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METHOD OF AND APPARATUS FOR CONTROLLING HEAT TRANSFER

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Fig. 1

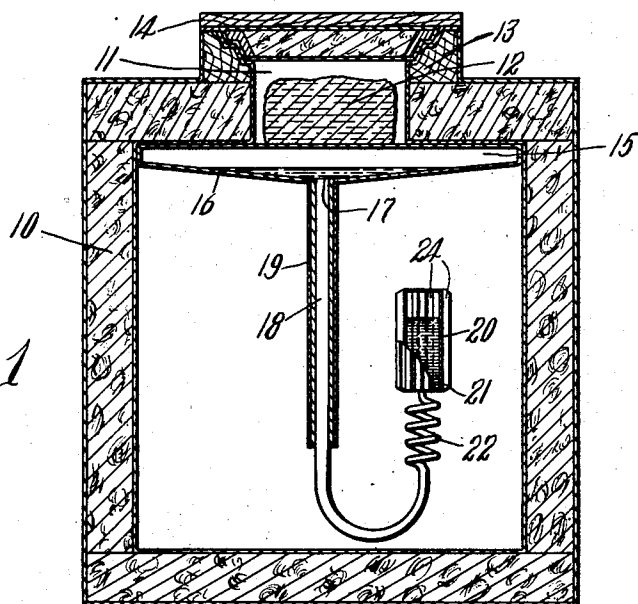
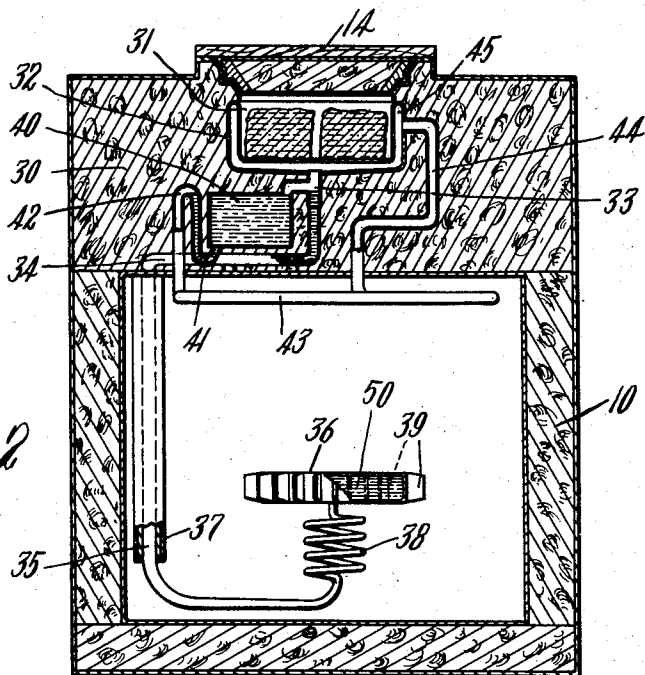


Fig. 2



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METHOD OF AND APPARATUS FOR CONTROLLING HEAT TRANSFER

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8 Claims. (Cl. 62—91.5)

This invention relates to a method of and apparatus for controlling the transfer of heat. While the invention is applicable to a wide range of uses, the embodiments thereof hereinafter described are more particularly designed for controlling the refrigerating effect of a low temperature refrigerant on the interior of a refrigerator cabinet. For many reasons the use of certain refrigerants, such as liquefied or solidified gases, is highly desirable. In general refrigerating substances of this type, as, for example, liquid air or solid carbon dioxide, exist at atmospheric pressure only at very low temperatures, these temperatures being ordinarily unsuitable for refrigerating purposes.

It is an object of the present invention to provide apparatus by which low temperature refrigerants may be conveniently used in the refrigeration of cabinets for food stuffs, the cabinet being maintained at any desired temperature within a reasonable range. The apparatus may be designed and constructed to provide a range of temperatures suitable for frozen foods such as ice cream or for unfrozen foods, such as fresh meat, vegetables, etc. Solid carbon dioxide has been used as a refrigerant for food stuffs, particularly in the transportation of food stuffs, for some time. It has been open to the objection that the refrigerating effect has been substantially uncontrolled so that initial temperatures in a cabinet chilled by such a substance are too low and the material therein is apt to be frozen too hard so as to cause deterioration of structure or flavor, and also to cause a waste of the refrigerant due to the excessive temperature difference between the interior of the cabinet and the outside atmosphere. The uncontrolled use of such refrigerants is also liable to result in undesirably high temperatures when the supply diminishes by the rapid initial consumption of the refrigerant.

According to the present invention a simple apparatus is provided by which the refrigerating effect of a refrigerant is automatically controlled to maintain the cabinet at any desired degree within a certain range. According to this invention, the temperature at which the cabinet is maintained may be quickly and easily adjusted, the apparatus being sufficiently sensitive to maintain the cabinet temperature at a point very close to the desired temperature in spite of irregular access of heat to the interior of the cabinet such as would be occasioned by opening a door of the cabinet or by the insertion of relatively warm objects into the cabinet.

To control the refrigerating effect of a low temperature substance like solid carbon dioxide, the refrigerant is separated from the interior of the refrigerator cabinet by a region of low pressure in a closed, gas-tight system, in which the heat in the cabinet is transferred to the refrigerant by

the free travel of vapor molecules which give up their energy when they strike the cold surface of the container for the refrigerant, and condense into liquid form. The rate of transfer of heat across the region of low pressure depends on the rate of vaporization of the liquid in the system. The latter depends, in turn, on several factors and is automatically controlled, according to the invention, in accordance with the temperature within the cabinet. Thus, if the temperature within the cabinet rises above the predetermined degree, the rate of vaporization is automatically accelerated to reduce the temperature in the cabinet. When the temperature is back to normal, the rate of vaporization is retarded to a point just sufficient to absorb the normal inflow of heat through the walls. The vaporization rate may be controlled by exposure of greater or less amounts of liquid to the heat within the cabinet and the increase or decrease of free surface of the liquid thus exposed for evaporation. In controlling the disposition of the liquid, a column of liquid is balanced against the vapor pressure of the liquid at cabinet temperature so that an increase in the vapor pressure resulting from a rise in cabinet temperature raises the column of liquid so that the upper portion is moved into thermal proximity to the refrigerated space in the cabinet.

For a more complete understanding of the invention, reference may be had to the description thereof which follows and to the drawing, of which,—

Figure 1 is a sectional view of apparatus embodying the invention.

Figure 2 is a section of a modified form of the invention.

Referring to Figure 1, the apparatus includes a suitable cabinet 10 of heat insulating material, this cabinet being constructed in any approved manner such as is well known in the refrigerating art. At the top of the cabinet a receptacle 11 may be provided to contain the primary refrigerant which may be a quantity 12 of solid carbon dioxide, or any other desired refrigerant. For the purpose of illustration, solid carbon dioxide is referred to in connection with the description of the invention, but it is to be understood that the invention is not limited to the use of any particular refrigerating agency. In order to provide sufficient capacity for the container 11, the walls thereof may be extended upwardly, as at 13, to receive a suitable insulating cover 14, by the removal of which access may be had to the receptacle 11 for the insertion of fresh refrigerant. Beneath the receptacle 11 is provided a metal box 15, a portion of the top of which may serve as the bottom of the container 11, so that the metal box 15 may be in direct contact with the refrigerant 12. The box 15 is preferably provided with a bottom 16 of large area, this

bottom sloping toward an aperture 17 leading into a flexible tube 18 which may be of rubber, lead, or any other suitable material or materials for the purpose, and is preferably surrounded for a portion of its length by a sheathing 19 of heat insulating material. As shown on the drawing, the heat-insulating sheath is on the portion of the pipe adjacent to the box 15 and preferably covers the downwardly extending portion of the pipe to or nearly to the turn. Except for the opening 17 the box 15 is gas-tight. The flexible tube 18 turns upwardly and enters the bottom of a gas-tight bulb 20, which is preferably made of metal. The box 15, the tube 18 and the bulb 20 form a gas-tight system within which is a quantity of liquid 21. The upwardly extending portion of the tube 18 is preferably un-sheathed so as to facilitate the passage of heat through the tube wall. This portion of the tube may, moreover, be of considerable length as in the form of a coil 22. For the introduction of the liquid 21, the air in the system is preferably removed so as to form a relatively high vacuum before the system is sealed off. The liquid in the system is preferably one having a low specific heat as a liquid, a high vapor tension and also a high specific gravity. The latter is desirable as it controls the necessary height of the column of liquid in the tube 18. For certain ranges of temperature, such liquids as carbon tetrachloride, ether, acetone, or chloroform are useful.

The operation of the apparatus shown in Figure 1 is as follows: Starting with the apparatus at ordinary atmospheric temperature, a quantity of cold refrigerant, such as solid carbon dioxide, may be inserted in the container 11. At this time the weight of the column of liquid in the tube 18 results in the bulb 20 being practically full of liquid 21. The chilling of the top of the box 15 by contact with the refrigerant 12 condenses the vapor within the box 15 adjacent to the cold ceiling. This reduces the vapor pressure within the box 15 and thus upsets the balance of pressures between the box 15 and the bulb 20 so that liquid flows upwardly into the box 15 forming a shallow pool therein having a considerable free surface, as illustrated in Figure 1. The reduction of pressure in the box 15 may also cause vigorous boiling of the liquid in this pool so that the pool is quickly chilled both by boiling and by the dropping of chilled condensate from the ceiling of the box. This chilling effect is transmitted through the bottom 16 of the box to the interior of the cabinet until the temperature within the cabinet is reduced to such a point that the vapor pressure within the upper portion of the bulb 20 is reduced to permit the pool in the box to drain back into the tube 18. The temperature at which this takes place obviously depends upon the vertical height between the surface of the liquid within the bulb 20 and the surface of the liquid within the box 15 or the tube 18. Consequently, by adjustably elevating or lowering the bulb 20, the equilibrium temperature within the cabinet may be readily adjusted. When the pool has drained into the tube 18 the rate of vaporization of the liquid is sharply reduced, and since the walls of the descending portion of the tube are protected by suitable insulation from the cabinet, there is little or no ebullition therein. The evaporation of liquid from the upper part of the column may be sufficient in some cases to transfer through the box 15 to the refrigerant a considerable part of the heat which normally flows through the walls of the cabinet. If a door is

opened for the insertion or removal of food, a puff of warm air is usually admitted to the cabinet. This warm air acts on the bulb 20 through the thin metal walls thereof to increase the vapor pressure therein and thus to force some of the liquid into the box 15, whereupon the increased exposed surface of the liquid in the box, as well as its increased exposure to the temperature in the cabinet through the bottom 16 of the box causes a rapid transfer of heat by vapor molecules from the bottom to the top of the box, the chilled condensate dropping back into the pool, and thus any occasional inflow of heat in addition to the normal flow through the walls of the cabinet is quickly absorbed by the box 15, so that the temperature of the cabinet is maintained very close to the temperature for which the apparatus is adjusted by the elevation of the bulb 20.

The liquid which drains from the box 15 into the tube 18 is usually chilled to a very low temperature. When such liquid flows into the bulb 20, the bulb may be so chilled as to be incapable of responding promptly to an increase of temperature in the box. To avoid such a lag in the operation of the apparatus, any convenient means may be employed to remove the chill quickly from the liquid entering the bulb. Such means may include the coil 22 which presents a large unsheathed area of tube surface. Inwardly and outwardly extending fins 24 may be mounted on the bulb to hasten the penetration of heat from the cabinet into the liquid within the bulb.

The form shown in Figure 2 is somewhat modified to take care of relatively large additions of heat to the cabinet through the opening of doors or the introduction of relatively warm materials thereinto. In this form of the invention the cabinet 10 is surmounted by an insulated top 30 containing a metal receptacle 31 for the refrigerant. Surrounding the sides and bottom of the receptacle 31 and spaced therefrom is an outer casing 32, the bottom of which is preferably sloped toward a drain pipe 33. The latter extends downwardly to a tube 34, from which a flexible tube 35 extends to a thermostatic bulb 36, the downwardly extending portion of the tube 35 being suitably insulated as by a sheath 37. The upwardly extending portion of the tube may be considerably elongated, the length being disposed in a coil 38 or any other convenient manner. The bulb 36 may be supplied with inner and outer metal fins 39 to facilitate heat absorption. Within the insulated top 30 is a reservoir 40 of suitable size, the top of which is connected to the side of the drain 33 immediately below the casing 32. From the bottom of the box 40 extends a drain pipe which has a U-bend 41 immediately beneath the box to form a trap, and an inverted U-bend 42 to form a siphon. The descending leg of the siphon 42 is attached to one end of a flat coil 43 of piping, the other end of this coil being attached to a return pipe 44 which enters the upper portion of the chamber 45 between the inner and outer casings 31 and 32. This chamber with the pipes, tubes, reservoir, and bulb 36 forms a gas-tight system containing a suitable quantity of suitable liquid 50 such as carbon tetrachloride, ether, acetone, chloroform or the like, the air being substantially exhausted from the system after the introduction of the liquid and prior to sealing. The piping in the coil 43 may be any desired length according to the heat-absorbing requirements of the cabinet. Sufficient liquid is supplied to the system to fill the bulb 36, the

tubes 34 and 35 and the reservoir 40, a little additional liquid being provided to furnish sufficient vapor to fill the pipes and coils of the system at ordinary working vapor pressure.

5 When the cabinet is in operation and at the desired temperature, the liquid substantially fills the bulb 36 and the tubes 34 and 35. During the normal operation of the apparatus, a small stream of liquid trickles from the chamber 45 into the reservoir 40 and through the siphon 42, the quantity being sufficient to absorb by evaporation in the coil 43 the normal influx of heat through the walls of a cabinet. If an additional quantity of heat is suddenly admitted as by the opening of a door, the vapor pressure within the bulb 36 increases and causes the liquid in the tube 34 to rise and overflow into the reservoir 40. The overflow may be sufficient to start the operation of the siphon 42 so as to drain the contents of the reservoir into the coil 43. This introduces into the coil 43 a considerable supply of liquid which is exposed to the newly introduced heat of the cabinet through the large aggregate area of the walls of the coil 43. The boiling of this liquid reduces the coil temperature quickly and results in the rapid absorption of heat from the cabinet to bring back the temperature of the cabinet to the desired normal. The vapor produced by the boiling travels quickly by reason of the low pressure in the system through the return pipe 44 to the chamber 45 where it is condensed against the cold receptacle 31. The condensate runs into the pipe 33 and thence into the reservoir 40. When the cabinet is sufficiently chilled to reduce the vapor pressure within the bulb 36, the liquid level in the bulb rises and there is a flow from the tubes 34 and 35 into the bulb. These tubes are kept full, however, by the trickle from the chamber 45, the trickle being arranged to overflow into the reservoir only when the tubes 34 and 35 are full.

It is apparent that many variations and modifications may be made in the invention as described without departing from the spirit and scope thereof as defined by the appended claims. I claim:

1. A method of controlling the continuous transfer of heat from a warm region to a cool region, which comprises enclosing a quantity of volatile liquid in a closed system, exposing one portion of said system to said cool region, exposing a second portion of said system to said warm region whereby any liquid in said second portion may be vaporized and the vapor in the first said portion may be condensed, exposing a third portion of the system to said warm region, and maintaining a supply of said liquid in said third portion under the pressure of a column of said liquid whereby increase of temperature of said third portion beyond a predetermined degree lifts said column and supplies liquid to said second portion to be vaporized.

2. A method of regulating the temperature of a refrigerator cabinet, which comprises enclosing a volatile liquid in a closed system, exposing a portion of said system continuously to a low temperature, exposing a second portion of said system to the interior of said cabinet whereby any of said liquid which enters said second portion is vaporized with absorption of heat from said cabinet, exposing a third portion of said system to the interior of the cabinet, maintaining a supply of said liquid in said third portion under the pressure of a column of said liquid connecting said

second and third portions, and adjusting the height of said column.

3. Apparatus for controlled heat transfer, comprising a closed system containing a quantity of volatile liquid and its vapor, said system having a vapor-containing portion to be chilled by thermal relation with a region of lower temperature, a vaporizing chamber to absorb heat from a region of higher temperature, and a reservoir containing liquid in thermal relation with said region of higher temperature, said apparatus having means including said reservoir for automatically regulating the supply of liquid in said vaporizing chamber in response to variations in the temperature of said region of higher temperature.

4. Apparatus for controlled heat transfer, comprising a closed system including a portion adapted to be chilled, a vaporizing chamber communicating therewith and adapted to be located in the region to be cooled, a vertically adjustable control bulb adapted to be located in the region to be cooled, a pipe having a flexible portion connecting said bulb with said vaporizing chamber, said pipe entering the lower portion of the bulb and having an upwardly extending portion, a volatile liquid in said bulb and filling said pipe whereby when the vapor pressure in the bulb exceeds the head of liquid in the pipe, some of the liquid in the pipe is forced into said vaporizing chamber.

5. In a refrigerating apparatus, a refrigerator cabinet, a closed system including a metal container having a condensing portion adapted to be chilled by a low temperature refrigerant and a vaporizing portion in heat-receiving relation to said cabinet, a closed metal bulb, a pipe leading downwardly from said container and bending upwardly to said bulb, a portion of said pipe being flexible to permit raising and lowering of said bulb, and a quantity of volatile liquid in said system sufficient to fill said bulb and pipe.

6. In combination with apparatus for transferring heat by vaporization of a volatile liquid at one point and condensation of the vapor at another point, means for automatically regulating the quantity of liquid present at the vaporization point in accordance with the temperature adjacent to said vaporization point, said means comprising a tube extending downwardly from said apparatus, a closed bulb, said tube having a flexible upwardly bent portion entering the bottom of said bulb, and a heat-insulating sheath on the downwardly extending portion of said tube.

7. In combination with apparatus for transferring heat by vaporization of a volatile liquid at one point and condensation of the vapor at another point, means for automatically regulating the quantity of liquid present at the vaporization point in accordance with the temperature adjacent to said vaporization point, said means comprising a tube extending downwardly from said apparatus, a heat-insulating sheath on said tube, a bare flexible extension on said tube bending upwardly, a metal bulb on the end of said extension, and means on said bulb for facilitating access of heat thereinto.

8. In combination a liquid, a reservoir for said liquid, a siphon for discharging said liquid from said reservoir, and temperature responsive apparatus including a column of liquid balanced against the pressure of a vapor for controlling the operation of said siphon.

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