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METHOD OF AND MEANS FOR CONTROLLING LOW TEMPERATURE REFRIGERANTS

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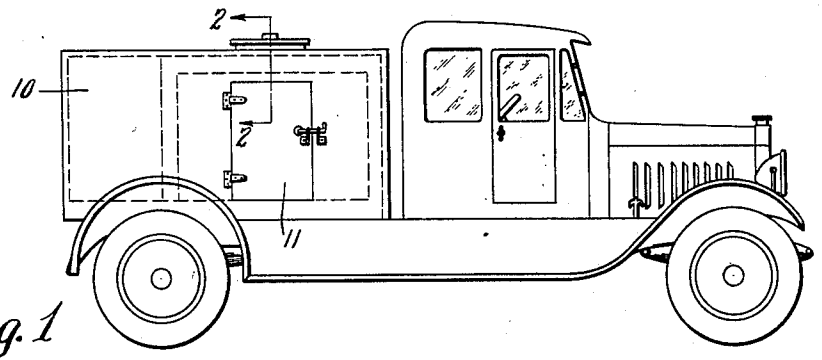

Fig. 1

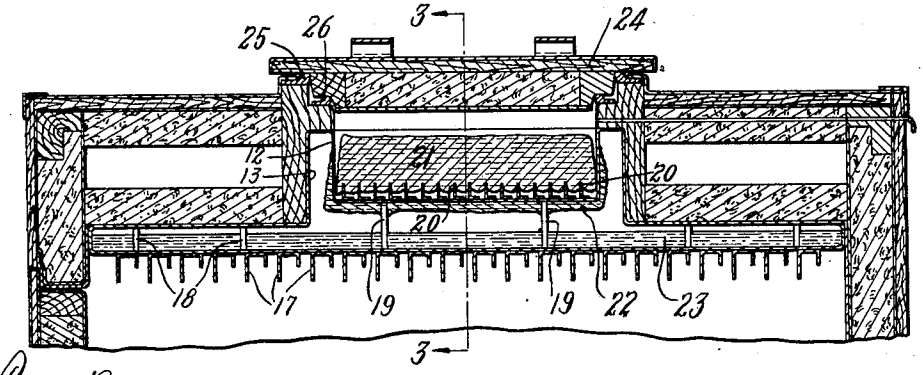

Fig. 2

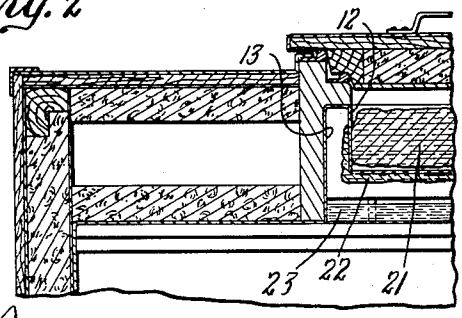

Fig. 3

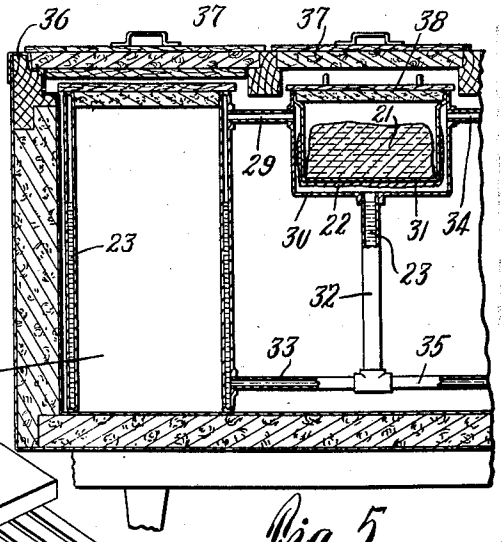

Fig. 5

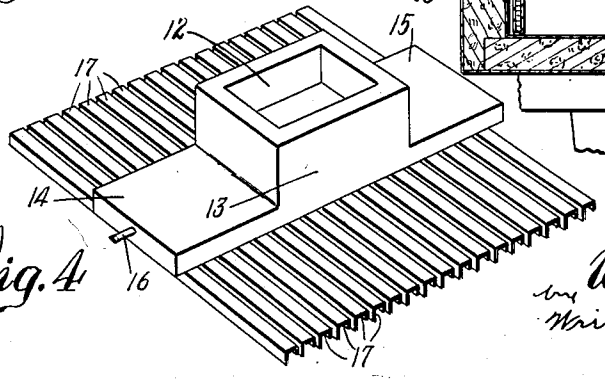

Fig. 4

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METHOD OF AND MEANS FOR CONTROLLING LOW TEMPERATURE REFRIGERANTS

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6 Claims. (Cl. 62—91.5)

This invention relates to a method of and means for maintaining a substantially constant temperature in a refrigerator cabinet by automatically controlling the refrigerating effect of low temperature refrigerants such as solid carbon dioxide. The use of solid carbon dioxide as a refrigerating agent has come into considerable favor due to the ease of handling and the absence of resultant liquid to be disposed of when the refrigerant changes state. There are, however, certain practical difficulties connected with the use of low temperature refrigerants such as solid carbon dioxide. The refrigerating effect of a block of solid carbon dioxide placed within a refrigerator cabinet is roughly proportional to its free surface, this effect being varied by different conditions such as the freedom of circulation of atmosphere and the conductivity of the support on which the block rests. Thus when a block of solid carbon dioxide is placed within a refrigerator cabinet upon a shelf or upon goods within the cabinet, the refrigerating effect is usually too great while the block is large, causing unnecessary and undesirably low temperatures within the refrigerator. These low temperatures are detrimental to many foodstuffs which require moderately low temperatures. Furthermore the excessively low temperatures in a refrigerator are wasteful in that an unneecessarily steep temperature gradient is established through the walls of the refrigerator which induces a larger inflow of heat with a resultant wasteful consumption of the refrigerant. When the block of refrigerant shrinks to small size it reaches a point where its size is insufficient to maintain the refrigerator at a temperature which is sufficiently low. Unless the block is then broken up so as to expose more surface, or more refrigerant is supplied to the refrigerator, the temperature within the cabinet rises beyond the desired maximum.

It is an object of this invention to provide apparatus for so controlling the refrigerating effect of carbon dioxide or other very low temperature refrigerants that the initial wastefully rapid consumption of refrigerant is avoided and the last of the block of refrigerant is utilized to maintain a substantially constant temperature within the refrigerator cabinet within a desired temperature range, this regulation of refrigerating effect being automatically self-controlling so as to require no attention on the part of the operator.

In any refrigerating system wherein a cabinet is cooled by a refrigerating substance, there is a temperature gradient from the atmospheric temperature to the temperature of the refrigerant. If the refrigerator cabinet is properly insulated as it should be, there is a sharp temperature drop between its outer surface and its inner surface, the inner temperature being preferably at or near that desired for the foodstuffs or other objects which are to be kept cool within the cabinet. For example, a cabinet for fresh meats should be maintained at about 35° F. while for ice cream a temperature of 5° to 8° F. is desirable. Where solid carbon dioxide is used as a refrigerant, there is necessarily a large temperature difference between the interior of the refrigerator cabinet and the refrigerant itself owing to the fact that the latter is approximately 118° below zero F.

It is a further object of this invention to provide self-regulating apparatus which will automatically vary the heat conductivity of the path between the interior of the refrigerator cabinet and the refrigerant, so that the heat flow along that path shall balance the inflow of heat through the walls of the cabinet, the apparatus automatically adjusting itself to take care also of occasional inflow of heat resulting from the opening of the cabinet doors for the insertion or removal of merchandise. It is desirable that the control apparatus be not only capable of adjusting itself automatically to regulate the flow of heat from the refrigerator cabinet to the refrigerant so as to equal the inflow through the walls of the cabinet, but also to respond quickly to a change of inflow so that when the cabinet temperature is raised by the opening of the doors the refrigerating apparatus quickly absorbs the extra heat and restores the cabinet temperature to its desired value.

It is a still further object of the invention to provide apparatus such that if desired the refrigerant may be somewhat remote from the cabinet. This affords considerable freedom in designing refrigerating apparatus, since it is not necessary that the refrigerant be within or immediately adjacent to the cabinet.

In carrying out the present invention so as to provide one form of apparatus having the desirable characteristics hereinbefore mentioned, I may provide a receptacle for the solid carbon dioxide such that a portion of its surface can be maintained at a temperature approximately equal to that of the refrigerant itself. To this end the receptacle is preferably made of metal and may be provided with a number of fins extending upwardly from its bottom, these fins be-

ing adapted to support the block of carbon dioxide. If desired, a non-freezing and non-volatile liquid may also be supplied to improve the thermal contact between the carbon dioxide and the bottom of the receptacle. The external surface of the bottom of the receptacle and a portion of its sides thus becomes a low temperature refrigerating surface as long as any appreciable amount of solid carbon dioxide is maintained within the receptacle. The refrigerating surface is included in an air-tight container of which the receptacle forms a part, this container being adapted to enclose a suitable substance having desirable melting and boiling points such as to permit it to exist in a liquid phase at a suitably low temperature to refrigerate a cabinet of given dimensions and insulation. The container holding this secondary refrigerant is preferably sealed so as to be air-tight after substantially all the air has been exhausted therefrom. The secondary refrigerant may be a substance such as, for example, carbon tetrachloride, this substance having a melting point at about 11° below zero F. During the operation of the apparatus, the relatively low temperatures within the gas-holding container result in a comparatively low pressure of the gas or vapor therein, hence the container acts as a sort of vacuum flask about the solid carbon dioxide to minimize undesired access of heat to the sides of the inner receptacle for the solid carbon dioxide. The container surrounding the receptacle is preferably of sufficient size to hold a considerable quantity of liquid carbon tetrachloride or other secondary refrigerant. This substance is kept at a desirably low temperature by evaporation of a portion of the liquid, this evaporation being facilitated by the comparatively low pressure maintained within the receptacle.

In starting the operation of the refrigerator, the vapor in the receptacle at first condenses in considerable quantity on the cold bottom and sides of the solid carbon dioxide receptacle, the temperature of the bottom of this receptacle being sufficiently cold to form a frost or layer of solid carbon tetrachloride. As the vapor is condensed on the cold surface of the receptacle in the form of frost, the pressure within the container is thus materially reduced. Under certain conditions this reduction may be sufficient to cause an ebullition of the liquid carbon tetrachloride. In any event the reduction of vapor pressure within the container by the withdrawal of vapor to form the frost layer accelerates evaporation of the liquid. This results in a rapid removal of latent heat of vaporization from the liquid body together with resultant cooling of the liquid and of its container. By this reduction of temperature, the container itself becomes the cold body within the refrigerator cabinet and exposed to the air within the cabinet, so that the cabinet is cooled thereby. The mean temperature of the air within the cabinet which is reached when the system is in a condition of equilibrium will depend on various factors such as the atmospheric temperature, the efficiency of the insulation of the cabinet, the size of the cabinet, and the size of the cold container. If the bottom of the solid carbon dioxide receptacle is of sufficient area, the liquid carbon tetrachloride may be maintained wholly or partly in solid form by the rapidity of evaporation and the consequent removal of latent heat of vaporization. Thus the container, in which is the secondary refrigerant for the refrigerator cabinet, may, under favorable conditions, be maintained at a temperature approximately 11 degrees below zero F. It is desirable, however, to proportion the various refrigerating surfaces in such a manner that it will not be necessary to use the minimum temperature of the carbon tetrachloride except when initially cooling the cabinet.

The temperature of the secondary refrigerant may be controlled by the frost layer of solid carbon tetrachloride formed on the cold surface of the solid carbon dioxide receptacle. This frost is a relatively poor conductor of heat so that a fairly steep temperature gradient is established therethrough, the thick coating of frost presenting to the gas within the container a surface temperature considerably above that of the solid carbon dioxide. This materially retards condensation of vapor in the vicinity of the frost layer, this retardation of condensation resulting in a similar retardation of evaporation from the liquid body. This is automatically variable to adjust itself to temperature conditions within the cabinet. If, for example, a cabinet door is opened after the system has reached a substantial equilibrium, the inflow of warm air from the outside atmosphere raises the mean temperature of the cabinet. This additional heat is absorbed by the surface of the container, the rise in temperature resulting in an increase of evaporation of liquid and an increase of vapor pressure within the container. A rise of pressure and temperature of the vapor tends to diminish the thickness of the frost layer on the surface of the solid carbon-dioxide receptacle so that a colder surface is presented by reason of the thinner frost layer separating the solid carbon dioxide from the gas. This results in an increased rate of condensation of vapor on the frost surface which speedily restores the frost layer to its normal equilibrium thickness, unless the additional supply of heat from the outside is kept up. Since practically all of the air originally in the container is withdrawn therefrom prior to the sealing thereof, the motion of vapor in the container is substantially unhindered, and vapor removed by condensation at one point is almost instantly replaced by more vapor. Apparatus of this kind may thus be made sensitive and quickly responsive to changes of temperature within the cabinet so that after a door is opened for a period and then closed the mean temperature of the cabinet is quickly restored. Since the diffusion of the vapor within the container is extremely rapid, due to the absence of inert gases such as air, this sensitivity and rapidity of response is not materially lessened if the liquid body of carbon tetrachloride is maintained at some distance (several feet or so) from the solid carbon dioxide container. Thus the liquid body of carbon tetrachloride may be kept in a closed vessel connected by a tube with a closed vessel surrounding the cold surfaces of the solid carbon dioxide receptacle, the system being maintained air-tight and at a very low pressure. Changes of vapor pressure within the vessel containing the liquid body will be quickly communicated for some distance through the connecting tube to the container surrounding the refrigerant. Thus the refrigerating effect is rapidly and efficiently transferred by molecular motion of the vapor.

While the mean temperature of the refrigerator cabinet can be controlled to some extent by the relative areas of cold surface on the solid carbon dioxide receptacle and the free surface of the liquid body as well as by the actual size of

these areas and the provision of efficient means for conducting heat within the cabinet to the secondary refrigerant, I may also vary the range of temperatures within the cabinet by the selection of different substances or mixtures of substances having desired characteristics of melting point, boiling point and volatility. If, for example, a refrigerating unit of a given size fails to maintain a certain refrigerator cabinet at a sufficiently low temperature when carbon tetrachloride is used within the refrigerator unit, I may use a mixture of carbon tetrachloride and chloroform, or another substance such as orthochlorotoluene. These substances having lower melting points than carbon tetrachloride are effective in establishing a lower range of temperatures within a given cabinet, since the minimum temperature of the secondary cooling surface is thus made lower.

An embodiment of the invention is disclosed in the description which follows and on the drawing, of which,—

Figure 1 is a side elevation of a motor truck having a refrigerator body including a refrigerating unit embodying the invention.

Figure 2 is a fragmentary section on the line 2—2 of Figure 1.

Figure 3 is a section on the line 3—3 of Figure 2.

Figure 4 is a perspective view of the refrigerating unit illustrated in the other figures.

Figure 5 illustrates a modified form of apparatus embodying the invention.

Referring to the drawing in detail, 10 represents a refrigerator cabinet which may, as shown, be mounted on a truck chassis for the transportation of perishable foodstuffs and the like, or may be a stationary refrigerator for any of the purposes for which refrigerators are ordinarily intended. As shown, the cabinet is provided with one or more side doors 11 to permit the insertion and removal of merchandise which is to be kept cool. The refrigerator unit, a perspective view of which is shown in Figure 4, may comprise a receptacle 12 for solid carbon dioxide, this receptacle being nested in a container 13 the side walls of which are spaced from the side walls of the receptacle 12 so as to form a chamber entirely surrounding the sides of the receptacle. The container 13 is also provided with a bottom member which is likewise spaced from the bottom of the receptacle 12. The container 13 may thus be described as a gas-tight hollow body with a re-entrant portion forming the receptacle 12 for the refrigerant. As shown in Figure 4 the container may be provided with extensions 14 and 15 to receive the liquid which is to be used as a secondary refrigerant. This makes possible a relatively large free surface for the liquid body so that evaporation thereof is facilitated. At one end of the container 13 is a pipe 16 through which the liquid may be introduced into the container, and through which also the air in the container may thereafter be exhausted by a suitable pump, whereupon the pipe 16 is sealed off. In order to increase the effectiveness of the secondary refrigerant, a number of metal channels 17, or other equivalent fins, may be welded, brazed or otherwise mounted on the bottom of the container 13 in intimate contact therewith. These channels preferably extend from one side of the cabinet to the other, or from one end of the cabinet to the other, according to the arrangement of the channels therein. Since a normally low pressure is maintained within the container 13, I may provide a number of supporting studs or pins 18 and 19 within the container to prevent collapse of the walls thereof. The studs 18, 19 may be spot welded to the bottom plate of the container 13, the upper ends of the studs 18 resting against the upper plates of the extensions 14 and 15, the upper ends of the studs 19 resting against the bottom of the solid carbon dioxide receptacle 12. As shown in Figure 2, the receptacle 12 may be provided with a number of fins 20 (not shown in Figure 4) in intimate contact with the inner surface of the bottom thereof. The solid carbon dioxide, a block of which is illustrated at 21, rests on the fins 20 when inserted in the receptacle, the fins thereupon working their way up into the block so that when the block is reduced to small dimensions the fins eventually cut the remainder of the block into small pieces and maintain its efficiency as a primary refrigerant until it is substantially gone.

On the bottom and a portion of the sides of the receptacle 12, a frost layer 22 is indicated, this frost layer acting as a partial insulating layer and thermal valve by which the condensation of vapor within the container and the resultant evaporation of more vapor from the liquid body 23 is accelerated or retarded according to the thickness of the frost layer. The container 13 with the channels 17 is preferably arranged at the top of the interior space within the cabinet, so that the air in the cabinet which is warmed by heat entering through the walls or through the doors will rise and give up its heat to the secondary refrigerant, this resulting in more rapid evaporation of a portion of the liquid 23 and a rise of temperature within the container, with a resultant reduction of thickness of the frost layer 22. The receptacle 12, as shown in Figure 4, is preferably open at its top. In order to protect the refrigerant placed therein a well insulated cover or lid 24 may be provided, this cover being adapted to rest on suitable gaskets 25 and 26 which efficiently insulate the top of the receptacle 12. Thus additional refrigerant may be supplied to the receptacle by removing the lid 24 without opening the cabinet itself.

A modified form of apparatus embodying the invention is illustrated in Figure 5. Therein is shown in section a suitable refrigerator cabinet having insulating walls 27. Within the cabinet I may place a number of containers which, as shown, may be in the form of double walled cylinders 28 of a suitable size to receive ice-cream cans or the like, the ends of the inner and outer walls of the cylinders 28 being sealed to close the container. This container may be connected near its top to a pipe 29 leading to a container 30. The latter has a reentrant portion 31 serving as a receptacle for solid carbon dioxide or equivalent refrigerant. To the bottom of the container 30 is attached a pipe 32, this pipe being connected to a return pipe 33 leading into the lower portion of the cylindrical container 28. On the other side of the container 30 there may be one or more additional hollow containers, each preferably being connected to the container 30 in the same manner as the cylinder 28, as, for example, by a pipe 34 and a return pipe 35, the latter being connected to the pipe 32. This illustrates a form of apparatus in which the liquid which is chilled by evaporation is remote from the container in which the insulating layer of frost is formed.

Due to the virtual absence of inert gas within the system, vapor from the liquid in the container 28 moves rapidly through the pipe 29 into the container 30 to replace the vapor condensed therein. Such vapor as condenses to liquid in the container

30 may return to the container 28 through the return pipes 32 and 33.

The cabinet illustrated in Figure 5 is of a type suitable as a dispensing cabinet for ice-cream or similar frozen foods. As shown, it includes a permanent insulating top 36 having a number of apertures therein which are closed by removable lids 37, these lids being preferably placed above each of the containers 28 and the container 30. If desired, an inner cover 38 may also be fitted over the refrigerant receptacle 31. Cans of ice-cream or the like may be inserted by the removal of one or more of the covers 37, the cans being preferably made to fit loosely within the inner walls of the containers 28.

It is obvious that the specific form and arrangement of the parts of the apparatus illustrated on the drawing may be varied considerably without exceeding the scope of the invention defined in the following claims.

I claim:

1. The method of refrigerating a cabinet or the like with a refrigerant having a temperature far below that desired for the cabinet which comprises interposing and confining between the refrigerant and the interior of the cabinet a liquid and its vapor with a freezing point above the temperature of the refrigerant, exposing said vapor to a temperature zone adjacent to said refrigerant lower than the freezing point of said vapor, whereby a portion of said vapor is condensed in a solid layer between the refrigerant and the uncondensed vapor, and exposing said liquid to a temperature zone substantially equivalent to the temperature of said cabinet.

2. The method of controlling the refrigerating effect of a very low temperature refrigerant on a refrigerator cabinet, which comprises interposing and confining between said refrigerant and the interior of the cabinet a volatile liquid and its vapor having a freezing point above the temperature of the refrigerant, maintaining said vapor substantially free from inert gases, exposing said vapor to a surface chilled by said refrigerant to a temperature below said freezing point whereby a portion of said vapor is condensed on said surface in a solid layer, and promoting the conduction of heat from the interior of said cabinet to said liquid.

3. Apparatus of the class described comprising a closed container having a liquid-holding portion and another portion in communication therewith and adapted to be chilled by solid carbon dioxide or the like, a mixture of chloroform and carbon-tetrachloride within said container, the contents of said container being substantially limited to said chloroform and carbon tetrachloride and their vapors, the proportion of these substances being according to the temperature desired for the liquid-holding portion of the container.

4. The method of controlling the flow of heat along a predetermined path to a refrigerant from a space to be refrigerated, which comprises maintaining across said path a layer of an enclosed volatile substance in its solid state and a layer of said substance in its gaseous state contiguous to said solid layer.

5. The method of controlling heat transfer to a primary refrigerant from a region refrigerated thereby, which comprises maintaining in the thermal path from said region to said refrigerant a volatile substance having a freezing point above the temperature of the refrigerant and a boiling point slightly below the temperature desired for the refrigerated region, and exposing said substance to ultimate heat-exchanging proximity to said refrigerant and to said region, whereby a layer of said substance in its solid state is formed adjacent to said refrigerant.

6. The method of controlling the refrigerating effect of a low temperature refrigerant on a cabinet to be refrigerated, which comprises maintaining between said refrigerant and cabinet a volatile heat-transferring substance simultaneously in its three physical states, to wit, solid, liquid and vapor.

WILLIAM F. BAIRD.