

Jan. 12, 1943.

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2,308,079

REFRIGERATING APPARATUS

Original Filed March 31, 1934 3 Sheets-Sheet 1

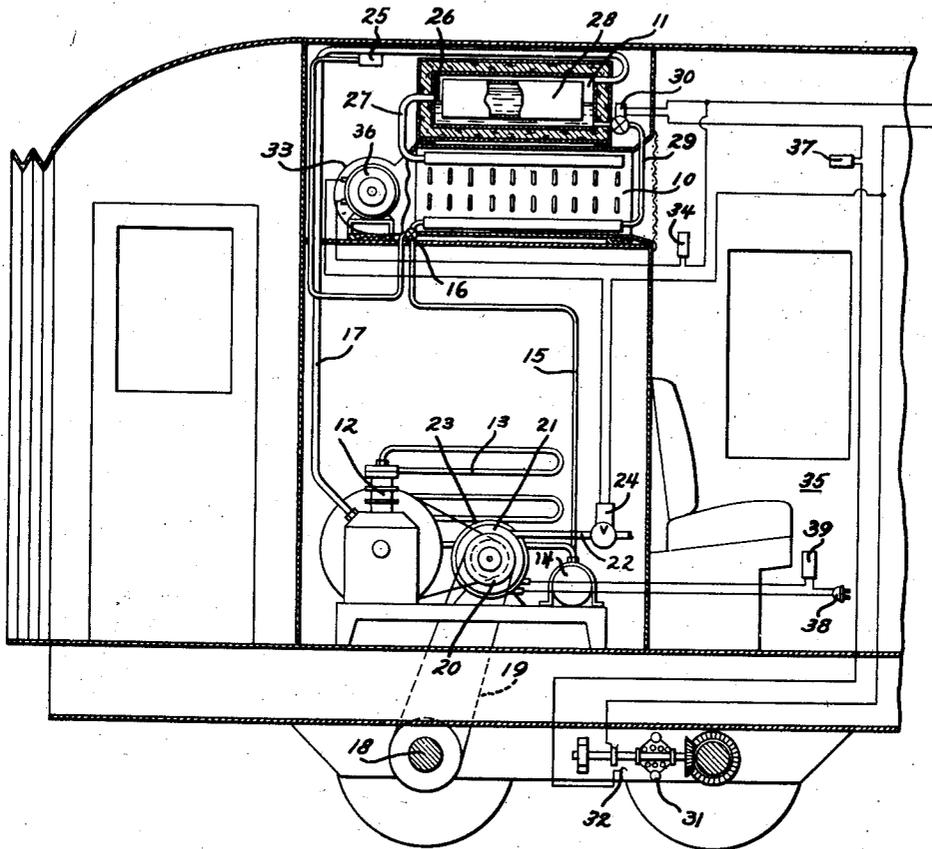


Fig. 1

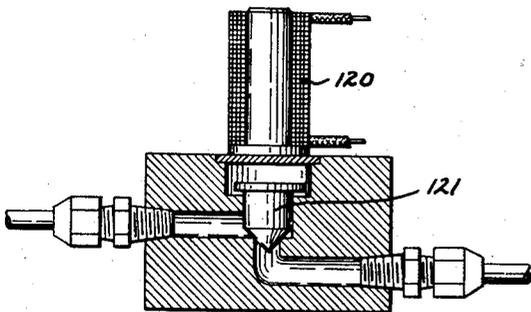


Fig. 4

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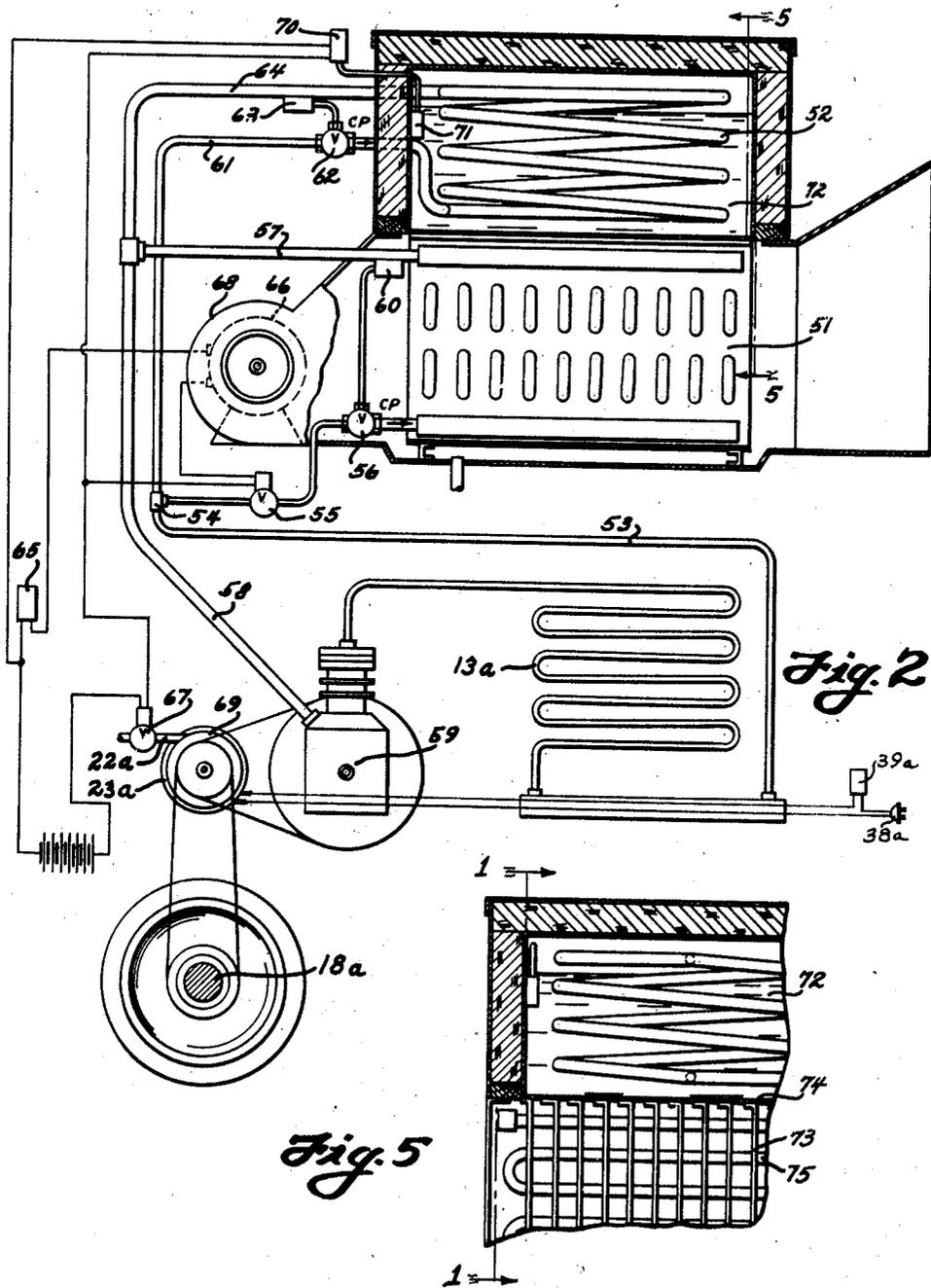


Fig. 2

Fig. 5

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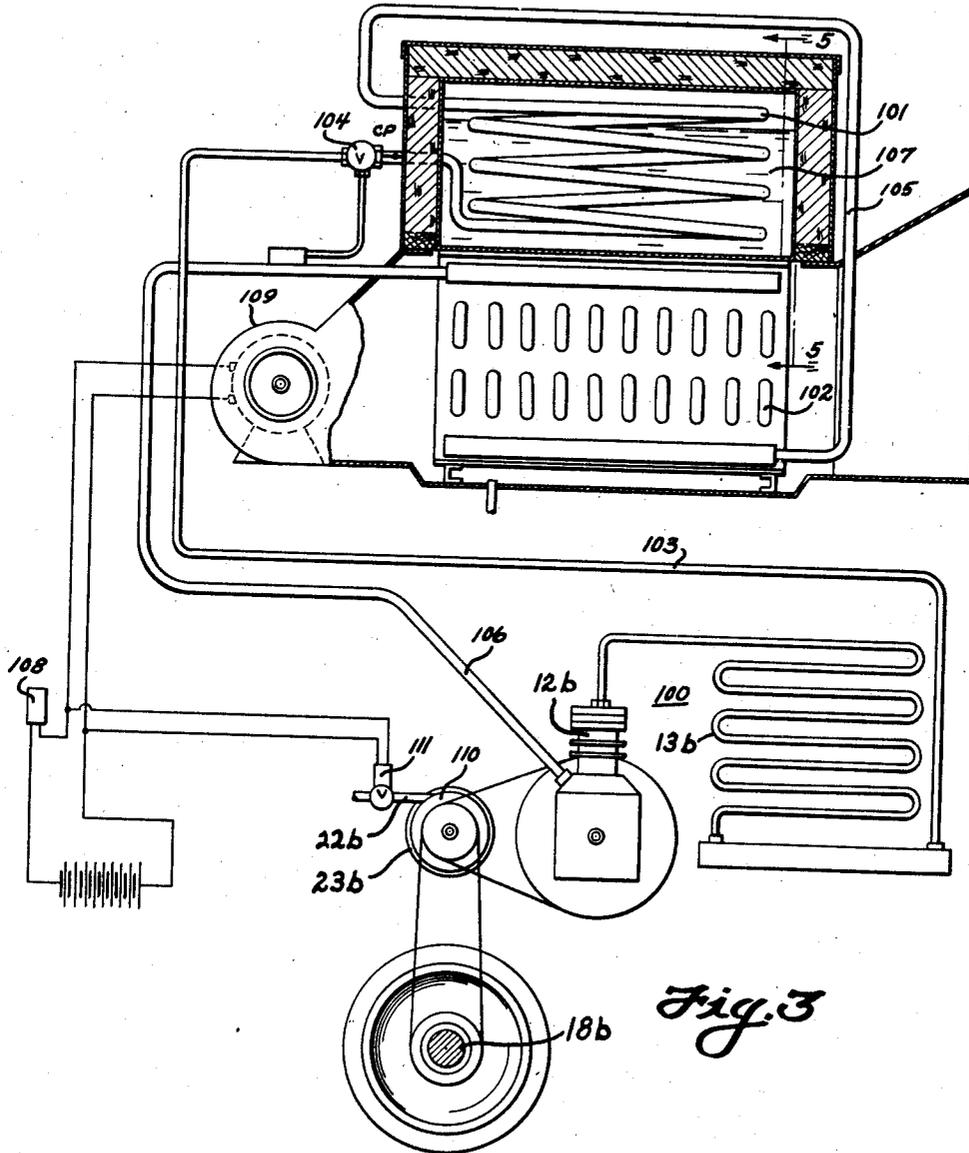
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Original Filed March 31, 1934 3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,308,079

## REFRIGERATING APPARATUS

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Original application March 31, 1934, Serial No.  
718,323. Divided and this application August  
3, 1939, Serial No. 288,193

3 Claims. (Cl. 62-6)

This invention relates to refrigeration and more particularly to the conditioning of air.

This application is a division of my copending application Serial No. 718,323 filed March 31, 1934, now Patent No. 2,197,722, issued April 16, 1940.

It is among the objects of this invention to condition air in an improved manner with the aid of a refrigerating apparatus in which a refrigerant is evaporated in thermal contact with air to be conditioned and with a holdover during periods when the refrigerating apparatus has excess refrigerating capacity and by refrigerating the air by thermal contact with the holdover when the refrigerating apparatus lacks sufficient capacity to condition the air.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein a preferred form of the present invention is clearly shown.

In the drawings:

Fig. 1 is a view, partly diagrammatic, and partly in vertical cross section of an apparatus embodying features of my invention;

Fig. 2 is a view, somewhat similar to Fig. 1, showing a modified form of my invention;

Fig. 3 is a view, similar to Fig. 1, of another modification of the invention;

Fig. 4 is a cross sectional view of a type of valve which may be used in practicing the invention; and

Fig. 5 is an enlarged cross-sectional view taken along the line 5-5 of either Figs. 2 or 3.

In practicing this invention, a refrigerating system is provided including an evaporator and a refrigerant liquefying unit operatively connected thereto. A holdover system is also provided in such a manner that it is refrigerated while the refrigerating system has excess refrigerating capacity and conditions the air when the refrigerating system lacks sufficient refrigerating capacity.

In the modification shown in Fig. 1, the evaporator may include an air cooling section 10 and a holdover cooling section 11 arranged in series refrigerant flow relationship. The refrigerant liquefying unit may include a compressor 12, condenser 13 and liquid refrigerant receiver 14. The liquid refrigerant from receiver 14 flows through the line or pipe 15, through the expansion device 16, to the evaporator sections 10 and 11, and the evaporated refrigerant returns through line 17 to the compressor 12.

The refrigerant liquefying unit is provided with

driving means for driving the same preferably by energy generated through the motion of the car. To this end, a wheel of the car, through the axle 18, belt drive 19, and speed reducing device 20, is drivingly connected with the compressor 12. If desired, although not necessarily, the speed reducing device 20 may be of a character automatically to drive the compressor 12 at substantially constant speeds notwithstanding variations in the speed of the car. However, it is to be understood that many of the advantages of this invention may be derived where the drive between the wheel and the car and the compressor 12 is such as to drive the compressor at varying speeds.

The speed reducing device may include a pneumatic clutch 21 which is actuated by air from line 22, connected if desired to the air brake system of the train. In addition the compressor is connected to a "stand-by" motor 23, to be actuated by current from the station when the train stops by a suitable plug. The solenoid valve 24 actuates the pneumatic clutch 21 in a manner to be more fully described.

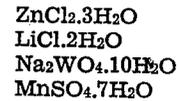
In the modification shown in Fig. 1, the arrangement is such that liquid refrigerant is maintained in thermal exchange relationship with the air to be cooled and with the holdover while the refrigerant liquefying unit is driven at a sufficient speed to have excess refrigerating capacity. To this end, the evaporator sections 10 and 11 are so arranged with respect to each other that both sections contain liquid refrigerant while the refrigerant liquefying unit has excess capacity. This is accomplished by providing an expansion device 16 of the type provided with a gas filled thermostatic bulb 25. The construction of the valve is similar to that of the valve shown in my prior Patent 1,920,505. The bulb 25, which corresponds to the bulb 46 of my prior patent, is charged with a certain amount of a gas which is so chosen that the gas will start to condense in the bulb at a predetermined temperature. Then, as long as the temperature of the thermostatic element is above the predetermined temperature, the pressure in the element does not vary much with changes in temperature and the expansion valve acts as a constant pressure valve. However, when the temperature of the element does fall to or below the predetermined degree, the expansion valve acts as a constant super heat valve since the pressure in element 25 then varies greatly with changes in temperature. Such a valve will prevent the pressure in the evaporator from rising above a predetermined point and, when the pressure goes be-

low that point, will act as a constant super heat valve. Expansion valves of this type are well known and are usually provided with diaphragms or bellows responsive to evaporator pressure such that they feed liquid refrigerant whenever the refrigerant pressure in the evaporator drops below the predetermined pressure. Preferably the device 16 is so calibrated that the refrigerant temperature is slightly above 32° F. but below the "comfort range" of the air to be conditioned. For example, the refrigerant temperature in the evaporator sections may be 35° F. A thermostatic bulb 25 is placed in contact with the suction line near the outlet of the section 11, and is connected with the expansion device 16 to throttle the same whenever the liquid refrigerant tends to be drawn through the line 17. This arrangement maintains liquid refrigerant in both sections 10 and 11, the level of refrigerant in section 11 being indicated at 26. Preferably the pipe 27 which discharges refrigerant from section 10 to section 11 is placed above the bottom of section 11 to provide a liquid refrigerant pocket in section 11. A holdover fluid is placed in cartridge 28 in thermal exchange relationship with the refrigerant in section 11.

When the refrigerant liquefying unit lacks sufficient refrigerating capacity, due to a decrease in speed of the car, or because the car has stopped, the arrangement is such that the air is refrigerated by a thermal contact with the holdover contained in the cartridge 28 in section 11. This is accomplished by providing means for draining the liquid refrigerant from the section 11 and by causing liquid refrigerant in section 10 to be evaporated by the air, and the vapors thus created to be condensed by thermal exchange with the holdover in cartridge 28, thus transferring heat from the air to the holdover and conditioning the air. A way of accomplishing this is by providing a drain pipe 29 connecting the bottom of section 11 with the bottom of section 10. This pipe is provided with a valve 30 adapted to be opened when the refrigerant liquefying unit lacks sufficient refrigerating capacity. For example, a speed responsive governor 31, driven from the wheels of the car is constructed to close the switch 32 whenever the car drops below predetermined speed or stops altogether. When the switch 32 is closed the solenoid valve 30 is opened and the liquid refrigerant in section 11 is partly or wholly drained into the section 10. When air, under these conditions, is blown over the section 10 by means of fan 33, liquid refrigerant in section 10 is vaporized, and the vapor rises through the pipe 27 into thermal contact with the cartridge 28 and is condensed thereby and the liquid thus formed is returned through the pipe 29 to the section 10. This action cools the air as it passes through the section 10 by thermal contact with the holdover while the refrigerant liquefying unit lacks sufficient capacity to condition the air.

The holdover fluid in cartridge 28 preferably includes a substance which has an effective phase changing temperature above 32° F. and below the comfort range of air being conditioned. If the evaporator temperature is maintained substantially at 35° F., then the holdover fluid may be a substance which freezes or otherwise changes phase slightly above 35° F. and below the comfort range of the air to be cooled. The freezing or phase changing temperature should be sufficiently low to properly condition the air. Examples of holdover substances which may be placed in the cartridge are: dioxan, benzene, nitrobenzene, bro-

moform, ethylenediamine, ethylenediamine hydrate, and dimethyl aniline, or the hydrates of the following salts:



or a mixture of butyl stearate with 5% carbon tetrachloride.

The air to be conditioned which enters the fan 33 may come from the interior of compartment 35 which receives the conditioned air, or it may come from the outside atmosphere, or both.

Means for starting and stopping the compressor may be provided. Thus a thermostat 34 is placed in compartment 35 which stops the motor 36 of the fan 33 and also controls the solenoid valve 24 to declutch the compressor from the axle 18. The thermostat 34 is calibrated to stop the motor 36 and compressor 12 at a predetermined low temperature limit and to start them at a predetermined higher limit.

Means are provided to cause the holdover in cartridge 28 to refrigerate the air for compartment 35 when the train slows down or stops and thus cannot drive compressor 12. Thus a second thermostat 37 is provided in compartment 35 which is in series with switch 32. The thermostat 37 controls the solenoid valve 30 in conjunction with the governor 31 to open the drain pipe 29 when the compartment 35 has warmed and the compressor can not be driven at a sufficient speed to provide the necessary refrigeration. The thermostats 37 and 34 are set at substantially the same temperature limits and when the compartment 35 gets too warm the thermostat 37 opens pipe 29 and thermostat 34 starts fan 33. The air thus driven over section 10 evaporates refrigerant, the vapors of which rise through the pipe 27, condense on cartridge 28 and drain back to section 10 through pipe 29. Thus the refrigerating power of holdover is used to refrigerate the air when the compressor 12 cannot be driven at a sufficient speed.

When the train is to remain standing for an unusually long time, beyond the refrigerating capacity of cartridge 28, the "stand-by" motor 23 may be "plugged in" to the station current by means of plug 38 and may operate the refrigerating system. If desired, a thermostat 39 may be provided in compartment 35 to start and stop the motor 23 and maintain proper temperatures in compartment 35. The air line 22 may be manipulated by a manual valve, not shown, to declutch the compressor from the axle 18 when the motor 23 is to be energized.

In the modification shown in Fig. 2, the arrangement is such that a holdover of slightly lower phase-changing temperature may be used, and in which the refrigerating capacity of the system is primarily utilized to condition air and only excess capacity is used to refrigerate the holdover. Thus a refrigerant liquefying unit is provided, which may be substantially identical with the unit shown and described with respect to Fig. 1. This refrigerant liquefying unit comprises a condenser 13a, a compressor 59 and driving means for the compressor which may be either the live axle 18a or the stand-by motor 23a. A pneumatic clutch 69 actuated by air from the line 22a is also provided. As explained in the preceding paragraph, a manual valve (not shown) may be placed in the air line so as to declutch the compressor 59 from the axle 18a when the motor

23a is to be energized. The refrigerant evaporator may include an air cooling section 51 and holdover cooling section 52. In this modification, the sections 51 and 52 are in parallel refrigerant flow relationship. Thus liquid refrigerant flows through the pipe 53 from the liquefying unit and divides at 54. One path of flow includes a solenoid valve 55, expansion valve 56, evaporator air cooling section 51, pipe 57 and suction line 58 back to the compressor 59. The expansion valve 56 is provided with a thermostatic bulb 60 substantially similar in construction and action of the valve 16 and bulb 20 of Fig. 1. The valve 56 is so calibrated that it maintains a predetermined refrigerant pressure corresponding substantially to 35° F. Another line of flow of the refrigerant includes the pipe 61, automatic expansion valve 62, evaporator holdover cooling section 52, return branch 64 connected to suction pipe 58. The automatic expansion valve 62 is calibrated to maintain a colder temperature and lower pressure on the section 52 than in the cooling section 51. For example, it may be calibrated to maintain a refrigerant temperature of 25° F. A thermostatic bulb 63 controls the valve 62 and prevents liquid refrigerant from being drawn into the compressor. Thus valve 62 is set so that it does not open until the suction pressure is low enough to evaporate refrigerant at a temperature low enough to freeze the holdover material in chamber 72. Valve 56 is set at a higher pressure and temperature. Thus, valve 62 would not open unless valve 55 were closed or the load on evaporator 5 fell low enough to allow the suction pressure to drop to the point allowing valve 62 to open.

Means are provided for causing the system to refrigerate air as long as required and thereafter to refrigerate the holdover. Thus a thermostat 65 is provided which governs the fan motor 66, the solenoid valve 55 and the solenoid air valve 67. The calibration is such that when a predetermined low temperature limit is reached, the fan 68 and the compressor 59 are stopped and the valve 55 is closed. This is accomplished by causing the thermostat 65 to open the circuit thus deenergizing motor 66 and the solenoids of valves 55 and 67. These valves, being similar to that shown in Fig. 4, close, thus stopping flow of refrigerant to section 51 and stopping air pressure to clutch 69 which declutches the same. However, a thermostatic switch 70 controlled by bulb 71 in holdover 72 is arranged in parallel with respect to valve 67 so that compressor 59 will not stop until the holdover 72 has been properly frozen. As long as the temperature in bulb 71 is above the freezing point of the holdover, the switch 70 remains closed and thus the compressor is operated to freeze the holdover if the air in the compartment of the car has been cooled.

When the car slows down or stops so that the compressor cannot be driven at sufficient speed, the fins 73 are refrigerated by conduction through the bottom 74 of the holdover tank. The upper part of the fins cool the upper part of the coils 75 of the section 51. These upper parts of the coils act as condensers for refrigerant standing in the lower parts of the coils. Thus the lower parts of the coils are refrigerated by evaporation of refrigerant in the lower parts, the condensation of the refrigerant in the upper parts of the coils and the return by gravity of the condensed refrigerant. It is to be understood that the valves 56 and 62 may be set to operate at same back pressures, in which case the holdover will be refrigerated simultaneously with the air.

In the modification shown in Fig. 3, the refrigerant liquefying unit 100 is substantially the same as that shown in Fig. 1. Thus, the refrigerant liquefying unit comprises a condenser 13b, a compressor 12b and driving means for the compressor which may be either the live axle 18b or the stand-by motor 23b. A clutch 110 is actuated by air from the line 22b. As explained in the description of the apparatus shown in Figs. 1 and 2, a manual valve (not shown) may be placed in the air line 22b so as to declutch the compressor 12b from the axle 18b when the motor 23a is to be energized. The holdover cooling section 101 and the air cooling section 102 of the evaporator are in series refrigerant flow relationship; but the refrigerant first flows through the section 101 and then through section 102. Thus the liquid refrigerant line 103 from the unit 100 is connected to an automatic expansion valve 104. From there the expanding refrigerant flows through the section 101, thence through the pipe 105 to the section 102 and returns through the suction line 106 to the unit 100. The holdover fluid 107 may be any of the substances heretofore named which change phase above 32° F. After the substance 107 has been frozen, the refrigerant commences or continues to flow through the pipe 105 in liquid form and is evaporated in section 102 and the air is conditioned. When the speed of the car reduces or stops, the air is cooled by thermal exchange with the substance 107 through the medium of fins of the type shown in Fig. 5.

The thermostat 108, placed in the compartment to be cooled, stops the fan 109 and declutches the clutch 110 through the action of solenoid valve 111 when the temperature falls below a predetermined minimum, and performs the converse when the temperature rises above a predetermined limit.

The thermostats shown may be made responsive to dry bulb temperatures, wet bulb temperatures or both, as desired.

The solenoid valves in the various modifications may be of the type shown in Fig. 4. The solenoid 120 lifts the valve member 121 when the solenoid is energized and permits it to fall when deenergized.

While the form of embodiment of the invention as herein disclosed, constitutes a preferred form, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

What is claimed is as follows:

1. An air conditioning apparatus for use in a vehicle having a live axle assembly comprising a phase-changing holdover; refrigerant evaporator means; a refrigerant liquefying means operatively connected to said evaporator means; said evaporator means including an air cooling section and a holdover cooling section; said refrigerant liquefying means comprising a compressor, means for operating said compressor and a clutch between said compressor and said compressor operating means; means whereby operation of said compressor supplies liquid refrigerant to both sections of said evaporator means simultaneously; means for circulating air to be conditioned over said air cooling section of said evaporator means; control means responsive to a change in the psychrometric condition of air for stopping said air circulating means and for declutching said clutch; and means responsive to the temperature of said holdover for preventing said control means from declutching said clutch until the

temperature of the holdover reaches a predetermined low temperature.

2. An air conditioning apparatus comprising a phase-changing holdover, evaporator means and a refrigerant liquefying unit operatively connected together, said evaporator means including an air cooling section and a holdover cooling section, said sections being in parallel refrigerant flow relationship, means for thermally exchanging heat between air to be conditioned and said air cooling section when said refrigerant liquefying unit has excess refrigerating capacity, a first valve in said air cooling section having means to maintain the evaporating pressure below a predetermined pressure in said air cooling section, a second valve in said holdover cooling section having means to maintain the evaporating pressure below a predetermined pressure in said holdover cooling section, a third valve controlling the flow of refrigerant to said air cooling section, means responsive to the temperature of said holdover for starting and stopping the operation of said refrigerant liquefying unit, means for thermally exchanging heat between air to be conditioned and said holdover when said unit lacks sufficient refrigerating capacity, said first and second

valves being arranged to be open simultaneously when said refrigerant liquefying unit has excess capacity.

3. Air conditioning apparatus comprising in combination, evaporator means having an air cooling section and a holdover cooling section arranged in parallel refrigerant flow relationship, refrigerant liquefying means in refrigerant flow relationship with said evaporator means, expansion valve means controlling the flow of refrigerant to said air cooling section, a second valve means controlling the flow of refrigerant to said air cooling section, expansion valve means controlling the flow of refrigerant to said holdover cooling section, means responsive to the temperature of the air controlling said second valve means, and means responsive to the temperature of said holdover for starting and stopping said refrigerant liquefying means, said valve means and the controls therefor being so constructed and arranged as to supply refrigerant to both evaporator sections when said refrigerant liquefying means has more capacity than required for properly cooling the air.

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