

April 14, 1959

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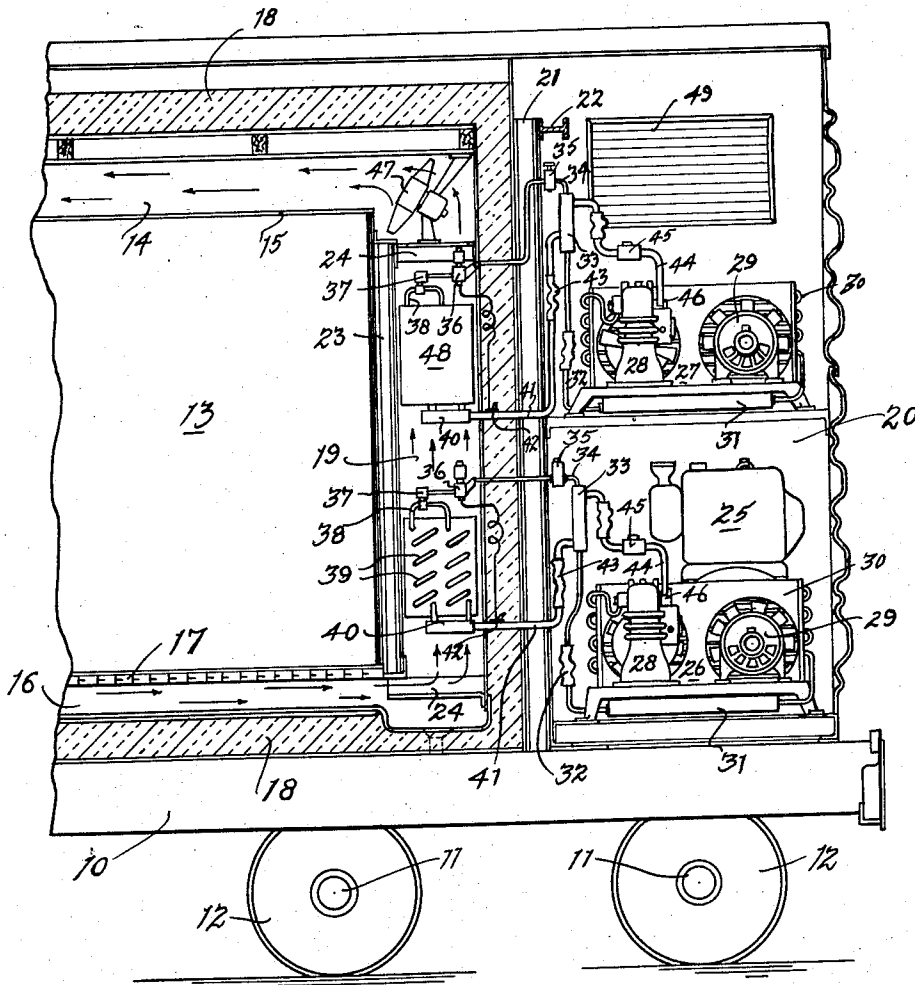
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MECHANICALLY REFRIGERATED RAILWAY CAR

Filed June 19, 1953

3 Sheets-Sheet 1

Fig. 1.



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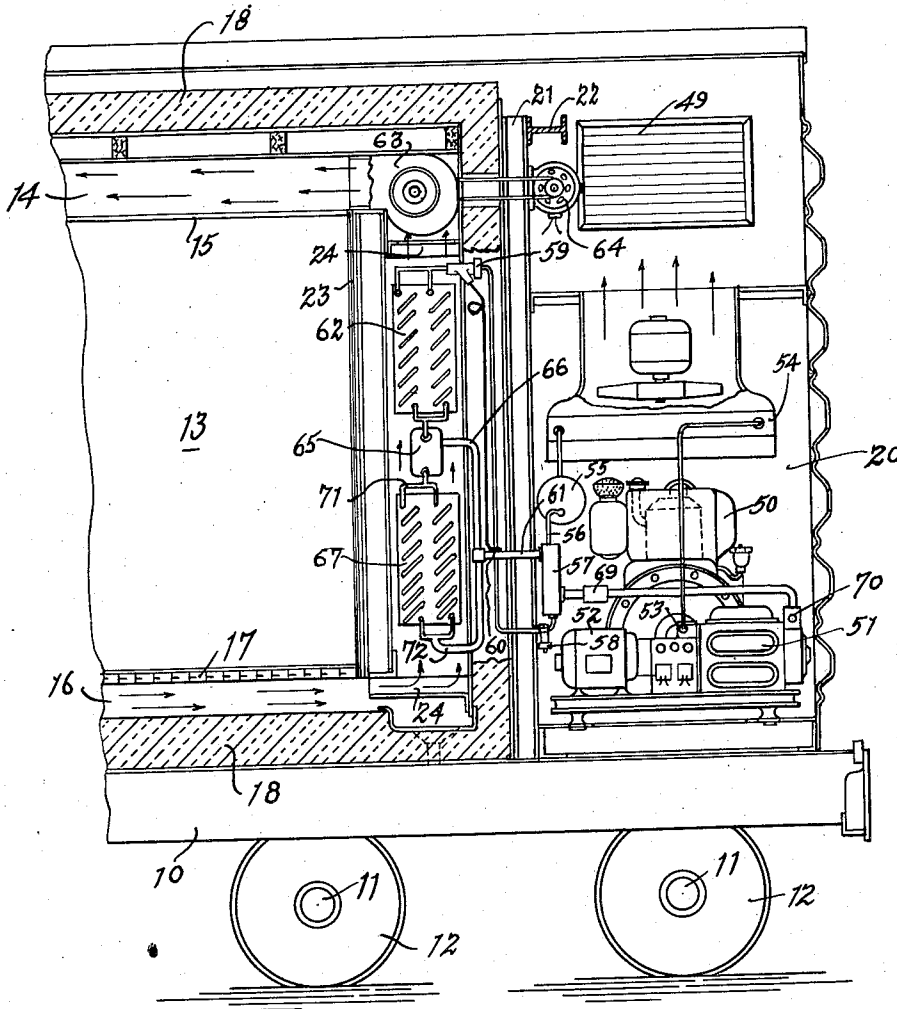
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Fig. 2.



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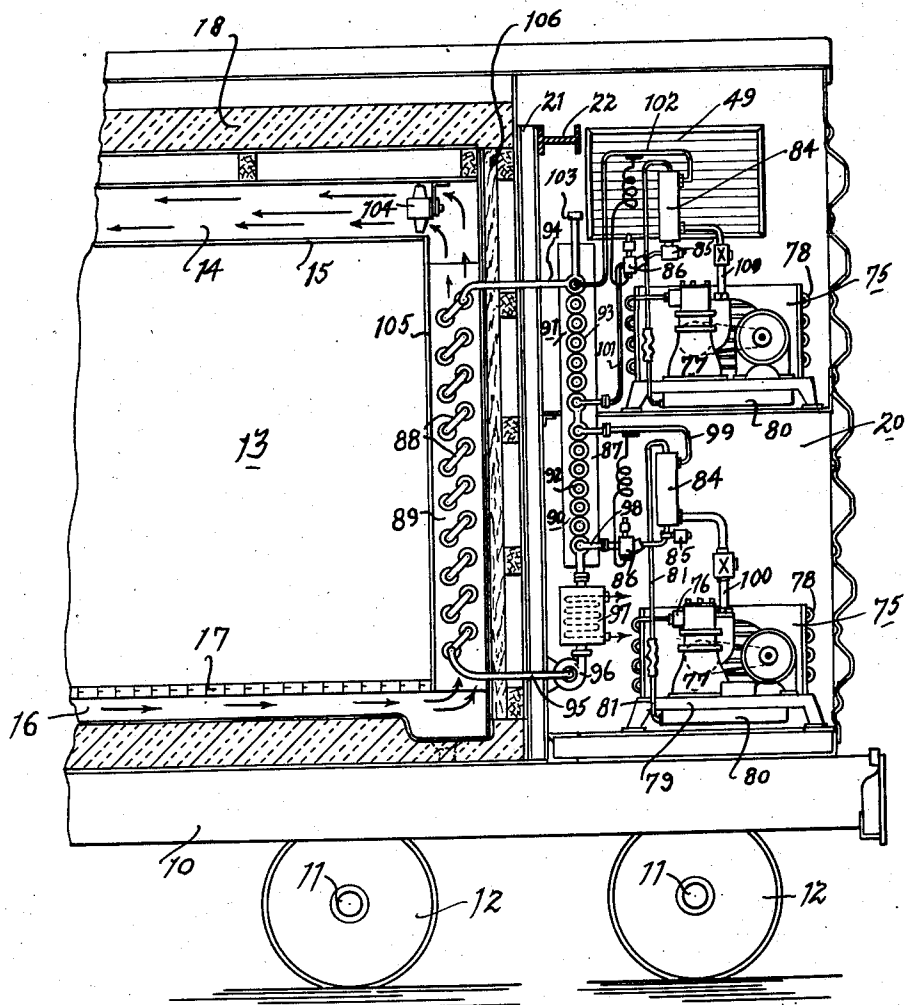
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Fig. 3.



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MECHANICALLY REFRIGERATED RAILWAY CAR

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Application June 19, 1953, Serial No. 362,775

5 Claims. (Cl. 62—239)

The present invention relates to mechanically refrigerated low-temperature transport vehicles, especially railroad refrigerator cars, and has for its purpose to provide efficient and economical refrigeration under the difficult conditions that exist for the operation of such cars in warm climates. The mechanical, refrigeration system for such cars is usually diesel-engine driven and naturally air cooled and for the sake of simplicity uses single-stage compression. The temperature required in the commodity compartment for the transportation of frozen food is between 0° F. and -10° F.; that is, evaporator temperatures as low as -20° F. combined with condensing temperatures of +120° F. or higher during maximum conditions. This means a very high compression ratio. The maintenance of temperatures of 0° F. or below in refrigerator cars is therefore a technical problem, which for its solution requires both a carefully designed car with a minimum of heat losses and air leaks and the best possible application of the refrigeration equipment.

The equipment used in refrigerated railroad cars comprises usually a diesel-electric system for electric operation of one or two motor-driven compressors. A direct drive between diesel engine and compressor is also feasible. The refrigeration system is usually of the conventional type for air recirculation through a direct expansion evaporator unit. The cooling unit together with a blower fan is usually located in an air flue or tunnel close to the machine compartment at one end of the car and the cold air is circulated between said air flue and the commodity space for refrigeration of the car.

When using a so-called envelope design the air circulation system surrounds the commodity space as an envelope without direct air communication between the flue or tunnel in which the cooling unit system is located and the commodity space. The enclosure walls separating the commodity space from the air circulation system or envelope are usually made of non-metallic material such as plywood or Masonite except for the ceiling partition, which preferably is made of sheet metal such as aluminum in order to increase the heat transfer between the cold air system and the commodity space. The space at the top of the car is large in volumetric capacity and so forms a plenum from which the cold air under pressure circulates downward along the sides of the commodity space.

In such an envelope design the circulating air usually enters the evaporator or cooling unit flue or tunnel at the floor of the car, rises over the heat transfer surface and is introduced by a blower into the ceiling plenum, which is separated from the commodity space by the metal ceiling mentioned above. In the plenum chamber a comparatively high air pressure is maintained all along the car and the cold air is therefore uniformly circulated through the relatively narrow side wall flues to the floor channel of the car and then returned to the cooling unit flue. During this passage the temperature of the air rises in proportion to the heat intake. A 50-foot super-insulated railroad refrigerator car of a good design would,

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at equilibrium have a heat intake of about 25,000 B.t.u.'s/hour with a temperature difference of around 100° F., which for an air flow of 4000 c.f.m. would theoretically correspond to a temperature rise in the circulated air of approximately 6° F. It would therefore be necessary to maintain an average temperature difference between air entering the cooling unit and air leaving the cooling unit of at least 6° F. in order to maintain constant temperature inside the car. However, the flow of air is not uniform over the whole cross section of the cooling coil, and the temperature of the return air is also not uniform due to uneven heat pick-up. These, together with several other factors, make it necessary to count a normal temperature difference between ingoing and outgoing air of 10° F. instead of 6° F. During pull down conditions or when heat is given off by the load, or under maximum operating conditions this temperature difference may easily reach 15 or 20° F. or even higher.

If the flow of circulated air is less than mentioned above, the necessary average temperature drop during the passage through the evaporator coil would of course have to be increased in order to maintain equilibrium. A reduction of the circulated air flow with corresponding relatively large air temperature changes during the cycle is possible if the heat transfer between the plenum chamber, where the air has the minimum temperature, and the commodity space is considerably larger than the heat transfer at other sections of the air envelope. The commodity space temperature will then be influenced mainly by the plenum chamber temperature and considerably less by the temperature in other sections of the envelope. Consequently it would be of advantage to keep the temperature of the metal ceiling itself very low and let the air temperature rise relatively more during its further passage, which would reduce the heat intake to the car. This does not mean that the enclosure walls between the commodity space and the envelope should be specially insulated. The wooden floor is normally a sufficient insulation at the bottom of the commodity space, and if the walls are made of ordinary wooden materials like plywood or Masonite, a thickness of 5/8" to 1" in combination with a metal ceiling will prove sufficient for maintaining a considerably lower average temperature in the commodity space than in the return air stream. A second advantage of reducing the amount of circulating air flow would be of course to reduce the fan power requirements. The less fan heat pumped into the circulating air the better. All this makes it desirable to use a minimum of air circulation, which is possible only if relatively large temperature differences of the air entering and leaving the refrigeration tunnel can be handled economically by the cooling unit. It is therefore one of the objects of this invention to provide for a maximum temperature drop in the air when passing through the cooling unit system without using an overall low evaporator temperature with its detrimental effect on the volumetric efficiency.

Other objects and advantages will be apparent from a study of the following specifications taken in connection with the accompanying drawings wherein the invention is illustrated as adapted to a railway car.

Although the invention is especially related to cars of the envelope design the principles of the invention can also be applied to cars of the open type of circulation, where the air in the commodity space is directly cooled by recirculation through the cooling unit system. It is also understood that the principles illustrated and described are equally adaptable to trucks and other produce-transporting vehicles.

Some subject matter described and not claimed in this application is described and claimed in copending applica-

tion entitled "Mechanically Refrigerated Railway Car," filed November 25, 1955, Serial No. 549,108.

In the drawings Figures 1, 2, and 3 are vertical fragmentary sectional views taken at one end of a railway refrigerator car equipped with refrigerating systems constructed in accordance with the invention.

According to the invention the cooling of the circulated air is done in two or more steps. Instead of having a cooling unit of practically uniform temperature two or more evaporators of different temperatures are arranged in series one after each other in a vertical air flue. The high temperature return air will according to the invention first pass over an evaporator section of relatively high temperature located at the lower part of the cooling unit and, being precooled thereby, will then enter another evaporator section of lower temperature for a final refrigeration down to the lowest possible temperature before it enters the ceiling plenum.

This stepwise refrigeration at two temperature levels can, according to the invention, be brought about either by using two separate compressors or by using one compressor filled with two different refrigerants. Two separate compressors have often been used instead of one compressor as a safety factor and in order to obtain a step start of the refrigeration compressors by the diesel-electric power plant. In railroad refrigeration both compressors have hitherto been connected with the same evaporator coil bank with parallel or intermixed piping for both evaporators while, according to my invention, the evaporator of one system is placed after the evaporator of the other system in the direction of the air flow and the systems are adjusted to different evaporation temperatures as will be later described in connection with Figure 1 of the drawings.

When using only one compressor two different temperature sections of the evaporator can be obtained by the use of two different refrigerants such as "Freon 12" and "Freon 22," which have different temperature pressure curves. At a back pressure of approximately 7 lbs. "Freon 12" boils at -5° F. while at the same pressure "Freon 22" boils at -25° F. If a mixture of these refrigerants enters the evaporator through the expansion valve and a back pressure is maintained at 7 lbs., principally the "Freon 22" will first evaporate at temperatures approaching -25° F. and the "Freon 12" will evaporate later when the liquid refrigerant has reached a higher temperature zone at the entrance of the return air stream. In order to enable evaporation at different temperatures the two evaporator sections are arranged with a flash chamber in between as will be described in connection with Figure 2 of the drawings.

The advantages of splitting the refrigeration capacity in one part delivered at a relatively high evaporation temperature and one part delivered at a lower temperature for the ultimate cooling of the air is obvious to those familiar with the thermodynamics involved. In case two exactly like compressor systems are used, a system working at for instance -5° F. evaporation temperature will have a capacity under railroad conditions almost double that of a compressor system working at -20° F. Therefore, by step-wise refrigeration a considerable increase in total capacity will be obtained as compared with both compressor systems working at -20° F. The same refers to one compressor working with a mixture of "Freon 12" and "Freon 22" with two evaporators at different temperatures and a flash chamber between the two evaporator sections.

The embodiments of the invention shown of Figures 1 and 2 have parts of the system containing the refrigerant located inside of the bulkhead between the machine compartment and the commodity space. The evaporator or cooling unit system, which usually is made of copper tubing with aluminum fins is a weak point in the system as far as leaks are concerned and it is therefore necessary to provide a very strong enclosure in order to protect the

weak evaporators from the load in the commodity space of the car. This means an expensive bulkhead design and also difficulties with regard to insulation and air tightness. If the refrigeration system is split with parts on both sides of the bulkhead it is also necessary to deliver the equipment in parts, which have to be connected by pipelines at the installation in the car. This increases the risk for leakage, etc.

According to a further embodiment of the invention as shown in Fig. 3 of the drawings, all the primary refrigeration equipment is located outside the insulation and a secondary pump driven liquid circulating system is used for the heat transfer between the refrigeration system and the recirculating air system. This secondary system may be filled with an anti-freeze solution or secondary refrigerant suitable for temperatures down to -40° F. without freezing. An adequate amount of an anti-corrosion agent should be added to the secondary system in case a brine or other corrosive refrigerant is used. This secondary liquid circulating system, according to the invention, should preferably be made of steel piping and the heat exchange unit in the air recirculating system should be of steel pipes with iron fins so that the coil bank will be able to take the full load from the loading compartment. The flow of secondary refrigerant in this fin pipe system should also be in counterflow to the airflow in order to bring the air down to lowest possible temperature. In the machine compartment a heat exchanger for instance in the form of double-pipe cooler is arranged between the primary Freon-system and the secondary circulating liquid system. This cooler with one or two sections in series can be connected to one or two compressors respectively with short pipe lines so that the whole refrigeration equipment can be assembled in a package and completely finished, filled and tested at the factory. When installing refrigeration equipment of this type in the car it is only necessary to connect the built-in secondary circulating system with the secondary branch of the double pipe cooler associated with the refrigeration condensing unit and fill the secondary circulating system with a suitable liquid.

According to the invention the primary branch of the double pipe cooler mentioned above may consist of two separate evaporator coils in series after each other and operating at different evaporator temperatures with the secondary refrigerant in counterflow. By arranging a counterflow between the secondary refrigerant and the circulating air and preferably by a step-wise cooling of the secondary refrigerant with two evaporators operating at different temperatures, it is possible to cool down the circulated air in the envelope system with a maximum total efficiency of the refrigeration system and at the same time provide a rational and simple bulkhead design as illustrated in Figure 3.

Reference is now made to the accompanying drawings wherein there is shown a railway refrigerator car having a frame 10 supported above axles 11 with wheels 12. The commodity is stored inside a compartment 13 to which access is afforded by side doors (not shown) that are suitably insulated. The compartment 13 is surrounded by a recirculation air system comprising a roof plenum 14 separated from the compartment by a metal ceiling 15, a floor channel 16 under a wooden floor 17 and wall flues separated from the loading space by spaced plywood or fibre board walls. The recirculation air system outside the commodity space 13 is insulated on all sides by a suitable insulation material 18. In the air circulation system there is arranged a vertical end wall flue 19 close to the machine compartment 20 and separated therefrom by an insulated bulkhead 21 that is supported by bulkhead reinforcing steel sections 22 that are attached to the frame of the car. The end wall flue 19 is separated from the commodity space 13 by means of another false bulkhead 23, which through horizontal members 24 is supported by the previously mentioned bulkhead 21 and sections 22.

This false bulkhead 23 is covered by a plywood apron tightly connected with the ceiling 15 and the floor 17 so that no air communication exists between the end wall flue 19 and the commodity space 13.

The machine compartment 20 in Figure 1, shows a diesel-generator 25 supplying electric power to two separate condensing units 26 and 27, each having a compressor 28 driven by a motor 29, a condenser 30 and a liquid receiver 31. The condensing units 26 and 27 are here shown as two completely separate units located above each other in the machine compartment 20, but the two systems could be mounted side by side on the same base with a common condenser split in two halves and with a single condenser fan for aircooling. Instead of belt driven compressors direct driven compressors may also be used or I may use motor-compressors of the hermetically sealed type. In the drawings, Figure 1 only illustrates, that according to the invention, two complete independent refrigeration systems are used in this embodiment of my invention. The refrigeration cycle will be the same in each unit and is as follows: From the high pressure outlet of the compressors 28 the refrigerant goes to the condenser coils 30 and from there to liquid receivers 31. A conduit with a flexible pipe 32 carries the liquid refrigerant to the inner branch of the heat exchanger 33 and from there through a liquid line 34 in which a solenoid valve 35 is mounted to the thermostatic expansion valve 36. After the expansion valve the refrigerant passes the distributor 37 and through feeder lines 38 to the evaporator coil bank 39, which may consist of two or more parallel rows of horizontal pipes built together with fins to provide a cooling unit of conventional type. On the suction side of the evaporator coil there is a manifold 40 for the evaporator pipes, which continues in the suction line 41, on which the bulb 42 of the thermostatic expansion valve 36 is located in the usual way. The suction line has a portion made of flexible tubing 43 ahead of the heat exchanger in order to eliminate leaks and continues on the other side of the heat exchanger in the suction line 44 in which a crank case pressure regulating valve 45 or other similar device is mounted in order to limit the load at higher evaporator temperatures. The suction line is finally connected with the intake valve of the compressor through the main back pressure valve 46. Each condensing unit is provided with a high and low pressure cut-out switch of conventional type and the operation of both compressors is controlled by a common thermostat with the bulb in the return air stream. The temperature control switch has double contacts to obtain an on-off temperature differential in order to prevent short cycling and will by conventional relays and contactors stop and start the compressors in the usual way. For the start of the compressors pneumatic timing relays should be used in order to prevent simultaneous starting of the compressor motors.

The air is recirculated in the envelope system by means of fans, which on the drawing are symbolized by a propeller fan 47 with built-in motor, but which also may consist of the centrifugal type with several fans mounted on the same shaft and driven by only one motor.

According to my invention the fans 47 pull the air through the end wall flue 19, whereby the air first passes the evaporator 39 and then a second evaporator 48 associated with the compressor 27. After passing both evaporators 39 and 48 the air is circulated by the fans 42 to the ceiling plenum 14, and over the metal ceiling 15. From there the air flows through narrow wall flues to the floor channel 16 and back to the end wall flue 19. The returned air, which is heated by its passage around the envelope will first be precooled by the evaporator 39, which is kept at a relatively high evaporation temperature with a comparatively high capacity of the condensing unit 26. At equilibrium a system, according to the invention, may have a return air temperature of say $+5^{\circ}\text{F.}$ and the first evaporator 39 an evaporation temperature of -10°F. The air leaving the first evaporator 39 may be cooled down to a

temperature of -3°F. when it enters the second evaporator 47 which is kept at an evaporation temperature of say -20°F. , by which the air temperature is brought down to -10°F. when entering the ceiling plenum 14 after passing the fan system, where the air is slightly raised in temperature by the fan energy. The cool air of -10°F. temperature will now pass along the metal ceiling 15 which will act as a secondary radiator for keeping the commodity compartment 13 at an average temperature of say 0°F. This secondary metal ceiling or radiator surface extending all along the roof, in a car of the type described, will have a surface of between 300 and 400 sq. ft. which is more than adequate to maintain an average compartment temperature of 0°F. under the described conditions.

The importance of lowering the temperature of the return air in two steps by two independent evaporators at different temperatures is previously emphasized. In the above example a commodity compartment temperature of 0°F. was chosen because hitherto a zero temperature has been considered adequate for frozen food transportation. There is, however, a trend to lower this temperature and some railroad refrigerator cars are built for a specified temperature of -10°F. For such low average temperatures in the commodity compartment it will be necessary to lower the temperature of the air leaving the cooling system to at least -20°F. , which would call for a final evaporator temperature of -25°F. or lower. In an envelope design of the described type it would be possible to allow a return air temperature around 0°F. and the first refrigeration step could therefore, according to the invention, be carried out at an evaporation temperature between -10°F. and -15°F. instead of -25°F. with corresponding gain in capacity of the compressor. In view of the rapid decrease of capacity at low temperatures and because of the poor volumetric efficiency of single stage compression during railroad conditions the benefit of stepwise refrigeration of the recirculated air will be especially great for refrigerator cars with temperatures below zero in the commodity compartment.

In order to maintain the best possible operating conditions for the two compressor systems working at different evaporator temperatures the expansion valves should be set for a larger flow of refrigerant in the first evaporator 39 than in the second evaporator 48. Likewise the low pressure cut-out can be set differently to compensate for the difference in evaporation temperatures.

The two compressor systems may according to the invention use different refrigerants, for instance, "Freon 12" in the first or lowest evaporator and "Freon 22" in the upper system.

The importance of using different refrigerants in the two systems is emphasized by the fact that there are two limitations in the use of a refrigeration system for an all purpose refrigerator car; that is, a car that will have to take care of both fresh products and frozen food loads. When fresh products are loaded into the car at a high temperature the load has first to be pulled down in temperature by the refrigeration system and then transported at a moderate low temperature above freezing. During the precooling or pull down period the evaporator temperature will often rise to $+50^{\circ}\text{F.}$ or higher, which means not only an increased refrigeration requirement, but also a greatly increased load on the motor and the condenser. In order to prevent motor overload when starting under high ambient temperatures or when precooling a warm load the previously mentioned crank case regulating valve 45 is placed in the suction line. This is a throttling valve which is designed to maintain a desired crank case pressure. The amount of valve opening is controlled by the crank case pressure and the valve may be set to limit the crank case pressure within its range. A usual setting for the refrigeration system in refrigerator cars using "Freon 12" as a refrigerant is 28 pounds. This corresponds to an evapora-

tor temperature of approximately $+30^{\circ}$ F. The maximum refrigeration capacity and maximum load on the motor is thereby determined. The other limitation of the refrigeration system is determined by the rapidly falling refrigeration capacity at low evaporator temperatures. A refrigerant like "Freon 22" having a lower boiling point is more suitable than "Freon 12" for systems where lower temperatures are required. Without going into detail "Freon 22" offers the possibility of increasing the capacity of a compressor charged with "Freon 12" approximately two-thirds more with the same bore, stroke, and speed. At car temperatures of 0° F. or below the factor of B.t.u. refrigeration per cu. ft. of compressor displacement makes it desirable to carry out the second step of refrigeration, according to the invention, with "Freon 22" as a refrigerant, thereby increasing the total refrigerating capacity by 20 to 25%. The refrigeration capacity and also the motor load would be approximately the same for each of the two exactly like compressor systems filled with "Freon 12" and "Freon 22," respectively, if the evaporator temperatures were for instance -5° F. in the "Freon 12" system and -20° F. in the "Freon 22" system. The same size evaporator and condenser can be used. However, the expansion valve for "Freon 22" must be set closer since the refrigerating effect per pound and cubic inch is larger for "Freon 22" than for "Freon 12." Under precooling conditions the "Freon 12" compressor is able to maintain an evaporator temperature of $+30^{\circ}$ F. without overloading the motor, while in a "Freon 22" compressor system this evaporator temperature would reach a gauge suction pressure of over 50 lbs. per sq. in., and greatly overload motor and condensers. A "Freon 22" system would generally have to be set at a maximum crank case pressure corresponding to an evaporator temperature below $+10^{\circ}$ F. in order to avoid undue overloading. Such a low evaporator temperature would for several reasons be unsuitable and it is therefore desirable that the first step of refrigeration under precooling be carried out with "Freon 12." Thus conditions at both precooling and minimum temperatures for an all purpose refrigerator car call for two step refrigeration with "Freon 12" in the first step and "Freon 22" in the second or generally with a refrigerant of comparatively low pressure in the first step and a refrigerant of higher pressure in the second step.

Two step refrigeration has also significance in view of the space and dimensions of the evaporator unit. At ordinary direct expansion, there is practically uniform temperature all over the evaporator and the heat transfer per unit of area decreases with increasing dimension of the coil bank in the direction of the air flow. The coil bank has therefore to be limited in this direction with an increased dimension across the air flue or tunnel for a given heat transfer area as a result. A large dimension of the coil bank in the longitudinal direction of the car will reduce the loading space and should be avoided. By two step refrigeration the coil bank can be extended in the direction of the air flow without reduced heat transfer per unit of area and a refrigeration flue or tunnel according to my invention can therefore be made comparatively narrow in the longitudinal direction of the car with increased loading space as a result.

One of the outstanding advantages of a dual refrigeration system is that it offers a safety factor against such failures as refrigerant leaks, etc. One system would always be sufficient to save a load if the other system is out. This valuable safety feature is, however, to a great extent eliminated if both systems work on a common evaporator coil bank with parallel evaporators and with automatic defrosting by built-in electric heaters, as is now practiced. Before the defrosting heaters can be contacted the systems have to be pumped down by closing the solenoid valves and the compressors stopped by the low pressure cut-out switch. If now one of the

systems has a leak in the low pressure part or a leaking solenoid valve there will be difficulties of maintaining defrosting conditions and the operation of the remaining unit will therefore be obstructed. This hazard will be eliminated and full advantage of the separate coil bank feature of the refrigeration system will be gained by making the evaporators large enough so that no defrosting enroute will be needed. For this purpose each evaporator should have a fin spacing of at least $\frac{1}{2}$ inch, a surface of not less than 300 sq. ft. and a volume of not less than 5 cu. ft. Manual defrosting by built-in electric heaters of say 6000 watts capacity should be arranged and the manually operated switch should simultaneously de-energize the solenoid valves for closing so that the compressors are shut down by the low pressure cut-out switch after pumping down the systems. The fans can be kept running when defrosting is carried out between trips. The built-in heaters can also be used for heating service of the car and operated by thermostatic control by the same temperature control switch as for refrigeration. The range of the control switch should go from -10° F. to $+70^{\circ}$ F. and double contacts to obtain an on-off differential provided both for compressor and heater contactor relays. The relays for heating should of course function so that compressors are pumped down before the heater contactor circuits are closed. A refrigerator car, according to the invention, with a control system as described above may serve as an all purpose car for thermostatic operation of both refrigeration and heating service. Before passing on to the remaining figures of the drawings, it should be noted that the apparatus compartments 20 as shown are each provided with suitable louvered vents 49 such as are generally provided in the sides of the car body in communication with the refrigerating apparatus accommodating chamber. While only one of these louvered outlets 49 is shown it will be understood that others may be located near the floor of the car and at each side thereof.

In Figure 2 of the drawings there is illustrated an embodiment of my invention in which I employ two refrigeration producing evaporators in the circulating air system with a single compressor. In this arrangement the chilling of the circulating air within the commodity compartment enclosing envelope is accomplished by the use of two different refrigerants; for example, "Freon 12" and "Freon 22." As here shown the machine compartment 20 has a diesel-generator unit 50 with a compressor 51 of V-type, directly driven by a motor 52. The refrigeration cycle in this system, according to the invention, is as follows: From the discharge valve 53 of the compressor 51 the refrigerant gases go to the condenser 54, where condensation of both "Freon 12" and "Freon 22" takes place at a pressure corresponding to the "Freon 22" requirements. The liquid receiver 55 receives the liquid refrigerants from the condenser and from there the liquid pipe 56 leads to the heat exchanger 57, then to the solenoid valve 58 and further to the thermostatic expansion valve 59, with the bulb 60 located on the suction pipe 61. After the expansion valve the mixture of "Freon 12" and "Freon 22" refrigerant enters the low-temperature upper section 62 of the evaporator where mainly "Freon 22" evaporates at a low temperature determined by the back pressure. The "Freon 22" gases formed at the evaporation force the remaining "Freon 22" and "Freon 12" through the pipes of the evaporator, whereby practically all of the "Freon 22" will be evaporated. The mixture of "Freon 22" gas and liquid leaves the first section of the evaporator and enters the flash chamber 65, where the liquid is separated from the "Freon 22" gas. The gas leaves the top of the flash chamber 65 through the suction pipe 66 which by-passes the second lower section 67 of the evaporator and delivers the "Freon 22" gas into the main suction pipe 61, which leads over the heat exchanger 57 and the crank

case pressure regulating valve 69 to the suction valve 70 of the compressor 51.

From the bottom of the flash chamber 65 a liquid line 71 takes mainly "Freon 12" into the previously mentioned second section 67 of the evaporator where "Freon 12" evaporates at a higher temperature than in the first section 62, as previously described. The "Freon 12" gases leave the evaporator 67 through the suction pipe 72 which continues in the main suction pipe 61 and back to the compressor 51.

In the car the recirculated air is pulled through the evaporator system by blower fans 63, driven by the motor 64 in the same way as previously described and will be cooled down to a temperature lower than the temperature of the commodity compartment in two distinct steps, first by "Freon 12" evaporation and then by "Freon 22" evaporation.

The balance of temperatures and pressures in various parts of the system after equilibrium is too complicated to fully analyze here, but it should be stated that the equilibrium will partly depend on the proportion of "Freon 12" and "Freon 22" in the filling of the system. Generally speaking the amount of "Freon 22" should be less than 50% by weight of the total filling, for railroad conditions a filling of not more than 30% of "Freon 22" in the total filling is normally sufficient. The size of the evaporators can be the same in both sections, but it is also conceivable to use a smaller upper section, as the capacity of the "Freon 22" evaporator will be smaller. There are also a great number of finer improvements and adjustments with regard to filling, liquid distribution, heat exchange, etc. which could be introduced in a system of this type. The drawing and the specification are for purpose of illustrating the principle only. This system having only one condensing unit can be thermostatically controlled and defrosted in the usual way. Built-in electric heaters may also be used for heating service, that is the system may be used for an all purpose car with a temperature control switch setting ranging from say -10 to $+70^{\circ}$ F.

In Figure 3 of the drawings there is illustrated still another embodiment of my invention. This embodiment is characterized by the fact that all parts of the mechanical refrigeration producing system under pressure are located outside the insulated commodity accumulating space of the car, and a secondary liquid circulating system is employed as an intermediate heat transfer system associated with the circulating air envelope which surrounds the commodity accumulating space of the car. The refrigeration system, comprises a diesel-electric power plant (not shown) for the operation of one or as here illustrated two compressor systems. Both the diesel-electric plant and the refrigeration equipment may be built as package units and may be mounted in a machine compartment at one end of the car or underneath the car. In this arrangement two condensing units are shown as mounted in the apparatus compartment 20 at the end of the refrigerator car. These condensing units are disposed one above the other and are designated by the numeral 75. The operating cycle of each of the compressor and condensing units 75 is substantially identical and, therefore, a description of the cycle in connection with the lower compressor and condensing unit 75 will be found equally applicable to the upper condenser and compressor unit 75, therefore, similar identifying numerals are applied to the corresponding parts of each system. From the discharge valve 76 of the compressor 77 the refrigerant goes through the condensor coil 78 to the liquid receiver 80, further through a connecting pipe 81 to the inner branch of a heat exchanger 84 from which a pipe provided with a solenoid valve 85 takes the refrigerant to the expansion valve 86.

At this point as distinguished from the previously described arrangements, I here show an evaporator for the multiple "Freon" system that is located in the refrigeration

apparatus compartment of the car. This evaporator comprises a double pipe cooler 87 which, as stated, cooperates with a fin pipe secondary fluid circulating system that includes a coil type heat exchanger 88, disposed in an air circulating flue 89, which connects at its top with the plenum 14 of the commodity space encircling envelope. The double pipe unit 87 has two inner, refrigerant circulating pipe systems 90 and 91 which are respectively associated with the lower and upper compressor units 75. Surrounding the inner refrigerant circulating pipe systems 90 and 91 there is a continuous conduit 92 that is formed by a concentrically arranged larger pipe 93, which extends over and completely encloses the refrigerant circulating pipe systems 90 and 91. In this manner there is formed an annular conduit through which a secondary circulating refrigerant may flow over the coil systems 90 and 91 of the two compressor units 75. At its upper end this outer or larger conduit 92 is connected by means of a pipe 94 with the upper end of the fin pipe coil system 88, located in the vertical flue 89 of the commodity space encircling envelope. The bottom of the coiled fin pipe system 88 is in turn connected to the lower end of the multiple evaporator system or annular conduit 92, through a pipe 95. This pipe connection is shown as having a fluid circulating pump 96 for circulating the secondary fluid of the system. The pipe connection 95 in addition to including the pump 96 is also shown as extending through an electric heater unit 97 by which, as an alternative form of operation, the circulating secondary fluid may be heated instead of refrigerated to provide a means for warming the commodity accommodating space 13 of the car.

As suggested there are two evaporators; the lower one of which is connected at its bottom to an expansion valve 86 by means of a connection 98 and at its top it is connected through a suction pipe 99 to the heat exchanger 84 which in turn is connected by a suction pipe 100 to the lower compressor 77. In like manner the upper section of the evaporator 87 is connected with the corresponding expansion valve 86 of the upper compressor unit system by means of a pipe 101 and in like manner the upper end of this double pipe unit 88 is connected through a pipe 102 to the corresponding heat exchanger 84 of this compressor unit. When in operation, the circulation of the lower evaporator section 90 is through the suction pipe 99 to the outer branch of the heat exchanger 84 and thence through the pipe connection 100 to suction valve of the lower compressor unit 77. In like manner a similar circulation of refrigerant will occur in the upper section 91 of the double pipe cooler or evaporator 87 which is associated with the upper compressor unit as described above. This second "Freon" system is preferably operated at a lower evaporator temperature than the first or lower section of the evaporator 87 and the cooling of the secondary liquid circulated by the pump 96 therefore takes place in two steps along the same principle as previously described.

In the secondary heat transfer system the circulation cycle will be as follows: From the circulation pump 96 the liquid is passed through the electric heater 97 for heating the secondary liquid for defrosting or heating service when desired. From the heater 97 the liquid passes to the outer annular conduit of both sections 90 and 91 of the double pipe cooler or evaporator 87, which is provided with an insulating enclosure. At the upper end of the double pipe cooler 87 and connected to the outer annular conduit there is a valved filling pipe 103 that extends out of the insulating enclosure. The secondary liquid enters the cooling unit 88 at its upper end and passes downwards in counterflow to the air which is pulled upwardly through the cooling unit flue 89 by fans, indicated on the drawing by the electric propeller fan 104. The cooling unit 88 is made of galvanized steel pipes provided with iron fins and with a fin spacing preferably not less than $\frac{1}{2}$ inch. The total heat trans-

fer area between the air and the cooling unit should not be less than 600 sq. ft. and the steel fin pipe system 88 should be so sturdily built that it will take the full shock load from the commodity without the protection of an interposed bulkhead. The design of the car will in this way be very simple and rational with only a 1" plywood apron 105 separating the cooling unit from the commodity compartment. Then the wooden cross beam construction 106 with the insulated bulkhead between the cooling unit 88 and the bulkhead steel sections 21 and 22 will transfer the shock load to the frame work of the car.

From the lower part of the cooling unit 88 the circulating secondary liquid is taken back to the pump 96 and recirculated. All connections in the secondary system are, according to the invention, to be made by rubber hose for the elimination of shock stresses and for low heat conductive piping across the bulkhead. The temperature control of this system, is according to the invention, carried out by simply letting a temperature control switch of conventional design (not shown) start and stop the pump motor. The thermostat bulb should as before be located in the return air stream. After stopping the circulation pump 96 the double pipe cooler or evaporator 87 with its evaporator sections 90 and 91 will quickly go down in temperature so that the low pressure cut-out will stop the compressors. When the thermostat calls for refrigeration the circulation pump 96 starts and the compressors will start as soon as the secondary liquid and the evaporators have reached a temperature corresponding to such a high suction pressure that the low pressure cut-outs close the compressor contactors again. The fans 104 will be running continuously. Defrosting enroute will not be necessary if the cooling unit 88 is sufficiently large, with wide fin spacing. Manual defrosting is, according to my invention, arranged by switching in the electric liquid heater 97 and simultaneously deenergizing the solenoids 85 in the "Freon" liquid lines so that the "Freon" systems are pumped down and the compressors stopped. The heater effect may be chosen around 6000 watt, which will heat the circulating secondary liquid above 32° F. in a matter of minutes as the total amount of liquid in the secondary system need not exceed 10 gallons. This heated liquid will quickly defrost the cooling unit and if the defrosting is carried out between trips the fans 104 may be kept running.

The heater 97 in the secondary liquid system will also provide heating service for the car when heating is required instead of refrigeration. By using a full range temperature control switch the heating can be thermostatically controlled with the solenoid valves 85 deenergized while the heater 97 is on. Under these conditions the "Freon" systems will be pumped down and the compressors stopped. The controls for an all purpose car are thus very simple. The "Freon" systems may be built as package units in a very compact way with the double pipe cooler 87 built in the package. Such a refrigeration system will have all refrigerant piping outside the package eliminated and can be delivered, filled and tested from the factory. A package of this type would be ideal for mounting underneath the car instead of inside a machine compartment and would have to be connected with the inside of the car only by flexible hose between the double pipe cooler 87 in the package and the secondary heat transfer system 88 in the air circulation system. The installation of such a system in a car, according to my invention, will offer maximum safety and efficiency for the exacting conditions prevailing in railroad service.

A secondary liquid circulation system should, according to the invention, have a temperature rise in the circulating secondary liquid about equal to the rise in temperature of the recirculated air when counterflow is arranged as described. The liquid flow should therefore

correspond to a temperature difference between the in and outgoing liquid of not less than 10° F. which at a refrigeration capacity of say 24,000 B.t.u./hour corresponds to a liquid flow of not more than 300 gallons per hour, which would call for only a very small circulation pump 96.

As indicated the use of a single compressor system with two refrigerants and two evaporators with a flash chamber, as described in connection with Figure 2, is also fully conceivable in this form of my invention. The use of one compressor with only one evaporator and one refrigerant for cooling a secondary liquid system 88 of the type previously described is also within the scope of my invention. Although the refrigeration with one compressor and one refrigerant cannot be carried out in more than one step with a practically uniform temperature on the evaporator, the advantages of a secondary liquid circulation system as an intermediate heat transfer system in mechanically refrigerated railroad cars should be obvious both with regard to simpleness of controls and with regard to the possibility of rationalizing both the car design and the design and application of the refrigeration condensing units.

As hereinbefore stated the arrangements described with two steps or stages in the refrigerating circuit of the car are important not only with regard to capacity and efficiency of the refrigeration system of the car but also because of the reduced dimensions and space requirements of the evaporator units.

While three more or less specific embodiments of the invention have been shown, it is to be understood that this is for the purpose of illustration only, and that the invention is not to be limited thereby, but its scope is to be determined by the appended claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A mechanically refrigerated railway car comprising an outer envelope for said car, a bulkhead spaced from one end of the envelope to divide said envelope into a refrigeration compartment and a machine compartment, thermal insulation lining said entire refrigeration compartment, a commodity compartment situated entirely within said refrigeration compartment and spaced from the walls thereof, said commodity compartment having a thermally conducting ceiling and thermally insulating walls and floor, one of said walls being substantially parallel to said bulkhead to leave a flue therebetween, a bottom heat exchange unit in the lower portion of said flue, a top heat exchange unit in the upper portion of said flue, exothermic refrigeration machinery in said machine compartment, means for connecting said machinery to said heat exchange units to produce a relatively high temperature in said bottom heat exchange unit and a relatively low temperature in said top heat exchange unit, means in said envelope for ventilating said machine compartment, a fan at the top of said flue, and means for operating said fan to induce a flow of air upwardly through said flue first over said bottom heat exchange unit then over said top heat exchange unit and subsequently out of said flue and over said thermally conducting ceiling.

2. A mechanically refrigerated railway car comprising an outer envelope for said car, a bulkhead spaced from one end of the envelope to divide said envelope into a refrigeration compartment and a machine compartment, thermal insulation on said bulkhead thermally separating said refrigeration compartment and said machine compartment, a commodity compartment situated entirely within said refrigeration compartment and spaced from the walls thereof, said commodity compartment having a thermally conducting ceiling and thermally insulating walls and floor, one of said walls being substantially parallel to said bulkhead to leave a flue therebetween, said flue being narrow in the longitudinal direction of the car, a bottom heat exchange unit disposed within the lower portion of said flue, a top heat exchange unit disposed within the upper

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portion of said flue, exothermic refrigeration machinery in said machine compartment for cooling said bottom and top heat exchange units, means for connecting said machinery to said heat exchange units to produce a relatively high temperature in said bottom heat exchange unit and a relatively low temperature in said top heat exchange unit, means in said envelope for ventilating said machine compartment, a fan at the top of said flue, and means for operating said fan in a direction to induce a flow of air upwardly through said flue first over said bottom heat exchange unit then over said top heat exchange unit and subsequently out of said flue and over said thermally conducting ceiling.

3. A mechanically refrigerated railway car comprising an outer envelope for said car, a reinforced bulkhead spaced from one end of the envelope to divide said envelope into a refrigeration compartment and a machine compartment, thermal insulation lining said entire refrigeration compartment, a commodity compartment situated entirely within said refrigeration compartment and spaced from the walls thereof, said commodity compartment having one wall substantially parallel to said bulkhead to leave a flue therebetween, said flue being narrow in the longitudinal direction of the car, a bottom heat exchange unit in the lower portion of said flue, a top heat exchange unit in the upper portion of said flue, exothermic refrigeration machinery in said machine compartment for cooling the bottom and top heat exchange units, means for connecting said machinery to said heat exchange units to produce a relatively high temperature in said bottom heat exchange unit and a relatively low temperature in said top heat exchange unit, means in said envelope for ventilating said machine compartment, a fan at the top of said flue, and means for operating said fan to induce a flow of air upwardly through said flue first over said bottom heat exchange unit then over said top heat exchange unit and subsequently out of said flue and over said thermally conducting ceiling.

4. A mechanically refrigerated railway car comprising an outer envelope for said car, a bulkhead spaced from one end of the envelope to divide said envelope into a refrigeration compartment and a machine compartment, thermal insulation on said bulkhead thermally separating said refrigeration compartment and said machine compartment, a commodity compartment situated entirely within said refrigeration compartment and spaced from the walls thereof, said commodity compartment having one wall substantially parallel to said bulkhead to leave

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a flue therebetween, a bottom heat exchange unit disposed within the lower portion of and extending substantially across said flue, a top heat exchange unit disposed within the upper portion of said flue, exothermic refrigeration machinery in said machine compartment adapted to cool the bottom and top heat exchange units, means for connecting said machinery to said heat exchange units to produce a relatively high temperature in said bottom heat exchange unit and a relatively low temperature in said top heat exchange unit, means in said envelope for ventilating said machine compartment, a fan at the top of said flue, and means for operating said fan in a direction to induce a flow of air upwardly through said flue first over said bottom heat exchange unit then over said top heat exchange unit and subsequently out of said flue and over said thermally conducting ceiling.

5. A mechanically refrigerated railway car comprising a car body, a bulkhead spaced from one end of the body to divide the body into a refrigeration compartment and a machine compartment, thermal insulating means serving to insulate said refrigeration compartment from the machine compartment, a commodity compartment having ceiling, floor and side walls situated within the refrigeration compartment and spaced from the walls thereof, one of said walls spaced from said bulkhead to form a vertical flue, said flue being narrow in the longitudinal direction of the car, top and bottom heat exchange units located in said flue, mechanical refrigeration compressor means located in said machine compartment adapted to cool said heat exchange units, means for connecting said compressor means to said heat exchange units to produce a relatively high temperature in the bottom heat exchange unit and a relatively low temperature in said top heat exchange unit, and means for circulating air through the vertical flue.

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