June 25, 1940. F. CONRAD 2,205,744

AIR CONDITIONING SYSTEM

Filed Jan. 25, 1933 3 Sheets-Sheet 1

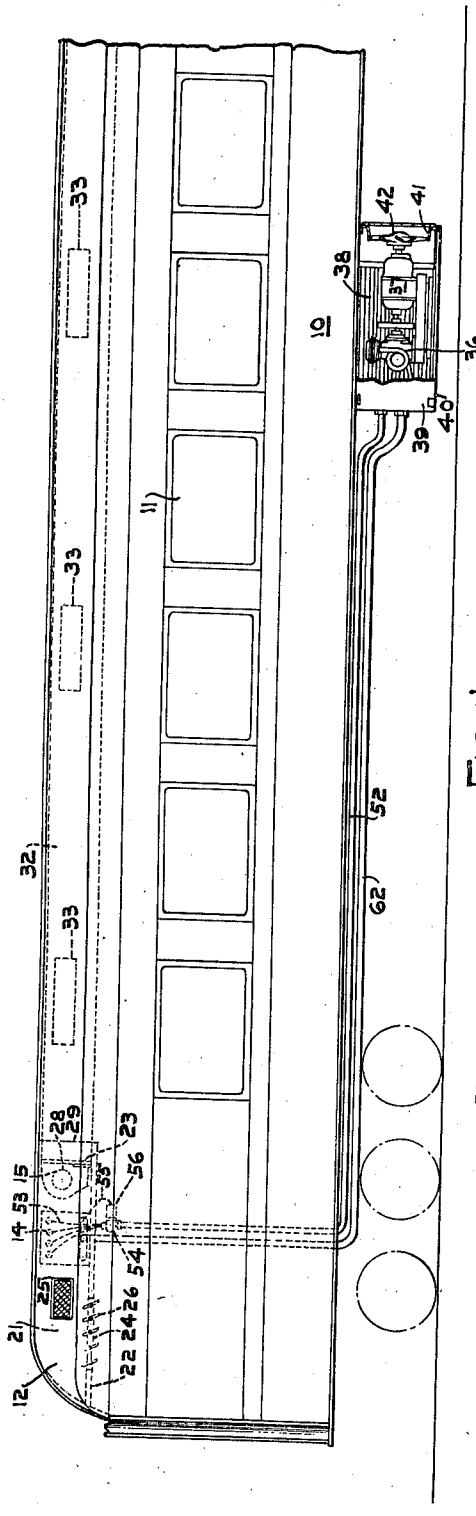

FIG. 1.

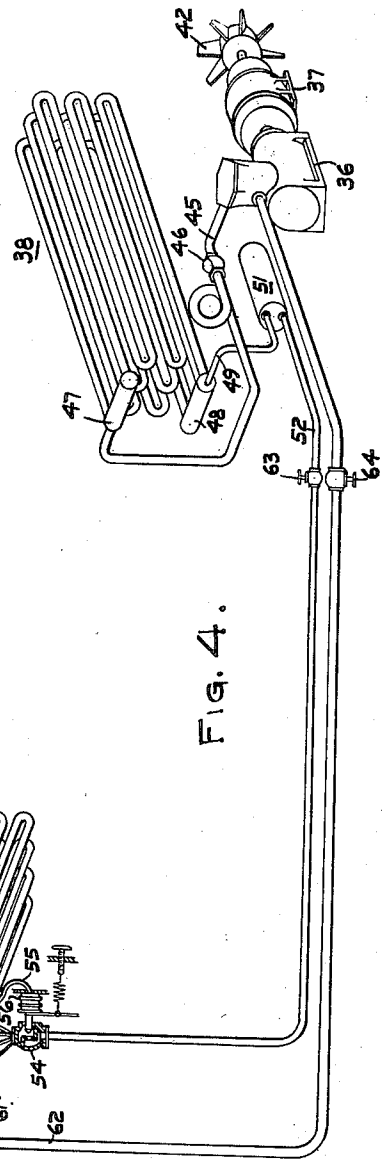

FIG. 4.

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AIR CONDITIONING SYSTEM

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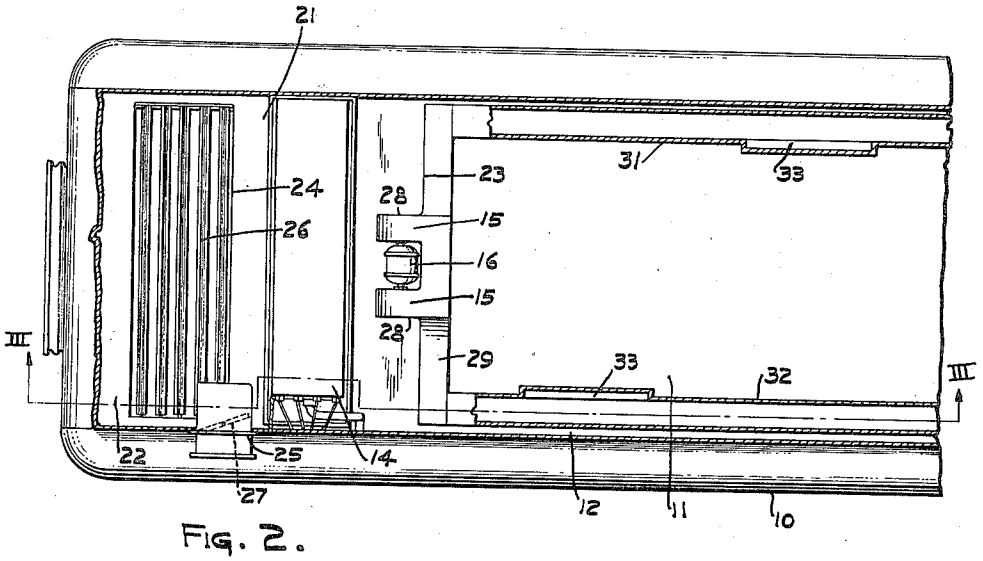

FIG. 2.

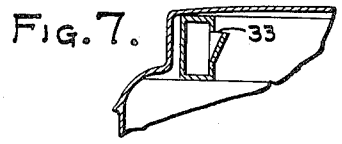

FIG. 7.

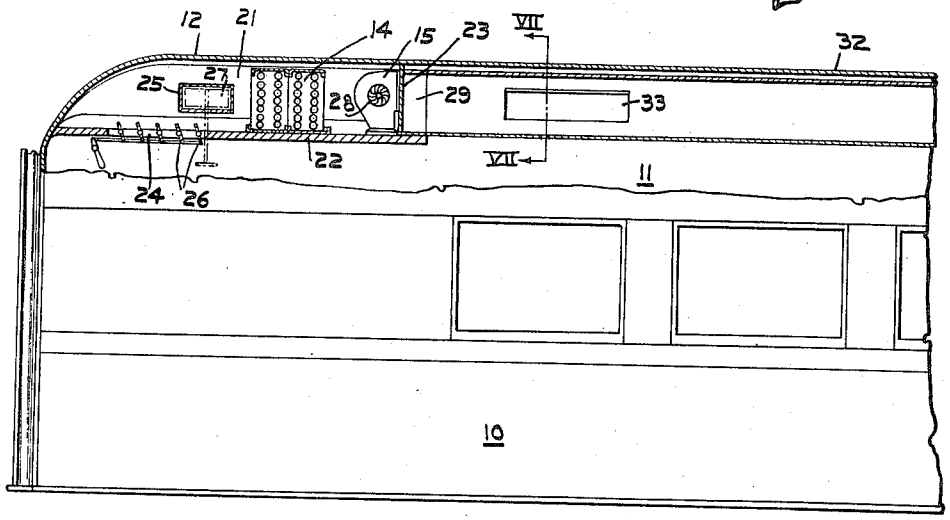

FIG. 3.

WITNESSES:

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AIR CONDITIONING SYSTEM

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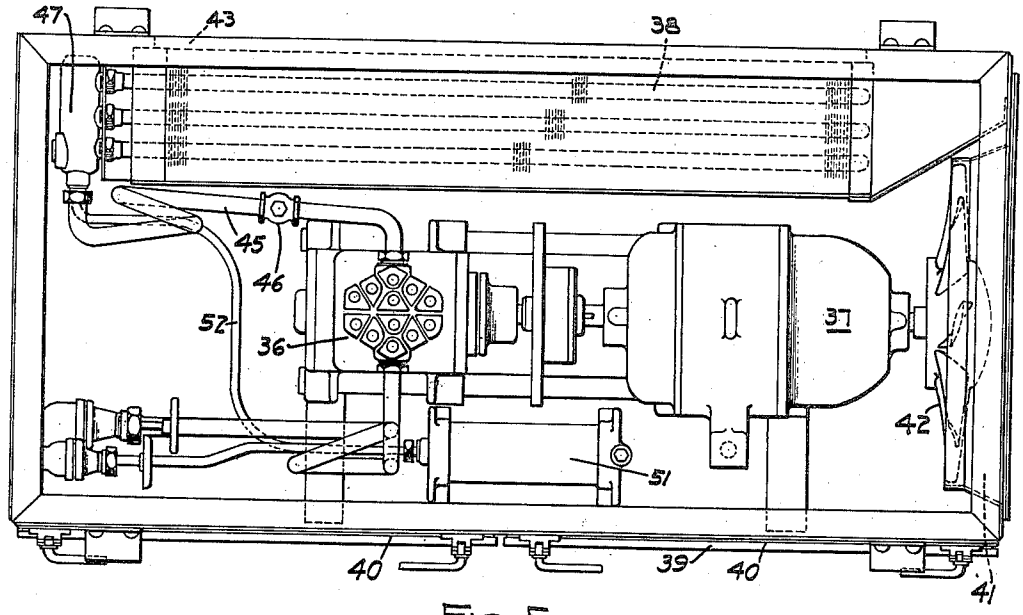

FIG. 5.

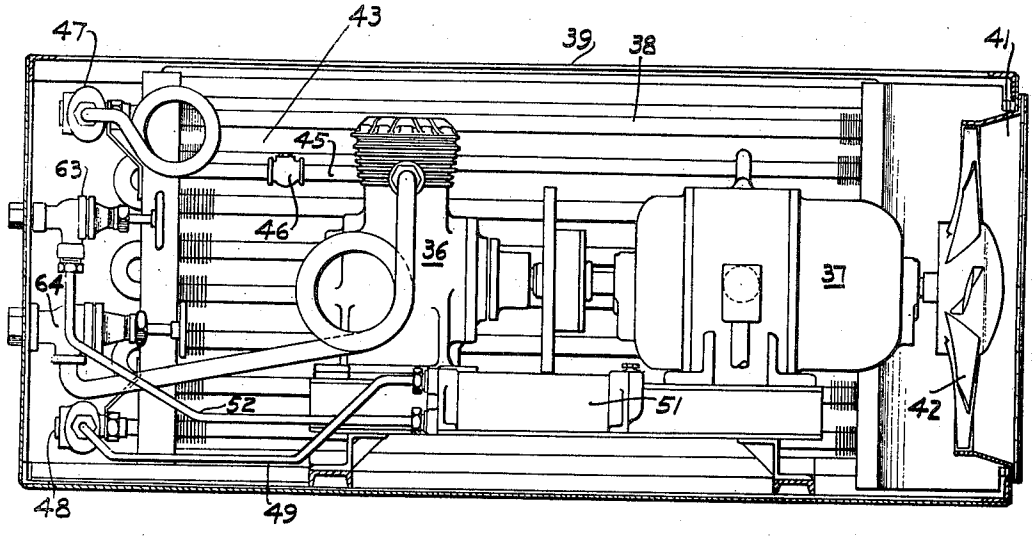

FIG. 6.

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Patented June 25, 1940 2,205,744

UNITED STATES PATENT OFFICE

2,205,744

AIR CONDITIONING SYSTEM

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Application January 25, 1933, Serial No. 653,516

6 Claims. (Cl. 62—129)

My invention relates to air conditioning systems and it has for an object to provide an improved system for cooling and dehumidifying air circulated within an enclosure.

My invention relates more particularly to air conditioning systems wherein a fluid is cooled by a refrigerating system and wherein the air to be conditioned is circulated in heat-exchanging relation with the refrigerated fluid, whereby the air is cooled and dehumidified. For example, my invention relates to a system wherein a refrigerant gas is compressed in a compressor, condensed in a condenser and vaporized in a heat absorbing element or evaporator, after which the vapor is returned to the compressor and the cycle of operation repeated. The air to be conditioned is circulated in heat-exchanging relation with the evaporator or heat absorbing element for cooling and dehumidifying it.

In the air conditioning of numerous types of enclosures, it has been found highly desirable to maintain a variable dry bulb temperature within the enclosure depending upon the dry bulb temperatures outside the enclosure. In other words, it has been found that if too great a temperature difference exists between the outside and the interior of the enclosure, people entering the enclosure are subject to discomfort. It has been found ideal to maintain a relatively higher temperature within the enclosure when the outside temperature is high and a relatively lower temperature when the outside temperature is low as distinguishd from a system wherein a predetermined constant temperature is maintained within the enclosure at all times irrespective of the outside temperature.

In the control of any of these systems as heretofore provided, various and numerous control instrumentalities such as, for example, thermostats, hygrostats, et cetera, have been required for regulating the refrigerating and the dehumidifying processes, all of which entail considerable cost and complication.

In accordance with my invention, I utilize a condenser in the refrigerating portion of the system which is cooled by exposure, either direct or indirect, to the ambient atmosphere so that the pressure prevailing within the condenser varies in accordance with the outside atmospheric temperature. Furthermore, I employ a refrigerator element or evaporator wherein the supply of liquid refrigerant from the condenser to the evaporator is controlled by some means, such as, for example, a capillary tube or tubes so that, when the outside temperature is relatively high and, consequently, the pressure in the condenser is high, more liquid refrigerant is forced to the evaporator than when the outside temperature is low. In this way, a greater refrigerating effect is obtained in the evaporator when the outside temperature is high and vice versa. In order to effectively utilize the variable amounts of refrigerant supplied to the evaporator, an evaporator of, for example, the coil type is employed, the arrangement being such that as operating conditions vary, such length of coil is rendered effective for the absorption of heat as is necessary to vaporize the liquid refrigerant supplied to the evaporator.

In the operation of apparatus constructed in accordance with my invention, the arrangement and coordination of the various parts are such that the system acts inherently to maintain a reduced temperature within the enclosure, which reduced temperature may be said to "float" up and down with the outside temperature, the amount of refrigerating effect increasing and decreasing a limited amount in response to changes in outside temperature so as to maintain a comfortable condition within the enclosure at all times.

It is, therefore, a more particular object of my invention to provide an air conditioning system which shall be so constructed and arranged as to inherently maintain a reduced temperature within the enclosure, which maintained temperature shall be such as to always afford a comfortable condition within the enclosure.

A further object is to provide, in air conditioning apparatus providing comfort cooling for an enclosure, an expansion mechanism of low cost and which operates to vary the flow of refrigerant to the evaporator in accordance with a psychrometric condition of the outdoor air.

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

Fig. 1 is a side view of a railway car having my improved air conditioning applied thereto;

Fig. 2 is a plan view of the car shown in Fig. 1 with portions broken away for clearness;

Fig. 3 is a side view of the apparatus shown in Fig. 2 and having portions broken away;

Fig. 4 is a diagram of the refrigerating system employed;

Fig. 5 is a plan view of the refrigerating machine assembly;

Fig. 6 is a side view of apparatus shown in

Fig. 5 with portions removed for clearness; and,

Fig. 7 is a sectional view of a detail, and is taken on line VII—VII of Fig. 3.

Referring now to the drawings, I have shown in Fig. 1 my improved system applied, by way of example, to a railway car 10 of conventional design, having a passenger compartment 11 and a clear story 12 disposed thereabove. In the present arrangement, I prefer to locate the air cooling and dehumidifying as well as the air distribution apparatus in the clear story 12 while the refrigerant compressor, condenser, et cetera, are preferably located beneath the car floor.

As shown in Figs. 2 and 3, the air conditioning apparatus includes an evaporator 14 disposed in the clear story 12 and extending transversely thereof. The air is circulated by blowers 15 driven by a motor 16. The blowers 15 and the evaporator 14 are located in a compartment 21. A ceiling partition 22 and a vertical, transversely extending partition 23 cooperate with the car structure to form the compartment 21. Air to be conditioned is admitted to the compartment 21 through openings 24 and 25, the opening 24 communicating with the passenger compartment 11 for the admission of return air and the opening 25 communicating with the exterior of the car for the admission of outside air. Manually operated dampers 26 and 27 may be provided for the respective openings 24 and 25 to adjust the circulation of air therethrough. The blowers 15 draw air from the openings 24 and 25 through the evaporator 14 to their inlet connections 28 and thence discharge the air to a transverse duct 29. The latter communicates, in turn, with longitudinally extending ducts 31 and 32 having spaced openings 33 therein for distributing the conditioned air to the passenger compartment.

Referring now to Figs. 5 and 6, these show the refrigerant compressing apparatus which includes a compressor 36 direct connected to a dynamo electric device 37 for driving the same. Located adjacent to the dynamo electric device and the compressor is a condenser 38, preferably of the finned coil type, for condensing the refrigerant vapor compressed by the compressor, all as well understood in the art. The compressor 36, dynamo electric device 37, and condenser 38 are all disposed within and supported by an enclosed housing or box structure 39 which, as stated heretofore, is preferably detachably suspended beneath the car floor as a single unitary structure. As will be noted from Fig. 1, the housing 39 and the condenser 38 at one side thereof extend longitudinally of the railway car 10. The box structure is preferably equipped with suitable access doors 40. The forward end of the box structure is provided with an opening 41 for the admission of outside air and a fan 42, preferably of the propeller type is secured to the forward end of the drive shaft of the motor 37 for effecting forced circulation of air through the box structure. This air is discharged out of the box structure through a discharge opening 43 located adjacent to the condenser 38, the arrangement being such that the outside air is forced over the motor device 37, the compressor device 36, and over the condenser 38 for absorbing heat therefrom. Such an arrangement provides a very compact form of compression mechanism wherein, not only is the motor and the compressor direct connected, but the condenser as well as the compressor and the motor are air cooled. In this way, the compression unit and the box structure for housing the same, entail a minimum amount of weight and occupy a minimum amount of space consistent with their capacity. In this connection, the propeller type of fan is very desirable inasmuch as this specific type of fan is capable of circulating the large quantity of air required by the relatively small condenser. At the same time, its physical proportions are such as to be capable of being housed within the confines of the compact box structure.

Referring now to Fig. 4, the compressor 36 discharges compressed refrigerant vapor through a conduit 45 to the condenser 38. A check valve 46 is preferably disposed in this conduit for preventing the return flow of compressed gases. The condenser 38 preferably embodies a plurality of coils of finned tubing arranged side by side and connected to a common inlet header 47, the arrangement being such that refrigerant vapor flows to the respective condenser coils in parallel. A discharge header 48 is connected to the other end of the coils and from this header condensed refrigerant liquid is conveyed by a conduit 49 to a liquid refrigerant receiver or reservoir 51. As shown particularly in Fig. 6, this reservoir is supported within the compressor box structure.

The refrigerant is conveyed from the receiver 51 by a conduit 52 to a plurality of capillary tubes 53. Like the condenser, the evaporator 14 is preferably formed of a plurality of coils of finned tubing, each coil being provided at its inlet end with its own capillary tube and all of the capillary tubes being supplied with refrigerant liquid from the common conduit 52. Located in the conduit 52 there is preferably provided a valve 54 which, under some conditions of operation, is open, but which may under certain other conditions be closed in response to the pressure prevailing in the vapor side of the evaporator 14, this pressure being imposed upon the valve by a conduit 55 connected with a sylphon bellows 56. The valve 54 may also be adjusted by manipulation of a hand-wheel shown at 59. The arrangement of the valve 54, capillary tubes 53, et cetera, constitutes the subject matter of my Patent No. 2,148,412, dated February 21, 1939, for Refrigerating apparatus, assigned to the Westinghouse Electric and Manufacturing Co.

Refrigerant vapor formed in the evaporator is discharged through a manifold 61 and a conduit 62 to the inlet of the compressor 36. Suitable cut-out valves 63 and 64 are located in the refrigerant condensate line 52 and in the return vapor conduit line 62. These valves are preferably located within or adjacent to the box structure 39 so as to facilitate removal of the motor-compressor-condenser unit as a unitary structure from the car.

In operation, refrigerant vapor, for example, methyl-chloride, is compressed in the compressor 36 and is discharged by the conduit 45 to the condenser 38 wherein it is liquefied in a manner well understood in the art. During operation, the fan 42 withdraws air from the outside atmosphere into the box structure and circulates this air at high velocity over the dynamo electric machine 37, the compressor 36 and the condenser 38 so as to absorb the required heat therefrom. The condensed refrigerant liquid enters receiver 51 from which it is conveyed by the conduit 52 to the capillary tubes 53 which, in turn, distribute it to the respective sections of the evaporator 14. The refrigerant vapor formed in the evaporator is withdrawn by the compressor, whereupon the cycle of operation is repeated.

During operation of the refrigerating cycle, the

blowers 15 draw air into the compartment 21, a portion of this air being derived from the passenger space of the car and the other portion being derived from the outside air inlet 25. A mixture of return and outside air is circulated over the evaporator 14, whereby this air has its temperature sufficiently depressed to effect dehumidification. The cooled and dehumidified air is circulated by the blowers through the ducts 29, 31 and 32 and distributed to the top of the passenger space of the car through the openings 33, from which it is directed upwardly into contact with the top of the car.

It will be understood that, in a railway car, on a hot day, the top and side walls, particularly the top, will be extremely hot, with the result that the conditioned air, which may be at a dry bulb temperature of, for example 60° F., will be heated. Furthermore, the conditioned air commingles with the relatively higher temperature air prevailing in the upper portion of the passenger space so that by the time the air reaches the lower passenger level, its temperature is well within the so-called "comfort zone."

The condenser 36, being cooled by atmospheric air, will have a pressure prevailing therein which is dependent upon the temperature of the outside atmosphere. In fact, the condenser temperature is always higher than the external air temperature. It will also be noted that I employ expansion valves of a fixed type, for example, capillary tubes, so that the rate of flow of liquid refrigerant to the evaporator is dependent upon the pressure difference existing between condenser 36 and the evaporator 14. Hence, it will be seen that, if there is an increase in outside air temperature, there will be a consequent increase in the pressure prevailing within the condenser 36 and in the evaporator 14 but, inasmuch as the increase in pressure will be greater in the condenser than in the evaporator, due to the relatively higher temperature of the condenser, the pressure differential between the condenser and the evaporator will increase with increases in outside temperature and decrease with decreases in outside temperature. Therefore, with higher outside temperatures, more pounds of refrigerant will be circulated through the evaporator 14 than with lower outside temperatures. In other words, the system is so constructed and arranged that the amount of refrigeration produced "floats" up and down with the outside temperature.

This may be illustrated by figures for two conditions, for 40° centigrade condensing temperature the pressure in the condenser would be approximately 126 pounds without allowance for increase of condenser temperature over air temperature. At 5° centigrade the evaporator pressure will be 43 pounds, making a pressure difference, which is absorbed in the pressure reducing element of 83 pounds. If we reduce the outside air temperature by 5°, making it 35° centigrade, the condensing pressure would be 105 pounds. If we assume evaporator temperature lowered the same amount, which however, would not be quite correct, the low temperature would be 0° which gives a pressure of 36 pounds making a pressure difference of 69 pounds as compared with 83 pounds with the 5° higher air temperature. In actual practice the conditions would be more favorable due to the fact that the condenser temperature is appreciably higher than the external air temperature, which puts the pressure variation on a steeper part of the curve and the evaporator temperature will vary at a less degree owing to the increased refrigerant effect.

Referring now to the action of the evaporator 14, as stated heretofore, this is composed of a plurality of finned coils and, as the refrigerating effect created depends almost exclusively upon the actual pounds of refrigerant evaporated, within the limits of the capacity of the compressor, the refrigerating effect may be varied by varying the delivery rate of the capillary tubes. In my system, the increased cooling effect is brought about, as explained above, by the increase in pressure differential between the condenser and the evaporator occasioned by increase in the outdoor temperature, which increases the flow of refrigerant through the capillary tubes. Conversely, the cooling effect is decreased upon decrease in the outdoor temperature.

The air circulated by the blowers leaves the evaporator coils at a relatively low temperature but at a high relative humidity. However, as stated heretofore, by coming in contact with the relatively warm wall portions of the car and also by commingling with the air in the upper portion of the passenger space, the conditioned air will have its dry bulb temperature increased and its relative humidity decreased a sufficient amount so that, by the time it reaches the passenger level, it is in a condition providing comfort for the passengers.

Although the temperature of the evaporator is higher for heavy loads and lower for light loads, the amount of refrigeration produced is greater in the first case than in the latter. This is readily apparent if we assume a compressor having a capacity of 1 cu. ft. per minute connected to an evaporator, the outgoing temperature of which was 5° C. of 41° F. and, assuming as heretofore, methyl chloride as a refrigerant, 1 cu. ft. of gas per minute will equal .44 pound of refrigerant per minute which, when evaporating at 5° C. will absorb 71 B. t. u.'s per minute which represents the refrigerating effect. The outgoing temperature of the evaporator being reduced to 0° C., 32° F., one cu. ft. of gas per minute at this temperature would equal .37 pound which, when evaporating, would absorb 64.3 B. t. u. which is a lower amount of refrigeration than obtained at the 5° point. If we now assume 10° C., 50° F., one cubic foot per minute is .52 pound, which at the corresponding temperature, absorbs 89 B. t. u. per minute in evaporating. These figures show that, although the evaporating temperature may be raised, the actual refrigeration will also be raised. In the above assumption, it is assumed that the evaporator is large enough to provide the maximum length of evaporator tube that may be required. This means that when less length of evaporator tube is required, the refrigerant is completely vaporized before reaching the end of the evaporator. Under such condition of operation, the length of tubing nearest the capillary tube would be cooled only for a length necessary to vaporize all the liquid, the balance of the tube simply conducting gas without great refrigeration effect.

From the foregoing, it will be apparent that with an increase in outside temperature, the refrigerating cycle inherently produces a greater refrigerating effect, thus discharging air into the top of the car body at a greater temperature reduction than when the outside temperature is lower. This regulation is effective without the provision of any automatic control devices. However, the variations in refrigeration capacity are inherently not of adequate scope to maintain

a constant temperature within the passenger space irrespective of outside temperature so that, as a result, the temperature inside the car does not remain stationary but floats up and down with the outside temperature, thereby always maintaining an ideal condition at the passenger level in the car.

During normal operation, the valve 54 is in open position and the capillary tubes serve as the sole restriction between the high and low pressure portions of the refrigerant system. However, for some unusual conditions of operation, the characteristic of the capillary tubes 53 may be modified by manual adjustment of the valve 54 to add resistance in series with the capillary tubes. Normally, the valve 54 functions as a cut-off valve. For example, should something interfere with the air circulation by the fan 42 and, as a consequence, should the pressure in the condenser 38 build up to some excessive point, more liquid will be forced into the evaporator 14 than can be vaporized therein and, as a consequence, liquid may be returned through the suction conduit 62 to the inlet of the compressor 36. At such times, the pressure in the evaporator 14 may reach an abnormal amount and the valve 54 will automatically close to prevent the supply of any additional liquid refrigerant to the evaporator until such time as the pressure in the latter returns to normal. Then again, when the compressor stops operating, there is a tendency for all the liquid in the condenser 38 and receiver 51 to be forced into the evaporator so that, upon a resumption of operation, the compressor 36 may withdraw liquid instead of vapor from the evaporator. At such times, the valve 54 closes due to the fact that, when the compressor 36 stops, circulation through the refrigerant system consequently stops and the vapor pressure builds up in the evaporator.

From the foregoing, it will be apparent that, in the operation of apparatus constructed in accordance with my invention, the arrangement and coordination of the various parts are such that the system acts inherently to produce an increased or decreased refrigeration effect depending upon outside temperature, the increases and decreases in refrigeration effect being insufficient to maintain a constant temperature within the enclosure but having sufficient variation to always maintain, within the enclosure, such a temperature gradient below the outside temperature as will insure, at all times, a comfortable condition within the enclosure.

While I have shown my invention in one form, 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. The method of conditioning air in a passenger vehicle which comprises passing air in heat-exchanging relation with a body of refrigerant for cooling the air and reducing its vapor content, conveying the cooled air to the passenger compartment, and discharging the cooled air in an upward direction into contact with warm portions of the vehicle adjacent the top thereof above the level occupied by the passengers, so that the temperature of the air is raised and its relative humidity lowered before descending to the passenger level.

2. The method of conditioning air in a passenger vehicle which comprises passing air in heat-exchanging relation with a body of refrigerant for depressing the dew point temperature of the air, conveying the treated air to the compartment for passengers, and then discharging the treated air in an upward direction into contact with the top of the vehicle so that superheating takes place before descending to the level occupied by the passengers.

3. The combination with a passenger vehicle having a compartment for passengers, of apparatus for conditioning air for the passenger compartment comprising means for cooling air and thereby reducing the vapor content thereof, means for conveying air in heat-exchange relation with said cooling means and for delivering the same to the passenger compartment, said last-mentioned means directing said cooled air upwardly into contact with the top of the vehicle so that the temperature of the air is raised and its relative humidity lowered before descending to the passenger level.

4. The method of air conditioning an enclosure for human comfort which comprises conveying air in contact with a heat absorbing refrigerant evaporator of the dry type and mixing the same with the relatively warm air of the enclosure, withdrawing refrigerant vapor from said evaporator and compressing the same, condensing the compressed refrigerant vapor in a condenser, conveying a stream of outdoor air in contact with said condenser for cooling the same, whereby the condenser pressure varies with a psychrometric condition of the outdoor air, delivering the condensed refrigerant at substantially condenser pressure to a liquid receiver, and varying the flow of condensed refrigerant from the liquid receiver to the evaporator by conveying the same through an expansion mechanism of constant restriction and including a capillary tube, whereby the amount of heat absorbed by the evaporator varies in accordance with said psychrometric condition of the outdoor atmosphere.

5. In an air conditioning system providing comfort cooling for an enclosure, the combination of an evaporator, means for effecting flow of air in contact with said evaporator to cool and dehumidify the air and mixing the same with the air in the enclosure, a compressor for withdrawing refrigerant vapor from said evaporator and compressing the same, a condenser for condensing the compressed refrigerant, means for effecting flow of outdoor air in contact with said condenser for cooling the same, whereby the refrigerant pressure in the condenser varies with a psychrometric condition of the outdoor air, a liquid receiver connected to said condenser and receiving the condensed refrigerant therefrom at substantially condenser pressure, and means for varying the flow of condensed refrigerant from the liquid receiver to the evaporator comprising an expansion mechanism of constant restriction and including a capillary tube, whereby the amount of heat absorbed by the evaporator varies in accordance with said psychrometric condition of the outdoor air.

6. An air conditioning system as set forth in claim 5, wherein the evaporator is of the dry type.

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