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MULTITEMPERATURE REFRIGERATION APPARATUS AND METHOD

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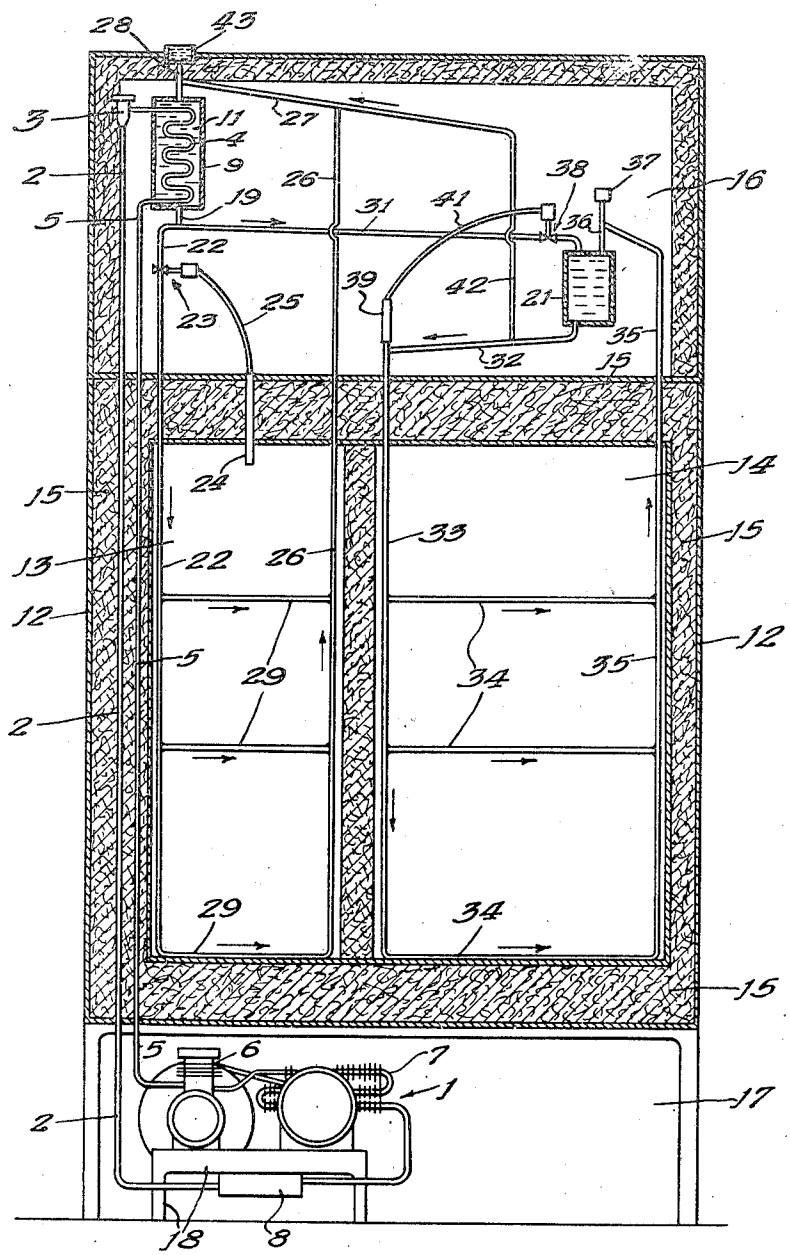

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MULTITEMPERATURE REFRIGERATION APPARATUS AND METHOD

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This invention relates to refrigeration, and more particularly to a multi-temperature refrigeration apparatus and method for maintaining different compartments of a refrigerator cabinet, or other segregated spaces, at different temperatures suited to the individual purposes of such compartments or spaces. By way of example, one of the compartments may be for freezing food products and storing them at low temperature and another or others of such compartments may be for storing other food products at one or more higher temperatures.

The principal object of the invention is to provide an improved refrigeration system of this character in which a thermosyphoning secondary refrigerant is employed in conjunction with a primary refrigerant or coolant and is circulated to and from the respective compartments or spaces by thermosyphonic acition resulting from changes in temperature and corresponding changes in fluid density of such secondary refrigerant. The system thus provides for circulation of the secondary refrigerant without mechanical pumping and for this reason, as well as by the elimination of other commonly used devices, can be built for a much lower first cost than can the conventional multi-temperature refrigeration system. The use of the thermosyphoning refrigerant in the manner contemplated also assures efficiency in operation and the maintenance of unusually uniform temperatures in the respective refrigerated spaces.

Another factor making for economy in the system is that only one evaporator is required to maintain widely differing temperatures in two or more different parts of the system.

A further important feature of the invention is the provision of a multi-temperature refrigerating system of the general type above indicated in which condensation of water vapor on the surfaces in the high temperature compartment and the frosting of such surfaces may be prevented, thus avoiding excessive dehydration of fruits and vegetables or other products which may be stored in this compartment and eliminating the problem of defrosting.

Many other advantages and desirable characteristics of the invention will be apparent from the following description taken in connection with the accompanying drawing, in which the single figure shows, in more or less diagrammatic form, a refrigeration system embodying the apparatus, and adapted to carry out the method, of the invention.

In said drawing we have shown a primary refrigerant circuit, including a conventional condensing unit 1, a liquid line 2, a thermostatic expansion valve 3, an evaporator 4 and a suction line 5. The condensing unit includes the usual motor-compressor unit 6, condenser 7 and receiver 8. From the latter the primary refrigerant, which may be Freon-12, passes through the liquid line 2 to the expansion valve 3, or equivalent throttling device. Upon expanding through the latter, said primary refrigerant drops to a predetermined low temperature in the evaporator 4, which may be of the dry expansion type and, in accordance with our invention, is positioned in a vessel 9 containing a secondary refrigerant 11 which circulates through the system and serves as the cooling medium for the compartments or spaces to be refrigerated, as will later be described. The secondary refrigerant is thus in heat exchange relation with the evaporator 4 by which it is cooled to the desired extent, as, for example, to —15° F. The unit, comprising the evaporator 4 and vessel 9 (which is constantly filled with secondary refrigerant), is therefore hereinafter referred to as a "heat exchanger" and it will be understood that the compressor-condenser-evaporator primary refrigerating system is shown by way of example only since, for certain adaptations of the invention, some other form of primary coolant, such as an absorption refrigeration system, might be preferred.

The system is shown as embodied in a cabinet comprising outer walls 12 within which there are located a low temperature freezing and storage compartment 13 and a high temperature storage compartment 14. Said compartments are surrounded by suitable insulation 15 and above them there is an insulated compartment 16 containing the heat exchanger above mentioned and other elements which will be hereinafter described.

The condensing unit 1 is contained within a space 17 beneath the insulated part of the cabinet and is shown as mounted upon a frame or pedestal 18.

The secondary refrigerant after being cooled to, say, —15° F. in the heat exchanger 9 flows downwardly therefrom through an outlet pipe 19 and, as shown, passes through two circuits, one leading to the low temperature compartment 13 and the other to the high temperature compartment 14, the latter circuit however including a mixing chamber 21 in which the secondary refrigerant is raised to a higher temperature

before being admitted to the high temperature compartment.

The first-mentioned circuit is downwardly through a pipe 22 in which there is a solenoid valve 23 under the control of a thermal switch 24 located in the high temperature compartment 13 and connected with said solenoid valve by suitable wiring contained in a conduit 25. When the valve 23 is opened the refrigerant flows downwardly through said pipe 22 and, as it receives heat from the compartment 13, its density decreases and circulation is set up to cause return thereof through a pipe 26 to a transversely extending pipe 27 connecting with an intake pipe 28 leading into the top of the vessel 9. Cross pipes 29 are provided between the pipes 22 and 26 and said pipes 22, 26 and 29 may be contained within hollow shelves and walls in the storage space, or may open into such hollow shelves and walls which may themselves serve as conduits to provide more extensive refrigerating surfaces if this should be desired.

As above indicated, the secondary refrigerant may be at a temperature of —15° F. upon leaving the heat exchanger and in that case may return to the heat exchanger at a temperature of, say, —5° F. The control switch 24 may be set to close the solenoid valve 23 when the temperature in the storage space drops to 0° F., thereby stopping circulation in this circuit. This temperature has been found to be a suitable one for storage of frozen foods and will be automatically maintained by the means just described.

It may be noted in this connection that the primary refrigerant vapor is returned to the condensing unit at a proper temperature to prevent liquefaction in the return line, and a low pressure cut-out may be used in the condensing unit so that the motor will be stopped when the suction pressure of the primary refrigerant drops to a predetermined control value.

The second circuit of the secondary refrigerant mentioned above is through a pipe 31, which is preferably inclined to the horizontal, leading to the mixing chamber 21 and through a pipe 32 leading from said chamber, a downwardly extending pipe 33, cross pipes 34 and a riser 35 in the compartment 14, said riser leading to an intake pipe 36 opening into the top of said mixing chamber 21. An air vent 37 is, or may be, provided at the top of the pipe 36 above the point of connection thereof with the pipe 35.

A solenoid valve 38 is provided in the pipe 31 and is controlled by a thermal switch 39 located in the pipe 32, or in the pipe 33 adjacent the junction of said pipes as shown in the drawing, said switch being responsive to the temperature of the liquid in the pipe in which it is located. Said thermal switch 39 is connected with the valve 38 by means of wiring contained in a conduit 41.

If it be desired to maintain the high temperature compartment 14 at a temperature of 40° F., the control may be set so that the secondary refrigerant will leave the mixing chamber 21 at a temperature of 34° F., it being understood that the cold refrigerant from the vessel 9 will have been mixed with the relatively warm refrigerant returning to the mixing chamber through the pipes 35 and 36 and that the control switch 39 may be set so as to close the valve 38 when the temperature of the refrigerant flowing from the mixing chamber 21 through the pipes 32 and 33 drops under 34° F.

When the temperature of the refrigerant flowing through the pipe 33, the cross pipes 34 and the riser 35 in the compartment 14 rises to about 38° F. the density of the liquid will decrease sufficiently to set up the circulation causing the return of the liquid to the mixing chamber at about that temperature.

It will be understood that, as in the case of the compartment 13, the secondary refrigerant may be circulated through hollow walls and shelves in the compartment 14 to provide more extensive cooling surfaces if this should be desired.

It will be noted that by thus maintaining the cooling surfaces in the compartment 14 above the freezing temperature of water and only slightly lower than the temperature of the air in the compartment there will be relatively little condensation of water vapor on the cooling surfaces and therefore dehydration of the products stored in this compartment will be prevented, or so limited as to maintain fruits, vegetables and like products in good condition; also frosting of the cooling surfaces will be prevented and the defrosting problem, so troublesome in most refrigerating systems, will be eliminated.

There is a third circuit of the secondary refrigerant, namely, from the pipe 32 through a vertical pipe 42 and the pipes 27 and 28 to the vessel 9 of the heat exchanger. The flow in the pipe 32 therefore divides ahead of the thermal switch 39 and a part of the relatively warm liquid is recooled in said heat exchanger. In this manner proper temperature of the portion of the secondary refrigerant used for cooling the high temperature compartment is maintained. The circulation in this circuit is due to thermosyphonic action resulting from the fact that the density of the secondary refrigerant in the conduits 42 and 27 is less than in the conduits 29 and 31.

A contraction-and-fill tank 43 is, or may be, provided at the top of the pipe 28 to provide for a sufficient volume of secondary refrigerant to insure a minimum level above the level of the connection from the return line 27. This is desirable since as the secondary refrigerant is cooled the total volume of this liquid in the system decreases. Without a reserve volume when the system is filled at room temperature, this reduction in volume might cause the liquid level to drop far enough to prevent the return of refrigerant through line 27 to the heat exchanger 9. While the tank 43 is shown as open at the top it should be noted that with sufficient reserve volume the tank may be sealed from the air in order to prevent any loss of secondary refrigerant by evaporation. Although a slight vacuum may then be created in the top of said tank 43 as the total volume of the refrigerant decreases due to cooling, the same vacuum then acts upon the dropper and riser lines and there will be no interference with the thermosyphoning as long as the inlet from the line 27 is not uncovered.

While we have shown only two compartments it will be understood that the principle of the invention may be extended to control the temperature of the air in more than two compartments, each at a different temperature, by using only one primary refrigerant heat exchanger. For example, the system is adaptable to the requirements of storage on ships of the United States Navy where three different storage temperatures are required, namely, 0° F. for frozen foods, 33° F. for dairy products and 45° F. for fruits and vegetables. Various other adaptations

are of course within the purview of the invention.

The thermosyphoning refrigerant should be a fluid having a high coefficient of cubical expansion (or capacity for change of density with temperature), a high specific heat, high thermal conductivity, low viscosity, low freezing point and high flash and fire points. While future developments may provide more ideal fluids for this purpose than are now available we have found that a mixture of methyl alcohol and water, with, say, two parts by volume of alcohol to one part by volume of water, is reasonably satisfactory since it has a freezing point below the lowest temperatures needed for refrigeration and has a considerable number of the other qualities above mentioned in reasonable measure. The new silicone oils have desirable properties for this purpose and probably will soon be available in sufficient quantities at reasonable prices, although they have heretofore been rather expensive. Among other possible alternative substances which may be used are pure methyl alcohol, pure ethyl alcohol, ethylene glycol, glycerine and other mixtures of alcohol and water.

A desirable feature of the invention in addition to those above mentioned is that with the cooling surfaces arranged as described there is little air temperature differential from top to bottom of the storage compartments even though the latter contain shelves, where as in the common household refrigerator there is considerable air temperature variation from one shelf to another.

Another feature of our system is that the only pressure which the conduits of the secondary refrigerant circuits, which as above stated may in part be hollow walls or shelves, need withstand is the small hydrostatic head of only a few feet of secondary refrigerant. If a primary refrigerant were circulated through evaporators placed within the spaces to be refrigerated the evaporator plates would have to withstand the high pressures of the primary refrigerant at the temperature of its vaporization. This would result in considerably greater danger of rupture and leakage than with our system.

Through the thermostatic controls above described very close control of the air temperature in the freezing and low temperature storage compartment may be maintained. This is important for there is now some evidence that large temperature fluctuations in the storage of frozen products may cause more loss of quality in the products while in storage than would be caused by an improper storage temperature.

As above indicated, there is a considerable saving in equipment and thus a lower first cost when our system is employed than is involved in the conventional refrigeration system for a multi-temperature cabinet. When designed for a two-temperature cabinet the conventional system requires two evaporators with two thermostatic expansion valves, two air sensitive thermal switches operating two solenoid valves in the respective liquid lines, and one suction pressure control valve in the suction gas line leaving the high temperature cabinet to prevent, or seek to prevent, frosting and consequent drying of stored foods. With our system one of said evaporators and one thermostatic expansion valve is eliminated as is the suction pressure valve. It will be evident that even further savings may be effected when more than two different temperature compartments or spaces are employed.

Another feature of the present system which is of practical importance is that the volume of the secondary refrigerant employed in the system is sufficiently large to obtain two beneficial results. First, the condensing unit will not short-cycle for when it starts at the cut-in point of the low pressure control, the temperature of a large volume of the secondary refrigerant must be reduced to the cut-out control point before the motor will be stopped. There is no need for a surge drum, or other devices, in the primary refrigerant circuit to prevent short-cycling. Second, in the event of a power failure, the rate of temperature rise of the air in the storage compartments of this unit is extremely slow because of the large heat capacity of the volume of secondary refrigerant in the system. For common durations of power failure, the tempertaure rise in this unit would not be sufficient to permit frozen products to defrost nor sufficient to cause food spoilage in the high temperature storage compartment.

It has been previously mentioned that the primary refrigerating system is illustrated only by way of example and that other primary coolants might be employed. It is even possible that for certain uses no source of mechanical energy would be required and that the outdoor air could be used as the primary coolant when it is at lower temperature than the desired temperature of storage. The primary heat exchanger could then be located out of doors at an elevation higher than that of the storage compartments. The secondary refrigerant would be cooled by the outdoor air and would then drop to the storage compartment or compartments where it would absorb heat and then through thermosyphoning action rise and return to the heat exchanger. Low temperatures of the outdoor air could thus be utilized to maintain higher but controlled temperatures in indoor storage compartments. For example, when the temperature of the outdoor air is fluctuating between limits of −10° F. and 30° F. a compartment storage temperature could be held substantially constant at 40° F. This would be particularly important for winter storage of apples or like products in certain of the northern states.

While the mixing chamber 21 is shown as in the upper compartment 16 it may be found desirable to locate it elsewhere, as, for example, in the upper part of the compartment 14 in which case its surface would constitute a part of the cooling surface within that compartment.

Other modifications which do not depart from the spirit or scope of the invention may suggest themselves to those skilled in the art.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, but the appended claims should be construed as broadly as permissible in view of the prior art.

We claim:

1. A refrigerating apparatus comprising a cabinet having a plurality of compartments therein to be refrigerated to different degrees; a primary refrigerating system including a compressor, a condenser and an evaporator; and a secondary refrigerating system including means for bringing a secondary refrigerant into heat exchange relation to said evaporator, means for circulating said secondary refrigerant through said compartments by thermosyphonic action resulting from changes of temperature thereof, and thermally-controlled devices for regulating the admission of said secondary refrigerant to the different

compartments and the refrigerating effect thereof, whereby each compartment may be maintained at a different temperature.

2. A refrigerating apparatus comprising a cabinet having a plurality of compartments therein to be refrigerated to different degrees; a primary refrigerating system including a compressor, a condenser and an evaporator; and a secondary refrigerating system including means for bringing a secondary refrigerant into heat exchange relation to said evaporator, means for circulating said secondary refrigerant through said compartments by thermosyphonic action resulting from changes of temperature thereof, thermally-controlled devices for regulating the admission of said secondary refrigerant to the different compartments and the refrigerating effect thereof, whereby each compartment may be maintained at a different temperature, and means for raising the temperature of a portion of said secondary refrigerant which is to be used for refrigerating a compartment to be maintained at relatively high temperature before admission thereof to said compartment.

3. A refrigerating apparatus comprising a cabinet having a plurality of compartments therein to be refrigerated to different degrees; a primary refrigerating system including a compressor, a condenser and an evaporator; and a secondary refrigerating system including means for bringing a secondary refrigerant into heat exchange relation to said evaporator, means for circulating said secondary refrigerant through said compartments by thermosyphonic action resulting from changes of temperature thereof, thermally-controlled devices for regulating the admission of said secondary refrigerant to the different compartments and the refrigerating effect thereof, whereby each compartment may be maintained at a different temperature, and means for raising the temperature of a portion of said secondary refrigerant which is to be used for refrigerating a compartment to be maintained at relatively high temperature before admission thereof to said compartment, said last-mentioned means comprising a mixing chamber in which cold secondary refrigerant coming from the vicinity of said evaporator is mixed with relatively warm secondary refrigerant returned from said high-temperature compartment to raise the temperature of said cold refrigerant before it is admitted to the latter compartment.

4. A refrigerating apparatus comprising a cabinet having a freezing compartment to be maintained at a sub-freezing temperature and a storage compartment to be maintained at a temperature above freezing; a primary refrigerating element adapted to be maintained at a low sub-freezing temperature; and a secondary refrigerating system including means for bringing a secondary refrigerant into heat exchange relation to said primary refrigerating element, means for circulating portions of said secondary refrigerant through the respective compartments aforesaid by thermosyphonic action resulting from changes in temperature of said refrigerant, and thermally-controlled devices for regulating the admission of said portions of the secondary refrigerant to said compartments and the refrigerating effect thereof, whereby said compartments may be maintained at the respective temperatures suited to the aforesaid functions thereof.

5. A refrigeration system comprising a cabinet having a plurality of compartments to be refrigerated and maintained at different temperatures; a primary refrigerant circuit including an evaporator and means for controlling the flow of primary refrigerant to and from said evaporator to maintain a predetermined low temperature therein; a secondary refrigerant circuit including a cooler in heat exchange relation with said evaporator, and means for controlling the flow of secondary refrigerant through said compartments by thermosyphonic action to separately regulate the temperature maintained by said secondary refrigerant in each compartment, whereby said compartments may be maintained at different temperatures.

6. A refrigeration system comprising a cabinet having a plurality of compartments to be refrigerated and maintained at different temperatures; a primary refrigerant circuit including an evaporator and means for controlling the flow of primary refrigerant to and from said evaporator to maintain a predetermined low temperature therein; a secondary refrigerant circuit including a cooler in heat exchange relation with said evaporator, and means for controlling the flow of secondary refrigerant through said compartments by thermosyphonic action to separately regulate the temperature maintained by said secondary refrigerant in each compartment, whereby said compartments may be maintained at different temperatures, said last mentioned means including thermally-controlled valves for controlling the flow of the secondary refrigerant to said compartments.

7. A refrigeration system comprising a cabinet having a plurality of compartments to be refrigerated and maintained at different temperatures; a primary refrigerant circuit including an evaporator and means for controlling the flow of primary refrigerant to and from said evaporator to maintain a predetermined low temperature therein; a secondary refrigerant circuit including a cooler in heat exchange relation with said evaporator, means for controlling the flow of secondary refrigerant through said compartments by thermosyphonic action to separately regulate the temperature maintained by said secondary refrigerant in each compartment, whereby said compartments may be maintained at different temperatures, said last mentioned means including thermally-controlled valves for controlling the flow of the secondary refrigerant to said compartments, a mixing chamber in which relatively warm secondary refrigerant returning from a compartment which is maintained at a relatively high temperature is mixed with cold secondary refrigerant from said cooler to raise the temperature of the latter, and means for conducting the mixed refrigerant to said last-mentioned compartment.

8. A refrigeration system comprising a cabinet having a plurality of compartments to be refrigerated and maintained at different temperatures; a primary refrigerant circuit including an evaporator and means for controlling the flow of primary refrigerant to and from said evaporator to maintain a predetermined low temperature therein; a secondary refrigerant circuit including a cooler in heat exhange relation with said evaporator, means for controlling the flow of secondary refrigerant through said compartments by thermosyphonic action to separately regulate the temperature maintained by said secondary refrigerant in each compartment, whereby said compartments may be maintained at different temperatures, said last mentioned means including thermally-controlled valves for

controlling the flow of the secondary refrigerant to said compartments, a mixing chamber in which relatively warm secondary refrigerant is mixed with cold secondary refrigerant from said cooler to raise the temperature of the latter, and means for conducting the mixed refrigerant to a compartment which is to be maintained at relatively high temperature.

9. In the operation of a multi-temperature refrigeration system the method which consists in circulating by thermosyphonic action a secondary refrigerant, having a high co-efficient of cubical expansion or of change in density with changes in temperature, into heat exchange relationship with a primary refrigerating element, to reduce the temperature of said secondary refrigerant to the minimum point necessary to enable it to refrigerate the coldest of a plurality of refrigerating compartments to be maintained at different temperatures, thereafter directing portions of said secondary refrigerant to the respective compartments, and regulating the amount of refrigeration of each of said compartments by the secondary refrigerant directed thereto, whereby each compartment may be maintained at a desired individual temperature.

10. In the operation of a multi-temperature refrigeration system the method which consists in circulating by thermosyphonic action a secondary refrigerant, having a high co-efficient of cubical expansion or of change in density with changes in temperature, into heat exchange relationship with a primary refrigerating element, to reduce the temperature of said secondary refrigerant to the minimum point necessary to enable it to refrigerate the coldest of a plurality of refrigerating compartments to be maintained at different temperatures, thereafter directing portions of said secondary refrigerant to the respective compartments, and regulating the amount of refrigeration of each of said compartments by the secondary refrigerant directed thereto by varying the temperature of the refrigerant directed to the different compartments and thermally-controlling the admission of refrigerant to each compartment, whereby each compartment may be maintained at a desired individual temperature.

11. A refrigerating apparatus comprising a cabinet having a plurality of compartments therein to be refrigerated to different degrees; a primary coolant; and a secondary refrigerating system including means for bringing a secondary refrigerant into heat exchange relation to said primary coolant, means for circulating said secondary refrigerant through said compartments by thermospyhonic action resulting from changes of temperature thereof, and thermally-controlled devices for regulating the admission of said secondary refrigerant to the different compartments and the refrigerating effect thereof, whereby each compartment may be maintained at a different temperature.

12. A refrigerating apparatus comprising a cabinet having a plurality of compartments therein to be refrigerated to different degrees; a primary refrigerating element; and a secondary refrigerating system including means for bringing a secondary refrigerant into heat exchange relation to said primary refrigerating element, means for circulating said secondary refrigerant through said compartments by thermosyphonic action resulting from changes of temperature thereof, thermally-controlled devices for regulating the admission of said secondary refrigerant to the different compartments and the refrigerating effect thereof, whereby each compartment may be maintained at a different temperature, and means for raising the temperature of a portion of said secondary refrigerant which is used for refrigerating a compartment to be maintained at relatively high temperature before admission thereof to said compartment.

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