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AIR CONDITIONING SYSTEM

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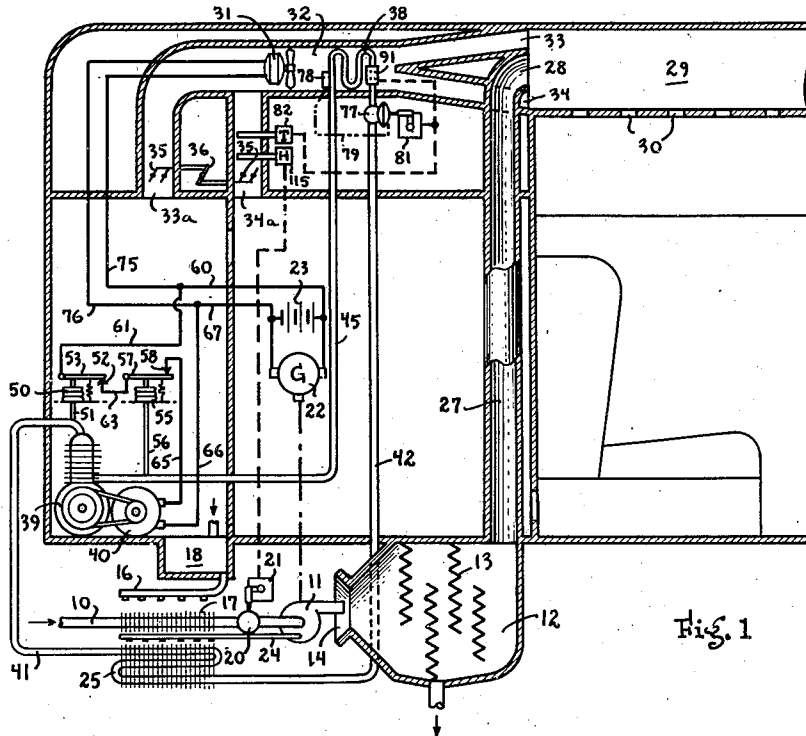


Fig. 1

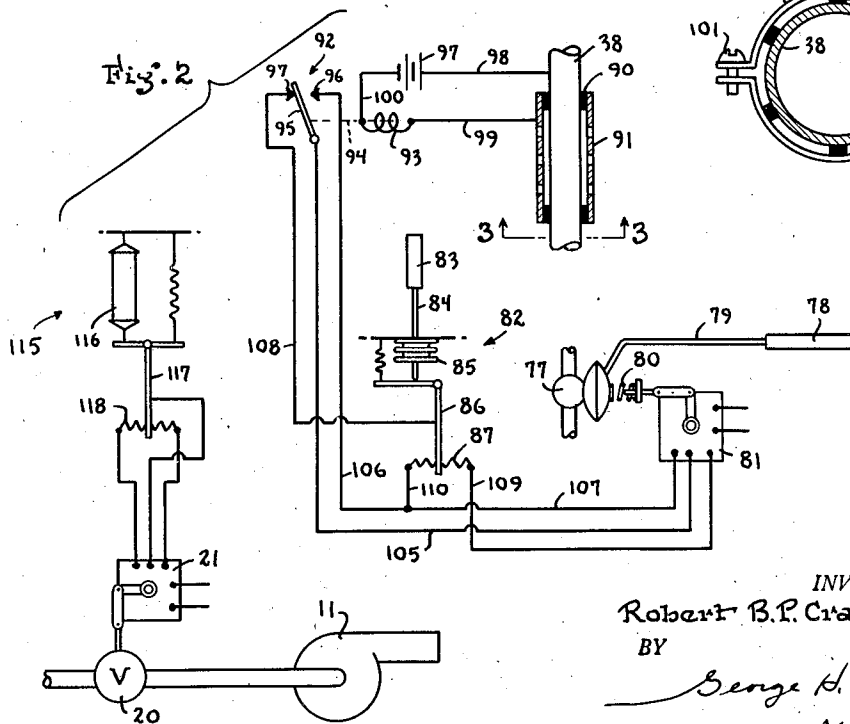


Fig. 3

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AIR CONDITIONING SYSTEM

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11 Claims. (Cl. 62—136)

This invention relates to an air conditioning system and while the invention is particularly adaptable in connection with railway car air conditioning, its principles are broadly applicable to air conditioning systems for all types of structures.

The invention is concerned primarily with producing cooling and dehumidifying and particularly, with maintaining air in a space at desirable conditions of humidity by means of expanding compressed air and separating the moisture therefrom. In railway car air conditioning, compressed air from the train line may conveniently be used for the purpose, the compressed air being expanded through a turbine and then having part of its moisture separated out in a separating chamber. Fresh air may be entrained with the air as it is expanded. Also, the invention contemplates that the power produced by the turbine be utilized to drive auxiliary equipment forming a part of the system. The invention also comprehends providing mechanical refrigeration means for performing sensible cooling of the air, the mechanical refrigerating apparatus being so controlled as to do only sensible cooling with the humidity being maintained at the proper level by controlling the amount of air being expanded through the turbine.

In accordance with the foregoing general precepts of my invention, its primary object is to provide an air conditioning system wherein humidity in a space is maintained by supplying relatively dry air which has been expanded through a turbine and passed through a moisture separating chamber and maintaining the temperature by effecting sensible cooling of the space air by means of mechanical refrigerating equipment.

Another object of the invention is to maintain temperature and humidity in a space by passing controlled volumes of air through a turbine to be expanded therein, separating moisture from the expanded air and maintaining the temperature by effecting sensible cooling of the air by means of mechanical refrigeration apparatus controlled in response to temperature.

Another object of the invention is to provide means for controlling a direct expansion refrigerating system so that it effects only sensible cooling, the controlled means acting to reduce the amount of refrigeration when moisture appears on the refrigerating coil, indicating that the coil has started to effect latent cooling.

Figure 1 is a cross-sectional view of the rear portion of a railway car illustrating a preferred

form of air conditioning system embodying my invention.

Figure 2 is a diagrammatic illustration of the control arrangements applying to the air conditioning system of Fig. 1.

Figure 3 is a cross-sectional view taken along the line 3—3 of Figure 2.

The present application is a division of my earlier filed application, Serial No. 261,487, filed March 13, 1939, Patent No. 2,304,151, issued December 8, 1942.

Referring to the drawing, an air conditioning system is shown in Figure 1 which, as shown, may be located in the end portion of a railway car. In this figure, compressed air from the train line or other suitable source flows through a pipe 10 to a turbine 11 located beneath the car, the air driving the turbine and expanding therein and being delivered to an eliminator or separator chamber 12 provided with a series of eliminating plates 13 for removing moisture from the air. The inlet of the chamber 12 through which the expanded air is delivered is provided with a suitable fresh air inlet opening 14 which is so formed that the air discharged from the turbine 11 will entrain fresh air which will flow through the opening 14 and mix with the expanded air from the turbine 11.

Prior to passing to the turbine 11, the compressed air in the line 10 is suitably cooled by passing through a spray from a series of spray nozzles 16, that portion of the pipe 10 located below the spray 16 being provided with a series of fins 17 spaced closely enough together so that water flowing thereover will be held thereon by capillary action between the fins, thus increasing the cooling effect of the water. The water to the spray 16 is delivered from a suitable storage tank 18 to which water is delivered from any suitable source and on a railroad train the water leaving wash basins, water fountains, etc., may be delivered to this tank 18 so that this water is put to a useful purpose. The compressed air which has now been reduced in temperature by the spray 16 flows to the turbine 11 under the control of a valve 20 operated by a proportioning motor 21 which is controlled in a manner to be later described. In order to utilize the energy given up by the compressed air in expanding in the turbine 11, this turbine may drive a generator 22 for supplying power to batteries 23 which in turn supply power to various portions of the air conditioning apparatus as will become apparent as the description proceeds. Condensate draining from turbine 11 goes by way of pipe 24 to refrigerant condenser

25, the condenser 25 consisting of finned tubes and the pipe 24 having separate nozzles so that the condensate is separated over the finned tubes.

The air leaving the turbine 11, which on expanding to atmospheric pressure has its temperature greatly reduced to a value below its dew-point, will produce a fine fog or mist in the chamber 12 when mixed with humid air entering at 14, and this air which is mixed with the fresh unconditioned air has this moisture removed by means of the eliminator plates 13 and the combination of the expanded air having a low dew-point with the fresh unconditioned air will produce a mixture of air having a low relative humidity. This air passes through a passage-way 27 within the rear compartment which leads to an outlet opening 28 communicating with another passageway 29 which may be located within the roof of the car and extending longitudinally thereof and provided with suitable downwardly directed openings 30 by means of which the air passes to the passenger space of the car. Return air is circulated through a path including the passenger space, rear compartment and chamber 28 of said car and mixed in the chamber 29 with the fresh conditioned air by means of a fan 31 located within a chamber 32 which has outlets 33 and 34 located above and below the conditioned air outlet 28 so that the air will be properly mixed with the fresh conditioned air. The chamber 32 has inlets 33a and 34a which may be located in the rear compartment of the car and the vestibule respectively and dampers 35 suitably interconnected by adjusting mechanism 36 are provided for regulating the flow of air through these return air inlets. These dampers may be adjusted in any suitable manner and for purposes of illustration have been shown as being manually adjusted and are so arranged that both dampers will be simultaneously opened or closed.

Located within the chamber 32 is a cooling coil 38 which is provided for removing sensible heat only from the recirculated air and this cooling coil forms the evaporator of a mechanical refrigerating system which includes a compressor 39 driven by a motor 40. The high pressure side of the compressor communicates by means of a pipe 41 with condenser 25 which in turn communicates by means of pipe 42 with the inlet of the evaporator 38. The outlet of the evaporator communicates with the inlet of the compressor by means of the pipe 45. The operation of the compressor as illustrated is controlled by a device responsive to the pressure on the high pressure side of the system and a device responsive to the pressure on the low pressure side of the system. For this purpose, a bellows 50 is connected by means of a pipe 51 with the pipe 41 connected to the high pressure side of the compressor, and the bellows 50 controls the position of an arm 53 which cooperates with a fixed electrical contact 52. The arrangement is such that as the head pressure on the compressor rises to a sufficiently high value the bellows 50 will expand and move the arm 53 out of engagement with the contact 52 and upon a drop in the head pressure to a predetermined value, the bellows will contract and the arm 53 will move back into engagement with the contact 52. A second bellows 55 is connected by means of a pipe 56 with the suction line 45 leading to the compressor inlet and this bellows controls the positions of an arm 57 with respect to a fixed electrical contact 58. The arrangement is such that upon a drop in suction pressure to a predetermined value, the contraction of the bel-

lows 55 permits the arm 57 to move downwardly out of engagement with the contact 58, and upon a rise in suction pressure to a predetermined value the bellows 55 will expand and move the arm 57 back into engagement with the contact 58. The arms 53 and 57 are normally biased in a clockwise direction by coil springs as shown.

The battery 23 is provided for supplying power to the compressor and motor 40 and when the switch arms 53 and 57 are in engagement with their respective contacts, power is supplied to the motor 40 as follows: from one side of battery 23 through conductors 60 and 61, arm 53, contact 52, conductor 63, arm 57, contact 58, conductor 65, motor 40, and conductors 66 and 67 back to the other side of the battery 23. Accordingly, it will be seen that the compressor is placed in operation whenever the suction pressure is above a predetermined value and the head pressure is below a predetermined value. But should the head pressure become high enough or the suction pressure become low enough the circuit to the compressor motor will be interrupted and the compressor will stop operating. The suction pressure controller will be set at such a value as, for example, 50 lbs. to 65 lbs., that during normal operation of the system the temperature of evaporator 38 will not become low enough to cause condensation of moisture thereon as it is intended that the evaporator effect only sensible cooling of the air, but will be between 55° F. and 70° F., for example.

The condenser 25 is preferably so located that the spray 16 will also cool the condenser in the same way as it does the pipe 10 which carries compressed air to the turbine or expansion device 11.

Power is supplied to the fan 31 for directing air through the chamber 32 by the battery 23 as follows: from one side of the battery through conductors 68, 75, the motor of fan 31, and conductors 76 and 67, back to battery 23. Suitable manual switches may be provided if desired for interrupting operation of the fan 31 and the compressed motor 40 whenever desired.

The flow of refrigerant through the cooling coil 38 is controlled by an expansion valve 77, this expansion valve being a thermostatic type having suitable means for varying the superheat setting thereof. The construction of this expansion valve forms no part of the present invention but may be constructed as illustrated in Patent No. 2,019,724, issued November 5, 1935, to C. A. Otto. Such an expansion valve comprises an operating diaphragm or bellows forming a pair of chambers, one of which is connected to a bulb 78 by means of a capillary tube 79, this bulb being provided with a suitable volatile fill and being positioned in contact with the outlet of the evaporator so that one of the chambers will be subjected to a pressure corresponding to the temperature of the refrigerant leaving the evaporator. (The details of the expansion valve mechanism may be more fully understood by inspecting Figure 2.) The other of the said chambers is subjected to the pressure of the refrigerant in the evaporator so that the operating diaphragm or bellows moves in accordance with variations in the superheat of the refrigerant at the outlet of the evaporator. The valve is biased towards closed position by means of a spring 80 (see Figure 2) and the tension of the spring may be adjusted by means of a proportioning motor 81 so that the valve is adjusted to maintain varying degrees of superheat which has the effect of vary-

ing the effective cooling surface of the evaporator.

The adjustment of this spring by the motor 81 is controlled by a thermostat 82, which thermostat is shown as comprising a bulb 83 located in the return air inlet duct 34a, this bulb being connected by means of a capillary tube 84 with the bellows 85 which controls the position of a slider arm 86 with respect to a potentiometer resistance 87. (Figure 2.) As the temperature of the air in the car or the air entering the inlet 34a increases, the bellows 85 will expand and move the arm 86 to the right with respect to the resistance 87. Upon a decrease in the temperature of the space being conditioned, the arm moves in the opposite direction with respect to the resistance 87.

Located around the evaporator adjacent the inlet portion thereof and insulated therefrom by suitable spacer members 90, is a perforated member 91 which is located in close proximity with the evaporator coil, this member being located close enough to the evaporator so that if any condensation forms thereon, a circuit is established between the evaporator coil and the member 91 which will energize a relay 92. This relay comprises a winding 93, and an armature 94 connected to a switch blade 95 which cooperates with fixed electrical contacts 96 and 97, the armature moving the blade 95 so that it engages contact 96 when the relay is energized and so that it engages the contact 97 when the relay is deenergized. A battery 97 may be provided to supply power to the relay 92 or any other suitable sources of power may be employed. As soon as condensation forms on the evaporator and a circuit between the evaporator coil 38 and the member 91 is completed by the moisture thereon, relay winding 93 will be energized as follows: from the battery 97 through conductor 98, evaporator coil 38, member 91, conductor 99, winding 93, and conductor 100 back to the other side of the battery 97. Energization of the relay causes arm 95 to move into engagement with contact 96 as described above.

The member 91 may be composed of a sheet of perforated material wound around the pipe and clamped together by means of a clamping screw 101 as shown in Figure 3. The spacer members 90 are separated as shown in Figure 3 to permit an upward flow between the evaporator coil and the member 91 so that evaporation of moisture which condenses on the evaporator coil may be rapidly effected, the perforations in the member 91 permitting that portion of the evaporator coil surrounded thereby to be contacted by the air passing through the chamber 32.

When the relay 92 is energized by reason of condensation of moisture on the evaporator indicating that the evaporator is removing latent heat from the air, the center and left hand terminals of the proportioning motor 81 are directly connected as follows: from the center terminal of the motor through conductor 105, switch arm 95, contact 96, and conductors 106 and 107 to the left hand terminal of the motor. When these terminals are directly connected in this manner, the motor 81 operates to completely close the expansion valve to prevent flow of refrigerant to the evaporator and when this happens the suction pressure on the compressor will rapidly decrease so that the compressor will shut down. Until the temperature in the evaporator rises sufficiently so that the moisture on the evaporator coil has been evaporated, the expansion valve

will remain closed so that there will be no further cooling thereby. As soon as the moisture on the evaporator coil has evaporated however, the circuit to the relay 92 will be interrupted and the arm 95 will move into engagement with the contact 97. The center terminal of the motor 81 will now be connected to the control arm 86 of the temperature responsive device 82 as follows: from the center terminal of the motor through conductor 105, arm 95, contact 97, and conductor 108 to the arm 86. The right hand end of the resistance 87 is connected by means of the conductor 109 to the right hand terminal of the motor 81 and the other end of the resistance 87 is connected by means of conductors 110 and 107 to the left hand terminal of the motor 81. It will accordingly be apparent that the motor 81 will operate in accordance with the temperature at the bulb 83 and as the temperature increases the motor will operate to adjust the setting on the spring 80 so that the expansion valve will maintain the refrigerant at the evaporator outlet at a lower degree of superheat so that a greater portion of the evaporator coil will be effective and more cooling will be produced thereby. Conversely, upon a decrease in temperature of the air entering the inlet 34a the spring 80 of the expansion valve will be adjusted so that a higher degree of superheat of the refrigerant at the evaporator outlet will be maintained and a smaller area of the coil will be effective for cooling purposes and the temperature of the air passing thereover will be reduced to a lesser extent. It will be apparent that when the relay 92 is energized by reason of condensation on the evaporator, the movement of arm 95 out of engagement with contact 97 interrupts the circuit to the control arm 86 so that the thermostat has no control whatever over the position of the expansion valve.

For controlling the operation of the valve 20 which regulates the flow of compressed air from the pipe 10 through the turbine 11 is a humidity responsive device 115 which responds to the humidity of the air passing from the rear compartment of the car through the return air inlet opening 34a. The humidity responsive device comprises a humidity responsive element 116 which controls the position of a slider arm 117 with respect to a potentiometer resistance 118, the slider and resistance cooperating to control the motor 21 which positions the valve 20. Upon an increase in humidity of the air in the space being conditioned, or of the air passing through the return air inlet 34a, the slider arm 117 will move to the right over the resistance 118 and cause the motor 21 to move the valve 20 towards open position by an amount which is proportional to the increase in humidity. As the amount of compressed air to the turbine 11 is increased, there will be a greater amount of cooled air with a low dew-point admitted to the chamber 12 and accordingly mixed with the cooled return air from the chamber 32 which will have the effect of reducing the relative humidity in the space being conditioned. This humidity responsive device may operate to move the valve from a fully closed position to a fully open position as the humidity in the space increases from 45% to 55% for example.

It will now be understood that according to the invention, the humidity in the space is controlled by controlling the supply of compressed air to the turbine 11 and as the humidity increases, the valve 20 moves from closed to open position.

The sensible cooling of the air in the conditioned space is effected mainly by the evaporator coil 38 of the refrigeration system which reduces the temperature of the recirculated air but which is controlled so that it does not effect any latent cooling of the air in the conditioned space so that the load on the refrigeration system is kept at a minimum. In order to secure this result the compressor is operated to maintain the suction pressure between values of 50 pounds to 65 pounds, for example, assuming a refrigerant such as Freon or F12 is utilized which will maintain the coil temperature between values such as 55° F. and 70° F., and by maintaining the suction pressure between these limits, under normal circumstances no moisture will condense on the evaporator coils. Should there be such condensation of moisture, however, indicating that the refrigerating system is effecting some latent cooling, the device 91 operates to energize the relay 92 which closes the expansion valve. Normally, however, the expansion valve is controlled in accordance with the temperature in the condensed space and this valve is adjusted to maintain a maximum superheat when the temperature in the space is 75°, for example, and to reduce the superheat as the temperature increases so that at 80°, for example, the amount of superheat will be at a minimum. Accordingly, substantially all of the sensible cooling of the air is effected by the refrigeration system at high efficiency and the latent cooling is effected by the compressed air of the expansion system, and the energy given up by the compressed air in the expanding thereof is utilized for driving the generator 22 to charge the battery 23 which furnishes energy for the compressor driving motor and the fan motor. This may be augmented by another source of power if necessary.

While a preferred form of the air conditioning system embodying my invention has been illustrated, particularly in connection with railway cars and the like, it should be understood that the system disclosed is applicable in general to air conditioning systems for all types of structures.

Having described a preferred form of my invention, it should be understood that various modifications may become apparent to those skilled in the art and such modifications will fall within the realm and scope of the invention. The invention is to be limited therefore, only in accordance with the scope of the claims appended hereto.

I claim as my invention:

1. In an air conditioning system for a railway car, means utilizing compressed air from the train line for causing a flow of fresh air into the car, means for expanding the compressed air to remove latent heat therefrom, means for causing sensible cooling of the air in the car, said means including an evaporator of a mechanical refrigeration system over which the air is circulated, the condenser of the refrigeration system being provided with a plurality of closely spaced fins, means for supplying waste water from the railway car to said fins to increase the cooling capacity thereof, and means utilizing the same waste water for cooling the compressed air before it is delivered to the expanding means.

2. In an air conditioning system for a space, in combination, means to supply dehumidified air to said space including means supplying compressed air, means cooling and expanding such air, and means for supplying cooled air to said space without removing moisture from such air including a

mechanical refrigeration system having an evaporator for cooling such air and control means therefor operative to maintain said evaporator at a temperature sufficiently high normally to prevent removal of water from the air cooled by the evaporator, said dehumidified air and said cooled air being mixed before being used.

3. In an air conditioning system, in combination, means for dehumidifying a first supply of air comprising means supplying compressed air, means cooling and expanding said first supply of air, means for cooling, without dehumidification, a second supply of air comprising a mechanical refrigeration system including an evaporator for cooling said second supply of air and control means for normally maintaining the evaporator temperature sufficiently high to prevent dehumidification of said second supply of air, and means for mixing said first and second supplies of air and delivering such mixture to a desired point of use.

4. In an air conditioning system, in combination, means for dehumidifying a first supply of air comprising means supplying compressed air, means cooling and expanding said first supply of air, means for cooling, substantially without dehumidification, a second supply of air comprising a mechanical refrigeration system including an evaporator for cooling said second supply of air, control means for normally maintaining the evaporator temperature sufficiently high to prevent dehumidification of said second supply of air and means responsive to the actual production of condensate by said evaporator for permitting said evaporator temperature to increase, and means for mixing said first and second supplies of air and delivering such mixture to a desired point of use.

5. In a system for cooling air, in combination, a mechanical refrigeration system including an evaporator over which the air is passed for cooling the air, and means responsive to the actual collection of moisture on said evaporator for permitting the temperature of said evaporator to rise until such moisture has been evaporated.

6. In a system for cooling air, in combination, a mechanical refrigeration system including an evaporator over which the air is passed for cooling the air, means responsive to a condition of the refrigerant in the system operative normally to prevent the temperature of said evaporator from falling below a value at which moisture is removed from the air passing over the evaporator, and additional means responsive to the actual collection of moisture on said evaporator for permitting the temperature of the evaporator to rise until such moisture has been removed.

7. A method of conditioning the air in a space which comprises cooling compressed air, expanding the cooled compressed air, removing moisture from the expanded air, entraining fresh air with the expanded air and delivering the mixture to the space, recirculating air through a path including the space, cooling the recirculated air in a portion of said path by removing sensible heat from the air without removing latent heat therefrom, controlling the sensible cooling of the recirculated air in response to the temperature of the air in a portion of said path, and controlling the amount of compressed air which is expanded and delivered to the space in response to the humidity of the air in a portion of said path.

8. In an air conditioning system for a space, a source of compressed air, an expanding means, means for directing said compressed air to said

expanding means wherein the compressed air may be expanded and cooled, means for cooling the compressed air passing to the expanding means, means for removing moisture from the expanded air, means for entraining fresh unconditioned air with the air leaving said expanding means and delivering the mixture of fresh and cooled air to the space, means for recirculating air through a path including the space, a sensible cooling means, means for directing said recirculating air over said sensible cooling means, means responsive to the temperature of the air in a portion of said path controlling said sensible cooling means, and means responsive to the humidity of the air in a portion of said path controlling the flow of air to the expanding means.

9. In an air conditioning system for a space, a source of compressed air, an expanding means, means for directing said compressed air to said expanding means wherein the compressed air may be expanded and cooled, means for cooling the compressed air passing to the expanding means, means for removing moisture from the expanded air, means for entraining fresh unconditioned air with the air leaving said expanding means and delivering the mixture of fresh and cooled air to the space, means for recirculating air through a path including said space, a sensible cooling means, means for directing said recirculating air over said sensible cooling means, said sensible cooling means comprising an evaporator of a direct expansion refrigerating system, means responsive to the temperature of the air in a portion of said path for controlling the flow of refrigerant through said evaporator, and means responsive to the humidity of the air in a portion of the path for controlling the flow of air to the expanding means.

10. In an air conditioning system for a space, a source of compressed air, an expanding means, means for directing said compressed air to said expanding means wherein the compressed air

may be expanded and cooled, means for cooling the compressed air passing to the expanding means, means for removing moisture from the expanded air, means for entraining fresh unconditioned air with the air leaving said expanding means and delivering the mixture of fresh and cooled air to the space, means for recirculating air through a path including said space, a sensible cooling means, means for directing said recirculating air over said sensible cooling means, said sensible cooling means comprising an evaporator of a direct expansion refrigerating system, means responsive to the humidity of the air in a portion of said path for controlling the flow of air to the expanding means, and means responsive to the condensation of moisture on said evaporator coil for interrupting the flow of refrigerant therethrough.

11. In an air conditioning system for a railway car space, means utilizing compressed air from the train line for causing a flow of fresh air into the space, means for expanding the compressed air to remove latent heat therefrom, means for circulating other air in a flow path including said space, means for causing sensible cooling of said other air, said means including an evaporator of a mechanical refrigerating system over which said other air is circulated, the condenser of the refrigerating system being provided with a plurality of closely spaced fins, means for supplying waste water from the railway car to said fins to increase the cooling capacity therefor, said waste water also being used to cool said compressed air before the same is expanded, means responsive to the humidity of the air in a portion of said flow path for controlling the supply of compressed air to the expanding means, and means responsive to the temperature of the air in a portion of said flow path in control of the flow of refrigerant through said evaporator.

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