

May 23, 1950

C. B. HALL

2,508,385

REFRIGERATOR CONTAINER COOLED BY CARBON DIOXIDE ICE

Filed Aug. 8, 1947

6 Sheets-Sheet 1

FIG. 1

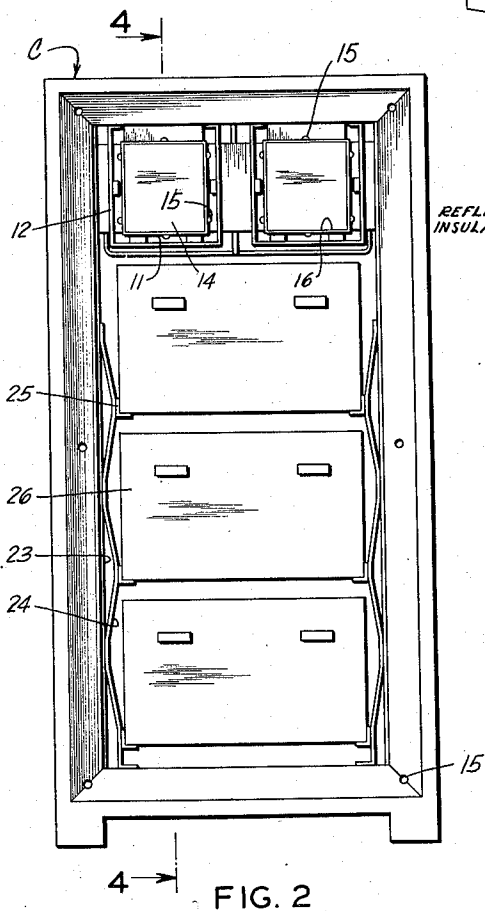
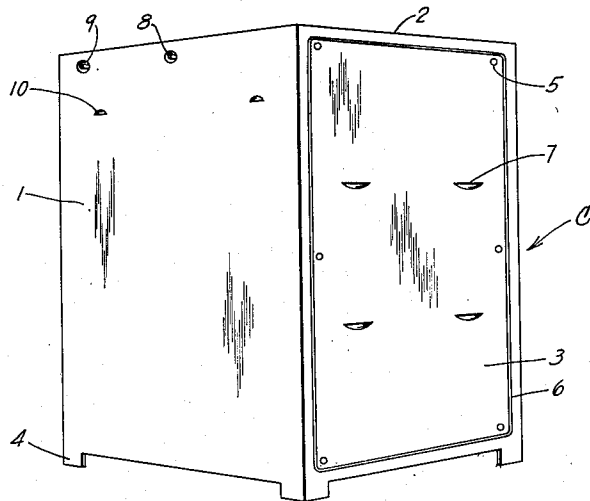


FIG. 2

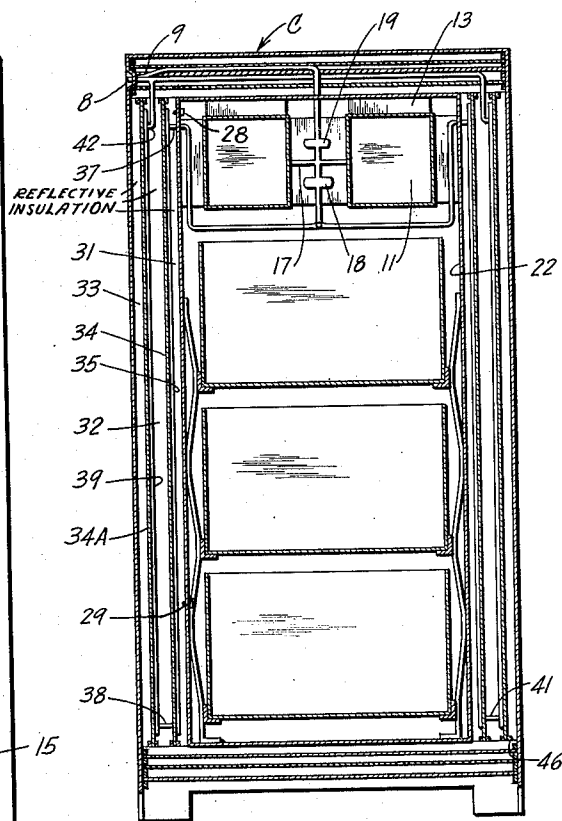


FIG. 3

INVENTOR
CHARLES B. HALL
BY *Jord Bmg*
ATTORNEY

May 23, 1950

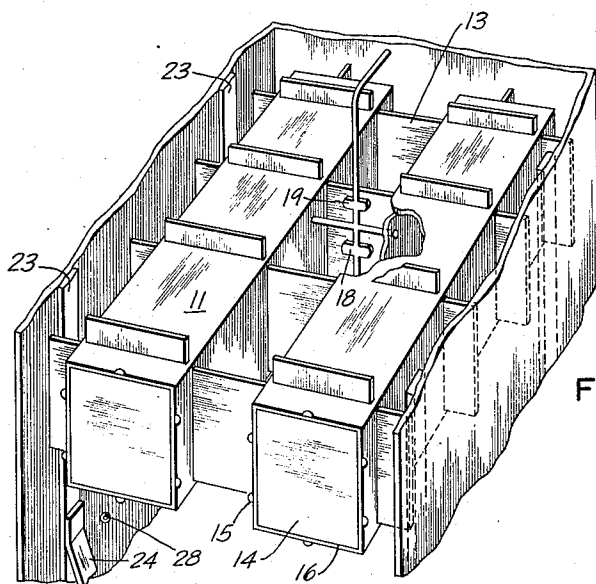
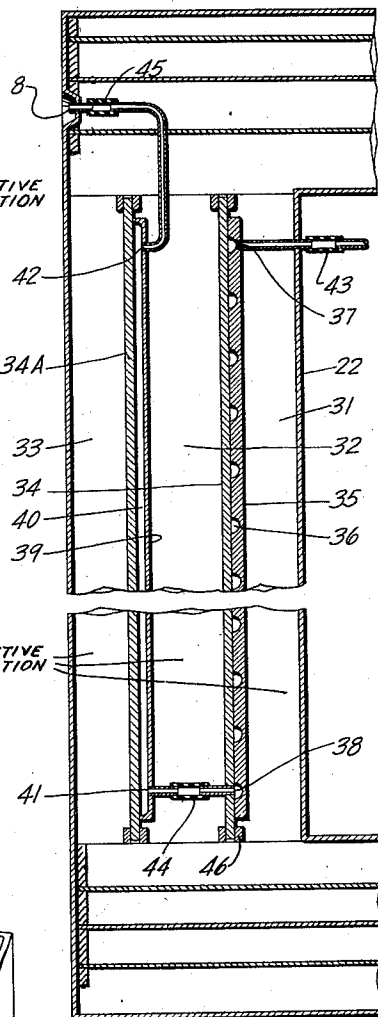
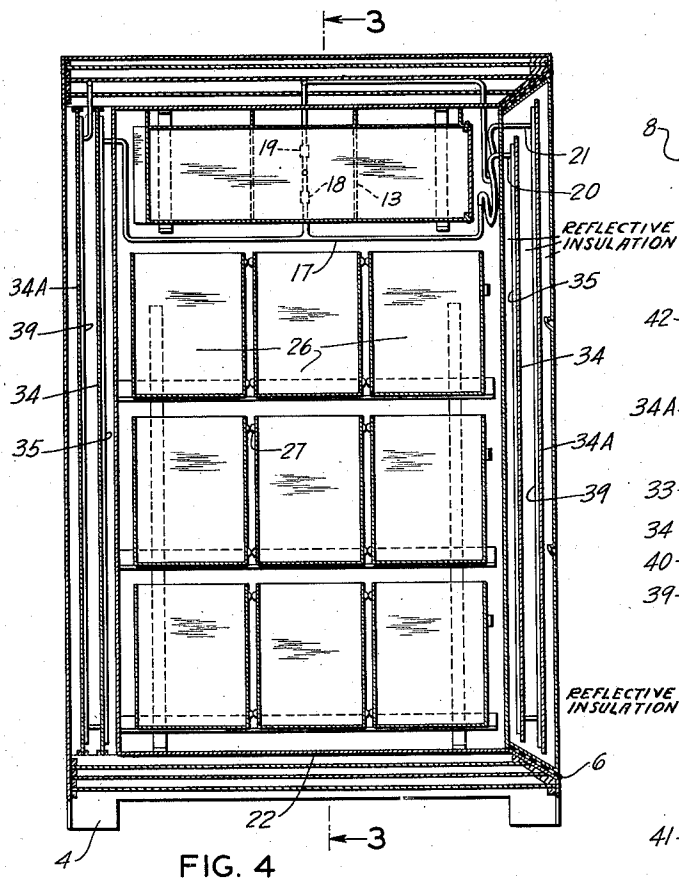
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6 Sheets-Sheet 2



INVENTOR
CHARLES B. HALL
BY *John B. King*
ATTORNEY

May 23, 1950

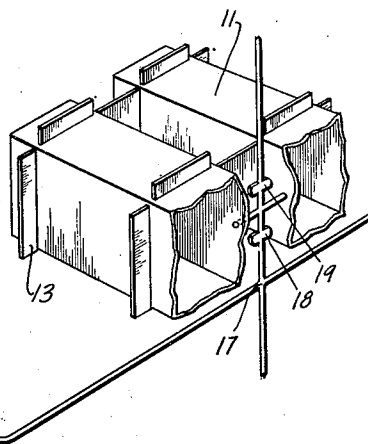
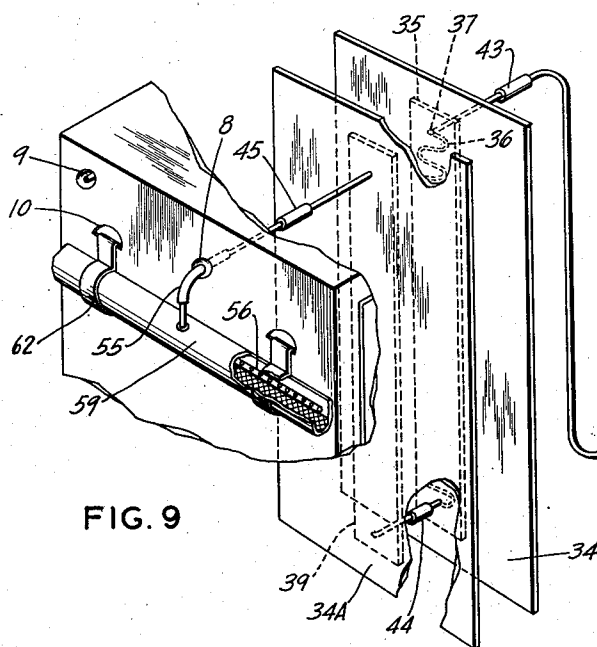
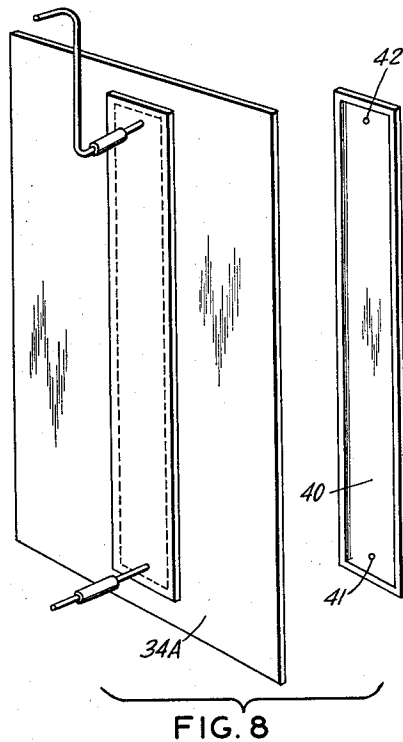
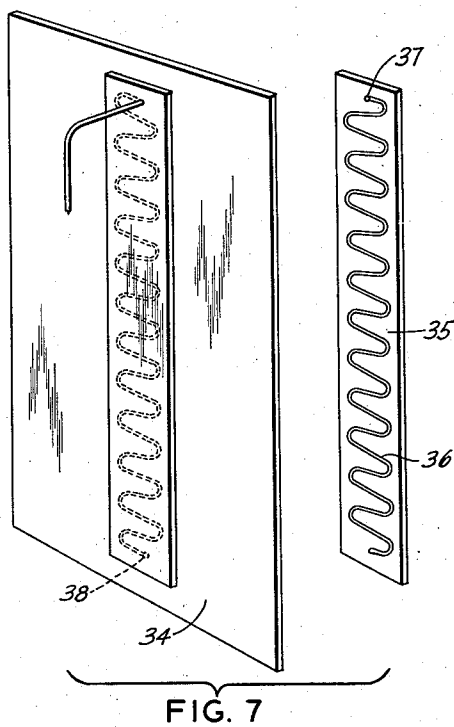
C. B. HALL

2,508,385

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6 Sheets-Sheet 3



INVENTOR
CHARLES B. HALL

BY *Fred Bing*
ATTORNEY

May 23, 1950

C. B. HALL

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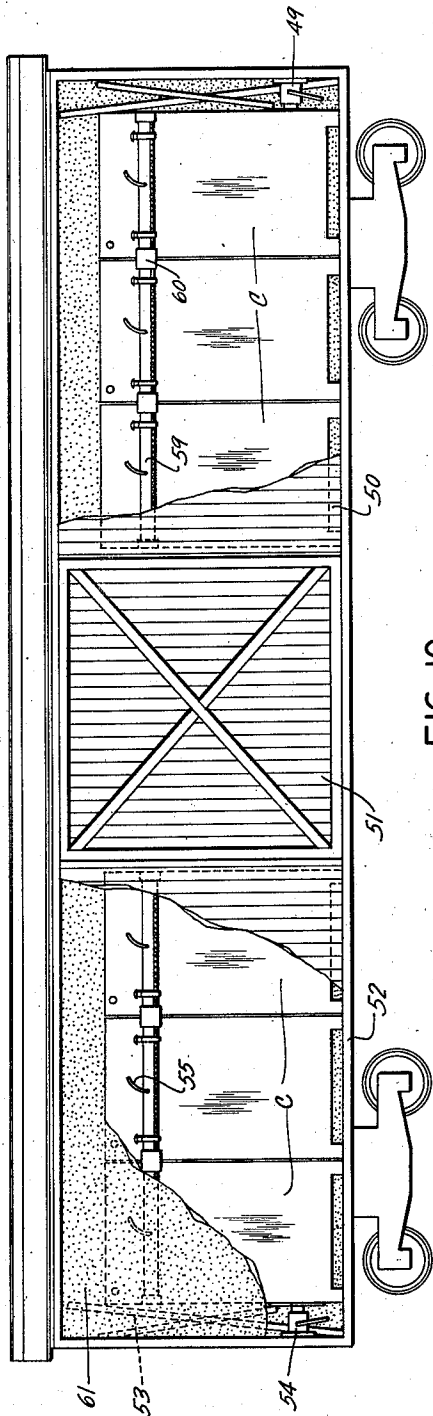


FIG. 10

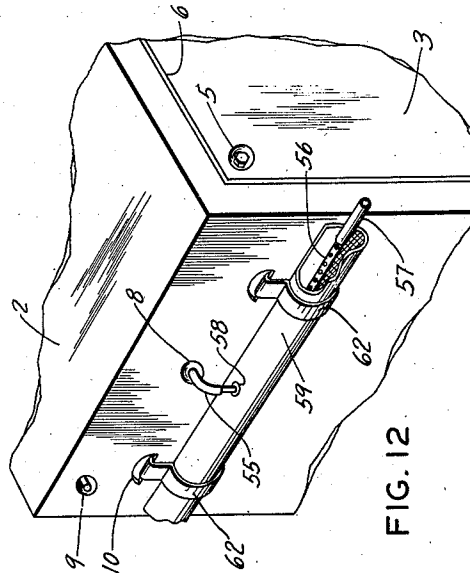


FIG. 12

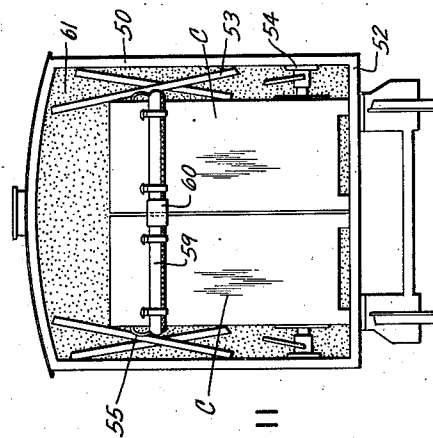


FIG. 11

INVENTOR
CHARLES B. HALL
BY *Herb Bing*
ATTORNEY

May 23, 1950

C. B. HALL

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REFRIGERATOR CONTAINER COOLED BY CARBON DIOXIDE ICE

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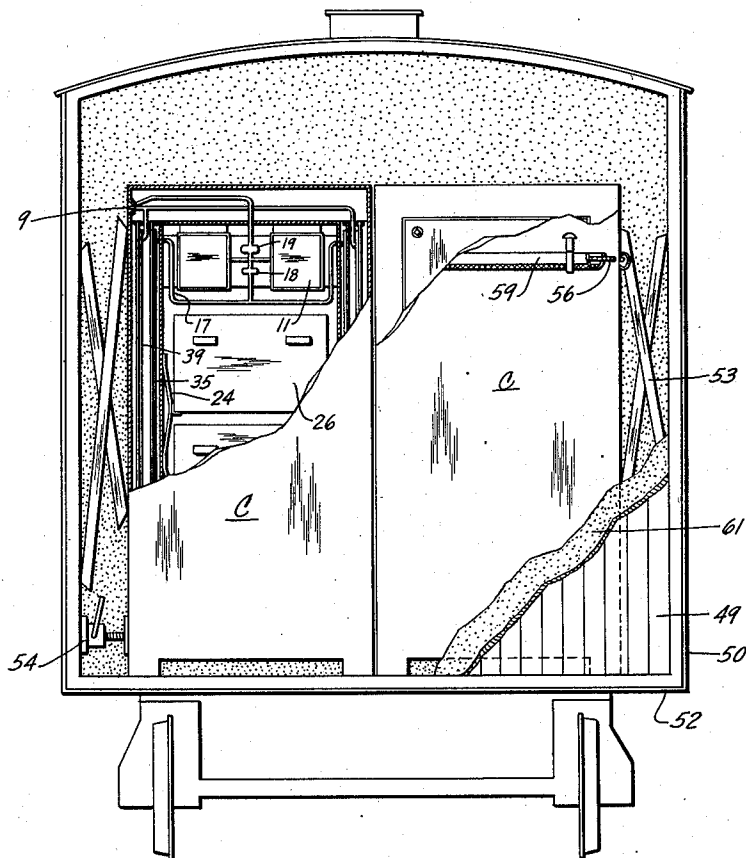


FIG. 13

INVENTOR
CHARLES B. HALL
BY *Fred Bing*
ATTORNEY

May 23, 1950

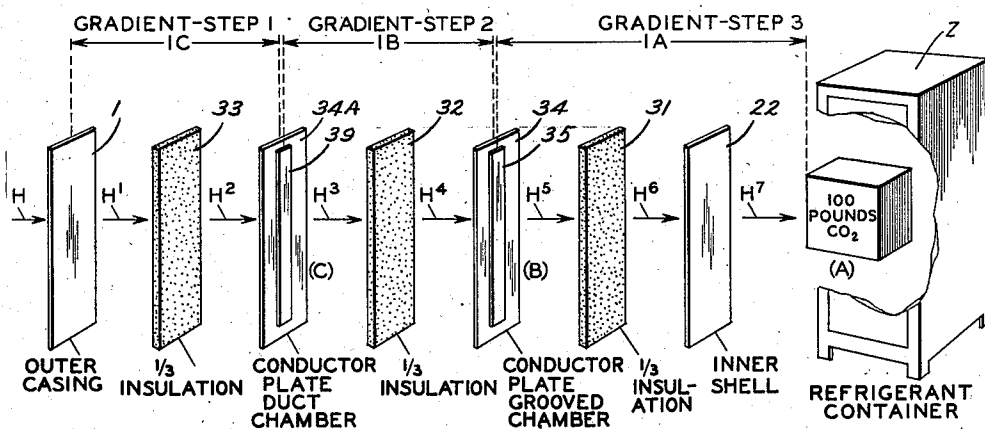
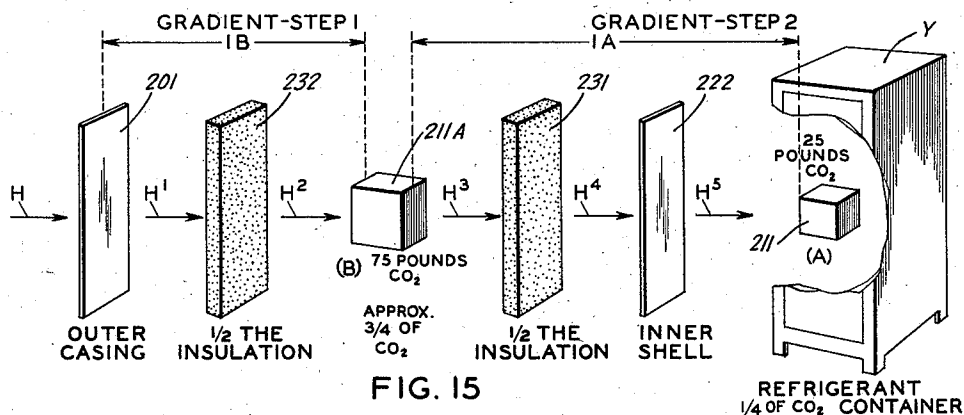
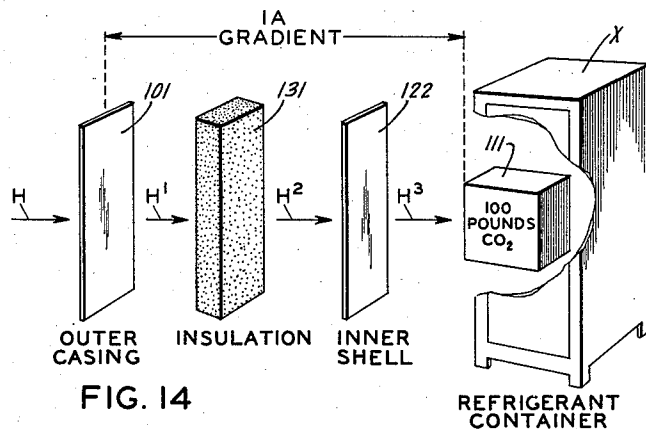
C. B. HALL

2,508,385

REFRIGERATOR CONTAINER COOLED BY CARBON DIOXIDE ICE

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6 Sheets-Sheet 6



INVENTOR
CHARLES B. HALL
BY *Lord Bing*
ATTORNEY

UNITED STATES PATENT OFFICE

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REFRIGERATOR CONTAINER COOLED BY
CARBON DIOXIDE ICE

Charles B. Hall, Chicago, Ill.

Application August 8, 1947, Serial No. 767,397

11 Claims. (Cl. 62—91.5)

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This invention relates generally to refrigerator containers, and more particularly to storage and shipping containers for use in the transportation of quick frozen foods, and all other products, requiring constant freezing, zero or sub-zero temperatures but usually from 0° F. to minus 20° F. The invention further relates to improvements in methods and apparatus for use with solid refrigerants, such as carbon dioxide (solid CO₂ or Dry Ice), and the like.

A principal object of this invention is to provide a method of refrigerating by means of solid refrigerants that shall be more efficient than prior methods and shall materially extend the period of time for which a given quantity of the refrigerant will maintain the desired low temperature in the lading space of the refrigerator container.

The invention described and claimed herein resides in a novel way of applying all of the refrigerating properties of solid carbon dioxide (Dry Ice) and of the carbon dioxide gas sublimated from the solid carbon dioxide, by interposing the refrigerants in such manner as to intercept heat passing into the interior of the container from the outside atmosphere, causing such heat to be returned to the outside atmosphere instead of continuing into the interior of the refrigerator container, and the apparatus designed to interpose the refrigerants and to accomplish the heat transfer to the carbon dioxide gas being vented to an outside gas system or the outside atmosphere.

The invention described and claimed herein further resides in the disclosure of an application of the "gradient step-down" principle of refrigeration, wherein the normal gradient of a refrigerator container is sub-divided into two or more "gradient steps."

Another principal object of this invention is the reduction of the gradient inducing heat transfer to the prime refrigerant of a refrigerator container through the application of the "gradient step-down" principle. It is an established fact in refrigeration that the greater the gradient, the differential in temperature between the outer surface of the container and that of the interior of the container, the more rapid the rate of heat transfer to the refrigerant. It is a purpose of this invention to divide the gradient of the container into steps, by interposing secondary chambers being chilled by gas sublimated from the solid carbon dioxide, to cause the formation of two or more gradient steps, only one of which will induce the transfer of heat to the prime refrigerant.

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Another object of this invention is the establishment of a closed gas system, including suitable chambers, interposed to intercept heat, the same gas being reapplied to the same path of heat in successive steps, in such manner that the gradient of the refrigerator container will be sub-divided into a series of steps.

Another object of this invention is to furnish a means for bringing the gas sublimated from solid carbon dioxide under control, housed in suitable refrigerating chambers, to act as a secondary refrigerant.

Another object of this invention is to provide a refrigerator container for the transportation of quick frozen foods and other products requiring a constant freezing, zero or sub-zero temperature, and using a solid refrigerant, which retains the carbon dioxide gas in a closed circuit to preclude the contact of said gas with the food products in the lading chamber, a condition which causes a drying-out and desiccation of the products.

A further object of this invention is to furnish a means for the control of the temperature of a refrigerator container by the use of a pressure control valve in a closed gas system, designed to release sublimated gas from the prime refrigerant chambers intermittently to the secondary refrigerating chambers, the variable frequency of this intermittent release being an effective temperature control.

A further object of this invention is to provide a sealed refrigerator container for the transportation of quick frozen foods and other products requiring constant freezing, zero or sub-zero temperatures, that will assure the maintenance of absolute sanitary conditions throughout an in-transit period.

A further object of this invention is to provide a refrigerator container for quick frozen foods and other products requiring constant freezing, zero or sub-zero temperatures, which will give adequate air circulation around the refrigerated products to insure absolute minimum growth of molds, inherent in cold storage operations.

A further object of this invention is to provide a refrigerator container, a multiple number of which may be used for the transportation of carload-lots of quick frozen foods and other products requiring constant freezing, zero or sub-zero temperatures, and one or more of which may be used for less-than-carload-lot shipments.

Another object of this invention is to provide a means for the even distribution of the refrigerant of a carload-lot shipment of quick frozen foods

and the like, by the use of a multiple number of refrigerator containers, as for example sixteen such containers, each container being charged with a pro-rata proportion of the total refrigerant provided for the entire carload-lot shipment.

A further object of the invention is to provide a refrigerator container which may be used for the transportation of a "pooled" carload-lot, or less, of quick frozen foods and the like, requiring constant freezing, zero or sub-zero temperatures, consigned to two or more consignees at two or more locations, without injury to that part of the shipment remaining after partial unloading, and without appreciable loss of refrigerant due to partial unloading.

A still further object of this invention is to provide an outside gas system to surround the top perimeter of a multiple number of refrigerator containers placed in a standard freight car, to be suspended from the containers, between the containers and the sides and ends of the freight car, to be charged with carbon dioxide gas vented from the gas system of refrigerator containers operated on the "gradient step-down" principle, for the purpose of providing supplemental refrigeration and insulation for the refrigerator containers placed in the freight car.

And still another object of this invention is to provide a means for installing a supplemental protective layer of blown insulation around, above and beneath a multiple number of refrigerator containers placed in a standard freight car, the minute openings between the particles of insulation to be filled with carbon dioxide gas, released from an outside gas system suspended around the top perimeter of the refrigerator containers.

Prior inventions have made a partial use of gaseous carbon dioxide, to supplement the refrigerant action of the solid carbon dioxide, by releasing the sublimated gas into the lading chamber, by releasing the gas into a secondary refrigerant such as a brine, by passing the gas around an area provided between the insulating walls and the lading chamber, by releasing the gas into the insulated area, and in many other devices, but in no prior method is found the full utilization of the gas as provided in this "gradient step-down" principle.

Still other and more specific objects and advantages of this invention will become apparent from the description hereinafter set forth of one embodiment or example thereof, and from the accompanying drawings to which the description has reference.

In the drawings:

Fig. 1 is an exterior front and side angle view with the door closed, of one embodiment of a refrigerator container;

Fig. 2 is a front view of the same container, with the door open;

Fig. 3 represents a vertical sectional view from the front taken on line 3—3 of Fig. 4;

Fig. 4 represents a vertical sectional view from the side taken on line 4—4 of Fig. 3;

Fig. 5 represents a fragmentary perspective view of the solid carbon dioxide chambers and the piping system for the release of the sublimated gas to the secondary refrigerant chambers;

Fig. 6 represents an enlarged, fragmentary cross section of a side wall, showing the assembly of the secondary refrigerating chambers;

Fig. 7 represents a perspective view of the component parts of the first secondary refrigerating chamber, or grooved chamber;

Fig. 8 represents a perspective view of the component parts of the second secondary refrigerating chamber, or duct chamber;

Fig. 9 represents a perspective, fragmentary view of the over-all gas system;

Fig. 10 represents a vertical cross sectional view of a freight car loaded with refrigerator containers, taken from the side of the car;

Fig. 11 represents a vertical cross sectional view of a freight car loaded with refrigerator containers, taken from the end of the car;

Fig. 12 represents a fragmentary, perspective view of an outside gas system, charged with carbon dioxide gas through a flexible connection joined to the vent of the refrigerator container;

Fig. 13 represents a fragmentary, transverse view of a loaded freight car, with the outside gas system and supplemental blown insulation in place, taken from the end of the car on a set-back basis;

Fig. 14 is a diagrammatic illustration of the path and transfer of heat to the refrigerant in an ordinary refrigerator container;

Fig. 15 is a diagrammatic illustration of the path and transfer of heat, as it would occur, if it were practical to install a part of the refrigerant between divisions of the insulation in the walls of a refrigerator container; and

Fig. 16 is a diagrammatic illustration of the path and transfer of heat to the secondary refrigerants and to the prime refrigerant, in a refrigerator container embodying the apparatus for the functioning of the "gradient step-down" principle.

The quick frozen food industry has become one of the fastest growing industries in a little more than one decade, and gives promise of continuing, even accelerating, this rapid pace of growth. One of the major problems of the industry is the maintenance of a constant, relatively low temperature from the moment of quick freezing until the time of intentional de-frosting for eating purposes. This problem is reasonably simple in the processor's plant, in the wholesaler's storage and in the retailer's display. To date, the maintenance of these constant low temperatures during in-transit periods has been exceedingly difficult, and much of the inferior quality product which has appeared on the market has had this inferior quality imparted to it during periods of transportation.

This invention will furnish the necessary refrigerated protection to all quick frozen foods and other products requiring constant freezing, zero and sub-zero temperatures, during in-transit periods, and during temporary delays in loading and unloading at shipper and consignee terminal points.

Shipments of quick frozen foods and the like may be readily classified into carload-lot shipments, and less-than-carload-lot shipments. Carload-lots are usually shipped by freight; less-than-carload-lots are usually shipped by express, truck or air. The period of in-transit time for less-than-carload-lots is usually briefer than that for long-distant, carload-lot shipments. Because of these two general classifications, the description which follows hereinafter is divided into two sections, first, the operations which are common to all shipments, and second, the additional protection provided for carload-lots.

By making use of the refrigerator container of this invention, all shipments of quick frozen foods, and other products requiring constant freezing, zero or sub-zero temperatures, may be

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made in ordinary freight cars, express cars, ordinary trucks and freight planes; refrigerated cars and refrigerated trucks will not be required.

The refrigerator containers designed and used for carload-lot shipments must of necessity be of a size which will permit the use of the maximum space of the freight car, and with this consideration in mind, it has been found that a container of a size which will permit the placement of eight such containers from end to end in the car, and two from side to side, utilizes the space in the average freight car to excellent advantage, although it is obvious that a container for this purpose need not be confined to these dimensions. Containers of this size may be readily handled by either manual or automatic lift trucks, and since such shipments will usually originate and terminate at cold storage terminals equipped for handling such shipments, no difficulty will be encountered.

The refrigerator containers designed and used for less-than-carload-lot shipments, will usually be of a size more conveniently handled in LCL traffic, though the larger container may be used where practical. The principles of construction and of operation are identical, except for the added exterior insulation and refrigeration provisions made in the freight car for the handling of long-distant carload-lot shipments.

The refrigerator containers are extremely durable in construction to withstand the severe handling involved in transportation and yet the over-all weight of the container is low due to the relatively lightweight material used in construction. It is important that excessive tare not be added to the weight of the shipment.

In the form chosen for disclosure herein, the invention is embodied in a refrigerator container C having an outer casing 1 of light weight but durable metal or like material, reinforced with bracing members as is the practice in such construction. The container C has an inner shell 22 that is of lighter weight metal or other material and is also braced with supporting members 23, and a door 3 afforded that is constructed to close flush with the outer casing, being secured by locked nuts fitted over threaded studs 5 protruding from the walls and inserted through recessed openings in the door. The outer casing or shell 1, and the inner shell 22 are supported in conventional heat-breaker relation, and the same is true with respect to the inner and outer walls of the door 3. Provision is made in the form of a rubber gasket 6 for sealing the door tightly, to insure air-tight protection to the lading compartment during transit periods, and recessed gripping wells 7 are provided for handling door. Each container is mounted on skid legs 4 formed by the extension of the corner bracing members, to permit handling with mechanical equipment. An outer gas vent 8 is recessed in the side or top of the outer casing for protection, and is threaded to permit the attachment of flexible pipe connections 55 in the freight car as will hereinafter be described in detail. An emergency pressure release vent 9 also afforded and is also recessed in the side or top of the outer casing.

Since no object on the exterior of the containers C protrudes beyond the surface of the outer casing, when loaded into freight cars, it is possible to place them flush against one another, forming a compact unit set away from the ends 49 and sides 50 of the car, with a six or eight inch space on all sides of the container,

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and with the doors of the containers turned inwardly against another container. This arrangement materially reduces the area of the container surfaces in the freight car exposed to heat transfer.

In the carload-lot containers, one or more solid carbon dioxide chambers (prime refrigerant chambers) 11 are provided, however, in the smaller less-than-carload-lot containers, only one prime refrigerant chamber is necessary. The prime refrigerant chambers 11 are suspended in brackets 12 from the top of the inner shell 22 and because of the relatively heavy weight of these loaded chambers, and due to the shunting and jarring of the freight cars in transit, and therefore of the refrigerator containers, substantial bracing members 13 are placed from the chambers to the inner shell and between the two chambers.

The doors 14 of the prime refrigerant chambers are arranged with rubber gaskets 16 and mechanical sealing devices 15, to insure gas-tight sealing of the doors of the prime refrigerant chambers. Suitable piping 17 is provided to exhaust the sublimated gas from the prime refrigerant chambers and an emergency pressure release valve 19 is installed in the piping circuit to cause the venting through the vent 9 to the outside atmosphere of any undesired pressure of gas which might accumulate.

Under and in accordance with the present invention the gaseous refrigerant that is sublimated from the solid carbon dioxide within the chamber or chambers 11 serves first, of course, to cool the walls of the chamber or chambers 11, thereby to cool the ambient air within the lading chamber of the container, and such gas is thereafter passed successively to a plurality of secondary refrigerating chambers that are disposed in heat transfer relation to a similar plurality of walls located in spaced relation to each other in the space between the inner and outer shells of the container C. Thus in the form herein disclosed, each wall of the container C has a pair of plates or walls 34 and 34A disposed therein in spaced relation to each other and to the inner and outer shells of the container, and these walls are made from a material such as metal so as to be good conductors of heat. The wall 34 is closest to the inner shell 22 and has a refrigerating chamber 35 associated in heat transfer relation thereto; while the wall 34A is disposed between the wall 34 and the outer casing 1 and has a secondary refrigerating chamber 39 associated therewith in a heat transfer relation. The gaseous refrigerant is under the present invention passed from the chamber or chambers 11 through the chamber 35, then through the chamber 39, and is then vented from the container C by the vent 8 as will hereinafter be described in greater detail.

It will be observed that a flexible pipe connection 20 has been made from the gas exhaust piping to the secondary refrigerating apparatus or chambers of the refrigerator container door for the input of carbon dioxide gas and another flexible connection 21 is provided for venting the gas from the secondary refrigerating apparatus of the door.

It has been found that this invention functions well for certain temperatures and certain purposes without the installation of a pressure control valve 18 in the closed gas system, however, the installation of such a valve is preferred, for by regulation of such valve 18, the

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cold gas in the secondary refrigerating chambers 35 and 39 may be changed with such frequency as may be required to maintain the desired temperature within the refrigerator container lading compartment.

Side supporting members of elongated S-shape 24 are welded at contact points to the inner shell bracing members 23, and to these S-shaped supporting members are attached angle iron tray holders 25 for receiving and holding the lading trays 26, or shelves, of the container. Trays, or shelves, are of open construction to permit free circulation of air around the lading. Protruding contacts 27 are attached to the tops and bottoms of the sides of the trays, to insure further air circulation and to give firm storage in the container to prevent shifting during transit.

Because of the novel secondary refrigerating chambers 35 and 39, installed in the side walls of the refrigerator container, and to insure a dryness of the insulation material in the side walls at all times, provision is made for the periodic drying of the insulation by forcing a slow stream of heated, dry air into the insulated walls, for which purpose a normally closed insulation-dryer inlet 28 and a normally closed insulation-dryer outlet 29 are provided in the inner shell of the refrigerator container.

The side walls and door of the refrigerator container are constructed with three layers of insulation 31, 32, and 33, Fig. 16, between which are interposed the two walls 34 and 34A with their secondary refrigerating chambers 35 and 39. This insulation may take the form of reflective insulation as indicated in Fig. 6, or may take the form of fibrous or like material in either bulk form or in sheets, as indicated in Fig. 16. It will be noted in Figs. 6 and 16 that one layer of insulation 31 is placed outside of the inner shell 22, after which the first of the secondary refrigerating chambers 35 and its heat transfer wall 34 are installed against shoulders 46. This chamber 35 is herein more specifically termed the grooved chamber, due to the nature of its construction, and is more fully described hereafter. This is followed by another layer of insulation 32 and then the installation of the second secondary refrigerating chamber 39 and its heat transfer wall 34A, the chamber 39 being herein designated as the duct chamber, and more fully described later. Another layer of insulation 33 is placed between this second secondary refrigerating chamber 39 and the outer casing 1. The insulations preferred in this invention are those known as Ferro-Therm or Fiberglas, however, it has been found that those commercial products known as Dry-Zero, rock wool, and several others will serve the purpose. Ferro-Therm insulation is commercially available and comprises a steel sheet covered on one face by an alloy coating of lead and tin with a finishing film of palm oil over this coating. Fiberglas insulation is also commercially available and is afforded by a body of relatively fine glass fibers that are usually deposited in the form of a mat or batt so that this batt may be disposed in the space between two walls. Dry Zero insulation is available commercially and is afforded in either bulk or batt form. The Dry Zero material is made from fibers of the pod of the tropical Ceiba tree. Rock wool is similarly available in either bulk or batt form, and this material is in the form of fibers made from a mineral or rock material.

The piping 17 provided for the escape of the carbon dioxide gas from the prime refrigerant

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chambers 11, is connected to the grooved secondary refrigerating chamber at 37 by a tube 43 made from a material of relatively poor heat conducting properties. Likewise, the same relatively poor heat conductor material is used to form a connection 44 between the grooved secondary refrigerating chamber 35 and the duct secondary refrigerating chamber 39, and a tube 45 between the duct secondary refrigerating chamber 39 and the vent to the outside atmosphere 8. Thus the various tubes 43, 44 and 45 serve as heat breaker connections. Through this arrangement, three separate refrigerating chambers are established, i. e., the prime refrigerant chamber 11, the grooved secondary refrigerating chamber 35 and the duct secondary refrigerating chamber 39.

Gas being exhausted from the prime refrigerant chambers 11, released under pressure upon the opening of the pressure control valve 18, is forced into the grooved secondary refrigerating chamber 35, and the old, higher temperature gas contained in chamber 35 is forced through the connection 44 into the duct secondary refrigerating chamber 39, which in turn causes the old, still-higher temperature gas in chamber 39 to be forced out through the connection 45 to be released through the vent 8.

While the two secondary refrigerating chambers 35 and 39 are for similar purposes, their operation and therefore their design, are somewhat different. The first of these secondary refrigerating chambers known as the grooved chamber has a specific reason for its design. A block of aluminum or other good heat conductor material, approximately $\frac{1}{2}$ inch thick and 10 inches wide, is cut with a $\frac{3}{8}$ inch grooved pattern 36 as shown in Figure 7. This block is then welded vertically to the center of a mounting plate 34, of a surface area of the length and width of the inside dimensions of the side wall, with the grooved surface placed inwardly toward the conductor mounting plate 34, to form the equivalent of a $\frac{3}{8}$ inch coil mounted on a conductor mounting plate. In fact, a coil so mounted, but with a good heat conductor joint throughout, may be used.

This small path for the passage of the gas downward, when released under pressure from the prime refrigerant chambers, is for the purpose of forcing all of the old, higher temperature gas forward in the gas system, without permitting counter-currents of the higher temperature gas to move upward or backward in the system.

The second of the secondary refrigerating chambers 39 is constructed by welding a duct of aluminum 40 or other good heat conducting material, approximately $\frac{1}{2}$ inch deep and 10 inches wide, vertically to a conductor mounting plate 34A of the same good heat conducting metal, a plate of the length and width of the inside dimensions of the side wall. When gas is forced out of the first secondary refrigerating chamber 35, at the exit 38 through the poor heat conductor connection 44, it rises from the entry 41 in the duct of the second secondary refrigerating chamber 39, the warmer gas being of lighter weight, to be vented from the refrigerator container through the exit 42 and the vent 8. While certain dimensions are used in the foregoing description for purposes of explanation, it is obvious these secondary refrigerating chambers may be constructed in various sizes and proportions as fit the requirements.

Another principal feature of this invention is the novel method for providing additional insu-

lation and refrigeration for a mass of refrigerator containers, in the storage of such containers in the freight car. This method is only possible because of the nature of the construction of the refrigerator container of this invention and its principles of operation, and for that reason is included in this application as another of the principal claims of this invention.

The loaded refrigerator containers C are shored into the freight car through the use of planking 53 and mechanical jacks 54, as shown in Figure 13. This is a progressive operation, performed as the containers are moved into the car. The following additional operations are also performed progressively as each container is placed in the freight car.

Perforated piping 56, sufficient to extend around the perimeter of the mass of refrigerator containers loaded into the freight car, is provided. This is jointed in practical lengths, approximately the length of one side wall of the refrigerator container, of a type easily joined and secured by a friction fitting 57, or some other simple means of connection. Each length has a connection 58 for the attachment of a flexible pipe 55, the other end of each flexible pipe being connected to the vent 8 of one of the refrigerator containers.

A perforated and screened metal cover 59, round except for a flat surface on the side toward the container, with a screened opening in the bottom, is provided in similar lengths and is similarly capable of being easily joined 60, to surround the perforated piping and disposed by means of bracing members about two inches from the circumference of the perforated piping. Strap hangers 62 are arranged to suspend the perforated piping 56 and the metal cover 59 from the recessed wells 10 of the outer casing of the refrigerator containers. When all containers have been loaded into the freight car, an outside gas system of perforated piping with protective metal covering, with screened bottom opening, will surround the perimeter of the mass of refrigerator containers, near the top of said containers, and disposed between the outer casing of the mass of containers and the sides and ends of the freight car.

As containers are loaded into the freight car and the outside gas system is installed and connected, a layer of loose insulation is blown into the freight car in all open area between the mass of containers and the roof, floor, ends and sides of the freight car, the outside gas system being completely enclosed in said layer of blown insulation.

The gas escaping from the refrigerator containers now passes from the vent 8 of said containers, through the flexible connections 55, into the perforated piping 56 of the outside gas system, then through the perforations into the metal cover 59, and from the screened openings of the metal cover into the blown insulation 61 surrounding the mass of refrigerator containers, to seep through the minute openings between the particles of blown insulation to form a blanket of insulation and refrigeration to further intercept heat entering through the walls of the freight car, before such heat can come into contact with the surface of the refrigerator containers.

In the operation or use of the containers of this invention, though they are of simple mechanical construction, care should be exercised in their packing, charging and loading to secure the best results. It is desirable to pre-cool the container in a cold room of approximately minus 20° F.

temperature, to insure a constant freezing, zero or sub-zero temperature immediately upon the lading being placed in the container. When the refrigerator container has been brought to the desired temperature, the lading compartment should be thoroughly sterilized with an ultra-violet ray lamp.

The lading which has been maintained at low temperature is then packed in the container trays and the trays positioned in the lading compartment of the refrigerator container. The prime refrigerant chambers are then charged with solid carbon dioxide (Dry Ice) and these chambers are sealed, after pressure valves have been checked. Carbon dioxide gas is then forced through the gas system, under pressure, to remove all air or warm gas from the system and to reduce the temperature of the gas system to the desired point. The gas system is then connected to the prime refrigerant chamber gas outlet. The lading compartment door is closed and sealed, to insure that this compartment will remain air-tight during transit.

If the shipment is less-than-carload-lot, the container or containers are then ready for shipment. If the shipment is a carload-lot, the loading operation requires further description.

For carload-lots, further insulation and refrigeration is provided. Beginning at the ends of the car and loading toward the middle, loaded refrigerator containers are placed two across in the car. Mechanical jacks and planking are used to shore in the containers, car dimensions being taken into consideration, to divide equally the surplus space which will remain around the mass of loaded containers, at the ends and sides of the car.

Joints of perforated piping, to form the outside gas system, are suspended by the strap hangers from the recessed wells in the ends and sides of the containers, and are joined one to the other, as the containers are placed into position. Connections between the container vents and the outside gas system are made, and the sawdust or other insulation is blown into the open areas surrounding the mass of containers. The gas escaping from the outside gas system will gradually seep through the insulation to fill all available openings, giving a drying and refrigerating effect.

The unloading operations begin with the removal of the blown insulation, by means of the reversed blower device. The outside gas system and the metal covers are removed as the containers are unloaded.

All refrigerator containers, whether carload-lot or less-than-carload-lot shipment are immediately placed in the cold room at the receiving terminal upon arrival and the container is checked for temperature and for condition of the lading.

The automatic operations of the refrigerator container en route is controlled by the transfer of heat to the prime refrigerant and the development and intermittent release of the evolved gas of sublimation to the secondary refrigerating chambers by action of the pressure control valve.

There are but two sources of heat in the interior of the refrigerator container, that which results from the oxidation of the products of the lading chamber, and that which enters the walls of the container by conduction or radiation. The heat of oxidation may be ignored, for the amount of heat so generated in a sealed container at freezing, zero or sub-zero temperature is negligible.

Such heat, if any, will by the laws of nature, rise

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to the upper area of the container to be brought into contact convectively with the conductor plate upon which rests the solid carbon dioxide, and will thus be transferred to the refrigerant.

Any heat entering the interior of the container, through the walls, will likewise rise by convective currents to be transferred to the prime refrigerant by contact with the conductor plate. All heat so transferred to the prime refrigerant will cause the sublimation of gas, to be forced under the pressure of the accumulated gas into the gas system and the secondary refrigerating chambers.

The "gradient step-down" principle is best described and explained by reference to Figures 14, 15 and 16, wherein the path of heat entering through the walls of refrigerator containers and the transfer of said heat to the container refrigerant, or refrigerants, is diagrammatically illustrated for first, an ordinary refrigerator container (Figure 14), secondly, a theoretical refrigerator container (Figure 15), and thirdly, a refrigerator container embodying the "gradient step-down" principle (Figure 16).

In Figure 14, the outer casing 101, the insulation 131, the inner shell 122, the refrigerant chamber 141, and a fragmentary view of an ordinary refrigerator container X are illustrated. Heat entering through the walls of the container is indicated by H, H¹, H², and H³ and the ascending sequence indicates the direction of flow.

From this illustration it will be observed that all heat which successfully enters the interior of the container, by passing through the walls of the container, is ultimately brought into contact with the refrigerant chamber, in this case there being only one refrigerant chamber, and is transferred by conduction to the refrigerant, causing a refrigerant consumption in direct proportion to the amount of heat absorbed.

In Figure 15, the outer casing 201, the outer insulation layer 232, a theoretical placement of a part of the refrigerant 211A between divisions of the insulation, the inner insulation layer 231, the inner shell 222, the refrigerant chamber 211 and a fragmentary view of a theoretical refrigerator container Y are illustrated. Heat entering through the walls of the container is indicated by H, H¹, H², H³, H⁴, and H⁵ and the ascending sequence indicates the direction of flow.

If it were practical to construct a refrigerator container as described in this drawing, a part of the refrigerant would be interposed between divisions of the insulation in such a manner as to intercept heat entering the container before such heat reached the interior of the container. Heat brought into contact with the refrigerating chamber 211A, containing that part of the refrigerant interposed in the walls of the container, would cause a consumption of the refrigerant in chamber 211A, and would not induce a transfer of heat to the refrigerant in chamber 211, thus conserving for a longer period of time that refrigerant in chamber 211. However, no practical gain results from this arrangement as an actual consumption of refrigerant occurs, partial consumption occurring in chamber 211A rather than in chamber 211.

In Figure 16, component parts of a refrigerator container embodying the "gradient step-down" principle of this invention are illustrated. In the construction of this container, the outer shell 1, the outer insulation layer 33, the second secondary refrigerating chamber (duct chamber) 39, and its heat transfer wall 34A, the center insula-

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tion layer 32, the first secondary refrigerating chamber (grooved chamber) 35 and its heat transfer wall 34, the inner insulation layer 31, the inner shell 22, the prime refrigerant chamber 14 and the fragmentary view of the refrigerator container C are arranged as the component parts and apparatus of said refrigerator container are placed in actual construction. Heat entering through the walls of the container is indicated by H, H¹, H², H³, H⁴, H⁵, H⁶ and H⁷ and the ascending sequence indicates the direction of the flow.

From the previous description of the construction and operation of this refrigerator container, it will be recognized that the prime refrigerant (Dry Ice) is placed in the prime refrigerant chamber 14, and that the evolved gas of sublimation accumulates in the gas-tight chamber until the desired pressure has been built up against the pressure control valve 13 in the gas system, whereupon it is released to be forced into the first secondary refrigerating chamber 35, which in turn forces the old, higher-temperature gas in chamber 35 into the second secondary refrigerating chamber 39, the old, higher-temperature gas of that chamber being forced from the gas system through the vent in the outer casing to the outside gas system, or to the atmosphere. Since the secondary refrigerating chambers are isolated against heat transfer from one to the other, and from all other sections of the gas system, by heat breaker connections made of poor heat-conducting material, this refrigerator container has three refrigerating chambers, the two secondary refrigerating chambers so disposed as to intercept heat from the sides before it reaches the interior of the container, and the prime refrigerant chamber which absorbs heat reaching the interior of the container with the resulting sublimation of further gas for the replacement of old gas which has been warmed somewhat in the secondary chambers.

Although the temperature of the prime refrigerant, and the gas in the various steps of the gas system, will vary somewhat, let us assume, for purposes of illustration and explanation, certain reasonable temperatures throughout the gas system. The temperature of the prime refrigerant may be assumed to be minus 110° F., that of the newly sublimated gas under pressure control in the prime refrigerant chamber as minus 85° F. to minus 60° F., that of the first secondary refrigerating chamber as minus 60° F., to minus 10° F., that of the second secondary refrigerating chamber as minus 10° F. to plus 30° F. and that of the gas being vented to the outside gas system, or to the atmosphere, as approximately plus 30° F.

It will be obvious to those skilled in the art that a transfer of a large percentage of the heat entering the walls of the container has been made to the cold gas of the second secondary refrigerating chamber, raising the temperature of the gas of this chamber from minus 10° F. to plus 30° F., after which it is vented from the container. Likewise, a large amount of the heat which was not intercepted by the second secondary refrigerating chamber, through the medium of the conductor mounting plate, has been transferred to the cold gas of the first secondary refrigerating chamber, raising the temperature of the gas of this chamber from minus 60° F. to minus 10° F., after which the gas is forced into the second secondary refrigerating chamber.

That heat which did enter the interior of the refrigerator container, and was brought into con-

tact with the prime refrigerant chamber for transfer to the prime refrigerant has consumed an amount of prime refrigerant in direct proportion to the amount of heat transferred, and further heat entering the prime refrigerant chamber or chambers has raised the temperature of the newly sublimated gas from minus 85° F. to minus 60° F.

If we assume all conditions of operation of the three containers described in Figures 14, 15 and 16 to be the same, except that of the difference in construction and the placement of the refrigerant, as illustrated in the three drawings, and we further assume the use of the same weight and volume of solid carbon dioxide as a refrigerant, the combined volumes of refrigerant in chambers 211A and 211 of the container illustrated in Figure 15, would be consumed in approximately the same period of time as that in the container illustrated in Figure 14, while maintaining relatively the same temperature in the lading compartment. However, since a very large percentage of the heat entering the refrigerator container illustrated in Figure 16 is transferred to the evolved gas in the secondary refrigerating chambers, only that heat reaching the interior of the container will induce heat transfer to the prime refrigerant. Therefore, the same quantity of prime refrigerant in this container will maintain the desired temperature in the lading compartment for a much longer period of time.

It will be noted in Figure 14 that the gradient 1A which induces the transfer of heat to the refrigerant is the temperature differential between the surface of the outer casing and that of the interior of the refrigerator container. In Figure 15, the gradient of this theoretical container has been divided into two steps, step 1B which is the temperature differential between the outer casing surface and that surrounding the interposed refrigerant container 211A, and step 1A which is the temperature differential between that surrounding the refrigerant chamber 211A and that surrounding the refrigerant chamber 211. Only the gradient step 1A induces the transfer of heat to the refrigerant in chamber 211.

In Figure 16, which is an embodiment of the refrigerator container of this invention and therefore an illustration of the "gradient step-down" principle, three gradient steps are established. The first of these, step 1C is the temperature differential between the surfaces of the outer casing and the second secondary refrigerating chamber, the second, step 1B, is the temperature differential between the surfaces of the second secondary refrigerating chamber and that of the first secondary refrigerating chamber, and the third, step 1A, is the temperature differential between the surface of the first secondary refrigerating chamber and that of the interior of the refrigerator container. Only the innermost gradient step, 1A, induces the transfer of heat to the prime refrigerant, and since this is only one part of the total gradient of the refrigerator container, the obvious result is a greatly reduced transfer of heat to the prime refrigerant and a substantial reduction in the rate of consumption of the prime refrigerant.

While I have described my invention in some detail, and with specific reference to one embodiment thereof, it will be apparent, especially to those skilled in the art, that various modifications may be made in the form of the container and in the apparatus for applying the principles

of the invention, and that certain features may be used to advantage, without a corresponding use of the other features, all without departing from the spirit of my invention. I therefore desire, by the following claims, to include within the scope of my invention, all such similar refrigerator containers, refrigerator cars, trucks, and other refrigerating devices, for this and all other end-use purposes, whereby substantially the results of my invention are obtainable by substantially the same means.

I claim:

1. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced relation thereto, a plurality of intermediate walls made from metal of high heat conductivity and disposed between said shells in spaced relation to said shells and to each other, insulating material disposed in the spaces between said walls and between said walls and said shells, means defining at least two secondary refrigerant passages disposed respectively along and in heat transfer relation with respect to different ones of said intermediate walls, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide, a refrigerant discharge passage from said primary chamber including a constant pressure control valve, means of low heat conducting material connecting said refrigerant discharge passage with one end of one of said secondary refrigerant passages and connecting the other end of said one passage to one end of the other secondary passage to transmit gaseous refrigerant successively through said secondary passages, and means affording a vent extending through said outer shell from the other end of said other secondary passage.

2. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced relation thereto, a plurality of intermediate walls made from metal of high heat conductivity and disposed between said shells in spaced relation to said shells and to each other, insulating material disposed in the spaces between said walls and between said walls and said shells, means defining at least two secondary refrigerant passages disposed respectively along and in heat transfer relation with respect to different ones of said intermediate walls, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide and having a refrigerant discharge passage, means of low heat conducting material connecting said refrigerant discharge passage with one end of one of said secondary refrigerant passages and connecting the other end of said one passage to one end of the other secondary passage to transmit gaseous refrigerant successively through said secondary passages, and means affording a vent extending through said outer shell from the other end of said other secondary passage.

3. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment an outer shell surrounding said inner shell in spaced non-heat-transmitting relation thereto, a plurality of intermediate walls

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made from metal of high heat conductivity and disposed between said shells in spaced relation to said shells and to each other, heat breaker means supporting said intermediate walls, insulating material disposed in the spaces between said walls and between said walls and said shells, means defining secondary refrigerant passages disposed respectively along and in heat transfer relation with respect to different ones of said intermediate walls, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide and having a refrigerant discharge passage, means of low heat conducting material connecting said refrigerant discharge passage with said secondary refrigerant passages in series and terminating in a vent extending through said outer shell.

4. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced relation thereto, means recessed into outer shell and affording a vent, a plurality of intermediate walls made from metal of high heat conductivity and disposed between said shells in spaced relation to said shells and to each other, insulating material disposed in the spaces between said walls and said shells, means defining secondary refrigerant passages disposed respectively along and in heat transfer relation with respect to different ones of said intermediate walls, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide and having a refrigerant discharge passage means of low heat conducting material connecting said refrigerant discharge passage with said secondary refrigerant passages in series and terminating at said vent.

5. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced relation thereto, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide, and having a refrigerant discharge passage, means in said walls between said shells comprising alternate layers of insulation and of heat conductive material, and means affording a continuation of said discharge passage extending through said outer shell and having sections isolated by heat breaker sections and disposed in heat transfer relation with said layers of heat conducting material in succession.

6. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced non-heat-transmitting relation thereto, a vent in said outer shell, a plurality of intermediate walls made from metal of high heat conductivity and disposed between said shells in spaced relation to said shells and to each other, heat-breaker means supporting said intermediate walls, insulating material disposed in the spaces between said walls and between said walls and said shells, means defining secondary refrigerant passages disposed respectively along and in heat transfer relation with respect to different ones of said intermediate walls, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant

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chamber adapted to contain solid carbon dioxide and having a refrigerant discharge passage, and means connecting said refrigerant discharge passage with said secondary refrigerant passages in series and terminating in said vent and arranged to cause downward flow and then upward flow of refrigerant gases in the successive secondary refrigerant passages.

7. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced relation thereto, a vent formed in said outer shell, a pair of intermediate walls made from metal of high heat conductivity and disposed between said shells in spaced relation to said shells and to each other, insulating material disposed in the spaces between said walls and between said walls and said shells, means defining two secondary refrigerant passages disposed respectively along and in heat transfer relation with respect to different ones of said intermediate walls, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide, a refrigerant discharge passage from said primary chamber, means of low heat conducting material forming a connection between said refrigerant chamber and the upper end of the inner one of said secondary refrigerant passages and connecting the lower end of said inner passage to the lower end of the outer secondary passage to transmit gaseous refrigerant successively through said secondary passages, and means connecting the upper end of the outer secondary passage to said vent.

8. In a refrigerator container for frozen foods or the like that require freezing, zero or sub-zero temperatures, an inner shell defining a lading compartment, an outer shell surrounding said inner shell in spaced relation thereto, means disposed within said lading chamber and adjacent the top thereof to define a primary refrigerant chamber adapted to contain solid carbon dioxide, and having a refrigerant discharge passage, means in said walls between said shells comprising alternate layers of insulating and of heat conductive material, means affording a continuation of said discharge passage extended through said outer shell and having sections isolated by heat breaker sections and disposed in heat transfer relation with said layers of heat conducting material in succession, and normally closed openings at opposite ends of said insulation layers through which drying air may be passed to remove condensed moisture from said insulation layers.

9. The method of loading foods and the like for transportation in frozen or sub-zero condition which consists in loading the food or the like into a plurality of containers each containing a supply of solid carbon dioxide adapted upon sublimation to escape from vents provided on the individual containers, placing such containers in side by side relation in a freight car and in spaced relation to the walls of the freight car, supporting a perforated distributing pipe about the perimeter of the group of containers, and connecting the vents of said containers to such distributing pipe to thereby distribute the sublimated carbon dioxide gas about the space between said containers and the walls of the car.

10. The method of loading foods and the like for transportation in frozen or sub-zero condi-

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tion which consists in loading the food or the like into a plurality of containers each containing a supply of solid carbon dioxide adapted upon sublimation to escape from vents provided on the individual containers, placing such containers in side by side relation in a freight car and in spaced relation to the walls of the freight car, supporting a perforated distributing pipe about the perimeter of the group of containers, connecting the vents of said containers to such distributing pipe to thereby distribute the sublimated carbon dioxide gas about the space between said containers and the walls of the car, and blowing insulation material into the space between said containers and the walls of said car.

11. The method of loading foods and the like for transportation in frozen or sub-zero condition which consists in loading the food or the like into a plurality of containers each containing a supply of solid carbon dioxide adapted upon

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sublimation to escape from vents provided on the individual containers, placing such containers in side by side relation in a freight car and in spaced relation to the walls of the freight car, filling the space between said containers and said wall with loose insulating material, and distributing the the vented carbon dioxide gas in the space occupied by said insulation.

CHARLES B. HALL.

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