Oct. 12, 1937. A. F. WILLAT 2,095,847

REFRIGERATING APPARATUS

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FIG. 4.

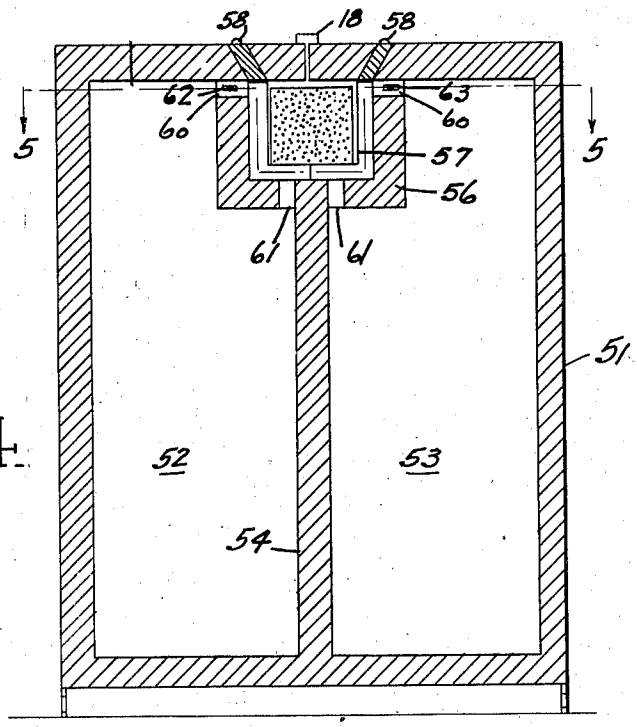
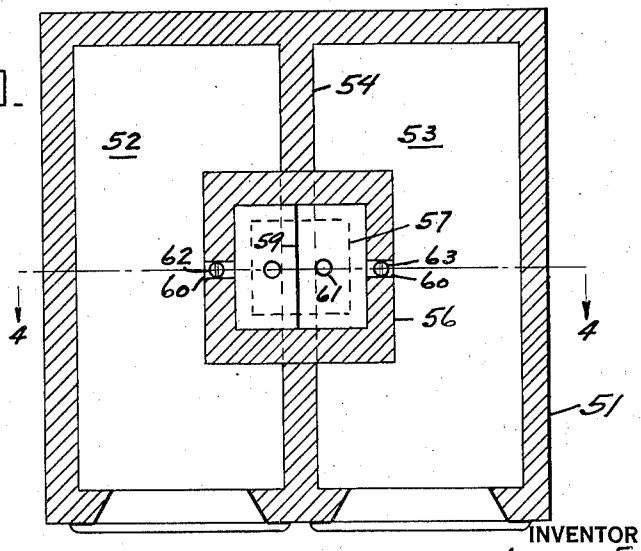


FIG. 5.



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REFRIGERATING APPARATUS

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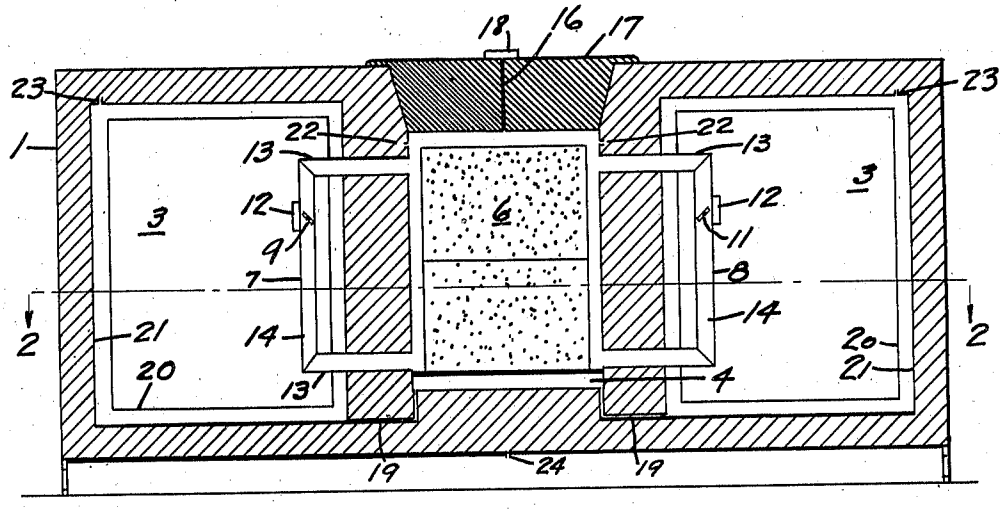

FIG. 1.

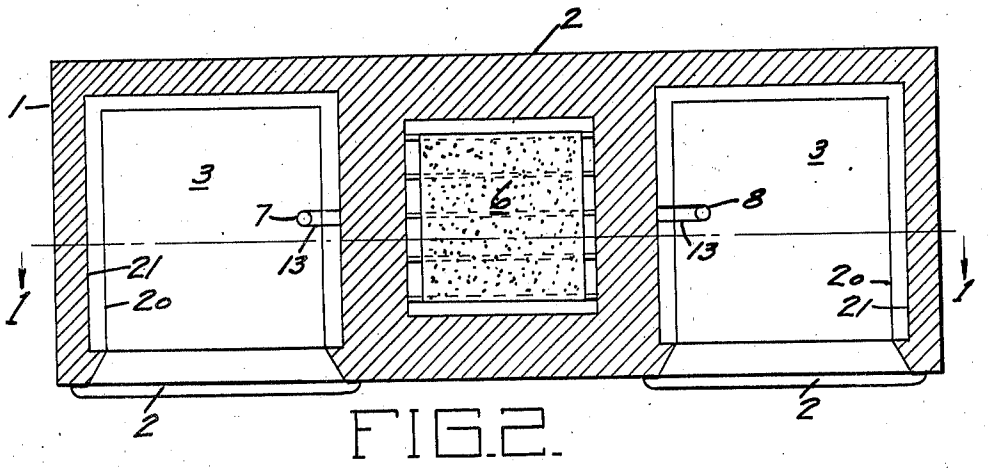

FIG. 2.

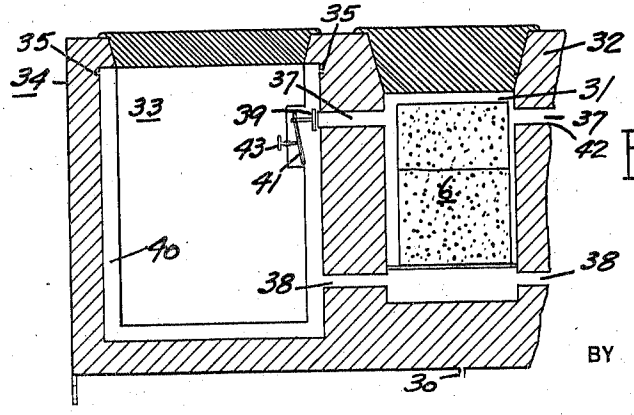

FIG. 3.

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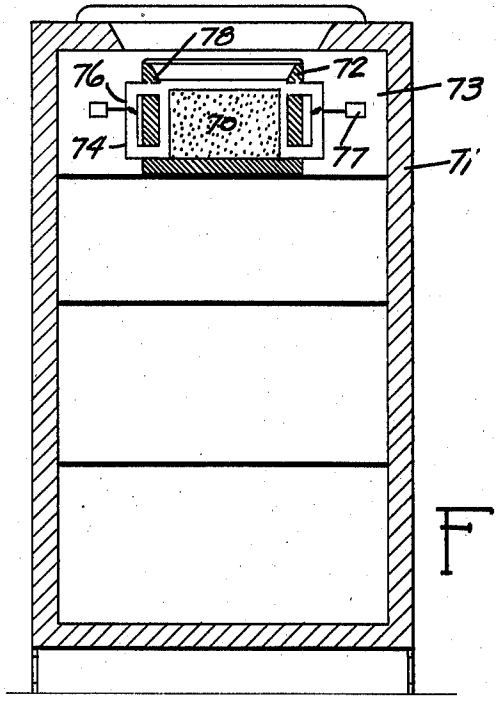

FIG. 6.

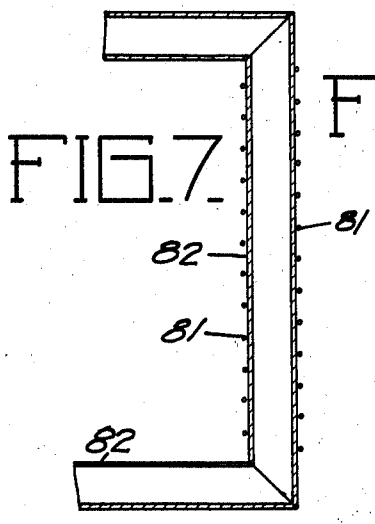

FIG. 7.

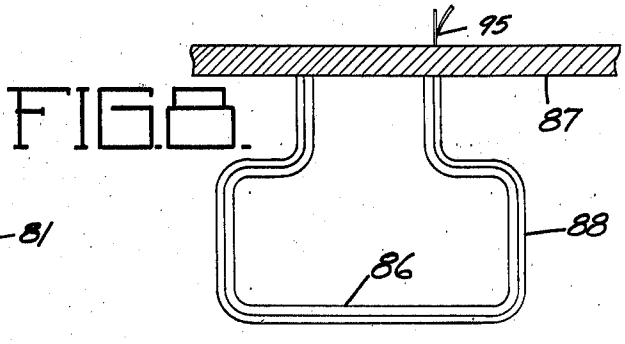

FIG. 8.

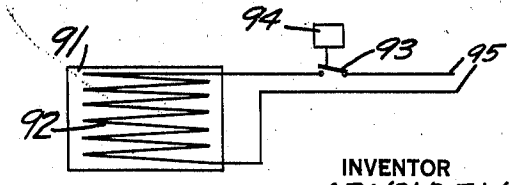

FIG. 9.

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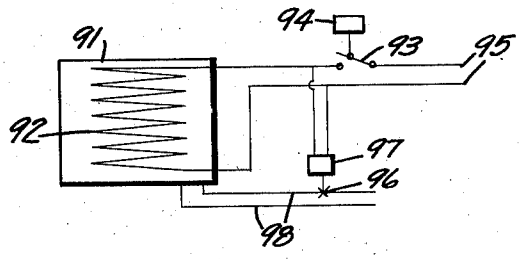

FIG. 10.

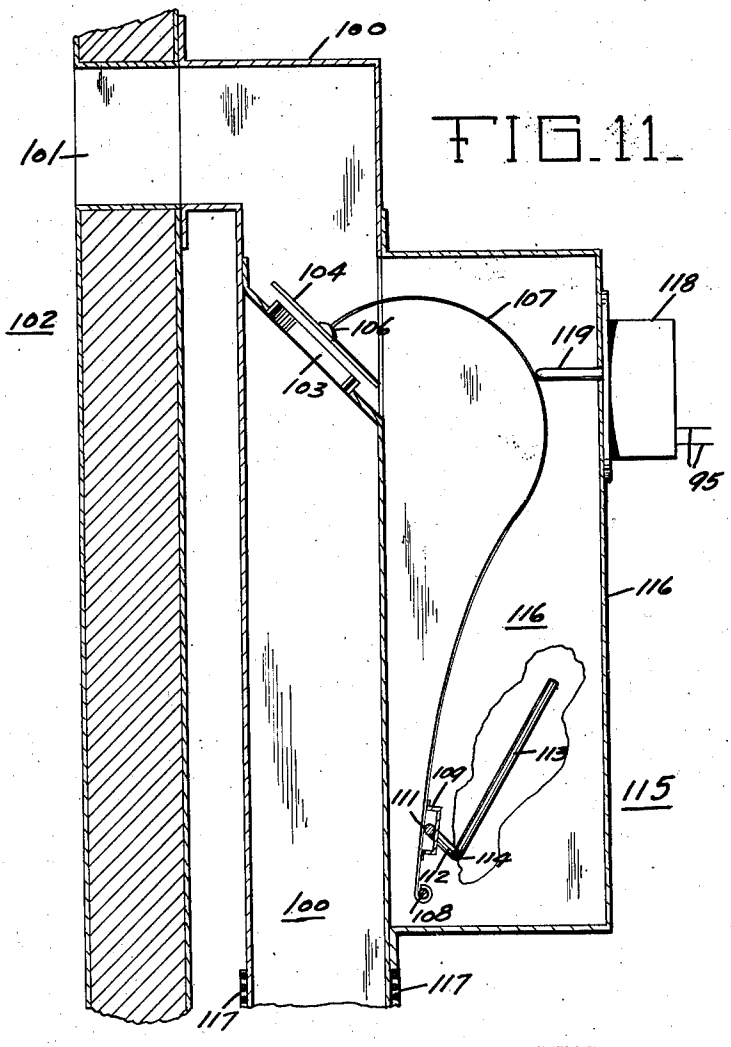

FIG. 11.

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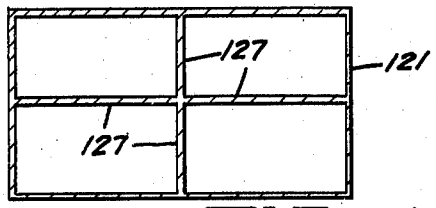

FIG. 14.

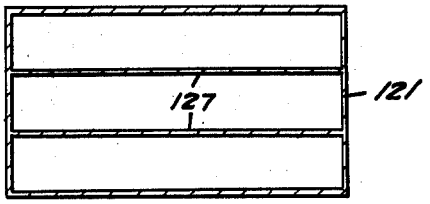

FIG. 13.

FIG. 12.

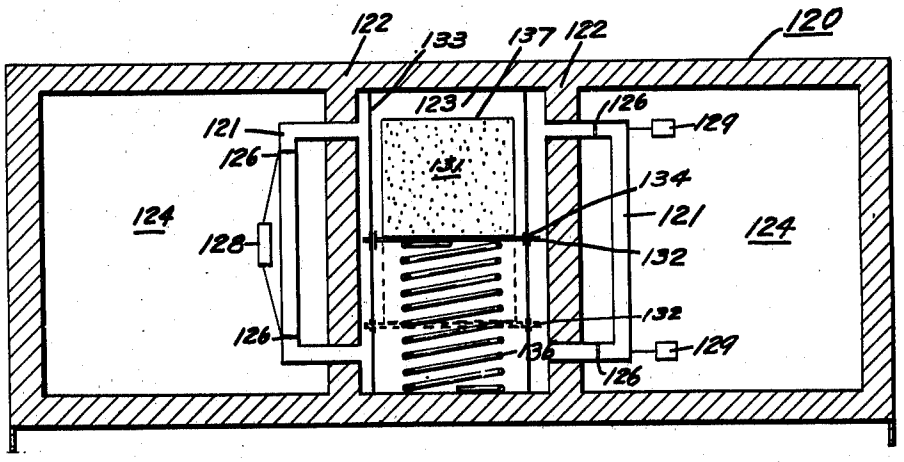

FIG. 15.

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Patented Oct. 12, 1937 2,095,847

UNITED STATES PATENT OFFICE

2,095,847

REFRIGERATING APPARATUS

Arnold F. Willat, San Rafael, Calif.

Application July 13, 1932, Serial No. 622,295

27 Claims. (Cl. 62—91.5)

This invention relates to a method of refrigeration and apparatus for maintaining a refrigerated space at a desired temperature. More particularly the invention is concerned with low temperature maintenance, in a space for products to be refrigerated, in a novel manner so that economical refrigeration is secured from a cold body or refrigerant.

As a refrigerating material solid CO_2 is preferably employed although features of the invention enable other refrigerants or cold bodies to be used to advantage. Certain novel features are disclosed enabling this very intense refrigerant, solid carbon dioxide, to be employed economically, as well as other like refrigerants, and different temperatures maintained with ease and accuracy in a refrigerated space as desired.

In accordance with this invention, a method of efficiently utilizing the heat absorbing value of solid carbon dioxide is provided. Thus, the solid CO_2 is preserved in such relationship to the space refrigerated that solid carbon dioxide is sublimated in accordance with the need for refrigeration and the space is kept cold within a relatively narrow temperature range, as desired. Thus, the solid carbon dioxide does not spend itself in cooling below a desired temperature the refrigerated space but, instead, its heat absorbing value is employed in maintaining the space at the desired temperature, usually 100° F. to 150° F. higher than the solid carbon dioxide. This feature of the invention is applicable to other refrigerants or cold bodies. Thus, it can be used with ice, bodies maintained cold by mechanical work or bodies first cooled to very low temperatures and then used as refrigerants by letting them absorb heat, usually that necessary to convert a salt or salt mixture, contained in the body, from solid to liquid form. The bodies may be cooled or super cooled, being refrigerated at night and used as cold sources during the day.

The invention is also concerned with refrigerating apparatus for a very efficient utilization of the heat absorbing value of the cold body. This apparatus enables the low temperature of a low temperature refrigerant as solid carbon dioxide to be efficiently applied to a refrigerated space so that the heat absorbing value of the refrigerant is utilized to advantage, while the space, and products therein, is not cooled below a desired temperature.

A particular refrigerating apparatus of this invention enables different temperatures to be maintained in different refrigerated spaces even though only one cold body is used. In this apparatus, for instance, it is possible to have one space maintained at —20° F., another at 0° F. and another at 40° F. so that various products can be kept to greatest advantage. Thus, the cold is not used up needlessly in cooling and maintaining a product at a lower temperature at which it will be preserved. For instance, ice cream and the like can be kept in the 0° F. compartment and soft drinks and the like in the 40° F. compartment so that they are chilled and palatable.

In the practice of the method, according to one form, the cold body, as solid CO_2, is placed in a heavily heat insulated container placed out of heat absorbing contact with the chamber to be refrigerated. In this form, heat is absorbed and removed from the refrigerated space only by a current of gas through the refrigerated space and back to the cold body. The temperature in the chamber is regulated by controlling gas passage through the conduit. Thus, when the refrigerated space is down to the temperature desired, gas passage is practically shut off through the conduit; enough gas may be permitted to pass to compensate for heat absorption by the refrigerated spaced from the atmosphere or the insulation between the cold body and the refrigerated space may be such that the body can absorb sufficient heat directly to maintain the refrigerated space at a temperature no lower than the minimum temperature, if the refrigerated space is not disturbed for a period of time.

When the temperature in the refrigerated chamber rises, as by reason of a hot body therein, the gas is permitted to pass freely through the conduit, a portion of which is in a heat absorbing relationship to the refrigerated chamber. The gas cools the heated portion of the conduit and carries off the heat, the hot gas returning to the solid carbon dioxide, or other refrigerant or cold body, and giving up its heat. In the case of solid carbon dioxide, more cold, heavy gas is caused to sublime by the relatively hot, return gas contacting the solid carbon dioxide, thereby increasing the quantity of gas and lowering the temperature of the gas passing through the conduit. The conduit is cooled by the cold gas therein and is thereby effective to maintain the chamber at the desired temperature.

I have found the use of the atmosphere of the cold body container to be very effective in refrigerating a chamber because of the accuracy and simplicity of control and because of the efficient refrigeration secured. This is particularly so in the case of solid CO_2. The atmosphere of

the container is circulated through the CO_2 container and through a conduit in the chamber to be refrigerated. Since a plurality of conduits may be extended from the cold body container, multiple refrigeration is made very easy and several chambers can be held at different temperatures.

The conduit portion which extends out of and away from the refrigerated chamber is preferably of relatively poor heat conducting material while the portion in the refrigerating chamber is a good heat conductor. By using such a construction, refrigeration of the chamber is facilitated while heat transmission by the conduit from the relatively hot refrigerated chamber to the very cold body or refrigerant is cut down to a minimum.

In other forms of apparatus, circulation of a cold gas other than the refrigerant is employed and in one form a conduit system is provided which includes the space to be refrigerated. Since the cold gas passes through the refrigerated space it will acquire a slight water content which, upon the gas contacting a colder surface, will form frost. Some solid carbon dioxide contains water and this increases the humidity of the carbon dioxide container, or the humidity of the container may be high for various other reasons and in controlling gas flow, valves or other movable mechanisms will become frosted to an extent rendering them inoperative. I have found generally that by providing the valve, or other flow control mechanism, in contact with the relatively hot, return gas, even though the gas may have a higher moisture content per unit quantity of gas than when the gas is cold, the valve, or other control mechanism does not become "frozen up" and so rendered inoperative. Thus, the refrigerated chamber can always be effectively refrigerated and the chamber will not be cooled down to an extreme temperature by freezing up of the valve, or other control mechanism.

When the solid CO_2 sublimes to liberate cold CO_2 gas, the liberated gas, about five hundred times the volume of the solid from which it came, must eventually be released. In accordance with this invention, the gas to be liberated is made use of to cool the refrigerated space and to cut down heat leakage from the atmosphere into the refrigerated space. The gas is passed into a thin, flat conduit forming a wall or walls of the refrigerated space as well as into the cellular insulation about the refrigerated space. The gas is kept under a back pressure by the release valve or exit orifice so that the gas sweeps through slowly and absorbs heat that would otherwise eventually leak into the refrigerated space. The back pressure maintained also prevents the CO_2 gas, which is heavier than air, from siphoning out of the low level exit and so providing an easy atmospheric exhaust for the CO_2 gas. The holding of a back pressure on the gas and the use of a low level outlet enable very efficient use to be made of the gas. Heretofore, only high level outlets have been used with the result that handling of the gas was not as facile as compared with handling with a low level outlet and holding a back pressure on the gas to be released.

The foregoing objects as well as other additional objects and features of the invention will appear in the following wherein the preferred method and preferred forms of apparatus are disclosed in detail.

In the drawings accompanying and forming a part of this specification, Figures 1 to 5 inclusive are sections through various refrigerating apparatus showing how the method of my invention is employed and also certain features and arrangements in the apparatus. Figure 1 is a section on line 1—1 of Figure 2 and Figure 2 is a section on line 2—2 of Figure 1. Figure 3 is a view partly in section through another refrigerating apparatus. Figure 4 is a section on line 4—4 of Figure 5 and Figure 5 is a section on line 5—5 of Figure 4.

Figure 6 is a section through an ordinary ice box adapted to use solid carbon dioxide.

Figures 7, 8, 9, 10, and 11 illustrate a novel way of de-icing a refrigerator.

Figures 12, 13, and 14 illustrate certain features of the invention relative to localized cooling in the conduit for the refrigerant.

Figure 15 is a section through a refrigerator embodying features of my invention.

In the refrigerator shown in Figures 1 and 2, a refrigerator of the upright type is conventionally indicated as comprising a box-like structure or container 1, the outer walls and doors 2 which are of any suitable heat insulating construction. Spaces or chambers 3 are to be refrigerated while space 4 is provided as the container for the cold body 6 which preferably are packages or lumps of solid carbon dioxide although a body maintained mechanically cold or a refrigerated container or body such as a solidified solution of a salt or mixture of salts can be used. The intense refrigerant is preferably stored out of heat absorbing contact with chambers 3 and the only heat removed from chambers 3 by the heat absorbing value of the refrigerant is by circulation of the atmosphere of the refrigerant container by conduits 7 and 8 through spaces 3. Thus, except for the heat absorbed by cold gas in conduits 7 and 8, substantially no heat will be absorbed and so removed by the refrigerant in space 4. This enables an accurate control of the temperature in spaces 3 and an economical application and utilization of the intense cold of such a refrigerant as solid CO_2 to domestic refrigeration. Thus, the extreme temperature of minus 110° F. of solid CO_2 can be economically utilized to maintain domestic refrigerating temperatures of say from 0° F. to 40° F.

Instead of insulating the cold body or refrigerant substantially completely from the chamber or chambers 3, the insulation can be such that the refrigerant absorbs some heat, just enough to keep the chamber 3 at the desired minimum temperature if it is not disturbed, the refrigerant taking up the heat leakage into chamber 3.

Valves 9 and 11 are placed in conduits 7 and 8 and are hand or thermostatically operated by devices 12 to control gas flow through the respective conduits to maintain chambers 3 at desired temperatures. Devices 12 can be placed at any convenient or desirable location in a chamber 3. Valve 9 can be manipulated so that sufficient gas is circulated through conduit 7 to maintain that chamber 3 at 0° F. while the other valve 11 can be manipulated to keep the other chamber 3 at 40° F. In this way an intensely cold refrigerant can be employed to refrigerate to different extents a plurality of separate spaces by circulation of the refrigerant container atmosphere in only thermal contact with the chambers to be refrigerated and back into both thermal and actual contact with the solid CO_2.

Portions of conduits 7 and 8 are preferably of poor heat conducting material to prevent heat

being transmitted from a relatively hot refrigerated chamber to the intensely cold refrigerant storage space. Thus, horizontal portions 13 are made of balsa wood, bakelite, tin or other poor heat conductor while vertical portion 14 is a good heat conductor of tinned copper or the like. In this way, heat removal is limited to that necessary to keep the refrigerated space at a desired temperature and the refrigerant is economically employed.

When a chamber 3 is above the desired temperature, the control valve 9 or 11 permits circulation of the refrigerant container atmosphere through the conduit in the chamber. The cold gas absorbs heat from the conduit, and the relatively hot gas returns to the cold body to be cooled, to the solid CO_2 container to be cooled and to cause more gas to sublime. In this way, with solid CO_2, gas formation is substantially limited to those periods when it is required to cool chambers 3 and then substantially in proportion to the demand for cold. The hotter the gas return, the more that is caused to sublime. Quick, thorough and economical refrigeration is thus made possible since sublimation of CO_2 is confined to that necessary to refrigerate a chamber to a desired temperature. When the temperature of the chamber reaches that desired, the cold body, usually solid CO_2, is shut off substantially completely from the chamber, being thermally insulated therefrom substantially entirely, although enough heat may be allowed to pass to the cold body to permit the cold body to keep the chamber at a minimum if it is not used for some time. The cold body, however, cannot cool the chamber excessively below the desired minimum and refrigeration is substantially accomplished, when the chamber is in use, by gas circulated through conduits 7 and 8 and back to contact the solid CO_2. This I have found to be more practical and successful than an uninsulated or only partially insulated CO_2 container as in the Josephson and Slate Patent 1,796,907, a more economical and accurate refrigeration being secured.

The foregoing principles are generically applicable in various ways. Thus, a refrigerator 71 (Figure 6) built to use ice can be adapted to use solid carbon dioxide 70 economically by providing an insulated container 72 to fit into ice space 73 of the refrigerator. The container includes one or more conduits 74 with valve 76 therein, controlled by device 77, to transfer heat from the products in the refrigerator to the solid carbon dioxide and secure a prompt removal and absorption of this heat. Excess gas from the carbon dioxide can be passed into the container insulation as at 78 and then to the atmosphere or to the interior of the refrigerator. Such a unit permits of the ready adaptation of ice boxes to solid carbon dioxide.

With solid CO_2, excess sublimed gas is released to the atmosphere, conveniently through passage 16 in weighted, removable cover 17 for container 4. Pressure release valve 18 controls gas exit from the refrigerator, preserving pressure on the solid CO_2 to cut down its release from the refrigerator so that the gas does not siphon out. If desired, instead of releasing all gas directly to the atmosphere, a portion or all of the gas, depending on the setting of valve 18, is conducted by ducts 19 into the space between walls 20 and 21 which form a double wall construction. In this way, the cooling and insulating effect of the CO_2, or cold atmosphere of the cold body container 4, is made use of to cut down heat transmission through the walls of the refrigerator.

If a cellular, porous or fibrous heat insulation is used as diatomaceous earth, sawdust, powdered cork, pressed fiber board or the like, as opposed to an impenetrable material, some of the gas is allowed to escape through ducts 22 into the insulation. Gas from between the double walls 20 and 21 is also allowed to escape to the insulation through ducts 23 and gas from the insulation is allowed to escape to the atmosphere through gas release orifice 24, preferably at the bottom of the refrigerator and either a pressure valve or a small orifice to hold a back pressure and prevent the cold, heavy gas siphoning out too rapidly. The gas displaces the air and cuts down and carries away, if allowed to escape, some of the heat from spaces 3. With ducts 22 and 23 discharging at a high level into the insulation and duct 19 discharging at a low level into the double wall, duct 24 is positioned at a low level so that the gas rises between the double walls and falls and sweeps through the insulation. The gas cuts down heat leakage through the walls and insulation as its temperature rises and it sweeps out through release orifice 24 which is small enough to maintain a back pressure on the gas and to prevent it from siphoning out.

In Figure 3, I have shown another refrigerator wherein an intense refrigerant as solid CO_2 or a cold body 6 is stored in a container 31 surrounded by heat insulating material 32 so as to be out of excessive heat absorbing contact with refrigerated space or chamber 33 in refrigerator 34. Chamber 33 is surrounded on five sides with thin, flat walls 36 spaced apart to form a conduit about the refrigerated space and to release gas through high level ducts 35 into the insulation 32 and then to the atmosphere through low level duct 30 which is small enough to hold a back pressure on the escaping gas.

Cold gas, either that subliming from solid CO_2 or passed from a cold body, can pass into the space 40 between the double walls to refrigerate chamber 33. Gas passage is regulated to control the temperature of space 33. Thus, valve 39 is mounted for operation by bimetallic strip 41 over an end of conduit 42 providing passage 37. Adjusting screw 43 enables the valve operation to be varied and the temperature of chamber 33 is changed.

In this case also, gas sublimation from the solid CO_2 is controlled in accordance with the necessity of furnishing cold to space 33 and only when cold is necessary does hot gas ordinarily return to the refrigerant, to increase sublimation from the solid carbon dioxide if that is the refrigerant used. The atmosphere of the refrigerant container is that circulated to cool the chamber 33.

In Figures 4 and 5, I have shown a refrigerator 51 in which principles hereinbefore disclosed are utilized. In this refrigerator chambers or spaces 52 and 53 are to be cooled. The two chambers are separated by wall means 54 of heat insulating material so that the temperature in one chamber will not affect the other. Wall means 54 contains and forms a container or chamber 56 at the top of the refrigerator. Within the chamber 56 but spaced therefrom is refrigerant container 57; chamber 56 is such that the refrigerant or cold body cannot cool the chambers below the minimum temperature when the chambers stand unused for a period; preferably the cham-

ber prevents the refrigerant or cold body from cooling the chambers at all unless gas flows through passages **62**. Depending on the intensity of the refrigerant employed container **57** may be made more or less of good heat conducting materials. Thus, I have shown it of metal and supported on the refrigerator by screws **58**, a wall **59** depends to wall **54** to separate the spaces **52** and **53**. A parcel of solid CO_2, a mechanically cooled body or a cold body, can be used as the refrigerant.

Passages **60** and **61** are provided in chamber **56**, passages **60** being at the top to permit hot gas to enter from the refrigerated space and passages **61** adjacent wall **54** to allow cold gas to fall. Valves **62** and **63**, hand or thermostatically operated, control gas admission by the passages **60** so that the desired temperature is maintained in the spaces **52** and **53** by controlling valves **62** and **63**, the spaces **52** and **53** can be maintained at different temperatures or the same temperature.

It is to be noted that valves **62** and **63** are placed in upper passages **60** so that they are in contact with relatively hot gas and do not become frosted and rendered inoperative by freezing. Valves placed in the downflow of cold gas soon become frozen and inoperative.

From the above it will be evident that intense refrigerants or cold bodies can be used to maintain domestic refrigerating temperatures by sealing the refrigerant off out of contact with the space to be refrigerated and conducting under regulated conditions a thermal agent from the refrigerant container to the space to be refrigerated and returning the hot thermal agent to the refrigerant to induce further refrigeration. While the thermal agent can be the atmosphere of the refrigerated space, as in the form shown in Figures 4 and 5, a gas can be employed which is kept entirely out of direct contact with the refrigerated space and which is the atmosphere of the cold body container, thereby obviating any danger of bacterial or odor contamination of the refrigerated space from the refrigerant.

The storing of the refrigerant under thermal conditions where excessive cooling of the refrigerated space is avoided and the only heat absorbed is that conducted by a controlled conduit system, in which CO_2 gas—the atmosphere in the cold body container—is preferably circulated and returned into direct contact with the solid CO_2 to cause further CO_2 sublimation, enables an economical and efficient utilization of the intense refrigerant to be secured.

A unit has also been disclosed enabling a present ice refrigerator to be adapted to solid carbon dioxide. This unit is placed in the ice space and when set to preserve a certain temperature does so as long as supplied with solid carbon dioxide.

The use of cold gas to improve cooling and insulation of a refrigerator has also been disclosed, the gas being passed into the space between double walls or into the insulation. Gas is allowed to escape through a low level exit provided by an orifice which restricts gas flow to prevent siphoning of the cold, heavy gas.

Another feature of my invention is shown in Figures 7 to 9 inclusive. This has to do with the "de-icing" of refrigerator units and is generically applicable to those bodies maintained at a temperature at which condensation and freezing takes place upon the body. Thus, in a domestic refrigerator, employing a mechanically cooled unit, it is necessary to "de-ice" about every ten days because the unit has become encrusted with a layer of ice formed from water vapor in the refrigerator. The "de-icing" operation includes a temporary disablement of the whole refrigerator by shutting off power to the mechanical unit supplying a refrigerant gas under pressure. The period of disablement varies in length depending on the procedure followed; all procedures involve the warming up of the refrigerated space so that the encrusted ice layer on the unit melts and falls off. During this operation, the contents in the refrigerator warm up and the facilities for "ice cube" and "quick cooling" for desserts and the like are not available for use.

In accordance with my invention, it is not necessary to disable the refrigerator or warm up the refrigerator to any substantial extent and so interrupt the normal operation of the refrigerator. It is my invention to melt the layer of frozen material, water or other material, joining the encrusted layer to the cooled unit so that the whole layer falls away and can be removed. Only a small quantity of heat is necessary to melt this small skin like layer—and the encrustation as a whole does not have to be converted to liquid.

In Figure 7, I have shown an insulated electric heating coil **81** placed around conduit **82** through which a cold gas is circulated to refrigerate products. Due to the low temperature maintained by circulation of cold gas, which may be CO_2 gas in conduits **7**, **8** or **74**, moisture collects on conduit **82** as ice. Coil **81** heats rapidly, upon current being applied, and the film of ice in contact with conduit **82** melts rapidly, releasing the encasing ice in a minute or two after the current is turned on. Since the heat is supplied at the point where the ice joins the conduit, a great quantity of heat is not necessary and the heat supplied is effective to release the ice encrustation.

As I have stated, the invention is generically applicable to de-icing generally and in Figure 8 I have shown a refrigerating unit **86** in a refrigerator **87**, the unit being supplied with a gas expanded to cool and absorb heat from unit **86**. The exterior surface of the unit, and those surfaces collecting ice, includes heating unit **88**. While in the drawings, the extent of the unit has been exaggerated somewhat, the unit is effective to liquefy the ice layer immediately against the unit so that the ice encrustation falls away.

In Figure 9, I have shown a refrigerating unit **91** combined with means for heating the unit, being an electric heating coil **92**. The coil is included in a circuit with a switch **93**. When it is desired to de-ice the unit, the switch is closed and, after a time interval, a minute or more, the switch is opened automatically by means **94** so that thereafter the de-iced refrigerator resumes normal operation. The time interval over which the heating coil must supply heat varies with the surface extent of the refrigerator unit and the rate of heat supply. In practice, successful de-icing is secured in about a minute. The time and fuss necessary to de-icing is effected by merely pressing a switch button and in a minute or two removing the tray for ice and water from the de-iced cooling unit.

The heating means are placed as close as practical to the exterior surface of the unit so as to heat and melt the layer of ice securing the encrustation to the cooling unit. Thus, little if any heat passes into the unit and the gas therein, the heat effectively releasing the ice.

In some instances, it is desirable to prevent

excessive circulation of the refrigerant during the heating and in Figure 10 I have shown a valve 96 in refrigerant circulation conduits 98. Valve 96 is closed automatically upon heating of the refrigeration unit 91 and for this purpose I include a solenoid 97 which operates, upon operation of switch 93, to close and open valve 96.

By preventing refrigerant circulation during "de-icing", an excessive demand upon the cold source is prevented. This is particularly so in the case where solid carbon dioxide is used for the heated gas returns to the cold solid to cause sublimation of additional cold gas. The net result is that the heat supplied to de-ice is partially offset by an increased gas formation and a loss in the solid. In Figure 11 I have shown a device particularly adapted to control a refrigerant as cold carbon dioxide gas both during de-icing and normal operation. A conduit 100 extends from an opening 101 to a compartment 102 for a cold body as a block of solid carbon dioxide. A valve seat 103 is positioned in the conduit cooperably with respect to valve disc 104 so that fluid flow through the conduit can be controlled. The valve disc is connected by a universal joint 106 to curved bimetallic strip member 107 which is hinged on a transverse rod 108 so that an end of the member 107 is fixed. A bracket 109 is secured to member 107 and an arm 111 of crank 112 is positioned between the bracket and member 107. A lever 113 is fastened to the arm 114 of crank 112, the arm 114 extending outside of housing 116 to receive the lever 113. Movement of lever 113 changes the position of valve disc 104 relative to valve seat 103 by moving member 107 about rod 108. The relative position of the valve disc to the valve seat determines the gas flow through the conduit and thereby the temperature in space 115 where products to be refrigerated are placed.

To move valve disc 104 to engage valve seat 103 upon energization of heating coil 117, solenoid 118 is secured on housing 116 so that plunger 119 engages bimetallic strip 107 upon current passing through circuit 95. In this way undue sublimation of solid carbon dioxide is avoided since the heated gas is not allowed to circulate. Upon deenergization of circuit 95, plunger 119 is released and bimetallic strip 107 returns the valve disc to a position in accordance with the setting by lever 113 and the temperature. The bimetallic strip is responsive to temperature and normally functions to operate valve disc 104 to control gas flow through conduit 100. While the gas in conduit is heated when valve disc 104 is held on valve seat 103 upon energization of heating means 117 and solenoid 118, the total amount of solid carbon dioxide required subsequently to overcome the de-icing operation is less than when free gas circulation is allowed through conduit 100 during de-icing.

In operating with refrigerants having a relatively low specific heat, the use of relatively large volumes is necessary to secure a given amount of cooling. During periods when refrigeration is not required and circulation of the refrigerant is practically at a minimum through the refrigeration unit in the space for products to be refrigerated, I have observed localized cooling of sections of the unit so that refrigeration went on. This is illustrated more or less diagrammatically in Figure 12. Thus, conduit 121, Figures 12 and 15, extends through wall 122 of solid carbon dioxide container 123 into space 124 for products to be refrigerated in refrigerator 120. Valve 126, controlling cold carbon dioxide gas flow through the conduit, is shown in closed position. Under these conditions cold, heavy gas enters along the lower surface of the conduit, following generally the path of the arrows and returning along the upper surface of the conduit to the solid carbon dioxide. This is undesirable for the lower portion of the conduit 121 is cooled and accurate control of refrigeration as well as uniform refrigeration are not secured.

I have found that by sub-dividing the conduit 121 into a plurality of small passages, localized gas flow is largely, if not completely, obviated. Thus, as appears in Figures 13 and 14, walls 127 divide conduit 121 into a plurality of passages, the total area of which is practically that of the conduit without the walls. The walls 127 can be either of good heat conducting material or not, depending upon the particular conditions of operation. With the walls of poor heat conductivity, the tendency for localized gas circulation is lowered and when valve 126 is closed, the gas remains practically quiescent in conduit 121. With still gas conditions in conduit 121, an accurate control of refrigeration of products in space 124 is secured.

Still gas conditions can be secured or improved by using several valves or other gas flow impeding means in conduit 121. Thus, as appears in the left hand portion of Figure 15, I utilize two valves 126 operated by a single thermostatic means 128 so that both valves shut off flow at the ends of the conduit and prevent entrance or exit of gas in the portion between the valves.

The valves can be positioned as shown in the right hand portion of Figure 15—close to the refrigerant source so that the refrigerant can have hardly any effect on the space 124. In this portion of Figure 15, the valves are separately controlled by means 129. Some localized gas circulation can occur under these circumstances but means 129 prevent undue cooling of any portion of the refrigerated space and shut off the associated valve upon the refrigerated space immediately adjacent the means 129 attaining the requisite temperature to operate means 129.

Under conditions of use, a refrigerator employing a refrigerant as solid carbon dioxide is replenished only periodically. A day or more may elapse between fillings and, during the interval, the refrigerant is used up. I have observed that under these conditions it was extremely difficult, if not impossible, to maintain a constant low temperature in the refrigerated space and that many times the temperature of the refrigerated space rose as the supply of refrigerant decreases. This difficulty I have been able to overcome by maintaining a more or less constant relationship between the upper surface or level of the refrigerant and the refrigerator so that the supply of cold, heavy gas from the cold body was of about the same height, irrespective of the quantity of effective cold body present. By maintaining the refrigerant in this way, the desired temperature can be maintained when the refrigerator is first replenished and when the refrigerant has materially diminished.

In Figure 15 I have shown a way of securing this operation. A refrigerant as a block of solid carbon dioxide 131 is placed on a tray or support 132. The tray is positioned between rods 133 which run through guides 134 in the tray. A spring 136 is placed between the tray and the refrigerator to support the tray. As the refrigerant is used, the spring lifts the tray and main-

tains the upper level 137 of the refrigerant in practically the same position, the tray moving between a lower position, as that shown in dotted lines in Figure 15, to an upper position, the upper level 137 being maintained at about the same position at all times in the refrigerator until the refrigerant is exhausted.

Instead of the height of the column of cold, heavy gas in the refrigerant compartment decreasing as the refrigerant is used up, the gas column is maintained and uniform refrigeration is secured during the existence of the refrigerant. With solid carbon dioxide, uniform refrigeration is secured, as I have disclosed, even though the carbon dioxide is materialy used up.

I claim:

1. A refrigerating apparatus including a chamber for products to be refrigerated, a container for said chamber, insulating material between said chamber and said container, another container for enclosing solidified carbon dioxide separated from but in a controlled heat exchange relation with the refrigerated chamber, a conduit for circulating gas about said refrigerated chamber in thermal contact therewith and returning said gas to said solid carbon dioxide, a gas inlet into said insulation, and an outlet orifice for gas from said insulation, said orifice holding a back pressure on said gas and being at a low level.

2. In a refrigerator having a space for products to be refrigerated, a conduit for conducting a cold fluid through said space to cool said space, and means for substantially preventing localized cooling in a portion of said conduit.

3. In a refrigerator having a space for products to be refrigerated, a refrigerant container, an outlet for cold gas from said container into said space whereby products in said space are cooled, and means for maintaining the upper level of the refrigerant at substantially a constant distance from said outlet during existence of said refrigerant in said container.

4. In a refrigerator structure, a refrigerant chamber having an outlet for cold gas, and a refrigerant support in said chamber including means for maintaining the upper level of a refrigerant on said support at a substantially constant distance from said outlet.

5. In a refrigerator structure, a refrigerant chamber having an outlet for cold gas, and a refrigerant support in said chamber including a spring for maintaining the upper level of a refrigerant on said support at a substantially constant distance from said outlet.

6. A movable conversion apparatus for enabling an intensely cold refrigerant to be used for refrigerating at moderate temperatures comprising a refrigerant container adapted to be positioned within a space to be refrigerated, a refrigerant gas conduit extending from adjacent the bottom of said container to adjacent the top of said container to provide a cooling element only adjacent to said container through which gas circulates to provide a heat absorbing medium for cooling said space, and a valve in the return portion of said conduit including a valve seat, a valve member and a bimetallic strip supporting said member and moving said member toward and away from said valve seat.

7. A movable conversion apparatus for enabling an intensely cold refrigerant to be used for refrigerating at moderate temperatures comprising a refrigerant container adapted to be positioned within a space to be refrigerated, a refrigerant gas conduit extending from adjacent the bottom of said container to adjacent the top of said container to provide a cooling element only adjacent to said container through which gas circulates to provide a heat absorbing medium for cooling said space, and a valve in the return portion of said conduit including a valve seat, a valve member and a bimetallic strip for moving said member toward and away from said valve seat.

8. A movable conversion apparatus for enabling an intensely cold refrigerant to be used for refrigerating at moderate temperatures comprising a refrigerant container adapted to be positioned within a space to be refrigerated, a refrigerant gas conduit extending from adjacent the bottom of said container to adjacent the top of said container to provide a cooling element only adjacent to said container through which gas circulates to provide a heat absorbing medium for cooling said space, and a valve in the return portion of said conduit including a valve seat, a valve member, and a thermal responsive element for moving said member toward and away from said valve seat.

9. In a refrigerator structure, a refrigerant chamber having a spaced outlet and return inlet for a refrigerating gas, a refrigerant support in said chamber, and means for maintaining the upper level of a refrigerant on said support in a substantially constant relationship to both said outlet and said inlet.

10. In a refrigerator structure, a refrigerant chamber having a spaced outlet and return inlet for a refrigerating gas, a refrigerant support in said chamber, and means for maintaining the upper level of a refrigerant on said support in a substantially constant relationship to said outlet.

11. A refrigerating unit, for a refrigerating chamber, including means for supporting said unit within said chamber in a refrigerating relationship to said chamber, said unit comprising a heat insulated receptacle for a refrigerant as solid carbon dioxide, said receptacle having an opening therein, a movable closure for said opening permitting replenishing of said refrigerant in said receptacle, and a conduit for conducting cold gas from said refrigerant outside of said receptacle to refrigerate said chamber, said conduit extending along an outside face of said unit from adjacent the bottom of said unit to adjacent the top of said unit and being carried substantially entirely by said unit.

12. A refrigerating unit, for a refrigerating chamber, including means for supporting said unit within and in an upper portion of said chamber in a refrigerating relationship to said chamber, said unit comprising a heat insulated receptacle for a refrigerant as solid carbon dioxide, said receptacle having an opening therein, a movable closure for said opening permitting replenishing of said refrigerant in said receptacle, and means for absorbing heat from said chamber, said means consisting of a conduit connected to said receptacle adjacent the bottom thereof and extending along an outside face of said receptacle to a connection to said receptacle adjacent the top of said receptacle so that cold heavy gas can pass into said conduit from said receptacle and rises through said conduit as said cold gas takes up heat from said chamber, to return to the top of said receptacle.

13. In combination, a chamber for a refrigerant as solid CO_2, said chamber having a gas outlet and a gas return inlet, and means for maintaining the upper level of said solid refrigerant in said

chamber in a substantially constant relation to both said outlet and said inlet.

14. In combination, a heat insulated chamber for a refrigerant as solid CO_2, a conduit connected to said chamber for conducting a relatively cold gas, means for preventing substantially gas passage through said conduit, and means for preventing localized cooling in said conduit adjacent said chamber when gas passage through said conduit is prevented substantially.

15. In combination, a heat insulated chamber for a refrigerant as solid CO_2, a conduit connected to said chamber for conducting a relatively cold gas, means for preventing substantially gas passage through said conduit, and means for preventing localized cooling in said conduit when gas passage through said conduit is prevented substantially.

16. A movable conversion apparatus for enabling an intensely cold refrigerant to be used for refrigerating at moderate temperatures comprising a refrigerant container adapted to be positioned within a space to be refrigerated, a refrigerant gas conduit extending from adjacent the bottom of said container to adjacent the top of said container to provide a cooling element only adjacent to said container through which gas circulates to provide a heat absorbing medium for cooling said space, and a valve in said conduit including a valve seat, a valve member, and a thermal responsive element for moving said member toward and away from said valve seat.

17. A cooling unit comprising a housing of heat insulating material having a chamber therein for containing a solid gas-emanating refrigerant, a heat conducting wall disposed in spaced relation to said housing and forming a conduit having an exposed heat-exchanging surface along one side of said chamber, a duct establishing communication between the lower part of said chamber and said conduit, a second duct establishing communication between said conduit and the upper part of said chamber, and thermostatic means responsive to the temperature of the gas circulating in said conduit for controlling the flow of gas therethrough.

18. A cooling unit comprising a heat insulated housing having a chamber therein for containing a solid gas-emanating refrigerant, a metallic partition having an exposed heat absorbing surface arranged in spaced relation along a face of said housing, a plurality of ducts piercing said heat insulated housing for establishing communication for a convection circulation of gas between said housing and said metallic partition, and thermostatic means responsive to the temperature of the circulating gas for controlling the rate of heat absorption of said metallic partition.

19. A cooling unit comprising a heat insulated housing having a chamber therein for containing a solid gas-emanating refrigerant, a metallic partition having an exposed heat absorbing surface arranged in spaced relation along a face of said housing, inlet and outlet ducts piercing said heat insulated housing for establishing communication for a convection circulation of gas between said housing and said metallic partition, a first valve adjacent said outlet duct, and a second valve adjacent said inlet duct, said valves being operable to control the rate of heat absorption of said metallic partition.

20. A solid carbon dioxide refrigerating unit comprising a housing of heat insulating material having a chamber for holding a quantity of solid carbon dioxide, means forming a conduit having heat-exchanging properties through which the gas emanating from said solid carbon dioxide may circulate and recirculate by convection, and thermostatic means within said conduit responsive to the temperature of the circulating gas for controlling the recirculation of gas therethrough.

21. A cooling unit for refrigerating purposes comprising a housing of heat insulating material having a chamber for holding a solid gas-emanating refrigerant, means forming a conduit having heat-exchanging properties through which the gas emanating from said solid refrigerant may circulate by convection, thermostatic means within said conduit for controlling the circulation of gas therethrough, and means for regulating the range of said thermostatic means during operation whereby the rate of gas emanation from said solid refrigerant may be determined at any time irrespective of the external temperature.

22. A solidified carbon dioxide refrigerating unit comprising a housing of heat insulating material having a chamber therein for containing a quantity of solid carbon dioxide, a heat conducting wall disposed in spaced relation with said housing and forming an exposed heat-exchanging surface along a face of said housing, means establishing communication between the interior of said chamber and the inside of said heat conducting wall for a closed-cycle convection circulation of the gas emanating from said solid carbon dioxide, and thermostatic means responsive to the temperature variations of the circulating gas for controlling the flow thereof and thereby the rate of sublimation of said solid carbon dioxide independently of the temperature external to said exposed heat-exchanging surface.

23. A solidified carbon dioxide refrigerating unit comprising a housing of heat insulating material having a chamber therein for containing a solid carbon dioxide, a heat conducting wall disposed in spaced relation with said housing and forming a conduit for a closed-cycle circulation of carbon dioxide gas having an exposed heat-exchanging surface arranged along a face of said housing, means for establishing communication between said chamber and said conduit to permit a circulation of gas evolved from said solid carbon dioxide, and a thermostatically controlled valve responsive to the temperature within said conduit for controlling the circulation of the gas therethrough, whereby the rate of gas emanation from said solid carbon dioxide will be determined by the heat absorbed by the gas from said heat-exchanging surface.

24. A solidified gas refrigerating unit comprising a housing of heat insulating material having a chamber therein for containing a solid gas-emanating refrigerant, a conduit having an exposed heat-exchanging surface arranged outside of and along a face of said housing, a duct establishing a path for gas evolved from said solid refrigerant extending from the lower part of said chamber to said conduit, a second duct establishing a path from said conduit to the upper part of said chamber, said ducts cooperating with said chamber and said conduit to provide a closed-cycle circulation of the gas emanating from said solid refrigerant, and a thermostatically controlled valve responsive to the temperature of the circulating gas for controlling the recirculation thereof and thereby the rate of sublimation of said solid refrigerant independently of the temperature external to said housing.

25. A self contained cooling unit for refrigerating purposes comprising a housing of heat insulating material having a chamber therein for holding a solid gas-emanating refrigerant, a metallic wall disposed in spaced relation along said housing and forming a conduit having a heat-exchanging surface, a plurality of ducts extending through the heat insulating material forming said housing for establishing communication for a convection circulation and recirculation of gas through said chamber and between said housing and said metallic wall, and thermostatic means, including a valve in said conduit, for controlling the rate of the circulation of said gas.

26. A cooling unit comprising a housing of heat insulating material having a chamber therein for containing a solid gas-emanating refrigerant, a conduit having an exposed heat-exchanging surface arranged outside of and along a face of said housing, a duct adjacent the bottom of said chamber establishing communication between said chamber and said conduit, and means for holding said solid gas-emanating refrigerant clear of said duct without interfering with the free flow of gas therethrough.

27. A cooling unit comprising a heat insulated housing having a chamber therein for containing a solid gas-emanating refrigerant, a metallic conduit having an exposed heat absorbing surface arranged in spaced relation along said housing, inlet and outlet ducts piercing said heat insulated housing for establishing communication for a convection circulation and recirculation of gas between said housing and said metallic conduit, a first valve in said outlet duct for controlling the discharge of gas from said chamber, and a thermostatically controlled valve responsive to temperature to control flow of gas circulating between said housing and said metallic partition, said first valve being operable to control the rate of circulation of said gas from said chamber and said thermostatically controlled valve being operable to control the rate of recirculation of said gas, whereby the heat absorption ability of said metallic conduit will be determined.

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