March 22, 1938. D. W. McLENEGAN 2,112,038

AIR CONDITIONING SYSTEM

Filed May 5, 1936 2 Sheets-Sheet 1

Fig. 1.

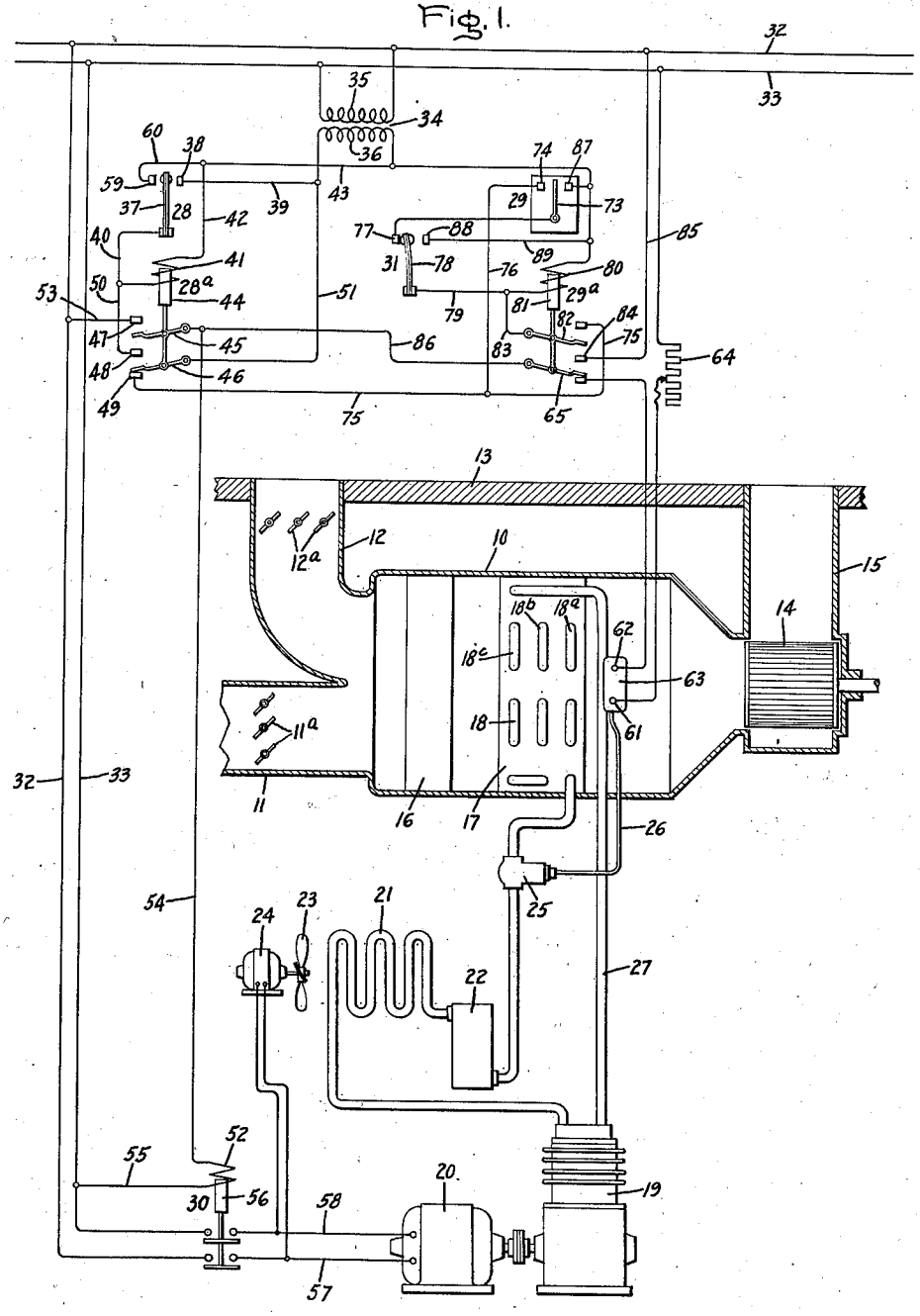


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Fig. 2.

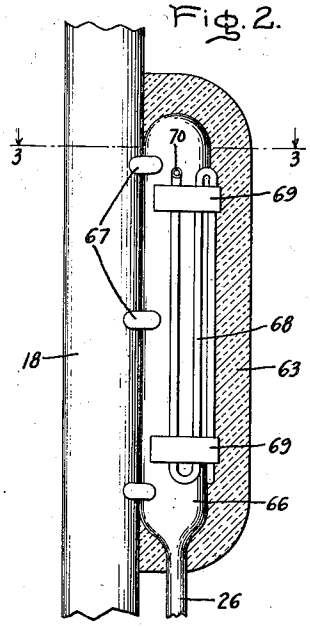



Fig. 3.

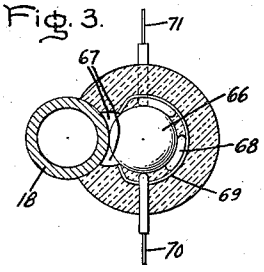
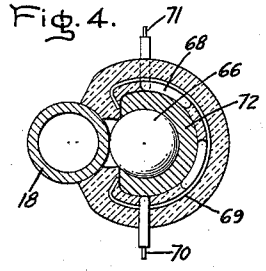



Fig. 4.

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# UNITED STATES PATENT OFFICE

2,112,038

## AIR CONDITIONING SYSTEM

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Application May 5, 1936, Serial No. 77,984

9 Claims. (Cl. 62—6)

My invention relates to air conditioning systems for cooling and dehumidifying the air within auditoriums, rooms and other enclosures.

It is an object of my invention to provide a system for cooling and dehumidifying the air within an enclosure including a cooling coil and an improved arrangement for readily changing the supply of cooling medium to vary the effective cooling surface of the coil in accordance with the temperature and humidity conditions of the air in the enclosure.

Another object of my invention is to provide a system for cooling and dehumidifying the air within an enclosure including a cooling coil and having a thermostatically operated valve for controlling the admission of refrigerant to the cooling coil and an arrangement for varying the ambient surrounding the control bulb of the valve to vary the length of the portion of the coil containing superheated refrigerant vapor.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawings in which Fig. 1 is a diagrammatic illustration of an air conditioning system embodying my invention; Fig. 2 is an enlarged detail view of the thermostatic bulb and heating coil therefor shown in Fig. 1; Fig. 3 is a sectional view on the line 3—3 of Fig. 2; and Fig. 4 is a sectional view of a modified form of the bulb and heater, shown in Fig. 2.

Referring now to the drawings, in Fig. 1 I have shown an air conditioning system comprising a casing 10 arranged to receive fresh air through a duct 11 and air from the room to be conditioned through a duct 12 which passes through a wall 13 of the room. The fresh air and the room air are mixed in the casing 10 and are drawn therethrough by operation of a fan 14 arranged at the discharge side of the casing. The amounts of fresh air and room air admitted to the casing are determined by adjustable dampers 11*a* and 12*a* respectively. The conditioned air is returned to the room through a duct 15 passing through the wall 13. A filter 16 is provided in the casing to remove dust and other impurities from the air, and the air is cooled by passing through a cooling element 17 arranged in the casing and comprising a sinuous coil 18 having a plurality of turns arranged in three banks extending entirely across the casing in the path of the air. Coil 18 is preferably of the type having a plurality of fins for providing a large heat absorbing area. The coil 18 is connected in the circuit of a mechanical refrigerating machine including a compressor 19 driven by a motor 20, a condenser 21 and a liquid receiver 22. Gaseous refrigerant is compressed in the compressor 19 and is discharged into the condenser 21 where it is cooled and liquefied by air circulated thereover by a fan 23 driven by a motor 24 connected across the motor 20. The condensed refrigerant collects in the liquid receiver 22 and is supplied to the coil 18 by operation of an expansion valve 25. The refrigerant is preferably admitted to the coil 18 so that it flows through the banks 18*a*, 18*b*, and 18*c* of the coil in succession in the opposite direction from that of the flow of air through the duct 10. The air thus passes from the least cold to the coldest portion of the coil. Refrigerant vapor is withdrawn from the coil 18 through a conduit 27 and is returned to the compressor 19. The valve 25 is of the well known thermostatically operated type and is provided with a thermostatic element such as a bulb containing a volatile liquid and mounted in heat exchange relation with the suction side of the coil 18. The bulb is connected with a valve operating bellows in the valve casing through a tube 26, in order to control the admission of refrigerant to the coil 18, in response to the temperature of the gaseous refrigerant withdrawn from the coil.

The refrigerating machine is controlled by a thermostat 28 having a relay 28*a* and being responsive to the temperature of the air in the room and by a humidostat 29 having a relay 29*a* and being responsive to the relative humidity of the air in the room. The thermostat 28 is arranged to control a switch 30 in the power supply line of the motor 20. Should the humidity of the air in the room be abnormally high the temperature of the air in the room may be reduced sufficiently to satisfy the thermostat 28 before the humidity has been reduced the desired amount to provide maximum comfort for the occupants of the room. In such cases it is desirable further to dehumidify the air, but any substantial decrease of the temperature of the air in the room must be avoided in order to maintain a comfortable temperature for the occupants of the room. However, it may be permissible to continue the cooling action at a reduced rate in order that the humidity may be further reduced.

In most air conditioned spaces some of the heat which must be removed by the air conditioning

system originates within the room itself. For example, occupants, electric lights, motors and other heat producing appliances and also the sun's rays entering through the windows, all generate heat within the room. It is necessary that the heat from such internal sources be removed from the room before any reduction of the temperature in the room below that of the outdoor air can be accomplished. It is evident, therefore, that part of the capacity of the cooling system must be devoted to the removal of heat from these internal sources. In air conditioning systems in which the internal heat of the space to be conditioned must be removed a small portion of cooled air may be circulated continuously without reducing the total sensible heat of the air in the space to be conditioned. It is possible in such systems to produce a substantial amount of dehumidification with only sufficient sensible cooling to offset the effect of the internal heat sources in the room so that dehumidification may be accomplished without reduction of the dry bulb temperature of the air in the room.

If the thermostat 28 is satisfied due to the reduction of the temperature of the air of the room to a predetermined low value before the humidity has been reduced to satisfy the humidostat 29, the humidostat will take over the control of the motor 20 and continue the operation of the motor until the humidostat is satisfied or until a minimum allowable temperature of the air in the room has been reached as determined by a low temperature limit thermostat 31. When the motor is under the control of the humidostat the supply of refrigerant to the coil is reduced and consequently, an increased percentage of the total coil length is filled with superheated refrigerant gas. With the flow of refrigerant restricted the balance of heat transfer capacity between the coil and the compressor is changed so that a lower refrigerant pressure is maintained in the coil. At this lower pressure the saturation temperature of the refrigerant is lower and the surface temperature of the coil is, therefore, lower in that portion of the coil in which the gas is not superheated. The dehumidification accomplished by this cold portion of the coil is increased as compared with the dehumidification during the normal operation of that portion but the total sensible heat removed from the air by the coil is reduced.

The above described arrangement for effecting a control of temperature and humidity by modifying the operation of the refrigerant supply controlling device in accordance with the humidity of the air in an enclosure is not my invention, but is the invention of Edward W. Roessler, and is described and claimed in his copending application Serial No. 77,949, filed May 5, 1936, and assigned to the General Electric Company, assignee of my present invention.

When it is desired to operate the air conditioning system illustrated in Fig. 1, electric energy is supplied to lines 32 and 33. This energizes a transformer 34 having a primary winding 35 and a secondary winding 36. If the temperature of the air in the room rises to a predetermined value a bimetallic strip 37 of the thermostat 28 engages a contact 38 and closes a circuit from one side of the secondary 36 through a connection 39, the strip 37 and a connection 40 to a coil 41 of relay 28a and thence back to the other side of the secondary 36 through a connection 42 and a line 43. The coil 41 will thereby be energized and will pick up an armature 44 of the relay 28a, raising arms 45 and 46 of the relay into engagement with contacts 47 and 48, respectively, and breaking engagement between the arm 46 and a contact 49. The raising of arm 46 closes a holding circuit for the coil 41 through connections 50 and 51, thereby maintaining the coil energized even though the strip 37 should move out of engagement with the contact 38. The raising of the arm 45 closes a circuit of a coil 52 of the switch 30 from line 32 through a connection 53, arm 45, a line 54 to the coil and thence back to line 33 through a connection 55. The energization of coil 52 picks up an armature 56 of switch 30 thereby closing the switch and connecting motor leads 57 and 58 to lines 32 and 33, respectively. The motor is thus energized to operate the compressor 19 and supply refrigerant to the coil 18. The operation of the motor will continue until a predetermined low temperature of the air in the room has been reached when the bimetallic strip 37 will engage a contact 59. This short-circuits the relay coil 41 through connections 42 and 60, strip 37 and connection 40, thereby deenergizing the coil and causing relay 28a to drop out and break the circuit of coil 52 to open switch 30. The motor 20 is thereby deenergized and the supply of refrigerant to the coil 18 discontinued.

When the air conditioning system is operating as just described the valve 25 is set to maintain a minimum temperature of the refrigerant withdrawn from the coil 18. In other words, a minimum length of the coil is maintained filled with superheated refrigerant vapor while the major portion of the coil contains saturated vapor and liquid refrigerant and is effective for dehumidifying the air passing over the coil and for substantially reducing the sensible heat of the air in the room.

It has been pointed out above that by operating only a portion of the cooling coil at low temperature, while the remaining portion contains superheated refrigerant vapor, the humidity may be decreased without substantially decreasing the sensible heat of the air in the room. This further reduction of humidity is accomplished, as has already been stated, by arranging the room humidostat so that it will take over operation of the refrigerating machine in the event that the humidity is still too high after the room thermostat is satisfied. I, therefore, provide a small heating coil adjacent the thermostatic element or bulb of valve 25 in order to vary the temperature of the bulb and modify its control effect. Under normal operating conditions in response to the room thermostat this heater is maintained energized so that only a relatively small amount of heat need be supplied to the bulb from the refrigerant withdrawn from the coil 18 in order to open the valve 25 and admit refrigerant to the coil. The coil is thereby maintained with a minimum length thereof containing superheated refrigerant vapor.

An arrangement of a refrigerator evaporator with a control having a heating element associated with the temperature responsive member thereof to provide a plurality of operating temperatures of the evaporator is not my invention, but is the invention of Ernest Zurcher and is described and claimed in his Patent No. 2,060,777, dated Nov. 10, 1936, and assigned to the General Electric Company, the assignee of this present application.

When the control of the refrigerating system

is taken over by the humidostat the heating coil is deenergized and all the heat applied to the control bulb necessary to operate the valve 25 must be received from the refrigerant withdrawn from the coil 18. The vapor withdrawn from the coil 18 must now attain a higher temperature before the expansion valve will operate to admit refrigerant to the coil and obviously a greater length of the coil will be maintained filled with superheated vapor and a relatively small portion of the coil will be utilized at a low temperature to dehumidify the circulated air.

Referring again to Fig. 1, terminals 61 and 62 of a heating coil arranged in a cover 63 about the bulb of the expansion valve 25 are connected in a circuit including a variable resistor 64, an arm 65 of relay 29a and the arm 45 of relay 28a. This circuit is closed whenever relay 28a is energized by the room thermostat to raise the arm 45. It is, therefore, energized whenever the control of the refrigerating machine is taken over by the room thermostat. Whenever the arm 65 is raised in response to operation of the room humidostat 29 the heating coil is deenergized and, therefore, a minimum length of the cooling coil is utilized for dehumidifying whenever the refrigerating machine is operated in response to the humidostat. The length of the portion of the coil 18 which is maintained filled with superheated refrigerant vapor during normal operation of the refrigerating machine may be varied by adjusting the rheostat 64 so that if desired the normal rate of cooling may be varied thereby.

In Figs. 2 and 3, I have indicated at 66 the bulb of the thermostatic expansion valve 25. This bulb is secured in good heat exchange relatinship to the suction side of the coil in any suitable manner, such as by soldering as indicated at 67. The heater previously referred to comprises an insulated heating wire 68 secured closely about the bulb 66 by spring clips 69. Ends 70 and 71 of the heater 68 are secured to the terminals 61 and 62 in any suitable manner, and the cover 63 which comprises a block of insulating material completely surrounding the bulb 66 and adjacent portions of the cooling coil 18 holds the heating wire 68 in contact with the bulb 66. Whenever the circuit of the heating wire 68 is closed and the wire heated the temperature of the bulb 66 is raised and a certain amount of liquid is vaporized therein, thereby changing the pressure in the bellows of the expansion valve; when the circuit is opened the bulb 66 quickly cools down to the temperature of the coil 18 adjacent thereto. Should it be desired to delay the heating effect of the wire 68 after the wire is energized a body of metal may be provided between the wire and the bulb which will have a heat storage effect. In Fig. 4 I have shown the thermostatic bulb 66 provided with a body of metal 72 secured to the bulb between the bulb and the heater 68, in order to obtain this "flywheel" or heat storage effect.

During the operation of the air conditioning system shown, should the humidity of the room still be above the desired value after the thermostat 28 has been satisfied, the humidostat 29 will be in position to control the motor and the relay 29a will operate to deenergize the heating wire 68 and to continue the operation of the refrigerating machine. When the humidity is too high a movable member 73 of humidostat 29 is in engagement with a contact 74 establishing a circuit from one side of the secondary 36, through the connection 51, arm 46 of relay 28a, a line 75, a connection 76, the member 73, a contact 77 and a bimetallic strip 78 of thermostat 31, and a connection 79 to a coil 80 of relay 29a and back to the other side of the secondary 36 through the line 43. This energizes the coil 80, raises an armature 81 of the relay 29a and lifts the arm 65 and an arm 82, thereby breaking the circuit of the heating coil 68 and closing a holding circuit for the coil 80 from line 75 through arm 82 and a connection 83 to maintain the relay 29a in its raised position even though the movable member 73 moves out of engagement with the contact 74. In its raised position the arm 65 engages a contact 84 closing a circuit from line 32 through a connection 85, arm 65, a connection 86 and line 54 to coil 52 and thence to line 33 through the connection 55 thereby energizing coil 52 and operating switch 30 to continue operation of the motor 20 of the refrigerating machine and supply refrigerant to the coil 18. Since the heating wire 68 is now deenergized a greater amount of heat must be received by the bulb 66 from the vapor withdrawn from the coil 18 in order to actuate the valve 25 and, consequently, the vapor in a greater portion of the coil 18 is maintained superheated, and a smaller portion of the coil is available for operation at a low temperature to dehumidify the air passing through the casing 10. Since a larger portion of the coil is maintained filled with superheated refrigerant vapor the temperature of the air passing through the casing 10 will not be decreased as much as during normal operation of the system. However, since a portion of the coil is still maintained at a low temperature some moisture will be abstracted from the air and the air will be further dehumidified without substantial decrease in the sensible heat of the air in the room.

The operation of the refrigerating machine under control of the humidostat will continue until the humidity has been reduced to a desired amount or until the temperature of the air has reached a minimum permissible value consistent with comfort. Should the humidostat be satisfied the movable member 73 will engage a contact 87 thereby short-circuiting the coil 80 through connection 79, strip 78, movable member 73 and a portion of line 43, thereby causing relay 29a to drop out and discontinue operation of the motor 20 by deenergizing coil 52 and opening switch 30. Should the temperature of the air in the room reach the minimum permissible temperature before the humidostat 29 is satisfied the strip 78 will engage a contact 88 and short-circuit the coil 80 through connection 79, strip 78 and a connection 89, thereby deenergizing the relay 29a and stopping the operation of the refrigerating machine. Should the temperature of the room for some reason increase until the thermostat 28 calls for cooling, the control of the refrigerating machine will be transferred from the humidostat 29 to the thermostat 28, since the operation of the thermostat will raise the arm 46 of the relay 28a thereby breaking the circuit to humidostat 29 causing the relay 29a to drop out and thereby again energizing the heating coil 68 through the arm 65. The control of the system in response to the room thermostat, therefore, takes precedence over the control in response to the humidostat.

It will be apparent from the foregoing that I have provided an air conditioning system for regulating both the temperature and humidity of the air within an enclosure and including a simple and improved arrangement for varying

the effective cooling surface of the refrigerating coil.

While I have disclosed a particular embodiment of my invention, various modifications will occur to those skilled in the art and I do not, therefore, desire my invention to be limited to the construction shown and described and I intend in the appended claims to cover all modifications thereof which do not depart from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A system for conditioning the air within an enclosure including a cooling element, means for supplying cooling medium to said element and for withdrawing cooling medium from said element, a valve for controlling the supply of cooling medium to said element, means responsive to the temperature of the cooling medium withdrawn from said element for actuating said valve to maintain a predetermined substantially constant temperature of the cooling medium withdrawn from said element, said temperature responsive means including a temperature responsive element arranged in heat exchange relationship with the outlet side of said cooling element subject to the temperature of the cooling medium withdrawn from said cooling element, and means responsive to a condition of the air within said enclosure and arranged to vary the temperature of said temperature responsive element for modifying the operation of said temperature responsive means to maintain a predetermined different substantially constant temperature of the cooling medium withdrawn from said element.

2. A system for conditioning the air within an enclosure including a cooling coil, means for supplying liquid refrigerant to said coil and for withdrawing vaporized refrigerant from said coil, a valve for controlling the supply of liquid refrigerant to said coil, means responsive to the temperature of the vaporized refrigerant withdrawn from said coil and actuating said valve for maintaining superheated the vaporized refrigerant in a predetermined length of said coil, said temperature responsive means including a temperature responsive element secured in heat exchange relationship with the outlet side of said coil and subject to the temperature of the vaporized refrigerant withdrawn from said coil, and means responsive to the humidity of the air within said enclosure and arranged to vary the temperature of said temperature responsive element for modifying the operation of said temperature responsive means to maintain superheated the vaporized refrigerant in a different predetermined length of said coil.

3. A system for conditioning the air within an enclosure including a cooling coil, means for supplying liquid refrigerant to said coil and for withdrawing vaporized refrigerant from said coil, a valve for controlling the supply of liquid refrigerant to said coil, means responsive to the temperature of the vaporized refrigerant withdrawn from said coil and actuating said valve for maintaining superheated the vaporized refrigerant in a predetermined length of said coil, said temperature responsive means including a bulb containing volatile liquid and secured in heat exchange relationship with the outlet side of said coil subject to the temperature of the vaporized refrigerant withdrawn from said coil, and means responsive to the humidity of the air within said enclosure and arranged to vary the temperature of said bulb for modifying the operation of said temperature responsive means to maintain superheated a predetermined different length of said coil.

4. A system for conditioning the air within an enclosure including a cooling coil, means for supplying liquid refrigerant to said coil and for withdrawing vaporized refrigerant from said coil, a valve for controlling the supply of liquid refrigerant to said coil, means responsive to the temperature of the vaporized refrigerant withdrawn from said coil for actuating said valve to maintain superheated the vaporized refrigerant in a predetermined length of said coil, said temperature responsive means including a temperature responsive element secured in heat exchange relationship with the outlet side of said coil subject to the temperature of the vaporized refrigerant withdrawn from said coil, means including a heating element for determining the temperature of said temperature responsive element, means for energizing said heating element, and means responsive to the humidity of the air within said enclosure and arranged to vary the energization of said heating element for modifying the operation of said temperature responsive means to maintain superheated the vaporized refrigerant in a different predetermined length of said coil.

5. A system for conditioning the air within an enclosure including a cooling coil, means for supplying liquid refrigerant to said coil and for withdrawing vaporized refrigerant from said coil, a valve for controlling the supply of liquid refrigerant to said coil, means responsive to the temperature of the vaporized refrigerant withdrawn from said coil and actuating said valve for maintaining superheated the vaporized refrigerant in a predetermined length of said coil, said temperature responsive means including a bulb containing a volatile liquid and secured in heat exchange relationship with the outlet side of said coil subject to the temperature of the vaporized refrigerant withdrawn from said coil, means including a heating element for determining the temperature of said bulb, means for energizing said heating element, and means responsive to the humidity of the air within said enclosure and arranged to vary the energization of said heating element for modifying the operation of said temperature responsive means to maintain superheated a different length of said coil.

6. A system for cooling the air within an enclosure including a cooling element, means for supplying liquid refrigerant to said element and for withdrawing vaporized refrigerant from said element, means including a valve for controlling the supply of liquid refrigerant to said element, means including a thermostatic element responsive to the temperature of the vaporized refrigerant withdrawn from said cooling element for actuating said valve to maintain a predetermined substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, means including a heating element arranged adjacent said thermostatic element and modifying the operation of said temperature responsive means for maintaining a predetermined different substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, and means for selectively controlling said last two means.

7. A system for cooling the air within an enclosure including a cooling element, means for supplying liquid refrigerant to said element and

for withdrawing vaporized refrigerant from said element, means including a valve for controlling the supply of liquid refrigerant to said element, means including a thermostatic element responsive to the temperature of the vaporized refrigerant withdrawn from said cooling element for actuating said valve to maintain a predetermined substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, means including a heating element arranged adjacent said thermostatic element and modifying the operation of said temperature responsive means for maintaining a predetermined different substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, a body of heat insulating material arranged about said heating element and said thermostatic element, and means for selectively controlling said last two means.

8. A system for cooling the air within an enclosure including a cooling element, means for supplying liquid refrigerant to said element and for withdrawing vaporized refrigerant from said element, means including a valve for controlling the supply of liquid refrigerant to said element, means including a thermostatic element responsive to the temperature of the vaporized refrigerant withdrawn from said cooling element for actuating said valve to maintain a predetermined substantially constant temperature of the vaporized refrigerant withdrawn from said element, means including a heating element for supplying heat to said thermostatic element, means varying the energization of said heating element and modifying the operation of said temperature responsive means for maintaining a predetermined different substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, and means including a body of heat conducting material arranged between said thermostatic element and said heating element for delaying the effect of a change of energization of said heating element.

9. A system for cooling the air within an enclosure including a cooling element, means for supplying liquid refrigerant to said element and for withdrawing vaporized refrigerant from said element, means including a valve for controlling the supply of liquid refrigerant to said element, means including a thermostatic element responsive to the temperature of the vaporized refrigerant withdrawn from said cooling element for actuating said valve to maintain a predetermined substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, means including a heating element for supplying heat to said thermostatic element, means varying the energization of said heating element and modifying the operation of said temperature responsive means for maintaining a predetermined different substantially constant temperature of the vaporized refrigerant withdrawn from said cooling element, means including a body of heat conducting material arranged between said thermostatic element and said heating element for delaying the effect of a change of energization of said heating element, and a body of heat insulating material arranged about said heating element and said thermostatic element.

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