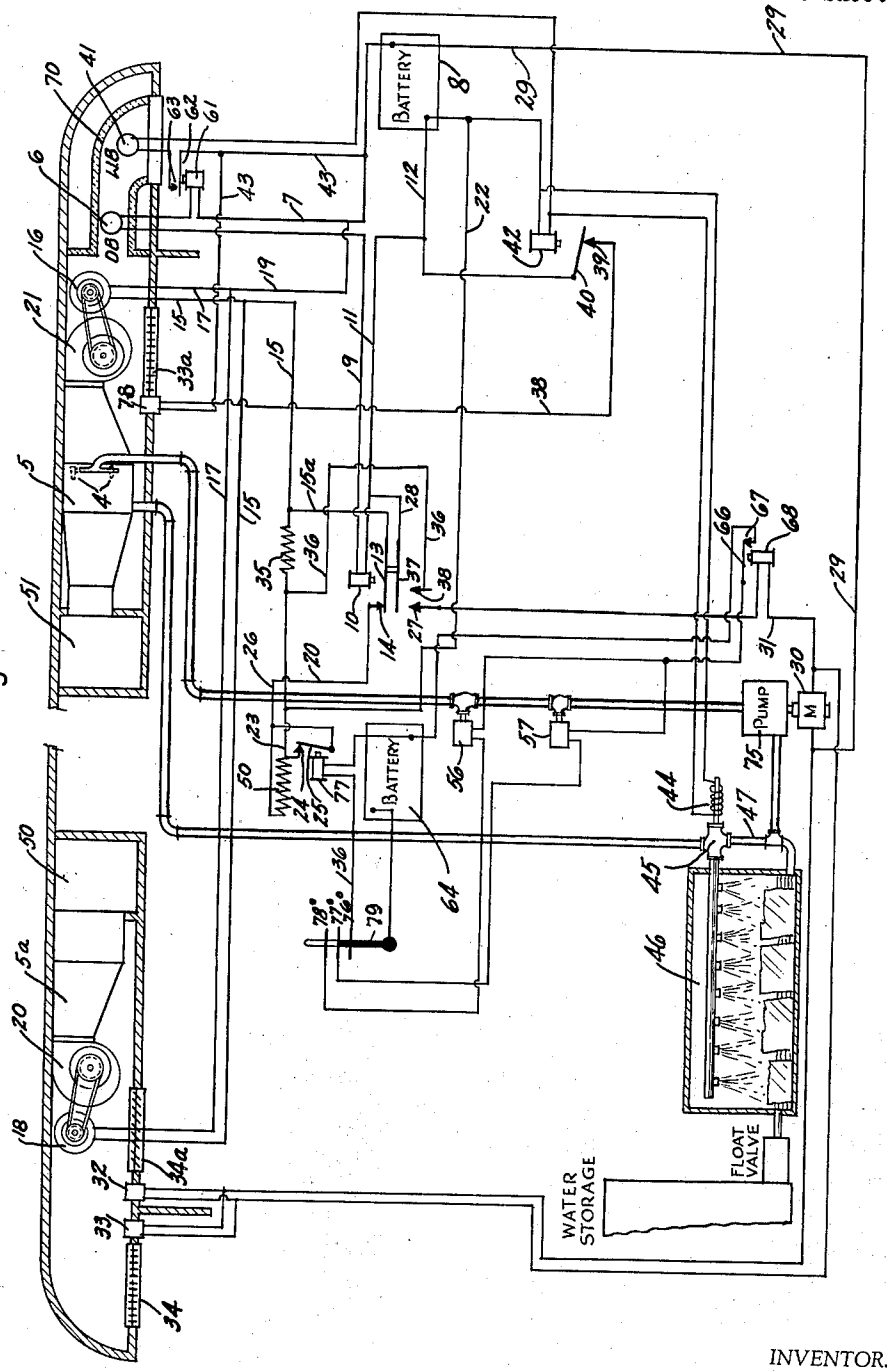
March 12, 1940. S. M. ANDERSON 2,193,152

AIR CONDITIONING SYSTEM UTILIZING REFRIGERATION

Original Filed Jan. 21, 1937 2 Sheets-Sheet 1

Fig-1



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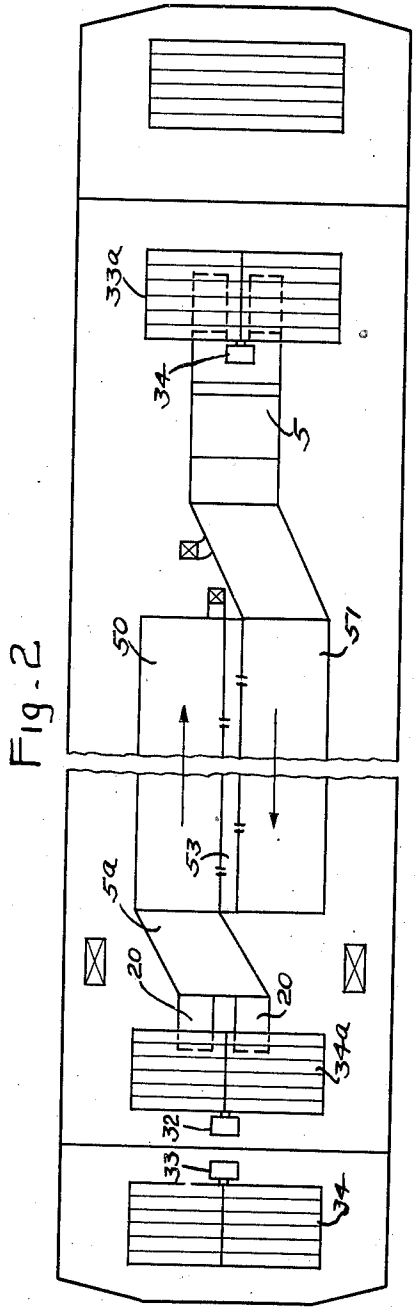

Fig. 2

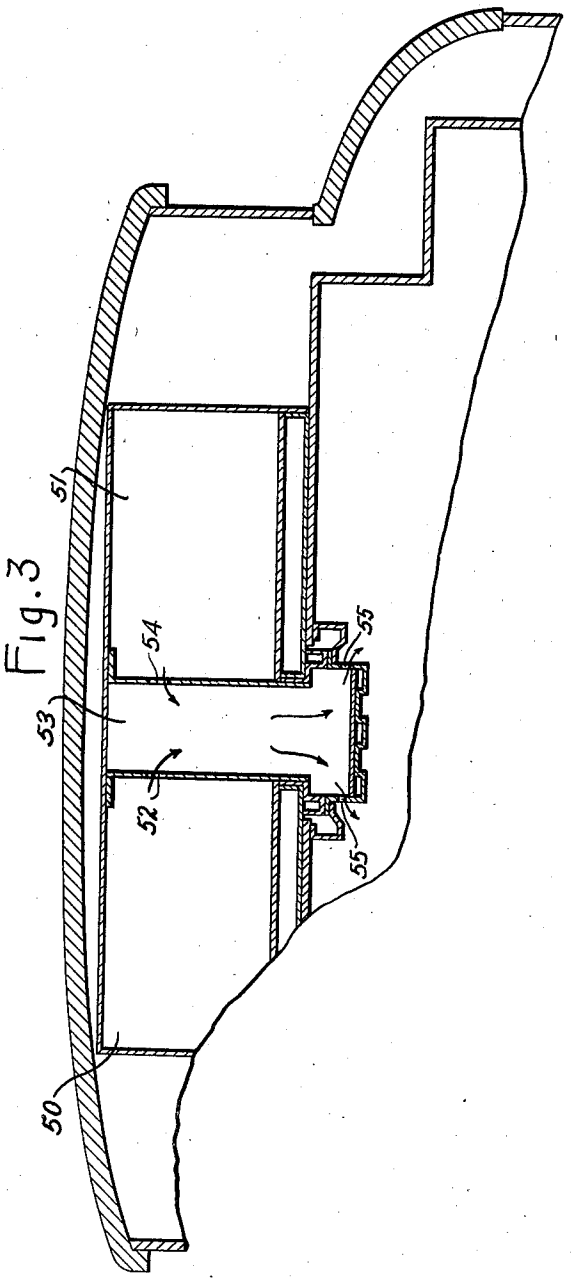

Fig. 3

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AIR CONDITIONING SYSTEM UTILIZING REFRIGERATION

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11 Claims. (Cl. 236—44)

This invention relates to air conditioning systems utilizing refrigeration and relates more particularly to an air conditioning system for passenger vehicles, combining evaporative cooling with cooling by refrigeration.

The passenger cars on some railroad lines on one continuous trip, pass through regions in which, in summer, different demands are made upon the air conditioning equipment. For example, a train may first pass through a region having a high wet bulb as well as a high dry bulb temperature, requiring considerable refrigerating energy for the cooling and dehumidification of the air. The train may next pass through a region having such a low wet bulb temperature that evaporative cooling may be effectively employed. Then, at night, a sufficient cooling effect may be secured by forcing an increased volume of outside air through the car.

According to this invention, a spray cooling system is supplied with refrigeration when conditions require such; is operated in evaporative cooling when effective, and when effective the sprays are discontinued and the cooling effect is secured by the circulation of an increased volume of outside air. Automatic controls responsive to the conditions of the fresh air entering the system, are provided for changing the method of operation of the conditioner and for maintaining the desired indoor conditions, with a minimum of equipment and without operating difficulties.

An object of the invention is to provide means and methods for effective air conditioning with and without refrigeration.

Another object of the invention is to provide a switching arrangement with controls for the effective conditioning of air utilizing refrigeration when needed and dispensing with refrigeration when not needed.

Other objects of the invention will be apparent from the following description taken together with the drawings.

The invention will now be described with reference to the drawings of which:

Fig. 1 is a diagrammatic view of the invention as applied to a railroad passenger car;

Fig. 2 is a diagrammatic view of the interior of a railroad passenger car equipped according to this invention, and

Fig. 3 is a view looking from one end with ends of car and ducts removed, into the car of Fig. 2.

The system illustrated was designed for a particular railroad line extending across a particular section of North America. The design was based upon the knowledge that during one period of travel the maximum outdoor temperatures to be expected were 95° dry bulb and 72° wet bulb. With such temperatures, it was determined that a sleeping car with 50 passengers could be maintained comfortable at a 77° dry bulb temperature and 62% relative humidity by the circulation of 2220 cubic feet per minute of 40% outdoor air and 60% recirculated air cooled by passage through water sprays chilled by an ice meltage at a rate of 5 tons per 24 hours, in an ice chamber.

During another period of travel the outdoor dry bulb temperature remains at 95° but the outdoor wet bulb temperature decreases to 61°. This permits evaporative cooling; the spray water is bypassed around the ice chamber, and all outside air passes through the conditioner. The spray conditioner is so designed that the recirculated spray water is chilled by evaporative cooling to 61° and the air leaving the conditioner will be cooled to about 62°. The discharge of this air into the car maintains the desired standard of 77° and 62% relative humidity.

During another period of travel the outdoor temperature at times as at night, drops to 72.8° dry bulb with 68.1° wet bulb. At such time, the sprays are discontinued and the fan system is converted to force 4,000 cubic feet per minute of outside air through the car. This maintains the car at 76° dry bulb and even though the relative humidity may rise as high as 76% inside the car, the effective temperature which is a measure of human comfort, is unchanged, and the air is comfortable.

Two thermostats mounted in the path of the fresh air entering the system, adapt the system for operation in a ventilating cycle when the dry bulb temperature of the fresh air is low enough; adapt the system for operation in an evaporative cooling cycle when the dry bulb temperature of the fresh air is not low enough for cooling by ventilation alone to be sufficient but the wet bulb temperature of the fresh air is below a predetermined point, and adapts the system for operation in a refrigerative cooling cycle when the temperature of the fresh air is such that cooling by ventilation and by evaporative cooling may not be sufficient.

The conditioner **5** in one end of the roof zone of the car is provided with the spray nozzles **4**, the fans **21**, the recirculated air dampers **33a** in an opening communicating with the passenger space, the insulated fresh air duct **70** providing fresh air from the car vestibule and in which are mounted the control thermostats **6** and **41**, and with the air discharge duct **51**.

The ice chamber 46 supplies ice water to the spray nozzles 4 during the refrigerative cooling cycle, and supplies recirculated water during the evaporative cooling cycle.

The ventilating unit 5a mounted in the other end of the car opposite the unit 5 comprises the fans 20, the fresh air dampers 34 in a fresh air opening connecting with a vestibule of the car, the recirculated air dampers 34a in an opening connecting with the passenger space, and the duct 50 which is arranged alongside the duct 51.

The ducts 50 and 51 discharge as shown by Figs. 2 and 3 into a common duct 53 which mixes the conditioned and non-conditioned air streams and diffuses them into the passenger space. During the ventilating cooling cycle, both units 5 and 5a supply fresh non-conditioned air into the passenger space. During the two cooling cycles, the fresh air dampers 34 to the unit 5a are closed so that the unit 5a supplies recirculated air which mixes with the cooled air prior to its discharge into the passenger space to provide the well known "by-pass" effect.

The operation of the system under automatic control will now be described with reference to Fig. 1.

Ventilating cycle

When the dry bulb temperature of the outside air is below a predetermined temperature, say 73° F., the necessary cooling effect may be secured by circulating relatively large quantities of outside air through the car. The thermostat 6, when the outside dry bulb temperature falls below the predetermined point, closes a circuit including the winding of the relay 61, the wire 7, battery 8, wire 9, the winding of the relay 10 and the wires 11 and 12.

The relay 10 pulls up the armature 13 against the contact 14 shunting the resistor 35 out of the circuit of the fans 20 and 21 to the battery 8. The circuit includes the armature 13, the wires 15 and 15a, the fan motors 16 and 18, the wires 17, the wire 19, the battery 8, the wires 22 and 23, the contact 24, the armature 25 and the wire 26 which connects to the contact 14.

This connects the fan motors 16 and 18 direct to the battery 8 so that they operate at full speed.

The armature 37 upon this energization of the relay 10 leaves the contact 38 and opens the circuit including the wires 28, 11 and 12, the battery 8, the wire 29, the pump motor 30, the wire 31, the winding of the relay 68, the contact 27 and the armature 37 thus preventing the operation of the pump 75.

The damper control motors 32 and 33 are connected to the pump motor 30 and when the pump motor 30 is deenergized, the motor 33 opens the fresh air dampers 34 and the motor 32 closes the recirculated air dampers 34a so that only fresh outside air is drawn in by the fans 20.

The fans 21 during this period also draw in their usual quantity of fresh air and also recirculated air, though if desired, the recirculated air dampers 33a may also be closed by their motor 78 during this ventilating cycle. During this cycle, if the air becomes too cold, the thermostat 79 opens the energizing circuit of the relay 77 causing the resistance 50 to be cut into the energizing circuit of the blower motors 16 and 18 to cause the blowers to revolve at a lower speed.

When the outside dry bulb temperature is too high for cooling by ventilation alone, the thermostat 6 acts to open the circuits which were previously described as being closed, and acts to close the circuits which have previously been described as being opened. The fans remain connected to the battery 8 but their circuit now includes the resistor 35, the return to the battery 8 formerly provided by the wire 15a, the armature 13, the contact 14 and the wires 20, 26 and 22 now being provided by the wire 36, the armature 37, the contact 38, the wires 11 and 12 to the battery. This places the resistor 35 in circuit with the fans and causes them to operate at reduced speed.

The pump 75 is started again and the fresh air dampers 34 to the fans 20 closed, and the recirculated air dampers 34a opened.

Evaporative cooling cycle

When the wet bulb temperature of the outside air is below a predetermined point, say 60° F., the thermostat 41 opens the circuit including the armature 62 and contact 63 of the relay 61, battery 8, and the relay 42, causing the armature 40 of the relay to fall against the contact 39 and close a circuit including the battery 8, the armature 40, the contact 39, the wire 38, the damper control motor 78, wire 43 and the battery 8. The motor 78 closes the dampers 33a so that only outside air enters the spray conditioner 5. At the same time, the solenoid 44, the winding of which is connected in shunt to the winding of the solenoid 42, is deenergized causing the valve 45 to discontinue the spraying of water upon the ice in the bin 46 and to open the by-pass pipe 47 so that during the evaporative cooling cycle, the water is by-passed around the ice bin.

Only outside air passes through the spray conditioner so that evaporative cooling is effective. The fans 20 supply recirculated air which mixes with the outside air after it is conditioned as will be explained later.

To prevent the system from attempting to operate in the evaporative cooling cycle and ventilating cooling cycle simultaneously as it might in the event that the wet bulb and dry bulb temperature of the air were both simultaneously below their predetermined control operating points, the relay 61 in series with the thermostat 6 is energized when the dry bulb temperature is below the selected temperature, and pulls up its armature 62 which with its associated contact 63 is in circuit with the wet bulb thermostat 41, to open this circuit.

Refrigerative cooling cycle

When both the wet bulb temperature and the dry bulb temperature of the outside air are above predetermined points, then cooling by ventilating or by evaporative cooling will not be sufficient so that the thermostats 6 and 41 act to cause the supply of refrigerated water to the sprays in the unit 5. As previously described, when the dry bulb temperature is above a predetermined point, the pump 35 is started, the fresh air dampers 34 in the inlet to the fans 20 are closed and the recirculated air dampers 34a are opened.

When the wet bulb temperature rises above a predetermined point, the thermostat 41 causes the relay 42 to be energized by the battery 8. The armature 40 is pulled up to leave the contact 39, and opens the energizing circuit including the battery 8 and the dampers control motor 78 which then opens the recirculated air damp-

ers 33a in the inlet to the unit 5. At the same time, the solenoid 44 which is connected in shunt to the relay 42, is energized to actuate the valve 45 causing the by-pass pipe 47 to be closed and the water returned from the conditioning unit 5 to be sprayed upon the ice in the ice bin 46.

During the cooling cycles, the fans 20 supply recirculated air which, with reference to Figs. 2 and 3, mixes with the conditioned air at its points of discharge into the car. The fans 20 draw during the evaporative cooling cycle and during the refrigerating cooling cycle, the operation of which will be described later, recirculated air through the dampers 34a and then discharge into the duct 50. The conditioned air from the unit 5 is discharged into the duct 51. The recirculated air is discharged from the duct 50 through the openings 52 into the mixing chamber 53 into which conditioned air enters through the openings 54 from the duct 51. The mixed recirculated air and conditioned air is discharged into the passenger space from the openings 55. Static pressure is built up in both ducts so that equal discharge throughout their length is obtained. The air is diffused and discharged with relatively low velocity into the car. By mixing the recirculated air and conditioned air prior to its discharge into the passenger space, greater air motion is obtained with less temperature difference between the air introduced into the passenger space, and the air in the passenger space.

During both cycles, the thermostat 79 controls the volume of spray water by adjusting the valves 56 and 57 in the water supply line to the unit 5. When the car temperature falls below say 78°, the thermostat acts to decrease the volume of water sprayed by throttling the valve 56. If the temperature continues to drop and falls below say 77°, the thermostat 79 acts to decrease further the water supply by throttling the additional valve 57. The valves 56 and 57 are connected in circuit with the battery 64 and the armature 66 and contact 67 of the relay 68 which relay is energized when the system is off the ventilating cycle by being connected in circuit with the pump motor 30.

The duct 70 leading from the vestibule of the car to the air conditioning unit 5 is insulated so that the wet and dry bulb thermostats 41 and 6 mounted thereon, respond to the condition of the outside air unchanged by sun effect upon the roof of the car, etc.

While one embodiment of the invention has been described for the purpose of illustration, it should be understood that the invention is not limited to the exact arrangement described, since many departures will suggest themselves to those skilled in the art, after having had access to this disclosure.

I claim:

1. Air conditioning apparatus for a railroad passenger car comprising a blower located in one end of the car, an air cooler located in the other end of the car, means forming fresh and recirculated air inlets into said blower, means forming fresh and recirculated air inlets into said cooler, means for mixing the air from said blower and from said cooler prior to discharge into the passenger space, cooling means for supplying a fluid to said cooler, and means for closing the fresh air inlet to said blower when said fluid is supplied to said cooler.

2. Air conditioning apparatus for a railroad passenger car comprising a blower located in one end of the car, an air cooler located in the other end of the car, means forming fresh and recirculated air inlets into said blower, means forming fresh and recirculated air inlets into said cooler, means for mixing the air from said blower and from said cooler prior to discharge into the passenger space, cooling means for supplying a fluid to said cooler, means for closing the fresh air inlet to said blower and for initiating said cooling means when cooling is required, and means for discontinuing said cooling means and for opening the fresh air inlet to said blower when the dry bulb temperature of the outside air is below a predetermined point.

3. Air conditioning apparatus for a railroad passenger car comprising a blower located in one end of the car, an air cooler located in the other end of the car, means forming fresh and recirculated air inlets into said blower, means forming fresh and recirculated air inlets into said cooler, means for mixing the air from said blower and from said cooler prior to discharge into the passenger space, cooling means for supplying a fluid to said cooler, means for closing the fresh air inlet and opening the recirculated air inlet to said blower and for initiating said cooling means when cooling is required, and means for discontinuing said cooling means and for opening the fresh air inlet and closing the recirculated air inlet to said blower when the dry bulb temperature of the outside air is below a predetermined point.

4. Air conditioning apparatus comprising a cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating refrigerating fluid to and from said cooler, means responsive to changes in the dry bulb temperature of the outside air entering said cooler for adjusting said last mentioned means for discontinuing the supply of fluid and for adjusting said air supplying means for decreasing the volume of recirculated air to said cooler when the dry bulb temperature of the outside air entering said cooler is below a predetermined point, and means responsive to changes in the temperature in the conditioned space for adjusting said air supplying means for increasing the volume of air supplied to said cooler when the temperature in said conditioned space is above a predetermined point.

5. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating water to and from said cooler, and means responsive to changes in the dry bulb temperature of the outside air for adjusting said last mentioned means for discontinuing the supply of water and for adjusting said first mentioned means for decreasing the volume of recirculated air supplied by said first mentioned means to said cooler and for increasing the volume of outside air supplied by said first mentioned means to said cooler when the dry bulb temperature of the outside air entering said cooler is below a predetermined point.

6. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating water to and from said cooler means responsive to changes in the dry bulb temperature of the outside air for adjusting said last mentioned means for discon-

tinuing the supply of water and for adjusting said first mentioned means for decreasing the volume of recirculated air to said cooler and for increasing the volume of outside air entering said cooler when the dry bulb temperature of the outside air entering said cooler is below a predetermined point, and means responsive to changes in the temperature in the conditioned space for adjusting said first mentioned means for increasing the volume of air entering said cooler when the temperature within said space is above a predetermined point.

7. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said said cooler, means for circulating water to and from said cooler, means responsive to changes in the dry bulb temperature of the outside air for adjusting said last mentioned means for discontinuing the supply of water and for adjusting said first mentioned means for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler when the temperature of the outside air entering said cooler is below a predetermined point, cooling means for cooling the water supplied to said cooler, and means responsive to the outside wet bulb temperature, said means responsive to changes in outside dry bulb temperature functioning to adjust said second mentioned means for initiating the supply of water to said cooler and to place the said first mentioned means and said water cooling means under the control of said outside wet bulb temperature responsive means when the dry bulb temperature of the outside air is above a predetermined point.

8. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating water to and from said cooler, cooling means for cooling the water supplied to said cooler, temperature responsive means responsive to changes in the dry bulb temperature of the outside air for adjusting said first mentioned means for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler, for adjusting said means for circulating water for discontinuing the supply of water and for adjusting said cooling means for discontinuing the cooling of the water when the dry bulb temperature of the outside air entering said cooler is below a predetermined point, and means responsive to the outside wet bulb temperature, said means responsive to changes in outside dry bulb temperature functioning to adjust said second mentioned means for initiating the supply of water to said cooler and to place the said first mentioned means and said water cooling means under the control of said outside wet bulb temperature responsive means when the dry bulb temperature of the outside air is above a predetermined point.

9. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating water to and from said cooler, means responsive to changes in the dry bulb temperature of the outside air for adjusting said last mentioned means for discontinuing the supply of water, means responsive to changes in the wet bulb temperature of the outside air for adjusting said first mentioned means for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler when the dry bulb and wet bulb temperatures of the outside air entering said cooler are below predetermined points, and cooling means for cooling the water supplied to said cooler, said means responsive to changes in the dry bulb temperature of the outside air functioning to adjust said second mentioned means for initiating the supply of water and said means responsive to changes in the wet bulb temperature functioning to adjust said first mentioned means for decreasing the volume of outside air and increasing the volume of recirculated air to said cooler, and for actuating said cooling means for cooling the water supplied to said cooler when the dry bulb and wet bulb temperatures of the outside air are above said respective predetermined points.

10. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating water to and from said cooler, means responsive to changes in the dry bulb temperature of the outside air for adjusting said last mentioned means for discontinuing the supply of water and for adjusting said first mentioned means for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler when the dry bulb temperature of the outside air entering said cooler is below a predetermined point, cooling means for cooling the water supplied to said cooler, said means responsive to changes in the dry bulb temperature of the outside air functioning to adjust said second mentioned means for initiating the supply of water when the dry bulb temperature of the outside air is above a predetermined point, and means responsive to changes in the wet bulb temperature of the outside air for adjusting said first mentioned means for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler and for discontinuing said cooling means when the wet bulb temperature of the outside air entering said cooler is below a predetermined point and the dry bulb temperature of the outside air entering said cooler is below a predetermined point.

11. Air conditioning apparatus comprising a spray cooler, adjustable means for supplying variable volumes of outside air and recirculated air from the space to be conditioned into said cooler, means for circulating water to and from said cooler, means responsive to changes in the dry bulb temperature of the outside air for adjusting said last mentioned means for discontinuing the supply of water and for adjusting said first mentioned means for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler when the dry bulb temperature of the outside air entering said cooler is below a predetermined point, cooling means for cooling the water supplied to said cooler, said means responsive to changes in the dry bulb temperature of the outside air functioning to adjust said second mentioned means for initiating the supply of water and to adjust said first mentioned means for decreasing the volume of outside air and increasing the volume of recirculated air to said cooler, when the dry bulb temperature of the outside air is above a predetermined point, and means including means responsive to changes in the wet bulb tempera-

ture of the outside air and including said means responsive to changes in the dry bulb temperature for increasing the volume of outside air and decreasing the volume of recirculated air to said cooler and for discontinuing said cooling means when the wet bulb temperature of the outside air entering said cooler is below and the dry bulb temperature of the outside air entering said cooler is below said respective predetermined points.

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