapidly until it engages the arm 275. In order for the switch 268 to tilt far enough to break the circuit through contacts 270 and 271 the arm 256 has to move downwardly far enough to move the arm 275 away from the stop 277. This movement is resisted by the spring 276 and the lever 256 will remain in engagement with the arm 275 until the pressure differential has increased a considerable amount sufficient to stretch the spring 276 whereupon the switch 260 will tilt far enough to break the circuit between contacts 270 and 271. As the pressure differential starts to decrease the spring 276 will quickly move the arm 275 against the stop 277 carrying the lever 256 therewith. The circuit through the contacts 270 and 271 is still interrupted at this time and will remain interrupted until the pressure differential has dropped sufficient to permit the spring 260 to move the lever 256 upwardly still farther. Since it takes a relatively small pressure differential to overcome the force of the spring 260 the pressure differential will have to drop considerably after the spring 276 has moved the arm 275 into engagement with stop 277. Since this action of the arm 275 will take place when the pressure differential has first started to drop, the circuit through contacts 270 and 271 will not

be remade by the mercury 272 until the pressure differential has dropped sufficiently for the spring 260 to move the arm 256 upwardly. Whereas the inherent differential of the mercury switch is relatively small, the use of the spring 276 permits a wide differential in the operating range of this controller so that the circuit through the mercury switch will not be broken until the differential reaches a predetermined amount and will not be remade until the differential has dropped to a relatively small amount.

The compressor is connected to the lines 77 and 78 through the differential pressure controller 250 and the high pressure cutout 75 through the following circuit: from the line 78, conductor 280, the mercury switch 268, conductor 281, compressor motor 22, conductor 282, the mercury switch 75 of the high pressure cutout and the conductor 283 to the line 77. It is accordingly seen that the compressor will be operated whenever the pressure differential across the valve 255 drops to a predetermined low value and stops whenever the pressure differential increases to a predetermined high value.

The back pressure valve 255 is illustrated in detail in Figure 5, and this valve includes an inlet 290, a valve member 291 cooperating with a valve seat 292 and an outlet 293. The valve is provided with a valve stem 295 extending vertically upwardly therefrom, the valve stem 295 being suitably connected to a diaphragm 296. Diaphragm 296 may be clamped between sections 297 and 298 of the valve body and a spring 299 biases the diaphragm 296 downwardly and the valve 291 to closed position. The upper end of the spring is received in a spring retainer 300 connected to the lower end of a rod 301 pivotally connected to the end of a lever 302 having an adjustable fulcrum 303. The opposite end of the lever 302 is pivotally connected to a link 304 by which the lever 302 is connected to the arm 305 of a motor 306, whereby the position of the lever 302 and the force exerted by spring 299 may be varied. A second spring 308 bears against the underside of the valve 291, the opposite end of this spring bearing against a plate 309 supported by an adjusting screw 310 having a suitable operating handle 311. Sealing bellows 312 is connected to the plate 309 and to an annular plate 313 held between the main valve body and the section 314 whereby the discharge side of the valve is effectively sealed from the atmosphere. The spring 308 is provided to vary the effect of the spring 299 on the valve for any given position of the spring retainer 300.

The operation of this valve will be readily apparent. As the pressure of the refrigerant entering the inlet 290 reaches a value sufficiently high to overcome the effect of spring 299, the pressure will exert an upward force on the diaphragm 296 whereupon the valve will be lifted from its seat, thus permitting the passage of refrigerant therethrough to the compressor. By adjusting the force exerted by the spring 299 the back pressure necessary to open the valve may be readily adjusted.

The temperature of the refrigerant flowing through the evaporator 20 will vary in accordance with the back pressure. As the back pressure is decreased the refrigerant will pass through the evaporator at a lower pressure and a lower coil temperature will be maintained whereas upon an increase in the back pressure the coil temperature will be increased. Therefore by varying the force exerted by the spring

299 the temperature within the coil 20 is effectively controlled so as to control the dehumidifying effect of this coil.

The motor 306 is provided for controlling the tension of the spring 299, this motor being a proportioning motor similar to the proportioning motors of Figure 1. The junction of the relay coils of this motor is connected by means of a conductor 320, the arm 140 of the temperature controller, conductor 321 to the arm 158 of the humidity controller. The end of one of the relay coils is connected by means of conductor 322 to the left end of resistance 161 and the other end of this resistance is connected by the conductor 324 to the extremity of the other relay coil so that the motor is operated in accordance with the position of arm 158 on the resistance 161 and the spring 299 of the back pressure valve is adjusted to exert less force on the valve as the humidity in the space being conditioned increases whereby the temperature of the refrigerant flowing through the evaporator 20 will decrease in accordance with the increasing humidity in the space. Resistance 144 of the temperature controller is connected to the motor 306 in the same manner as in Figure 1 to act as a limit control, the right end of this resistance being connected by means of conductor 326 to the right end of resistance 161 and the resistance 210 being connected between the conductors 322 and 320 to offset the effect of resistance 144 which is connected when the arm 140 is at the left of resistance between the conductors 320 and 324 so that the resistance 144 has no effect on the motor 306 or the temperature of the refrigerant flowing through the evaporator unless the temperature in the space attains an excessively high value. Should the temperature in the space reach a high enough value so that the arm 140 moves over the resistance 144, the motor 306 will operate to decrease the effect of spring 299 regardless of the humidity in the space, to thereby lower the temperature of the coil 20.

The use of the back pressure controller forms a very effective method of controlling the temperature of the evaporator according to the demand upon the evaporator since the cooling effect of the evaporator will vary in accordance with the pressure of the refrigerant therein. By using the differential pressure controller for operating the compressor, the back pressure on the compressor will be maintained at a maximum value since the compressor operates only when the differential across the back pressure controller is at a minimum value, so that the compressor operates at maximum efficiency for any pressure maintained within the evaporator. In other words, the back pressure on the compressor will vary in accordance with the pressure maintained in the evaporator.

The cycle of operation of the system in this figure is precisely the same as that of Figure 1, the only difference being in the means for controlling the operation of the compressor and the means for controlling the temperature of the evaporator coil.

In the system illustrated in Figure 6, the same cycle and method of operation as that illustrated in Figure 3 is employed in connection with a unit air conditioner utilizing self contained temperature responsive elements on the various controlled devices.

An air conditioning chamber is represented by the reference character 400, this chamber including a fresh air inlet 401 and a return air

inlet 402. Mounted within the chamber 400 are the spray pipe 18, the heating coil 19, and the cooling or evaporator coil 20. A fan 403 is provided for drawing air through the chamber 400 and supplying the conditioned air to the space which is to be conditioned.

A valve 405 is positioned in the steam line to the coil 19 for controlling the supply of steam to this coil. This valve may be a conventional diaphragm valve having a diaphragm in the chamber 406 by which the position of the valve is controlled. A capillary tube 407 connects the diaphragm chamber 406 to a bulb 408 positioned in the path of return air to the conditioner, the tube, bulb and space above the diaphragm in the chamber 406 being filled with a suitable volatile fluid which expands upon a rise in temperature in the return air duct. The valve is accordingly positioned in accordance with the return air temperature.

The spray 18 is controlled by a valve 185, a motor 189, and a humidity responsive device in the same manner as illustrated in Figures 1 and 3 whereby the air is supplied with moisture when the humidity within the space being conditioned is below a predetermined value.

The valve 26 for controlling the flow of refrigerant from the condenser 24 to the evaporator 20 is provided with a bracket 410 on which is positioned a motor 411 and a bellows 412. Pivotaly supported at 413 to the end of the bracket 410 is a lever 414 having a portion 415 resting on the top of the stem 50 which controls the tension of the spring 45 in the expansion valve. This lever is urged against the top of stem 50 by means of a spring 420 connected at its lower end to the bracket and adjustably connected at its upper end by means of an adjusting screw 421 to the lever 414. The bellows 412 is positioned to the left of the pivot 413 and is connected by means of a capillary tube 422 to a bulb 423 located in the return air line to the chamber 400, this bellows having a plunger 424 extending upwardly from the top thereof and engaging the underside of the lever 414. The bellows 412, tube 422, and bulb 423 are filled with a suitable volatile fluid and as the temperature within the return air line increases, the fluid within the bulb, tube, and bellows expands causing the expansion of the bellows 412 whereupon the lever 414 is urged upwardly against the bias of spring 420. It will readily be seen therefore that upon a rise in return air temperature to a sufficiently high value, the tension of the spring 45 within the expansion valve is reduced by reason of the upward movement of lever 414 whereupon the effective cooling area of the evaporator coil 20 is increased in accordance with an increase of return air temperature.

Operated by the motor 411 is a push rod 430 which acts upon a lever 431 pivoted at 432 and having an end portion extending under a projection of the lever 415. Operation of the motor 411 causes the plunger 430 to be moved up or down whereupon the position of the lever 414 may be raised by the lever 431 upon a sufficient movement of the plunger 430 upwardly. This motor is controlled by the humidity responsive element and more particularly by the arm 140 and resistance 144. This motor may be of the same internal construction as the proportioning motors illustrated and described in Figure 1. The junction of the relay coils of this motor is connected by means of a conductor 435 to the

arm 140 and the opposite ends of the coils are connected by means of conductors 436 and 437 to the ends of resistance 144. It will be readily understood that when the humidity in the space reaches an excessively high value, or in other words, when the arm 140 moves over the resistance 144 in response to an excessive humidity in the space being conditioned the motor 411 will be caused to move the plunger 430 upwardly an amount proportional to the amount of movement of the arm 140 over the resistance 144. If this movement of the plunger 430 by the motor 411 is sufficient to raise the lever 431 beyond the position of the projecting portion of lever 414, this lever will be moved upwardly farther than it is moved by the bellows 412 and the valve 26 will be caused to open in response to a lower superheat at the evaporator outlet so that the effective cooling area of the evaporator coil is thereby increased.

By this arrangement the expansion valve is operated primarily by the temperature of the return air to the air conditioning chamber but should the humidity in the space reach an excessive value the humidity responsive device may assume control over the valve to decrease the tension of the spring and increase the effective cooling area of the evaporator coil, the cycle of operation here being the same as in Figures 1 and 3. The compressor 21 may be operated in the same manner as in Figure 3, the control means therefor including the differential pressure control 250 of the same construction as that shown in Figure 4 and the high pressure cut-out 75 similar to that of Figures 1 and 3.

The back pressure controller 255 may be identical in internal construction with that of Figure 5. A bracket 440 is secured to the upper portion of the valve housing, a lever 441 being pivoted at one end of the bracket, this lever having a portion 442 resting against the top of rod 301 extending upwardly from the valve housing. This rod controls the tension of the spring 299 within the valve housing and accordingly the back pressure on the compressor as in Figure 5. A spring 443 is connected to the bracket 440 and to the lever 441 by means of an adjusting screw 445. Positioned to the left of the pivot of the lever 441 is a bellows 446 having a portion 447 acting against the lever 441. A capillary tube 448 is connected to the bellows 446, this tube being connected at its other end to a bulb 449, the bellows, tube, and bulb being filled with a suitable volatile fluid. A motor 450 is supported on the opposite end of the bracket 440, this motor being similar in construction to motor 411 and including a plunger 451 and a lever 452 pivoted at 453. Lever 452 extends under a projecting portion of the lever 441 as illustrated in the drawings. The motor 450 is operated by the arm 139 and resistance 143 of the humidity controller. Wires 456, 457, and 458 connect the controller to the motor in a manner heretofore set forth in connection with motor 411.

The motor 450 and lever 452 form the main control for the back pressure valve 255 since the bellows 446 is set to respond only to an excessive temperature of the return air and it is contemplated that under normal conditions this bellows will have no effect upon the position of the lever 441. Accordingly as the humidity in the space rises to such a value that arm 139 moves across resistance 143, motor 450 will operate to raise the free end of lever 452 which in turn will cause the free end of lever 441 to be

raised, thus permitting the rod 301 to rise and lower the tension of the force exerted by spring 299 so that the back pressure required to open the valve will be decreased and the temperature of the refrigerant within the evaporator will be lowered so as to obtain an increased dehumidifying effect of the coil 20.

If the temperature of the return air should reach an excessive value even though the humidity is not high enough to operate the back pressure valve 255, the lever 442 will be raised by the bellows 446 thus allowing upward movement of rod 301 and decreasing the tension of the spring 299.

It will thus be seen that in this form of the invention the sequence of operation is substantially the same as that of Figure 3 but the electric motors controlled by the temperature controller have been eliminated and replaced by the self-contained temperature responsive elements. While the bulbs 408, 423, and 449 have been shown as being positioned within the return air duct it is obvious that they could be located at any suitable place in the room being conditioned if desired. It is also obvious that the system illustrated in Figure 1 might be provided with self-contained temperature responsive operating units if desired.

Referring now to the form of invention shown in Figure 7 the same sequence of operation and the same results are obtained with the use of a pneumatic control system in place of the electrical control system shown in the preceding figures.

An air conditioning chamber 500 is provided with a return air inlet 501 and a fresh air inlet 502, a fan 503 and an outlet 504. The heating coil 19 and the evaporator coil 20 are positioned in the chamber 500 and a humidifying means 505 is also positioned in the chamber. This humidifying means is represented as being in the form of a tank 506 located in the bottom of the chamber 500 and being supplied with water by means of a pipe 507 controlled by means of a float 508 to maintain a constant level of water in this tank. A heating coil 509 is positioned in the tank for heating the water therein, the supply of heating fluid through this coil being controlled by a valve 510.

The refrigeration system for supplying refrigerant to the evaporator 20 may be similar to that illustrated and described in Figure 3, the compressor being controlled and operated in a similar fashion, namely, by the use of a differential controller and a high pressure cut-off.

Mounted within the space being conditioned is a thermostat generally indicated by the reference character 512, this thermostat being of conventional construction and may include a cylindrical element 513 having a high coefficient of expansion, this element carrying a rod 514 adjustably connected to the top of the element 513 by a screw threaded member 515. The lower portion of the member 513 is fixed, and mounted in the path of movement of the rod 514 as the cylinder 513 expands or contracts is a bell crank shaped flapper valve 516 pivoted at 517. A nozzle 520 is positioned in the path of movement of a flapper valve 516 and as the cylinder 513 expands in response to a temperature within the space the valve 516 will be permitted to pivot about 517 into a position in which the flow of air from the nozzle 520 is cut off. The adjusting member 515 has connected thereto an arm 522 pivotally connected to an arm 524 operatively

connected to a bellows 525 and it will be apparent that as the bellows 525 expands or contracts the control point of the thermostat 512 may be readily adjusted. The operation of this bellows 525 will be discussed below.

Also mounted within the space being conditioned is a humidity responsive device indicated generally by the reference character 530. This device includes any conventional form of humidity responsive element 531 connected at its upper end to the adjustable screw member 532 screw threadedly received in the upper portion 533 of a supporting member 534, the lower end of humidity responsive element 531 being connected to the pivoted flapper valve 535. A spring 536 connects to one end of this flapper valve, the other end of this spring being connected at 537 to the supporting element 534. Cooperating with the flapper valve 535 is the nozzle 538 of an air line and it will be readily apparent as the humidity in the space increases the valve will be moved towards the nozzle closing position under the influence of spring 536. An arm 540 is connected to the side of the adjusting screw member 532 and is pivotally connected at 541 to the arm 542 connected to the bellows 543 whereby the control point of the humidity responsive device may be adjusted in response to the expansion or contraction of the bellows 543.

The valve 510 for controlling the flow of steam or other heating medium to the coil 509 in order to procure humidification in the air conditioning chamber includes a valve element 550 cooperating with the valve seat 551 and a bellows 552 supported by a cap 553 and operatively connected by means of a valve stem 554 to the valve element. A spring 555 is provided for biasing the valve towards open position and as the pressure within the bellows 552 increases, the valve is moved towards closed position, thus cutting off the supply of heat to the coil 509.

Air is supplied to the bellows 552 by means of an air line 560 having a branch line 561 provided with a restriction 562 having a suitable adjusting means 563 for controlling the flow of air therethrough. The outlet of the restricting means 562 is connected to a pipe 564 and to this pipe is connected the bellows 552 by means of a pipe 565. The pipe 564 is also connected to a pipe 566 terminating in the nozzle 538. It will now be apparent that when the nozzle 538 is open, the pressure within the bellows 552 will be relieved since there is only a restricted flow of air through the restriction 562 and the spring 555 will accordingly maintain the valve 550 in open position. As the humidity in the space starts to increase and the humidity responsive element 531 becomes elongated, the flapper valve 535 is moved under the influence of spring 537 towards closed position whereupon the flow of air from the nozzle 538 is reduced and the pressure begins to build up within the bellows 552 thus causing the valve to begin moving towards closed position and cutting down the supply of steam to the coil 509. The amount of air that is allowed to leak through the nozzle 538 will be in direct relation to the humidity within the space and accordingly the valve 550 will be moved to a position corresponding to the relative humidity and after the humidity reaches a high enough value thus cutting down the flow of air from the outlet 538 to a sufficient extent, the force exerted by the bellows 552 will be sufficient to cause complete closure of the valve thus definitely cutting off the supply of steam to the coil 509 whereupon

the humidity supplied to the air being conditioned is reduced to a minimum.

The valve 570 for controlling the supply of steam or other heating medium to the heating coil 19 may be of the same construction as the valve 510 and may include a valve element 571, valve seat 572, an operating bellows 573, and spring 574. A branch line 575 connects the air supply line 560 with a restriction 577 having adjusting means 576, a pipe 578 leading from the outlet of the restriction and connected to the interior of the bellows 573. This pipe 578 also connects with a pipe 579 leading to the nozzle 520. As the temperature in the space being conditioned increases, the flapper valve 516 moves towards closed position, the supply of air issuing from nozzle 520 decreases and the pressure within the bellows 573 increases whereby the valve moves towards closed position. After the temperature has increased to a predetermined amount the supply of air leaving the nozzle 520 will have decreased sufficiently so that the pressure within the bellows 573 will have caused complete closure of the valve 571 and the supply of steam to the coil 519 will be entirely cut off.

A reverse acting relay is represented by the reference character 580 and this relay may be of the same construction as that shown and described in the application of John M. Larson and Karl Egenbaum, Serial No. 158,744 filed August 12, 1937. This relay may comprise generally a body 581 having an air supply inlet 582, an air outlet 583, and a relief outlet 584. The port 584 is controlled by a valve element 585 connected to the bottom cross piece 586 of a yoke 587 which surrounds the body 581. A spring 588 is provided for biasing the valve element 585 to closed position and the yoke 587 downwardly. Communicating with the valve chamber 590 by means of a port 591 is a bellows 592 fixed to the upper wall of this valve chamber and located in an opening in the upper part of the body 581. The upper portion of this bellows bears against a strap 593 and it will be readily apparent as the pressure within the valve chamber increases the bellows 592 will expand and thus move the valve towards open position. Connected to the top wall of the body 581 by means of a nipple 594 is a second bellows 595 the upper portion of which is connected to the top strap of the yoke 587. This bellows connects by means of a pipe 596 to the pipe 566 which leads from the restriction 562 to the nozzle 538. Air is supplied to the valve chamber 590 by means of an air line 600 leading to a restriction 601 having adjusting means 602, a pipe 603 leading from the restriction to the valve chamber.

The valve 585 will be moved to open position whenever the combined pressure existing in the bellows 592 and 595 is sufficient to overcome the force of spring 588. Assuming that this spring exerts a force of 15 lbs. to close the valve, it will be apparent that the combined pressure in the bellows 592 and 595 must be 15 lbs. before the valve will begin to open. The pressure existing within the bellows 595 will depend upon the pressure in the line 566 which in turn depends upon the position of the valve 535. Assuming that this valve is wide open the humidity in the space being relatively low there will be no pressure within the bellows 595 so that a pressure of 15 lbs. will have to be built up within the bellows 592 before the valve 585 begins to open. The pressure in the outlet 583 from the valve chamber will be the same as that within the

bellows 592 so that the pressure of the air passing through this pipe will be the same as that which is built up within the bellows 592 before the valve begins to open. As the humidity within the space begins to increase and the flow of air from the nozzle 538 decreases the pressure within the pipe 596 and the bellows 595 will start to build up. If this pressure has built up to 5 lbs. for example, it is apparent that a pressure of 10 lbs. within the bellows 592 will be sufficient to open the valve 585 so that the pressure within the line 583 will then be 10 lbs. instead of 15 lbs. as formerly. Accordingly as the pressure in the line 566 increases the pressure in the line 583 will decrease proportionately.

The line 583 connects by means of branch lines 610, 611 with accumulators 612 and 613. These accumulators may comprise suitable expansion elements fixed at their upper ends and biased to collapsed position by means of springs 614 and 615, respectively. Carried by the bottom of these expandable elements by means of rods 616 and 617 are valve elements 618 and 619, respectively. These valve elements control the flow of air from ports 620 and 621. The port 620 connects by means of a pipe 622 and 623 to a restriction 624 to which air is admitted by means of an air supply pipe 625. Pipe 622 also leads to the interior of a bellows 630 mounted on a bracket 631 suitably fastened to the top of the back pressure valve 255. As the pressure in bellows 630 decreases the bellows contracts and permits the lever 632 connected to the rod 301 to move upwardly thus relieving the tension of spring 299 and lowering the back pressure on the compressor.

The expandable element 612 is designed to start opening when the pressure existing therein begins to drop from a maximum value which is maintained therein when the nozzle 538 is wide open and the pressure in line 583 is at a maximum. For example, assuming a line pressure of 15 lbs. when the pressure drops to 9 lbs., for example, this valve will begin to open and at 6 lbs. the valve may be wide open. The opening of this valve relieves the pressure in the line 622 and therefore the pressure within the bellows 630 thus reduces the back pressure on the compressor. It will be apparent therefore that as the humidity in the space increases to a high enough value the pressure in the line 596 increases, the pressure in the lines 583, 610, and 611 decreases permitting the valve 618 to open whereupon the pressure within the bellows 630 decreases and the temperature of the evaporator coil 20 is lowered in response to the rising humidity.

A second reverse acting relay 640 similar in construction to the relay 580 has the upper bellows 641 connected by pipe 642 to the pipe 579 leading to the nozzle 520 of thermostat 512. Air is supplied to the lower bellows 643 by means of an air supply line 644 provided with a restriction 645 from which line 646 leads to the valve chamber 647. This valve chamber communicates by means of a pipe 648 with the bellows 649 and 650 of a pair of accumulators similar to the accumulators 612 and 613. The accumulator 650 is designed to permit the opening of the valve 652 when the pressure in the bellows drops to 9 lbs., for example, assuming an air line pressure of 15 lbs. This valve controls the exhaust of air from a pipe 653 connected to pipe 654 to which air is supplied from the supply line 655 through the restriction 656 and the pipe 657. Air is also delivered from the pipe 657 by means of a pipe 658

to the interior of a bellows 660 supported on a bracket 661 which in turn is suitably mounted on the upper portion of the expansion valve casing 26. A drop in pressure in the bellows 660 permits the lever 661 which connects the bellows and the valve stem 50 to pivot in a counter-clockwise direction and relieve the tension of the spring 45, it being understood that this valve has the same internal construction as that shown in Fig. 2.

It will now be apparent that when the temperature in the space reaches a sufficiently high value so that the pressure in the bellows 641 builds up by reason of the movement of flapper valve 516 towards the orifice 520, this building up in pressure being accompanied by a decrease in bellows 643 and therefore in the accumulator 650, the spring biasing the bellows will cause the valve 652 to move away from the end of pipe 653 thereby allowing the venting of air from the bellows 660 which in turn decreases the tension of the spring in the expansion valve allowing the valve to open in response to a lower superheat whereby the effective cooling area of the evaporator coil 20 increases.

It should be understood that the initial rise in humidity causes a collapse of the bellows 612 but the bellows 613 remains expanded sufficiently to keep the valve 619 in closed position until the pressure in this bellows drops to a considerably lower value than that at which the valve 618 opens, for example, it may require a drop in pressure to 4 lbs. before valve 619 will begin to open. Likewise the initial rise in temperature will cause valve 652 to be opened but valve 670 operated by the bellows 649 will remain closed until the pressure in the line 648 and the bellows 649 drops to a value of say 4 lbs. In other words, the valves 619 and 670 do not begin to open until the valves 618 and 652 have completely opened.

The valve 619 opens in response to a rise in humidity to an excessively high value such that the flapper valve 535 is nearly or entirely closed whereupon the pressure in the line 596 increases to very nearly line pressure and accordingly the pressure of bellows 592 and the lines 583 and 611 will have dropped to a very low value. The opening of valve 619 will cause a decrease in pressure in the bellows 660 which will cause an expansion of the spring in the valve 26 and the superheat required to open the valve will be decreased and the effective cooling area of coil 20 will increase. Similarly, if the temperature in the space reaches a very high value the pressure within the bellows 649 will become low enough to permit the opening of valve 670 thus relieving the pressure in the bellows 630 and lower the back pressure upon the evaporator. It will therefore be seen that the bellows 613 acts as a limit control to increase the effective cooling area of the evaporator as the humidity within the space reaches an excessively high value irrespective of the temperature within the space and similarly the bellows 649 acts as a limit control to reduce the back pressure upon the compressor if the temperature in the space reaches an excessively high value regardless of the humidity existing therein. The system so far described therefore has the same sequence of operation as that described in connection with Figure 3.

In addition, suitable control devices 680 and 681 may be positioned in the fresh air inlet. Control 680 may include a cylindrical member 682 having a high coefficient of expansion and to which is connected a rod 683 having a low

coefficient of expansion and pivotally connected at its upper end to a lever 684 pivoted at 685, this lever controlling the flow of air from an orifice 686. This orifice 686 is connected by means of pipes 687, 688, and 689 to the restriction 690 to which air is delivered by means of a supply line 691. Pipe 689 also connects with a pipe 692 connected to the interior of the bellows 525. Also connected by means of a branch pipe 693 to the pipe 692 is the bellows 543. As the pressure within the bellows 543 decreases the control point of the humidity responsive device is lowered proportionately by means of adjusting screws 532. Decrease in pressure within bellows 525 increases the control point of the temperature responsive device. As the outside temperature drops below a predetermined value, the expansible element 682 will contract whereupon the pivoted valve member 684 will move upwardly and vent the line 687 whereupon the pressure in the bellows 525 and 543 will decrease, the control point of the humidity responsive element will be lowered and the control point of the temperature responsive element will be raised. This control function is intended to take place during the heating cycle when the outdoor temperature drops to such a value that frosting of the window panes would result were the humidity not lowered. With a lowered relative humidity the temperature within the space should be raised in order to maintain a substantially constant effective temperature and accordingly the control point of the thermostat is raised so that the temperature maintained in the space will be higher as the relative humidity is lowered.

The controller 681 is similar to the controller 680 except that this controller causes the opening of orifice 700 upon an increase in temperature of the fresh air supply above a predetermined value. The valve 701 is positioned below the orifice 700, this valve being pivoted at 702 and connected to the rod 703 which is in turn connected at the bottom to the member 704 having a high coefficient of expansion. Accordingly when the outdoor temperature rises above a predetermined value the expansion of member 704 will cause the valve 701 to move away from the orifice 700 whereby the line 688 is vented and the pressure within the bellows 543 and 525 is reduced thereby lowering the control point of the humidity responsive device 530 and raising the control point of the temperature responsive element 512. In order to secure best results in summer air conditioning, the temperature of the air within the conditioned space should increase as the outdoor temperature increases but at a somewhat slower rate in order that too much discomfort will not be felt by the occupants of the space in going from indoors to outdoors. However, when the temperature of the space is increased during the summertime, in order that conditions will remain comfortable, the relative humidity should be decreased to some extent as the indoor temperature increases. By reason of the controller 681 raising the control point of the thermostat and lowering the control point of the humidity responsive element this result is successfully attained.

It will now be apparent that the control system of Figure 7 accomplishes pneumatically the same results as the control system of Figure 3 and includes in addition thereto the feature of lowering the relative humidity within the space when the outdoor temperature drops below a predetermined value so that frosting on the win-

dows will not take place. The lowering of the relative humidity is accompanied by an increase in temperature in the space so that the effective temperature thereof may be kept substantially uniform. In the cooling season when the outdoor temperature rises the indoor temperature is also increased at a slower rate so as to maintain the proper relationship between the indoor temperature and the outdoor temperature. This increase in indoor temperature is accompanied by an appropriate decrease in relative humidity so as to maintain proper comfort conditions.

The operation of the various systems may be briefly summarized as follows: when the indoor temperature is below a value of, for example, 70°, heat will be supplied to the space by the heating coil 19, the amount of heat being supplied by this coil varying in accordance with the temperature in the space. When the temperature reaches 70° the supply of heat to this coil will be cut off and if the temperature in the space rises to, for example, 70½°, the spring in the expansion valve 26 will be adjusted to decrease the superheat required to open this valve so that the effective cooling area of the coil 20 will increase as the temperature rises. This spring may be adjusted so that at 73°, for example, the valve will be operated by the smallest amount of superheat, or in other words, at 73° the area of the coil available for cooling will be at a maximum.

The humidity controller may operate to maintain a humidity of, for example, 50% in the space being conditioned. A drop in humidity below this value will cause the valve controlling the humidifier to open so that water vapor will be supplied to the space, the amount of water vapor being supplied increasing as the humidity in the space decreases. When the humidity rises to 50%, for example, the humidifier may be entirely shut down under the action of the humidity controller but should the humidity rise to say 51% the temperature maintained at the evaporator 20 will begin to be lowered, in Figure 1 by lowering the suction pressure maintained by the compressor and in the other forms of the invention by lowering the back pressure of the evaporator. The humidity controller may control the temperature of the coil so that at 55% relative humidity for example the coil will be operating at its lowest possible temperature.

Assuming now that the humidity in the space is at the desired value of say 50% and the temperature has risen above 73°, the expansion valve 26 will be operated to maintain the effective cooling area of the evaporator at the maximum value, but after the temperature exceeds 73°, for example, the temperature of the evaporator will be under the control of the temperature responsive device even if the humidity in the space is at the desired value of 50%. If the temperature conditions do increase above 73°, the temperature of the evaporator will be progressively lowered.

Assume now that the temperature in the space is at the desired value of 70° but the humidity has risen above 55%. The rise in humidity from 50 to 55% will lower the temperature of the evaporator to its minimum value but since the temperature controller is not calling for cooling, the effective cooling area of the evaporator will be at a minimum. As the humidity increases above 55% the tension of the spring within the expansion valve will be lessened and the effective cooling area of the evaporator will increase as the humidity in the space increases above 55%.

It will of course be obvious that should the temperature in the space be so low that heat is being supplied thereto by the coil 19, the operation of the evaporator for dehumidification, if the humidity in the space is too high, will not be affected and conversely if the humidity in the space is below 50% so that humidity is being supplied to the air, the operation of the evaporator in lowering the temperature within the space, if the temperature therein is above 70½°, for example, will not be affected.

It will also be obvious that, if desired, the controls may be reversed so that the effective cooling area of the evaporator is primarily under the control of the humidity responsive means, and the temperature of the evaporator is primarily under the control of the temperature responsive means, although the arrangement illustrated is the preferable one.

Moreover, instead of using a single temperature responsive device and a single humidity responsive device, each of the potentiometer arms 138—140 and 157—159 may, if desired, be controlled by a separate humidity or temperature responsive device.

Having described the preferred forms of my invention, many modifications will be apparent to those skilled in the art and I wish it to be understood that my invention is limited only by the scope of the appended claims.

I claim:

1. In an air conditioning system, a refrigeration apparatus including an evaporator for reducing the temperature of the air to be conditioned, a valve for controlling the flow of refrigerant to the evaporator, means responsive to suction pressure and the temperature of the refrigerant at the evaporator outlet for controlling the position of said valve whereby the superheat at the outlet of the evaporator may be controlled and flooding of the evaporator prevented, means responsive to the attainment of a high temperature in the space being conditioned for further controlling said valve to reduce the degree of superheat maintained at the evaporator outlet and to the attainment of an excessively high humidity in the space for also controlling said valve to reduce the degree of superheat, and means responsive to the attainment of a high humidity in the space being conditioned for reducing the temperature of the refrigerant in the evaporator and to the attainment of an excessively high temperature in the space for also reducing the temperature of the refrigerant in the evaporator.

2. In an air conditioning system, means for conditioning air including a heating means, a humidifying means and a cooling and dehumidifying means, said cooling and dehumidifying means comprising a refrigeration system including an evaporator, an expansion valve for controlling the flow of refrigerant to the evaporator, means responsive to the superheat at the outlet of the evaporator for controlling the position of said valve, means responsive to the temperature in the space being conditioned for controlling the heating means and for controlling the amount of superheat required to cause the opening of said valve, means responsive to the humidity in the space being conditioned for controlling the humidifying means and the temperature of the refrigerant in said expansion coil, limit control means responsive to an increase in temperature from a normal range to an excessive temperature range in the space for de-

creasing the temperature of the refrigerant in the evaporator, and means responsive to excessive humidity conditions in the space for decreasing the amount of superheat at the evaporator outlet required to cause the opening of said valve.

3. In an air conditioning system, a refrigeration system including a compressor, a condenser and an evaporator, valve means for controlling the flow of refrigerant from the condenser to the evaporator, means responsive to the temperature of the air being conditioned for controlling the valve means whereby the effective cooling surface of the evaporator is varied in accordance with the temperature of the air being conditioned, back pressure controlling means for controlling the pressure in the evaporator, humidity responsive means in control of said back pressure controlling means, and means responsive to the pressure differential across said back pressure controlling means for controlling the operation of the compressor.

4. In an air conditioning system, a refrigeration system including a compressor, a condenser, and an evaporator, valve means for controlling the flow of refrigerant from the condenser to the evaporator, back pressure controlling means including humidity responsive means for controlling the pressure in said evaporator whereby the temperature of the refrigerant in the evaporator varies in accordance with the humidity in the space being conditioned, and means responsive to the pressure differential across said back pressure controlling means for controlling the operation of the compressor.

5. In an air conditioning system, a refrigeration system including a compressor, a condenser and an evaporator for controlling the condition of air, valve means for controlling the flow of refrigerant from the compressor to the evaporator, back pressure controlling means for controlling the pressure in the evaporator, means responsive to the psychrometric condition of the air being controlled by the evaporator in control of said back pressure controlling means, and means responsive to the pressure differential across said back pressure controlling means for controlling the operation of the compressor.

6. In an air conditioning system, a refrigeration system including a compressor, a condenser and an evaporator, thermostatic valve means for controlling the flow of refrigerant from the condenser to the evaporator, back pressure control means for controlling the pressure within the evaporator, electrically operated means in control of said thermostatic valve means to vary the superheat maintained at the evaporator outlet, electrically operated means in control of the back pressure controlling means for varying the pressure maintained within the evaporator, temperature and humidity responsive means in control of both of said electrically operated means, and means responsive to the differential in pressure across said back pressure controlling means for controlling the operation of said compressor.

7. In an air conditioning system, a refrigeration system including a compressor, a condenser and an evaporator, means including a back pressure controller for controlling the temperature of said evaporator, means responsive to the humidity of the air being conditioned for adjusting said back pressure controller, means responsive to the attainment of an excessive temperature of the air being conditioned for further adjusting said back pressure controller, an expansion valve for controlling the flow of refrigerant from the

compressor to the evaporator, means responsive to the temperature of the air being conditioned for controlling said valve, and means responsive to the differential in pressure across said back pressure controller for controlling the operation of said compressor.

8. In a refrigeration system including a compressor, a condenser and an evaporator, a back pressure controller for controlling the temperature of the evaporator, said back pressure controller including a valve for controlling the flow from the evaporator to the compressor, means responsive to the pressure on the suction side of the evaporator for controlling the position of said valve, spring means opposing the opening of said valve, and means responsive to the pressure drop across said back pressure controller for controlling the operation of said compressor.

9. In a refrigeration system including a compressor, a condenser and an evaporator, a back pressure controller for controlling the temperature of the evaporator, said back pressure controller including a valve for controlling the flow from the evaporator to the compressor, means responsive to the pressure on the suction side of the evaporator for controlling the position of said valve, spring means opposing the opening of said valve, means responsive to the pressure drop across said back pressure controller for controlling the operation of said compressor, said last named means including a circuit controlling means, and means responsive to the pressure on the high pressure side of said valve and the pressure on the low pressure side of said valve for controlling said circuit controlling means.

10. In an air conditioning system, temperature changing means for a space to be conditioned, humidity changing means for a space to be conditioned, means responsive to the temperature of the space being conditioned in control of said temperature changing means, means responsive to the humidity of the space being conditioned in control of said humidity changing means, means responsive to increases in outdoor temperature above a predetermined value or decreases in outdoor temperature below a second predetermined value for raising the control point of the temperature responsive means and lowering the control point of the humidity responsive means.

11. In an air conditioning system, a refrigeration system including a compressor, a condenser and an evaporator, an expansion valve for controlling the flow of refrigerant from the condenser to the evaporator, means responsive to the temperature of the space being conditioned for controlling said valve so that said valve is caused to allow the passage of increasing amounts of refrigerant to the evaporator as the space temperature increases, a device for controlling the pressure in said evaporator, means responsive to the humidity of the air being conditioned for adjusting said device so that the pressure in the evaporator decreases as the humidity increases, means responsive to increases in outdoor temperature for decreasing the effect of said temperature responsive means on said expansion valve and simultaneously increasing the effect of said humidity responsive means on said pressure controlling device.

12. An evaporator for controlling the condition of air, a thermostatic expansion valve for controlling the supply of refrigerant to said evaporator, said valve including a valve member and a valve seat, spring means biasing said valve

member towards said valve seat, pressure responsive means responsive to the superheat at the evaporator outlet for opening said valve against the force exerted by said spring means, an electric motor controlling the force exerted by said spring means, and means responsive to the psychometric condition of the air being controlled by the evaporator in control of said electric motor, whereby the amount of superheat at the evaporator outlet and accordingly the effective cooling surface of the evaporator is varied in accordance with the psychometric condition of the air being controlled by the evaporator.

13. In a refrigeration system, including a compressor, a condenser and an evaporator, a back pressure regulator in the line between the evaporator and the compressor for controlling the pressure within the evaporator, a differential pressure controller for controlling the compressor in accordance with the pressure drop across said back pressure regulator, said differential pressure controller comprising a bellows connected to the high pressure side of the back pressure regulator, a second bellows connected to the low pressure side of the back pressure regulator, a lever actuated by said bellows in accordance with variations in pressure differential between said bellows, circuit controlling means for said compressor operated by said lever and moved to circuit opening position upon the attainment of a predetermined pressure differential between said bellows, a spring biasing said lever toward circuit making position, a pivoted device mounted in the path of said lever toward circuit breaking position and biased in a direction to oppose said movement of said lever, and means limiting movement of said device in said direction.

14. A differential pressure controller including a pair of expansible chambers, said expansible chambers having communication with fluids at different pressures and expanding in response to increasing pressure of said fluids, a lever pivoted intermediate said members and bearing against the movable portions thereof, spring means biasing said lever in the direction opposite to that in which it is moved in response to an increase in the pressure differential between said chambers, a control device operated in response to a predetermined movement of said lever, a second spring means, a second lever connected to said second spring and biased in the path of movement of one end of said first lever when said first lever is moving in response to an increase in pressure differential within said expansible chambers, and means limiting the movement of said second lever in the direction in which it is moved by said second spring means.

15. Valve controlling means for a valve having a pressure responsive device for causing the opening of said valve and a spring opposing the opening of said valve, means controlling the force exerted by said spring and accordingly the force required to open said valve, said means comprising a stem connected to said spring, the position of said stem controlling the tension of said spring, a lever having one end portion bearing against said stem and being pivoted at the other end to a supporting means, means biasing said lever against said stem, condition responsive means for moving said lever away from said stem against the force of said biasing means whereby the stem is free to move in the same direction and relieve the force of said spring, said lever having a portion projecting beyond said

stem, a second lever underlying the projecting end of said first lever, and second condition responsive means acting upon said second lever to move said first lever away from said stem, whereby said spring is under the control of two separate actuating means.

16. In an air conditioning system, temperature changing means, humidity changing means, condition responsive means in control of said temperature and humidity changing means, means responsive to increases in outdoor temperature above a predetermined value or decreases in outdoor temperature below a second predetermined value for varying the control point of the condition responsive means in a manner so that the temperature maintained by the temperature changing means is increased and the humidity maintained by the humidity changing means is decreased.

17. In an air conditioning system, a condition responsive means, a pressure operated device connected thereto to vary the control action of said condition responsive means in accordance with the pressure in said device, means supplying pressure to said device, said pressure supplying means having a bleed line connected thereto and provided with a pair of parallel arranged orifices, valve means controlling the flow of air from said orifices, means causing one of said valve means to open as the temperature at a predetermined location drops below a predetermined value, means causing the other of said valve means to open as the temperature at a predetermined location rises above a predetermined value, both of said valve means being closed when the temperature at said locations is between said values.

18. In an air conditioning system, condition changing means, pressure operated means controlling the condition changing effect of said condition changing means, means supplying pressure to said pressure operated means, a bleed line terminating in a pair of parallel arranged orifices connected to said pressure supplying means, valve means controlling said orifices, pressure operated means for moving said valve means to closed positions, means biasing said valve means to open positions, one of said last named pressure operated means being arranged to permit the opening of the valve means controlled thereby when the pressure therein drops to a predetermined value, the other of said last named pressure operated means being arranged to permit the opening of the valve means controlled thereby when the pressure therein drops to a lower predetermined value, a first condition responsive means controlling the pressure within one of said last named pressure operated means, and a second condition responsive means controlling the pressure in the other of said last named pressure operated means.

19. In an air conditioning system, a refrigeration system including a compressor, a condenser and an evaporator, a valve for controlling the flow of refrigerant from the condenser to the evaporator, an electric motor in control of said valve, a back pressure controller controlling the flow of refrigerant from the evaporator to the compressor, an electric motor in control of said valve, means responsive to the humidity in the space being conditioned in control of both of said motors, and means responsive to the temperature in the space being conditioned in control of both of said motors, whereby the flow of refrigerant to the evaporator and the pressure in

the evaporator are both responsive to the temperature and the humidity in the space being conditioned.

20. In an air conditioning system, a refrigeration apparatus including an evaporator for reducing the temperature of the air to be conditioned, an expansion valve for controlling the effective cooling surface of said evaporator, an electric motor in control of said valve, a back pressure valve for controlling the temperature of said evaporator, an electric motor in control of said valve, means responsive to medium high temperature and excessively high humidity in the space being conditioned in control of said first mentioned electric motor, and means responsive to medium high humidity and excessively high temperature in the space being conditioned in control of the second mentioned electric motor.

21. In an air conditioning system, a refrigeration apparatus including an evaporator for reducing the temperature of the air to be conditioned, a valve for controlling the flow of refrigerant to said evaporator, means responsive to the superheat at the outlet of the evaporator for controlling the position of said valve, and means responsive to the attainment of a high temperature in the space being conditioned for further controlling the position of the valve to reduce the degree of superheat maintained at the evaporator outlet and to the attainment of an excessively high humidity in the space for also controlling said valve to reduce the degree of superheat.

22. In an air conditioning system, a refrigeration apparatus including an evaporator for reducing the temperature of the air to be conditioned, means for controlling the temperature and effective cooling surface of said evaporator, said means including means responsive to medium high temperature and excessively high humidity in the space being conditioned for controlling the amount of effective cooling surface of the evaporator, and means responsive jointly to variations in temperature within an excessively high temperature range and to variations in humidity within a medium high humidity range in the space being conditioned for varying the temperature of the evaporator.

23. In an air conditioning system, means for conditioning air including a heating means, a humidifying means, and a cooling and dehumidifying means, said cooling and dehumidifying means including an evaporator coil of a refrigeration system, first control means for varying the temperature of said evaporator coil and second control means for varying the effective cooling surface of said evaporator coil, means responsive to the humidity in the space being conditioned for controlling the humidifying means and said first control means for varying the temperature of said evaporator, means responsive to the temperature of the space being conditioned for controlling the heating means and second control means for varying the effective cooling surface of the evaporator coil, means responsive to excessive humidity conditions in the space for controlling the second control means for increasing the effective cooling surface of the evaporator coil, and means responsive to excessive temperature conditions in the space for controlling the first control means for decreasing the temperature of the refrigerant in the evaporator.

HAROLD L. STEINFELD.