

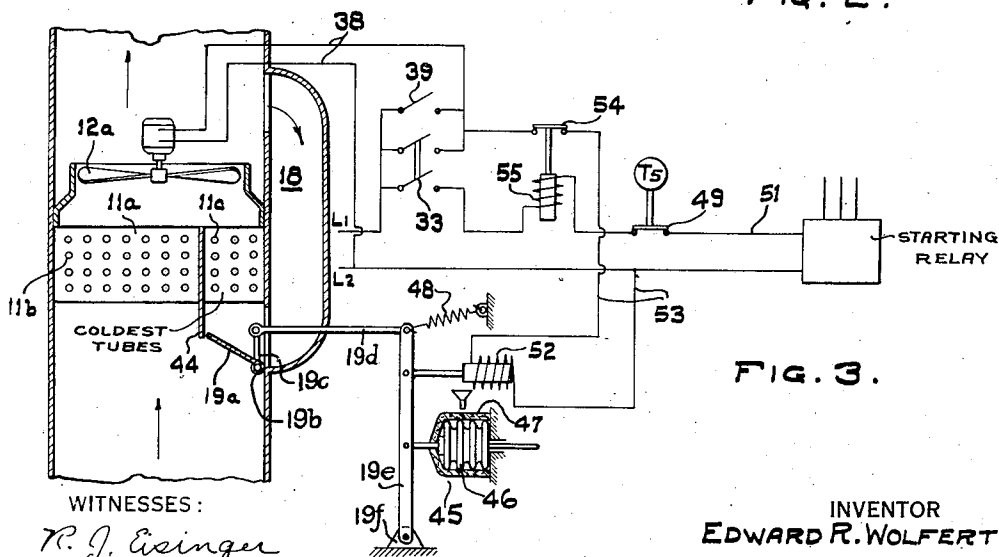
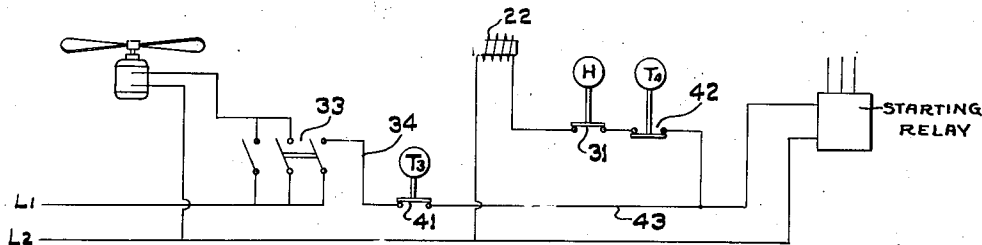
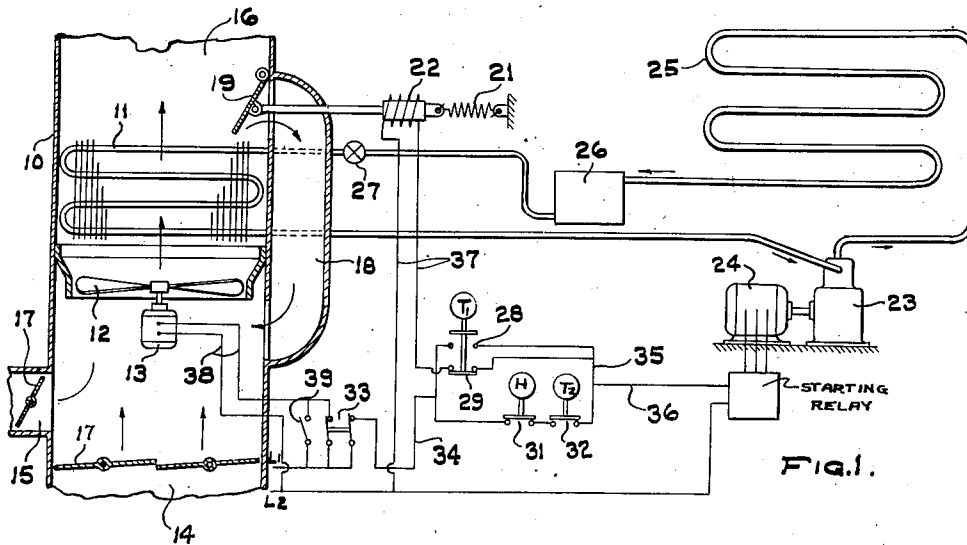
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E. R. WOLFERT

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AIR CONDITIONING APPARATUS

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WITNESSES:

R. J. Eisinger
G. R. Lutz.

INVENTOR
EDWARD R. WOLFERT
BY *Malteig*
ATTORNEY

UNITED STATES PATENT OFFICE

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AIR CONDITIONING APPARATUS

Edward R. Wolfert, Wilksburg, Pa., assignor to
Westinghouse Electric & Manufacturing Com-
pany, East Pittsburgh, Pa., a corporation of
Pennsylvania

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

5 The present invention is more particularly applicable to air cooling apparatus, such as a unit or room cooler, comprising a cooling coil disposed in a casing or a cabinet and means for circulating air through the casing in contact with the
10 cooling coil and into the room.

In the ordinary room cooler, the cooling action is initiated and terminated in response to dry bulb temperature in the room, to maintain the same substantially constant. The temperature
15 of the cooling coil is substantially constant and is chosen to be ordinarily below the dew point so as to effect dehumidification as well as cooling. However, the amount of dehumidification under varying conditions is not controlled but is only
20 such as accompanies the cooling action required to obtain the desired dry bulb temperature.

It is an object of my invention to vary the operation of the apparatus so as to control the humidity as well as the temperature of the conditioned enclosure.

In accordance with my invention, I provide a passage extending from the discharge or downstream side of the cooling coil and circulating fan to the inlet or upstream side thereof, whereby a portion of the air that has passed over the coil is again passed over the coil to provide a greater degree of dehumidification. By recirculating a portion of the air which has been discharged from the coil, the volume of air delivered
35 to the enclosure is reduced, but such reduced volume of air is cooled to a lower temperature and, therefore, dehumidified to a greater degree. In one embodiment of the invention, the recirculated air is mixed with the air conveyed to the
40 coil for cooling and dehumidification, so that the temperature of the air received at the inlet side of the coil is reduced. This lower temperature results in reduced suction pressure and temperature of the refrigerant in the coil, so that the
45 air is cooled to a lower temperature.

In a second embodiment of the invention, a portion of the air that has passed over one part of the coil is returned to the inlet side of the coil and passes over a second part of the coil for further dehumidification. In its first passage over the coil, most of the superheat or sensible heat above the dew point is removed, so that the air is discharged in substantially saturated condition. Thus, in its second passage over the coil, a greater
55 amount of dehumidification is effected. By

controlling recirculation of air over the second part of the coil, the amount of dehumidification effected may be varied.

In accordance with a further feature of my invention, I provide a control system whereby operation of the cooling coil is effected and flow
5 through said passage is shut off independently of the humidity in the enclosure when the temperature is above a predetermined value, and whereby flow through said passage and operation of
10 the cooling coil are effected in response to high humidity when the temperature is below said predetermined value. Provision may also be made for terminating cooling action when the temperature reaches a minimum value of comfortable
15 temperature.

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

Fig. 1 is a diagrammatic view of one embodiment of air conditioning apparatus and a control system therefor;

Fig. 2 is a wiring diagram of a modified form
25 of control system; and

Fig. 3 shows another embodiment of air conditioning apparatus and a control system suitable therefor.

Referring to the drawing in detail, I show a
30 duct or casing 10 having a cooling element 11 disposed therein to contact with the air flowing through the duct. The cooling element is preferably in the form of a cross finned coil. A fan
35 12 driven by a motor 13 is provided for effecting flow of air from a return air inlet 14 and an outside air inlet 15, over the coil 11, and for discharging the same through an outlet 16 to the space to be air conditioned. Dampers 17 may
40 be provided in the air inlets for controlling the flow of air therethrough.

In accordance with the present invention, I provide a passage 18 communicating at one end with the duct 10 at a point beyond or on the downstream side of the coil 11 and communicating at its other end with the duct on the upstream side of the fan 12. A damper 19 is provided for controlling flow of air through the passage 18. The damper 19 is biased to closed position by a spring 21, and is adapted to be opened
50 by a solenoid 22.

Refrigerating mechanism for supplying liquid refrigerant to the coil 11 is provided and includes a compressor 23 driven by a motor 24, a condenser 25, a liquid receiver 26, and a suitable ex-

pansion valve 27, which is preferably of the type known as a thermostatic expansion valve, for controlling the admission of refrigerant to the coil or evaporator 11. Such a valve controls the flow of refrigerant in accordance with the capacity of the cooling coil to evaporate refrigerant, and permits the pressure and temperature of vaporization to vary with the wet bulb temperature or total heat of the air passing over the coil 11.

The control system includes a thermostat T₁ for maintaining the enclosure at the desired temperature. The thermostat T₁ has a switch 28 which is closed when the temperature rises above said temperature and opens when the temperature has been reduced to a slightly lower value, and it also has a switch 29 which operates in the reverse direction. A humidostat H has contacts 31 which close in response to a predetermined high value of a humidity condition, such as relative humidity, and which opens in response to a slightly lower value. If desired, a humidostat responding to wet bulb temperature or dew point may be used. A low limit thermostat T₂ may also be provided, and has a switch 32 adapted to open in the event that the temperature reaches an uncomfortably low value. The thermostats T₁ and T₂ and the humidostat H are subjected to the air in the enclosure or space to be air conditioned, being disposed either in the enclosure or in the return air inlet 14, so as to respond to the temperature and humidity thereof.

The circuits for the solenoid 22 and the starting relay of the motor 24 extend in common from a line conductor L₁, through one pole of a cooling switch 33 to a conductor 34, the latter being connected to one terminal of the switch 28 and one terminal of the switch 31. The other terminal of the switch 31 is connected to one terminal of the switch 32. The other terminals of the switches 28 and 32 are connected to a conductor 35. It will be noted that the switches 31 and 32 are in series with each other and in parallel with the switch 28. From the conductor 35, the circuit 36 for the motor starting relay extends through said relay to a line conductor L₂. A circuit 37 for the solenoid 22 extends from the conductor 35 through the switch 29 and the solenoid 22 to the line conductor L₂. A circuit 38 for the fan motor 13 is connected to line conductor L₁ through the other pole of the switch 33 and also by a fan switch 39 in parallel therewith, and it is also connected to the line conductor L₂.

The operation of this embodiment is as follows: To effect cooling and dehumidifying operation of the apparatus, it is necessary first to close the switch 33, which effects continuous operation of the air circulating fan 12 and which enables operation of the cooling coil and of the damper 19 under automatic control. If the temperature in the enclosure is above the value desired to be maintained therein, the thermostat T₁ closes the switch 28 and opens the switch 29. The circuit for the motor starting relay is completed, thereby causing the motor 24 to drive the compressor 23 for effecting refrigerating action. The switch 29 opens the circuit 37 to the solenoid 22 so that the spring 21 closes the damper 19. Air is now circulated over the cooling coil 11 without recirculation of air through the passage 18. The maximum amount of air is discharged through the outlet 16 to the enclosure, the cooling action being utilized in this case to effect the maximum amount of reduction in dry

bulb temperature, although some dehumidification is effected unless the humidity is very low. While the thermostat T₁ calls for cooling, the humidostat H cannot effect recirculation.

When the temperature in the enclosure has been brought down to the desired value, the thermostat T₁ opens the switch 28 and closes the switch 29, placing the solenoid circuit 37 in condition to be closed by the humidostat switch 31. If the humidity in the enclosure is high, the humidostat H closes the switch 31, thereby closing both the starting relay circuit 36 and the solenoid circuit 37 through the switches 31 and 32. Energization of the solenoid 22 opens the damper 19 so that a portion of the air which has passed over the cooling coil 11 and is in substantially saturated condition passes to the suction side of the fan 12, and is recirculated over the cooling coil to provide a greater degree of dehumidification. In the embodiment of Fig. 1, this air is mixed with the warmer air from the inlets 14 and 15, to provide a mixture of lower temperature than the air from the inlets 14 and 15, so that the cooling coil 11 operates at lower suction pressure and temperature to effect a lower temperature of the discharged air. Thus, with the damper 19 open, a smaller quantity of air is delivered to the enclosure but it is at a lower temperature and consequently of lower absolute humidity, so that a greater portion of the cooling action of the coil 11 is used for dehumidification of air for the enclosure and a smaller portion for dry bulb temperature reduction.

While the apparatus is operating with the damper 19 open as described for dehumidification, the sensible heat cooling or dry bulb temperature reduction is less than the ordinary heat leakage, so that the temperature ordinarily will not be reduced to any great extent below that maintained by the thermostat T₁, but it will increase the intervals between operation of the thermostat T₁ calling for cooling. If and when the thermostat T₁ does operate to call for cooling before sufficient operation with recirculation for dehumidification has been effected, the opening of the switch 29 effects closing of the damper 19 so that the apparatus operates for maximum temperature reduction until the desired temperature is again reached.

If the amount of sensible heat cooling effected with the damper 19 open is substantially in excess of the sensible heat load of the enclosure, as on a day which is very humid but not very hot, the temperature in the enclosure may tend to drop to an uncomfortably low value. The thermostat T₂ responds to such temperature drop by operating the switch 32 to open the starting relay and solenoid circuits to discontinue further cooling.

It will be noted that, as soon as operation for maximum dehumidification under control of humidostat H is completed, the damper 19 is closed so as to effect maximum delivery of air to the enclosure. Thus, when the fan 12 is operating either for maximum cooling or for ventilation, maximum air delivery is provided. Operation of the fan 12 for ventilation without cooling action may be effected by closing the fan switch 39.

In Fig. 2, I show a modified form of control system for the air cooling apparatus of Fig. 1. In this case, a thermostat T₃ operates to maintain the desired temperature in the enclosure by actuating a switch 41. A humidostat H closes its switch 31 in response to high humidity, as in

Fig. 1. A thermostat T_1 , which opens a switch 42 in response to a higher temperature indicating that the temperature in the enclosure cannot be held down to a sufficiently low value while the damper is opened, may be provided. The starting relay and solenoid circuits extend in common from the line conductor L_1 , through one pole of the cooling switch 33 to the conductor 34, as in Fig. 1. One terminal of the switch 41 is connected to the conductor 34 and the other terminal to a conductor 43. The terminals of the starting relay are connected to the conductor 43 and the line conductor L_2 , respectively. A solenoid circuit extends from the conductor 43 through the switches 42 and 31 in series and through the solenoid 22 to the line conductor L_2 .

The thermostat T_3 closes the switch 41 to effect cooling action whenever the temperature of the enclosure is above the desired value, and opens the switch 41 to terminate cooling action whenever the temperature is below said value. While the refrigerating mechanism is in operation, if the humidity in the enclosure is above the desired value and the temperature is not excessively high, the switches 31 and 42 are closed to energize the solenoid 22 and open the damper 19. Recirculation of cooled air is then effected for greater dehumidification as already described. If the sensible heat cooling that accompanies operation with the damper 19 open is insufficient to prevent an excessively high temperature, then the thermostat T_4 opens the switch 42 to close the damper 19. The apparatus then operates to effect maximum sensible heat cooling and minimum dehumidification until the temperature is brought down to a somewhat lower temperature to permit the switch 42 to close. It will be noted that, in this embodiment, operation with recirculation has preference when the temperature is within limits of comfortable temperature, but that operation without recirculation is effected when the temperature becomes excessive. It will also be noted that operation with recirculation cannot be effected except when the main thermostat T_3 calls for cooling.

In Fig. 3, I show an embodiment of my invention in which the recirculated air may be kept separate from the main stream of warm air, and in which varying quantities of air may be recirculated. A partition 44 divides the tubes of a cooling coil or element 11a into two groups, 11b and 11c, the latter being disposed adjacent the outlet of the passage 18, and comprising the coldest tubes. When a cold liquid is used, it is first conveyed through the tubes 11c, and, when a vaporizable refrigerant is used, the completion of the vaporization is effected in the tubes 11c, so that, in either case, the tubes 11c are colder than the tubes 11b. A damper 19a, for regulating the quantity of recirculated air is arranged as shown on the drawing, being movable about a pivot 19b from the position shown in which maximum quantity of cold air from the passage 18 is recirculated, through intermediate positions, in which decreasing quantities of cold air and increasing quantities of warm air are admitted to the tubes 11c, to the position closing the outlet of passage 18 in which case no air is recirculated and only warm air passes over the tubes 11c. In this embodiment, a circulating fan 12a is disposed on the outlet or downstream side of the cooling element to permit separate air streams.

The damper 19a is actuated by a wet bulb thermostat 45 which may comprise an expansi-

ble chamber 46 covered by an absorbent material 47 that is kept in moist condition, and which is subjected to the air in the enclosure being conditioned. As the wet bulb temperature of the enclosure increases, the chamber 46 expands and moves the damper 19a to the left to increase the quantity of recirculated air and, as the wet bulb temperature decreases, the chamber 46 contracts and a spring 48 moves the damper to the right to reduce the quantity of recirculated air. The chamber 46 actuates the damper 19a through a crank or lever 19c, a connecting rod 19d and a lever 19e pivoted to a fulcrum 19f, as will be quite apparent from Figure 3.

A thermostat T_5 , which maintains the desired dry bulb temperature of the conditioned enclosure, actuates a switch 49 in the circuit 51 of the compressor motor starting relay, as in the previous embodiments. A solenoid 52 is provided for operating the damper 19a to close the passage 18 when cooling action is terminated. It is actuated by a circuit 53, which extends from the line conductor L_1 , through the switch 39 or the pole of the switch 33 that controls the fan circuit 38, through the contacts 54 of a relay 55 and through the solenoid 52 to the line conductor L_2 . The winding of the relay 55 is connected in the starting relay circuit 51 and arranged to open the contacts 54 when energized.

In the operation of the embodiment shown in Fig. 3, the switch 33 must be closed to permit cooling operation. The thermostat T_3 responds to a predetermined maximum temperature by closing the circuit 51 to start cooling action and opens the switch in response to a slightly lower temperature to terminate cooling action. While cooling action is effected, the damper 19a is operated by the wet bulb thermostat 45 to regulate the quantity of recirculated air. As the wet bulb temperature increases, the damper 19a increases the quantity of air that is recirculated, so that greater dehumidification is effected. In this case, the recirculated air is conveyed over the colder tubes 11c in order to reduce the temperature thereof to a lower degree and thereby to effect maximum dehumidification. The recooled air from the tubes 11c is mixed with the once cooled air from the tubes 11b by the fan 12a and a portion of the mixture is conveyed by the passage 18 to the tubes 11c. As the wet bulb temperature decreases, the damper 19a decreases the quantity of recirculated air permitting a greater quantity of warm air to pass to the tubes 11c. As soon as cooling action is terminated, the winding of the relay 55 is deenergized to close the contacts 54. If the fan 12a is operating, the circuit 53 is closed to energize the solenoid 52, so that the damper 19a is moved to the extreme right-hand position in which flow through the passage 18 is cut off. Thus, maximum effect of the fan 12a for ventilation is provided.

In speaking of recirculation of cooled and dehumidified air over the cooling element, I mean, of course, recirculation of the air before it is delivered to the air conditioned enclosure.

From the above description, it will be seen that I have provided relatively simple and inexpensive air conditioning apparatus, particularly suitable for unit conditioners and small installations, in which the humidity as well as the temperature may be regulated to maintain the same within comfortable limits.

While I have shown my invention in three forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible

of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In apparatus for air conditioning an enclosure, the combination of a surface cooling element for cooling air and reducing the moisture content thereof, fluid translating means for effecting flow of air to be conditioned over said cooling element, means for conveying air from said cooling element to said enclosure, means for selectively withdrawing a portion of the cooled air from said conveying means and recirculating the same over said cooling element, whereby the apparatus may be operated either without recirculation to effect primarily temperature reduction of the air delivered to the enclosure or with recirculation to effect maximum reduction in moisture content thereof, and means for controlling the second-mentioned operation in response to a humidity condition of the air in the enclosure.

2. In apparatus for air conditioning an enclosure, the combination of a surface cooling element for cooling air and reducing the moisture content thereof, fluid translating means for effecting flow of air to be conditioned over said cooling element, means for conveying air from said cooling element to said enclosure, means for selectively withdrawing a portion of the cooled air from said conveying means and recirculating the same over said cooling element, whereby the apparatus may be operated either without recirculation to effect primarily temperature reduction or with recirculation to effect maximum reduction in moisture content thereof, and means for controlling the first-mentioned operation in response to temperature and the second-mentioned operation in response to a humidity condition of the air in the enclosure.

3. In air conditioning apparatus, the combination of a cooling element, means for circulating air over said cooling element for cooling and dehumidifying the same, means for recirculating a portion of the cooled and dehumidified air over the cooling element for further dehumidifying the same, and means responsive to a humidity condition of air for controlling said recirculating means.

4. The combination with air conditioning apparatus comprising air cooling means, and means for conveying air in heat exchange relation with said air cooling means and delivering the same to an enclosure at a variable rate, of means for effecting operation of said apparatus at maximum rate of air delivery in response to a predetermined maximum temperature in the enclosure, means for effecting operation of said apparatus at a reduced rate of air delivery for effecting greater dehumidification in response to a humidity condition in the enclosure when the temperature is between said predetermined maximum temperature and a predetermined minimum temperature, and means for terminating cooling action of the apparatus in response to said predetermined minimum temperature in the enclosure.

5. The method of operating air conditioning apparatus having a cooling element for cooling and dehumidifying air for an enclosure which comprises effecting operation of the cooling element and delivering all of the cooled air to the en-

closure in response to a predetermined temperature of the enclosure, and effecting operation of the cooling element and recirculating a portion of the cooled air over the cooling element for further dehumidification in response to a high humidity condition in the enclosure when the temperature is below said predetermined temperature.

6. In air conditioning apparatus for an enclosure, the combination of cooling means, means for circulating air over said cooling means, means for recirculating a portion of the air over said cooling means, a damper for controlling air flow through the last-mentioned means, means responsive to a humidity condition of the air in the enclosure for controlling said damper, and means responsive to a predetermined maximum temperature for effecting operation of the cooling means and closing said damper independently of the action of the humidity responsive means.

7. In air conditioning apparatus for an enclosure, the combination of cooling means, means for circulating air over said cooling means, means for recirculating a portion of the air over said cooling means, a damper for controlling air flow through the last-mentioned means, means responsive to a humidity condition of the air in the enclosure for controlling said cooling means and said recirculating means when the temperature in the enclosure is between predetermined upper and lower limits, means for effecting operation of the cooling means and rendering the recirculating means ineffective in response to a temperature in the enclosure above said upper limit, and means for shutting off operation of the cooling means in response to a temperature below said lower limit.

8. In air conditioning apparatus, the combination of duct means, a cooling element therein, a fan for circulating air through the duct means and over the cooling element, means providing a passage from the duct means beyond the cooling element and the fan to the duct means at a point ahead of the fan and the cooling element for recirculating air for further dehumidification, a damper for controlling flow through said passage, means responsive to temperature of air for controlling the operation of the cooling element, and means responsive to humidity of air for controlling said damper.

9. In air conditioning apparatus, the combination of duct means, a cooling element therein, a fan for circulating air through the duct means and over the cooling element, means providing a passage from the duct means beyond the cooling element and the fan to the duct means at a point ahead of the fan and the cooling element for circulating air for further dehumidification, a damper for controlling flow through said passage, means responsive to temperature of air for controlling the operation of the cooling element, and means for effecting operation of the cooling element and opening said damper in response to high humidity of air.

10. In air conditioning apparatus, the combination of duct means, a cooling element therein, a fan for circulating air through the duct means and over the cooling element, means providing a passage from the duct means beyond the cooling element and the fan to the duct means at a point ahead of the fan and the cooling element for circulating air for further dehumidification, a damper for controlling flow through said passage, means responsive to a predetermined high

temperature of air for effecting operation of the cooling element and closing said damper, and means responsive to a temperature of air below said high temperature and to a high humidity of air for effecting operation of the cooling element and for opening said damper.

11. In air conditioning apparatus, the combination of duct means, a cooling element therein, a fan for circulating air through the duct means and over the cooling element, means providing a passage from the duct means beyond the cooling element and the fan to the duct means at a point ahead of the fan and the cooling element for circulating air for further dehumidification, a damper for controlling flow through said passage, means responsive to a predetermined high temperature of air for effecting operation of the cooling element and closing said damper, means responsive to a predetermined low temperature of air for shutting off operation of the cooling element and closing said damper, and means responsive to a temperature of air between said high and low temperatures and a high humidity of air for effecting operation of the cooling element and opening said damper.

12. In apparatus for supplying cooled and dehumidified air to an enclosure, the combination of a cooling element, means for conveying air in contact with the cooling element and to the enclosure, means for varying the flow of air so as to supply air from the cooling element to the enclosure at a relatively high rate or at a relatively low rate, means for supplying cooling fluid

to the cooling element, humidity-responsive means for controlling the cooling fluid supply means to supply cooling fluid to the cooling element and the flow-varying means to provide a relatively low rate of air supply upon demand for dehumidification, and means operable in response to a predetermined maximum temperature to control the cooling fluid supply means to supply cooling fluid to the cooling element and the flow-varying means to provide a relatively high rate of air supply independently of the action of said humidity-responsive means.

13. In air conditioning apparatus for an enclosure, the combination of means for cooling air and delivering the same to the enclosure, said cooling means being adjustable from a first condition of operation to a second condition of operation to increase the ratio of latent heat removal to sensible heat removal, means responsive to a high humidity and a temperature between predetermined maximum and minimum temperatures for effecting operation of said air-cooling means under said second condition, means responsive to a temperature above said predetermined maximum temperature for effecting operation of said cooling means under said first condition independently of the action of said humidity-responsive means, and means responsive to a temperature below said predetermined minimum temperature for terminating operation of said cooling means independently of the action of said humidity-responsive means.

EDWARD R. WOLFERT.